A HYBRID MODEL FOR IT INVESTMENT ANALYSIS: APPLICATION TO RFID ADOPTION IN THE RETAIL SECTOR

By

NARGES A. KASIRI

Bachelor of Science in Computer Engineering
Sharif University of Technology
Tehran, Iran
1996

Masters of Science in Computer Science
Eastern Michigan University
Ypsilanti, Michigan
2003

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
DOCTOR OF PHILOSOPHY
July, 2010

A HYBRID MODEL FOR IT INVESTMENT ANALYSIS: APPLICATION TO RFID ADOPTION IN THE RETAIL SECTOR

Dissertation Approved:

Dr. RameshSharda

Dissertation Adviser

Dr. Marilyn Kletke

Dr. Rick Wilson

Dr. Todd Arnold

Dr. Bill Hardgrave

Dr. Mark E. Payton

Dean of the Graduate College

ACKNOWLEDGEMENTS

First and foremost, I would like to thank my supervisor, Professor Ramesh Sharda. I will always be grateful to him for his guidance throughout this long journey and, in particular, for his broad view and knowledge in exploring different topics and methodologies. He has always been very patient with and encouraging to me, giving me a chance to explore various interests.

I would also like to thank my committee members, Professors Todd Arnold, Bill Hardgrave, Marilyn Kletke, and Rick Wilson for their support and guidance not only during the dissertation process, but during all of my time spent at OSU.

Special thanks are due to Dr. Hardgrave for facilitating the data collection and for his support, without which my work could not have been completed.

To my husband, Mahdi, and little daughter Anahita, I will always be grateful for your love, support and encouragement. I would like to thank my mother, F.S. Shariati, for her never ending love, as well as my father who is in the heavens, and my siblings, Zahra, Hossein and Elaheh. Thank you for all the sacrifices you made for making my education possible.

Last but not least, I thank my peers at OSU and everybody else who supported me over the past few years. I never forget your help.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

The economics of Information Technology is one of the major factors in Information Technology (IT) adoption. There are two different aspects in IT adoption: behavioral issues and organizational issues. Many empirical and theoretical Management Information Systems (MIS) studies, such as those using the Technology Acceptance Model (TAM) (Davis, 1989), have looked into behavioral factors that influence technology adoption in organizations. On the other hand, organizational issues in IT adoption, such as financial outcomes of an IT investment, are also considered IT adoption barriers. The first step for an IT investment decision maker is to measure its Return on Investment (ROI) and ensure that such an investment is truly in the interest of the organization. In particular, in these difficult economic conditions, executives have to invest wisely to justify their IT budget and improve their efficiency in order to stay competitive in the market.

Carr (2003) argues that being a premier user of information technology gave companies a strategic advantage in the 1990's. The costs of investing in cutting-edge technology were high, but costs were returned quickly and technology gave the businesses competitive advantages. Nowadays there are not so many new ways of utilizing technology, so spending large sums of money on investing in IT is not as profitable (Carr, 2003). However, investing in the long-term use of IT in a thoughtful way can still lead to a strategic advantage if it is part of a rich business model in which IT capabilities are matched in innovative ways to the organization's business processes and goals. Innovation can still bring strategic advantages even though IT seems to be ubiquitous and commoditized.

Although innovative ideas with high risks can still bring strategic advantages for businesses, such ideas are not as available as they were in the 1990's and earlier. RFID is a new area to explore in retail and manufacturing operations, for example, and investing in such technology with uncertain returns has a high risk. Item-level RFID projects are being implemented in pilot sites, but there is much uncertainty as to how profitable they will be. This means that investing in this new technology is still challenging for organizations.

The economics of IT has been studied in MIS literature for a long time (Remenyi, 2000; Hochstrasser, 1994; Hitt and Brynjolfsson, 1996; Cronk and Fitzgerald, 2002; Counihan et al., 2002; Farrell, 2003). Case studies as well as empirical and quantitative techniques including simulation models have been used in this research area. Issues such as the intangible benefits of IT to organizations as well as the time-frame for investment analysis make IT investment evaluation a difficult task. Intangible IT benefits, for example customer satisfaction in high tech stores, are hard to identify and measure. In addition, some benefits of investing in IT are achieved over time. For instance, investing in a wireless network infrastructure leads to more investment opportunities by which organizations can acquire many benefits over time. Real options is one of the techniques used in the economics of IT to measure the future growth benefits of IT infrastructure investments (Dos Santos, 1991).

This study combines real options and system dynamics as two quantitative approaches in the economics of IT, to develop an ROI model that can overcome some of the complexity of the cost benefit analysis in IT investments. Item-level RFID information technology in retailers is used as a test case for the ROI model. This technology is in its infancy in retailing, and organizations are seeking an extensive cost benefit analysis effort.

Problem Statement and Background

The adoption of Radio Frequency Identification (RFID) technology is on the agenda for many retailers. Many industries, such as healthcare, the military, and financial services, are working on implementing this technology. However, research shows that retailers will take up the largest part of the market; their RFID market value will form more than 40% of the RFID market by 2016 (Figure 1) and item level share will be more than 50% of the investment (Figure 2). In the current economic situation, retail managers need to lower costs and stay competitive in the market more than at any other time. RFID technology impacts all retail operations; however, before initiating any investment, managers have to understand the potential pay-offs of investing in this technology. Some major retailers and manufacturers, such as Wal-Mart and its suppliers, have already adopted RFID at the pallet level. However, item-level RFID deployment is in the early stages and has only been implemented in pilot level studies. Because of the current economic condition, managers need a cost benefit analysis before investing in a new technology such as RFID in order to justify spending heavily. Moreover, managers need to know when is the best time to deploy RFID to take the most advantage of their investment.

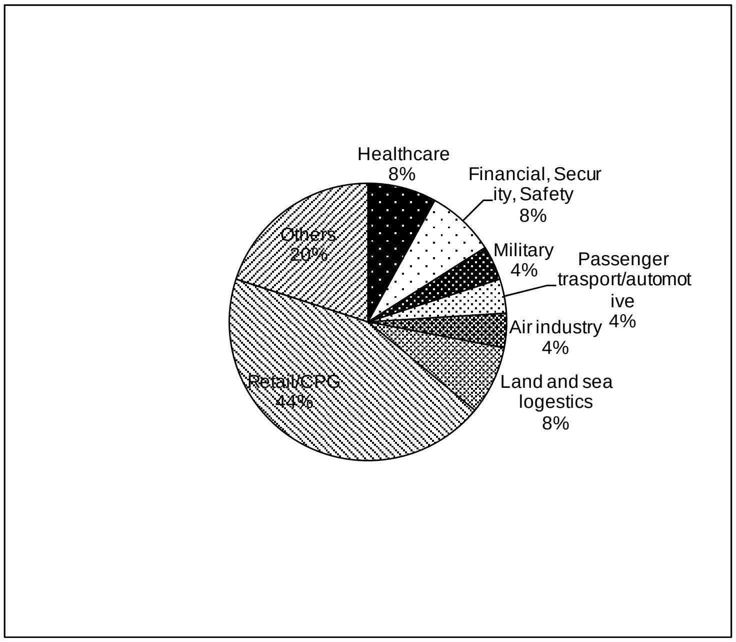

Figure 1 RFID market value perspective by 2016 (IDTechEx)

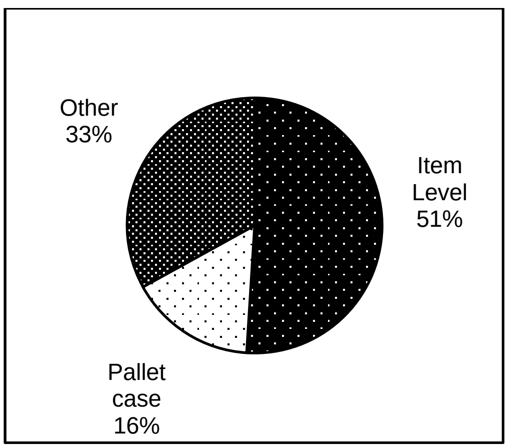

Figure 2 Item-level RFID market value (IDTechEx)

Barcodes are the current identification technology used in retailing. Figure 3 shows the current cost of RFID components vs. one-dimensional and two-dimensional barcodes. As shown in the figure, the cost of RFID is significantly higher than the cost of barcodes. Managers need to justify investment in RFID, that is, to ascertain that its benefits exceed the costs. The cost of RFID tags, particularly in item-level implementation, as opposed to pallet, or case level, is a major challenge in the adoption of technology. Adoption of RFID may be inevitable, but early adoption has a high cost along with its many benefits. The question for retail managers is when is the best time to implement this technology. There are two competing factors in RFID investment: on the one hand, the cost of implementation goes down as the technology matures and on the other hand, waiting to employ this technology might lead to losing some competitive advantages. As shown in Figure 4, given the decreasing price for RFID components and the increasing realization of its benefit over the horizon, at some point in time the benefits of implementing RFID exceed its cost (Swamy and Sarma, 2003). Waiting for the best time to invest in this technology is a managerial flexibility that can be considered a waiting option. A real options technique helps to determine the best time to implement this technology by pricing the waiting options.

Real options models deal with investment valuations as an ongoing process with uncertainties, in which managerial flexibilities are considered from the outset. Each application of RFID leading to some benefits is considered an option that can be evaluated in this model.

	1D Barcode	2D Barcode	RFID
Data Capacity	.03 kb	Up to 2.5 kb	Up to 16 kb
Read Rate	Depends on scanner	Depends on scanner	Up to 640 kb/s
Reader Cost	$150-$550	$450-$900	$2800 (Includes 2 antenna)
Cost per barcode/tag	<$0.01	<$0.02	$0.13-$1.25
Method of reading	Line of sight, non-contact	Line of sight, non-contact, omnidirectional	Non-contact, does not need to be line of sight
Problems	Difficulty reading if poorly printed or damaged	Requires line of sight, may have difficulty reading if damaged beyond 20%	Difficulty reading in presence of metals or liquids

Figure 3 Barcode vs. RFID

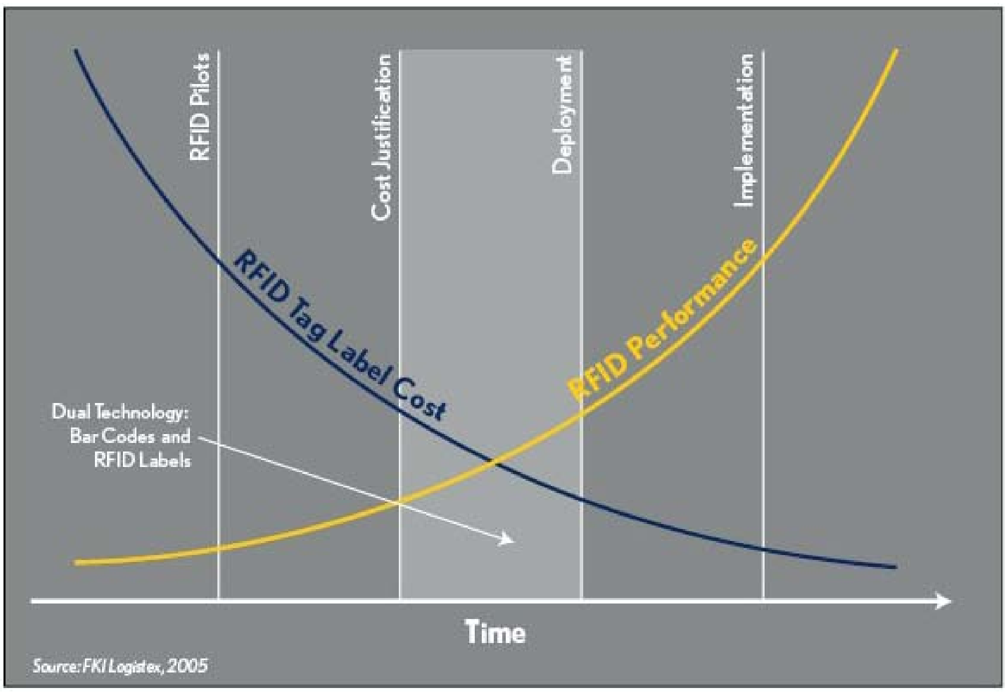

Figure 4 Barcode to RFID timeline (Cash, 2005)

The difficulty of a real options model for IT investment evaluation is estimating the parameters. This dissertation proposes an ROI-model in which a System Dynamics (SD) sub-model is used to capture and measure all the benefits of this technology. The SD sub-model estimates real options parameters by accounting for most of the intangible and tangible benefits and by simulating how RFID influences a retailer's operations. Based on different contexts, the simulation can capture the variability of RFID benefits in order to estimate the parameters in the real options model.

The Hybrid ROI Model

The proposed theoretical ROI model can be applied to any IT investment.

Figure 5 shows the schematic of the hybrid IT investment analysis model. The first step in this model is realizing the available IT investment options. For example in RFID investment, one option is an investing-time option, i.e., when to invest in this technology. The next step is estimating the parameters of the real options model. Parameters such as the cost of investment, the expected payoffs, and the variability of the expected payoffs have to be estimated. The variability of return, in particular, is difficult to predict.

In the next phase, a system dynamics model helps to estimate the parameters of the real options model. The SD model allows us to map the impact of the new investment on all business processes, and to identify and quantify the benefits of such an investment in an organization. Simulating the SD model leads to producing the data needed to estimate the variability of the benefits/payoffs of such an investment. Given the estimated parameters, the real options model can recommend the best time to invest in this technology.

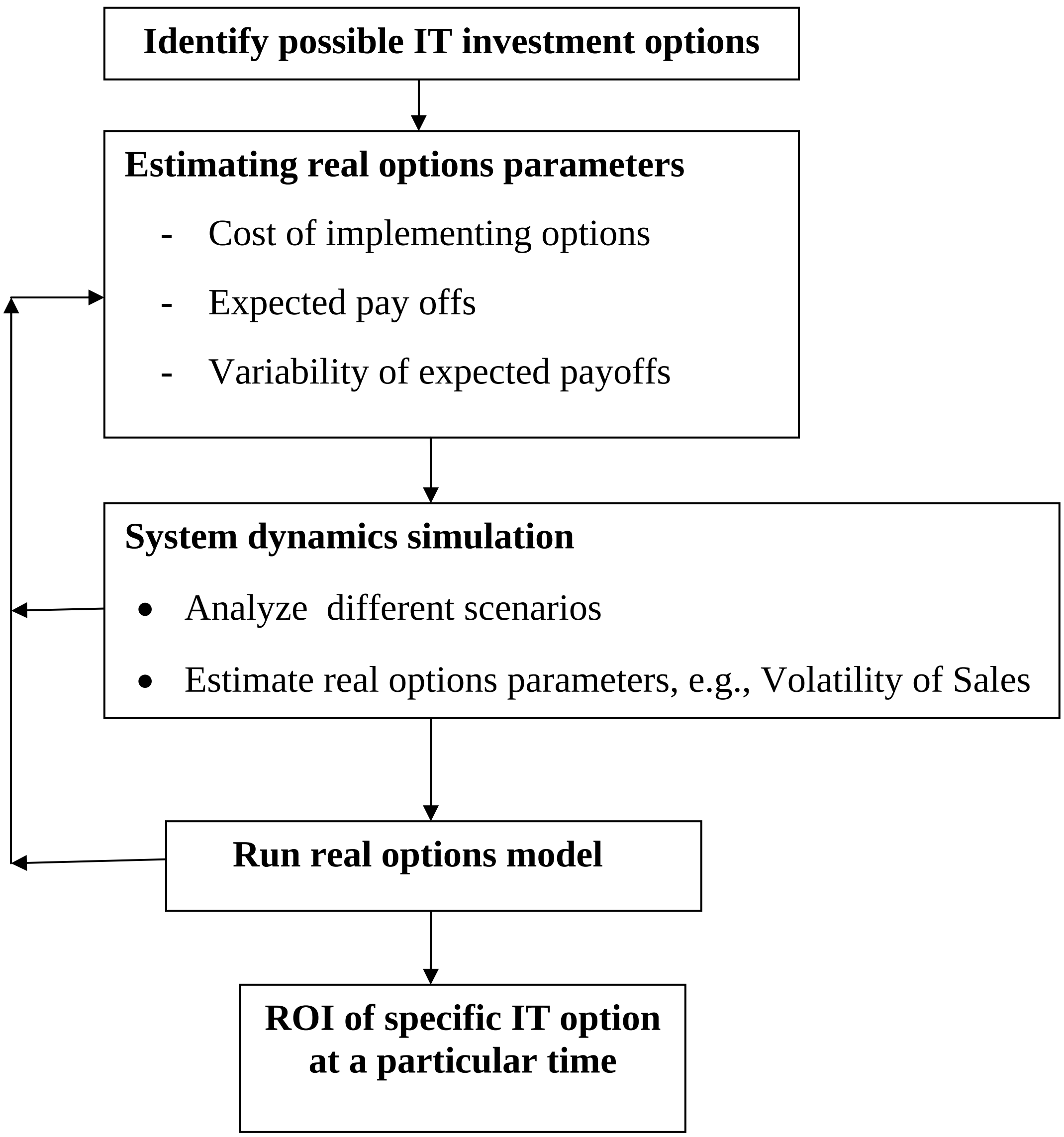

Figure 5 Hybrid ROI model

Research Contributions

Both real options and system dynamics have been used in economic analysis of IT investments independently. However, combining these two techniques develops a robust model that can take advantage of the strengths of both techniques. Using a simulation model allows us to generate estimates of costs and benefits for a new technology that has never been tested in practice on a large scale. The simulation allows us to analyze real life scenarios that are time consuming and expensive to do in practice. Furthermore, the results of the simulation is used to set up the parameters of the real options model. The real options model has much strength but most importantly for us, it takes into account the managerial flexibilities of IT investment such as the postponing option. The proposed hybrid model is unique in integrating two major techniques in the area of the economics of IT.

This study applies the hybrid model to a challenging IT investment problem in the retail sector. Item-level RFID is going to be the next generation of auto identification in retailers. This application allows us to see how this model can help managers overcome the complexity and uncertainties in investment timing. The practical aspect of this study is that managers can picture how their investment in various areas leads to different levels of benefits and when those benefits are achieved.

In summary, this hybrid model borrows theories and concepts from multiple domains: an option theory in finance is combined with an IT application in the retail and marketing domain. In addition, multiple research methods are applied throughout the study. A qualitative study (Delphi technique) is used to build a conceptual model for simulation and quantitative analysis by real options. All of these make the hybrid model a robust and innovative model that can be applied to any IT investment problem.

This chapter introduced the topic of the research, outlined the need for the study, and described the theoretical and practical contributions of this research. The next chapter reviews the literature in retail operations, system dynamics, and real options. In chapter 3, the research methodology is presented and the Delphi study and its results are explained. Chapter 4 describes the simulation model and includes the analysis of various scenarios. The real options model is discussed in chapter 5. Chapter 6 concludes the dissertation by elaborating on its contributions, limitations, and future directions.

CHAPTER II

LITERATURE REVIEW

RFID in Retail Management

The first wave of technology that changed retail operations management significantly was Point of Sale (POS) systems with barcode scanning. These systems provided information on customers' purchases which was useful in managing inventory, the supply chain, promotions, and advertising (Fraza, 2000). The next generation of technology for retailers, RFID, can provide information to track customers as they enter the store, walk through the aisles, search for and select items, and finally purchase them. In RFID technology, radio waves automatically detect items, reading multiple items simultaneously and instantly. Items containing RFID tags do not need to be "in the line of sight" of the readers, but can be read from a few feet afar. Therefore, RFID is intended to replace or supplement barcodes in retail operations management (Karkkainen and Holmstrom, 2002; Prater et al., 2005).

There are two types of RFID tags: active and passive. A passive tag is less expensive and does not contain a battery (Rawal, 2009). Power from the tag reader activates it and extracts information upon request. Passive tags must be within meters of the reader to be detected. Active tags, on the other hand, have a battery. They are more powerful and can be detected within a longer range from the reader but are also more expensive. For item-level RFID in retail situations, passive tags are probably more appropriate in terms of costs as well as functionality (Prater et al., 2005; Gaukler et al., 2007).

Given these flexibilities in using RFID technology, retailers need to see how item-level RFID improves retail management. Retail operations management includes 6 major elements: store factors, service factors, merchandise management, pricing, supply chain management, and technology (Krafft and Mantrala, 2006). Deploying RFID at the item level has a one-time fixed cost associated with the infrastructural equipment, such as readers. However, in a cost benefit analysis, the total cost (variable + fixed) of an investment has to be justified based on all its benefits. Implementation of this technology impacts all retail operations and benefits them in different ways. Following is a brief review of potential advantages of RFID to each element in retail management.

Store factors are those conditions that help customers have a more pleasant shopping experience. For example, locating items more quickly or faster checkout makes consumers feel more efficient in their shopping.

Service factors are determined mainly through the level of convenience for the customer. In RFID equipped stores, for instance, a Personal Shopping Assistant (PSA) with a touch-screen equipped tablet PC is attached to each cart. These PSAs provide “decision convenience” by offering information about each item, “access convenience” by locating items needed, and “transaction convenience” by automating checkouts and returns. All of these factors enhance customer service in a retail store (Krafft and Mantrala, 2006).

Merchandise management intends to provide items for customers when customers need them. RFID helps to manage the availability of items on the shelves. Real time monitoring of items on the shelves gives better information visibility to store managers. In addition, reducing out-of-stock problems, and increasing inventory accuracy, together guarantee that items are available on time, meeting customer demand and enhancing the merchandise management process (Doerr and Gates, 2003).

Pricing can also be improved through RFID deployment. Price is one of the major factors in increasing retailers' profit. Among retailers, there has been a paradigm shift from price optimization to pricing process improvement. Pricing optimization models in microeconomics are intended to determine the optimal price of products to maximize the profit. A pricing process, on the other hand, is the decision-making process that involves one or more price components such as discounts, rebates, and bonuses to determine the final price of a product. With real-time information provided by RFID, retailers can observe customers' shopping behavior and use this information to help set the initial pricing and markdown prices. Moreover, promotion and marketing will also change with real-time data focused on customers' behavior (Krafft and Mantrala, 2006).

Supply chain management is improved significantly by fewer out-of-stock occurrences and less inventory inaccuracy (Atali et al., 2005; Heese, 2007; Hardgrave et al., 2008). Information visibility provided by RFID decreases the uncertainty in the supply chain and consequently decreases high inventory costs and errors in forecasting the number of promotional items needed (Delen et al., 2007; Zhou, 2008). This area of research has been studied more extensively than other areas in retail management.

RFID offers a wide range of benefits and is the technology that can give a competitive advantage to retailers in managing stores (IBM, 2004). How item-level RFID influences all components involved in retail management needs to be studied comprehensively in order to measure the benefits of this technology in a cost benefit analysis. The benefits from different applications are either tangible (direct), such as those in the supply chain, or intangible (indirect), such as those in improving customer service. A decision to invest in RFID should take into account the future flexibilities afforded by the basic investment. Each future application of RFID is considered an extra value (option) that can be exploited through the basic RFID infrastructure. Of course, some of these options may not be employed at all, but the real options model discussed in the next section makes it possible to consider them.

Real Options in IT Investment

Information technology investments, similar to financial and other kinds of investments, involve a lot of uncertainties with regard to outcome, and thus it is hard to evaluate them at the beginning. IT investment payoffs are achieved over time and usually are reflected in both profitability and quality in an organization. An example of the former is when an IT investment leads to the speeding up of tasks, thus reducing the work force. An example of the latter is when an IT investment decreases the errors in task processing and thus increases the accuracy of task results (Devaraj and Kohli, 2000).

