INTRODUCTION OF RFID TECHNOLOGIES IN A MANUFACTURING SYSTEM

A Discrete Event Simulation Approach

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Abstract: Radio-Frequency IDentification (RFID) is a set of technologies which allow rapid, effective and nearly errorless identification of products. It is often compared to identification by bar code, and is considered as an evolution of the latter. In this paper, we discuss the introduction of RFID in a real manufacturing entity which produces Configured-To-Order (CTO) printers. A discrete event simulation model of the factory is developed in order to evaluate the impact of the technology on processes and system performance. Results show that processing time savings and resource reallocation triggered by RFID use, have an influence on yield, cycle times and rate of late orders.

1 INTRODUCTION

Radio-Frequency IDentification is a set of technologies which allow rapid and effective identification of products. Information that allows object identification is stored in a tag.

Main advantages of Radio-Frequency IDentification are:

- Remote, without line of sight and simultaneous products identification.
- Individual identification of each tagged object, by contrast to bar codes which generally identify an object type and not the object itself.
- Possibility of editing of the information which is stored in tags.

RFID, or more precisely ancestors of it, exist since the second world war (Landt, 2005), but, only in recent years, it gained significant interest from industries and academics (Sarac et al., 2010). Based on (Rogers, 1962)'s description of diffusion of innovations, (Housseman, 2011) says that we are probably witnessing the beginning of a real maturation of RFID technologies.

Wal-Mart and the US Department of Defense RFID adoption cases are often cited in the literature, partly because they were the pioneers. In 2005, Wal-Mart required its top 100 suppliers to use RFID tags on shipping crates and pallets (Roberti, 2003).

(Sarac, 2010) gives examples of RFID potential benefits in supply chains: Reduction of inventory losses, shrinkage, and misplacement errors, reduction of theft, reduction of Bullwhip effect, increase of processes efficiency and speed, improvement of information accuracy... However, radio-frequency identification is not exclusive to supply chains, studies on the impact of these technologies covers a wide range of domains such as healthcare systems (Housseman et al., 2011), maintenance activities in the aeronautics industry (Jimenez et al., 2010) and insect tracking in biology (Vinatier et al., 2010)...

In this paper, we address the issue of RFID introduction in a manufacturing case. Main advantages of the technology, in this study, are processing time reduction or suppression and possibility of resource reallocation thanks to the first advantage. Therefore, a simulation study is conducted to estimate RFID impact on a real system of Configuration-To-Order of printers, in terms of cycle time, yield, resource utilization and rate of late orders.

The remainder of the paper is organized as follows. Section 2 presents objectives of the study. Section 3 presents the studied problem and the simulation model. Section 4 describes experiments and results. Finally, in the last section, some concluding remarks and research perspectives are discussed.

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2 OBJECTIVES OF THE STUDY

The manufacturer in this study is currently conducting a project to increase traceability of its products during shipping. The project began in late 2008 and will last three years. Among several technologies, RFID will be used. On this occasion, a question is raised: Will system performance be improved if RFID is also used in internal processes? Indeed, if so, the implementation of RFID will be facilitated by previous experience gained through the project.

In addition, the manufacturer is interested in improving its internal processes by other means than RFID. In fact, improvements upstream of the shipping may boost performance of the entire supply chain and profitability of the project. By a careful observation of the real system, we identified some directions of improvement such as reallocation of human resources based on resource utilization or work in process indicators.

Moreover, for different reasons, the manufacturer has in mind some scenarios and changes in his internal processes that he wishes to test. For example, using a single building instead of two (see Section 3). Another example is processing new types of products.

Therefore, a simulation model was developed to answer all these questions. Even thought the study aims to address all the issues previously raised, this paper will only address RFID issue. Results of the simulation are an estimation of impact of RFID introduction in the manufacturing case.

3 PROBLEM DESCRIPTION AND SIMULATION MODEL

In this study, the simulation model represents a real activity in a factory, in the north of France. The factory is part of an international group and has different activities. The activity we are interested in is Configuration-To-Order (CTO) of printers. It is spread over two buildings: The Logistic Center (LC) and the Setup Center (SC). In the first building, items are stored until customers orders are placed. Once this is done, items are sent to the second building in order to be assembled together.

3.1 Processes in the Logistic Center

Figure 1 shows the two buildings and processes that are executed inside them. Even though real and modeled processes are rather complex, they are explained in a concise and simplified way below.

