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A Simulation Model of a Retail Distribution Centre with RFID Technology

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ABSTRACT

This paper presents a simulation model that has been developed to analyse how the application of Radio Frequency Identification technology (RFID) affects material handling activities in a retail distribution centre. The simulation model handles both stochastic and dynamic behaviours, and describes how the receiving, picking and shipping activities will behave and perform over time when RFID tags are applied to all individual products and units throughout the retail supply chain. The simulation model indicates that there is a great potential for increasing the efficiency of a distribution centre using RFID.

INTRODUCTION

Radio Frequency Identification (RFID) technology has shown potential as a means of increasing efficiency and effectiveness in supply chains (Kärkkäinen & Holmström 2002). Several companies have been able to improve their business processes e.g., improving efficiency in distribution centres, by using RFID technology (Falkmann 2000) (Frontline Solutions 2000). RFID technology uses radio-frequency waves to transfer data between a reader and a tag (transponders) that is attached to the movable item to be identified. This means that no physical line-of-sight or contact between the reader and the tagged item is required. There are several functionalities and types of tags. Tags can be read-only or read-and-write, which enables adding information to the tag. The information on the tags can range from static identification numbers to user-written data. Furthermore, memory capacity and the data transfer range also depend on the tag used. The readers can be at fixed points or mobile and be able to read and write information on many tags simultaneously, called “anti-collision”. Unfortunately, the use of this technology has thus far been limited to tracking high value products or products in closed loop settings where the tags are continually reused. Studies of applying Auto-ID technology, such as RFID, in distribution centres on unit and product level have suggested that there is a great opportunity to improve both efficiency and customer service (Alexander et al. 2002).

Once it has overcome various technical and economic obstacles, RFID will have the potential to one day be attached to ordinary consumer products and packages. Currently open standards and the price per tag restrain retail supply chains from applying them to consumer products, but the performance capabilities of RFID technology are being pushed forward, and price reductions are being worked on. By 2010, industry sources expect the price per tag is to have fallen to less than 0.01 EURO (Harrop 2002). This means that RFID tags could be a substitute to the traditional barcodes.

The purpose of this paper is to present a simulation model that has been developed to analyse how the application of RFID technology can affect material handling activities and the order process in a retail distribution centre. The simulation model describes how the receiving, picking and shipping activities at the distribution centre could behave and perform over time when RFID tags are applied to all individual products and units throughout the retail supply chain. In addition, the simulation model describes out of stock situations at a retail outlet when an RFID system can capture the behaviour of each individual product. The next section is a brief empirical description of the distribution centre and the retail outlet. Then, simulation scenarios are described and the simulation results presented. Finally there will be a short discussion.

DISTRIBUTION CENTRE

The modelled distribution centre handles about 2 700 types of ambient fast-moving consumer goods and processes around 350 000 traded units per week, which are distributed to over 150 retail outlets. The distribution centre is made up of four sections, à 4000 square meters, where each section contains different product groups and is divided into zones. The material handling activities within sections are highly independent of one another. Orders received from retail outlets are divided into pick orders designed for every section or zone to enable efficient order picking. Furthermore, each section has its own allocated resources. This enabled us to concentrate on developing a model that describes one of the four sections in the distribution centre. The modelled section contains about 690 types of products, such as nuts, candy, chips, cans, tins, pet food, soup etc. The section consists of two zones that cover 4 aisles each. Though each zone runs a picking route where the pick locations are fixed and situated on the lowest rack level, whereas the other levels, 2-5, are used as buffer storage. In every section there are two reach trucks, and over 50 pick trucks are used all over the distribution centre. In every section there are two dedicated docking bays assigned for receiving goods, and six for deliveries to retail outlets. The three main activities in the retail distribution centre related to the material flow are receiving, picking and shipping.

