

A Simulation Model for Enhancing Warehouse Manual Processes in a Paper-Converting Company Using RFID Technology

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Abstract

In recent times, the interest in using radio frequency identification (RFID) technology in supply chain activities has increased due to potential benefits in customer responsiveness and inventory and logistical costs reduction. RFID technology offers tremendous opportunities for those companies trying to reduce cycle times through automation, lower operational risks, improve return on investment, and enhance customer satisfaction and loyalty. Keeping track of inventory within supply chain operations is nearly impossible, but RFID technology is helping some organizations identify and track their assets throughout the manufacturing process. Managing wireless identification and tracking with RFID in warehouses and distribution centers represent a more innovative approach to conduct business, which creates new benefits for competitiveness.

Though, it's very important that users understand RFID capabilities and limitations to accurately assess the impact it can have on their business. This paper will describe the development of a simulation model to represent manual tasks and processes in a paper converting company's warehouse. Within a warehouse facility, several operations are identified and modeled using a software program. The "as-is" model is used to assess and recommend opportunities for the integration and use of RFID technology that may enhance existing operations to increase the efficiency of the facility. The "to-be" model will be analyzed to determine the value and implementation of using RFID at the facility. Results from the study suggest the facility can benefit from the emerging technology for certain warehouse tasks.

Introduction

Recently and obligated by the world economic recession, manufacturing companies have recognized the notable importance of the topic of leaner, more efficient processes, especially those small and medium sized businesses trying to maximize their resources in order to compete adequately.

Businesses of the third world countries experience a still more difficult task because the introduction of new technologies turns into an enormous sacrifice for shareholders, senior management and involved departments. Keeping track of inventory within supply chain operations is nearly impossible, but RFID technology is helping organizations identify and track their assets throughout the supply chain activities. Managing wireless identification and tracking with RFID in warehouses and distribution centers represent a new way to conduct businesses, which creates new benefits and challenges. Consumers are required to be aware of the RFID's capabilities and limitations to accurately evaluate the impact it can have on their operations.

It has been demonstrated that several similar operations in warehouses can be performed at a high efficient rate if the implementation steps are followed correctly when applying the RFID technology and if the observation process is close enough to detect failures in the initial stages of the implementation.

Radio-frequency identification (RFID) is an automatic identification method, relying on storing and remotely retrieving data using devices called RFID tags or transponders. RFID is classified as a wireless automatic identification and data capture (AIDC) technology¹. Basically an RFID system is composed of three layers: (i) a Tag containing a chip attached to the physical object to be identified; (ii) a reader and its antennas that allow tags to be interrogated and to respond without making contact and (iii) a computer equipped with a middleware application that manages the RFID equipment, filters data and interacts with enterprise application⁶.

This technology can be used to identify products at item level, can be read with no requirement for line of sight and can operate in harsh environments, where dirt, dust and moisture conditions can affect other types of Automatic Data Capture Systems, such as bar codes and light emitting devices. Moreover, multiple tags can be read simultaneously, and tags can also be programmed easily. In addition, tags are capable of carrying more information than bar code technology, thus enabling RFID to store additional information such as location, move history, destination, expiration date and environmental conditions (temperature, moisture, etc.)⁴.

The technology used in RFID has been around since the early 1920s according to one source (although the same source states that RFID systems have been around just since the late 1960s). In 1946, Léon Theremin invented an espionage tool for the Soviet Union which retransmitted incident radio waves with audio information. Even though this device was a passive covert listening device, not an identification tag, it has been attributed as the first known device and a predecessor to RFID technology. Related equipment such as the IFF transponder was invented by the British in 1939 and the first application goes back to World War II, when Britain pioneered the use of radio-wave navigation and identification of friend or foe aircraft for night operations⁵.

A very early demonstration of reflected power (modulated backscatter) RFID tags, both passive and active, was done by Steven Depp, Alfred Koelle and Robert Freyman at the Los Alamos Scientific Laboratory in 1973. The portable system operated at 915 MHz and used 12 bit tags. This technique is used by the majority of today's UHF and microwave RFID tags. The first patent to be associated with the abbreviation RFID was granted to Charles Walton in 1983 (U.S. Patent 4,384,288)⁸.

RFID technology operation starts when tags awakened by low cost activators transmit not only their unique identification code, but location and status information as well. Tag signals are picked up by network receivers up to 100 feet away, thus allowing a single receiver to collect tag data from a number of activation points. Figure 1 (Source: AA3WK's) shows how RFID technology works.

