RFID Implementation and Simulation-based System Dynamics for optimizing warehousing strategies under multiple criteria

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ABSTRACT

This paper is based on the application of RFID technology and simulation to a typical warehouse that manages pallets, where decision making has to be made dynamically and at a faster rate. Moreover, it integrates optimization under multiple criteria to the model, given that there is a need to get a better use of the space available in the warehouse, but at the same time, it needs to take into account that both distance travelled in picking and quantity of inventory for each product are minimized, while satisfying the client at a certain level of service. Real-time data obtained by RFID technology were shown to be very helpful when applying it to a warehouse in Colombia and simulation results have shown that there was a significant impact reflected in an increase of the service level offered to the client.

Keywords: RFID, Simulation, Multi-criteria Optimization, Warehouse, Decision Making

1. INTRODUCTION

Most warehouses nowadays have adapted their infraestructure in order to compete with the global market. Trends have shown that today there are even smaller warehouses than before, given that customers are asking in lower quantities but at a faster rate. Although physical infraestructure is yet an important part of the warehouse because it guarantees a capacity to operate, more attention has to be given to the processes that occur within the warehouse and most importantly, the way information is managed and processed in order maintain a higher dynamics in decision making.

Recently, in Colombia, there have been several cases of the application of technologies for a better tracebility of a product and a higher control over them and over the resources and equipment used within a warehouse. New technologies such as EPC/RFID (Electronic Product Code and Radio Frequency Identification) have been considered as a predominant tool for the tracebility of products and have come to replace, in many industries, the famous barcoding. The correct implementation of this technology can lead to a better use of inventory and a significant reduction of stockouts while increasing sales. This type of technologies help identify, more easily, the positions and spaces available for inventory and the stages that each of the products undergoes before leaving the warehouse.

This paper is based on a project were the implementation of RFID technology was needed for the optimization and traceability required among a manufacturing business and its supplier of containers and packaging. At the same time, several optimization models were integrated in order to obtain an overall increase in its utilities, which required of a better use of the facility in terms of space and the resources available, but at the same time, guaranting an increase in sales and a greater satisfaction of the client.

It is organized as follows: First, the type of warehouse problem approached is described. Second, the optimization model under multiple criteria is presented. Third, the method used to solve the optimization model under multiple criteria through the use of the simulation of multiple scenaros is proposed. Fourth, a description of the integration of the algorithms in the software is presented. Fifth, an alarm system for inventory control is presented by using RFID technology.

2. PROBLEM FORMULATION

The warehouse racks are organized by product families, which are palletized; however, ocasionally some products are mixed in the shelves due to space problems. E.g., a rack that should be dedicated for an specific item, sometimes has a space temporarily assigned for another. Additionally, the products' location in the shelves are given by row (x) and column (y), but not by depth (z), i.e., a shelf that has a capacity to store 3 pallets, in the system will be referenced as the same space (x, y), thus it is not possible to know if the pallet in matter is the first, second or is the last one, only an experienced warehouseman might know the exact position of the item and how many pallets are needed to remove in order to reach it. This condition becomes a problem for the racks whose capacity is that of 11 pallets, which will also delay the process of picking the items.

The shelves are sectorized by product type and also by state, this could be: Quarantene, Approved, Rejected or Retained. The state of Quarantine is established when the product hasn't been inspected previously by the customer, so tests are done in order to locate it in the racks and avoid the contamination of the rest of the products in the warehouse. Once the material passes satisfactorily the quality control tests, a label of Approved is placed and the pallet is positioned on the approppiate rack. If the product doesn't pass the quality control tests, then it will be located in the Rejected zone or in the Retained zone depending on the case. The zones are properly signposted. It is absolutly necessary that a pallet must be in the rack of Approved and with the correspondant green label that indicates the same condition, so the warehouseman can take a product out to accomplish a production order and locate it in the orders rack.

