**RFID Implementation of Supply Chain: Comparison of Three Case Studies**

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**Abstract:** This paper integrates the impact of different approaches in implementing Radio Frequency Identification (RFID) technology, namely supply chain inventory management system based on RFIDs to address the challenges encountered in the operation of the warehouses, item-level inventory tracking at retail stores, and customer order processing and distribution using RFIDs; to eventually propose RFID based supply chain management. Supply chain management (SCM) involves an effective information sharing, inventory management, transportation, sourcing and pricing strategies. This paper highlights upon how RFID can improve SCM drivers, one by one, and together that improve overall synergy. This paper extends the solutions of case studies and proposed improvements to RFID solutions in ERP applications. The paper also highlights the motivation to such implementations as these solutions offer further cost savings and performance gains. Consequently we conclude that RFID is a vital technology for the success of SCM and bridging the gaps among the existing enterprise applications.

*Keywords:* Radio Frequency Identification (RFID) technology, Supply Chain Inventory Management.

1. INTRODUCTION

The Radio Frequency Identification (RFID) is an automatic identification system without contact and without a need for line-of-sight (Finkenzeller, 1999) with applications significant impacting supply chain management. When the United States Department of Defense (DOD) decided to adopt the technology as a means of tracking its inventory (Sen, 2009), WalMart swiftly took advantage of RFID technology by mandating its suppliers to tag all goods supplied to its supermarket chain (Matta 2008). As the prices of RFID tags reasonable, RFID technology is successfully implemented in almost all segments of supply chain management for inventory tracking. It is also demonstrated that RFIDs have been successfully implemented in the retail industry in particular for fast checkout operations (Rathore 2011). The RFID technology is used in services sector as well, for inventory management and secured communications (Felix 2014). RFID technology holds promise in   
transforming supply chain management by providing real time intelligence for tracking   
enterprise assets (Khan &Valverde 2014) and has shown to be beneficial to improve the profits and internal communications of the firm (Valverde & Saade 2015) (Valverde, Saade & Barrad 2016). RFID technology also facilitates the reengineering of legacy systems into modern supply chain systems by providing a tool information sharing across the supply chain (Valverde & Talla 2012)(Talla & Valverde 2012).

In this paper, we examine three case studies: (a) An RFID based supply chain inventory management solution for the petroleum development industry (Adoga & Valverde 2014), (b) An RFID simulation for the supply chain management in the dental industry (Felix 2014), and (c) An RFID based intelligent system that integrates with an E-commerce application in an unattended store (Rathore & Valverde 2011). The aim of this study is to develop a comprehensive questionnaire for gathering quantitative data while leveraging the work performed in these case studies.

As per (Adoga & Valverde 2014), the challenge to maintain an accurate data in warehousing and inventory management operations in Shell Petroleum Development Company, Nigeria (SPDC) prompted for considering an implementation of an RFID based inventory management system as it can help in the resolution of problems. These challenges include inaccurate stock accounting, theft, and high man-hour requirement for stock taking activities among other things. The approach was to engage a consultant who can first analyse existing inventory management system in SPDC, identify issues and challenges (through interviews with key personnel’s in the department and personal observation by touring facilities) and to evaluate and propose upon how an RFID based supply chain inventory management system can be used to resolve and control the issues. A simulator with RFID technology was developed and its impact for a two month period was evaluated in (Adoga & Valverde 2014). Simulations have a good history of supporting the design of supply chain management systems (Grittner & Valverde, 2012).

In (Felix & Valverde 2014), the UK dental products, both supplies and equipment, were highlighted in a rising demand with aging population and the need for secured information of demand and inventory data. As health care continued to improve, the life expectancies continued to rise in developed countries. On the other hand, older segments of the population are well positioned to pay for the needed procedures because they control sizable amounts of discretionary income (Datamonitor 2008). The UK dental market space has witnessed significant growth rates, with stronger inventory focus. (Felix 2014) focused on enhancing efficiency of inventory management and dental solutions with the usage of online platforms and RFID in the UK dental sector.

In (Rathore & Valverde 2011), it is presented that an evolving E-commerce on the Internet certainly needs an efficient and secure way of executing sales transactions. The emergence of cost effective wireless RFID provides a new way of tracking and implementing security and conducting business. It will enhance confidence in business process automation. In a virtual shopping over Internet, a buyer selects items, places in shopping cart, and proceeds for checkout. In a physical store, a buyer in a physical store picks up all RFID tagged items in a shopping basket, and proceeds to checkout via an RFID activated exit, that can automatically completed an invoice and receive a payment without a need for agent. This solution allows a physical store to be integrated with E-commerce application to make it a complete 100% unattended store.

