Global Journal of Researches in Engineering
Civil And Structural Engineering
Volume 13 Issue 4 Version 1.0 Year 2013
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-4596 & Print ISSN: 0975-5861

Impact of Radio Frequency Identification (RFID) Technology on Supply Chain Efficiency: An Extensive Study

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Abstract - Wireless technologies such as Radio Frequency Identification (RFID) and Global Position System (GPS) play important role as value added services in communication systems and mobile commerce these days. The aim of Supply Chain Management is to produce, distribute, logistics and deliver goods and equipment in right location, right time, right amount to satisfy costumers, with minimum time and cost waste. So implementing techniques of radio frequency identification (RFID) that reduce project time and cost, and improve productivity and performance is very important. The purpose of this study is to explore the benefits and liabilities of the use of this technology in supply chain operations and its benefits is centered on goals relative to the optimization of logistics activities; specifically related to inventory management, bullwhip effect and replenishment policies. Besides, some approaches to evaluate the benefits of RFID in supply chain along with a brief analysis of return-on-investment (ROI) to RFID implementation in supply chain operations are identified and discussed.

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GJRE Classification : *FOR Code: 130212p, 090599*

Strictly as per the compliance and regulations of :

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Keywords : RFID technology, supply chain management, inventory management, return-on-investment (RIO).

I. Introduction

Radio Frequency Identication (RFID) is an automatic identication and data capture technology which is composed of three elements: a tag formed by a chip connected with an antenna; a reader that emits radio signals and receives in return answers from tags, and finally a middleware that bridges RFID hardware and enterprise applications (McFarlane, Sarma, Chirn, Wong, and Ashton, 2003). A typical supply chain consists of supplier, manufacturer, distributor, retailer, and customer. This could be multiple tiers of suppliers, manufacturers and distributors. Through radio waves, it provides a real-time communication with numerous objects at the same time at a distance places without contact or direct line of sight (Garcia, Chang, & Abarca,2007)& (Gaukler, 2005). Its advanced identification and communication characteristics can improve the product traceability and the visibility among supply chains. It can increase accuracy, efficiency and speed of processes and it can also reduce storage, handling and distribution costs and improve sales by decreasing the number of stock outs (Visich, Khumawala, and Zhang). Companies such as GAP, CVS, Gillette, Proctor & Gamble and Wal-Mart have recognized the importance of leveraging this technology to improve and increase operating efficiencies in the supply chain, which is benefiting from recent advances in electronic cataloguing. With RFID systems, companies would have increased product visibility, reduce out-of-stock items, trim warehouse costs, eliminate stock errors, reduce theft and shrinkage and allow companies to regularly update their logistics and inventory databases. Current applications of RFID focus on inventory management, logistics and transportation, assembly and manufacturing, asset tracking and object location, environment sensors, etc. (Gaukler and Seifert, 2007). Some sectors have more opportunity to gain from the various RFID applications, such as retail, healthcare, textile, automotive and luxury goods industries (Visich, Khumawala, and Zhang).

II. Literature Review

Radio frequency identification (RFID) is an emerging technology that has been increasingly used in logistics and supply chain management (SCM) in recent years. This technology can identify, categorize, and manage the flow of goods and information throughout a supply chain. It offers the potential to greatly improve supply chain performance due to its ability to provide rich and timely information that increases visibility and control over the supply chain. Applications of RFID in supply chain have increased. Bagchi et al. 2007 reported the prediction of RFID growth as from $1 billion in 2003 to $4 billion in 2008 to $20 billion in 2013. Thonemann (2002) reported that after the deployment of RFID technologies, Procter & Gamble and Wal-Mart simultaneously reduced inventory levels by 70%, improved service levels from 96% to 99%. They also reduced administration costs by re-engineering their