Traditional Return on Investment analysis approaches, such as Net Present Value (NPV) or Discounted Cash Flow (DCF), evaluate the discounted value of a new project in order to justify its budget. If a new project will enable some potential future projects, then the discounted values of all those projects are considered in the valuation of the new project. The problem with traditional approaches is that they do not consider managerial flexibility in their cost benefit analysis. For example, a manager could abandon a project if it is not profitable. A traditional approach is not able to incorporate the possibility that the manager might abandon the project in the future. Managerial flexibilities such as abandonment, expansion, deferment, and switching help managers handle the uncertainties of IT investments, and taking them into account can change the value of a new project (Tiwana et al., 2007). Not considering such flexibilities in the primary valuation of the project might change an in-the-money (profit) investment to an out-of-the-money (loss) project.

The relatively new real options technique is based on options theory in the finance area. An option is the right, but not the obligation, to buy or sell an asset within a certain period of time. Call and put options are two types of option contracts. A call option means that the holder of an option has the right, but not the obligation, to buy the option at a determined price (strike or exercise price) within a specified time period. On the other hand, in a put option, the holder of an option has the right, but not the obligation, to sell the option at an exercise price within a determined period of time.

Dos Santos (1991) suggests that real options can be utilized for IT investment valuation. He argues that most of the value of a new IT platform in a multi-stage project is obtained through future projects that use that technology. IT benefits are usually indirect and achieved over time through further applications developments (Renkema, 2000). A new IT platform does not make significant changes in the quality of service and performance factors, and thus its investment valuation probably shows a negative NPV.

However, future applications developed under the new platform can make significant changes, and considering them in the investment analysis can turn an out-of-the-money investment into an in-the-money investment. Future applications can be seen as growth options which can be considered within the managerial flexibilities (Dai et al., 2007). In an RFID deployment, for example, when a retailer purchases an RFID infrastructure, it also acquires call options to “expand” this new platform by developing and applying the technology in all of the retailer’s operations, such as check out, pricing, or supply chain management. This means that the retailer could exercise the options and expand this platform if the new platform works as expected. If not, the management has no obligation to exercise the options. Just as in financial options, the option’s strike price is the cost of new applications under the new platform. Other managerial flexibilities in operational decisions include “postponing” new applications, “switching to” another platform, and “speeding up” the project (Goswami et al., 2008). All these flexibilities can be considered as options, and from a real options perspective, all of them have to be included in the economic value of the new IT platform.

The Decision Tree Analysis (DTA) technique also accounts for uncertainty and managerial flexibilities in investment analysis. DTA, which can map out all alternative managerial actions in a tree structure, takes into account sequential investments with their probabilities at discrete points in time. However, real options are considered more useful for analyzing and considering managerial flexibilities in investment options with uncertainty for several reasons. A major reason is that a DTA model uses a risk-adjusted discount rate to obtain the net present value of various alternatives at each point in time. Finding risk-adjusted discount rates for different periods is a difficult task. The advantage of real options models such as the Black-Scholes model is that they use a risk-neutral discount rate to calculate the net present value of options (Trigeorgis, 1995).

Many studies in IT investment have employed a real options perspective (Kambil et al., 1993; Kumar, 1999; Benaroch, 2002; Clemons and Gu, 2003; Sambamurthy et al., 2003; Dai et al., 2007). The challenge in using real options pricing models, such as the Black-Scholes model, in IT investment analysis is estimating the parameters of the model (Benaroch and Kauffman, 1999). For example, it is difficult to measure the volatility of Return on Investments for a new technology such as item-level RFID because it has no record of performance and has been employed in industries only at the pilot level.

Guilford and Kutis (2005) indicate that RFID technology does not show a positive Return on Investment using traditional cost benefit analysis because traditional approaches cannot capture the real benefits of RFID. In their cost benefit analysis of RFID deployment, Whitaker et al. (2007) used the survey respondents' expectations of return for RFID investment, as opposed to capturing an actual return. Doerr et al. (2006) used subject matter experts' estimates as opposed to modeling the processes influenced by RFID. Parameters for more tangible benefits in the retail environment, such as reducing out-of-stock problems or inventory inaccuracy, can come from the literature (case studies or analytical models). However, estimating the parameters of the somewhat intangible benefits at the sales floor level, such as improved customer service, is more difficult. The tangible and intangible benefits to RFID- equipped retailers, such as those derived from improved price change processes, reduced labor led by automating business processes, and error reductions have not yet been reported in the literature. Thus the challenge of estimating all the parameters for applying a real options model still remains.

This study uses a system dynamics model to quantify the intangible benefits of item-level RFID by simulating the automation processes on the retailer's shop floor. The system dynamics model also serves to estimate and capture those tangible benefits of which there is not enough knowledge in the literature. This model can capture the variability of such intangible and tangible benefits based on context variables, e.g., the size of the retailer and available technological resources.

This ROI-model uses system dynamics to map all retail management operations affected by the implementation of RFID, in order to capture the changes in the dynamic elements. The SD model estimates the parameters of a real options model that is able to measure the values of strategic options available for development over a long time horizon. We next introduce and summarize the system dynamics literature.

System Dynamics in IT

System dynamics has developed a wide range of applications in many domains since being introduced by Forrester (1958) in industrial systems. He later expanded his work and used system dynamics to model and to simulate a classic supply chain (Forrester, 1961). Since then, system dynamics has contributed to theory building, problem solving, and research methodology. In methodological contributions, for example, SD has been used with operations research and management science approaches (Angerhofer and Angelides, 2000) where SD and operations research are considered complementary techniques in which SD can provide a more qualitative analysis for understanding a system, while operations research techniques build analytical models of the problem (Stotz and Grobler, 2006).

System dynamics has been used extensively in the area of information technology, which usually changes an organization's business processes and behavior. Using system dynamics, possible changes in organizations are projected and analyzed through conceptual models and simulations (Sterman, 2000; Gregoriades and Karakostas, 2004; Céline et al., 2005). The SD technique also has been used in evaluating IT investments: Marquez and Blanchar (2006) developed a system dynamics model to analyze a variety of investment strategies in a high tech company. Their simulation allows them to analyze strategies and trade-offs that are hard to investigate in real cases. A system dynamics model can capture IT benefits that are sometimes nonlinear and achieved over years (Dardanet al., 2006). However, only a few studies have used system dynamics to simulate retailers' operations (e.g. Lach, 2002). This study seeks to combine the SD modeling technique with the real options technique in order to value RFID technology for retailers. A system dynamics approach as a predictive tool maps complex relationships among the retail management processes into a model by which one can dynamically measure the effect of any changes in the parameters over time. This model measures the economic value of integrating RFID throughout the value chain in retailer operations, from supply chain management to pricing and customer service management (Curtin et al., 2007). The economic values from the SD model can then be used to estimate the parameters for the real options model.

Most SD studies have been case studies, where information and data are collected before the models are designed and simulated (Hafeez et al., 1996). The SD modeling here includes two phases: qualitative and quantitative. In the qualitative phase, a Delphi study was conducted to develop a conceptual model of a retailer's business flow. A qualitative study is necessary to acquire the conceptual knowledge about the business units, retailers' operations, and information flow throughout sales floors. Causal loop diagrams are system dynamics tools for presenting the cause-and-effect relationships in operations. The causal loop diagrams in this study are based on the literature and validated with experts' opinions from the Delphi study. In the quantitative phase, the conceptual model developed from this information is used to derive mathematical equations for the simulation. Simulating a dynamic model of retailer operations management allows us to analyze different scenarios in a retailer equipped with item-level RFID.

The MIS field is becoming a mature discipline in which the known techniques such as system dynamics and real options have been applied to many areas. Combining such known techniques brings new strength to the field, as the literature does not report many integrated techniques. This study attempts to build a new combined approach (SD plus Real Option) to overcome the weaknesses of each approach and to apply this technique to a new domain (RFID in retail). Retailing is a major area of study in marketing. Looking into the use of an information technology such as RFID in a marketing field such as retailing through applying a real options technique from finance combined with a system dynamics model from engineering is an extensive and broad effort in an MIS study using multi-disciplinary techniques.

CHAPTER III

RESEARCH METHODOLOGY

The research method for this study combines both qualitative and quantitative approaches. **Figure 6** illustrates the stages in the research framework. Qualitative approaches such as the Delphi technique are used for developing the conceptual model of retail operations management (causal loops and related parameters). The next step is to quantify operations factors in the conceptual model using the system dynamics simulation, i.e., deriving equations for the model and analyzing different scenarios. The results of the simulation indicate the various factors and parameters which are influenced by RFID technology and enable us to estimate the parameters of the real options model, such as the expected return and the variations in return on item-level RFID investment. The final step is to apply the theory of real options in order to find the best time for item-level RFID investment and to analyze various hypothetical and practical scenarios via the ROI model.

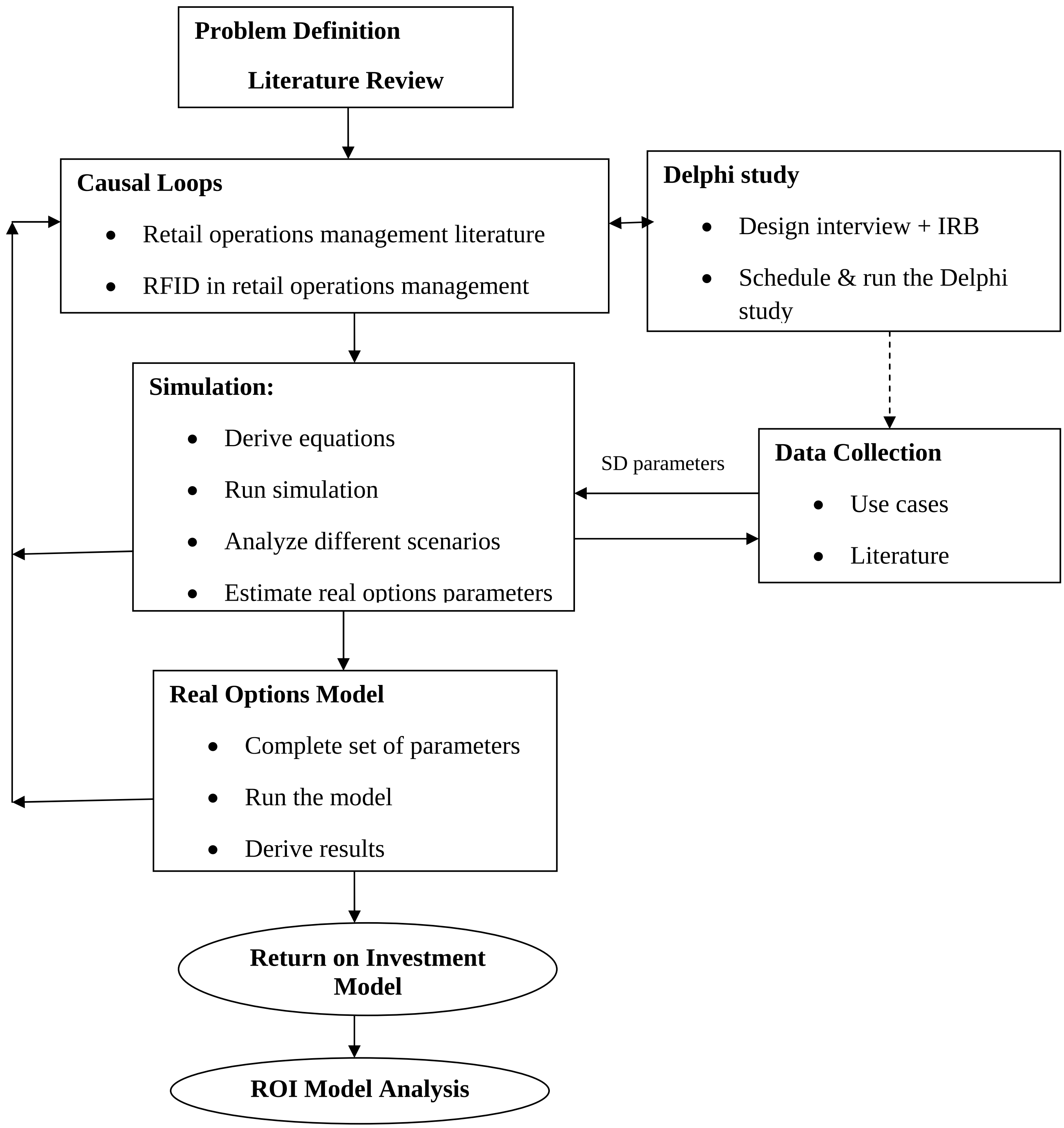

Figure 6 Research framework

Delphi Study

The purpose of the Delphi study in this research was to understand how item-level RFID influences the operations in a retail store. The Delphi technique involves a series of data collections to obtain feedback from a panel of experts and enable them to reach a final consensus. It allows us to collect data from a dispersed panel of experts as opposed to alternatives such as brainstorming and interviews that require face-to-face interactions. An IRB approval was obtained for conducting this study (attached at the end of this document).

The Delphi technique has been used in business research related to uncertainties in the performance of new projects and investments (Linstone and Turoff, 2002) and in exploratory studies in operations management (Malhotra et al., 1994; Akkermans, Bogerd, Yücesan, and Wassenhove, 2003; MacCarthy and Atthirawong, 2003; Ogden, Petersen, Carter, and Moncska, 2005). Malhotra et al. (1994) conducted a Delphi study to identify and rank major manufacturing issues in the 1990s. Ogden et al. (2005) used the Delphi method to identify future factors influencing the supply chain. Akkermans et al. (2003) looked into how Enterprise Resource Planning (ERP) systems can influence operations in supply chain management. MacCarthy and Atthirawong (2003), using a Delphi study, identified factors influencing location decisions in international operations.

Selection and Size of the Panel

Panel size and the qualifications of the experts are two issues in a Delphi study (Linstone and Turoff, 2002; Delbecq, Van De Ven, and Gustafson, 1975). A literature review by Reid (1988) shows that there is no recommendation for a specific sample size, and the size of panels in the studies reviewed varied from 10 to 1,585. Murphy et al.

(1998) show that as the number of experts increases, the reliability of the panel judgments increases as well. However, they mention that there is no evidence on the relationship between the reliability and validity of the final consensus and the size of the panel. In a Delphi study, the expert panel is not intended to be representative of the population for statistical purposes (Powell, 2003).

Some criteria are proposed in the literature for selecting qualified panel members, such as a high commitment to collaborate with the team until the end, when a consensus is reached. Panel members were chosen based on their knowledge in research and their experience in practice. Every panel member was involved in some RFID implementation.

Heterogeneity among the panel experts protects the judgments from being dominated by a specific member or subgroup in the panel (Linstone and Turoff, 2002; Scavarda et al., 2006). Twelve senior retail experts who have been involved in item-level RFID case studies in the retail sector were invited to participate and ten of the twelve agreed to join the panel. All participants in this study remained anonymous in order to reduce bias in the responses to the questionnaire. Four experts were from consulting companies in RFID and six were from nation-wide retailers, so their expertise covered a wide range of categories in retailers. The retailers were from leading apparel stores as well as giant grocery stores. The potential benefits of item-level RFID have been discussed in the literature, and consultants are usually the advocates of such benefits but retailers are skeptical by nature. Forming such an expert panel was difficult, given that not many pilot studies have been done so far and it was particularly important that both consultants and retailers evaluate the benefits of item-level implementation.

Questionnaire

The questionnaire (APPENDIX A) included open-ended questions based on causal loop diagrams derived from the literature in various areas of retail operations, including the store execution of supply chain, marketing, and merchandising, as well as analytical and empirical item-level studies. As mentioned earlier, the purpose of the Delphi study was to validate these causal loop diagrams.

Level of Consensus

One criterion for stopping the data collection series is if there is no significant change in the experts' opinions from one round to another. However, if no consensus is reached at this time, the coordinator/researcher in the Delphi study will, through his/her feedback, encourage the group to make changes in their opinions. A consensus is reached if the scores or opinions centralize.

The Delphi study was conducted in two rounds and over a period of four weeks. In the first round, six experts were interviewed over the phone and four were interviewed in a face-to-face meeting. Face-to-face interviews took about an hour and thirty minutes, and phone interviews took about 30 minutes. The second round was done through email; experts expressed their opinions on the summary of the first round and finally reached a consensus in this round.

Delphi Study Results

This section describes the validated causal loop diagrams that show how item-level RFID impacts retail operations management in three areas: supply chain, marketing, and merchandising. The results of the Delphi study are presented in two parts. The first part presents the cause-and-effect relations confirmed by the experts in the causal loop diagrams. The second part presents the divergence in opinions among the experts. While the experts agreed on causal relationships, they varied in the weights they assigned to those relationships depending on their particular retail contextual factors. The following sections report the Delphi study findings in more detail.

Introduction to causal loop diagrams

Causal loop diagrams show the relationships between variables in a system. A link between two elements shows that changes in one element lead to changes in the other one (Figure 7). The direction of the link shows the direction of influence between two elements. For example, in Figure 7 an arrow from customers to revenue shows that if the number of customers changes, then the revenue will change as well. The sign of each arrow shows the direction of change between each pair of elements. A positive sign means both elements change in the same direction while a negative sign means the elements change in opposite directions. For example, in Figure 7 a positive sign on the connection from customers to revenue implies that both elements change in the same direction. i.e., a higher number of customers increase the revenue just as a lower number of customers decrease the revenue. Sometimes an entity impacts another with some delay (Figure 8, shown by cross lines on the connections). For example, a higher number of customers leads to immediate increases in sales and profit, but the positive connection between customers and staffing (more staff hours are needed to manage more customers) is delayed because more staff cannot be hired immediately upon an increase in the number of customers.

Feedback processes in the causal loops are the key components by which a variable re-affects itself over time through a chain of causal relationships (Figure 8). For example, there is a positive loop connecting staffing, service factors, and customers: if the number of customers increases, then more staff is needed. On the other hand, more staff leads to better service in the store and consequently attracts a higher number of customers. A positive feedback loop occurs when an element such as the number of customers influences itself positively over time.

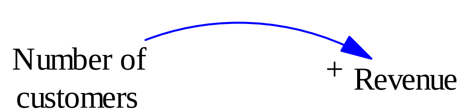

Figure 7 Positive relation in causal loops

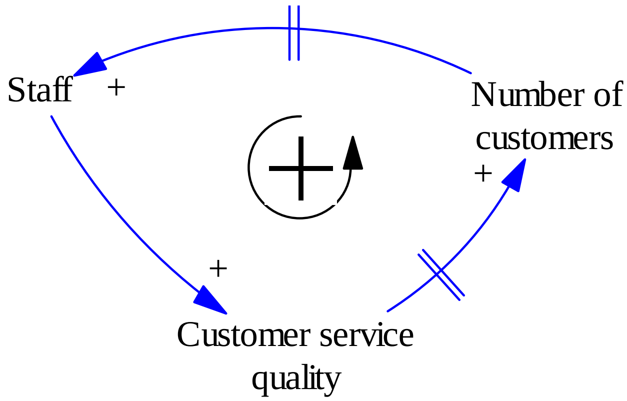

Figure 8 Feedback loop and relationships with delays

Supply chain management causal loop

The store execution of the supply chain, i.e., every operation involved in inventory/shelf control and management, from receiving items from distributors to delivering them to customers, was examined. Retailers can take advantage of item-level RFID to track their individual products on shelves and in the backstore (Kambil and Brooks, 2002). Item-level RFID provides different levels of information visibility, depending on various deployment levels. This study looks at three levels of enhanced information visibility: automatic PI, real time visibility, and storewide visibility. These visibility levels lead to the same type of benefits but to different extents (Figure 9). The benefits include improving inventory accuracy and reducing Out of Stock (OOS) by managing shrinkage, reducing forecasting errors, reducing transaction errors, and saving labor in the supply chain operations. These benefits result in more customers who can purchase their desired products and consequently increase sales.

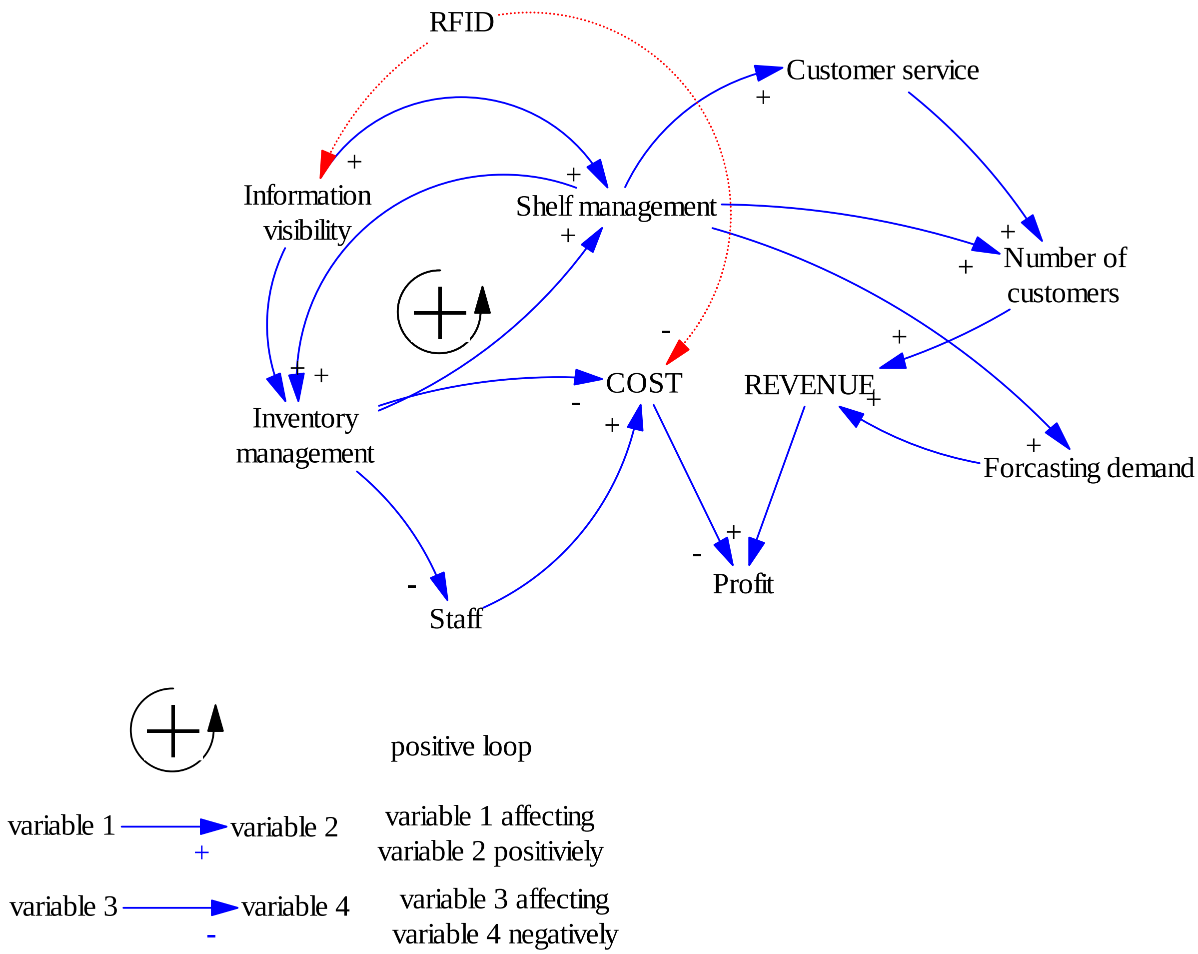

Figure 9 Supply chain management causal loop

Automatic PI

In the lowest level of enhanced visibility, the backstore inventory management process is improved by providing readers in the backstore and at Point of Sale (POS). Inventory records are updated at the backstore entrance/exit doors and at POS when an item is purchased.   Cycle counting and Perpetual Inventory (PI) are performed automatically through the use of handheld readers, which work much faster than manual operations. The visibility of items in inventory improves inventory accuracy, and the record of items on the shelves is more accurate. Shrinkage, including theft and misplacement, is detected easily and more often through automatic PI. This level of deployment seems to have the lowest cost and fewest technical restrictions among the three levels. Case studies of Dillard's (Hardgrave, 2009a), American Apparel (2009), and Bloomington's (Hardgrave, 2009b) have measured the benefits of item-level RFID on inventory management in retail stores when handheld readers are used in PI and cycle counting, in addition to readers at the POS and backstore exit/entrance doors.

