

The Role of RFID in Supply Chain Management Macro Processes

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Abstract—The role of RFID in supply chain management is increasing at a faster rate. This technology has great potential in increasing the SCM surplus and enable firms to gain and sustain a competitive advantage. This paper will present how adopting RFID technology will impact the supply chain management macro processes, which are; supplier relationship management (SRM), internal supply chain management (ISCM) and customer relationship management (CRM). Several activities in each process with regard to RFID adoption will be discussed.

Index Terms—RFID, customer relationship management (CRM), internal supply chain management (ISCM) supplier relationship management (SRM).

I. INTRODUCTION

Supply chain management is the flow of services or goods from the suppliers, through the manufacturers, distributors, and to the end users. Researchers have defined supply chain management as a successful integration and coordination of activities that are associated with goods being moved from the stage of raw materials to the end user stage, in order to have a sustainable competitive advantage. This covers activities such as sourcing and procurement, systems management, order processing, production scheduling, transportation, inventory management, customer service and warehousing [1]. Nowadays, there are number of technologies that could make the process of supply chain management easier and more efficient such as Radio Frequency Identification (RFID), Point of Sales (POS), Electronic Data Interchange (EDI) and Data Mining (DM).

In this paper we will focus on Radio Frequency Identification (RFID), which is one of the technologies that has lived to the promise and has been growing with new applications. RFID is a wireless technology which works on transmitted radio signals to track, tag, trace and recognize movements of items in real time. These items include cases, containers, products and even humans. RFID technology has three major components. First is the transponder, also referred as RFID tag that is fixed on the items which also identifies them. The second component is a reader, which is used as a communication channel. The third one is an application that collects data, which includes an antenna and

a software solution [2]. This research is an attempt to explain how adopting RFID technology can aid in Supply Chain Management macro processes eventually leading to overall coordination. Each supply chain macro process will be discussed along with relevant activities and the role of RFID technology and its impact.

II. RFID TECHNOLOGY

A. What Is RFID

RFID is considered an automatic identification technology that identifies items and collects data on these items. It needs no intervention from people for entering data unlike other automatic technologies such as smart cards and bar codes. RFID is a wireless technology that transmits information without any physical connection or need of line of sight, which is needed by some optical technologies like bar codes.

An RFID tag or a transponder contains a microchip, which is used to store data that identifies the item it is attached to and antenna in order to transmit the data through radio waves. The reader or an interrogator sends radio signals and prompts the tag to broadcast the data stored in the chip. The reader then starts converting the radio waves that are returned from the tags to digital data and sends them to a computer system [3].

B. Types of RFID Tags

There are three types of tags, passive, active and semi-passive or semi-active. The passive tags are in a sleep state till the reader awakens them. The reader's field in the passive tags is used as a charger to power the tags. Since the passive tags need a strong signal they are usually used for applications that have short ranges and need a powered reader that has antenna that could read the information. The passive tags are not heavy; they are light and have a long life span [4].



(a) Passive (b) Active
Fig. 1. Samples of passive and active RFIDs.

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The second type, which is the active tag, has an internal battery that powers the tag and could last for several years.

These tags are used for applications that have long range, till 100m. They contain a read/write memory and have higher capacity than the passive tags. As a result of these capabilities, the tags are heavier than the passive tags, and have a limited life span and are more expensive [4]. RFIDs are commercially available in different sizes, shapes and forms that can be chosen for appropriate applications. Fig. 1 shows samples of active and passive RFIDs.

The third type is known as a semi-passive tag, also called semi-active tag. This tag basically communicates with the readers as a passive tag. However, it has its own battery that helps support some specific functions [4].

A major characteristic that differentiates passive and active tags is that active tags need to have a power source attached to them. This limitation is another reason for active tags to be of bigger size than that of the passive ones, have shorter life span and more costly too. However, the advantage is that it covers greater ranges than that of the passive tags. Most of the passive tags are read only, while the active tags have to ability to read-write/rewrite several times.