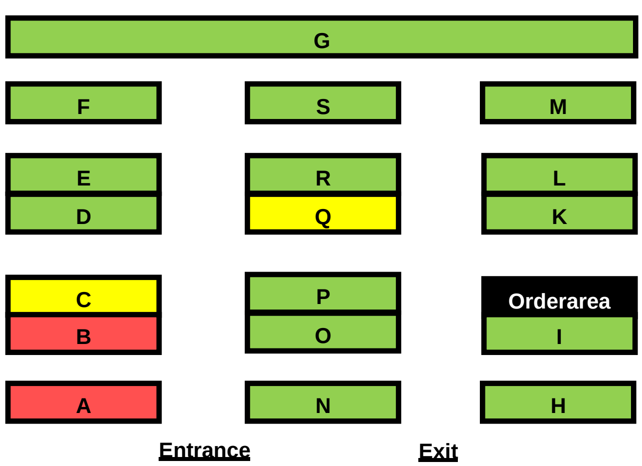

Figure 1: Warehouse layout

When placing the products, it is only taken into account that the pallet is located in the proper rack, nevertheless, it is not taken into account the specific location, i.e., the material is not placed according to its demand, if it is high, the pallet should be placed in the lower shelves or/and first.

The warehouse's zones are organized as it is shown in Figure 1. The green area represents the Approved zone, the yellow area represents the Quarantine zone and the red area represents the Rejected and Retained zone, finally the black area is the order zone.

3. OPTIMIZATION MODEL UNDER MULTIPLE CRITERIA

When making decisions in a warehouse, one encounters a principal aspect that needs to be taken into consideration at all times, inventory management. That is why the traceability of a product is very important in a warehouse and that is why RFID integration was need in the model developed. By knowing where and how much time a product is been stored, many problems can be solved at the same time. Storage costs are everyday more expensive and, as mentioned before, the client is buying at lower quantities but at a faster rate. This is why this optimization model is based on three aspects: (1) utilization of spaces in a warehouse, (2) picking distances around the warehouse and (3) quantity of inventory stored for long periods of time. That is why the optimization model is based on three objectives; each one refers to an aspect mentioned above.

Sets:

i= products$i \in N$

j= racks$j \in J$

t= period of time$t' \subseteq t,\ t \in T$

Variables:

$$y_{ijt} = \begin{cases} 1, \textit{if the producti is located in the rackj at timet} \\ 0, \textit{on the contrary} \end{cases}$$

$$x_{it} = \begin{cases} 1, \textit{if the producti is picked up at the time } t \\ 0, \textit{on the contrary} \end{cases}$$

u_{it}= *trips the fork lifts take to pick up product i*

Parameters:

q_{it} = Quantity of product i requested at time t

v_i= volume of the product i in m3

de_j= distance from entrance to rack j

d_{jk}= distance from rack j to rack k

ds_j= distance from rack j to exit

$$e_{it} = \begin{cases} 1, \textit{if the productienters the warehouse at the time } t \\ 0, \textit{on the contrary} \end{cases}$$

$$s_{it} = \begin{cases} 1, \textit{if the productileaves the warehouse at the time } t \\ 0, \textit{on the contrary} \end{cases}$$

Objective Function:

(1)

(2)

$$Zmin = \sum_t \sum_j \sum_i q_{it}\, v_i y_{ijt}$$

$$Zmin = \sum_t \sum_j \sum_i u_{it} de_j\, e_{it} y_{ijt} + \sum_t \sum_j \sum_i u_{it} x_{it} d_{jk} y_{ijt} + \sum_t \sum_j \sum_i u_{it} x_{it} ds_j s_{it} y_{ijt}$$

$$Zmin = \sum_t \sum_j \sum_i q_{it} y_{ijt}$$

In this case it will be only evaluated, from the mathematical model,equation (2), thus (1) and (2) will be evaluated jointly with the results of (2) by simulation of multiples scenarios. The different scenarios depend on the order in which the products will be picked each day.