Receiving Activities

The receiving activities are unloading, verification, labelling and transportation to buffer storage. The distribution centre automatically generates orders or indicates that an order should be generated when the stock level falls below a predefined point. Orders are in pallet quantity and are delivered according to a product-specific schedule. When the delivery truck carrying the ordered pallets arrives at the distribution centre it is directed towards a specific docking bay and is unloaded by the truck driver. The received pallets are verified for product type, quantity and due-by date by an incoming goods controller. The controller and the truck driver then sign the proof of delivery documents when all delivered pallets are verified and unloaded. One incoming goods controller is assigned to every section of the distribution centre. The pallets are then labelled and transported and put into the buffer storage by a reach truck using a manual method intended to place the pallet as close as possible to the pick location.

Picking Activities

The picking activity is one of the crucial activities in a distribution centre; therefore pick efficiency is one critical factor for success. When an order is received at the distribution centre, the ordered products are first allocated. Then at specific times orders are printed and manually split into pick orders for each zone or section to enable efficient order picking. When an order picker has obtained a pick order he/she collects empty roll containers and then begins to pick the order. The picking procedure consists of: travel to pick location, label, unit pick, and then stack the unit in the roll container. When stacking the units the picker has to make sure that the picking labels are properly placed on the traded unit so the contents of the roll containers can be checked. Furthermore, when stacking, the picker considers that the units should be stacked solidly and without causing damage. Time for the picking procedures is illustrated in Table 1, where the activities are performed in the simulation model with an exponential distribution. When a pick location is empty a reach truck driver is notified by a picker. The reach truck driver manually searches for the oldest pallet and replenishes the pick location. The picking trucks have the capacity to carry three roll containers, each of which, in the modelled section, has an average capacity of 35 units. When the roll containers are filled they are placed at the shipping dock assigned for that specific order.

	1 Unit		2 Units		3 Units		4 Units		5 Units	
	Without RFID	With RFID	Without RFID	With RFID	Without RFID	With RFID	Without RFID	With RFID	Without RFID	With RFID
Labelling	3	0	4	0	5	0	6	0	3	0
Unit pick	7	7	9	9	11	11	13	13	15	15
Stacking	4	2	5	3	6	4	7	5	8	6

Table 1. Time in seconds for the picking procedures relative to number of units picked.

Shipping Activities

The shipping activities involve the activities of verifying orders and loading delivery trucks. At the shipping docks an outgoing goods controller verifies the orders, making sure retail outlets get what they ordered. The controller organises the roll containers into the correct docking lane and order sequence depending on delivery route. Verifying an order is made through counting the amount of units and checking that the labelling corresponds with the product. The complexity of numerous product types, quantities and deliveries makes it almost impossible to check all shipments. Currently the distribution centre manually checks about 20% of the shipments to retail outlets. When a shipment is verified and organised, the delivery truck is loaded.

Retail Outlet

The modelled retail outlet usually orders about 9200 units per week from the distribution centre. The retail outlet does not have any backroom inventory, so orders are generated when the shelves are replenished. It is when the shelves are replenished that the outlet knows what products to order. The retailer orders up to a predefined order level and receives the order in accordance with a weekly delivery schedule. Orders are sent to the distribution centre within specific time frames, depending on the retail outlet. The retail outlet is open between 08:00 and 18:00 except on Sundays, when it is closed. The products modelled in the retail outlet are those that are handled in the modelled section of the distribution centre. In the model the daily demand of products is set to a constant distribution throughout each day. However, the demand is weekday-dependent and varies between 200-500 units per day. Furthermore, there are weekly variances in demand. These variances are between 2000-3000 units per week, with an average of 2700 units per week. To capture these variances in demand the model is provided with data from 4 different weeks in April, May and July. The inventory levels for all products at the outlet are set to have an availability of 96.5%, which reflect an ordinary situation of a retail outlet of this size and concept.

THE SIMULATION MODEL

Simulation, according to Banks et al. (2001), is an “imitation of the operation of a real-world process or a system over time”. Simulation is a description of how a model performs and behaves over time when different rules and policies are applied. A simulation model is developed to better understand relationships and operations over time as a function of policies and parameters (Banks 1998). By adjusting parameters and processes, different scenarios can be explored without disrupting the real system. This ability to evaluate scenarios makes simulation a useful technique for analysing how activities in a retail distribution centre respond when RFID tags are applied to all products and units. The computer software, AutoModTM, which was used to develop the model, is a discrete event simulation tool. In discrete systems the variables in the model only change at discrete sets of points in time, whereas in continuous models variables continuously change over time. This means that the tool used handles both stochastic and dynamic behaviours. Furthermore the software visualises the model in three dimensions, making it easier to gain insight and understanding of the model.