C. RFID Characteristics

RFID operates on frequency that designates the radio waves intensity that is used to send information and is the key factor for determining the level of performance and applications for the system. Roughly all RFID systems operate on one of four frequencies, low frequency (LF), high frequency (HF), ultra high frequency (UHF) and microwave (MF). Their ability to read near metal or wet surface reduces from low frequency to microwave frequencies. The applications of low frequency RFID include livestock tracking, card key access control, beer key tracking, etc. Airline baggage handling and library book tracking are among applications of high frequency RFIDs. The application of supply chain tracking, warehouse management etc, are possible through ultra high frequency setups. Finally the applications of microwave frequency RFIDs are electronic toll collection, railroad monitoring, etc. Table I shows the frequencies and their characteristics extracted from Tajima [3].

TABLE I: THE CHARACTERISTICS OF RFID

Frequency	Tag Type	Read Range	Tag Size	Data Transfer rate	Tag Cost
Low Frequency (125-134 KHz)	Passive	<0.5m	Larger	Slow	High
High Frequency (13.56 MHz)	Mainly passive	1m	Larger	Medium	Lower than LF
Ultra High Frequency (860-930 MHz)	Active and passive	3.0m	Smaller	Fast	Lowest
Microwave (2.45 GHz)	Active and passive	10m	Smaller	Fastest	High

D. Cost Considerations

RFID technology helps the companies save money through enhanced inventory management, labor reduction, managing assists efficiently and advanced security. By

implementing the RFID technology domestically, the U.S economy is estimated to save more than \$500 billion per year. Wal-Mart estimated savings of 6-7% in 2005 by using RFID [5], which is around \$1.4 billion of its supply chain costs. In the current era it can be easily deduced that proper application of RFID solutions can surely create cost savings in any organization. However, it has to be acknowledged that RFID implementation may need a large amount of budget and time. Therefore, organizations have to be selective in their processes that can be candidates to be part of RFID solution implementations.

E. Challenges and Recommendations for Implementing RFID

There are many issues and challenges regarding RFID technology that should be addressed. Companies that adopt RFID technology have to face the challenge of integrating the RFID with the systems that the company is currently using. For example, RFID generates large amount of data comparing to the barcode technology. This will require the company to acquire a new data warehousing system, analyze and separate the data that could be used from the RFID data stream to make sure that the data is appropriately processed and it is mined effectively [6].

Another important challenge that companies will face is the privacy, security and integrity of the system. Since RFID is a wireless technology, there are some security concerns that arise when there is a communication between the readers and the tags. The communication could be exposed to traffic analysis and vulnerable data security. The security concerns arise during the data transmission, data storage or in the physical storage site. Some of these concerns have been addressed by the RFID vendors through blocking the transmission of data when there is jamming, using number of querying protocols and blocker tag techniques and encrypting the data when transferring it [6].

The availability of number of standards for using RFID also restrains the benefits of the technology. For instance there is the EPCglobal and ISO, and they developed their own standards. As a result companies that have global supply chains have to eventually choose one standard, which may work in a certain country and not in another.

III. THE SCM MACRO PROCESSES

In this section, the three supply chain management macro processes will be discussed along with respective major activities in each category.

A. Supplier Relationship Management Process

Supplier relationship management (SRM) is the set of processes that requires the use of principles and tools of managing, organizing and enabling the interaction, communication and collaboration between an enterprise and its suppliers. The objective is to minimize the risk of overhead and maximize the relationship value across and within the whole supplier relationship life cycle. The SRM has many definitions and is also referred as vendor relationship management. Its major objectives are to create a joint value between the suppliers and enterprise based on trust, open communication, collaboration and teamwork.

This relationship made it possible for organizations to finance all their activities such as, product development, manufacturing, and services through outsourcing [7]. According to Van Zyl [8] in 2005, purchased items represent approximately 60% of the total cost of goods sold as opposed to 20% a decade ago. He further added that many companies and organizations have realized how important it is to focus their resources more on their core businesses and competencies and to use outsourcing for the auxiliary functions to maintain their complete advantages.