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supply chains. In a literature review on Build-to-Order Supply Chain (BOSC) management, Gunesekaran and Ngai (2005) highlight RFID technology as one of the important information technologies for BOSC that increases efficiency and accuracy. Extending this study, Ngaiet al. (2006) reviews and classifies the literature on RFID technologies that was published between 1995 and 2005. They analyze qualitative and quantitative development of the knowledge in this area. Nemeth et al. (2006) present a state-of-the-art on RFID systems and the challenges and possibilities of the integration to supply chains. Chao et al. (2007) reviews the literature on trends and forecast of RFID technologies from 1991 to 2005 by a historical review method and bibliometric analyze. They focus on the RFID innovation, deployment by enterprises and market diffusion in supply chain management. Recently, Delaunay et al. (2007) presents a survey on the causes of inventory in accuracy in supply chain management. Dolgui and Proth (2008) also present a literature review on RFID technology in supply chain. They focus on the advantages of this technology in inventory management. They also analyze some problems and present perspectives dealing with privacy and authentication properties of it. The contribution of this technology to supply chains is not only in increasing the efficiency of systems but also in supporting the reorganization of the systems that become more efficient.

III. Objectives of the Study

The main objective of the study is to investigate the role of RFID technology to improve the efficiency of the firms' own supply chains. To attain the main the main objective, the specific objective of the study are as follows:

i. To identify the benefits of RFID-enabled supply chain;
ii. To analyze the return that flows from this technology based integrated supply chain; and
iii. To explore the issues those create obstacles to enjoy the benefits of RFID supportive supply chain.

IV. Rationale of the Study

Supply chain management plays a great role in the 21st century for the success of domestic and global companies. RFID technology has an extensive role in supply chain operations. This technology is able to accelerate the performance of supply chain. As a result, todays firms than ever emphasis on the application of this technology to their own supply chains (SC). With the importance of this technology in supply chain management, many authors have tried to write on this matter. Many articles have been published in different popular journals. But among them, a few articles explore the reality of this technology in SC. Here, we have tried to describe extensively, the role of this technology to improve the SC performance and ultimately in the success of firms.

V. Research Methods

To satisfy our objectives of the study, descriptive research method is followed. By considering time, money and distance constraints, our attempt is based largely on secondary data. Here, we have tried to study literature extensively in the areas of supply chain management, logistics, RFID technology, and inventory management published from 1995 to 2011. Data and information from secondary sources were collected by reviewing different published articles, online journals, working papers, existing case studies and websites.

VI. Findings

The findings of the study have been presented under the following heads

a) Benefits of RFID-enabled supply chains

RFID technology offers several contributions to supply chain through their advanced properties such as unique identification of products, easiness of communication and real time information (Saygin et al. 2007), (Michael and Mc Cathie , 2005). It can improve the traceability of products and the inventory visibility throughout the whole supply chain, and also can ensure reliable and speed up tracking, shipping, checkout and counting processes, which leads to improved inventory flows and more accurate information. Leung et al. (2007) presents the benefits of RFID, as shown in Figure 1, in three main groups; revenue, operating margin, capital efficiency.