Real time visibility

The second level of enhanced visibility occurs when smart shelves are added to the previous level. This level provides real-time shelf visibility on the store floor as well as at the back of the store and, compared to the first level, further improves inventory accuracy, shelf replenishment, and loss detection (Doerr and Gates, 2003). The visibility of items on shelves leads to real-time detection of misplacement and theft and thus adjustment of the inventory level. Shelf visibility also allows retailers to monitor customer shopping behavior to some extent. A case study conducted at Tesco in the UK, which implemented smart shelves to track DVDs and software games, discusses how this tool can boost customer satisfaction (Berthiaume, 2004). However, the cost of deploying smart shelves is significant. In addition, some practical issues with smart shelf mobility have delayed their use even at the pilot levels.

The Delphi study experts confirmed the results of analytical research that shows RFID adoption at the shelf level can release shelf space and reduce inventory holdings (Szmerekovsky, Tilson, and Zhang, 2009) because shelf replenishment can be done more frequently. In addition, inventory inaccuracy is reduced because misplacement and theft are detected faster and execution errors are lowered. In particular, when demand uncertainty increases, enhanced item-level visibility on the shelves enables retailers to improve performance compared to retailers without such visibility.

Storewide visibility

The storewide level of RFID implementation provides maximum information visibility and contributes to inventory management to an even greater extent than do the other two levels. For example, if items are misplaced, they can still be detected with this level of visibility. In addition, benefits such as identifying customer shopping behavior and preventing theft by detecting patterns are achieved at a much higher rate. Tools such as smart dressing rooms, smart carts, and automatic checkouts can all be provided more easily with storewide visibility. No pilot study or analytical models that investigated the potential benefits at this level of visibility were found.

Marketing management causal loop

The purpose of marketing operations is to promote goods and services within the store. Three processes involved in marketing operations were examined: customer shopping experience, promotion planning and execution, and pricing management. All three have been influenced by RFID-enabled changes (Figure 10).

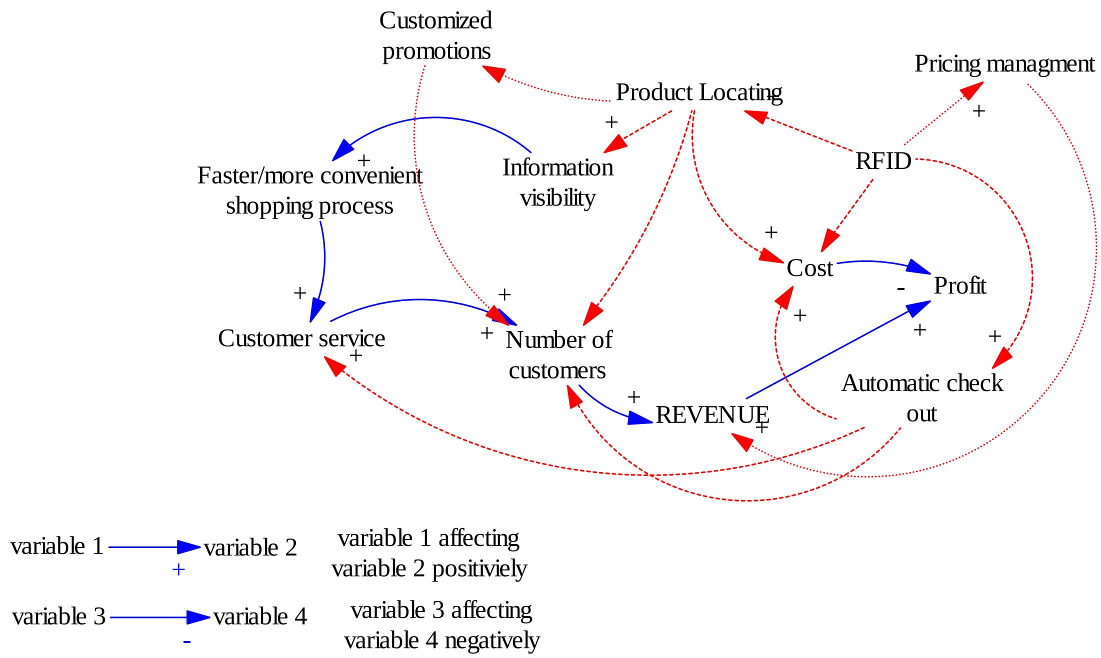

Figure 10 Marketing management causal loop

Customer shopping experience

Various applications of enhanced visibility in stores can transform the customer shopping experience. For example, shopping carts and dressing rooms can be equipped with RFID readers and touch-screen monitors that allow customers to search for information on products and locate items throughout the stores. A few use cases studies have been conducted on the impact of RFID on customer shopping experience. For example, a small apparel store in Ohio (Industry Standard Store) deployed smart dressing rooms to investigate their feasibility and effect on the customer shopping experience. The study showed that such applications of item-level RFID are attractive to customers, particularly to young people. Retailers are just starting to experiment in this area.

There are also some case studies (by the Metro group) on how RFID tools such as smart carts or smart dressing rooms can make customers' shopping experiences faster and more convenient (Krafft and Mantrala, 2006; Frédéric et al., 2009). Assuming that inventory management has deployed item-level RFID in its operations, smart carts, smart dressing rooms, and automatic checkout all contribute to speeding up shopping and providing a more convenient shopping environment. These tools also free up staff time. For example, in automatic checkout, the time previously spent in manually checking out customers can be spent providing better customer service.

The impact of RFID on customers' shopping experience is primarily related to the customers' response, either positive or negative, to RFID tools. Automatic check-out, smart carts, or smart dressing rooms/kiosks are all changing the way customers behave in stores. This study looks into the effects of RFID tools assuming that the customers' responses to the deployment of these RFID tools are positive.

Automatic check-out

Automatic check-out charges customers' accounts automatically when customers pass through the check-out lines so customers spend less time in check-out lines and feel more efficient. In addition to saving time for customers, automatic check-out saves labor that can be spent providing customer service. It also reduces check-out (transaction) errors by removing manual operations.

Product-locating tools

One application of RFID at the item level is helping customers locate the products they need. Product-locating tools such as smart carts, smart dressing rooms, or kiosks, enable customers to locate products more easily and obtain information on any individual item faster. Customers can find answers to most of their questions regarding product availability and location. A faster and more convenient shopping experience changes the store image and, in the long term, increases the number of customers.

Promotion planning and execution

In addition to the benefits to customers mentioned above, retailers can monitor and identify patterns of shopping in their customers. For example, useful information can be derived from the type, size, and color of items that customers take to the dressing rooms. These patterns help retailers design their display items according to their customers' needs.

Promotional discounts and bonuses at both the individual/customized level and the store level can be managed more efficiently in stores equipped with item-level RFID. Loyalty cards, which give retailers information about their customers' behavior, have been around for a while, but RFID tools such as smart carts or smart dressing rooms allow retailers to offer a better set of promotions and complementary deals and bonuses. In barcode systems, customers' shopping lists are revealed at the point of sale, when customers check out. RFID, on the other hand, can provide a list of items that customers intended to buy through the data collected on customers' searches, even if they did not. This list might be different from the POS list for various reasons such as unavailability of items on shelves. In addition, promotions are currently offered to customers after they receive their receipt; with RFID, the bonuses and promotions are offered before the POS, while the customer is still shopping and has a higher chance of using them. Moreover, given the enhanced store visibility, storewide discounts and promotions are offered, and monitored in order to guarantee item availability and avoid OOS.

Gillette and Wal-Mart (EPC Global, 2008) conducted use case studies to measure how much sales improved through better promotion execution. They monitored the promotional items in distribution centers, the backstore, and promotional displays to provide the items on time and avoid OOS and achieved a 19% increase in their sales.

Pricing management

The Delphi study experts believed that enhanced information visibility does not change the original price of items. However, enhanced information visibility on shelves and in backstores leads to fewer and lighter markdown prices. About 30% of items are not placed on shelves in a timely manner and thus stay in the backroom so long that they come to the floor at already marked-down prices (Aberdeen Group, 2008). On-time and fast shelf replenishment increases the number of items sold at full price and decreases the number of markdowns. This benefit results in a higher average price for each product and directly increases the revenue.

Merchandise management causal loop

Merchandise management intends to provide items for customers when customers need them, and RFID helps to manage that effort (Doerr and Gates, 2003). Enhanced visibility of items on the shelves helps store managers increase the availability of the products to customers. In addition, improved shrinkage management and improving assortment management enhance the merchandise management process (Figure 11).

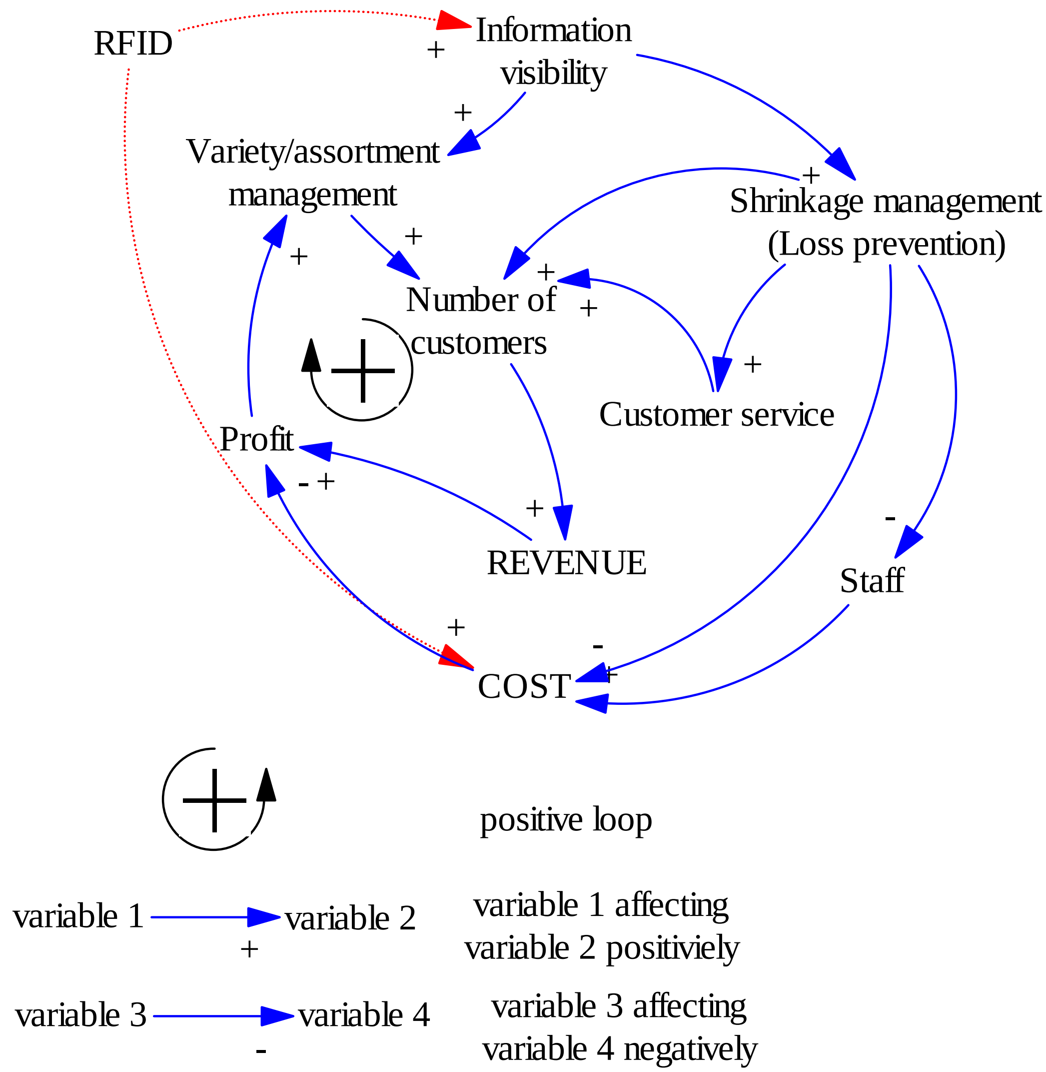

Figure 11 Merchandise management causal loop

As mentioned by Szmerekovsky et al. (2009), enhanced visibility of shelf information reduces the shelf space needed for an item and releases capital by reducing the inventory holdings. Therefore, retailers, using the extra capital and space, can offer a wider range of items.

Enhanced information visibility and applications such as smart carts and smart dressing rooms also help managers determine what products are complementary. For example, loyalty cards provided by RFID enable retailers to monitor customers' behavior as they enter a store and look at different products. This monitoring helps managers select a more appealing variety and assortment of products. However, the experts mentioned that designing the shelves and determining the variety and assortments are not part of retail store operations. Those decisions are usually made by a centralized marketing operation within retailers but across stores.

Divergence of opinions

Interviewing a diverse group of retail experts revealed that the retail environment is a major factor affecting the magnitude of RFID-enabled changes in retail operations. Although the experts' opinions converged and confirmed the performance measures and causal loop diagrams, they supported different degrees of strength in the relationships. Factors such as customers' and managers' attitudes towards this technology, the size of the inventory, and existing technology and practices, for example, determine the extent to which item-level RFID can influence operations. Managers, staff, and consumers' responses to this technology may be the most important organizational key to achieving any RFID-enabled changes in retail operations. Customers' privacy concerns and their willingness to use smart dressing rooms, automatic checkouts, and smart carts influence most of the benefits achieved through marketing and merchandising (Roussos, 2006).

In the supply chain, retailers with large backstores suffer from inventory inaccuracy that consequently leads to OOS and demand forecast errors. Thus, an item-level RFID solution primarily in the supply chain operations leads to significant improvements that are not considered as important by retailers with small backstores, who do not encounter such problems in their supply chains. However, retailers with small backstores are more concerned with the promotions and advertising that can be achieved, for example, by implementing smart dressing rooms/kiosks in their marketing and merchandising operations. In addition, retailers with small backstores replenish shelves directly when shipments are received from distribution centers. In such situations, shelf information visibility does not lead to faster shelf replenishments, and therefore there is no effect on variety and assortment management. Thus, the size of the backstore determines whether the supply chain or the marketing merchandising is a priority in item-level implementation.

Another environmental factor is existing technology and practices. For example, if Electronic Article Surveillance (EAS) is not currently used, then item-level RFID plays the role of a surveillance technology. If traditional EASs are already used, RFID can coexist with them; however, it might not replace them. Some experts thought that both current EASs and RFID should work together. They believed that the current EASs are important in order to threaten shoplifters by their size and visual deterrance. Also item-level RFID makes it much easier to offer time-sensitive promotions to customers. In pricing management, for example, some retailers such as Kmart and Kohl’s currently use half-day promotions in their pricing. The contextual factors determine the priority of each area such as marketing, merchandising, and the supply chain in implementing RFID. In fact, various types of retailers may focus on implementing item-level RFID in different dimensions depending on industry factors such as the size of inventory and their existing technology and practices.

The Delphi study results, derived from experts' opinions in the retail industry supported by the literature and case studies in the field, indicate that benefits in merchandising and marketing may not be realized as directly as those in the supply chain, but one should not underestimate their effects.

In the next chapter, the validated causal loop diagrams are translated into mathematical equations in order to generate quantitative data and measure the benefits of item-level RFID in various areas of operations.

CHAPTER IV

A SYSTEM DYNAMICS SIMULATION MODEL OF RETAIL OPERATIONS

This chapter discusses the system dynamics model of retail operations. A review of system dynamics modeling in the IT literature is followed by a description of the system dynamics (SD) model for retail operations in more detail. The model includes the stock-and-flow diagrams for different item-level RFID initiatives, constant and stochastic parameters, and outcome variables. The results of the simulation are presented at the end.

System Dynamics in Retail Operations

Simulation and modeling are used when pilot studies and experimenting with real systems are expensive or sometimes impossible. Simulation models allow us to investigate various interesting scenarios before making any investment. In fact, in simulations, the real-world operations are mapped into the simulation model. The model consists of relationships and consequently equations that all together present the real-world operations. The results of a simulation model, then, depend on the set of parameters given to the model as inputs. There are various simulation paradigms such as discrete event, agent based, or system dynamics. One of the factors that determine the type of simulation technique is the level of abstraction in the problem. Discrete events and agent-based models are usually used for middle or low levels of abstraction. They usually consider individual elements such as people, parts, and products in the simulation models, whereas system dynamics models are macro-level simulation models in which aggregate values and trends are considered (Borshchev and Filippov, 2004).

System dynamics was first introduced by Forrester (1958) to address problems in industrial systems. He later expanded his work and used system dynamics to model and simulate a classic supply chain (1961). SD has also been used in operations management such as in supply chain management. Angerhofer and Angelides (2000) present taxonomy of research studies on SD modeling in supply chain management. These studies look at the effect of various factors such as lead time, demand amplification, ordering policies, etc. on the performance of supply chains from manufacturers to retailers (Barlas and Aksogan, 1996; Anderson et al., 1999; Akkermans et al., 2003; Angerhofer and Angelides, 2006). For example, Barlas and Aksogan (1996) in a case study along with an SD simulation show how product diversification increases sales by better meeting customer expectations and at the same time increases lost sales as a result of lower stock levels held for each product. Most SD models in the literature look into the effects of various parameters along the supply chain, i.e., the coordination of operations from manufacturer, distribution center, retailer, and final customer (Barlas and Aksogan , 1996; Hafeez, et al., 1996).

This study develops an SD model for retail operations management that includes modeling the operations in marketing, merchandising, and store execution of supply chain management. This model intends to explore how item-level RFID can change retail operations. The system dynamics model is described in detail in the next sections.

Retail Operations System Dynamics Model

In system dynamics modeling, validation of the structure is the most important part of the study (Barlas, 1994). Causal loop diagrams, as the conceptual model of the operations representing the cause and effect relationships, should be validated. Given the validated causal loop diagrams from the Delphi study, the next step is to build stock-and-flow diagrams (SFD) in order to derive the equations in the simulation model. SFDs represent the relationships in more detail than does a causal loop diagram. Stocks are fundamental elements that generate behavior in systems, and flows or rates are what make stocks change (Figure 12). For example, inventory in the backroom is a stock. Rates of shipment arrival and shelf replenishment are two flows that change the inventory level. The inventory level is increased if shipments arrive and is decreased if items leave to replenish shelves. Major stocks need to be identified and, based on the causal loops diagram (CLD), the flows are identified and the SFD is completed in order to derive the equations. SFDs are built for three processes: one to model backstore operations management, one to map shelf operations management, and a third one to present marketing and merchandising operations management. Because these three SFDs are interrelated, the comprehensive retail operations model integrates the SFDs into one model. The stocks considered in retail operations are backstore inventory, shelf items, number of customers, sales, lost sales, and staff level in the store. The relationships described in CLDs change the levels of these stocks and are implemented through the flows in SFDs. For example, a theft event decreases either inventory level or shelf level while it also decreases sales. Some stocks that have close relationships with the major stocks, such as “Sale” stock, are included in these three major diagrams. Integrating these SFDs produces   a comprehensive SFD for retail operations that are influenced by item-level RFID. The following sections discuss SFDs for shelf, inventory, and marketing/merchandising management.

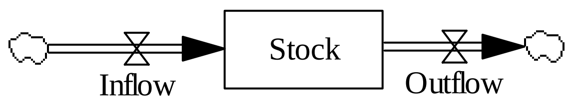

Figure 12 Stock-and-Flow Legend, Inflow and outflow changing the accumulation of the stock

Shelf management stock-and-flow diagram

The stock-and-flow diagram in Figure 13 maps shelf operations in retail stores. Items on shelves are brought from the inventory and purchased by customers. When the number of items on a shelf reaches a minimum level, a replenishment request is sent to the backstore, and shelves are filled if enough items are available. Customers come to the store on a daily basis and purchase items if they are available on the shelves. There are two major stocks: one represents the shelf level on record; the other represents the real number of items on shelves. Any discrepancy between these two levels is caused by theft, misplacement, and transaction errors. RFID visibility can decrease the discrepancy between shelf records and the real situation by a percentage that is set as the RFID visibility parameter. If this parameter is equal to 1, there is perfect visibility on shelves, i.e., no discrepancy; if it is equal to zero, there is no RFID visibility. Moreover, there are frequent manual checks of the shelves when the shelf record is updated to the real number of items on shelves and consequently the discrepancy becomes zero.

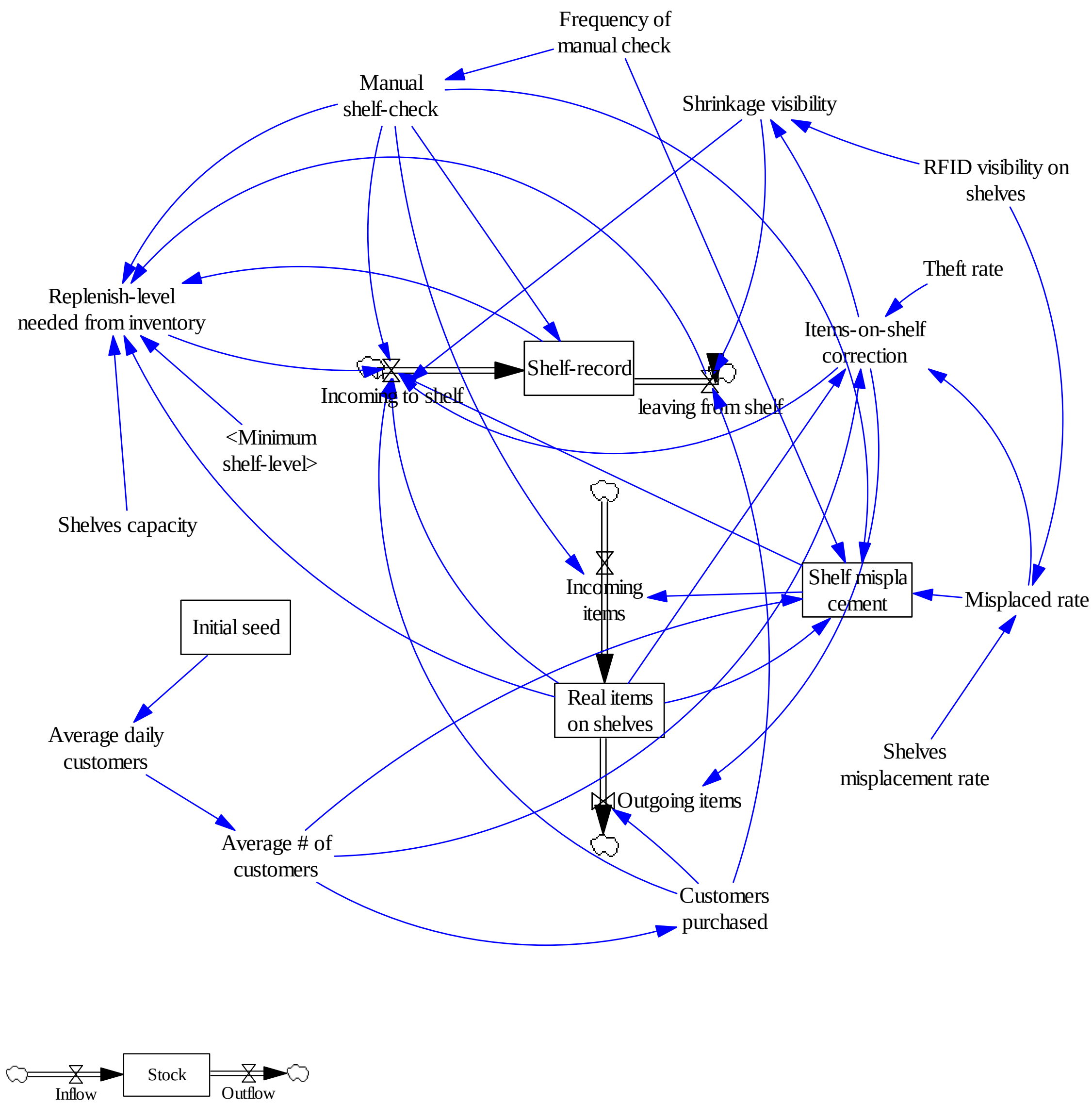

Figure 13 Stock-and-flow diagram for shelf management

Shelf replenishment (filling the shelves from inventory) is normally done if the number of items on a shelf (shown in the records) is less than the minimum number of items set as a parameter. Now, since there is some discrepancy between records and the real situation, the system may not show that the shelf level is below the minimum. An OOS event happens if customers need to take items from shelves but the shelves are empty (as shown in 'real items on shelves' stock) However, since the shelf records are not updated, the store staff do not realize that there is an OOS condition and shelves are not replenished. The number of customers who were not able to purchase items during the OOS is stored and accumulates over the simulation horizon. As RFID visibility increases, the discrepancy decreases and OOS events decrease as well. In addition, if RFID visibility increases, stores can conduct fewer manual checks and save labor hours.

