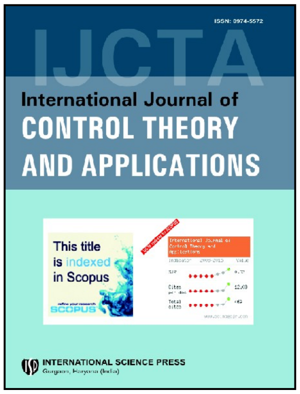

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Optimizing Safety Inventory through RFID Implementation in Multistage Supply Chain

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Abstract: In reality it is noticed that mismatch of stock information plus reflected in the information systems record has been accepted because of inventory inaccuracy. Economic impacts at each stage of SC exceed the cost of direct loss. The difference as well results in shortage as information distortion and increasing the cost of holding travels along the SC. Inventory inaccuracy challenges the high performance supply chain system. We are focusing on RFID technology as a solution and adopting a systematic approach through the implementation of systematic models to measure the less distortion of information plus saving resulted from timely, would expand the application of RFID technology in global supply chain management (SCM).

Key words: Analytical models, information distortion, RFID, Inventory inaccuracy

INTRODUCTION

Safety inventory can be understood as mismatch between the recorded inventory in the supply chain (SC hereafter) and existing stock in the information technology system. Such mismatch arises due to three different sources [2]: (a) misplacement, (b) scanning errors and (c) shrinkage. The manufacturers suffer a loss in the range of 0.22% - 0.73%, and loss in shrinkage of 1.75% of US$ 58 billion income suffered by retailers (a report by the IBM Business Consulting Services, in supply chains on seven product categories [3]). The loss occurs due to the inventory inaccuracy both in the upstream and down stages in a SC. The inventory inaccuracy can arise due to: (1) Physical loss that occurs due to supplier fraud, obsolescence and shrinkage, (2) informational loss. The infrequent audit because of time and cost constraint can be supported by barcode system in the current process and technology. To get the information about the safety stock at the decision making position becomes inescapable, As a result, from the failure of information misrepresentation stemming from additional costs.

RFID implementation is considerably the most promising solution to achieve a high performance SC. It resolves and controls the inventory inaccuracy problem. RFID benefit depends on two characteristics: (a) the errors cannot be reduced by visibility: in a timely manner data of actual inventory plus accurate information about inventory to match the verification supply by RFID. As result, it helps manager to take best decisions through taking the timely inconsistency information hooked on deliberation. (b) reduction of inventory error with supporting technologies by prevents RFID, like television systems, closed circuit.

RELATED WORK

RFID implementation by far is not very common in industry in large scale. It is revealed from the reports provided by different technology solution providers that they indicate various RFID values but not able to quantify them [5]. As a result, unequivocal investigative way out are required to measure the financial returns of RFID execution concretely by stimulating some pilot research works to close the credibility gap. More ascertained inventory control techniques to measure the accurate cost of RFID can be found out by the help of model using lively programming [2]. Various analyses about the impacts on retail stores due to product misplacement have been discussed in the literature. The main objective is to eliminate the errors through RFID implementation and optimization of the order policy by taking discrepancy into account [6]. A retail firms is also required to make both stocking quantity decisions and marketing efforts [7]. Quantifying the benefit from implementing RFID and various factors that may affect the RFID implementation in the retail environment has been discussed as well. [7]. The very important finding of this study is that firm's willingness to pay more by implementing RFID is directly related to reduce inventory accuracy for products with a low profit margin.

We discuss whole SC in two stages and the impact of RFID adoption along the supply chain. It has been seen that supply chain coordination improves through the adoption of RFID and hence, decentralized supply chain frequently more beneficial than one stage of the supply chain [8]. We have used the Newsvendor model frame-work for measuring the profit difference between stock error. This frame-work helps to estimate RFID benefit by incorporating error information on the inventory which is negative for the manufacturer but positive for the retailer. On the other hand, in the manual barcode systems, the wholesaler faces errors with three-stage supply chain. In this case a new cost component is incorporated into Newsvendor model frame-work.

This paper discusses three main areas as opposed to the previous works. First of all, we draw a distinction between the prevention and RFID benefits of visibility. As opposed to RFID implementation with visibility, those providing prevention get benefited more but at the cost of high investment. It is important for different industries to decide optimal RFID application. This decision entirely depends on quantifying RFID visibility and prevention benefits. The existing literatures do not draw any distinction between the above benefits [5]. They simply assume that implementation of RFID eliminate the errors. We in this paper, by using quantitative frame-work, analyze different RFID benefits and thus justify different RFID implementations [1].