The simulation model represents a retail distribution centre and a retail outlet. Consumers, product manufacturers and transportation activities are also, to some extent, embedded into the model since they affect the activities within the distribution centre. They were also included in the model in order to capture the dynamic behaviours of the retail supply chain. In order to model the material handling activities in the distribution centre, the information and material flow from all the retail outlets are of great importance. Since one retail outlet is modelled, the other retail outlets are embedded through providing the distribution centre with real order data, where order amount and point in time when pick orders are generated are taken into consideration. This enabled us to obtain a comprehensive representation of how the activities in the distribution centre perform and behave. Input data were collected from more than one month's on-site study of the retail chain, using interviews, archives and observations.

There are assumptions made in the simulation model that affect its performance when analysing how RFID technology affects material handling in a retail distribution centre. In the model, the performed activities are assumed to have total accuracy, with or without RFID. Furthermore the assumption was made that the distribution centre never ran out of units, thus causing incomplete orders and out-of-stock situations at both retail outlets and the distribution centre.

Performing scenarios where RFID technology is applied on products and units in the retail supply chain are not only created by adjusting parameters such as handling time; RFID technology changes the processes within the retail supply chain. For example, an RFID system could make it possible to capture the behaviour and location of each individual product and unit through tagging in real time. For every product, the current stock levels and delivery status could then be distributed throughout the retail supply chain. This provides an opportunity to change the order process among actors within supply chains. Two scenarios were conducted with the model where the order process was altered.

RESULTS AND DISCUSSION

The receiving, picking and shipping activities within the distribution centre are all affected by an RFID system where tags are applied to all products and units. The activities turn out to be more efficient, using fewer resources and becoming quicker when implementing RFID, since several operations became unnecessary.

Receiving Activities

The capability to identify products in a wireless and automated way is one of the advantages of RFID. To identify products, they can simply be passed through readers or read from a wireless interface. When receiving pallets, the products do not have to be verified or labelled by an incoming goods controller since they are automatically identified when they are unloaded and passed through the readers. This resulted in one less resource needed in each section of the distribution centre. The proof of delivery could also be obtained automatically without manual effort and sent electronically to those involved. Because RFID makes it possible to survey current stock levels, the reach truck could be guided directly towards a suitable location instead of using the manual method. This also made it possible to begin replenishment of pick locations just as they are being emptied. This increased the efficiency of the picking activity, since pickers do not have to spend as much time waiting for the products to be replenished by the reach truck.

Picking Activities

With an RFID system the picking activities could become more accurate, quicker and more efficient. Pickers could be alerted if they pick the wrong product or wrong quantity of product. They would not have to spend time checking what they have or have not picked.

Furthermore, the picker would not need to label the product, which increases pick efficiency and eliminates the problem of incorrect labelling. Not having to label the units makes the stacking easier because the picker does not have to consider that the picking labels need to be properly displayed. Tagging could therefore ensure that the picking is done more efficiently and in accordance with what the retail outlet needs. In the simulation model, the effect of RFID tagging is a change of time required to perform the pick activities, which is illustrated in Table 1.

The result of the simulation model indicates that there is a potential of increased pick efficiency when RFID tags are applied to units. The average picking time for a pick order was decreased roughly by 25 % and is illustrated in Figure 1, where the first bar is without RFID and the second bar with RFID. The modelled section picks about 450 orders per week, resulting in 3 fewer pick resources used. Since the distribution centre has four sections, this results in approximately 12 fewer pick resources needed at the distribution centre.

