The Impact of RFID on Firm and Supply Chain Performance: a Simulation Study

Research-in-Progress

Xiaoran Wu
University of North Carolina at Charlotte
Xwu5@uncc.edu

Jing Zhou
University of North Carolina at Charlotte
Jzhou7@uncc.edu

Sungjune Park
University of North Carolina at Charlotte
supark@uncc.edu

Chandrasekar Subramaniam
University of North Carolina at Charlotte
csubrama@uncc.edu

Abstract

Radio Frequency Identification (RFID) is a tracking technology that enables firms to digitize their supply chain processes and manage their supply chain activities efficiently and effectively. This study develops an analytical model of the impact of RFID use on inventory accuracy and on the firm-level and supply chain-level performance of a single product line. Due to the complexity of the analytical model, we propose to analyze the model using simulation and to gain insights into the behaviors of the various players in the supply chain. This research in progress will help better understand RFID value in supply chain, from an inventory management perspective and also bring into focus the impact of product type and technology development status on technology use.

Keywords: RFID, RFID impact, supply chain, inventory inaccuracy, simulation, supply chain performance

Introduction

Radio Frequency Identification (RFID) has been cited as "the best thing since bar-code" in managing supply chains (e.g. Economist 2003). RFID can enable firms to digitize their supply chain processes and manage their supply chain activities efficiently and effectively. Some industry reports claim that the potential benefits of RFID in supply chains will come in many forms. For example, Accenture estimated that 100% of the labor cost in physical counting could be eliminated and the savings in receipt could be 6.5% through RFID (Lacy 2005); IBM's estimate on inventory reduction was 5% to 25% from RFID (Economist 2003); and SAP (2003) estimated that with RFID theft loss would be reduced by 40% to 50%. However, these reports d0 not describe the specific processes that lead to the benefits of RFID. Recent academic empirical research on the benefits of RFID, such as out of stock reduction (e.g., Hardgrave et al. 2005), has focused on specific retail chains, such as Wal-Mart and may not be readily generalizable to other retail settings. Lee and Ozer (2007) argued that there is still a credibility gap on the proclaimed values of RFID and encouraged researchers to close the gap by using more systematic research methods.

DeHoratius and Raman (2008) reported that 65% of the inventory records in retail stores were not accurate in their case study. Raman et al. (2001) found that such inaccuracies could reduce 10% of profit because of higher inventory cost and lost sales, which make inventory inaccuracy a critical issue in supply chain management. Our research studies the value creation of RFID in a multi-echelon supply chain from an inventory inaccuracy perspective. Our model also include RFID's technology development status and its use for different product types since the unique technical features of RFID may fit with characteristics of some products better than with others.

Our study extends current RFID research in several ways. First, the study will provide better insights on how RFID value is derived in a supply chain by modeling the operating characteristics of RFID-enabled supply chain. Second, the use of simulation approach allows us to go beyond the impact of RFID on a single organization or a dyadic relationship in a single period and to study a multi-echelon supply chain in multiple time periods with different types of products. Third, this research takes into account the technology development status of RFID and this consideration will position our study in a more realistic setting, compared with existing literature where RFID was treated as a perfect technology providing 100% supply chain visibility. Fourth, the study considers RFID's cost in a complex supply chain setting and measures RFID value from total gross profits (henceforth, profits) at both firm and supply chain levels. Overall, we believe that our study is a step toward concretely measuring the value of RFID in supply chains and can be used with other research on supply chain technologies to better understand the management of inventory accuracy problem.

In the next section, we review the extant research on RFID value and inventory inaccuracy. In the third section, we explain the research setting. We then describe how supply chains without RFID and supply chains with RFID are modeled. Finally, we discuss the experiment design, performance measures, and the plans for the study completion, including plans for model validation.

Literature Review

From an inventory management perspective, inventory inaccuracy, which is the difference between inventory record and physical inventory, is a critical issue. While many organizations have automated their inventory management by using information systems, inventory levels in these systems do not always match with physical inventory levels (Fleisch and Tellkamp 2005). In addition, not all the physical inventory is available to sell. Among different sources for inventory inaccuracy in supply chains, inventory shrinkage, misplacement and transaction errors are the most common. Transaction errors mainly occur as cashiers scan products when customers check out. Since most RFID adopters have not applied RFID at this level, our study only considers the first two sources of errors where RFID can help to improve inventory accuracy.