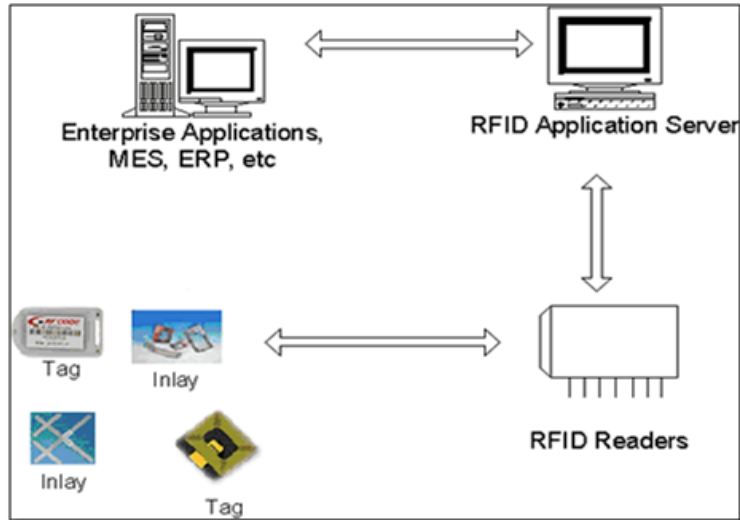


Figure 1: RFID Technology Deployment

The studied firm, Paper Products Inc (PPI, invented name to protect company's privacy), is a paper-converting company with more than 50 years of operations in the Dominican market and is the Number 1 paper-converting business in the DR.

PPI's principal products are valve and sewn paper bags for cement, flour, animal food, etc, made from Kraft paper; tissue paper and napkins manufactured with tissue paper, and notebooks with bond paper as its primary component. All three paper types come as paper rolls for ease of handling and protection of the material.

The main operations of its warehouse and production plant include the mobilization, storage and conversion of hundreds of Kraft, bond and tissue paper rolls each month using paper rolls clamps as the principal equipment for paper rolls transportation (Figure 2, Source: PulpandPaper-Technology.com). Those operations are affected by inventory inaccuracy, constant stock-outs of raw materials that generate lost sales and high inventory cost created by overstocks and other related costs, due to human errors occurrence when operators try to retrieve the data of paper rolls' labels, process that is very prone to mistakes.

Sweden and Czech Republic's suppliers provide most of the Kraft paper rolls, with a three to four months period of delivery lead time. Kraft paper sacks and bags represent the most profitable business for the company.



Figure 2: Transportation of Paper Rolls to Warehouse

Most bond paper vendors are located in Argentina and United States and Brazil and Venezuela's manufacturers fulfill all the demand of tissue paper rolls. The extended delivery times have a significant impact on the production planning activities because most final products, specially paper sacks and bags can only be manufactured with specific paper codes, meaning that stock-outs can result in the impossibility of fulfill customer orders, meaning that those customers can be lost or can decrease their businesses with the company substantially. The mentioned facts highlight the importance of Paper Products Inc achieving a high level of inventory accuracy and product tracking, which are some of the benefits that RFID technology can offer to this type of business.

Some goals of this project are to reduce manipulation in employee information, costs and process inaccuracies. Similar achievements are presented by Fosso Wamba et al⁶ in their work. They focus on a three-layer supply chain on warehousing activities and emphasize many SCM opportunities especially in terms of business process optimization. Fleisch and Tellkamp² present results of their simulation studies that show that supply chain cost and level of out-of-stock can be reduced eliminating inventory inaccuracy, even if the level of process quality, stolen and unsaleable items remains unchanged. Lee et al¹¹ developed a simulation model to study how RFID can improve supply chain performance by modeling the impact of RFID technology in a manufacturer-retailer supply chain environment. They demonstrated that there are opportunities for RFID technology to provide significant benefits in a supply chain, well beyond the automation oriented advantages such as labor savings.

Michael and McCathie¹² present the pros and cons of using RFID in the Supply Chain Management (SCM), concluding that, however, irrespective of those factors, the ultimate aim of RFID in SCM is to see the establishment of item-level tracking which should act to revolutionize SCM practices, introducing another level of efficiencies never before seen. Bendavid et al¹ examine the impacts and potential benefits generated by an RFID application in one specific supply chain. Through a detailed investigation of the underlying business processes, they demonstrate how process optimization can be achieved when integrating RFID technology into information systems applications. Folinas and Patrikios³ analyze the way RFID is implemented, presenting in detail a four-phased framework as a useful road map for RFID implementation. They conclude that implementing RFID technology in most companies is a complicated procedure, but through the right planning it offers significant advantages to the business and the each area of the organization should be evaluated independently to determine where RFID can provide additional functionality.