In order to consider an optimal throughput performance, we consider a virtual design of the warehouse that was done in (Manotas, L. and Ramirez, D., 2011), which considered a static problem that was solved through a Cube-per-order adapted methodology. Yet, the model introduced today considers a dynamic model that can be visualized through simulation and can be changed as part of the planning done at a tactic level.

It is important to mention that the way to solve this model is not based on optimizing the pure mathematical model but in a methodology that involves techniques already used to solve each model independently and simulate the different scenarios to obtain the best solution available. This is why the model developed was based on simulation and the techniques used are already known in literature. The results from this model are measured by the three objectives and this forms a Pareto Optimal Solution that is a set of solutions that can bring best results in all three of the aspects. Depending on what is the decision maker's priority, he will prefer one solution than other. See Figure 2 with the Pareto Solution Graph for two objectives.

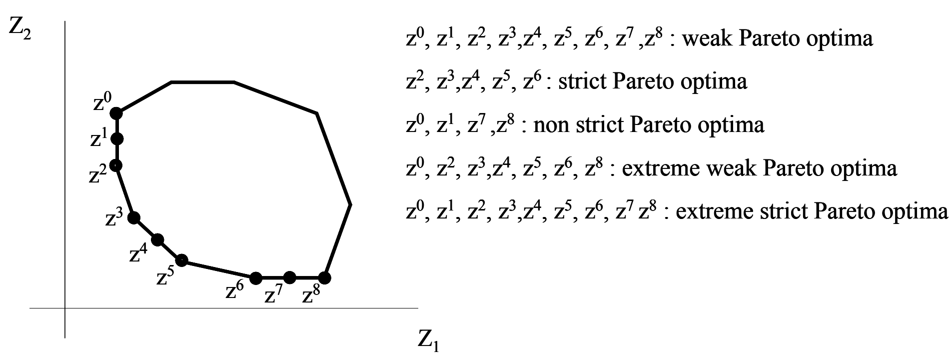

Figure 2: Weak and Strict Pareto Optima where Z defines a polyhedron (T'KINDT and BILLAUT. Figure 3.3. p.48)

The first aspect is referred to how products must be stored in order to obtain a higher utilization of the spaces available in the warehouse. Yet, it is important to take into consideration the rotation of the products, given that those items that have a higher rotation must be nearby the exit and this relates directly to the second aspect which is the minimization of picking distances and the amount of inventory stored for long periods of time. There is a well-known heuristic known as cube-per-order that can solve this problem by assigning zones to certain types of products, depending on both their volume and rotation. In the next section this heuristic will be described. The next decision that must be made is based the assigning of the forklifts when doing the picking of the different orders during the day. At the beginning of the day, a list of orders is received and the optimal ordering is based on the best Pareto Optimal scenario chosen by the decision maker.

4. SOLUTION TO THE OPTIMIZATION MODEL

The solution method of the equation (2) starts with the procedure described above, related to the cube-per-order rule (Manotas, L. and Ramirez, D., 2011). Then, the products that arrive with more frequency will be the ones that need to be nearest to the entrance and those who have production orders with more frequency will be the ones that need to be nearest to the exit. Nevertheless,these two conditions are related, but we need to consider the multiples states that were declared before.

In a regular warehouse, we can find out the following product flow, according to its state as we can see in Figure