After reviewing extant literature that addresses inventory inaccuracy problem by using RFID technology, we identified three streams for RFID value research, shown in Table 1.

Table 1. Literature Review on RFID Value Research

Research Focus	Research Methods	References	Summary and Main Limitations
Understand difficulties and efficiency of RFID integration and evaluate associated costs and benefits for RFID applications in supply chains.	Empirical, especially case-studies	Delen et al. (2007), Ngai et al. (2007), Wamba et al. (2008)	Single case or a few cases One or two levels of supply chain in a single period One or two sources of errors Cost is the main measure One type of product RFID is viewed as perfect Naïve system as benchmark
Model operating characteristics of a business system to investigate how RFID could impact basic business control policies.	Analytical, operation research	Atali et al. (2006), Kok and Shang (2007), Gaukler et al. (2007), Rekik et al. (2009)	
Model detailed operating characteristics and dynamics of a system to help better understand RFID effects in more complicated settings.	Simulation approach	Lee et al. (2005), Kang and Gershwin (2005), Fleisch and Tellkamp (2005), Wang et al. (2008)	

The first stream focuses on understanding the difficulties and efficiency of RFID integration and associated costs/benefits of RFID application in supply chain activities. This stream mainly applies empirical approach, especially case studies (e.g., Delen et al. 2007; Ngai et al. 2007), and examines RFID value in one single case or a couple of cases and in totally different industry sectors. Delen et al. (2007) conducted a case study in which actual RFID data collected from the cases shipped from one supplier to a retailer was used to assess the value of RFID. They identified performance metrics that can be computed from RFID readings and discussed how these measures can improve logistical performance at a supply chain operation level. Ngai et al. (2007) studied RFID integration in a mobile commerce system. By developing an RFID prototype system to analyze the impacts of RFID on locating, tracking, and managing containers in a depot, they found that RFID helps improve visibility, decrease errors and accelerate operational processes.

The second stream of research concentrates on how RFID could impact basic business control policies, by modeling operating characteristics of a business system (e.g., Atali et al. 2006, Gaukler et al. 2007). Since this stream often investigates RFID value in a single organization or a supply chain including only two levels and one source of errors causing inventory inaccuracy problem, analytical modeling approach is mainly used and cost is the outcome investigated. For example, Atali et al. (2006) studied a single item periodic review inventory problem for a single stage supply chain but they considered shrinkage, misplacement and transaction errors as the sources of inventory inaccuracy in their model. Rekik et al. (2009) analyzed the role of theft only in retail stores for information inaccuracy problem. They provided the optimal inventory policy for three different approaches examined in their study and proposed a critical tag cost that makes RFID technology implementation cost-effective. Majority of existing studies on RFID applications in supply chains are case studies or apply analytical approach. While case studies provide insights for RFID applications in specific cases and analytical models offer more generalizable results, they tend to be either too specific in case studies or too general due to the assumptions applied in analytical research in order to mathematically solve the problem.

The third stream of research models detailed operating characteristics and dynamics of a system to understand the impact of RFID in a complex setting (e.g. Fleisch and Tellkamp 2005). Simulation approach fits well with this type of research. For example, Lee et al. (2004) conducted a quantitative analysis to assess the potential values of RFID in inventory reduction and service level improvement. They found that RFID can reduce the distribution center inventory by 23% and completely remove backorders.

They also showed that RFID can help reduce order quantity thereby reducing inventory levels of distribution centers up to 47%. These results are based on the assumption that RFID read rate is 100%. Fleisch and Tellkamp (2005) also considered RFID as a perfect technology which can remove all inventory accuracy errors. However, studies on RFID impacts using simulation approach are rare and often use naïve system (i.e. managers ignore the existence of inventory inaccuracy) as benchmark for RFID value. The use of simulation approach in our paper is also in line with Lee and Ozer's (2007) call to investigate the value of RFID from a ground-up view, because this method provides a better way to observe the complex dynamics of an RFID-enabled inventory system over time.

Problem Description

The model in our study represents a typical supply chain including a manufacturer, a distributor and a retailer with different products observed over *T* simulation periods. Figure 1 shows the configuration of the supply chain. The retailer places orders and receives products from a distributor, which obtains the products from the manufacturer in order to fulfill the retailer's demands. Theft and misplacement occur and cause inventory accuracy problems at each party of the supply chain. Our model focuses on RFID's application for inventory tracking and replenishment of finished goods.