SRM increased and created new opportunities for many organizations to gain a competitive advantage by gaining access to unique knowledge, talent, and ideas, and at the same time different resources and capabilities. And according to Douglas [9], SRM represents an opportunity to build on the success of strategic sourcing and traditional procurement initiatives. The major reasons according to him were the developing partnering relationships with key suppliers to reduce costs, innovate with new products and create value for both parties based on a mutual commitment to long-term collaboration and shared success. Thus, SRM facilitates reducing cost, which is considered as its second most important objective even though it can sometimes create some conflict with the focus on value creation. Moreover, SRM increased the rate of information sharing between companies, which led to many benefits such as, asset and cost efficiency, better customer service and responsiveness, substantial marketing advantages, and profit stability and growth [8].

B. Internal Supply Chain Management Process

Internal supply chain management relates to the chain of activities within a company that seals with providing a product to customer. Internal supply chain management involves many different tasks within organizations production, distribution, and sales. The objective of internal supply chain management is to envisage company's activities and increases the events during its influx work and show of the up and down actions [10]. It models outbound, inbound, operations, and production. It can be severed into raw material, finished goods, and raw material with their intrinsic process. A good internal supply chain management reflects in the company's performance and customer service [11]. Internal supply chain management is a fraction of a given supply chain management that happens within an individual company. Improving an understanding of the company's internal chain is often suitable starting point for company's considering a supply chain management action [12].

C. Customer Relationship Management Process

These days, organizations around the world face a business environment that is very challenging and as a result the importance of Customer Relationship Management (CRM) is growing rapidly. It is used as a means to address number of issues such as the changes in the economic conditions, the constantly increasing competition and depending on promotions that uses the intimate knowledge of customers that is acquired by marketing programs and relationship development.

The CRM has been defined in several ways and the CRM letters are also presented in different ways, such as Customer Relationship Management, Continuous Relationship Marketing and Customer Relationship Marketing.

Nevertheless, all these terms stands for the same process, which is increasing the value offered to customers through marketing activities. CRM also aids in providing an intimate knowledge of customers by management, collection and leverage of the customer information and the contact history [13].

The CRM is vital in the supply chain management as it deals with the customers who are the most important part of any business. To have warehouses, procurements, distributions and manufacturers is important, but business cannot sustain without customers. The Customer Relationship Management consists of sales force, marketing and call centers technology. Having customer knowledge means that you know who your customers are, how to communicate with them and what their needs are. Once you create customer database, you can use new marketing tools and business analytics to find new relationships and customize each category. From these data, it becomes easier to target the customers and customize the proper way of communication such as phones or emails where you can meet their needs [14].

IV. THE ROLE OF RFID IN SCM MACRO PROCESSES

A. Role of RFID in Supplier Relationship Management Activities

As mentioned before supplier relationship management is the process and interaction between the suppliers and enterprises, these processes include among others; design collaboration, sourcing, negotiation, procurement, supplier collaboration and all upstream logistics or activities. The emergence of IT played a crucial role in increasing efficiency of these processes. Some of the technologies like EDI, E-Commerce, ERP systems were reported to have significant impact on the way business is conducted and recently Radio Frequency Identification (RFID) has been found to be very promising. In the following we will discuss the scope of RFID in some of the SRM processes:

1) Design collaboration

This process aims to jointly design products with suppliers, like, "Sharing of engineering change orders between a manufacturer and its suppliers and the creation of bill of material cross-reference databases" [15]. Design collaboration with suppliers gives the opportunity to reduce the costly delays that might happen and at the same time create huge value if it was accomplished effectively. However, this process could be difficult sometimes especially when manufacturing/supplying complex products that are performed on different and dislocated companies such as aircrafts or automobiles, which is stirred on principles of distributed productions. Stankovski *et al.* [16] mentioned that, "since production is done in distributed companies, it is necessary to achieve communication between designers, implemented at production control level of communication in the company".

Thus, by implementing the RFID technology, suppliers can control level of communication and information sharing, as RFID has the ability to collect, gather and track information about all the material and products flowing

across the supply chain in almost real-time. This gives suppliers the opportunity to communicate and collaborate the design of the products with enterprises through data collection and data sharing, and even reduce complexity. The characteristics of RFID to support automatic data collection and data sharing can potentially lead to reduction in data-entry errors and delays, and significantly improve the quality and timing of the information shared with supply chain partners [17].