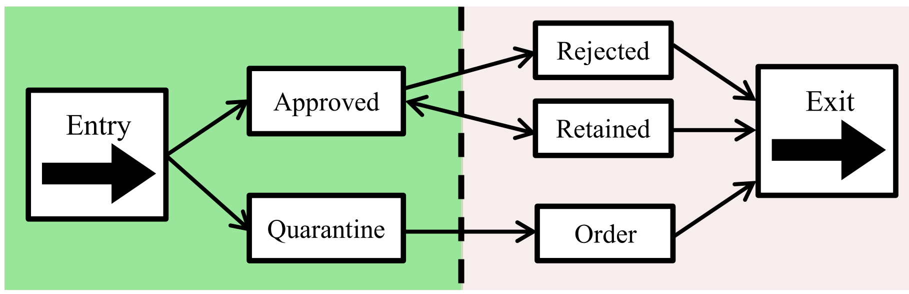

Figure 3: Flowchart of the products in the warehouse

According to this flowchart, two important zones are shown: the entry zone and the exit zone. The arrangement will depend on the number of products moving from one shelf to another. Therefore, the heuristic takes into account to divide the warehouse in zones, just as it is done in the procedure of cube-per-order, however, unlike this method, it will be worked the relative importance depending on the flow of the pallets by product, divided by the quantity of what goes out versus what comes in. Then it will be named two subgroups: exit zone and entry zone. In each group are delimitated the zones 1, 2 and 3, as the cube-per-order rule explains(Kallina & Lynn, 1976), where 1 is the closest to the exit or entry, correspondingly.

The methodology designed by steps is the next:

A. Select an optimal distribution of products in the warehouse

1. Build the layout plan of the warehouse and divide it in zones, and classified it in 3 zones
2. Calculate the capacities for each zone
3. Calculate the number of pallets that get in and out the warehouse by product family in a period of time I, that is the daily demands of the product multiplied by the number of days that the warehouse manage inventory.
4. Make two lists, one for the products that go out and other for the ones that get in. the products must by organized from the highest to the lowest of the step 3. And for the products that get in, it should be indicated with 1 if the product enter to Quarantine or 0 if not.
5. Assign the products to the zones of entry and exit, according to the order suggested in the list made in step 4 and respecting the capacity of each zone. In the assignation of the exit zone, it should be placed first the order area, and then the rest of the products in the racks.
6. Make an specific list of the racks, with the products placed, having into account both lists (the one that result from the entries and the one that result from the exits)
7. Evaluate the initial Objective Function
8. Select two zones and exchange them
9. Evaluate if the Objective Functionwith those modifications
10. If the value as a result of the evaluation in step 9 is lower, then go to step 11, if not, go back to step 8 and modify the previous solution.

11. Select the improved solution and go back to step 8.
12. The exit criteria for this heuristic would be established by the percent of change between an arrangement and other. It should be stopped this procedure, once the percentage of change hasn't shown significant variation.

Additional to the use of this heuristic, it was necessary to solve a typical inventory management problem in order to assure that we can minimize the amount of inventory stored in the warehouse. This is basically done by getting the use of RFID technology in order to store data and get a feedback on all products previous to making a decision. The businesses may consider several policies in order to know when to do the replenishment and what will be the amount, yet, internally a reorganization of the slowest moving products must be done.

B. Simulate different scenarios in order to generate possible Pareto Solutions

1. From the list of orders, simulate picking of the products in the order it appears.
2. Evaluate the three objectives presented above.
3. Save this first solution.
4. Generate a random order of the list and simulate picking of the products in that order.
5. If one of the objectives improve the previous solution, save it. Else, eliminate it. Go to 4.
6. Generate Pareto Optimal Solutions and present results.

5. INTEGRATION OF THE OPTIMIZATION ALGORITHMS INTO A SOFTWARE

The approach of an UML (Unified Model Process) of the optimization algorithms should be developed as is shown in the Figure 4, based in the processes described in the methodology:

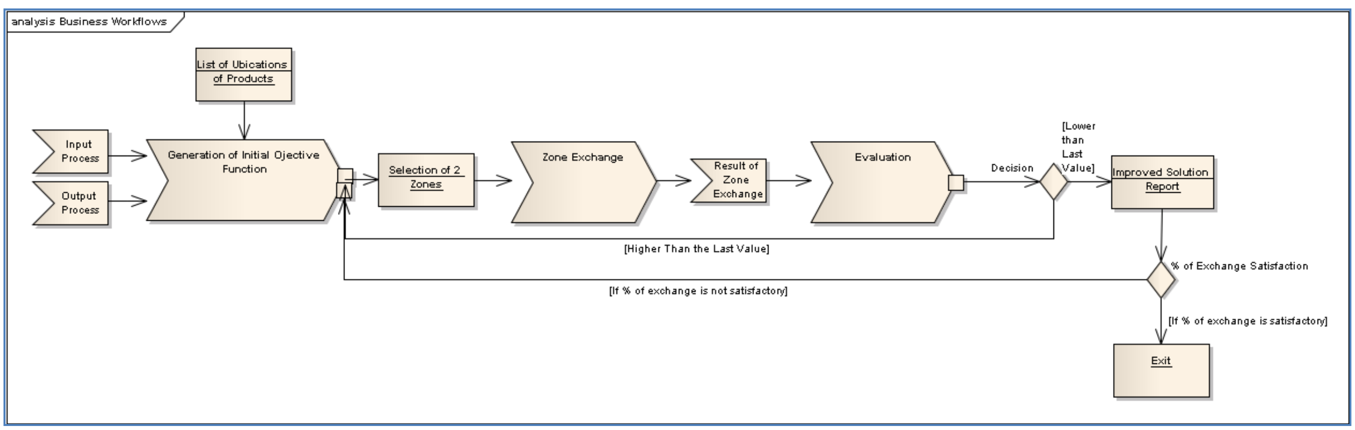

Figure 4. Unified Model Process

The approach of an UML definition data of the Software that will be programmed to run the algorithms and show the results basically will have at least this data:

- Layout: Describes all layouts of the Warehouse.
- Location: Describes all locations of the Layouts.
- Inventory: Describes all the movements of Products.
- Inventory Detail: Describes all the status changes of the Inventory.
- Product: Describes all products stored in the Warehouse.
- Product Family: Describes all the families of the Products.

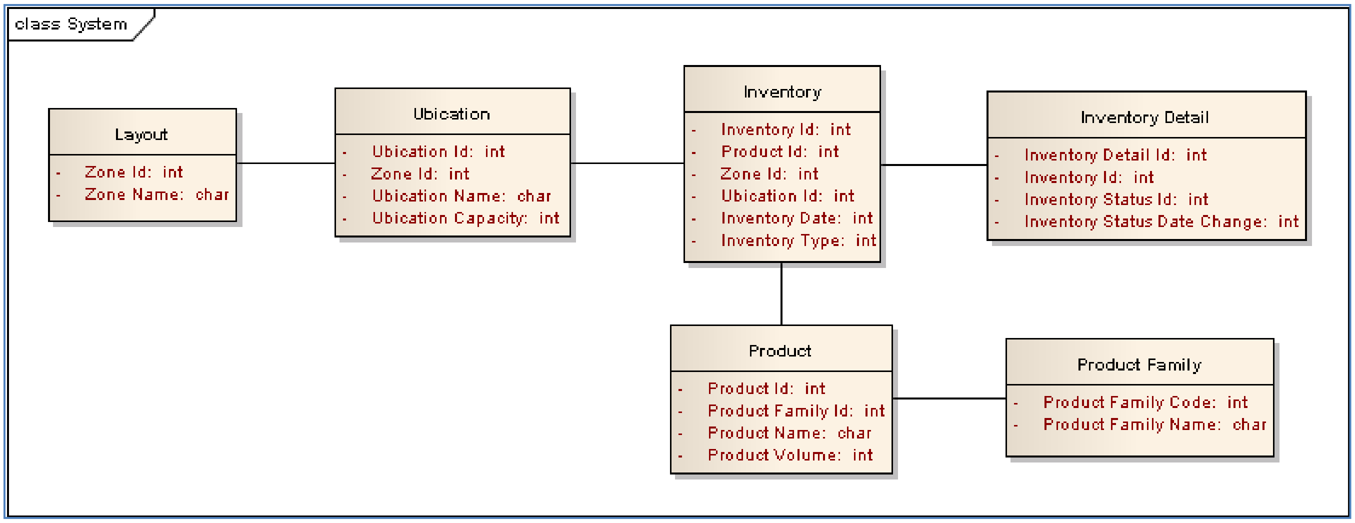

Figure 5.Unified Model Process definition data of the software

6. RFID INTEGRATED ALARM SYSTEM

The idea of the alarm system is to determine that the product that is going in or out of the warehouse is actually the correct and in the exact amount (100% of precision) and avoids any human error at the moment of counting the product. In Figure X that follows, it is able to see how this tracking system works.