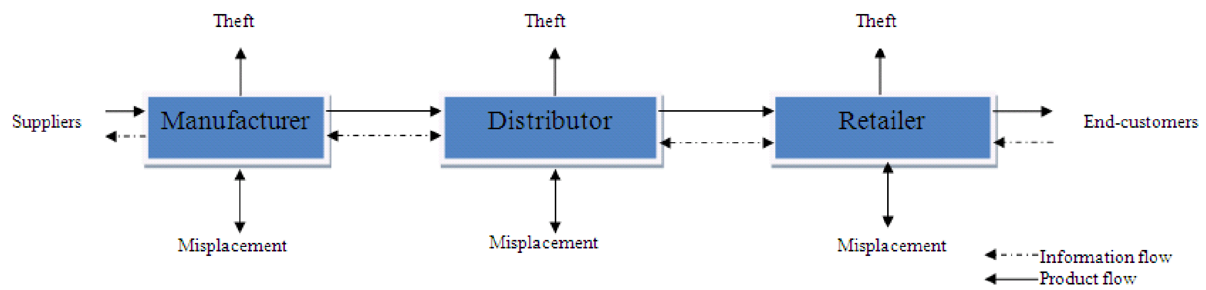

Figure 1: The supply chain studied

Table 2. Scenarios in RFID Impact Study		
Scenario	Model	Description
Scenario 1	Base case without RFID	Barcode or the similar identification technology is used, inventory inaccuracy problem exists, and the inventory inaccuracy is ignored by managers and inventory control system.
Scenario 2	Full RFID implementation	RFID tags are installed on products by the manufacturer and used by all the downstream parties of the supply chain.
Scenario 3	Partial RFID implementation	RFID is installed by the distributor; only the distributor and the retailer use RFID technology but the manufacturer may also benefit from more accurate order information.
Scenario 4	Informed system without RFID	Inventory manager is aware of inventory discrepancy and would like to use the historical data to update the distribution of error sources after each inventory count.

The purpose of our exploratory study is to understand the mechanism by which RFID impacts inventory accuracy rather than to provide conclusive evidence of RFID's role in reducing inventory inaccuracy. Specifically, we are interested in investigating how RFID affects different sources of inventory errors and thereby improves inventory accuracy for each party in the supply chain. It is important to understand that when one of the parties in the supply chain installs RFID tags to the product, only the downstream parties benefit directly from the RFID information. Any benefit to upstream parties is due to the indirect effects of more efficient ordering by the downstream parties. Hence, to gain maximum insights from the simulation, we pick 4 scenarios that represent two benchmark scenarios and two most likely configurations of RFID implementation scenarios (Table 2). Scenario 1 represents a naïve system which helps us set the upper limit for potential benefit from RFID implementations. Scenario 4 still does not use RFID, but is a more realistic benchmark because firms can mitigate inventory inaccuracy problem by using their historical data about the errors. Scenario 2 represents a complete implementation where all parties are impacted by RFID's use. Scenario 3 represents the installation of RFID tags by distributor which then directly affects the retailer (a scenario where retailer installs RFID will not directly benefit the other parties in the supply chain). It is important to note that if scenarios 2 and 3 show significant benefits from RFID and interesting insights into an RFID-enabled supply chain, more scenarios can be created based on the results from our initial round of simulations.

Simulation Models

In our model, the retailer faces a deterministic end-customer paying demand in each period, which generates the revenues in the supply chain. The retailer can fulfill customer demand as long as enough products are in stock (i.e. there is no difference between shelf and backroom). Our study assumes that end-customers will walk away without purchasing if their demands cannot be fulfilled immediately, which represents lost sales for the retailer. This consideration makes the present study more realistic, compared to studies in existing literature which assume backorders for unsatisfied demand from end-customers (e.g. Lee at all 2004). In each period, the retailer places an order based on inventory and outstanding orders under a (s,S) replenishment policy. The distributor tries to fulfill incoming orders from the retailer. If an order cannot be fulfilled, the distributor will enter the order into order backlog and will fulfill it in a future period. In each period, the distributor places its order to the manufacturer, if necessary, based on its replenishment policy (s, S), as well as its inventory, backorders and outstanding orders placed in previous periods. The manufacturer behaves very similar to the distributor for fulfilling orders, except that the manufacturer produces products, according to its current inventory and backorder, as well as the productions in previous periods under a certain production policy. During all the processes discussed above, every party of the supply chain faces the inventory inaccuracy problem and consequently suffers inefficient inventory management, higher inventory levels and poor customer service. Overall, supply chain performance is curtailed mainly due to inventory inaccuracies, which can be reduced or eliminated by RFID.