The main purpose of this project is to identify key tasks and processes, mostly manual and non-automated in a paper converting company's warehouse, obtain its current performing measures and compare them with the outcome of a warehouse simulation model that will be created and developed with RFID capabilities and features, hence operations with most probability of improvement within the warehouse can be identified.

Methodology

For the development of the simulation model, the project has followed a three-phase methodology that includes an Opportunity Seeking, a Scenario Building and Validation and a Scenario Demonstration and Analysis stages. This project has employed an Object-Oriented Analysis and Design Approach (OOAD), a methodology approach that is used in identifying problems and proposing solutions for them. This approach has been a powerful tool broadly used in the systems engineering and programming arena.

OOA/D can be subdivided in two phases: the Object-oriented analysis (OOA) and the Object-oriented design (OOD) (Wikipedia). The OOA phase is the examination of a problem by modeling it as a group of interacting objects. An object is defined by its class, data elements and behavior. In the presented warehouse system, we can define paper rolls as class and the processes of transporting, inventorying and picking as its behaviors⁹. The OOD phase, on the other hand, is transforming an object-oriented model into the specifications required to create the system. Moving from object-oriented analysis to object-oriented design is accomplished by expanding the model into more and more detail¹⁰. OOA focuses on what the system does, OOD on how the system does it. Figure 3 shows the phases of the methodology for this project.

The first step of the Opportunity Seeking phase is represented by the Determination of the primary motivation to adopt RFID. It focuses on describing and commenting the reasons to consider the use of RFID technology over other current technologies: bar coding, portable scanners, fixed scanners, etc, to enhance the warehouse operations. The next step was the identification and listing of all current warehouse processes and activities related with the movement, handling and stocking of raw materials.