Secondly, to get better assessment of the figures of inventory error (for example variance & mean) in place of applying RFID, our model reveals additional information beyond the data created by RFID and measure the advantages of RFID in the course of perceptive accurate mistakes in a well-timed approach.

Thirdly, we intend to reduce the inefficiencies in inventory management and process control that takes place in the presence of information distortion. Thus, the basic idea here is to calculate the RFID benefit by minimizing information distortion.

MODELING THE DECENTRALIZED SYSTEM

We consider here a decentralized supply chain system consisting of a wholesaler, retailer, a distributor and tiers of suppliers with a single product. All stages suffer from inventory shrinkage. We are considering three different scenarios where RFID vis-à-vis non-RFID impact has been examined.

Case1. (Base case: without RFID implementation): In this case, the shrinkage per time period $\xi_t^{i,1}$ is not visible to the decision maker. It is due to the fact that physical audit cycle is generally larger than the order cycle. It is quite possible that the decision maker is able to calculate the shrinkage mean $\mu^{i,1}$ and variance $(\sigma^{i,1})^2$ after noticing this shrinkage problem at stage *i*. The above mean and variance can be calculated by using previous physical audit data [1].

Case 2. (**With RFID tag case with visibility**): In this case, we consider a product that is attached with RFID tag in the most upstream stage of the entire supply chain. The idea here is to align the recorded and actual inventory *by* identifying shrinkage $\xi_t^{i,2}$ in a timely manner, but shrinkage remains the same as no RFID with $\mu^{i,2} = \mu^{i,1}$ and $\sigma^{i,2} = \sigma^{i,1}$, which helps to aid to support the recorded and real stock with recognize shrinkage $\xi_t^{i,2}$ in a well-timed mode, but shrinkage continue to be similar since $\mu^{i,2} = \mu^{i,1}$ & $\sigma^{i,2} = \sigma^{i,1}$ with no RFID.

Case 3. (With RFID tag case prevention & visibility): With RFID technology integrated with other supporting technologies in the supply chain, the actual shrinkage per time period is known and could be reduced to $\xi_t^{i,3}$, with mean $\sigma^{i,3}$ and variance $(\sigma^{i,3})^2$, and $\mu^{i,3} \le \mu^{i,2}$ and $\sigma^{i,3} \le \sigma^{i,2}$. If the overall demand $D_t^{i,j}$ of stage *i, i* =1, 2, *I*, scenario *j, j* = 1, 2, 3 at time period t, in the presence of shrinkage, consist of two components: the revenue and the shrinkage $\xi_t^{i,j}$ contributing by the paying demand $z_{t-1}^{i-1,j}$. The end customer demand is $z_{t-1}^{0,j}$ the paying demand of the first stage, which is the matching for the three situations, plus that of further stages is the order $z_{i-1}^{i,1,j}$ as of its through downstream stage *i*-1 by time period *t*-1. The ending consumer demand is the paying demand in first stage $z_{t-1}^{0,j}$, which is the similar for the three cases, plus that the order $z_{i-1}^{i,1,j}$ of other stages at time period *t*-1 from its direct downstream stage *i*-1. The shrinkage $\xi_t^{i,j}$ are assumed to be normally distributed plus the end customer demand $z_t^{0,j}$, which variance $(\sigma_d)^2$ and $(\sigma^{i,j})^2$, and mean μ_d and $\mu^{i,j}$ respectively.

At time period *t* ,the order process at stage *i* of case *j* is specified as follows.

1. $x_{t-1}^{i,j}$; = Starting inventory

2. $z_{t-1}^{i,j}$ = Replenishment arrives with lead time 1;

3. $\xi_{t-1}^{i,j}$ = Shrinkage occurs if there is any;

4. $z_{t-1}^{i-1,j}$ = Paying demand arrives; empty demand in period t is backlogged through unit penalty p^j plus surplus inventory is reserved for sale at period t+1 by part holding cost h^i ;

5. $x_t^{i,j} = x_{t-1}^{i,j} + z_{t-1}^{i,j} - z_{t-1}^{i-1,j} - \xi_t^{i,j}$ is Ending inventory;

6. Places all order of size $z_t^{i,j}$ and stage predicts the demand in the next time period in the direction of upstream stage $i+1$ during order to carry its stock echelon up to $S_t^{i,j}$. In the entire SC the ending consumer demand and inventory inaccuracy information are assumed to be shared. This hypothesis generally grasps in a vertically integrated SC. Companies adopting certain business models in support of decentralized supply chains(DSC), inventory information plus demand is shared, for example Vendor Managed Inventory, Collaborative Planning Forecasting and Replenishment [8][12].