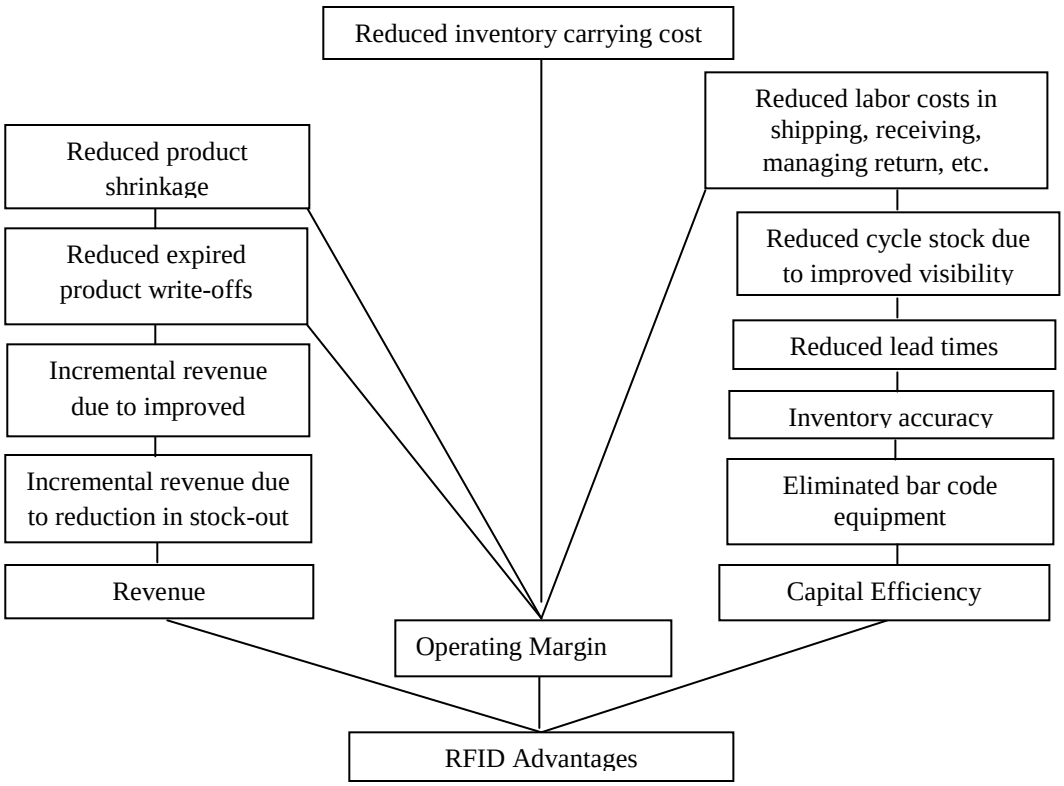

Figure 1 : Benefits tree of RFID-enabled supply chain

Among a number of benefits, we are particularly interested in three main problems of supply chain management that can be improved through RFID; inventory inaccuracy, the bullwhip effect and replenishment policies:

b) Inventory mismanagement

Inaccuracy problems in inventory management are important in supply chain management. Although many companies have automated their inventory management using information systems, inventory levels in information systems and the real physical inventory levels often do not match (Kang & Gershwin, 2004). The difference between these inventory levels is called inaccuracy and can deeply affect the performance of firms. Dehoratius & Raman (2008) report that 65% of the inventory records in retail stores were inaccurate. The result was obtained in a case study, by examining about 370,000 inventory records from 37 stores of an important retailer (Gamma). Raman et al. (2001) reports that such inaccuracies could reduce the profit of retailers by 10% due to higher inventory cost and lost sales. We can classify the different causes of inventory inaccuracy into them in four groups; transaction errors, shrinkage errors, inaccessible inventory and supply errors. Transaction errors were introduced in inventory management by Iglehart and Morey (1972). Several authors followed this study (Krajewski et al. 1987). Transaction errors include shipment errors, delivery errors, scanning errors and also incorrect identification of items (Lee, Cheng and Leung, 2005). Shrinkage (named also stock loss) errors include all types of errors that cause loss of products ready for sale. There are several studies on this subject (Bullard and Resnik, 1983). According to a retail survey report of the University of Florida, shrinkage errors represent 1.69% of sales for retailers (Hollinger & Davis, 2001). Shrinkage errors include employee theft, shoplifting, administration and paperwork errors, vendor fraud and unavailable products for sale. Theft represents an important part of shrinkage errors. There are several studies on internal and external theft in supply chains. According to the previous studies, theft levels represent about 1-2% of total sales (Chappell, Durdan, Gilbert, Ginburg, Smith, & Tobolski) (A simulation study of a retail supply chain, 2005).

Inaccessible inventory can be explained as products which are not in the correct place and are not available for customers. Inaccessible inventories, called also misplaced items, have been studied by many authors. Employees can put products in wrong shelves or customers can set an item that they took from a shelf to another shelf. If misplaced items are found too late and become out of date, mode or season, the inaccessible products become unsalable products and

thus cannot be sold. Raman et al. (Raman, DeHoratius, & Ton, 2001) present a case study where misplaced items reduced profits by 25%. Product quality, yield efficiency and supply process can affect inventory accuracy (Rekik, 2006).