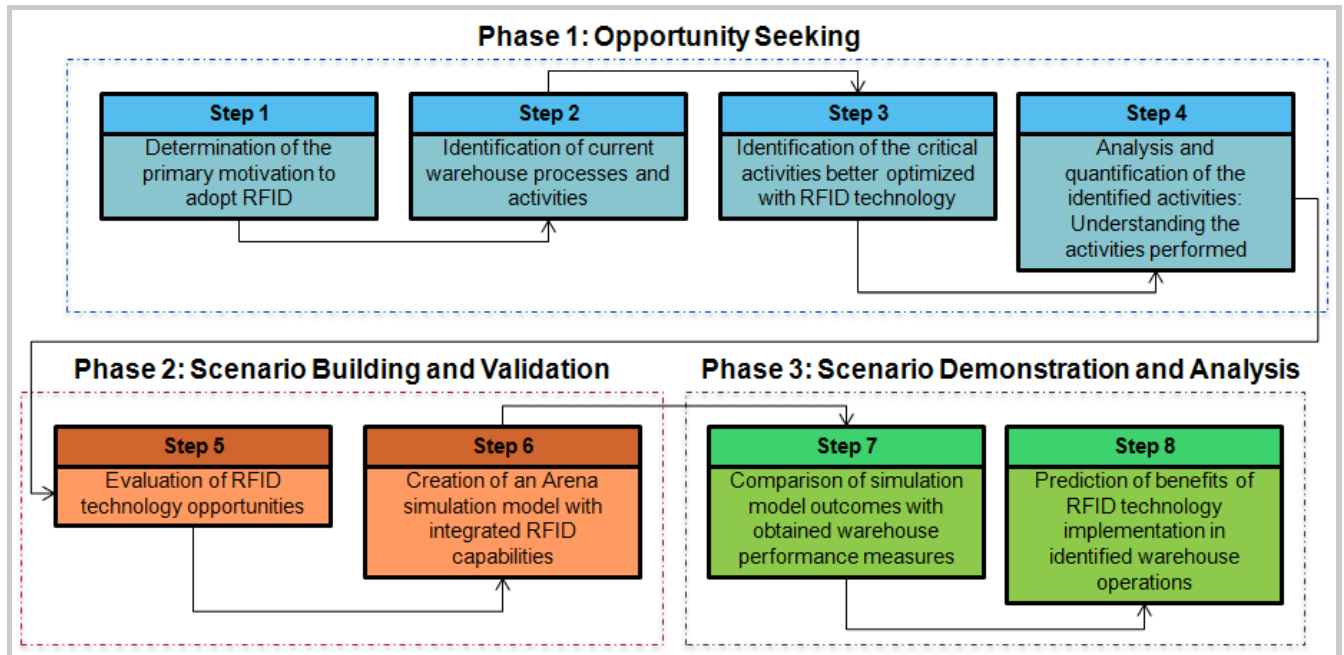


Figure 3: Phases of Research Methodology

Next, we have the Identification of the critical activities that can be better optimized with RFID technology. Those processes are thought to be most significantly improved with the application of RFID technology will be made. Factors like time needed to perform, grade of difficulty, risk involved and others in the execution of the processes was considered. The Analysis and quantification of the identified warehouse activities was performed in order to understand and quantify what can be the benefits of the application of RFID technology.

The phase of Scenario Building and Validation encompasses the Evaluation of RFID technology opportunities looking for the estimation of the opportunities involved in RFID implementation. Then, a creation of a simulation model with integrated RFID capabilities was pursued, trying to mimic the actual physical system in the warehouse. Finally, a comparison of simulation model outcomes with obtained warehouse performance measures as part of the final phase, Scenario Demonstration and Analysis, is going to be executed. This phase continues with an evaluation of the outputs of the simulation model versus the performance measures of the warehouse processes, trying to present a comparative situation between the current activities and the expected enhanced processes in the warehouse environment.

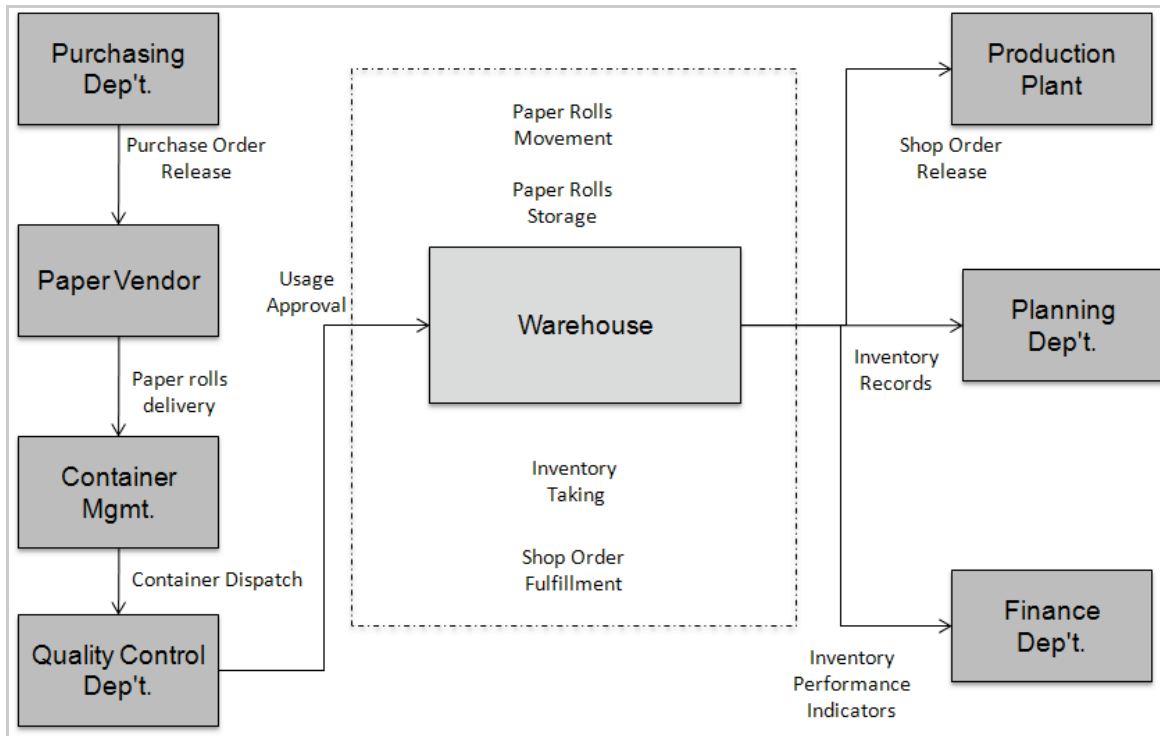


Figure 4: High Level System Diagram

The project ends with the Prediction of benefits of RFID technology implementation in identified warehouse operations. Several benefits will be projected for the paper-converting company if a correct implementation of the RFID technology is achieved in the warehouse facilities.