The research problem is modeled using discrete event simulation which generally provides more information about the system. In addition to the assumptions mentioned above, the model in our study also assumes that the manufacturer's upstream supplier has infinite capacity, expediting backlog amounts is not considered, and we do not discount future cash flows.

Base Case^o [1]

The sequence of events in the retailer is as follows and most of them apply to all other scenarios.

(1) At the beginning of period t, inventory manager/automatic inventory control system in the retailer reviews inventory position and places an order $O_{r,t}^{o}$ to the distributor by following (s,S) policy, if necessary. The replenishment lead time is denoted as L, a certain number of periods. The order cost per unit is denoted as c_r.

(2) During the period t, sales $a_{r,t}^{o}$ and inventory errors (theft $g_{r,t}^{o}$ and misplacement $k_{r,t}^{o}$) take place based on the demands from paying customer $A_{r,t}^{o}$, theft $G_{r,t}^{o}$ and misplacements $K_{r,t}^{o}$, and actual inventory.

(3) At the end of the period t, holding cost occurs based on on-hand inventory record including misplaced items and h_r denotes the holding cost per unit. Cost from lost sales also occurs if there is unfulfilled end-customer demand and z_r denotes lost sales cost per unit. However, there is no cost for unmet demand from non-paying customers who take away products without paying.

[1] This study uses "o" to represent the base case in the notation.

(4) If the period t is a counting period, a physical audit of the inventory is conducted at the end of the period and the inventory record is reconciled, i.e., inventory errors are corrected and all misplaced items are found and returned to salable inventory. Otherwise, inventory errors are accumulated continuously.

Based on Atali et al. (2006), the formulation for the retailer in the base scenario is as follow. At the beginning of period t, the retailer faces a total demand of $D^o_{r,t}$ which is calculated as $D^o_{r,t} = A^o_{r,t} + G^o_{r,t} + K^o_{r,t}$ where $A^o_{r,t}$, $G^o_{r,t}$ and $K^o_{r,t}$ follow certain distributions. The retailer reviews the inventory position under the inventory policy (s^o_r, S^o_r) and places an order if necessary. When the retailer finds that the inventory record, $\hat{I}^o_{r,t}$ is zero at the beginning of the period, it will only compare outstanding orders to the reorder point s^o_r to make a decision on whether an order must be placed. If order is placed, the order quantity depends on the difference between up-to-order S^o_r and outstanding orders at that moment. When the retailer's inventory record is not equal to zero, the order quantity is based on inventory position under(s^o_r, S^o_r) . Otherwise, no order will be placed.

For the realized sales in the period t, we use a formulation similar to that of Kang and Gershwin (2005): $a^o_{r,t} = \begin{cases} A^o_{r,t} & if\ D^o_{r,t} \le I^o_{r,t} + R^o_{r,t} \\ \left(I^o_{r,t} + R^o_{r,t}\right)\left(\frac{A^o_{r,t}}{D^o_{r,t}}\right) & Oterwise \end{cases}$. Here, $I^o_{r,t}$ is the salable inventory at the beginning of the period t; $R^o_{r,t} = DL^o_{d,t-L}$ and $R^o_{r,t}$ is product quantity received at the retailer at the beginning of the period t, which was shipped from the distributor to the retailer in period t-L. Realized theft $g^o_{r,t}$and misplacement $k^o_{r,t}$ follow similar formulation. At the end of the period, the inventory state of the retailer evolves, according to the following equations: $i^o_t \equiv Mod(t, N^o)$. The inventory errors are accumulated if there is no physical counting at the end of the period t.

$$Q^o_{r,t+1} = \begin{cases} 0 & if\ i^o_t = 0 \\ Q^o_{r,t} + g^o_{r,t} & therwise \end{cases} \quad \text{and} \quad B^o_{r,t+1} = \begin{cases} 0 & if\ i^o_t = 0 \\ B^o_{r,t} + k^o_{r,t} & Otherwise \end{cases}.$$