Overall demand at stage i at time period t of case $j = D_t^{i,j}$

True distribution of $D_t^{i,j} = \bar{F}_t^{i,j}$

Estimated distribution of $D_t^{i,j} = F_{t-1}^{i,j}$

Mean of $F_t^{i,j} = M_{t-1}^{i,j}$

Variance of $F_t^{i,j} = V^{i,j}$

Mean of $\bar{M}_t^{i,j} = \bar{F}_t^{i,j}$

Variance of $\bar{F}_t^{i,j} = \bar{V}^{i,j}$

Order at stage i at time period t of case $j = z_t^{i,j}$

Shrinkage at stage I at time period t of case $j = \xi_t^{i,j}$

Mean of the end customer demand $z_t^{0,j} = \mu_d$

Variance of the end customer demand $z_t^{0,j} = (\sigma_d)^2$

At stage i of scenario j mean of shrinkage = $\mu^{i,j}$

At stage i at time period t of situation j Inventory level = $x_t^{i,j}$

At stage i at time period t of case j order-up-to level= $S_t^{i,j}$

At stage i unit shortage cost = p^i

At stage i Unit holding cost $= h^i$

At stage i Unit purchase cost $= c^i$

Time value of money per time period by discount factor $= \alpha$

THE ORDER-UP-TO POLICY

Following the order decisions, the decision at stage i at time period t of cases j, where j=1,2,3; the decision maker makes an order of $D_{t+1}^{i,j} = z_t^{i-1,j} + \xi_{t+1}^{i,j}$, at time period t+1. The recursive relationship can be interpreted as follows

$$D_{t+1}^{i,j} = z_{t-1+1}^{0,j} + \sum_{k=1}^{i} \xi_{t-i+k+1}^{j,j} \tag{4.1}$$

Since the shrinkage at each stage and end customer demand follow normal distribution, their sum $D_{t+1}^{i,j}$ also follows normal distribution. While one makes forecast of $D_{t+1}^{i,j}$ in stage i, he or she takes the benefit of common knowledge in the downstream stages. In particular, the forecast in stage i as shown in equation 4.1 depends on the information availability of the inventory inaccuracy and demand of the end customer in all its downstream stages. The stock inaccuracies in all the downstream stages of stage $i \sum_{k=1}^{i-1} \xi_{t-1+k+1}^{k,j}$ and note the fact that the end consumer demand $z_{t-i+1}^{0,j}$ are realized, the only pertinent indecision lies in the inventory inaccuracy of the next period $\xi_{t+1}^{i,j}$. So the true distribution $F_t^{i,j}$ of the overall demand $D_{t+1}^{i,j}$ is with mean

$$M_t^{i,j} = z_{t-i+1}^{0,j} + \sum_{k=1}^{i-1} \xi_{t-i+k+1}^{k,j} + \mu^{i,j} \tag{4.2}$$

And the variance is given by

$$V^{i,j} = (\sigma^{i,j})^2 . \tag{4.3}$$

In case 1 without RFID implementation, in each time period without the idea of the actual shrinkage quantity, the manager only knows the mean and variance. It deviates from true one $F_t^{i,1}$ and implies the demand distribution of $D_{t+1}^{i,1}$ that the decision maker estimates as $\bar{F}_t^{i,1}$. All level to make a better decision, Manager can still get benefit of the expected mean and variance of the shrinkage at its own place. Particularly, the estimated distribution $\bar{F}_t^{i,1}$ of $D_{t+1}^{i,1}$ is with mean