These three case studies presented differing needs and solutions via RFID applications: one focusing on inventory management using RFID technology for accurate data and faster tracking of inventory items, the second focusing on simulating an implementation, and the last one aiming at integrating an E-commerce application with an unattended store so that customer can reserve items and pick-up at an unattended store thereby saving on operational expenditure of a physical store.

In this paper, we integrate the subject matters of above case studies and develop a comprehensive system that addresses as many activities of business processes as possible. However, at this stage of work, we focus on inventory management, inventory tracking, inventory solutions, and E-commerce application to attach to unattended stores, in an effort to further improve upon cost-effectiveness of business processes.

2. RFID IMPLEMENTATION METHODS

The RFID technology is proposed for inventory tracking, automatic updates of inventory records, and integration of an E-commerce application with an unattended store. An RFID solution for store NG1101 would require a series fixed readers mounted at dedicated locations inside and at the exit side of a store with a number of mobile readers for the outdoor area (Adoga & Valverde 2014). The tag readers will be connected to the inventory management module of an Enterprise Resource Planning (ERP) database system that will detect and trace the movement of tagged items in and out of the stores. The mobile readers will help in the outdoor storage area that will not be covered by the fixed scanners during stock accounting. The layout of a typical store is presented in Figure 1 (Adoga & Valverde 2014).

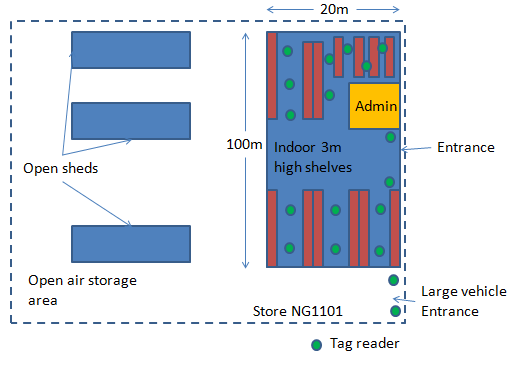


Figure 1. Store layout with multitag readers (Adoga &Valverde 2014)

The RFID reader devices are installed at fixed locations in a store and mobile RFID readers within the store communicate with management system that actually maintains inventory database as depicted in Figure 2. The deployment of RFID readers should be sufficient enough that no RFID tag becomes undetected. It is ensured during a rigorous testing process. It is also advised to keep redundancy built into the system. (Adoga & Valverde 2014) used a small prototype of limited scope built with the help of a mobile desktop based RFID and investigated the practical challenges of developing and deploying a full fledge solution.

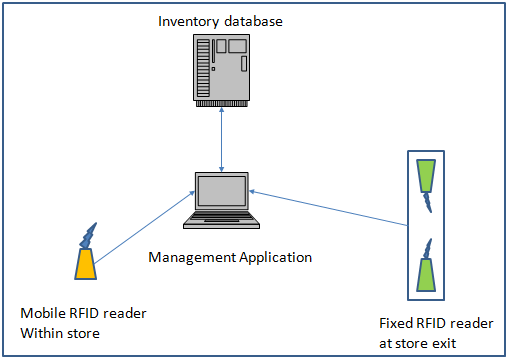


Figure 1 RFID based inventory detection (Adoga & Valverde 2014)

The Dental Distribution Company operates in a simple Supply Chain. The company receives orders from customers, purchases products at Manufacturers or Suppliers, maintains inventory and delivers to its customers. The inbound and outbound logistics are simulated following the flow of materials as presented in Figure 3 (Felix & Valverde 2014).

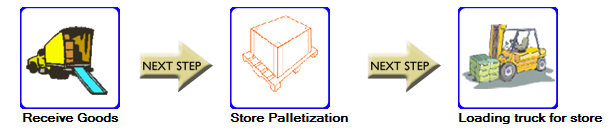


Figure 3 Flow of material for simulation (Felix & Valverde 2014)

The RFID technology is used for end-to-end operations using an independent module called as Real Time Security System (RTSS) as presented in Figure 4, and ensures secured transactions (Rathore 2011).