If the period t is a counting period, with a physical inventory counting at the end of the period, accumulated theft is detected and removed from inventory record. Misplaced items are also detected and returned to correct locations, so that the salable inventory is increased. However, this action of returning misplaced items does not change inventory record. With the physical counting, inventory record is aligned with the salable inventory. If the period t is not a counting period, inventory record in information system only updates with orders received and sales in the period. The inventory record and salable inventory are calculated at the end of the period t as followings.

$$\hat{I}^o_{r,t+1} = \begin{cases} I^o_{r,t+1} = \hat{I}^o_{r,t} + R^o_{r,t} - a^o_{r,t} - Q^o_{r,t} - g^o_{r,t}, & if\ i^o_t = 0 \\ \hat{I}^o_{r,t} + R^o_{r,t} - a^o_{r,t} & Otherwise \end{cases}.$$

Without physical counting, theft and misplacement reduce salable inventory. To simplify the formulation, our study will simply let salable inventory equal to inventory record when the period t is a counting period.

$$I^o_{r,t+1} = \begin{cases} \hat{I}^o_{r,t+1} = I^o_{r,t} + R^o_{r,t} - a^o_{r,t} - g^o_{r,t} + B^o_{r,t} & i^o_t = 0 \\ I^o_{r,t} + R^o_{r,t} - a^o_{r,t} - g^o_{r,t} - k^o_{r,t} & Otherwise \end{cases}.$$

For the retailer, the single period profit incurred in the period t is:

$$\pi^o_{r,t} = \begin{cases} p^o_r a^o_{r,t} - c_r O^o_{r,t} - h_r \hat{I}^o_{r,t+1} - z_r\left(A^o_{r,t} - a^o_{r,t}\right) - c_{r,c} - c_{r,q} \sum_{j=0}^{N^o-1} g^o_{r,t-j} & if\ i^o_t = 0 \\ p^o_r a^o_{r,t} - c_r O^o_{r,t} - h_r \hat{I}^o_{r,t+1} - z_r\left(A^o_{r,t} - a^o_{r,t}\right) & Otherwise \end{cases}.$$

where p_r^o is the product price per unit for end-customer, $c_{r,c}$ is the cost of conducting a physical counting at retailer, and $c_{r,q}$ is the cost per unit for detected theft. In T periods, the profit for the retailer is: $\pi_r^o = \sum_{t=1}^{T} \pi_{r,t}^o$

While the formulation of the distributor and the manufacture is similar to that of the retailer, there are some assumptions made for these cases. We assume that there is less pilferage and misplacements for the distributor and the manufacturer because only employees are responsible for these two types of inventory errors, compared to the retailer in which both end-customer and employees are responsible for pilferage and misplacements. For backorder, our study does not consider backorder for the retailer, but it allows the distributor and the manufacturer to take backorder when an order from the retailer or distributor cannot be met. Overall, the total profit of the entire supply chain of the product line in T simulation periods in the base case is: $\Pi^{\mathrm{o}} = \sum_{\eta=\{r,d,m\}} \sum_{t=1}^{T} \pi_{\eta,t}^o,$ where r, d and m represent the retailer, the distributor and the manufacturer, respectively.

Full RFID Implementation[2]

In scenario 2, the supply chain is designed with full RFID implementation. With RFID, inventory manager can detect theft and misplaced inventory, adjust inventory record from theft, and return the misplaced items back to the store shelf at the end of each period. In our study, RFID is modeled as an imperfect technology, which means some of RFID tags cannot be read correctly and only part of misplaced items can be detected and returned. Undetected misplaced items are accumulated but the accumulated misplaced items are much smaller than those in the Base case. Moreover, RFID can help prevent theft due to the tracking of the tags (Patton and Hardgrave 2009). The distribution of quantity lost from theft has a smaller mean and variance in this case than in Base case. Because of the imperfect status of RFID technology, the system still needs physical inventory counting but at a much smaller frequency.