In the LC (in orange on Figure 1), activity is divided into two rather separate parts: Goods receiving and storage, on the one hand, and items destocking and orders preparation, on the other hand.

Regarding the first part of the activity, goods are delivered by trucks, three times a day. In each truck, there is a variable number of products. These are of different types (hundreds types in the real system, grouped into six types in the model). The arrival of a truck triggers the beginning of goods receiving process. Indeed, LC employees unload the truck, perform computer input, bar codes reading, and resize pallets if needed (in case of oversized and undersized pallets). When receiving process is finished for the entire contents of the truck, pallets are stored one by one in racks.

The second part of the activity in the LC is orders destocking and preparing. Each order consists of a single printer and several options. When the demand is known, items from different orders are grouped and destocked by *tours* in order avoid unnecessary roundtrips of employees and pallet trucks. During destocking process, some bar codes readings are performed and can be suppressed if we use RFID. After destocking of all products of a tour, items of the same order are placed together on a pallet and their bar codes are read to prevent discrepancies, this process is called *order preparing*. From this step, items of the same order are gathered together on a single pallet. Therefore, we shall no longer speak about items but orders or printers. The last process in the LC is shipping of orders to the SC. Indeed, a computer input is performed for each tour of orders, items are loaded in a truck and sent to the SC. Note that computer input can be suppressed by using RFID.

3.2 Processes in the Setup Center

When orders arrive to the SC, employees unload the truck and execute a computer input process in order to update the database. Then, orders are unpacked in parallel workstations. In order to keep traceability, bar codes on packaging are cut and held with orders to configuring process. During the latter, printers are assembled with their options in parallel workstations. After configuring, some printers may be defective and require repair. The other printers go to computer input process at the exit of the building. In addition to computer input, printers are filmed, labeled and placed in a shipping area in order to wait for shipping trucks arrival.

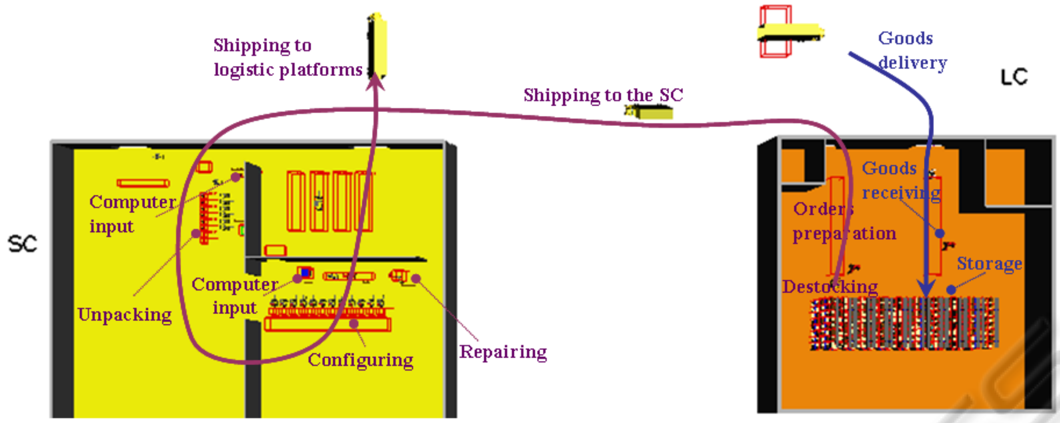

Figure 1: Screen shot of the simulation model of the studied factory (Automod).

4 EXPERIMENTATION

The simulation model in this study was developed using Automod Version 11.2. Simulation was run for one month of working days, and replicated 120 times for each scenario, because of the stochastic nature of the model.

4.1 Performance Indicators

The manufacturer usually measures the performance of his system by using cycle time and resource utilization indicators. Hence, we keep these indicators to measure RFID impact on the system. In addition, yield indicator seems to be an obvious and necessary issue. Indeed, if simulation results show short cycle time and low resource utilization, it may be due to low yield and not to a good performance.

4.1.1 Yield

In all scenarios, the number of orders received during a month of simulated time is the same. Moreover, at the beginning of the simulation, there is the same number of work in process (WIP), in all scenarios. At the end of the simulated month, in general, orders are not completely satisfied, some of the orders are still waiting or being processed in the system. We call yield the number of finished goods processed during the simulated month. Regarding yield, the objective is to reach its maximum, which is the number of orders placed during the simulation month plus work in process of the beginning of the simulation.