Figure 4: RTSS Architecture (Rathore & Valverde 2011)

A RFID tag (transponder) in the vicinity of RFID reader (interrogator) provides user interface. The RFID reader interacts with the tag and receives a raw data message from the tag. The raw message is relayed to RTSS server. The RTSS server processes raw data message (binary and Hexadecimal) in ISO 15693 format. The message is then translated into a meaningful string format. (Rathore & Valverde 2011) proposed this system for a physical store without checkout attendant, but with RFID activated checkout cash counter, and further suggested to integrate the system to an E-Commerce application. The RTSS interface uses the message to initiate a transaction over B2B or B2C e-commerce application.

3. COMPARISON OF CASE STUDIES

Three case studies that we examined considered different business processes and RFID implementation for Inventory management.

3.1 Inventory Management in Manufacturing (Oil & Gas)

A supply chain involves different processes: Suppliers, Manufacturer, Warehouses, Wholesaler, Retailer, and finally the customer. The major drivers in a supply chain are: Facilities, Inventory, Transportation, Information Technology, Sourcing, and Pricing. The warehouse and logistics play very important role in smooth operation of a company and in improving customer service level. (Agoda & Valverde 2014) proposed an implementation of RFID for Oil & Gas Company, especially installing RFID devices at strategic locations. Traditional inventory management uses manual processes which are expensive and time consuming while an automated process to inventory management would impact the supply chain surplus positively. The RFID technology integrated into an ERP system would certainly improve responsiveness and efficiency of a supply chain. Once a decision is made to implement RFID technology, it is important to implement the system in such a way that no inventory item gets undetected. To this objective, the case study involved the analysis of warehouse and existing inventory management system in Shell Petroleum Development Company (SPDC) in Nigeria with a view of identifying all operational challenges and solutions. A systems architecture of a solution is presented and a partial prototype is implemented with the purpose to highlighting how modern information technology and communication tools can add value in the supply chain management of SPDC. In this effort, (Adoga & Valverde 2014) took one store NG1101 of SPDC and considered an implementation of RFID. The paper presented strategic locations for placing RFID detectors inside and at the exits of NG1101 as presented in Figure 1. The NG1101 store has four meter high shelves; the RFID reader needs a near field of at least four meters to effectively detect the tag, which would required an RFID reader with a theorectical wave length of 25m and frequency of 12MHz, and commercially available readers of 13.56MHz would be very suitable. The system would be deployed in the manner depicted in Figure 1. (Adoga & Valverde 2014) used a USB based 915MHz UHF reader (read range of 10cm, for reasons discussed earlier) along with some RFID on metal tags and other variants of passive tags. The simulation provides an overview of RFID implementation and offers a motivation to such implementation for inventory management.

3.2 Inventory Management in Service Sector (Dental care)

A services organization such as a hospital requires medical supplies and equipment. Maintaining a healthy level of inventories for providing better healthcare is always a challenge in hospital settings. Therefore, healthcare companies operate in supply chains that actually enhance supply chain surplus while providing a better customer satisfaction. In a supply chain, flow of materials (inventory in transit) should be smooth and faster for the supply chain to be more responsive and efficient. Faster the inventory records are updated whether it is at inbound logistics or at outbound logistics, the holding costs of inventory in transit can be reduced, making the supply chain to be efficient; and serve customer needs, turning the supply chain to be responsive. (Felix & Valverde 2014) considered a dental supplies distribution company that operated in a supply chain relationship, and examined problems experienced at different stages of inventory management. The dental distribution company was actually using bar codes and scanners as it main technology for semi-automatic identification for capturing data. (Felix & Valverde 2014) conducted interviews for identifying activities for RFID implementations for both inbound and outbound logistics as shown in Figure 3. The company receives customer orders, purchases products from suppliers and ships them to customers. (Felix & Valverde 2014) proposed RFID technology solutions to problems identified in the company. The proposed solutions are simulated and compared with their existing supply chain system and metrics; and demonstrated significant improvements to data accuracy, responsiveness and efficiency of supply chain.

(Felix & Valverde 2014) went on simulating an implementation using Microsoft simulator and presented significant improvement (around 80%) in inbound and outbound logistics. Currently Microsoft offered a simulator for RFID as found on (Microsoft 2015). Therefore, (Felix & Valverde 2014) successfully presented that RFID is surely a cost effective alternative to barcode method. Although it is a well-known fact, that RFID is a better solution than barcode solution, it’s always worthwhile to evaluate a business case. Assuming conservatively that time taken for a barcode operation is one minute, (Felix & Valverde 2014) estimates that the gains would be of about 90% and proved with a simulation.