For the retailer in the full RFID implementation case, the single period profit incurred in the period t is

$$\pi_{r,t}^* = \begin{cases} p_r^* a_{r,t}^* - (c_r + \alpha c_g) O_{r,t}^* - h_r \hat{I}_{r,t+1}^* - z_r\left(A_{r,t}^* - a_{r,t}^*\right) - c_{r,q}\left(g_{r,t}^* - B_{r,t}^*\right) - c_{r,c} & if\ i_t^* = 0 \\ p_r^* a_{r,t}^* - (c_r + \alpha c_g) O_{r,t}^* - h_r \hat{I}_{r,t+1}^* - z_r\left(A_{r,t}^* - a_{r,t}^*\right) - c_{r,q}\left[g_{r,t}^* + (1-\omega) k_{r,t}^*\right] & Otherwise \end{cases}.$$

In this scenario, the system treats undetected misplaced items $(1-\omega)k_{r,t}^*$ as theft at each period when calculating the profit for the retailer, where ω is the RFID tag read rate to represent imperfect status of RFID technology. $p_r^* = p_r^o$, and α is the proportion of RFID tag c_g shared by the retailer. In T simulation periods, the profit for the retailer is: $\pi_r^* = \sum_{t=1}^{T} \pi_{r,t}^*$

In this scenario, the shrinkage and misplacement at the distributor are not only smaller than those at the retailer but smaller than those of the distributor in the Base case. In addition, the distributor tries to satisfy the order first at the beginning of the period t. For the distributor in this full RFID implementation scenario, the single period profit incurred in the period t is

$$\pi_{d,t}^* = \begin{cases} p_d^* O_{r,t}^* - [c_d + (\alpha+\beta) c_g] O_{d,t}^* - h_d \hat{I}_{d,t+1}^* - z_d BL_{d,t}^* - c_{d,q}\left(g_{d,t}^* - B_{d,t}^*\right) - c_{d,c} & if\ i_t^* = 0 \\ p_d^* O_{r,t}^* - [c_d + (\alpha+\beta) c_g] O_{d,t}^* - h_d \hat{I}_{d,t+1}^* - z_d BL_{d,t}^* - c_{d,q}\left[g_{d,t}^* + (1-\omega) k_{d,t}^*\right] & Otherwise \end{cases}.$$

$p_d^* = (c_r + \alpha c_g)$ and β is the proportion of RFID tag cost $c_g$shared by the distributor. $BL_{d,t}^*$ is the back order in the period t. For the manufacturer, we assume there is even less shrinkage and misplacement than those for the distributor. The manufacturer will also take backorder and deliver the backorder in a future period with lead time L. For the overall supply chain, the total profit in T simulation periods is: $\Pi^* = \sum_{\eta=\{r,d,m\}} \sum_{t=1}^{T} \pi_{\eta,t}^*$.

[2] This study uses *" to represent full implementation of RFID in the notation.

Partial RFID Implementation[#3]

In this scenario, RFID is not installed by the manufacture but by the distributor. This scenario is the most likely case of partial RFID implementation, since implementation at the distributor will directly benefit the retailer but not the manufacturer. A partial RFID implementation at the retailer without including the manufacturer and distributor is the same as a firm-level RFID implementation and our focus is to understand the impact of RFID on supply chain performance. However, in future studies we will examine other possible ways of partial RFID implementation in supply chains.

The formulation of this partial implementation is very similar to those in base case for the manufacturer and full implementation scenario for the distributor and the retailer. In this case, only distributor and the retailer share the cost of RFID and directly benefit from RFID use; the manufacturer does not bear any RFID cost, however it may benefit indirectly through more accurate order information from downstream parties of the supply chain.

Informed System'[4]

Without RFID implementation, the parties in the supply chain lack inventory visibility. However, in our informed case, inventory manager is aware of the inventory inaccuracy problem and uses some historical data about unobservable error sources (Kang and Gershwin 2005) to compensate inventory discrepancy problem (e.g., by deducting an estimated total error demand for retailer, e_r at the end of each period). This case provides a more realistic benchmark and hence enables us to measure the incremental value of RFID (Lee and Ozer 2007) more accurately. Since this method is applied at a single retailer in Kang and Gershwin (2005), it is reasonable to extend this informed policy to each party of the given supply chain in our model and examine the results. This scenario serves as a more reasonable benchmark for RFID value in supply chain and helps overcome the weakness in existing literature of comparing RFID with a naive non-RFID system. In this scenario, inventory level is given as:

$$\hat{I}'_{r,t+1} = \begin{cases} I'_{r,t+1} = \hat{I}'_{r,t} + R'_{r,t} - a'_{r,t} - Q'_{r,t} - g'_{r,t} + (N'-1)e_r & if\ i'_t = 0 \\ \hat{I}'_{r,t} + R'_{r,t} - a'_{r,t} - e_r & Otherwise \end{cases}.$$

When the period is a physical counting period, all the theft and misplaced items are detected and corrected in the system, so the system needs to add back all the adjustments made since last counting.