Inflows are those events such as shelf replenishment that increase the level of a stock, i.e., the shelf level. Outflows are those events such as customer purchase that decrease the level of a stock, i.e., the shelf level. All the relationships in the stock-and-flow diagram have to be translated to mathematical equations. The following are the equations used in the shelf management stock-and-flow diagram.

Shelf-record (t) = Shelf-record (t-dt) + IF (Manual shelf-check=0)

THEN –Shelf_record (t-dt) + (Incoming to shelf - leaving from Shelf) *dt

ELSE Incoming to shelf - leaving from Shelf) *dt

Inflows

Incoming to shelf = IF replenish_level needed from inventory=0

THEN IF Manual shelf-check =0

THEN IF items_on_shelf correction = Shrinkage Visibility

THEN Real items on shelves +shelf misplacement

ELSE IF Shrinkage Visibility =0

THEN +Real items on shelves + shelf misplacement_items_on_shelf correction

ELSE Real items on shelves +shelf misplacement_items_on_shelf correction + Shrinkage Visibility

ELSE available Shelf_replenishment items

ELSE IF Manual shelf_check=0

THEN Real items on shelves + shelf misplacement_items_on_shelf correction + available Shelf_replenishment items - Customers purchased

ELSE available Shelf-replenishment items

Outflows

Leaving from Shelf = Shrinkage Visibility + Customers purchased

Real items on shelves (t) = Real items on shelves (t-dt) + (Incoming items-Outgoing items) * dt

Inflows

Incoming items = IF (Manual shelf-check=0)

THEN shelf misplacement + available Shelf_replenishment items

ELSE available Shelf_replenishment items

Outflows

Outgoing items = items-on-shelf correction + Customers purchased

Shelf misplacement(t) = shelf misplacement (t - dt) +

IF (Frequency of manual check=Manual shelf-check)

THEN - shelf misplacement (t- dt)

ELSE IF (Real items on shelves> 0)

THEN (Misplaced rate*Average # of customers) * dt

ELSE 0

Auxiliary variables

Manual shelf-check = IF (Manual shelf_check=0) THEN Frequency of manual check ELSE -1

Shrinkage Visibility = items-on-shelf correction*RFID visibility on shelves

Customers purchased = Average # of customers - Shelf OOS

Average daily customers = RANDOM NORMAL(12, 48 , initial seed, 9 ,initial seed)

Average # of customers = Average daily customers*(1+rate of sales improvements for product locating tools)

replenish-level needed from inventory = IF Manual shelf-check=0

THEN IF (Real items on shelves - leaving items) <=Minimum shelf_level

THEN Shelves capacity - Real items on shelves + leaving from Shelf

ELSE 0

ELSE IF Shelf-record -leaving from Shelf)<=Minimum shelf_level

THEN Shelves capacity – Shelf_record + leaving from Shelf

ELSE 0

Misplaced rate = (1-RFID visibility on shelves)*shelves misplacement rate

Shelf OOS = IF (Real items on shelves<Average # of customers)

THEN IF (Real items on shelves<0),

THEN Average # of customers

ELSE Average # of customers - Real items on shelves

ELSE 0

There are generally two types of OOS: “not in the store” and “in the store but not on shelves” (Gruen and Corsten, 2008). The OOS on shelves shows that items are not on the shelf but it does not show whether they are in the backstore. A store OOS may happen when there is a forecasting demand error where the number of items in the inventory is not enough to meet the expected demand.

Item-level RFID speeds up manual counting operations and saves labor time significantly. However, retailers are not looking at the monetary value of reduced staff hours; they just consider this benefit as an opportunity for staff to serve customers and improve customer service.

Table 1 lists the parameters of the shelf operations model. The shelf capacity, minimum shelf level, frequency of manual check, RFID visibility, and daily number of customers are the constant parameters in this model; misplacement, theft, and transaction error rates are stochastic parameters similar to theft/misplacement rates in the inventory model (Raman et al., 2001; Fleisch and Telkamp, 2005). The daily number of customers is also a stochastic parameter with a normal distribution (Gaukler et al., 2007).

Table 1 Shelf operations model parameters

Process	Parameters	Assumed values	Reference
Shelves operations	RFID visibility on shelves	Store specific	
	Frequency of shelves manual check		
	Staff-hour per manual check		
	Shelves capacity		
	Minimum shelf level		
Shelves operations	Rate of misplacement on shelves	Uniform distribution (0,.05)	Raman et al. (2001); a median of 3.4% of SKUs not found on sales floor, Fleisch&Telkamp (2005), used default 2% of items as misplaced
	Rate of theft on shelves	Uniform distribution (0,.05)	1 to 5% of inventory, Fleisch&Telkamp (2005), default 1.5%; Significant lost at 5%
Incoming customers	Daily # of customers visiting stores	Store specific	Gaukler et al., 2007

Inventory management stock-and-flow diagram

The stock-and-flow diagram in Figure 14 presents the simulation model for operations in the backstore. It includes placing orders if the level of inventory reaches the reorder point and receiving the orders after the lead time has passed. Receiving a request for shelf replenishment sends items from the backstore to the shelves. Similar to the shelf management SFD, the diagram shows two stock levels for inventory. "Inventory Record" stock represents the inventory record that stores keep based on PI inventory systems and frequent cycle counting. "Real Items in Inventory" stock shows how many items really exist in the backstore. In this diagram, receiving order is an inflow and shelf-replenishment is an outflow. The inflow is triggered if the level of inventory reaches the reorder point. An order for a new shipment is placed, and new items arrive after the lead time has passed. The outflow is triggered by a request for shelf replenishment with a certain amount. Inventory inaccuracy is the discrepancy between the inventory level on the records and the actual number of items in the backstore. The discrepancy can be caused, for example, by theft or misplacement. Theft and misplacement are outflows from the actual inventory but they do not appear on the inventory record. RFID visibility rate (0-1) is a percentage that shows how close these two stocks are. For example, a perfect RFID visibility (= 1) means that all theft and misplacement is detected so there is no discrepancy and no inventory inaccuracy. As RFID visibility decreases, discrepancy and inventory inaccuracy increases. Out of stock (OOS) occurs when the inventory on record is higher than the real number of items in the inventory and the system does not trigger a reorder event. In such a situation, when the store needs items for shelf replenishment, no items are in the inventory. This is considered OOS and leads to a loss in sales.

The inventory record is updated if a manual check is performed or if there are not enough items to replenish the shelves. The latter case results in OOS if the level of the inventory does not meet the level of customers, and an out of stock event leads to updating inventory records.

Another stock involved in the inventory operations is “staff hour,” which accounts for the labor used in inventory operations such as cycle counting and shelf replenishment. Labor hours are also significantly reduced by employing RFID readers. RFID tags need not be in the line of sight and can be automatically read within feet of the readers. In addition, readers can read multiple tags simultaneously. These benefits result in significant savings in labor operations in backstore inventory. The inventory is checked periodically, and the frequency of manual checks is a parameter that is set at the beginning of the simulation. The discrepancy becomes zero after each manual check. Enhanced RFID visibility can also decrease the number of manual checks and consequently decrease labor hours. In a case study done with Motorola, because of the fast reading ability of RFID tags, Falabella retail store increased inventory counting from monthly or even quarterly to daily operations and decreased staff from 50 laborers working over two full nights to one person reading the floor items before the store opened (Motorola, 2008). Various case studies report reduction rates in labor hours. Bloomingdale’s and Dillard’ case studies (Hardgrave 2009a, 2009b) report a 96% reduction in labor hours from cycle counting through barcode systems to cycle counting with RFID handheld readers. The American Apparel use case study also reports reduction within the same range.

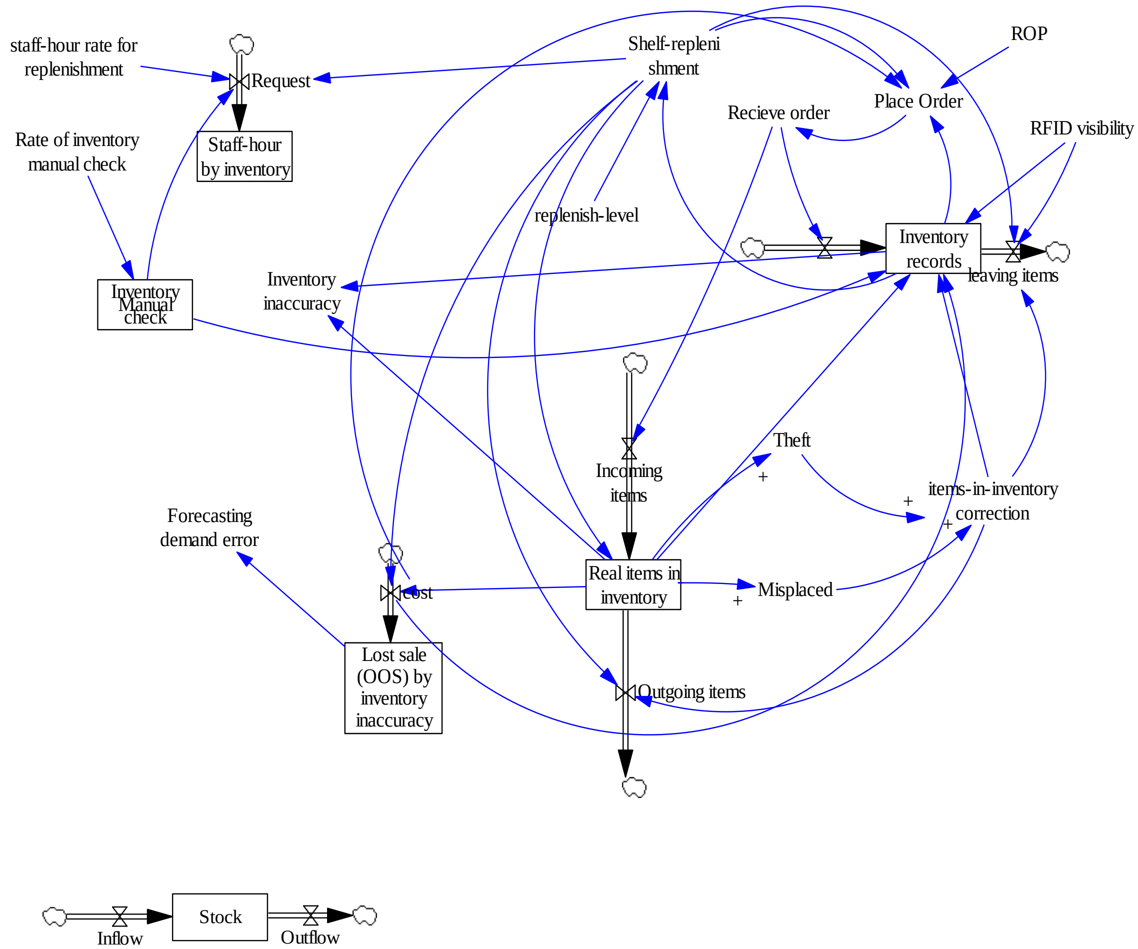

Figure 14 Stock-and-flow diagram for inventory management

The parameters of the inventory operations model are listed in Table 2. The misplacement, theft, and transaction error rates are stochastic parameters of the model. Previous studies show that the rate of misplacement and theft can vary from 1% to 5% in retail stores. Raman et al. (2001) report that a median of 3.4% of items are not found on the sales floor because of misplacement and theft. Fleisch and Telkamp (2005) looked a range of 1-5% to analyze different scenarios in their simulation model. These studies also show that misplacement and theft follow a uniform distribution.

Order size, frequency of manual check, and RFID visibility are the constant parameters of the model and are set at the beginning of the simulation. The reorder point (ROP) is calculated based on the lead time and demand in the system (ROP = average (d) * lead time + z * stddev (d) * sqrt (lead time)). Appendix B includes the automatically generated code for equations used in this stock-and-flow diagram.

Table 2 Inventory operations parameters

Process	Parameters	Assumed value	Reference
Inventory operations (constant parameters)	RFID visibility on shelves	Store specific	SS reduction at pallet-case level (Bottani and Rizzi, 2008)
	Reorder point		
	Frequency of inventory manual check		
Inventory operations (stochastic parameters)	Rate of misplacement in inventory	Uniform (0,.05)	Raman et al. 2001; a median of 3.4% of SKUs not found on sales floor, Fleisch&Telkamp (2005), used default 2% of items as misplaced
	rate of theft in inventory	Uniform (0,.05)	1 to 5% of inventory, Fleisch&Telkamp (2005), default 1.5%+distribution) Significant lost at 5%
	Transaction errors	Uniform (0,.01)	Lee and Ozer (2005)

Marketing and merchandising management stock-and-flow diagram

The SFD in Figure 15 shows how marketing and merchandising operations were simulated. Marketing operations include product-locating tools such as smart carts, automatic check outs, and smart dressing rooms as well as pricing management. "Sales" stock is the major stock in this diagram. Marketing and merchandising operations can change the number of customers and consequently change the sales. In merchandising, stores intend to provide more product availability in the stores. Fewer OOS events mean that products are more available in stores. In addition, events such as OOS may cause some customers to leave the store without shopping, which impacts the sales numbers. In fact, an OOS item indicates that a number of service failures have occurred, and these failures result in lower customer satisfaction and decrease the store and brand loyalty (Gruen and Corsten, 2008). Customer satisfaction can be measured as the percentage of customers who actually purchase products compared to potential customers who were willing to purchase that item. With fewer OOS events through enhanced visibility, the customer satisfaction index is increased (Sarac et al., 2008).

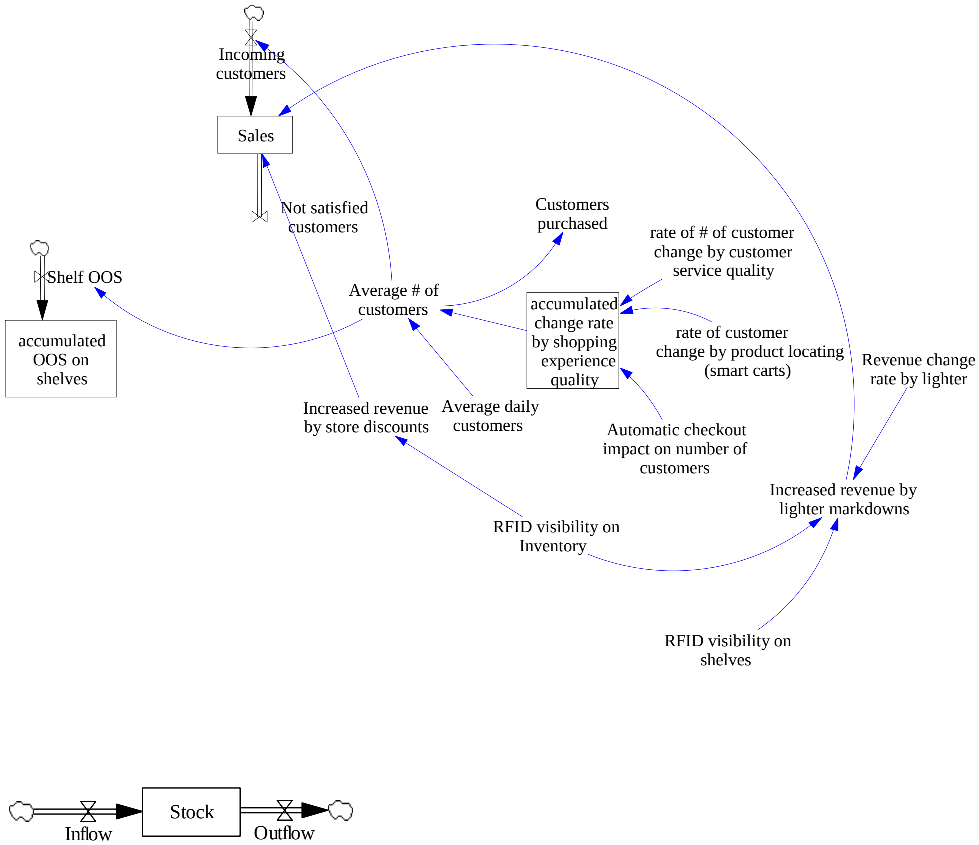

Figure 15 Stock-and-flow diagram for merchandising and marketing management

The parameters of this model are listed in Table 3: rate of change in customers caused by utilizing tools such as smart carts and dressing rooms, rate of change in revenue due to the lighter and fewer markdown prices, and RFID visibility in the backstore and on the floor. Appendix B includes the automatically generated code for equations used in this stock-and-flow diagram.

Table 3 Marketing/merchandising parameters

Process	Parameters	Assumed value	Reference
Shopping experience operations	Rate of change in customers by customer service quality and customer-initiated product search (automatic checkout, smart dressing room, smart carts)	Uniform (.01,.03)	Kurt Salmon Associates report. In fact the same study showed that although 42% of customers are using the store more frequently, 20% of customers surveyed are using the store less frequently.
	Rate of staff hours per customers	---	Average shopping 28 minutes. One OOS cost a customer 6 minutes to wait (Gruen&Cursten, 2008).
Promotion execution	Rate of revenue change by lighter/fewer markdowns	Uniform (.01,.03)	KSA (Kurt Salmon Associates) reports

Comprehensive model of retail operations

As mentioned earlier, the System Dynamics model intends to take into account the benefits of item level RFID throughout retail operations. Figure 16 shows the integrated stock-and-flow diagram that combines the stock-and flow diagrams for inventory management, shelf management, marketing and merchandising management. These processes need to be combined because they have some interrelationships. The purchasing process starts when a customer goes to a shelf and takes an item if available. A shelf replenishment request with the amount of items needed is sent to the inventory management process. The shelf record then is updated when replenishment units are received from the inventory. If product locating tools in the merchandising and marketing process are used, the number of customers shopping in the store increases and the rest of processes run the same way as discussed earlier.

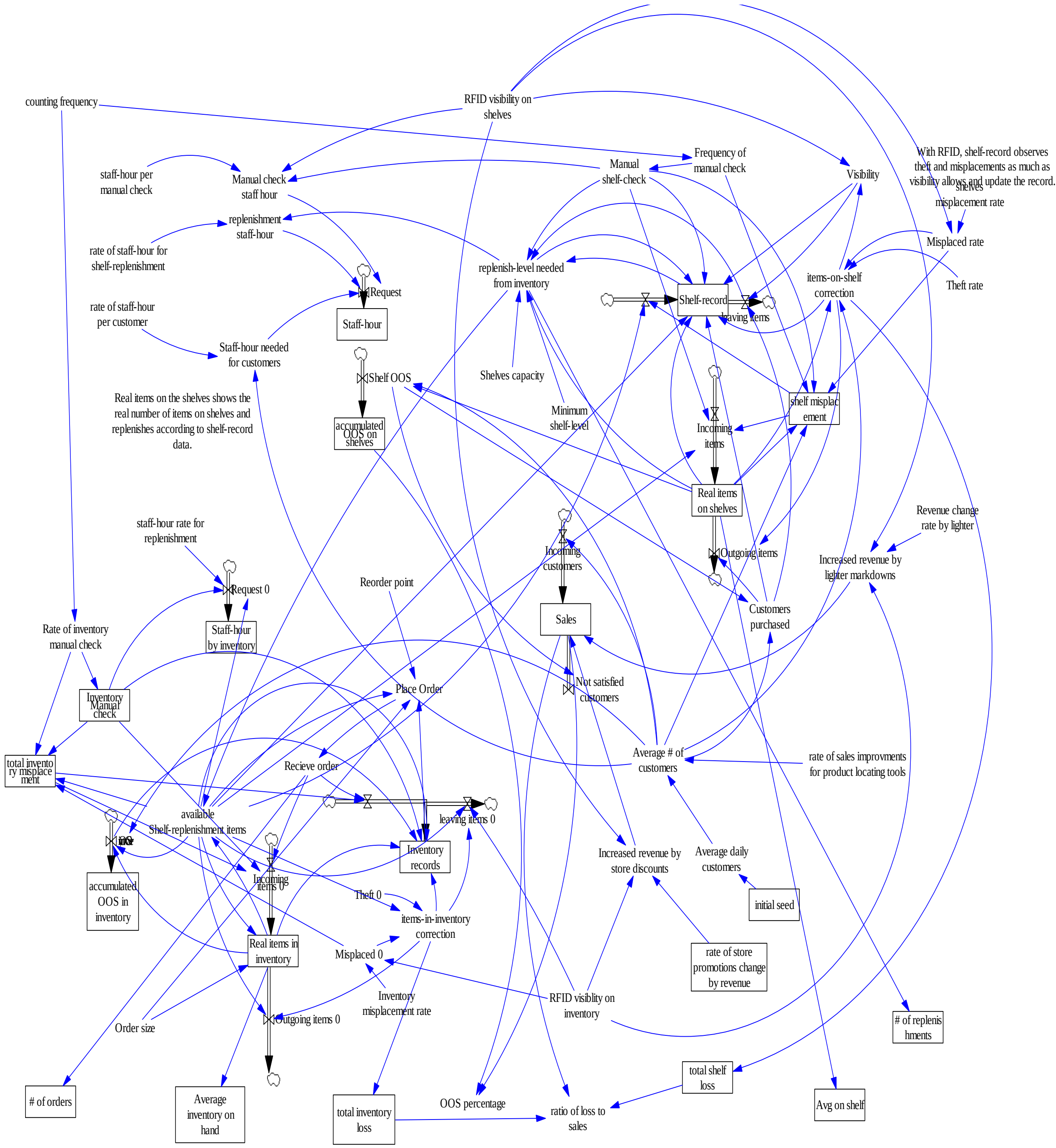

Figure 16 Integrated Stock-and-Flow model

Simulation Analysis

Simulation parameters such as theft and misplacement rates come from the literature as listed in the previous sections. Some inventory and shelves parameters such as the size of shelves, inventory, and orders are store specific and depend on the size of a store that itself is a function of the number of daily customers. For a given number of customers, three steps are followed to come up with a reasonable set of inventory and shelves parameters (Figure 17).

After the number of customers is set to a certain number, in the first phase, a perfect store in which there are no thefts, misplacements, or transaction errors is set up. Next, shrinkage and transaction problems are introduced in order to observe how those problems lead to OOS. Finally, various item-level RFID tools are introduced in order to demonstrate how performance measures such as OOS and sales change.