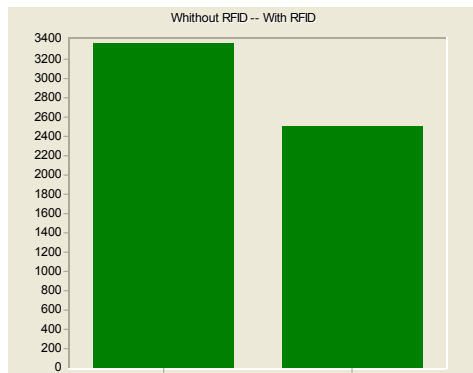


Figure 1: Average time to pick an order with and without RFID technology.

Shipping Activities

By using RFID tags on units, verifying picked product types and quantities could be achieved automatically and objectively without manual controllers and with higher accuracy. To verify the orders, roll containers could simply be passed through readers at the shipping dock as they are loaded into the delivery truck. With an RFID system, the manual verification activity is not needed, which results in one less resource used in every section of the distribution centre. Furthermore, time is saved, allowing the postponement of activities or earlier deliveries to retail outlets.

Retail Outlet and Order Process

With an RFID system the order process could be changed to improve on-shelf availability, which enhances customer service. In the outlets, readers on shelves could monitor each product status, providing accurate data on shelf availability. Orders could then be generated automatically, by the retail outlet or by the distribution centre, since the consumption of products could be monitored in real time. The retail outlet does not have to rely on personnel to place orders within time periods when the demand is unknown. Pick orders could be generated the minute before a product is supposed to be picked and just-in-time for delivery, thus fulfilling the actual consumer demand.

Two scenarios have been conducted where the inventory level of each individual product in the retail outlet could be captured in real time. In scenario one, the original delivery schedules were used and the pick orders was generated when they were about to be picked. This made the order reflect the current demand and not what the retail outlet needed last night, when the order was usually generated. Furthermore the order was generated later, since there was no

time spent on verifying the picked order. This resulted in fewer out-of-stock situations; see Figure 2. The first bar in Figure 2 illustrates the number of out-of-stock situations with the original order process, the second bar illustrates scenario one and the third bar scenario two. The second scenario was based on generating orders when an out-of-stock situation was about to happen. When any of the modelled products reached an inventory level of one product, an order was generated and sent to the distribution centre where it was immediately picked and delivered. With this order process, which is based on what products are moving from the shelves, the out-of-stock situations nearly disappeared; see Figure 2. The number of deliveries was still one each day, except on some weekends when the demand was high.

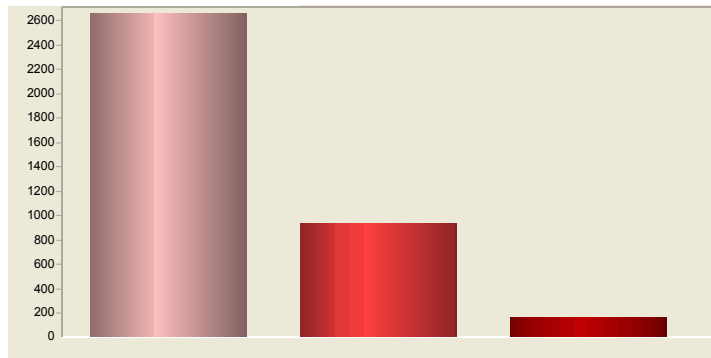


Figure 2: Number of out-of-stock situations in a three week period.

CONCLUSIONS

The results from the simulation model indicate that an RFID system in which RFID tags are applied to products and units has a potential to increase the efficiency of the distribution centre. The speed of the distribution function was increased because the time to perform the activities was reduced, resulting in increased efficiency of resources. Labour generally represents the greatest cost in a distribution centre, and in the scenario performed approximately 20 fewer resources were needed in the distribution centre. Order picking represents the core activity of the distribution centre, and is the most labour intensive part of the distribution centre. The efficiency of the picking activity improved with RFID technology and resulted in saving approximately 12 picking resources. The simulation model also demonstrates how out-of-stock situations could be reduced by using the ability to capture the current inventory level of each individual product in the retail outlet through tagging. In the scenarios conducted to analyse the order process, the order was generated when it was about to be picked or when an out-of-stock situation was about to happen, all of which decreased out-of-stock situations.

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