Radio Frequency Identification Based System Design for Logistics Application

Huong Yu Chung, Zamberi Jamaludin, Lokman Abdullah
Faculty of Manufacturing Engineering, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia.
zamberi@utem.edu.my

***Abstract*— Recently, RFID has been the focal point of technology in automatic information transfer mechanism to enhance product visibility throughout supply chain. In logistics and manufacturing, it is of utmost important to optimize utilization and control of material flow. This paper outlines the design approach for application of RFID technology in supply chain with focus on logistics process such as distribution, storage and delivery. The automatic device tracking system via RFID technology outlined in this paper is to be implemented in an actual manufacturing plant. The primary objective is to extend the benefits of RFID deployment in actual industrial application for cost reduction and improved efficiency. Conclusions and potential future advances are presented at the end of this paper.**

***Index Terms*— RFID, logistics process, distribution, storage, delivery.**

I. INTRODUCTION

Globalization, outsourcing of production and services have increased the complexity of supply chain [1]. The high complexity of supply chain leads to the high demand in reliability and visibility of information, as well as evaluation of product tracking capability using automated system. Eventually, auto-identification technology was introduced for tracking and tracing of goods [2]. Among the auto-identification technologies, radio-frequency identification (RFID) has shown the most promising technology in optimizing the information flow efficiency in supply chain management [3].

Logistics as an essential part of supply chain management has played a key role in managing physical flow. The definition of logistics management has been revised [4] as the activities involved efficient and effective planning, implementing, and controlling of the forward and reverse flow and storage of products, services and associated information between the point of origin and the point of consumption, with aim to meet customer requirements. Integration of RFID system in logistics management has further improve visibility in asset tracking to reduce the occurrence of larceny and out-of-stock situation, as well as reduce cost in term of labour and inventory [5].

Since 1995s, various researches and reviews have been performed on applications of RFID in supply chain management [6-8]. The main objective of this paper is to highlight recent development in the evolution of RFID application, with specific scope on logistic within supply chain. This paper is organized as follows: Section 2 presents a brief introduction of RFID technology. In Section 3, applications of RFID and its impacts in each logistics processes are presented. Finally, in Section 4, conclusion is presented.

II. OVERVIEW OF RFID TECHNOLOGY

Radio Frequency Identification (RFID) is an automatic identification technology that allows transmission of unique information of an object or a person based on the detection of electromagnetic signals [9]. RFID technology is able to operate in off-sight situation and applicable for larger detection area range as compared to barcode. A typical RFID system consists of four main components: an interrogator (also known as reader), a transponder (tag with integrated circuit), antennas and host computer as shown in Figure 1.

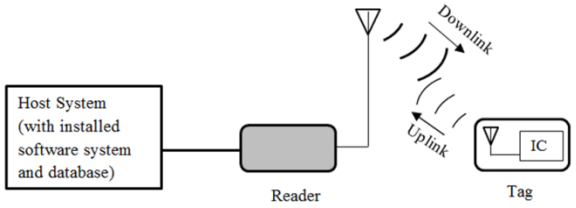

Figure 1: Overview of an RFID system

Reader transmits RF signal via the reader antenna to tags within the red zone (downlink communication). Unique data of an object or a person is stored in the integrated circuit of tag. Passive tag within read zone captures the received energy from the reader to energize the integrated circuit inside. Powered tag sends back a signal containing stored data via tag antenna (uplink communication). However, active tag that consists of standalone power source is able to send signal periodically to reader without the use of any interrogates. Reader antenna receives and decodes response signal from tag prior to sending to the host computer for further data processing relating to business and management value functions [10].

III. APPLICATIONS OF RFID IN LOGISTICS MANAGEMENT

The key role of RFID in logistics applications is tracking of goods from the point of manufacture to the point of sales [3]. The tracking and tracing process via RFID technology starts from the tagging of products at manufacturer (upstream level of supply chain). The manufacturer stores the unique data of tagged products into RFID tag, under the standard form of Electronic Product Code (EPC). The tagged products are then deliver from manufacturer to distributor, and lastly to retailer (downstream level of supply chain) as shown in Figure 2. Overview, RFID system in

logistics management is applied to enhance operational performance and improve customer satisfaction [11].

In the following reviews, the purposes of RFID applications in three main logistics activities [5] are presented based on previous research papers. RFID technology has evolved into hybrid application as RFID system configuration alone is not applicable to fulfill tracking requirement in highly robust situation of logistics [12]. RFID technology has been greatly developed in order to fulfill every industry requirement in reliable information support system.