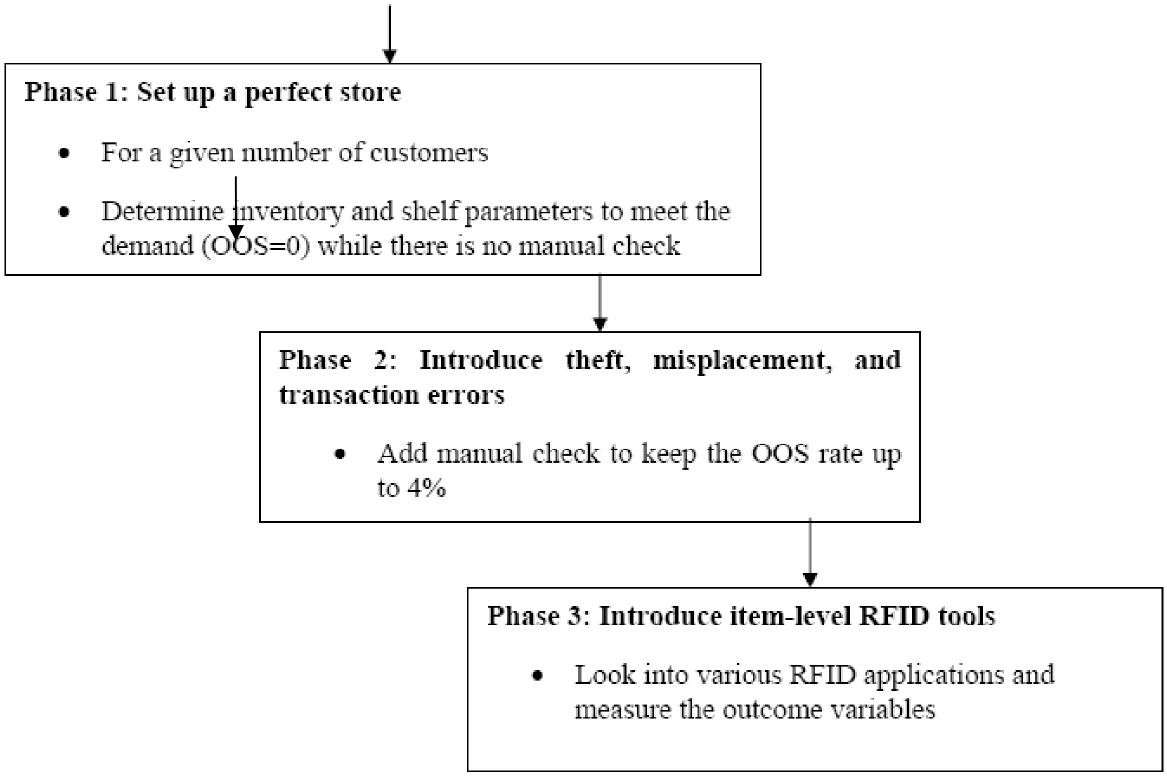

Figure 17 Setting up simulation parameters

Phase 1: Set up a perfect store

The purpose of phase 1 is to set up a perfect store in which there is no shrinkage (Figure 17). The parameters are set such that the inventory costs(holding cost as well as ordering cost) are down and customers' needs are met (i.e., there is no OOS). Starting with a particular product that has a certain daily demand, the constant parameters of the model, such as the size of the shelves and backstore needed for the given item, are determined.

Let us assume that the daily demand is, on average, equal to 30 units. The daily demand is generated based on a normal distribution with mean of 30 and standard deviation of 9. The objective of this phase is to find optimal values for inventory and shelf parameters. The process starts with large numbers for inventory order size, shelf size, and ROP. Then in an iterative process, the value of these parameters is reduced one at time while keeping OOS zero to fulfill every demand. Table 4 shows the last step of iteration, which yields the final value of the parameters if shipments are received twice per week, the minimum order size is 100, the minimum shelf level is 40, and the minimum shelf capacity is 100. Decreasing any of these numbers results in some further OOS. For example, if the minimum shelf level is decreased to 30, OOS will be 0.011.

The optimal values are determined for the situation when orders arrive once per week for the backstore and shelves are replenished twice per week. This set of numbers is used for the rest of the simulation analysis. The simulation horizon is one season that is 100 days and each period is one day. There is no cycle counting or shrinkage at this phase.

Table 4 Designing a perfect store

Shelf capacity	Minimum shelf level	Average items on shelf	order size	ROP	Average inventory	OOS	# of orders per week	# replenishments per week
150	50	103	100	48	103	0	2	2
150	40	92	100	45	102	0	2	2
100	40	75	100	45	100	0	2	2.5
100	30	71	100	45	103	0.011	2	2.4
150	40	97	180	45	140	0	1	2
100	40	76	180	45	140	0	1	2.5

Phase 2: Introduce theft, misplacement, and transaction errors

Theft, misplacement, and transactions errors are now introduced into the perfect store that was set up in phase one, in order to see how much OOS is generated (Figure

17). The values are 2% misplacement, 1% transaction error, and 3% theft. There is no cycle counting in the store. As shown in Table 5, the OOS rate is very high due to inventory inaccuracy caused by theft/misplacement/transaction error. The OOS is 60% if there is no manual counting. More frequent manual checks help to bring down the inventory inaccuracy and consequently lower the OOS. The more frequent the cycle counting, the lower the discrepancy between what is actually in the store and what the inventory records show. An OOS of 4% that is reasonable happens with a manual check rate of every 30 days (Gruen and Cursten, 2008).

Table 5 Shrinkage and transaction errors in a perfect store

Shelf capacity	Minimum shelf level	Q	ROP	OOS	Frequency of manual checkup
150	40	180	45	.60	No manual checkup
150	40	180	45	.28	Bimonthly
150	40	180	45	0.04	Monthly

Phase 3: Introduce item-level RFID Applications/Solutions

In this phase, the effects of some item-level RFID initiatives are observed for a single store (Figure 17). Next, a Monte Carlo simulation is run across multiple stores to see how variations in the parameters lead to variation in outcome performance measures.

Now an item-level RFID solution is introduced to the store to see whether OOS and sales numbers change. One scenario is to have automatic PI with handheld readers and readers at POS and inventory entrance/exits.

In the lowest level of enhanced visibility, the inventory management process is improved by providing readers in the backstore and at the point of sale (POS)

(Hardgrave, 2009a, 2009b; American Apparel, 2009). Inventory records are updated at the backstore entrance/exit doors and at POS when an item is purchased. Cycle counting and PI are performed automatically through the use of handheld readers, which work much faster than manual operations. The visibility of items in inventory improves inventory accuracy, and the record of items on the shelves is more accurate as well. Shrinkage, including theft and misplacement, is detected easily and more often through automatic PI. As shown in Table 6, once-a-week cycle counting using handheld readers reduces inventory inaccuracy and subsequently OOS to zero.

Table 6 Automatic PI performance

Shelf capacity	Minimum shelf level	Q	ROP	OOS	Frequency of manual checkup
150	40	180	45	.60	No manual checkup
150	40	180	45	.28	Bimonthly
150	40	180	45	0.04	Monthly
150	40	180	45	0.004	biweekly
150	40	180	45	0.004	Weekly
150	40	180	45	0	daily

The next section reports the results of a Monte Carlo simulation.

Monte Carlo Simulation

This simulation model intends to capture the variability of item-level RFID benefits. It has some constant and some stochastic parameters. Having all parameters set at the beginning of the simulation, one can run the simulation to resemble one particular store. The variables of interest, such as sales and OOS cost listed in Table 7, show the performance of item-level RFID in one single store. However, one needs to go beyond the performance numbers for a single store and observe how these performances are sensitive to different situations for various retailers. In fact, the value of the stochastic parameters in the model should be changed in order to see how variables of interest in the model change. A Monte Carlo simulation, also known as multivariate sensitivity simulation (MVSS), automatically captures the variability of outcomes in the model. MVSS is used when there is uncertainty in multiple parameters and the values of multiple parameters are changed simultaneously to see their joint interactions with outcome variables. Values for many of the parameters were chosen based on literature. In some cases, reasonable estimates for the parameters were assigned if the estimates could not be based on the literature. The parameters in the model are either stochastic with a given distribution or constant. Stochastic parameters in this model include the rate of misplacement (inventory and shelf), rate of theft (inventory and shelf), rate of transaction errors, and number of daily customers in a store. A uniform random distribution is used for theft/misplacement and transaction errors (Fleisch and Telkamp, 2005) and normal distribution for incoming customers (Gaukler et al., 2007; Fleisch and Telkamp, 2005) to generate the values of these parameters within a given range in order to measure, for example, how outcomes such as sales or OOS change. It is possible to automatically run hundreds of simulations while generating the value of stochastic parameters and to save the changes in the variable outcomes. Constant parameters such as ordering size and reorder point are those with a certain value set at the beginning of the Monte Carlo simulation.

Table 7 Simulation model, outcome variables

Variable	Assumed values	Reference
Sales	Store specific	
OOS_S, OOS costs	OOS from 8 to 10% and happens for different reasons. About half of that is caused by misplacement, theft, transaction errors that is 4% of sales. However, about 60% of customers pick another replacement item in the store and only 40% is the lost sale.	Gruen & Cursten, 2008

Various scenarios in the Monte Carlo simulation

This section reports the results of the Monte Carlo simulation for different applications, including automatic PI, real-time visibility, and product locating tools. The simulation runs across 200 stores for each option while the stochastic parameters are changed for each application. Stochastic parameters such as theft, misplacement, transaction errors, and number of incoming customers change from store to store. Theft follows a uniform distribution that changes from .01 to .03. Misplacement also has a uniform distribution and changes from .01 to .02. Transaction errors follow a uniform distribution as well, within a range of 0 to .01. In addition, the daily number of customers changes across the stores and follows a normal distribution with an average of 30 and standard deviation equal to 9.

No RFID in stores

This scenario looks at average number of items sold and average OOS if there is no RFID in the system. Manual checking is done once a month. As shown in Table 8, the average number of items sold is 2910. Numbers listed for No RFID are useful later when the performance of RFID applications is compared with the No RFID case.

Table 8 Monte Carlo: No RFID

Average # sold (μ)	2910
stddev (σ)	478
Average OOS	3.4%

Automatic PI

Handheld readers facilitate quicker and more frequent manual checks. This reduces inventory inaccuracy and subsequently OOS caused by theft/misplacement/transaction errors. As shown in Table 9, OOS is zero when there are daily manual checks. The average number of items sold increases from 2,910 in No RFID case to 3,026. Daily manual checks and enhanced visibility bring the impact of transaction errors and misplacement/theft to zero.

Table 9 Monte Carlo: Automatic PI

Average # sold (μ)	3026
stddev (σ)	571
Average OOS	0.000

Real time visibility

This initiative provides real-time shelf visibility on the store floor as well as the backstore and further improves inventory accuracy and shelf replenishment (Doerr and Gates, 2003). The visibility of items on shelves leads to real-time detection of misplacement and theft and thus adjustment of the inventory level. The result of this application is similar to that with the automatic PI (Table 9).

Lighter and lower markdown prices

Enhanced information visibility on shelves and in backstores provided by automatic PI or smart shelves leads to fewer and lighter markdown prices. In fact, on-time and fast shelf replenishment increases the number of items sold at full price and decreases the number of markdowns. A case study by Kurt Salmon Associates shows that revenue increases up to 5% (Kay, 2008). An additional stochastic parameter is considered, rate of increase in revenue with lighter/fewer markdowns, to see the effect of enhanced visibility on the markdown process. This parameter follows a uniform distribution and changes from .03 to .05 across 200 stores. As shown in Table 10, the number of items sold is not changed compared to the previous cases. However, because the average price of the product in stores increases by 3% to 5% with a uniform distribution, the revenue increases by 3.8 percent on average.

Table 10 Monte Carlo simulation; lighter and fewer markdowns

Average # sold (μ)	3026
stddev (σ)	571
Average OOS	0.000
Average increase rate	3.8%

Forecasting errors

Demand forecasting errors are also a source of OOS in the store. The actual demand is not captured in the store because a shopper may not buy or may shift her buying pattern due to an OOS. This may cause differences between the demand history and the sales history, and the store cannot capture the true demand (Gruen and Corsten, 2008). If OOS is reduced through enhanced visibility, then the demand forecasting error is reduced as well. For example, if there is 10% OOS, the true demand is 33, that is, 10% more than the effective demand (an average of 30). The store inventory and shelf parameters were set up with an average demand of 30. In such a situation, even with perfect visibility, there should be some out of stock due to demand forecasting errors. Table 11 shows the improvement in sales given the changes in sales number. Here the amount of increase in sales given the visibility in the store is measured.

Table 11 Improving forecasting errors

Average # sold (μ)	3037
Average increase rate	.3%

Product locating tools

Product locating such as smart carts and smart dressing rooms help customers find their desired items easier and faster. They also free up staff time that can be spent improving customer service and increasing customer satisfaction. A case study by Kurt Salmon Associates shows an increase of 3% in the number of customers who were able to find and buy their desired items (Kay, 2008). Here, a uniform distribution that changes within a range of 1.5% to 3.5% across 200 stores is used. Results listed in Table 12 show that the average number of items sold increases to 2986 from 2910 in the No RFID case.

Table 12 Monte Carlo simulation: product locating tools

Average # sold (μ)	2,986
stddev (σ)	579
Average OOS	0
Average improvement	2.5%

Comparing various applications

Table 13 lists the number of items sold under various options. Automatic PI and real time visibility provide the highest number of items sold. They include the decreases in areas of theft, misplacement, transaction errors, and forecasting errors. The product locating option helps customers find their desired product and increases the number of items sold by 76.

Table 13 Performance comparison across options

Options	Average sales(μ)	Increase over no RFID option	Stddev of sales(σ)	Coefficient of variation (σ/ μ)
No RFID	2910	0	478	16%
Automatic PI (OOS, forecasting errors)	3037	127	571	18%
real time visibility	3037	127	571	18%
Product locating	2986	76	579	19%

In the next chapter, the outcome variables of the simulation model are used as the input parameters for a real options analysis (Table 13). The increased number of items sold determines the expected payoff (S) out of each scenario in the Black-Scholes model, and the standard deviation (σ) shows the volatility of the expected payoff of a particular investment.

CHAPTER V

ITEM-LEVEL RFID IN RETAIL: REAL OPTIONS INVESTMENT ANALYSIS

There has been extensive research on the applications of real options theory in the cost-benefit analysis of IT investments (Dai et al., 2007; Clemons and Gu, 2003; Sambamurthy et al., 2003; Benaroch, 2002; Renkema, 2000; Kumar, 1999; Kambil et al., 1993; Dos Santos, 1991). Item-level RFID is a fast-emerging technology for retailers and, similar to other IT investments, has a strategic impact on retail operations. It is considered the next generation of auto-identification in the retail industry. While retailers are exploring the benefits of this technology in retail operations management through pilot and case studies, their biggest challenge is justifying the significant investment. Traditional approaches such as NPV and DCF have been used so far to investigate the costs and benefits of implementing RFID (Bottani and Rizzi, 2008; Sarac et al., 2008; Doerr et al., 2006). However, because of the uncertainties and risks involved, real options method seems a more appropriate technique for analyzing this investment (Wu et al., 2009; Liao and Lu, 2009; Goswamiet al., 2008; Patli, 2004). Given the high level of uncertainty in such an investment, Wu et al. (2009) and Patli (2004) demonstrate that a traditional technique can result in a negative NPV. Liao and Lu (2009) use real options to analyze the value of RFID across the supply chain. Goswami et al. (2008) develop a conceptual model with a real options perspective that allows managers to identify various applications of RFID at different stages and help them justify an investment plan.

The focus in this research is on the timing of investment in item-level RFID. Using real options, this study intends to answer the question of when is the best time to adopt item-level RFID. The following sections describe the available options and demonstrate how those options can be assigned a value.

Recognizing Options for RFID Investment

The first step in analyzing the investment timing problem is to identify the available options. In order to identify available applications and possible areas of investment, it is necessary to find out where and how item-level RFID can be integrated into the retail operations management. The results of the Delphi study are used to recognize the possible applications of this technology along with available options. Table 14shows the areas in which item-level RFID can impact the operations. One option is providing automatic PI in stores. Automatic PI is obtained if there are RFID visibilities in the backstore and frequent manual checks using handheld readers. More frequent manual checks decrease OOS events by reducing the inventory inaccuracies caused by misplacement, theft, and transaction errors. In addition, forecasting demand errors which result in OOS decrease. The results of the simulation show that real time visibility is associated with a high cost while its in-store benefits do not exceed those provided by automatic PI. Implementing product locating tools such as smart carts or smart dressing rooms is another option that helps more customers find the products they desire.

Table 14 Potential investments

Application	How	Benefits
Automatic PI	Using handheld reader for frequent cycle counting	Reducing OOS caused by misplacement/theft/transaction error/forecasting error/lighter or fewer markdown
Real time visibility	Using smart shelves	Reducing OOS caused by misplacement/theft/transaction error/forecasting error/lighter or fewer markdown
Product locating	Using customer shopping assistants such as smart carts and smart dressing room	Increasing the number of customers who can find their desire products

Valuing the Options: Black-Scholes Model

In order to make an investment decision, each available option must be assigned a value. A timing option exists when an investor has to choose from a set of mutually exclusive times such as ‘invest now’ or ‘invest later.’ In this case a positive NPV is not sufficient for project acceptance and instead of taking every project with a positive NPV, investors must take the NPV-maximizing alternative (Trigeorgis, 1995).

One of the most widely used models for valuing options is the Black-Scholes model (Black and Scholes, 1973). It was originally invented in a finance context to determine the future price of stock options but has also been used in investment analyses in other areas such as energy, real estate, and pharmaceutical investments (Trigeorgis, 1995; Copeland and Antikarov, 2001). The original Black-Scholes model was used for no-dividend European options that are exercised only at the maturity time (T). The option to wait is a simple independent call option that can be exercised at any time before maturity (American options). This option is different from a growth option, whose value comes from future investment opportunities that the investments open up.

Black's approximation is a variation of the Black-Scholes model that deals with American options (Hull, 2006). In this method, the prices of European options that mature at times t(any time before T) are calculated and the price of the American option is set to the greater of those prices (Benaroch and Kauffman, 1999).

The RFID investing time option is a wait option and the question to explore is the best time to exercise the option, i.e., the best time to invest in RFID.

Following is the Black-Scholes formula:

$$C = S\,N(d_1) - X e^{-rT} N(d_2)$$
$$d_1 = [\ \ln(S/X) + (r + \sigma^2/2)\,T\ ] / \sigma T^{1/2}$$
$$d_2 = d_1 - \sigma T^{1/2}$$

Here,

C = price of the call option

S = price of the underlying stock

X = option exercise price

r = risk-free interest rate

T = current time until expiration

N(.) = area under the normal curve

There are two competing factors in the Black-Scholes formula: X, the cost of making the investment, and S, the present value of investment payoffs. The cost of RFID (X) goes down during the deferral period, as the technology becomes more mature, while the expected payoffs (S) might also go down because of the revenue loss during the deferral time. The value of the option at time t <= T can go higher or lower depending on the values of these two competing factors.

Generally, a fee is associated with obtaining a stock option or real option if there is a risk of losing the option. In infrastructure growth options, for example, the initial investment opens up other opportunities; thus the initial sunk (already incurred) cost is considered as the cost of obtaining other options. In an investment timing option, sometimes this cost is zero if the investors do not need to obtain the option and there is no risk of losing the option either. In the case of item-level RFID, there is no risk of losing the option to invest and the retailers can implement the technology as soon as they decide to do so; thus the cost of obtaining the item-level RFID investment timing option is zero.

Real options parameters

Table 15 shows the definitions of real options' parameters in an IT context. When analyzing an option, the current value of the option determined by the Black-Scholes model should be known. S is the present value of expected risky payoffs of RFID over the horizon if it is implemented now. The exercise price (X) is the cost associated with implementing this technology in a particular store. The normality assumption of the S distribution and the present value of revenue distribution in a retail setting also need more investigation. The volatility, σ, is the standard deviation of expected payoffs from the RFID investment.

Table 15 Options pricing model vs. RFID investment options

Parameters	Option Pricing	RFID Technology
S	Current underlying asset price	The increase in sale (from the **simulation**) **–** loss revenue during deferral time (from the **simulation**) **–** operational cost (tag costs)
X	Exercise price	Anticipated development cost (initial cost + maintenance cost)
T	Time to expiration	Maximum deferral/wait period in years
r	Risk-free interest rate	The same
σ	Std. dev. of returns	Volatility of RFID expected revenue

Estimating the payoffs and variability of expected payoffs can be difficult because there are no past data on the performance of such a new technology. Historical data are usually used to estimate the payoff and variability of expected payoffs in financial options pricing. Some techniques, for example, use the prices of stocks during a period of one month or one year to calculate the variability of expected payoffs (Hull, 2006). This study uses the simulation results to estimate the expected payoffs and volatility (σ) of the expected payoffs, which are the most difficult parameters to estimate (Benaroch and

Kauffman, 1999). The risk-free interest rate is considered to be equal to7% (Benaroch and Kauffman, 1999).

Given all the parameters in the real options model, the value of the RFID postponing option at different periods of times before its maturity can be determined using the Black-Scholes formula. The option value is calculated for each year over a 5-year horizon. The year that the option takes the highest value is suggested as the best time to exercise the option and invest in item-level RFID (Benaroch and Kauffman, 1999).

Costs

The cost of implementation has two categories: fixed and variable costs. A one-time or fixed cost is associated with infrastructure expenses such as reader systems, antennas, and software integration; and recurring costs include the cost of tags, maintenance, and support (Table 16). The fixed cost is the exercise price (X) in the black-scholes model and varies from one option to another based on the details of implementation.

The variable cost is the tag cost that is a function of the number of items in stores and currently sells for between 10 and 15 cents for an item; therefore, the annual variable cost is the number of items sold annually times the tag cost ,e.g., $0.10. The variable cost is considered the operational cost that is used in the black-scholes model (S= expected revenue - operational cost). The fixed costs of different elements are listed in Table 16 (Bottani and Rizzi, 2008; Doerr et al., 2006).

Table 16 Cost of RFID equipments

RFID tag	10 cents
RFID reader	$2000
RFID gate	$2500
RFID handheld reader	$2500

Valuing the Automatic PI Option

In order to value the option, its benefits and costs must be determined. The benefits can be divided into two types: incremental unit sales and incremental revenue. Incremental unit sales benefits such as reducing OOS through managing misplacement, theft, transaction errors, and forecasting demand results in selling more items. Therefore, the benefits are limited to the extra items sold. On the other hand, incremental revenue benefits such as having lighter and fewer markdowns increases the gross margin for every single item that is sold, so its impact is much higher than the increase in number of sales. The ROI analysis looks at the benefits of automatic PI including reduced OOS, reduced transaction errors, lower and fewer markdowns individually and combined to see how the results change.

Bottani and Rizzi (2008) analyzed the cost and benefit of RFID at pallet and case levels in retailers' supply chain. They implemented RFID at the pallet level and the case level in the backstore changing the visibility at the receiving gates and entrance doors from the backstore to the sales floor. One can use their cost figures to come up with a proportional cost adapted to a different size of store. If the initial cost for a store with a capacity of 400,000 units is $160,000, then for a store with a capacity of 4700 (our problem size), the cost will be around $1880 (Kearney et al., 2004). This ROI analysis is for a case in which there are 20 products in the same category as the item investigated in the simulation model. In addition, two different types of items are considered here: one in an apparel store and a cheaper item in a grocery store.