2) Supply collaboration

This process means that once there is an agreement between the buyer and the supplier, they collaborate and work together on forecasting, production plans, and inventory levels in order to have a common plan, and improve the supply chain performance [15]. RFID increases data sharing about product and supply chain between buyers and suppliers as long as they are collaborative. For example, exchanging electronic bills of lading, could be readily automated with the use of RFID, and would consequently reduce the manual tracking of paper trails [3].

Attaran [18] acknowledged that appropriate implementation of RFID solutions can improve the supply collaboration, which consist of collaborative planning, forecasting and replenishment (CPFR), and ensure the accuracy of the demand, order and sales' forecasts because it has the ability to provide more scalability through integrating with CPFR process. He further added that RFID provides enhanced visibility along the supply chain and facilitates the sharing of historical data and forecasts among supply chain partners that aids CPFR adoption.

3) Upstream logistics

The RFID can play different roles in the upstream logistics such as, tracking products and controlling quality among others. While RFID gives firms the ability to track all of raw materials, work-in-process inventory, finished products, it can also provide the real time status of assembly during production. Tajima [3] provided several examples of leading organizations that use RFID solutions for various processes. Ford used wireless Kanban system based on RFID, which improved tracking of parts through the assembly process. Harley-Davidson used RFID for easier product customization by linking a motorcycle's serial number to individualized assembly instruction.

B. Role of RFID in Internal Supply Chain Management Activities

RFID technology is not just a standby for barcodes but has proven to be a revolutionary element in internal supply chain management. It makes the internal supply chain management more accurate, reliable, and efficient. Several researchers have discussed the benefits of RFID in internal supply chain management. For example, RFID helps to minimize the manual work, minimize the cost, develop visibility, and develop planning [19].

Sabbaghi & Vaidyanathan [6] presented the application of RFID in demand planning, fulfillment and returns management. In demand planning, one of the prime difficulty they quoted is the shortage of credible data in passing stages with credible due dates. Data obtained from RFID can

minimize inexactness in data due to human errors or absence of data. Choosing the correct time in the market will help to improve the production strategies.

Fulfillment is considered to be the main process that involves gathering customer demands and delivering the order through efficient internal supply chain management. RFID has the potential to aid in resource assignment, order routing, etc that can minimize logistics errors like sending product to wrong places. Sabbaghi & Vaidyanathan [6] identified some applications like RFID gates, mounted in strategic period in the allocation site, can be used to read tags and automatically update stocking quantities as its tagged. The arriving goods can be identified against the right purchase order and minimize conflict.

Another common problem faced by organizations is product returns, which need proper reverse logistics in place. For example, Electronic security marker (ESM) can speed up the return management by serving retailers. An ESM connect specifies products that return to retailers by placing product stages on their high-end items and components. This will facilitate adding stock to inventory increasing availability [6].

C. Role of RFID in Customer Relationship Management Activities

Almost all industries around the world are developing rapidly which means that the number of competitors is growing. This also poses a challenge to all organizations in keeping the customers satisfied and loyal while increasing sales. Different stand alone software are used by various industries to cater to the need of customer relations. Since the focus of the paper is RFID we will focus only on the solutions that use this technology. RFID technology has been used in number of industries such as, airline, health care, food safety management as well as in the supply chain [20]. RFID could effectively interact with the customers in all times and trace the customer's behavior, which will help managers to easily coordinate promotions and manage marketing [21]. It will enable the business to sustain growth and increase competitive advantage by attracting new customers and having them visit the stores repeatedly [20]. When compared to supplier relationship management and internal supply chain management activities RFID has broadly been in use in customer relationship management. The application aspect also varies significantly on the type of business and it would be difficult to talk in general about the applications. Therefore, we will focus on one industry, which is the apparel industry which is popularly known to use the RFID technology.