$$\bar{M}_t^{i,1} = z_{t-i+1}^{0,1} + \sum_{k=1}^{i} \mu^{k,1} \tag{4.4}$$

The variance is given by

$$\bar{V}^{i,1} = \sum_{k=1}^{i} (\sigma^{k,1})^2 \tag{4.5}$$

In cases 2 and 3, with RFID implementation, the exact shrinkage $\xi_t^{i,m}$, $m = 2, 3$ that takes place by the decision making point and RFID provides visibility in the direction of SC, can be identified. RFID facilitates, carry awareness to the decision making process and the SC on the way to catch up the adjustment in shrinkage process promptly. During this logic, the manager can approximate the order correctly. It indicates that the expected distribution $\bar{F}_t^{i,j}$ of $D_{t+1}^{i,m}$ approximate the true one with:

$$\bar{M}_t^{i,m} = M_t^{i,m} \tag{4.6}$$

and

$$\bar{V}^{i,m} = V^{i,m}. \tag{4.7}$$

Suppose the discounted expected cost is $\prod^{i,j}$ at stage *I* of scenario *j*, an infinite time horizon with respect to $\bar{F}_t^{i,j}$, it consist of shortage, costs of product purchase and holding. At an arbitrary period (normalized at *t*) the cost-minimization problem is invented as

$$\min \Pi^{i,j} = \sum_{k=t}^{\infty} (1-\alpha)^{t-1} E_t \left[c^i (S_k^{i,j} - x_k^{i,j}) + h^i (S_k^{i,j} - D_{k+1}^{i,j})^+ + p^i (D_{k+1}^{i,j} - S_k^{i\,j})^+ \right] \tag{4.8}$$

where E_t denotes the expectation taken at the decision point of time period *t* and α is the discount factor of time value of money per time period, shrinkage realizations before time period *t* and uncertain on the end consumer order [1][12]. The most favorable order-up-to level $S_t^{i,j*}$ at stage *i* of case *j* can be solved as $S_t^{i,j*} = \bar{F}_t^{i,j^{-1}} \left[\dfrac{p^i - \alpha c^i}{h^i + p^i} \right]$ [14].

As $\bar{F}_t^{i,j}$ pursue a normal distribution, $S_t^{i,j*}$ can be derived as

$$S_t^{i,j*} = \bar{M}_t^{i,j} + k^{i*} \sqrt{\bar{V}^{i,j}} \tag{4.9}$$

Where $k^{i*} = \Phi^{-1} \left(\dfrac{p^i - \alpha c^i}{h^i + p^i} \right)$ with the standard normal distribution Φ.

The most favorable order-up-to level $S_t^{i,j*}$ is not stationary. It depends on change of order forecast. The cost in equation 4.8 can be interpreted as discounted long term cost. The order quantity $z_t^{i,j}$ at stage *i* of scenario *j* support on the order-up-to policy is as follows

$$z_t^{i,j} = E_{\xi_t^i} \left[S_t^{i,j} - S_{t-1}^{i,j} + z_{t-1}^{i-1,j} + \xi_t^{i,j} \right]. \tag{4.10}$$

In (4.10) the first two terms indicate the alteration of the predictable order. As the last two terms are the one-for replacement on the whole demand with order amount as of stage *i*-1 plus shrinkage number at stage *i*. through the recursive relationship in (4.10), shown that

$$z_t^{i,j} = E_{\xi_t^i}\left[S_t^{i,1*} - S_{t-1}^{i,1*} + S_{t=1}^{i-1,1*} + \ldots + S_{t-i+1}^{1,1*} + z_{t-i}^{0,1} + \sum_{k=0}^{i-1} \xi_{t-k}^{i-k,1} \right]$$

$$= i(z_{t-i+1}^{0,1} - z_{t-i}^{0,1}) + z_{t-i}^{0,1} + \sum_{k=0}^{i-1} \mu^{i-k,1} \quad (4.11)$$

$$z_t^{i,m} = i(z_{t-i+1}^{0,m} - z_{t-i}^{0,m}) + z_{t-i}^{0,m} + \sum_{k=1}^{i}\sum_{l=1}^{k-1}(\xi_{t-k+l+1}^{l,m} - \xi_{t-k+1}^{l,m}) + \sum_{k=0}^{i-2} \xi_{t-k}^{i-k,m} + \mu^{i,m}, = 2,3\,. \quad (4.12)$$

NUMERICAL ANALYSIS

The result reflects the size and price for a prearranged parameter set and comparative load of the impacts of RFID on information distortion. For a improved diagram, in place of using mannequin numbers, the cram focused on a SC customized as of the dataset in [1] [16]. The dataset highlighted 38 genuine world multi-strata SC which can be applied to assess and experiment investigative replica. The 8th SC in of the electro medical plus electrotherapeutic equipment manufacturing in the dataset are selected as diagram because as per the industrial report by [17], the manufactured goods entity cost of this industry is comparatively high plus shrinkage exists in this industry plus might have enough money in tagging the item-echelon RFID. The model under study focuses on a serial SC that traces a manufactured goods from its mainly costly part during one of its suppliers (the RFID tag is unspoken to connect to this part and used in the whole SC) to the ended manufactured goods in one of its retailers in the supply chain network [1][16].