Table 17 shows the option value for incremental unit benefits of automatic PI in an apparel store. Assume that the product price is $25 and the gross margin is $2. We also assume that the RFID tag prices go down by 12% each year. As the tag price goes down, the variable cost decreases. The option value at year 3 is the highest value over the 5 years so year 3, when the tag price is .077, is the best time to invest in this initiative. The option value that is the return on a given investment for a given year includes all the revenue lost during the waiting time, so in spite of the revenue lost during the first 3 years, the apparel store managers can realize the most value by implementing this technology at year 3 versus investing in other years (Figure 18).

Table 17 Automatic PI, incremental units benefits, apparel items

Recommended deferral time (years)	1	2	3	4	5
Tag price ($)	209	4058	5245	3492	0
Option value ($)	0.10	0.088	0.077	0.068	0.059

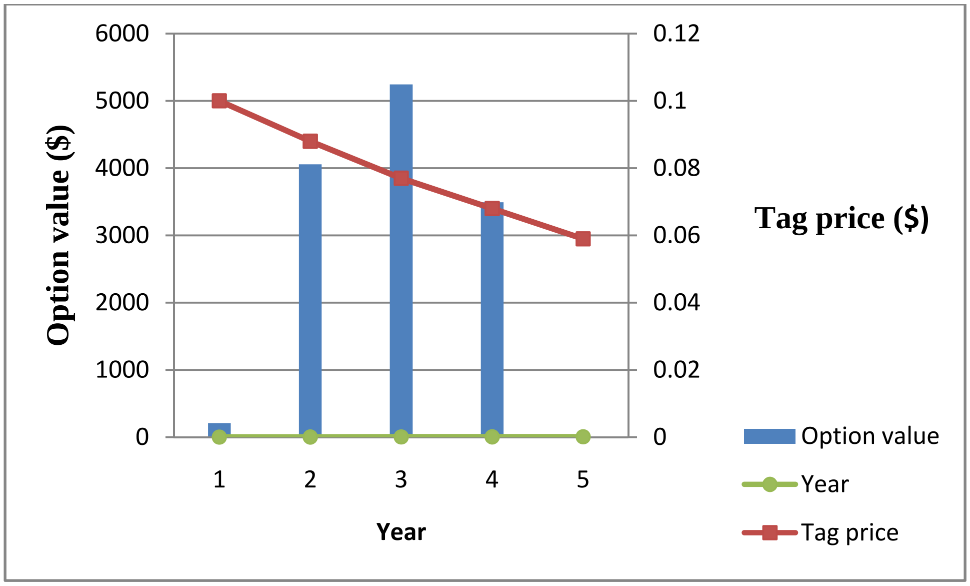

Figure 18 Automatic PI, incremental units benefits, apparel items

The best time to invest is a function of the tag price but also depends on the product price. For example, for a grocery item that costs $10 with a gross margin of $1, the highest option value occurs at year 4 when the tag price is around 3 cents (Figure 19, Table 18). In fact, the lower the gross margin of the product, the higher the return from a cheaper tag price.

Table 18 Automatic PI, incremental units benefits, grocery items

Recommended deferral time (years)	1	2	3	4	5
Tag price ($)	0.07	0.056	0.044	0.035	0.028
Option value ($)	Negative S	Negative S	555	1415	186

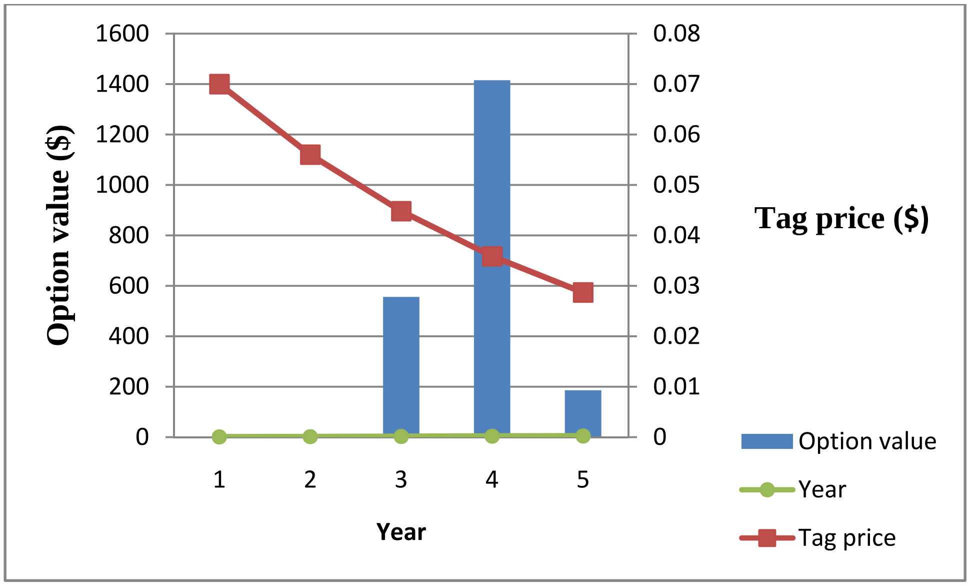

Figure 19 Automatic PI, incremental units benefits, grocery items

Taking into account the incremental revenue benefits, i.e., the lighter and fewer markdowns, there will be a jump in the expected revenue as shown in Table 19. Therefore, the expected revenue is significantly higher than the initial and variable costs and the highest profit is obtained if the option is exercised at year one when the tag price is equal to 10 cents (Figure 20).

Table 19 Option values for lighter and fewer markdowns along with other automatic PI benefits in apparel

Recommended deferral time (years)	1	2	3	4	5
Tag cost ($)	0.1	0.088	0.077	0.068	0.059
Option value ($)	763,678	393,021	57,427	Negative S	Negative S

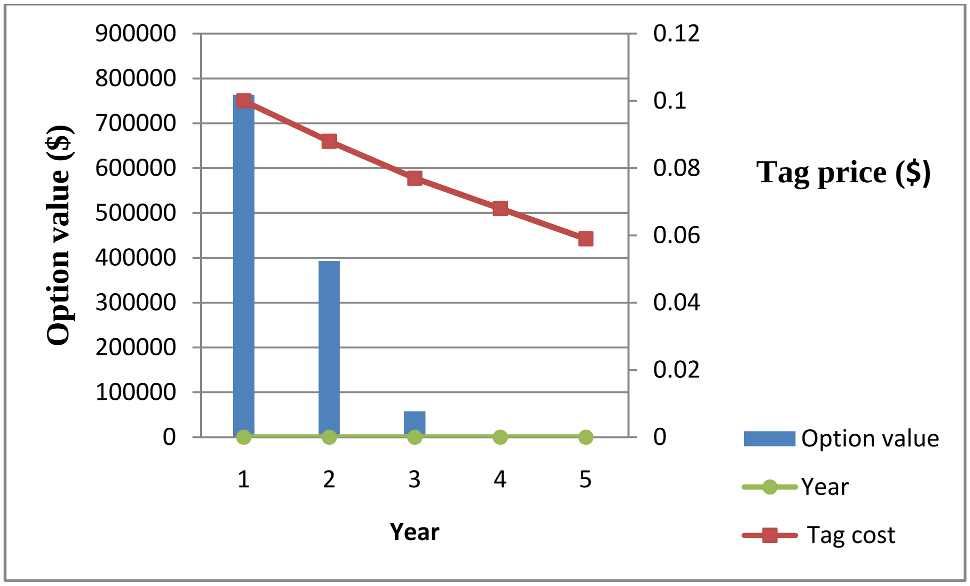

Figure 20 Option values for lighter and fewer markdown along with other automatic PI benefits in apparel

Valuing Real Time Option

The simulation showed that the benefits for real time visibility can be obtained through automatic PI in which handheld readers can be used as frequently as needed to avoid the inventory inaccuracies caused by misplacement, theft, and transaction errors. However, smart shelves, which provide real time visibility, are very expensive—up to 10 times as expensive as the initial cost for automatic PI tools. As shown in Table 20, if all benefits except for markdowns are taken into account then the option values are either zero or negative over the horizon even as the tag price changes from 10 cents to 5 cents.

Table 20 Real time visibility with no markdown option value

Recommended deferral time (years)	1	2	3	4	5
Tag price ($)	Negative S	Negative S	Negative S	Negative S	Negative S
Option value ($)	0.1	0.088	0.077	0.068	0.059

However, if lower and fewer are counted markdowns, as shown in Table 21, investing in the first year with a tag price of 10 cents is still the best choice. Given the option value for automatic PI (Table 19) and real time visibility (Table 21), one would go with the higher return, which happens through the implementation of the automatic PI option.

Table 21 Real time visibility option value

Recommended deferral time (years)	1	2	3	4	5
Tag price ($)	735,704	373,732	45,734	Negative S	Negative S
Option value ($)	0.1	0.088	0.077	0.068	0.059

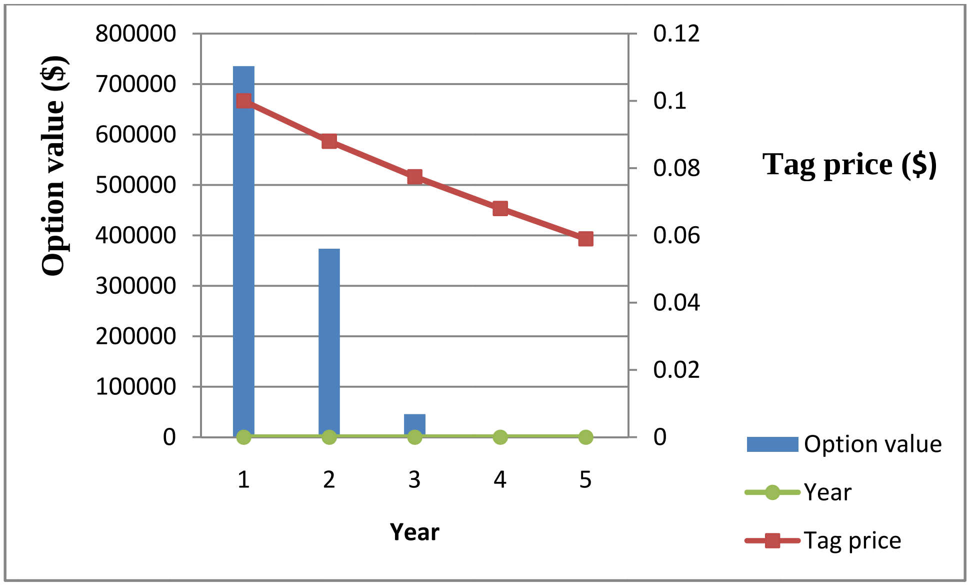

Figure 21 Real time visibility option value

Valuing Product Locating Option

Product locating tools such as smart carts and smart dressing rooms help customers find their desired items. This benefit is an incremental sales unit benefit. Option values listed in Table 22 show that the highest benefit is gained at year 3 when the tag price is around 5 cents (Figure 22).

Table 22 Product locating tool option values

Recommended deferral time (years)	1	2	3	4	5
Option value ($)	0.0	1,454	2,574	1,735	0.0
Tag price ($)	0.07	0.061	0.054	0.047	0.042

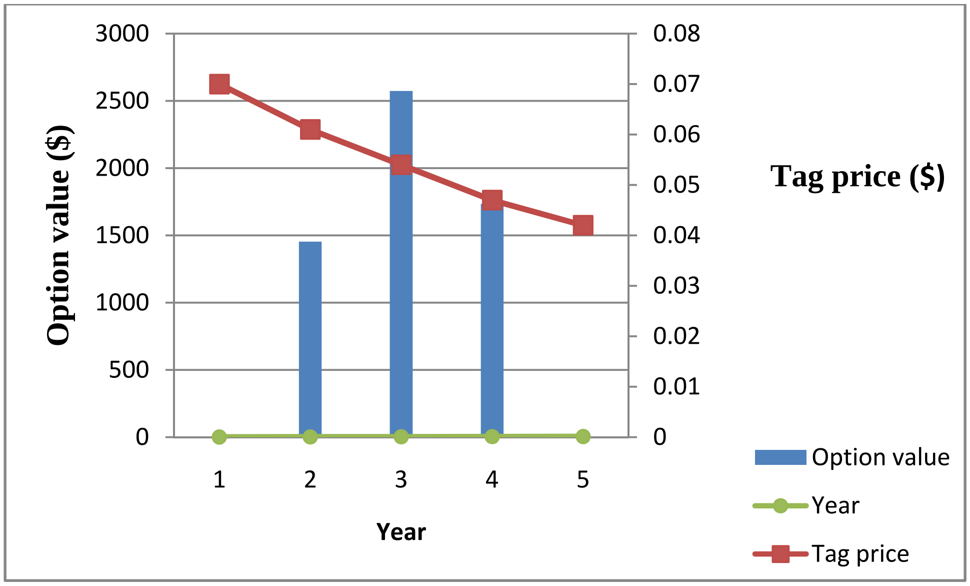

Figure 22 Product locating tool option values

Combined Option

The benefits listed in Table 22 are only those gained through the individual product locating option. If the product locating option is combined with the automatic PI in an apparel store (without markdown), the two options can share some of the initial infrastructure cost and their combined benefits (Table 23, Figure 23) exceed the sum of the benefits (Table 17,Table 22).

Table 23 Product locating + automatic PI (no markdown) for an apparel item

Recommended deferral time (years)	1	2	3	4	5
Option value ($)	51032	33218	12658	Negative S	Negative S
Tag price ($)	0.1	0.088	0.077	0.068	0.059

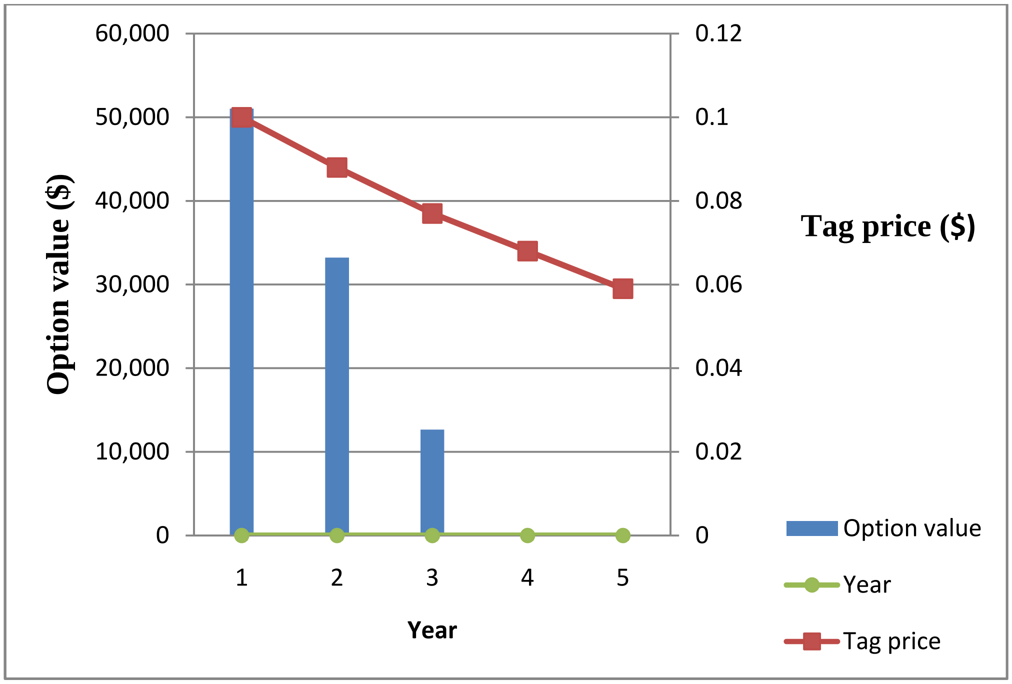

Figure 23 Product locating + automatic PI (no markdown) for an apparel item

The same is true in grocery stores as shown in Table 24. The maximum profit is gained at year 4 when stores implement both options and the tag price is .068 (Figure 24).

Table 24 Product locating + automatic PI (no markdown) for a grocery item

Recommended deferral time (years)	1	2	3	4	5
Option value ($)	Negative S	Negative S	0.0015	442	185
Tag price ($)	0.1	0.088	0.077	0.068	0.059

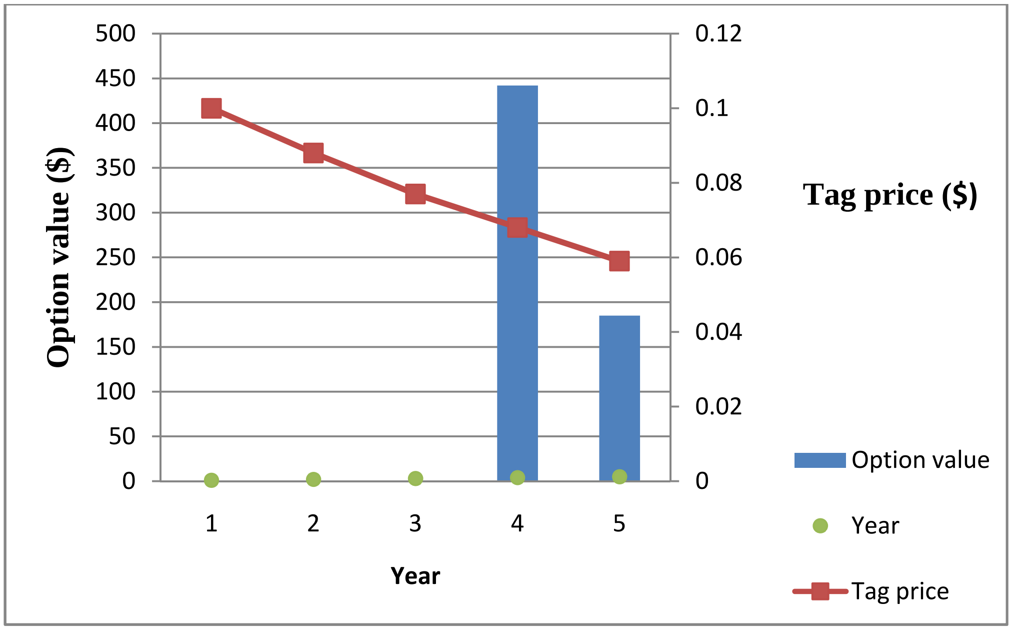

Figure 24 Product locating + automatic PI (no markdown) for a grocery item

If the lighter and fewer markdowns benefit for a grocery item is included in the combined option, the maximum value happens in the first year when the tag price is 10 cents (Table 25, Figure 25).

Table 25 Markdown benefit included in the combined option for grocery

Recommended deferral time (years)	1	2	3	4	5
Option value ($)	293560	155604	27774	Negative S	Negative S
Tag price ($)	0.1	0.088	0.077	0.068	0.059

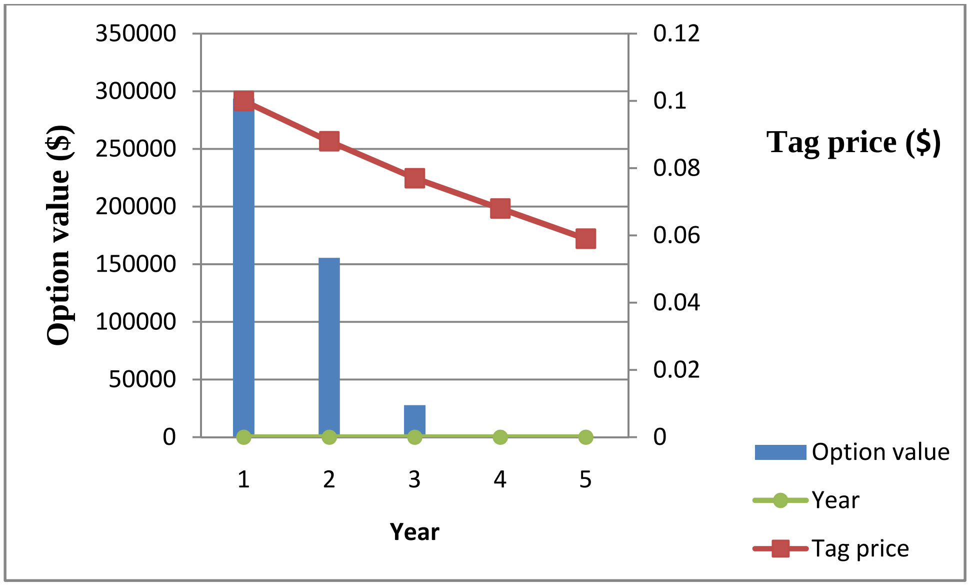

Figure 25 Markdown benefit included in the combined option for grocery

The lowest price for a product at which implementing these options has a positive return is a tag price around 7 cents and a minimum product price of $1.80 (Table 26).

Table 26 Lowest product price in combined option

Recommended deferral time (years)	1	2	3	4	5
Option value ($)	Negatives	Negatives	0.00	371	188
Tag price ($)	0.1	0.088	0.077	0.068	0.059

Sensitivity Analysis

A sensitivity analysis was performed to see how changes in the parameters might change the results. This section looks into the Automatic PI option but the other options show similar patterns. One parameter at a time, e.g., initial cost, was changed and the effect on the results was noted. The tag price was set to.07 for a $25 apparel item with a gross margin of $2.

Initial investment

The initial cost was changed to 50% higher and 50% lower to see whether the best-investment timing changes (Table 27). The highest option value in both cases (50% higher or 50% lower) stays the same and happens at year one. The value of the option changes because the initial cost changes but the optimal solution, which is to invest in year one, does not change. In fact, the fixed costs have only a marginal impact on the option values, as is also confirmed by the Grocery Manufacturing of America study (Kearney, 2004).

Table 27 Initial cost sensitivity analysis

	Recommended deferral time	1	2	3	4	5
Investment cost =$1880	Option value	9,692	4316	8	Negative S	Negative S
Investment cost 50% higher = $2820	Option value	8,815	3586	0.4035	Negative S	Negative S
Investment cost 50% lower = $940	Option value	10,568	5045	153	Negative S	Negative S

Volatility of expected payoff

Table 28 shows how option values change if the volatility of the expected payoff goes up to 40% or falls to 10%. The results are insensitive to these changes, and the best timing option stays the same at the 7- cent tag price.

Table 28 Volatility of expected payoff sensitivity analysis

	Recommended deferral time	1	2	3	4	5
Volatility = 20%	Option value	9,692	4316	8.59	Negative S	Negative S
Higher volatility = 40%	Option value	9,692	4320	79.13	Negative S	Negative S
Lower volatility = 10%	Option value	9,692	4316	0.05	Negative S	Negative S

Discount rate

The results of the sensitivity analysis for the discount rate for calculating the expected payoff are listed in Table 29. Although the value of the option rises with lower discount rates, the best timing option stays the same at a tag price of 7 cents.

Table 29 Discount rate sensitivity analysis

	Recommended deferral time	1	2	3	4	5
Discount rate = 12%	Option value	9,692	4316	8	Negative S	Negative S
Discount rate = 10%	Option value	10,282	4803	73	Negative S	Negative S
Discount rate = 7%	Option value	11,265	5624	391	Negative S	Negative S

Analysis of the Results

The model developed in this study is the integration of system dynamics simulation and real options model. Generating real options parameters through a simulation technique such as system dynamics creates an ROI model that can be applied to different IT investment problems such as growth options or investment timing options. In this study, the real option analysis looked into the investment timing option for the item-level RFID in the retail sector. Managers have timing flexibility for investing in this technology and can postpone their decision. With the postponement or wait option in hand, retailers should not only look for a positive NPV but also find out when the NPV is maximized. Some parameters of the model such as the expected payoffs and volatility of the expected payoff come from the simulation model. The robust simulation model allows us to estimate the item-level RFID benefits in terms of increased sales numbers for any given store at any size when the parameters are set. Consequently, the real options model calculates the options return values for given parameters. For example, tag price is one of the parameters in the ROI return. In a realistic model, the tag prices should go down over time with a certain rate (e.g., 12%). Tag prices, being the major part of the total cost in the model, dominate the results of the ROI model. Another parameter of the ROI model is the price of an item. The average product prices and consequently the gross margins are different in apparel stores versus grocery stores. Therefore, in the case of cheaper products, the optimal tag price is proportionally lower. Indeed, tag price and the average product price (which depends on the type of retailers) are the major parameters that influence the results significantly.