RFID technologies provide better product traceability through its real time data capture properties that enable improvements in the supply chains against these inventory inaccuracy errors. It is in particular very successful to eliminate transaction errors (Zipkin, 2006). Although RFID cannot eliminate all errors, they can be detected quickly and by considering the existence of this problem in planning processes, they can be dealt with effectively. Several authors were interested in RFID technologies to be able to eliminate these errors.

c) Bullwhip effect

The bullwhip effect is an important phenomenon of supply chain management that has been studied for about fifty years. It was explained by Stevenson, (2007) that the demand variations of the customer become increasingly large when they diffuse back-wards through the chain. The bullwhip effect was first introduced by Forrester, (1958). He observed a fluctuation and amplification of demand from the downstream to the upstream of the supply chain. He stated that the variance of the customer demand increases at each step of the supply chain (customer, retailer, distributor, producer, and supplier). Furthermore, he concluded that the main cause of this amplification is the difficulties in the information sharing between each actor of the supply chain.

In 1999, Philips conducted a project on bullwhip effects in some of its supply chains and developed a collaborative-planning tool to reduce inventory and increase customer service levels. The results of this project showed important savings; minimum yearly savings of around US $5 million from $300 million yearly turnover. More recently, Lee et al. (2005) deal with this subject. They present two main sources of bullwhip effect. The sharp variance of customer demand for seasonal items complicates the down-stream actors' purchasing. Batching continuous orders in the periodic ordering systems cause demand variance up to the supply chain. He also reports that the bullwhip effect can significantly be reduced through information sharing.

d) Replenishment Policies

In inventory management, replenishment policies are very important methods for de-termining the frequency and the size of orders to maximize customer satisfaction with low ordering, holding and stock-out costs. There are several replenishment policies under continuous or periodic review inventory systems. ompanies try to choose the best policy for them. Inventory replenishment decisions are made based on inventory levels in the information system. Real-time inventory information obtained by RFID technologies ensures the accuracy of these levels. Hence, companies may change their replenishment strategies. The effects of RFID technologies on replenishment policies have been studied by many authors. Kok and Shang, (2007) Lee et al. (2004) and Kang and Gershwin, (2004) are some of them.

e) Inventory Invisibility

The automatic identification of products inside the store would increase the inventory visibility and its accuracy. This will have an impact in four fronts: shrinkage, customer service, stock outs and inventory levels. Decrease shrinkage levels, increase profits. Customer service and the shopping experience can be enhanced by providing complementary applications enabled by RFID. Stock out levels can be decreased as consequences of the increased inventory visibility. Decreased stock outs increase sales and ultimately, increase profits. Decreased stock outs levels also increase the customer service. Finally, inventory levels can be reduced, increasing the ROI.

VII. Approaches to Evaluate the Benefits of RFID Technologies in Supply Chain

We can study a system in different ways. Law and Kelton (2000) present these alternative ways as showed in Figure 2 in two groups; experiments with the actual system and experiments with a model of the system that contains physical and mathematical models.

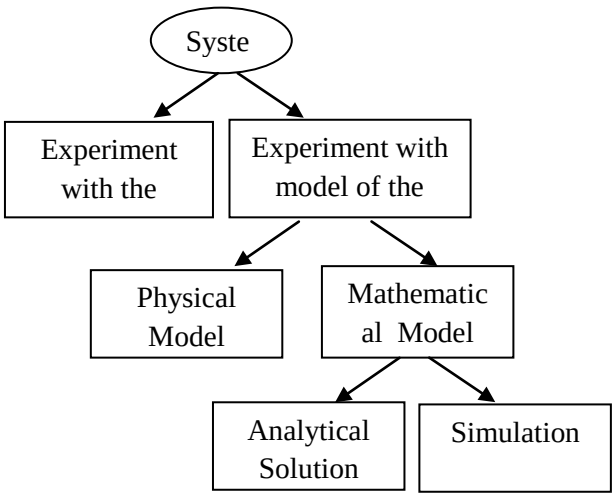

Figure 2 : Methods to study a system

In this section we focus on analytical models and simulations of mathematical models.