Experimental Design

The simulation is built with C language and all four scenarios described above are simulated for each product separately. Each simulation will run 200 time periods (weeks), similar to other studies (Brown 2001: Fleisch and Tellkamp 2005). The inventories for all parties of the supply chain will be set up to the order-up-to levels in a synchronized state at the beginning of the simulation, following (Basinger 2006). In every simulation run, inventory record, salable inventory, sales, delivery, order, sales, backorder/sales loss, theft, misplacement, profits of each party in the supply chain and entire supply chain will be recorded. We will start recording these data after simulation outputs become stable.

Factors in Simulation Models

This study first examines the differences among the four scenarios and then evaluates the value of RFID in supply chain, for different product types and different RFID read rates. The simulation parameter values to be used will be determined based on further literature review.

Scenarios

As explained earlier in the problem description section, the four scenarios represent different levels of RFID implementation in the investigated supply chains. Base case and informed case provide a traditional and a more realistic benchmark respectively for RFID value research.

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3 This study uses "#" to represent the partial implementation of RFID in the supply chain.
4 This study uses " ' " to represent the informed case.

Products

RFID may not be valuable for all product categories (A.T. Kearney 2004). Intuitively, one may think that a product with a higher price will benefit more from implementation of RFID. However, Dehoratius and Raman (2008) found that inventory inaccuracy problem is negatively associated with the cost and dollar value of a product. Therefore, in our study we investigate how different products, in terms of price and demand, influence the benefits from RFID. Three types of products with different demands and prices are studied. Product A can be a bottle of detergent from P&G in any convenience store, which has stable demand with low price. Product B can be a cotton shirt or jeans from GAP and its demand is reasonably predictable and price is higher than product A. Product C can be an expensive electronic product, such as cell phone or laptop from Blackberry or HP, whose demand is highly variable.

RFID Development Status

We recognize that technical issues, such as positioning, direction, error correction algorithms can impact RFID read accuracy. However these technical issues are not a main focus of our study and, hence, we aggregate these factors to one single measure of RFID read rate to represent current development status of RFID technology. The read rate is expected to affect the performance, because it reduces the inventory accuracy. Hence, the RFID read rate is considered as an experimental factor.

Performance Measures

Our study will use each party's profit, average inventory, inventory accuracy and supply chain profit as performance measures for each product investigated in each scenario. Profit of each party in the supply chain will be compared to examine which party gets the biggest gain from RFID. Overall supply chain performance will help demonstrate the value of RFID for the entire supply chain, based on the comparison among the four scenarios. A number of parameters need to be estimated for running the simulations. For each product tested in the model, the different value of these parameters will be applied. To determine the values of the parameters, extensive literature review will be conducted.

Model Validation Plan

It is important to use appropriate data in validating a research model, and hence we will make use of all available, published data for the parameters of the research model in our simulation experiments. We will also try to consult subject matter experts who are familiar with RFID use in supply chains to validate the components of simulation model and to get realistic parameter values. Graphical plots from the simulation outputs will be examined regularly in order to make sure the model accurately represents the real world. After conducting simulation experiment, we will examine published industry data and compare our outputs with those of real supply chains that resemble our model. The greater the commonality, the greater our confidence in the research model (Law and Kelton 2000).

Conclusion

This research was motivated by the ability of RFID technology to cope with inventory inaccuracy problem, one of the greatest obstacles in successful inventory management. Our study provides a mechanism on how RFID can impact supply chain performance through increasing inventory accuracy within a multi-echelon supply chain in multiple time periods with different types of products. Furthermore, we apply a more realistic benchmark to derive a more realistic value of RFID, compared to existing literature. We also model the impact of RFID-enabled system that is not 100% reliable to reflect the real development status of RFID technology for supply chain management applications. We plan to conduct an extensive literature review to determine the values for the parameters and distributions in order to run the simulation model for examining RFID value in our research setting. We will also extend our experiment by testing jointing effect of the factors discussed in this paper and examining different inventory policies and cost sharing policies to study the consequence of those policies on supply chain performance. The preliminary result of our simulation experiments will be presented in the conference.

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