In addition, the sensitivity analysis of the results shows that parameters such as the discount rates, the volatility of the expected payoff (estimated in the simulation model), and the initial investment cost have only a marginal impact on the outcomes. However, the limitation of our ROI analysis was estimating the initial cost of the infrastructure by using proportional figures from other case studies in the literature that had done similar work. The sensitivity analysis looked into the variation of the result if the initial cost is changed. The results show that although the option value changes according to the changes in the initial cost, the investment timing is not changed.

The ROI analysis also considered combined options. In analyzing combined options one should consider the combination of two or more options as a new option by itself and proceed to calculate its value. In the case of combined options, some of the initial costs and variable costs are shared and the total benefits outweigh the initial as well as the variable costs (tag costs). Thus the tag price and the type of retailer are not that critical in the optimal timing for investment, if all benefits are considered simultaneously.

The practical implication of the ROI model is the major achievement of this study. Most retailers are at the planning stage of item-level RFID investment and are struggling with the ROI analysis. The ROI analysis developed in this study can guide the mangers by providing important insights for such an investment. Not only do managers learn about the best investment timing for their specific setting but they also can observe what factors are driving the results of the ROI. For example, the result of a particular case may be recommending a store to wait a couple of years in order to invest in RFID. Given that all the revenue lost during the waiting time is taken into account, managers know they will be better off if they take advantage of their waiting flexibility. In addition, they learn factors such as the tag price dominates the analysis and can monitor the market during the waiting time in order to receive more information on uncertainties exist in the parameters of the model and major determinants of the return.

CHAPTER VI

SUMMARY AND CONCLUSIONS

Contributions to Theory and Practice

System dynamics and real options techniques have been used separately in the economics of information technology. The Management Information Systems discipline is becoming a mature field, within which many known quantitative research techniques have been used. Combining these techniques to overcome their weaknesses and to develop new solutions for current problems in IT investment leads to more robust and innovative methods (Fichman, 2004; Ives et al., 1980; Hevner et al., 2004). Real Options is known as an ROI technique that captures managerial flexibilities in uncertain conditions. System dynamics, on the other hand, maps complex processes in the organizations to analyze how IT can change organizational processes, and its applications have been studied in many areas. The unique contribution of this dissertation is to combine them as two major techniques in order to present a robust and innovative model for analyzing return on investments in item-level RFID. Estimating real options parameters such as the variability of ROI is usually difficult. To address these difficulties in estimating the real options model's parameters, the proposed system dynamics sub-model simulates retailers' shop floor operations.

The hybrid model addresses a problem that the retail industry is facing. Item-level RFID technology in retail management is in its infancy and will be the focus of investments for the next few years. This technology needs a rigorous ROI model to help managers in the process of making their investment decisions. Studies have investigated RFID benefits in different areas of retail operations such as supply chain management (Atali et al., 2005). Lee and Ozer (2007) mention that ROI models are missing in evaluating RFID benefits. This study develops a comprehensive ROI model to capture benefits in retailers' operations management from customer service and pricing to the supply chain.

Real options modeling allows a cost benefit analysis to take into account managerial flexibilities when there is uncertainty in the investment. On the other hand, system dynamics can build a predictive model, in which one can simulate different real-life and hypothetical scenarios in order to provide measurements that can be used in the real options model. The proposed Return on Investment model is an innovative technique that takes advantage of long-established quantitative techniques and is validated in practice through test cases. The ROI model is applied to RFID, one of the most recent areas of IT investment. Validating the ROI model in the RFID domain increases its validity as well as its implications for practice.

The proposed hybrid model uses a robust methodology as well by combing qualitative and quantitative techniques in various steps. Results from the Delphi study, a qualitative study, are used to develop the conceptual model of the operations that is later used as the basis for the quantitative step, which uses the simulation model as well as the real options model.

Limitations

There are some limitations in the methodology part of this research including the Delphi study and the simulation. Similar to other qualitative studies, the expert panel was limited to 10 people. Collecting information from more people will add to the diversity of various cases and consequently allow the testing of a wider range of scenarios in the simulation model.

The results of this study are limited to the various scenarios and assumptions made in the simulation model. Using simulation is valid as long as real data are not available. Conducting more case studies and using results from real implementations will significantly improve the credibility of these results.

On the practical side, this study looked at the operations that can be managed on a retail floor. Some of the item-level RFID benefits such as those in designing the promotions are achieved across stores and at a higher level of management than operations. However, those types of benefits have to be considered in order to determine the total benefits of investment options for retail stores

Future Directions

The system dynamics simulation is a macro level simulation that looks into the operations at an aggregate level. An extension of this research is to use some micro level simulations, such as an agent-based simulation, to track products on an individual basis and study the behavior of the system in more detail.

This study looks into the impact of RFID on current retail operations. A major area of future research is to explore areas of retail operations in which RFID can significantly change the way operations are performed. In other words, how can item-level RFID and the information collected from it be used in reengineering store processes in order to make operations more efficient and effective?

As mentioned before, this conceptual model is based on the opinions of experts in the US retail sector. One expansion is to conduct a comparison study in which the investment decisions in the US are compared with those in other countries pioneering in RFID technology in retail, such as Germany, to identify the differences and areas of improvement in both places.

Conclusion

The proposed hybrid model is a unique combined technique that is used for the first time in the economics of IT. This approach tapped into the different domains of finance, marketing, and IT and used various methodologies—the Delphi method, simulation, and real options analysis—in order to develop a robust, vigorous, and innovative model.

Applying this model to a real investment problem in the retail sector developed a framework to help retail managers learn what options are available and how they can analyze the value of the options. Interesting results show that the benefits of RFID go beyond the supply chain operations. While the supply chain benefits are direct and more imminent, other management operations such as marketing and merchandising are potential areas to investigate.

REFERENCES

Abell, P. (2003). Item tracking: Myths and realities. *RFID Journal*, March 15, 2010, available at www.rfidjournal.com/article/pdf/484/1/1/rfidjournal-article484.PDF.

Aberdeen Group (2008). *Know what's in store with RFID*. White Paper, Boston, MA.

Alexander, K., Gilliam, T., et al. (2002). Applying auto-ID to reduce losses associated with shrinkage. *MIT Auto-ID Center White Paper* IBM, Business Consulting Services.

Akkermans, H., A., Bogerd, P.,Yücesan, E., and Wassenhove, L. N. V. (2003). The impact of ERP on supply chain management: Exploratory findings from a European Delphi Study. *European Journal of Operational Research,* 146(2), 284-301.

American Apparel RFID Project- Case Study (2009).*RFID Monthly,* June.

Anderson, E.G. Jr. and Fine, C.H. (1999). Business cycles and productivity in capital equipment supply chains. In: Tayur, S., Ganeshan, R., Magazine, M. (eds) *Quantitative models for supply chain management*. Boston: Kluwer.

Angerhofer, B. J., and Angelides, M. C. (2000).System dynamics modeling in supply chain management: Research review. *Proceedings of the 2000 Winter Simulation Conference*, 342-351.

Angerhofer, B. J., and Angelides, M.C. (2006). A model and a performance measurement system for collaborative supply chains. *Decision Support Systems* archive, 42(1), 283-301.

Atali, A., Lee, H., and ÖlpOzer, O. (2005). If the inventory manager knew: Value of RFID under imperfect inventory information. White paper, Stanford University.

Bai, L., Szmerekovsky, J., and Zhang, J. (2009). Modeling inventory inaccuracy and demand deviation to assess the value of RFID. *International Journal of Operations and Quantitative Management,* 15(3), 157-172.

Barlas, Y. (1994). Model Validation in System Dynamics. Proceedings of the 1994International System Dynamics Conference, Methodological Issues Vol., 1-10, Stifling, Scotland.

Barlas Y. ,and Aksogan, A. (1996). Product diversification and quick response order strategies in supply chain management. International System Dynamics Conference, Cambridge, MA, USA.

Benaroch, M. (2002). Managing information technology investment risk: A real options perspective. *Journal of Management Information Systems*, 19(2), 43-84.

Benaroch, M., and Kauffman, R. J., (1999). A case for using real option pricing analysis to evaluate information technology project investments, *Information Systems Research*, 10(1), 70-86.

Berthiaume, D. (2004). RFID boosts customer satisfaction at Tesco - smart shelves show potential to improve visibility. *Chain Store Age,* January, 24A - 25A.

Black, F., and Scholes, M. (1973).The pricing of options and corporate liabilities, *Journal of Political Economy*, 81, 637-659.

Bottani, E., Rizzi, A. (2008). Economical assessment of the impact of RFID technology and EPC system on the Fast Moving Consumer Goods supply chain, *International Journal of Production Economics*, 112(2), 548–569.

Borshchev, A., and Filippov A. (2004). From system dynamics and discrete event to practical agent based modeling: Reasons, techniques, tools. The 22nd International Conference of the System Dynamics Society. Oxford, England.

Carr, N. G. (2003). IT Doesn't Matter, *Harvard Business Review*, 81(5), 41-49.

Cash G. (2005). RFID for the Real World. White paper. FKI Logistex Warehouse & Distribution.

Céline, B**.**, Cloutier, M., and Cassivi, L. (2005). Performance evaluation of management information systems in clinical trials: A system dynamics approach. International System Dynamics Conference, Boston, MA.

Clemons, E. K., and Gu, B. (2003). Justifying Contingent IT Investments: Balancing the Need for Speed of Action with Certainty Before Action, Journal *of Management Information Systems*, 20(2), 11-48.

Copeland, T., and Antikarov, V. (2001). Real options: A practitioners guide. New York: Texere Publishing.

Counihan, A., Finnegan, P., and Sammon, D. (2002). Towards a framework for evaluating investments in data warehousing, *Information Systems Journal*, 12, 321-338.

Cronk, M. C., and Fitzgerald, E. P. (2002). Constructing a theory of 'IS business value' from the Literature. *Electronic Journal of Business Research Methods*, 1(1), 11-17.

Curtin, J., Kauffman, R. J., et al. (2007). Making the 'MOST' out of RFID technology: Are search agenda for the study of the adoption, usage and impact of RFID. *Information Technology and Management*, 8, 87-110.

D'Antoni, H. (2003). Behind the numbers: How to be sure tech dollars pay off, Info. *Week*, December 8, 72-74.

Dai, Q., Kauffman, R., and March, S. (2007). Valuing information technology infrastructures: A growth options approach, *Information Technology and Management*, 8(1), 1-17.

Dardan, S., Busch, D., et al. (2006). An application of the learning curve and the nonconstant-growth dividend model: IT investment valuations at Intel Corporation. *Decision Support Systems*, 41(4), 688-697.

Davis, F. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology.*MIS Quarterly*, 13, 319-340.

DeHoratius, N., and Raman, A. (2008). Inventory record inaccuracy: An empirical analysis. *Management Science*, 54(4), 627-641.

Delbecq, A., Van De Ven, A. H., and Gustafson, D. H. (1975). *Group Techniques for Program Planning*, Glenview, IL: Scott Foresman.

Delen, D., Hardgrave, B. C., and Sharda, R. (2007). RFID for better supply-chain management through enhanced information visibility, *Productions and Operations Management Journal*, 16(5), 316-324.

Devaraj, S. and Kohli, R. (2000). Information technology payoff in the health care industry: A longitudinal study, *Journal of Management Information Systems*, 16, 41–67.

Doerr, K., Gates, W. (2003). An integrated multi-criteria and simulation approach to cost benefit analysis of inventory tracking. *INFORMS annual meeting*. Atlanta, Georgia.

Doerr, K. H., Gates, W., et al. (2006). A hybrid approach to the valuation of RFID/MEMS technology applied to ordnance inventory. *Int. J. Production Economics*, 103(2), 726-741.

Dos Santos, B.L. (1991). Justifying investment in new information technologies, *Journal of Management Information Systems*, 7(4), 71-89.

EPC Global (2008). Improving retail promotional execution, March15, 2010, available at http://www.epcglobalus.org/KnowledgeBase/Browse/tabid/277/DMXModule/706/Default.aspx?EntryId=1171.

Farrell, D. (2003). The real new economy. *Harvard Business Review*, 81(10), 104.

Fichman, R. G. (2004). Going beyond the dominant paradigm for information technology innovation research: Emerging concepts and methods, *Journal of the AIS*, 5(8), 11.

Fleisch, E., and Tellkamp, C. (2005). Inventory inaccuracy and supply chain performance: A simulation study of a retail supply chain. *International Journal of Production Economics*, 95, 373-385.

Forrester, J. W. (1958). Industrial dynamics: A major breakthrough for decision makers. *Harvard Business Review*, 36(4), 37-66.

Forrester, J. W. (1961). *Industrial dynamics*. Portland (OR): Productivity Press.

Fraza, V. (2000). Ending inventory errors in 60 days. *Modern Materials Handling*, 55(3), A11.

Frédéric, T., Jasser, A., and Elgar, F. (2009). Understanding the value of integrated RFID systems: A case study from apparel retail. *European Journal of Information Systems*, 18(6), 592-614.

Gaukler, G. M., Seifert, R. W., and Hausman, W. H. (2007). Item-level RFID in the retail supply chain. *Production and Operations management Journal*, 16(1), 57-65.

Gaukler, G. M., and Seifert, R. W. (2007). *Applications of RFID in supply chains*. In H. Jung, F.F. Chen, and B. Jeong (Eds.), *Trends in supply chain design and management: Technologies and methodologies*. London: Springer-Verlag.

Goswami, S., Teo, H. H., et al. (2008). Real options from RFID adoption: The role of institutions and managerial mindfulness. *ICIS 2008 Proceedings* Paper 128.

Gregoriades, A., and Karakostas, B. , (2004). Unifying business objects and system dynamics as a paradigm for developing decision support systems. *Decision Support Systems*, 37(2), 307-311.

Gruen, T. W., Corsten, D., and Bharadwaj, S. (2002). Retail out-of-stocks: A worldwide examination of extent causes and consumer responses, *Grocery Manufacturers of America*, Washington, D.C.

Gruen, T. W. and Corsten, D. (2008). A comprehensive guide to retail out-of-stock reduction in the fast-moving consumer goods industry, *Grocery Manufacturers of America*, Washington, D.C.

Guilford, S., and Kutis, M. (2005). RFID benefits: Looking beyond ROI. MBA Thesis, Graduate School of Business and Public Policy, Naval Postgraduate School, Monterey, CA.

Hafeez, K., M. , Griffiths, J., et al. (1996). Systems design of a two-echelon steel industry supply chain. *International Journal of Production Economics,* 45, 121-130.

Hardgrave, B. C. (2008). RFID as electronic article surveillance EAS: Feasibility assessment. White Paper, Information Technology Research Institute, University of Arkansas, Fayetteville, AR.

Hardgrave, B. C. (2009a). *Item-level RFID for apparel: The Dillard's RFID initiative*. White Paper, Information Technology Research Institute, University of Arkansas, Fayetteville, AR.

Hardgrave, B. C. (2009b). *Item-Level RFID for apparel: The Bloomingdale's RFID initiative*. White Paper, Information Technology Research Institute, University of Arkansas, Fayetteville, AR.

Hardgrave, B. C., Langford, S., Waller, M., and Miller, R. (2008). Measuring the impact of RFID on out of stocks at Wal-Mart. *MISQE,* 7(4), 181-192.

Heese, H. S. (2007). Inventory record inaccuracy, double marginalization and RFID adoption. *Production and Operations Management* 16(5), 542-553.

Heim, G. R., Wentworth, Jr. W. R., and Peng, **X**. (2009).The value to the customer of RFID in service applications. *Decision Sciences*, 40(3), 477-512.

Hevner, A. R., March, S.,T., Park, J. and Ram, S. (2004). Design science in information systems research, *MIS Quarterly*, 28(1), 75-106.

Hitt, L., M., and Brynjolfsson, E. (1996). Productivity, business profitability, and consumer surplus: Three different measures of information technology value, *MIS Quarterly*, 20(2), 121-142.

Hochstrasser, B. (1994). Justifying IT investments. In *Information management: The evaluation of information systems investments.* Willcocks, L. (Ed.).London: Chapman and Hall.

Hull, J.C., (2006). *Options, futures, and other derivative securities* (sixth edition), Princeton: Prentice Hall.

IBM (2004). Item-level RFID technology redefines retail operations with real-time, collaborative capabilities. New York: IBM Corporation.

Ingenbleek, P. (2007). Value-informed pricing in its organizational context: Literature review, conceptual framework, and directions for future research. *Journal of Product and Brand Management*,16(7), 441-458.

Ives, B., Hamilton, S. and Davis, G., (1980). A framework for research in computer-based management information systems. *Management Science*, 26(9), 910-934.

Kambil, A., and Brooks, J. (2002). Auto-ID across the value chain: From dramatic potential to greater efficiency and profit. White paper. MIT Auto-ID Center, Cambride, MA.

Kambil, A., Henderson, J., and Mohsenzadeh, H. (1993). Strategic management of IT investments: An options perspective. In *Strategic IT Management: Perspectives on Organizational Growth and Competitive Advantage,* Banker, R., D., Kauffman, R. J. and Mahmood, M.,A. , Harrisburg, PA: Idea Group Publishing, 161-178.

Karkkainen, M., and Holmstrom, J. (2002). Wireless product identification: Enabler for handling efficiency, customization and information sharing. *Supply Chain Management: An International Journal*, 7(4), 242-252.

Kay, M. (2008). An apparel research study and analysis, RFID well within reach. Apparel Magazine, June issue.

Kearney, A.T., IBM (2004). A balanced perspective: EPC/RFID implementation in the CPG industry. Whitepaper Prepared for Grocery Manufacturing of America.

Krafft, M., Mantrala, M. K. (2006). *Retailing in the 21st Century: Current and future Trends*. New York:Springer.

Kumar, R. (1999). Understanding DSS Value: An options perspective, *Omega, 27*(3),295-304.

Lach, P. L. (2002). Towards a systemic understanding of the dynamic interest income performance of a retail bank. South Africa: University of South Africa.

Lee, H., and Ozer, O. (2007). Unlocking the value of RFID. *Production and Operations Management* 16(1), 40-64.

Levy, M., and Weitz, B., (2006). *Retailing management*. Englewood Cliffs, NJ: McGraw-Hill/Irwin. Prentice Hall, [Prentice Hall is in Englewood Cliffs; delete McGraw-Hill/Irwin], 305.

Liao, Y., and Lu, Y. (2009).Justifying RFID technology in supply chain: A real options perspective. International Conference on Information Technology and Computer Science, ITCS, 2, 566-570, Kiev, Ukraine.

Linstone, H. A., Turoff, M. (2002). *The Delphi method: techniques and applications*. Reading, MA: Addison-Wesley.

Loebbecke, C., and Palmer, J.W. (2006). RFID in the fashion industry: Kaufhof department stores ag and Gerry weber international AG, fashion manufacturer. *MIS Quarterly Executive*, 5(2), 15-25.

MacCarthy, B. L., and Atthirawong, W. (2003). Factors affecting location decisions in international operations—a Delphi Study. *International Journal of Operations and Production Management*, 23(7), 794-818.

Malhotra, M. K., Steele, D. C., and Grover, V. (1994).Important strategic and tactical manufacturing issues in the 1990s.*Decision Sciences*, 25(2), 189-214.

Marquez,A.C.,Blanchar, C., (2006). A decision support system for evaluating operations investments in high-technology business, *Decision Support Systems*, 41(2), 472-48.

Motorola.(2008). Focused RFID solution: The right fit for apparel and footwear. White paper.

Murphy, M. K., Black, N. A., Lamping, D. L., McKee, C. M., Sanderson, C. F. B,Askham, J., and Marteau, T. (1998).Consensus development methods and their use in clinical guideline development. *Health Technology Assessment,* 2(3), 1-88.

Ogden, J. A., Petersen, K. J., Carter, J. R., and Monczkan, R. M.(2005).Supply management strategies for the future: A Delphi study. *The Journal of Supply Chain Management,* 41(3), 29-48.

Patli, M. (2004). Investments in RFID: A real options approach. A Patni Whitepaper.

Powell, C. (2003). The Delphi technique: Myths and realities. *Journal of Advanced Nursing*, 41(4), 376-382.

Prater, E., Frazier, G. V., and Reyes, P. M. (2005).Future impacts of RFID on e-supply chains in grocery retailing. *Supply Chain Management: An International Journal*,10(2), 134-142.

Rawal, A. (2009). RFID: The next generation auto-ID technology. *Microwave Journal*, 52(3), 58-60.

Reicheld, F.F. (1996). Learning from customer defections. *Harvard Business Review*, 74 (2),56–69.

Reid, N. C. (1988). The Delphi technique, its contribution to the evaluation of professional practice. In R. Ellis (Ed.), *Professional competence and quality assurance in the caring professions*. Beckenharn, Kent: Croom-Helm, 230-262.

Rekik, Y., Sahin, E., and Dallery, Y. (2008). Analysis of the impact of the RFID technology on reducing product misplacement errors at retail stores. *International Journal of Production Economics*, 112(1), 264-278.

Rekik, Y., E. Sahin, E., and Dallery, Y. (2009). Inventory inaccuracy in retail stores due to theft: An analysis of the benefits of RFID. *International Journal of Production Economics*, 118(1),189-198.

Remenyi,D. (2000). The elusive nature of delivering benefits from IT investment. *Electronic Journal of Information Systems Evaluation*, 3(1), 1-10.

Renkema, T. J. (2000).The IT value quest: How to capture the business value of IT-based infrastructure. New York: John Wiley.

Roussos, G. (2006). Enabling RFID in retail. *Computer*, 39(3), 25-30.

Sahin, E., Dallery Y., et al. (2002). Performance evaluation of a traceability system: An application to the radio frequency identification technology. *Systems, Man and Cybernetics, IEEE International Conference.*

Sahin, E. (2004).*A qualitative and quantitative analysis of the impact of auto id technology on the performance of supply chains*. Doctoral dissertation, Ecole Centrale Paris, Chatenay-Malabry, France.

Sambamurthy, V., Bharadwaj, A., and Grover, V. (2003). Shaping agility through digital options: Reconceptualizing the role of IT in contemporary firms, *MISQ*, 27(2), 237-263.

Sarac, A. ,Absi, N., and Dauzère-Pérès, S. (2008). A simulation approach to evaluate the impact of introducing RFID technologies in a three-level supply chain. Winter Simulation Conference, 2741-2749, Miami, FL.

Scavarda, A. J., Bouzdine-Chameeva, T., et al. (2006).A Methodology for Constructing Collective Causal Maps, *Decision Sciences,* 37, 263-284.

Sharpless, H. (2005). Marketing benefits tops in RFID adoption, May, 2010, http://www.rfidproductnews.com/issues/2005.05/feature/marketingbenefits.php

Sterman, J., (2000). Business dynamics: Systems thinking for a complex world, New York: McGraw-Hill, Irwin.

Stotz, M., andGrößler, A. (2006). Identifying fruitful combinations between system dynamics and soft OR. *Operations Research Proceedings,* Springer, 609-616.

Swamy, G., and Sarma S. (2003). Manufacturing cost simulations for low cost RFID systems. MIT Auto ID. Whitepaper. Cambridge, MA.

Szmerekovsky, J., Tilson, V., and Zhang, J. (2009). Pricing and allocation of retail space with one RFID enabled supplier and one non-RFID enabled supplier. *International Journal of Revenue Management,* 3*(1)***,** 37-55.