a) Analytical models

Analytical models correspond to the simplications of a real system through mathematical

expressions in order to analyze and optimize the system according to an objective function. Analytical models have been studied in supply chain for about four decades. However, the literature on analytical modeling of RFID technologies in supply chain is limited. The main topics that analytical models often deal with are inventory systems with different replenishment policies and Newsvendor models. The first analytical modeling approach on inventory inaccuracy due to transaction errors was presented by Iglehart and Morey (1972). They study a single-item, periodic-review inventory system with a reorder point up-to-level replenishment policy (s, S). They propose a formula to optimize the frequency of physical inventory counting, in order to correct inaccurate data, and safety stocks in order to protect the system against out-of-stocks. In analytical models, various hypotheses and approximations are considered. Thus the results of these models are limited. However, simulations provide better observation of a real system in order to analyze its performances and behavior over time.

VIII. Return-on-Investment (ROI) Analyzes of Rfid Implementation in Supply Chains

ROI analyzes are conducted to evaluate whether an investment is profitable on a period of time. They have often been studied through analytical models, simulations, case studies and experiments. As mentioned before, RFID technologies can provide several benefits on supply chains; cost reduction such as labor cost, inventory cost, process automation, or efficiency improvements and value creation such as increase in revenue, or increase in customer satisfaction (Nystrom, Lin, and Yu, 2006.). However, the cost of RFID is still larger than current identification technologies (P. Zipkin, 2007) and companies must decide whether to invest or not to acquire RFID technologies.

a) ROI from RFID based supply chain

(5 business cases that offer a clear illustration)

i. *The case for tracking returnable assets*

For many companies, the loss of returnable assets (pallets, roll cages, plastic crates, etc.) represents a huge waste of money. By identifying them with an RFID tag, they are able to trace and manage them more efficiently, knowing exactly which asset has been sent to which customer, how many they should still have on site, etc. The tags on items leaving or entering stores are read automatically whenever a truck is being loaded or unloaded. The ROI for such applications is quite obvious, as the use of RFID helps companies to avoid losing thousands of items each year, worth up to 400€ for a roll cage.

ii. *The case pallet loading and unloading in distribution centers*

RFID can reduce the time required to load or unload trucks. Today, most companies still use barcodes for these tasks and each item (e.g. carton boxes on a pallet) have to be scanned individually. By using RFID to identify the transported goods and installing an RFID gate at the loading and/or unloading gate, information can be read automatically when entering or leaving distribution centers. But not only does it allow a time saving, thanks to RFID, the error rate is also significantly reduced: products loaded onto the wrong truck or wrong products being unloaded can be detected immediately. Here again, the ROI is quite obvious, as the handling of goods being delivered incorrectly or inappropriately (use of transportation, manpower, etc.) is high and reduces the margin companies earn on their sales. Last but not least, the use of RFID for these tasks also implies higher security for work floor operators, who no longer need to execute potentially dangerous movements using a handheld scanner to scan every single barcode on a product pallet.

iii. *The case for asset management*

For many organizations it is important to know the exact location of their assets, such as electronic apparatus, furniture, etc. and how they are being used. Tagging these assets allows them to better manage these goods “in the field” and to reduce their stock. In hospitals, for example, medical staff can lose precious time searching for a machine that might be in use on another floor. Or sometimes unnecessarily expensive machines are purchased when it should be possible to work efficiently with fewer. Using RFID for asset management also makes it possible to store information about the maintenance of a machine more conveniently, on the machine itself, instead of in a computer programme or even a paper file. Finally, through using RFID, the inventory management of these assets is simplified.

iv. *The case for in store inventory*

Many stores are losing a lot of time doing their inventory, counting each item in their stock manually. To do this inventory, they often need to close their shop for one or two days and the risk of making errors while counting is high. Using RFID can help to make this tedious task much quicker and easier. Of course, to get the necessary Return on Investment, this can only apply to items which value justifies the use of an RFID tag, as it might be the case for clothes, electronic apparatus, etc. Not only is the inventory going much faster but the information on the counted items is transmitted directly to the central system and with much greater accuracy. This RFID application also enables stores to identify more quickly which items are out of stock and must be refilled.

v. *The case for food traceability*

In the fresh food industry, the use of an active RFID tag makes it possible to check if the cold chain has been respected adequately throughout the supply chain. A sensor placed on each box of perishable food makes it easy to identify exactly which boxes have been affected by a temperature problem and have to be refused, without necessarily rejecting a complete shipment. The same kind of application can be used in the blood transfusion chain, where temperature can be controlled together with the contents of a bag and its location.