Impact of RFID on Information Distotion

According to eq. 4.1 and 4.2, the difference in variance for the three scenarios is reflected in Figure 1. It substantiates the investigative findings that the information misrepresentation magnifies down the SC without RFID.

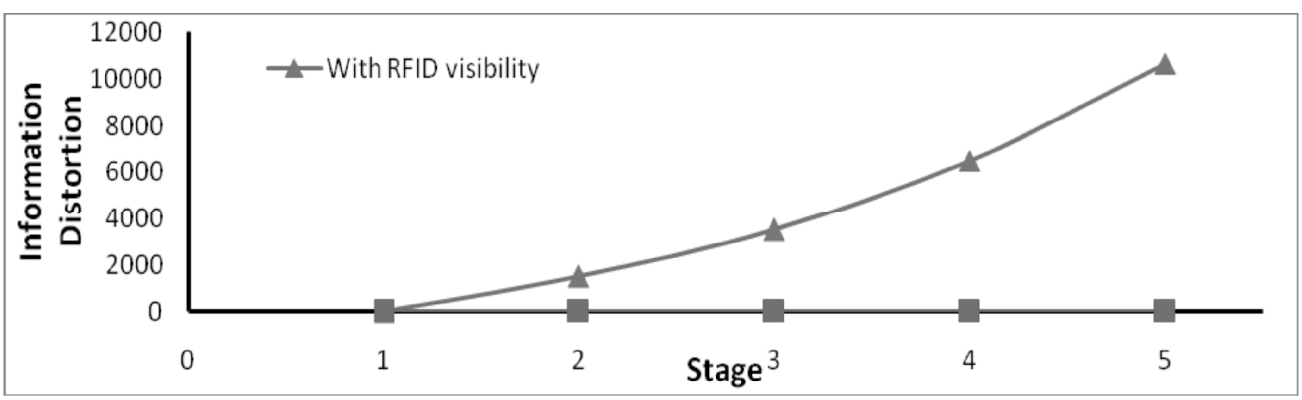

Figure 1: Information distortion in a 5-stage supply chain

Impact of RFID on Cost

Figure 2 shows that the standard lessening of the whole cost because of RFID is 0.2%, if only visibility is presented and 1.5%, if half of the shrinkage is eradicated. Further, it can also be observed from Figure 2 that the benefit of RFID by reason of prevention exceeds because of visibility. This happens largely due to the goods that are comparatively costly inside this product-echelon RFID application and then the avoidance of loss of each single manufactured goods is crucial. Savings in avoidance is more important in this situation, reliable with our study in Section 4.2. This finding moreover suggests the importance of taking actions after the identification of inaccuracy for high-ending goods. Overall leaders in product-echelon RFID system paid extra concentration to stop stealing and forging of sky-scraping ending goods in SC instead of just tracking [18]. To be the best support for the conclusion, these industry practices are considered.