A High Level System Diagram (Figure 4) was developed to show the company's warehouse and other departments involved in the management of the paper rolls. It also shows inside-warehouse main activities: paper rolls movement, storage, inventory taking and shop order fulfillment or picking process. The last two activities are the main focus of this project. Figure 5 presents a Class Diagram, used to model the static aspect of the of the Warehouse system by showing its class and their relationships.

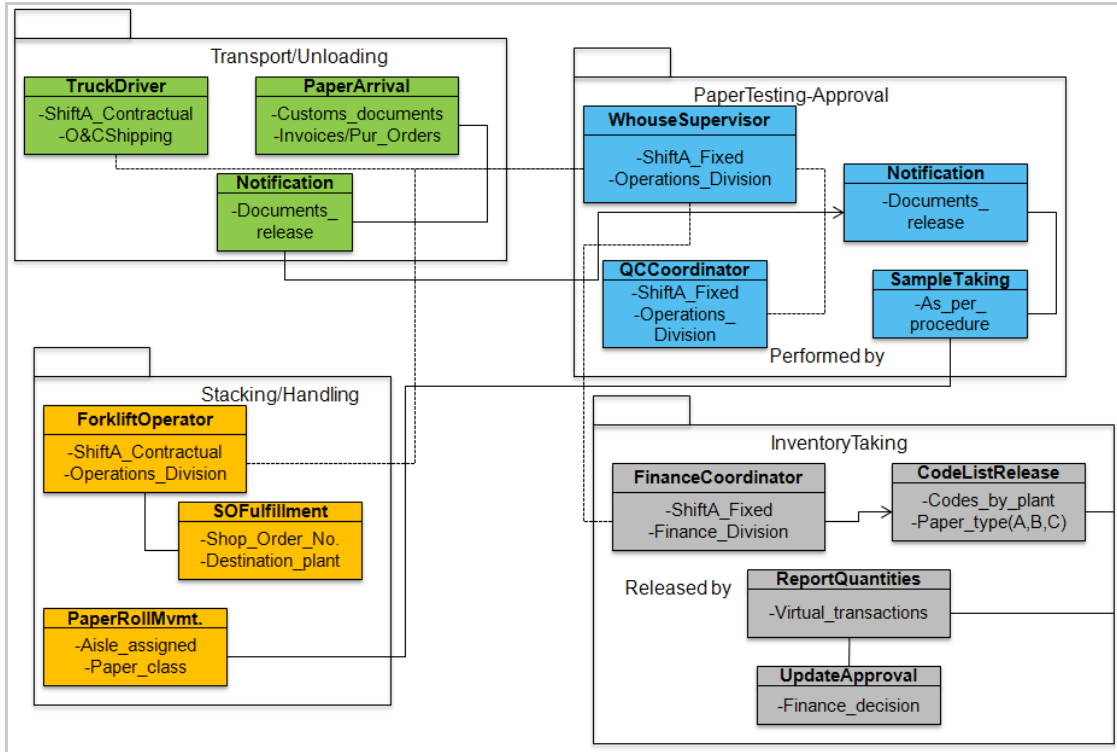


Figure 5: Class Diagram for Paper Rolls Management

Computer Simulation, defined as a broad collection of methods and applications to mimic the behavior of real systems, usually on a computer with appropriate software⁷ was used to represent the picking and inventory taking processes. It has become more popular and powerful than ever since computers and software capabilities are improving every day. Specifically, Arena 10.0 software used for this project simulation due to its characteristics of combining the ease of use of high-level simulators with the flexibility of simulation languages.

Figure 6 shows the primary resources of the simulation model, including the entities (Kraft, tissue and bond paper rolls); the facilities (Warehouse, Ramp Area, Production Plant), the resources (paper rolls clamps, operators, RFID tags, antennas and middleware) and the different parameters considered in the construction of the model: distances from ramp area to warehouse, warehouse to production plant, observed times for picking process and inventory taking, etc.

Parameters	Entities	Resources	Facilities
Distance from ramp area to warehouse	Kraft paper rolls	Forklifts (clamp type)	Warehouse
Distance from warehouse to production plant	Tissue paper rolls	Operators	Ramp
Observed times for rolls transportation	Bond paper rolls	RFID tags	Production Plant
Observed times for order picking		RFID antennas	
Observed times for inventory taking		RFID middleware	

Figure 6: Primary Resources of the Warehouse’s Simulation Model

Figure 7 illustrates the animation of the proposed scenario when the RFID technology is deployed at the warehouse facility. It includes the inventory taking process and paper roll picking to fulfill shop orders, as well as the movement of the paper rolls from the ramp area to the warehouse facilities and from the storage area in warehouse to the production plant and vice versa (returns of portion of paper rolls not utilized).