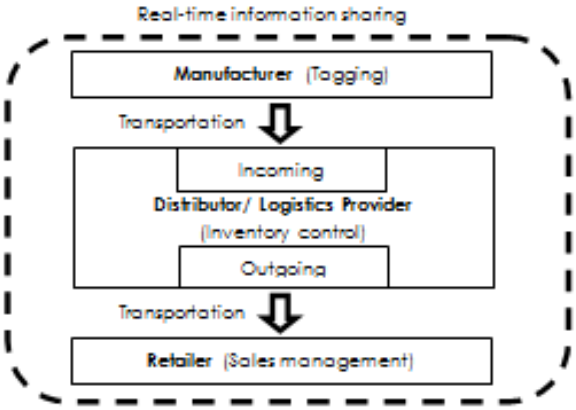

Figure 2: Overview of RFID applications in supply chain

A. RFID Technology in Distribution

Distribution process in the supply chain is to manage material whether in the states of raw materials, manufactured parts or finished goods within internal operation of distribution centre. It includes operations of receiving incoming products and shipping outgoing products at distribution centre [12]. The descriptions of receiving and shipping operations with RFID involvement are summarized in Figure 3 and 4. Value-added activities are done based on appropriate material handling requires for received material in ensuring material quality and safety.

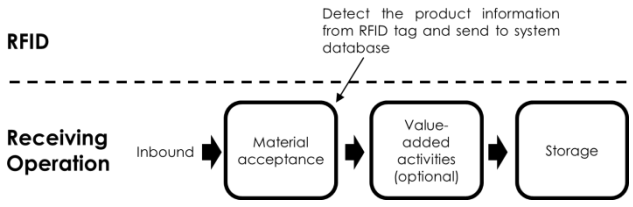

Figure 3: RFID application in receiving operation

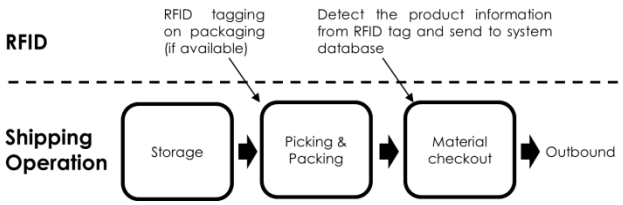

Figure 4: RFID application in shipping operation

RFID technology in distribution process is often used to confirm the validity of receive order and delivery order, as well as monitor the status of goods, equipment or personnel whether under secure environment. Real-time product monitoring has presented [13] at distribution center with the use of RFID tags and gates reader to avoid product loss or error in placement. RFID technology in outbound logistics have been proved [14-15] able to reduce average waiting time of truck at departure dock. Material checkout procedure in shipping operation has been simplified with information collecting by off-sight RFID technology and direct comparison of collected information with RFID database. RFID technology in container terminal have further developed [16-17] to improve the localization of container and control the movement of container either in receiving or shipping operation Deployment of RFID technology in automotive industry has been proved to be valuable in scheduling vehicle deployment [18], able to automate material booking and provide appropriate instructions for the machine [19].

All reviewed paper confirmed the tracking capability of RFID has improved the product visibility throughout receiving and shipping operations. The significant impacts of RFID technology in distribution process are accurate localization of tagged product [13, 16-17] and reducing processing time on record and verify product identity [14-19]. RFID technology has improved managerial performance of distribution process by simplifying paper work on product recording [14-15] and performing scheduling to avoid insufficient resources or facility [18-19].

B. RFID Technology in Storage

Storage process in the supply chain is to manage material whether in the states of raw materials, manufactured parts or finished goods within warehouse area. Inbound material in warehouse area is known as stock keeping unit (SKU). Automate quantity and quality monitoring of SKU is the main reasons of RFID deployment in storage process. Monitoring process in warehouse is to ensure SKU in satisfied condition before deliver to customers, and prevents any lost and deterioration of SKU occurs. Summary of RFID involvement in storage process are shown in Figure 5.

RFID technology act as real-time data collection technique is mainly mentioned with how to employ the real-time information to improve warehouse management. Examples of information collected in warehouse are SKU identity, location, and quantity, as well as warehouse environment variables (humidity, temperature, lighting, etc).

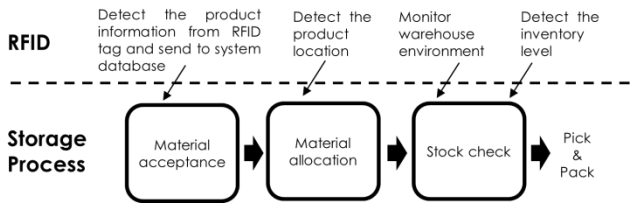

Figure 5: RFID application in storage process

A RFID-based intelligent warehouse management system was proposed [20] to automate order replenishment by facilitate shelf monitoring on SKU movement and quantities. Information collected in warehouse area also able to provide accurate location of warehouse vehicle and optimize its utilization with shortest pick-up route [21]. It also able to compromise the uncertainties in closed loop pallet management with fuzzy algorithm and schedule the picking order [22].

Hybrid system of RFID and environmental sensor provide crucial information in monitoring quality of SKU. RFID monitoring system [23] helped to avoid damage on food items by overheat or external crushing force. A RFID-based risk control and monitoring system on wine quality has developed [24] to ensure controlled temperature and humidity in wine cellar is suitable for the respective wine. However, [25] has argued that hybrid system is costly and not applicable for central control air handling unit. RFID food quality monitoring is supposed based on storage time and expert knowledge on maximum storage time for each item.