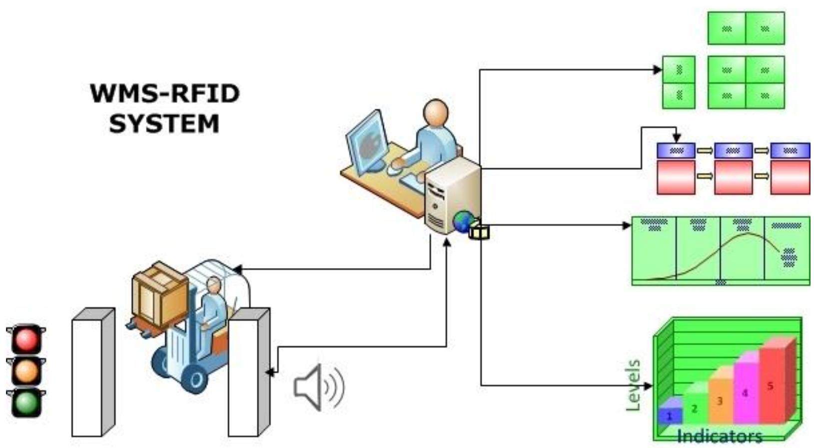

Figure X. Integration RFID WMS

Merchandise going in:

The warehouseman goes to the computer and introduces all the information (type, quantity, expiration date, status, supplier, etc.) in the system. Next, they organize all the products that are going in and label them with the corresponding tag and input the entry order. After that, they pick up the pallets and place them in the position given by the optimization model.

Merchandise going out:

The warehouseman seek the products in the system, the optimization model will give the location of the pallets that are in the Approved zone and which expiration date is the nearest one (First In, First Out). Then, the operator places the product in the order area. Once the order is ready to go to the production area, the warehouseman assigns to the pallets the exit order in the computer and after this, the merchandise is permitted to leave of the warehouse.

Any product cannot go in or out of the warehouse if:

- It hasn't been registered in the system first.
- It has no tag
- The item is expired (passed the expiration date)
- Its status is not "Approved" (only in the case its entering the production plant)
- It doesn't have an entry or exit order
- It is not in the order that the warehouseman is taking out of the warehouse (only if its leaving)

In any of these cases, the antennas will make the alarm sound, warning the operator that a non-approved pallet is being taken in or out.

It is also important to note that the manager of the area will keep record of the activities performed in the warehouse and make decisions with certified data. Through this, he will be able to have statistics of the processes and have access to some useful alarms, such as: inventory levels, obsolete products, errors, etc.

7. Conclusions

This paper introduced a novel method for solving decision making problems in warehouses, by approaching two basic problems that every warehouse possesses, that is, spaces assignment and product handling. In order to solve the problem in real-time and in a dynamic way, an integrated optimization model under multiple criteria is presented. Also, it captures data at a faster rate through the use of RFID Technology and can respond immediately to any change that needs to be made during the operation. Apart from this, the alarm system introduced works online; therefore, it makes the administrator react faster in case any abnormality exists. The warehouse will have higher levels of traceability.

On the other hand, an optimization model composed of multiple criteria was introduced and a proposed solution was presented in this paper. This model has being build up in a simulation software so it could show results of different scenarios and can help support decision making made in the company where it is implemented. Initial results have shown that the service level has increased. Yet, these results have only been obtained through the use of some historical data that the company has. Future results will contemplate the operation working with the implementation of the software as presented above with the UML approach.

In general, this research paper was focused on solution approaches proposed for warehousing problems. This method can be applied to any type of warehouse that handles the same characteristic. We encourage readers to apply them in their research studies or consulting jobs, given that it is easy to apply and it works with today's technology, such as Radio frequency identification and simulation software.

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