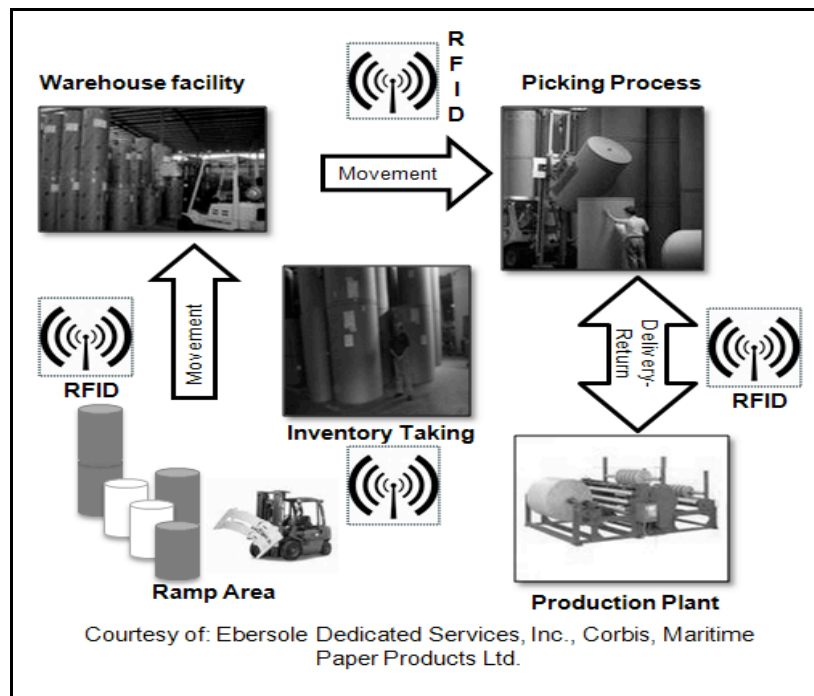


Figure 7: Animation of Eventual Scenario of Paper Rolls Management

Expected Results

When the outputs of the simulation model being developed using RFID capabilities become available, they will be compared to the observed current warehouse performance measures. The expected reduced times of critical operations will allow the prediction of the possible benefits of the implementation of the RFID technology in the warehouse activities, especially in inventory taking and picking processes. Some of those benefits can be listed as:

- Improved productivity through performing data capture quickly. RFID will decrease the time period of taking inventory from several days to just hours and will substantially minimize the current high utilization of personnel, equipments and resources for those tasks.
- Increased sales through reduced stock outs. As stock accuracy improves, the inventory record accurately shows which raw materials are actually available and which not, allowing most feasible planning schedules, better achievement in manufacturing runs and more final products ready to be sold.
- Improved cash flow through increased inventory turns and improved utilization of assets. RFID technology permits an improved deployment of managing inventory methods like FIFO (First In First Out) and LIFO (Last In First Out).
- Significant safety stock reduction at the item-level. The improved visibility that RFID technology offers will allow reduced excess buffer stock points and will improve order delivery times.
- Improved productivity in the warehouse critical processes, through reduced handling expenses. Most of the costs associated with labor are a direct result of the time workers spend capturing information and verifying the accuracy of tasks performed. RFID readers positioned at checkpoints in the workflow will perform data capture quickly, without the need of time-consuming manual verification steps.
- Increased facility storage capacity. The actual scenario at Paper Products Inc dictates that paper rolls, ink totes and other critical raw materials should be stocked maintaining product labels visible to operators, make extremely difficult to take advantages of storing capacity of the warehouse facility. That won't be necessary when utilizing RFID tags embedded into the products.

Conclusion

Affected by a series of issues triggered by manual operations and ineffective processes in its warehouses, Paper Products Inc deals with poor inventory accuracy, delayed manufacturing runs and eventually lost sales due to unavailability of raw material, as well as constant stocks outs by uncertain inventory records, thousands of dollars in overstock and other related concerns that are being addressed with the outcomes of the simulation model.

It is expected that if an RFID technology system is properly integrated in a warehouse environment similar to the one studied in the project, it will highlight the listed opportunities and benefits mentioned in the previous section. Also, Paper Products Inc should benefit of more affordable costs of RFID technology systems, which has been reducing due to day to day research and improvement in the technology.

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