Tiwana, A., J. Wang, J., Keil, M., and Ahluwalia, P. (2007). The bounded rationality biasin managerial valuation of real options: Theory and evidence from IT projects. *Decision Sciences*, 38(1), 157.

Trigeorgis, L., (1995). *Real options: An overview of real options in capital investments: Models, strategies, and applications,* L. Trigeorgis, (Ed.) Westport, Conn.: Praeger, 1-28.

Raman, A., DeHoratius, N., and Ton, Z.(2001). Execution: The missing link in retail operations. *California Management Review,* 43, 136–152.

Van Der Zee, J. T. M., and De Jong, B. (1999). Alignment is not enough: Integrating business and information technology management with the balanced business scoreboard. *Journal of Management Information Systems,* 16(2), 137–56.

Whitaker, J., Mithas, S., et al. (2007). A field study of RFID deployment and return expectations. *Production and Operations Management Society,* 16(5).599-612.

Wu, X., Yue, D. and Bai, J. (2009). A real options approach to strategic RFID investment decisions. IEEE International Conference on RFID, Orlando, FL.

Zhou, W. (2009). RFID and item-level information visibility. *European Journal of Operational Research*, 198(1), 252-258.

APPENDIX A

Delphi Study Questionnaire

Project Title: Integrating Retail Operations with Item Level RFID*: A Delphi Study*

This questionnaire intends to identify the units and processes in retail operations that are affected by item-level RFID. We look at 4 different processes in retail operations management: Pricing management, Merchandise management, Store and service factors, and Supply chain management. Of course, customers have to be willing to use this technology in order for us to observe the impact of item-level RFID in retail operations. Assuming that the technology will be accepted by customers, we would like to capture any changes item-level RFID make in retail operations in stores.

Each section includes some background information followed by open-ended questions for the first round. The purpose of open-ended questions is to evoke the experts' opinions on causal relationships between units and processes in retail operations affected by RFID. In the consecutive rounds, some if-then statements based on the experts' answers to the previous round are presented to the experts. These statements express the causal relationships among units and processes influenced by RFID. In each consecutive round, the experts are asked if there are any units or any relationships missing in the presented statements. We keep updating the causal relationships until there is no further change. The current version of second round questions is based on what we have found in the literature.

1. Pricing management

1.1 Price determination; First round

Background. Enhanced information visibility provided by item-level RFID and personal shopping assistance, such as smart carts, allows retailers to monitor customers as they enter stores. For example, retailers can come up with a better set of promotions and complementary deals and bonuses if they know customers' shopping lists. The shopping basket was provided in barcode systems at the point of sale. However, RFID can provide a list of items that customers intended to buy, even if they did not. This list might be different from POS list for different reasons such as unavailability of items.

Q. How can information visibility provided by RFID help managers improve price determination processes? Please specifically mention the units and processes that are influenced.

1.2 Price implementation; First round

Background. Dynamic price signs and tags are the new generation of electronic label pricing (ELP) that allow retailers to update the prices from a computer station. With the new generation of ELPs through item-level RFID tags, retailers do not need to manually set initial prices or markdown prices for each and every item in stores. All they need is to update the items prices automatically by updating the related databases.

Q. How does this new ELP generation, do you think, impact pricing implementation in retail stores? Please specifically mention units and processes that are influenced by ELP.

2. Merchandise management

2.1 Merchandise variety and assortment management; First round

Background. Enhanced information visibility provided by RFID helps managers determine what products are complementary to others. Product locating tools, such as smart carts, provided by RFID allow retailers to monitor customers' behavior as they enter a store and look through different products. This monitoring gives managers better ideas on selecting the variety and assortment of the products. A better variety/assortment means customers are more likely to find the products they are looking for.

Q. How does RFID information visibility improvements in variety/assortment management impact retail operation management? Please specifically mention the units and processes that are influenced by RFID enhanced information visibility.

2.2 Loss Prevention; First round

Background. One way to achieve better product availability is to reduce item shrinkage caused by shop-lifting as well as misplacing items on the shelves. Item-level RFID tags allow retailers to track assets and automatically detect product shop-lifting and misplacements through real time RFID information.

Q. How will using RFID as electronic article survailance (EAS) replacement improve the operations involved in retail stores? Please specifically mention units and processes that are influenced by RFID in lost prevention.

3. Service and store factors

3.1 Automatic check-out; First round

Background. Faster checkouts provided by automatic check-out via item-level RFID allows customers spending less time in shopping and makes consumers feel more efficient in their shopping.

Q. How will automatic check-out provided by item-level RFID improve store and service opeations in retail stores? Please specifically mention the units and processes that are influenced by utilizing this tool.

3.2 Product Location; First round

Background. An application of RFID at item-level is helping customers to locate the products they need. Smart carts, as a product locating tool for example, enable customers to locate products more easily and obtain information on any individual product faster.

Q. How will product locating tools provided by item-level RFID improve store and service opeations in retail stores? Please specifically mention the units and processes that are influenced by utilizing these tools.

4. Supply chain management

4.1 Inventory accuracy; First round

Background. Real time information visibility of items in the backstore as well as items on the shelves leads to having an accurate count of available items in stores. This is considered a significant improvement in inventory accuracy in the supply chain.

Q. How will improvments in inventory accuracy provided by item-level RFID impact units and opeations in the supply chain? Please specifically mention the units and processes that are influenced by utilizing this technology.

4.2 Shelf-replenishment; First round

Background. Shelf stock replenishment takes advantage of item-level RFID and reduces lost sales by providing more product availability. Information visibility provided by item-level RFID allows shelf replenishment as frequently as needed to meet customers' needs.

Q. How will improvments in shelf replenishment provided by item-level RFID improve opeations in the supply chain? Please specifically mention the units and processes that are influenced by utilizing this technology.

APPENDIX B

Simulation Equations

(01) "# of orders"= INTEG (

IF THEN ELSE(Recieve order=0, 0 , 1),

0)

(02) "# of replenishments"= INTEG (

IF THEN ELSE("replenish-level needed from inventory"=0 , 0 , 1),

0)

(03) accumulated change rate by shopping exprience quality= INTEG (

accumulated change rate by shopping exprience quality*("rate of # of customer change by product locating (smart carts)"

+Automatic checkout impact on number of customers+"rate of # of customer change by customer service quality"

),

Average daily customers*("rate of # of customer change by product locating (smart carts)"

+Automatic checkout impact on number of customers+"rate of # of customer change by customer service quality"

))

(04) accumulated OOS in inventory= INTEG (

inventory OOS,

0)

(05) accumulated OOS on shelves= INTEG (

Shelf OOS,

0)(06) Automatic checkout impact on number of customers=

0

Units: [-0.05,0.05,0.01]

(07) "available Shelf-replenishment items"=

IF THEN ELSE("replenish-level needed from inventory", IF THEN ELSE(Real items in inventory

>"replenish-level needed from inventory" , "replenish-level needed from inventory"

, Real items in inventory),0)

(08) "Average # of customers"=

(accumulated change rate by shopping exprience quality)+Average daily customers

(09) Average daily customers=

RANDOM NORMAL(12, 48 , 30 , 9 ,30)

Units: [?,500,1]

RANDOM NORMAL(1, 30 , 10 , 6.3 ,10) --RANDOM NORMAL(1, 19 , 10 ,

3 ,10)

(10) Average inventory on hand= INTEG (

Real items in inventory/100,

0)

(11) Avg on shelf= INTEG (

Real items on shelves/100,

0)

(12) Customers purchased=

"Average # of customers"-Shelf OOS

(13) FINAL TIME = 100

Units: Month

The final time for the simulation.

(14) Frequency of manual check=

100

Units: week [0,?,1]

(15) Incoming customers=

"Average # of customers"

(16) Incoming items=

IF THEN ELSE("Manual shelf-check"=0 , shelf misplacement+"available Shelf-replenishment items"

, "available Shelf-replenishment items")

(17) Incoming items 0=

IF THEN ELSE(Inventory Manual check=0, total inventory misplacement+Recieve order

,Recieve order)

(18) Increased revenue by lighter markdowns=

Revenue change rate by lighter*(RFID visibility on shelves+RFIDvisiblity on inventory)/2

(19) Increased revenue by store discounts=

rate of store promotions change by revenue* (RFID visibility on shelves+RFIDvisiblity on inventory)/2

(20) INITIAL TIME = 0

Units: Month

The initial time for the simulation.

(21) Inventory Manual check= INTEG (

IF THEN ELSE(Inventory Manual check=0, Rate of inventory manual check, -1

),

5)

Units: [0,50,1]

(22) Inventory misplacement rate=

0

(23) inventory OOS=

IF THEN ELSE("available Shelf-replenishment items">0, IF THEN ELSE(Real items in inventory

<> 0, IF THEN ELSE(Real items in inventory

< "Average # of customers", "Average # of customers"-Real items in inventory

, 0), "Average # of customers") , 0)

(24) Inventory records= INTEG (

IF THEN ELSE(inventory OOS=0,

IF THEN ELSE(Inventory Manual check=0,

-Inventory records+Real items in inventory+ Recieveorder+total inventory misplacement

-"available Shelf-replenishment items"- "items-in-inventory correction"

,

Recieve order-leaving items 0

) ,

-Inventory records+Real items in inventory+ Recieve order-"available Shelf-replenishment items"

- "items-in-inventory correction"

),

Order size+Reorder point)

IF THEN ELSE(Manual check=0 , (-Inventory records+Real items in

inventory)*0, IF THEN ELSE(cost=0, Recieve order-leaving items,

-Inventory records+600))

(25) "items-in-inventory correction"=

(Misplaced 0+Theft 0)*"available Shelf-replenishment items"

Units: items

(Misplaced 0+Theft 0)*"available Shelf-replenishment items"

(26) "items-on-shelf correction"=

IF THEN ELSE((Real items on shelves> 0) , (Misplaced rate+Theft rate)*"Average # of customers"

, 0)

Units: items

IF THEN ELSE((Real items on shelves> 0) , INTEGER((Misplaced

rate+Theft rate)*Real items on shelves), 0)

(27) leaving items=

Visibility+Customers purchased

Units: items

(28) leaving items 0=

RFID visiblity on inventory*"items-in-inventory correction"+"available Shelf-replenishment items"

(29) Manual check staff hour=

IF THEN ELSE("Manual shelf-check"=0, "staff-hour per manual check" * (1-RFID visibility on shelves

), 0)

(30) "Manual shelf-check"= INTEG (

IF THEN ELSE("Manual shelf-check"=0, Frequency of manual check, -1),

5)

(31) "Minimum shelf-level"=

50

Units: items [0,500,1]

if items on the shelf < minimum then replenish the shelves; lead time=1 so should check to see if shelves level is at least not empty until the end of the next period.

(32) Misplaced 0=

(1-RFID visiblity on inventory)*Inventory misplacement rate

IF THEN ELSE((Real items in inventory> 0) , RANDOM UNIFORM(0, 0.03, 0.01)*Real items in inventory , 0)

(33) Misplaced rate=

(1-RFID visibility on shelves)*Shelf misplacement rate

IF THEN ELSE((Real items on shelves> 0) , RANDOM UNIFORM(0, 0.05, 0.01)*Real items on shelves , 0)

(34) Not satisfied customers=

Shelf OOS

(35) OOS percentage=

IF THEN ELSE((Sales+accumulated OOS on shelves)=0 , 0 , accumulated OOS on shelves

/(Sales+accumulated OOS on shelves))

(36) Order size=180

(37) Outgoing items=

"items-on-shelf correction"+Customers purchased

(38) Outgoing items 0=

"available Shelf-replenishment items"+"items-in-inventory correction"

(39) Place Order=

IF THEN ELSE(Inventory records-"available Shelf-replenishment items"<Reorder point

,

Order size,

0)

IF THEN ELSE(Inventory records-"available Shelf-replenishment items"<Reorder point, Order size- (Inventory records-"available Shelf-replenishment items"), 0)

(40) "rate of # of customer change by customer service quality"=

0

(41) "rate of # of customer change by product locating (smart carts)"=0

(42) Rate of inventory manual check=30

(43) "rate of staff-hour for shelf-replenishment"=1

(44) "rate of staff-hour per customer"=0

Units: [0,0.05,0.01]

(45) rate of store promotions change by revenue= 0

(46) ratio of loss to sales=

IF THEN ELSE(Sales=0 , 0 , (total shelf loss+total inventory loss)/Sales)

(47) Real items in inventory= INTEG (

IF THEN ELSE(Incoming items 0=0 , IF THEN ELSE(Real items in inventory<

"available Shelf-replenishment items"

, -Real items in inventory

, IF THEN ELSE(Real items in inventory>Outgoing items 0, -Outgoing items 0

, -"available Shelf-replenishment items"))

, IF THEN ELSE(

Real items in inventory<"available Shelf-replenishment items", -Real items in inventory

+Order size, Incoming items 0-Outgoing items 0

)),

Order size+Reorder point)

Units: items

INTEGER (IF THEN ELSE(Incoming items 0=0 , IF THEN ELSE(Real items in inventory<"available Shelf-replenishment items" , -Real items in inventory , IF THEN ELSE(Real items in inventory>Outgoing items 0, -Outgoing items 0 , -"available Shelf-replenishment items")) , IF THEN ELSE(Real items in inventory<"available Shelf-replenishment items", -Real items in inventory +Order size, Incoming items 0-Outgoing items 0)))

(48) Real items on shelves= INTEG (

Incoming items-Outgoing items,

Shelves capacity)

(49) Recieve order=

Place Order

Units: items

DELAY FIXED(Place Order*300 , lead time , 0)

(50) Reorder point=

48

Units: items [0,300,1]

now Load of one shelf but safety stock= shelves capacity *(2 - (RFID visibility on shelves + RFID visiblity in inventory)/2) if visibility perfect keep items only for the next period. if not keep twice as much. So reduced safety stock is rfid visibility percentage of shelves capacity

(51) "replenish-level needed from inventory"=

IF THEN ELSE("Manual shelf-check"=0, IF THEN ELSE((Real items on shelves

-leaving items) <="Minimum shelf-level", Shelves capacity-Real items on shelves

+leaving items

, 0) , IF THEN ELSE

(("Shelf-record" -leaving items)<="Minimum shelf-level", Shelves capacity

-"Shelf-record"+leaving items, 0))

Units: items

IF THEN ELSE("Manual shelf-check"=0, IF THEN ELSE(Real items on

shelves<="Minimum shelf-level", Shelves capacity-Real items on

shelves , 0) , IF THEN ELSE (("Shelf-record" -leaving

items)<="Minimum shelf-level", Shelves capacity

-"Shelf-record"+leaving items, 0))

(52) "replenishment staff-hour"=

IF THEN ELSE("replenish-level needed from inventory"=0, 0, "rate of staff-hour for shelf-replenishment"

)

(53) Request=

Manual check staff hour+"replenishment staff-hour"+"Staff-hour needed for customers"

(54) Request 0=

IF THEN ELSE("available Shelf-replenishment items"=0 , IF THEN ELSE(Inventory Manual check

=0, 10 , 0) , IF THEN ELSE(Inventory Manual check=0, 10 + "staff-hour rate for replenishment"

, "staff-hour rate for replenishment"))

(55) Revenue change rate by lighter=0

(56) RFID visibility on shelves=

0

Units: [0,1,0.1]

(57) RFID visiblity on inventory=

0

Units: [0,1,0.1]

(58) Sales= INTEG (

(Incoming customers-Not satisfied customers)*(Increased revenue by lighter markdowns

+Increased revenue by store discounts+1),

0)

Units: items

(59) SAVEPER =

TIME STEP

Units: Month [0,?]

The frequency with which output is stored.

(60) shelf misplacement= INTEG (

IF THEN ELSE(Frequency of manual check="Manual shelf-check", -shelf misplacement

, IF THEN ELSE((Real items on shelves> 0) , Misplaced rate*"Average # of customers"

, 0)),

0)

(61) Shelf misplacement rate=

0

(62) Shelf OOS=

IF THEN ELSE(Real items on shelves<"Average # of customers", IF THEN ELSE

(Real items on shelves<0, "Average # of customers" , "Average # of customers"

- Real items on shelves), 0)

IF THEN ELSE(Real items on shelves<"Average # of customers", IF

THEN ELSE(Real items on shelves<0, "Average # of customers" ,

"Average # of customers" - Real items on shelves), 0)

(63) "Shelf-record"= INTEG (

IF THEN ELSE ("replenish-level needed from inventory"=0, IF THEN ELSE("Manual shelf-check"

=0, IF THEN ELSE("items-on-shelf correction"

=Visibility, -"Shelf-record"+Real items on shelves +shelf misplacement-leaving items

, IF THEN ELSE (Visibility=0,-"Shelf-record"+Real items on shelves+shelf misplacement

-"items-on-shelf correction"

-leaving items,-"Shelf-record"+Real items on shelves +shelf misplacement

-"items-on-shelf correction"-leaving items

+Visibility)),"available Shelf-replenishment items"-leaving items), IF THEN ELSE

("Manual shelf-check"=0, -"Shelf-record"

+Real items on shelves+shelf misplacement-"items-on-shelf correction"

+"available Shelf-replenishment items" -Customers purchased,"available Shelf-replenishment items"

-leaving items

)),Shelves capacity)

IF THEN ELSE ("replenish-level"=0, IF THEN ELSE("Manual shelf-check"=0, IF THEN ELSE("items-on-shelf correction"=Visibility, -"Shelf-record"+Real items on shelves -leaving items, IF THEN ELSE (Visibility=0,-"Shelf-record"+Real items on shelves -leaving items-"items-on-shelf correction",-"Shelf-record"+Real items on shelves -leaving items-"items-on-shelf correction"+Visibility)), "replenish-level"-leaving items), IF THEN ELSE("Manual shelf-check"=0, -"Shelf-record"+300-Real items on shelves+Visibility,"replenish-level"-leaving items))

(64) Shelves capacity=150

(65) "Staff-hour by inventory"= INTEG (

Request 0,0)

(66) "Staff-hour needed for customers"=

"rate of staff-hour per customer"*"Average # of customers"

(67) "staff-hour per manual check"=

2

Units: [0,10,1]

(68) "staff-hour rate for replenishment"=

2

Units: [0,20,1]

(69) "Staff-hour"= INTEG (Request,0)

(70) Theft 0=0

IF THEN ELSE((Real items in inventory> 0) , RANDOM UNIFORM(0,

0.03, 0.01)*Real items in inventory , 0)

(71) Theft rate=

0

Units: items [0,0.1,0.01]

IF THEN ELSE((Real items on shelves> 0) , RANDOM UNIFORM(0,

0.05, 0.01)*Real items on shelves , 0)

(72) TIME STEP = 1

(73) total inventory loss= INTEG (

"items-in-inventory correction", 0)

(74) total inventory misplacement= INTEG (

IF THEN ELSE(Inventory Manual check=Rate of inventory manual check, -total inventory misplacement

, "available Shelf-replenishment items"*Misplaced 0),0)

(75) total shelf loss= INTEG (

"items-on-shelf correction",0)

(76) Visibility=

"items-on-shelf correction"*RFID visibility on shelves

Units: items

APPENDIX C

IRB Approval

Oklahoma State University Institutional Review Board

Date:	Monday, May 18, 2009
IRB Application No	BU0917
Proposal Title:	Integrating Retail Operations with Item Level RFID: A Delphi Study
Reviewed and Processed as:	Exempt

Status Recommended by Reviewer(s): Approved Protocol Expires: 5/17/2010

Principal Investigator(s):

Narges Kasiri 101 Hanner Stillwater, OK 74078	Ramesh Sharda 104D Business Stillwater, OK 74078

The IRB application referenced above has been approved. It is the judgment of the reviewers that the rights and welfare of individuals who may be asked to participate in this study will be respected, and that the research will be conducted in a manner consistent with the IRB requirements as outlined in section 45 CFR 46.

X The final versions of any printed recruitment, consent and assent documents bearing the IRB approval stamp are attached to this letter. These are the versions that must be used during the study.

As Principal Investigator, it is your responsibility to do the following:

1. Conduct this study exactly as it has been approved. Any modifications to the research protocol must be submitted with the appropriate signatures for IRB approval.
2. Submit a request for continuation if the study extends beyond the approval period of one calendar year. This continuation must receive IRB review and approval before the research can continue.
3. Report any adverse events to the IRB Chair promptly. Adverse events are those which are unanticipated and impact the subjects during the course of this research; and
4. Notify the IRB office in writing when your research project is complete.

Please note that approved protocols are subject to monitoring by the IRB and that the IRB office has the authority to inspect research records associated with this protocol at any time. If you have questions about the IRB procedures or need any assistance from the Board, please contact Beth McTernan in 219 Cordell North (phone: 405-744-5700, beth.mcternan@okstate.edu).

Sincerely,

Shelia Kennison, Chair
Institutional Review Board

VITA

NARGES KASIRI

Candidate for the Degree of

Doctor of Philosophy

Thesis: A HYBRID MODEL FOR IT INVESTMENT ANALYSIS: APPLICATION TO RFID ADOPTION IN RETAIL SECTOR

Major Field: Business Administration

Biographical:

Education:

Completed the requirements for the Doctor of Philosophy/Education in Business Administration at Oklahoma State University, Stillwater, Oklahoma in July, 2010.

Completed the requirements for the Master of Science/Arts in your major at Eastern Michigan University, Ypsilanti, Michigan, USA in 2003.

Completed the requirements for the Bachelor of Science/Arts in Computer Engineering at Sharif University of Technology, Tehran, Iran in 1996.

Experience:

Graduate Teaching Associate, MSIS Department, Oklahoma State University, Fall 2008 – current.

Graduate Research Assistant, MSIS Department, Oklahoma State University, Fall 2005 – Summer 2009.

Visiting Researcher, RFID Research Center, Walton School of Business, University of Arkansas, Summer 2009.

Research Consultant, Financing Healthcare IT, Empirica International Research and Consulting Firm, Bonn, Germany, Summer 2008.

Professional Memberships:

Association of Information Systems, Decision Science Institute, INFORMS.

Name: Narges A. Kasiri Date of Degree: July, 2010

Institution: Oklahoma State University Location: Stillwater, Oklahoma

Title of Study: A HYBRID MODEL FOR IT INVESTMENT ANALYSIS: APPLICATION TO RFID ADOPTION IN The RETAIL SECTOR

Pages in Study: 131 Candidate for the Degree of Doctor of Philosophy

Major Field: Business Administration

Scope and Method of Study: One of the major obstacles in Information Technology (IT) adoption is its return on investment analysis. IT benefits in organizations are hard to measure and are usually realized over time. System dynamics approach has been used in IT literature to identify the impact of IT on business processes. Given benefits of any IT system in organizations, however, there is a high degree of uncertainty in achieving such benefits. Managerial flexibility in decision making process of implementing a new IT helps managers to overcome this uncertainty over time. Traditional cost benefit analysis such as NPV that is typically used to value any technology is unable to value managerial flexibilities while real options theory offers a model that can value a new investment as uncertainties about the system decreases over time. In this dissertation, we are proposing a new hybrid model for IT return on investment (ROI) that combines system dynamics and real options as two major techniques in economics of IT. This robust hybrid model takes advantages of both techniques while overcoming their weaknesses. We propose a systems dynamic solution to simulate the way an IT influences and improves an organization to be able to estimate the parameters used in the real options model. The hybrid model is used to find the best time for investing in item-level RFID in the retail sector.

Findings and Conclusions: The results of return on investment analysis on item-level investment show that the variable cost of investment that is the tag prices dominates the return on investment. Other factors such as product unit price and consequently type of retail stores are important as well. The system dynamics simulation provided some major parameters of the real options model such as the expected payoffs and volatility of the expected payoffs that were hard to find in the literature.

ADVISER’S APPROVAL: Dr. Ramesh Sharda