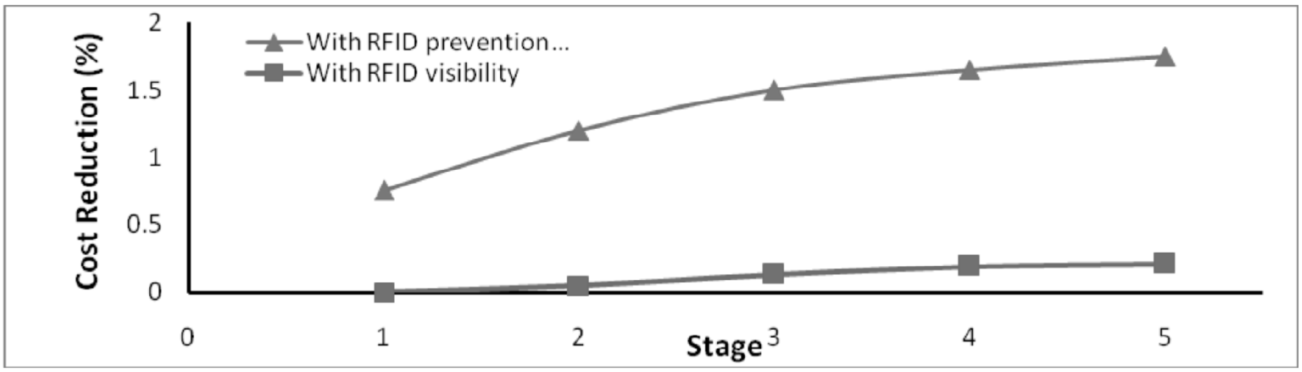

Figure 2: The impact of RFID implementation on supply chain cost

A set of investigations are taken up to observe how the complete benefit of RFID is affected by the introduction of some key cost parameters, namely *ci*, *hi* and *pi*. The numerical results believe the product cost as a significant factor. The product cost is sliced down from 90% to 40% of *ci* for case 3. Figure 3 reflects that the expenditure is abridged by US$435 per stretch of occasion on standard when the manufactured goods cost is gone down with 10%. Further, sensitivity analysis signifies that it is easier to have enough money in the application of item-echelon RFID in manufacturing with extra pricey goods. The main purpose behind this decision is to bring theft under control while achieving substantial saving. It is also observed that there is a steady increase in the complete worth of the price economy from the first to the fourth stage and there is a pointed decrease from the fourth to the fifth stage.

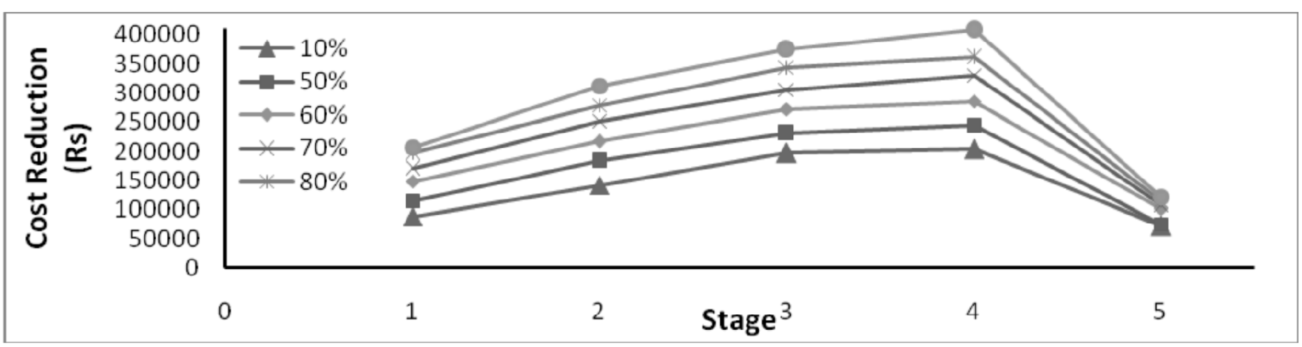

Figure 3: The impacts of product price on RFID benefit due to visibility and prevention

It happened due to the forces of visibility and prevention. Within the fifth stage, the part cost is much less than the downstream phase resulting in considerable drop in the cost reduction of avoidance. So to economize on the investment on RFID prevention may not be considered as a prudent decision for the fifth stage. It reiterates the how RFID produces worth is of result to effectual savings.

CONCLUSION

This paper highlights on incorporation of inventory inaccuracy in the multistage SC order making process. In particular, this paper focuses on impacts of RFID on accretion of information misrepresentation and differentiates the benefit of RFID from prevention and visibility. Firstly, benefits of RFID transfer accumulates from downstream to upstream stages. Consequently, the cost-effectiveness of executing RFID technology is important in whole supply chain thought. Secondly, variations in applications of RFID result in dissimilar savings through unlike benefits. To comprehend how RFID generates worth (during prevention or visibility) plus the quantitative returns of a firm savings show business input for practitioners to accomplish correct decisions of opting RFID use. Thirdly, it is noticed that visibility is preferred by the manufacturing by means of higher indecision of supply difference plus avoidance is preferable to manufacturing through higher cost of goods.

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