Yang *et al.* [2] proposed an intelligent RFID-based CRM system for apparel retail that would create value in terms of responsiveness, relatedness and refinement. Their system could identify a customer automatically and make personalized recommendation increasing responsiveness and strengthening customer relationships. A framework of the RFID-based CRM system included two broad categories related to retailer and customer. In the retail base it has RFID-based customer information, RFID-based garment information and sales management module which were mainly designed by embedding RFID technology. In the

customer base it has personalized recommendation and service module and web-based communication and service module. These bases are connected through the main database of the customers and the products. In the following the main characteristics of the modules presented by Yang *et al.* [2] will be discussed emphasizing the use of RFID in their processes.

The *RFID-Based Garment Information Management (RGIM) Module* quantifies and classifies each and every garment or cloth in the store. They are classified according to their brand, price, fabric and so on and quantified based on Kansei Engineering (which is a method that translates the impressions and feeling to product parameter [22]). The criteria of the cloth's style are designed based on opposite pairs that could be graded for example, feminine and masculine, arbitrary and formal. The cloths in the store are tagged by an RFID and all the data about the quantification and classification; their position in the shelves and the stock balance is coordinated in the product database.

The *RFID-Based Customer Information Management (RCIM) Module* analyzes and manages the personal information of the customers that include their basic personal information, the records of their shopping and the preference information. RFID can be efficiently used to store the personal information as well as the preferences like recent needs, favorite color, taste or style and the shopping pattern. The records of customers shopping on the other hand, includes the dates of items they purchased, the items they tried and the shopping routes. All these information are recorded in the individual database of the customer.

The *Personalized Recommendation and Service (PRS) Module* is used to recommend cloths in order to satisfy the customers and their needs as well as improving the sales rate. The module takes care of the customer preferences and recommends clothing according to their tastes and matches.

The *Sales Management (SM) Module* makes the sales transaction process more clear and if a sudden problem occurred, it will respond efficiently. Each item is tagged by an RFID where the RFID reader placed on the checkout counters could trace it.

The *Web-Based Communication and Service (WCS) Module* has a communication platforms set for the customers in order to voice the services, product options and question whenever they want. It enables the customers to comment on the clothes grade and the services purchased. Moreover, if there were any discounts or new arrivals, they will be sent to the customers.

In the following some of the recommendation while installing RFID solutions is presented with regard to apparel industry.

- 1) *Customer Privacy*: When issuing tag cards to the customers, they should be informed that the data collected is used only for statistical analysis and the part that identifies the customers personally won't be used. Moreover, the customers should have the option if they want to continue using the system or stop [21].
- 2) *Familiarizing the Customers*: Using the RFID technology, customers could be identified the minute they enter the stores. This could be used to notify the sales person that the customer first dealt with or the

sales person that issued the card for the customer. This way the customer will be contacting with the person that they feel comfortable with and help to build a trust relationship [20].

- 3) *Identifying Customers*: Since the information of the customer is seen the minute the customer enters the store, the sales person could approach the customer by name and that will help in the RFID tags thefts. Seeing that the same gates are used for protection from cloths thefts, they can also be used for protection from RFID cards thefts [20].

An example of apparel industry and its adoption of RFID solution were discussed above. It can now be easily inferred that similar solutions can also be designed and developed for any industry. Appropriate procedures and processes should be identified and the potential of RFID can be utilized at its best.

V. CONCLUSION

Supply chain management is the flow of goods and services from the suppliers, to the manufactures to the distributors, and finally to the end users. The increase in global business has made the organizations seek the aid of technologies to enhance their business processes. One such technology that has been successful in making supply chain coordination effective is the RFID technology. The technology is discussed briefly and its types and characteristics were presented.

Supply chain activities can be divided into three main macro processes; supplier relationship management, internal supply chain management, and customer relationship management. Each macro process was addressed and its activities were discussed briefly. The potential of RFID in supporting the SCM macro process was discussed with several examples from literature. A case of apparel industry from literature was discussed to demonstrate the potential of RFID in customer relationship management. The rich literature proves that RFID can revolutionize the business strategies and can ensure profits to any organization subject to proper design and implementation.

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