3.3 RFID based retail store operation (Unattended)

In case of shopping over Internet using an E-Commerce application, a buyer selects items, places them in a shopping cart and proceeds for payments. As an initial step, (Rathore & Valverde 2011) proposed solution where all items in a brick-and-mortar (physical) store are RFID tagged, and a buyer picks up all the items that are needed and proceeds to an RFID activated checkout exit where all items are automatically invoiced without a need for scanning. As a physical cash counter is not needed, the store is referred to as unattended. While the system doesn’t totally eliminate manpower for security at checkout, it will reduce the need for manpower significantly thereby offering cost savings. (Rathore & Valverde 2011) also proposed that the same RFID system can be integrated with an Internet based E-commerce application in an effort to extend the application to make it a complete 100% unattended store. In case of E-Commerce and an unattended store, the most important aspect of executing such transactions is security; therefore (Rathore & Valverde 2011) identified security as a primary concern and proposed a Real Time Security System (RTSS). (Rathore & Valverde 2011) presented a complete architecture of an end-to-end solution with RFID technology, integration with inventory database application testing methodology; and further proposed to integrate the system with an E-Commerce retail order processing.

4. IMPROVED RFID BASED SOLUTIONS

The RFID tags automate inventory record updates at inbound and outbound logistics and provide significant cost savings in a supply chain. In (Felix & Valverde 2014), while detection of merchandise is RFID based, the inventory management system actually is a database system as a module of ERP system can actually implement more functionality. For example, when an inventory item is in need, the system can list all alternate products to suit the budget need of customer. In case of dental care, such alternate solutions can be often worthwhile to review to suit to the differing needs and budget constraints of customers. Then, the inventory management system of ERP can include a rule-based expert system to find such alternate solutions for further improvement in customer service level and customer satisfaction.

In (Rathore & Valverde 2011), RFID solution is proposed for automatic checkout operation at retail stores that operates with unattended but RFID enabled checkout counter, and went on proposing a solution E-Commerce for customers over Internet. Then, the E-Commerce application can actually communicate with different unattended store servers, check inventory status to find a nearest store that has all merchandise availability, and actually reserve them for customer for pickup. In some cases if all merchandise is not available at one unattended store, based on customer agreement to pick up merchandise from more than on store, the system can reserve multiple pickup stores to a customer. Such solutions further improve customer service level and customer satisfaction. In contemporary E-Commerce applications, user selects a store and then looks for availability of items in that location, whereas in the proposed solution, user proceeds with order entry, then the system provides options to pick up from nearest store(s). This way user stays on course with the order, and company can enhance revenues and profits.

In (Adoga & Valverde 2014), the emphasis is on RFID implementation at assigned locations so that no RFID tag is undetected. Inherent redundancy of RFID detectors ensures better detection and server unifies duplicate detections. Investment in RFID detectors can be progressive, with initial installations to be just sufficient, and redundancy can follow successful execution and cost savings of RFID implementations. Today’s applications can proactively communicate with inventory via RFID automatic detection and highlight any discrepancies in inventory records, so that managers can investigate the reasons for discrepancies and take appropriate actions. Such automatic detection on a periodic review of inventory is often time consuming and expensive if the review is manual. RFID technology can substantially reduce cost of such inventory reviews.

5. CONCLUSIONS

In this paper, three distinct RFID technology case studies that addressed issues in different industry sectors covering manufacturing and services are examined. The focus of case studies and implementation details are further examined and integrated into essentials of a typical company implementing RFID technology. Furthermore, this paper went on proposing improved solutions. RFID technology was highlighted as the main technology used for systems integration in supply chain management. RFID can work to integrate the different processes in the order to cash cycle, from the order that could be used to integrate with E-commerce applications for the identification of items and automated checkouts, to the inventory management of materials that could benefit from RFID technology for a more efficient way of handling inventory in the warehouse from its arrival, to its storage and location. Different industries were analyzed from different sectors and the benefit of RFIDs can cover of wide spectrum of industries and processes. Future work will involve challenges in integrating these improved solutions into RFID based ERP system that provides a comprehensive solution to inventory and logistics management in a supply chain, and quantifying the gains of such implementation. ERPs could benefit tremendously from RFID technologies mainly as a way to interface production systems, warehouses and ordering systems.

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