All the reviewed paper in storage process agreed that RFID technology is able to enhance operational performance by improving visibility on SKU identity, quantity and location. The impacts of RFID technology have further emphasized [20-21] in improving visibility and utilization of warehouse vehicle. Reduction of cost and time in warehouse operation, such as putaway and picking, are realized with RFID technology, as optimizing utilization of warehouse vehicle and storage space [20-22]. Real-time information provided by RFID technology is able to improve customer satisfaction on warehouse service as immediate action can be performed, such as arrange fastest route in picking order [21], stock replenishment on low SKU level [20], prevent damage on products [23] and product quality handling as react on environment change drastically [24-25].

C. RFID Technology in Delivery

Delivery process in the supply chain logistic is to transfer material whether in states of raw materials, manufactured parts or finished goods within business to business (B2B) logistics or business to customer (B2C) logistics. RFID deployment in delivery process is mainly for product security and quality purpose.

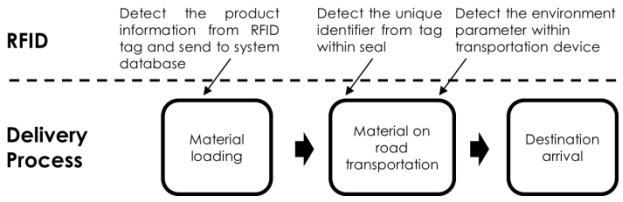

Figure 6: RFID application in delivery process

Product security issue refers to the loss of material on transport due to terrorist attack, thief intrusion and vehicle hijack. Product quality issue relates to hazard environment within confined delivery storage contaminates quality of transferred material. Figure 6 summarizes the details operation of delivery process that involved RFID assistance in real-time information collection.

In attempt to improve secure environment during transportation, an electronic seal has been designed [26] with passive RFID system to monitor seal status and send unauthorized seal open signal to active RFID system for notifying central network on seal operation. The electronic seal with Global Positioning System (GPS) has further developed [27] to track cargo location in real-time mapping whenever any reroute vehicle or unauthorized seal opening occurs. The needs of continuous reporting real-time situation on delivery operation are emphasized [28-29] by using Global System for Mobile Communication (GSM). Hybrid of 3G network and RFID [30] allowed web-based monitoring on delivering vehicle and products. For matter of product quality, RFID application in cold chain logistics has presented [31] to monitor temperature, humidity and shelf life of palletised agricultural product. RFID application with multi-temperature joint distribution system has further developed [32] to enable products under different temperature requirements deliver at one cycle.

Reviewed papers on delivery process have similar opinion of RFID enabled high visibility on material on transport with accurate material information and location. The operational performance of delivery process is enhanced with RFID in term of reducing delivery cycle time and flexibility in arranging delivery route [28-30]. Customer satisfaction in delivery service is advanced as product quality [31-32] and security [26-29] are assured. Unpredicted occurrences can be confronted immediately as real-time information is continuous report to the central with RFID system.

D. Discussion

Based on the literature review, RFID technology is applicable to improve material management in manufacturing plant. In summary of RFID application in manufacturing plant, tagged item can be monitored in term of the real-time location and environment variables. RFID monitoring enables status of tagged item to be visible throughout supply chain activities. This fact encourages manufacturer to implement RFID system in optimize time and space in inventory control, as well as production efficiency.

Among the logistics activities, distribution process is the most influential logistics process in manufacturing enterprise, where inaccurate information of material flow would affect production efficiency. Metal-based assets such as pallet, trolley, and container usually used in closed loop material transfer process such as distribution process. The asset carries material from one station to next station and returns back emptied to original station. However, reviewed papers showed less RFID application has implemented on metal-based asset within manufacturing plant, such as automotive, heavy industrial and military that prioritized product security and pallet durability [33] .

Metal-based assets have high tracking value as normally they are customized and high investment cost. Status of metal-based assets should be known in real-time to ease planning of production that involved distribution process. Even with RFID system applied on metal-based assets, investment cost of RFID technology is high because active RFID tags are used [15]. Passive RFID tags which are lower cost is not suggested to be used on metal-based assets because metal would reflect and shield electromagnetic waves from reader, as well as detune the tag circuit [34]. Therefore, less RFID application has been performed on metal-based assets with passive RFID tag.

IV. CONCLUSION AND FUTURE RESEARCH

Adoption of RFID technology in logistics activities enabled product information visible either in item or pallet level throughout the supply chain. The reviewed literatures has showed great potential of applying RFID technology in

distribution, storage and delivery processes that requires high demand on real-time logistics data to improve both operational and managerial performance.

Impact of RFID deployment in logistics activities are grouped into quality, cost, accuracy and visibility. Logistics performance is improved with quality assurance on products, optimum decision made on situation response, accurately perform as scheduled, and reduce overall processing time and cost. With improvement on operational performance, customer will satisfied to purchase quality, affordable cost and on-time needs product.

Future research can include passive RFID system in metal-based asset tracking within automotive industry. It is expected that RFID-based asset management will reduce the cost of transferral loss and logistics operation cycle time, as well as provide accurate localization of asset whereabouts.

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