IX. Challenges of Rfid Supportive Integrated Supply Chain Management

Although RFID-enabled supply chain generates a number of positive issues, yet it is suffered from various pitfalls. These pitfalls interrupt the efficiency of integrated supply chain operations. These challenging issues are as follows:

i. A key challenge of RFID supportive supply chain management is the continually evolving standards in technology, application, data, conference, firmware changes, and tracking methods.
ii. Different companies often use different standards making cooperation between suppliers and manufactures difficult.
iii. Illicit tracking of this technology related tags presents problem, like; scanning and cloning of RFID tags can potentially provide undesired access to important facilities or use for payment in commercial transactions.
iv. Implementations are complemented by varying specifications and regulatory requirements, such as; operational frequencies and power specifications vary from country to country.
v. An issue involving supply chain partners is the lack of integration, for instance, when the manufacturers' resource planning systems are not linked in real -time to shop floor systems.
vi. Another issue is the partners' resistance to information sharing, which is necessary to achieve maximum benefit from RFID technology.
vii. In the past, too many companies were implementing RFID for technology's sake, without understanding or establishing a valid business case to support their investment decision. In these instances, the cost often tends to be an issue with the price of a tag being too high in comparison to the price of the product to be identified or traced. This makes the use of RFID completely irrelevant.
viii. Another common problem can be the nature of the task to be accomplished. Even if RFID opens the door to creativity, for certain processes, the implementation might be more complicated than with another kind of technology.
ix. Environmental considerations need to be taken into account. As RFID works using radio frequencies, some materials or other elements in the working environment might hinder the transmission of information. Therefore, RFID is not necessarily the best fit technology to answer the needs of a company. For some projects, they might be better off using voice recognition or barcodes to achieve better results at a lower price. Moreover, very often, RFID cannot be considered as a "stand alone" technology either.
x. A first step towards a successful RFID project is thus engaging the right business consultant, who should be able to analyze in detail the issues a company is faced with and help establish if RFID is indeed the best fit technology.
xi. As RFID is a technology based on radio frequency, it is necessary to take a certain number of criteria into account when implementing a solution. Identifying the factors that could possibly result in noise and disturb the transmission of information is crucial, as in some cases, this could make the implementation of RFID impossible.
xii. Also, a company that decides to implement RFID for one or several processes needs to define very clearly which information should be read from each tag. Indeed, it is possible that a warehouse operator is wearing clothes that contain an RFID tag, and this would be information the company is definitely not interested in. Therefore, the tasks that correspond to operational processes to be enhanced should be defined clearly. These parameters combined which help collect the relevant information is known as "data qualification".
xiii. Another issue that might arise when using RFID is that simply reading the information on the tag will not provide the sought-after information. An example to illustrate this point is that of a truck loading or unloading: are the goods being shipped or received? Or what if, in a warehouse, one tag is within reach of two antennas and read by both? "Location virtualization" (several antennae placed on the same gate, defining two distinct reading zones) will solve this kind of problem. Yet, again, to ensure a good solution requires a thorough analysis.

X. Conclusion

Globalization, competition, and increasingly sophisticated and informed customers are creating ever greater supply chain challenges for today's businesses. While achieving supply chain excellence in the face of these challenges is difficult, companies that lead in supply chain improvement may be able to build competitive advantage. This study is conducted to

provide information on the current use of RFID technology in supply chain operations and its impacts on supply chain management systems. RFIDs have tremendous opportunities for increasing value out-of-stock items, trim warehouse costs, eliminate stock errors, reduce theft and shrinkage and allow companies to regularly update their logistics and inventory databases. Furthermore, it enables firms with such capability to competitive globally. As RFID technology can provide important business benefits, the results of this research deliver a better understanding of current problems and issues in RFID technology introduction and show which factors influence the level of success of such projects.

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