4.1.2 Resource Utilization

Resource utilization expresses the part of time when a resource works divided by the time when it is available. In this study, resource is available during opening hours minus breaks. Resource utilization gives valuable information about bottlenecks and waste in the system. When it is too high ($> 90\%$), in a part of the system, long waiting times might be due to this part. When it is too low ($< 50\%$), managers could allocate less resources to execute the task.

4.1.3 Cycle Time

One of the key performance indicators of this study is *cycle time*. Indeed, in a competitive environment, manufacturers and all levels of the supply chain, in general, try to better satisfy customers. This requires, among other things, the satisfaction of their orders at the earliest. In a Configuration-To-Order environment, assembly begins after the customer's order is placed. Therefore, customers wait, at least, for the cycle time and shipping time, whereas, in a Make-To-Stock environment, finished products are made in advance, and customers orders can be fulfilled without any waiting. All this explains the importance of the *cycle time* indicator. In this study, cycle time is the duration between the instant when an order is known and the instant when it leaves the overall process of CTO and is waiting for shipping. The manufacturer has a maximum cycle time objective to meet, but logistic and configuration buildings are managed separately. So the manufacturer prefers to resolve the main cycle time into two separate cycle times, one for the LC, and another for the SC.

4.1.4 Rate of Late Orders

The rate of late orders has a direct effect on customers satisfaction. If an order is shipped late, the customer will probably be unsatisfied. In our case study, the manufacturer should fulfill orders in 5 days. But, for the practical reasons explained earlier, the main objective is resolved into two separate objectives, 2 days for the LC and 3 days for the SC. In a real system, it is difficult to completely eliminate orders that are not fulfilled on time. Therefore, the aim for this indicator is to have a smaller rate of late orders, by using RFID for example.

4.2 Scenarios

Processes were explained in section 3. Many manual bar code readings are executed during these processes and can be suppressed by using RFID. Moreover, using an RFID technology can shorten or suppress some tasks (computer input, unpacking...). Table 1 shows impacts of RFID on LC and SC processes in a detailed way. For experimentation, we use three scenarios: A baseline scenario which represents the current state of the system and two RFID scenarios. The latter two are similar, except for a human resource which is simply suppressed in the first case and reallocated in the second. Indeed, the process of computer input is completely suppressed in RFID scenarios because items coming from LC will go through an RFID portal and will be automatically identified. Therefore, the human resource allocated to the process will be suppressed in the first RFID scenario, in order to be used in some other non modeled activity. In the second RFID scenario, the human resource is reallocated to the assembly process, because results show that assemblers are the busiest resources of the system (see Table 2).

4.3 Results

In this section, results are presented per performance indicator. Figures 2, 3, 4, 5 present values of indicators for each scenario. The baseline scenario is in blue, the first RFID scenario is in purple and the second is in green. Table 2 contains the same information as figures plus a comparison between the baseline scenario and each RFID scenario.

4.3.1 Yield

Figure 2 shows that LC yield increases in a very negligible manner in both RFID scenarios. While, SC yield increases by 1% in the first RFID scenario and

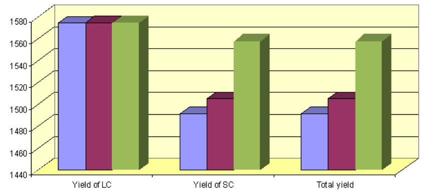

Figure 2: Yield.

by 4% in the second RFID scenario (always as compared to the baseline scenario). The total yield is the same as SC yield since SC exit is the system exit. These results were expected. Indeed, since RFID shortens some processes, resources may be able to fulfill more orders.

4.3.2 Resource Utilization

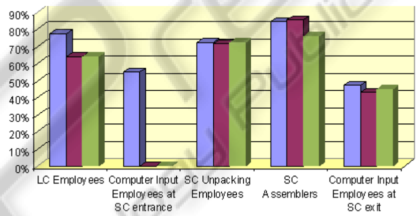

Figure 3: Resource utilization.

In Figure 3, we can see that, depending on the resource type, resource utilization can either increase or decrease in RFID scenarios by comparison to the baseline scenario. Indeed, some tasks are shortened by using RFID but number of fulfilled orders increases in RFID scenarios, as mentioned earlier in yield section. These two contradictory trends explain the obtained results. We can also see that performances of the first and the second RFID scenarios are close, except for assemblers (we recall that there is an additional assembler in the second RFID scenario) .

4.3.3 Cycle Time

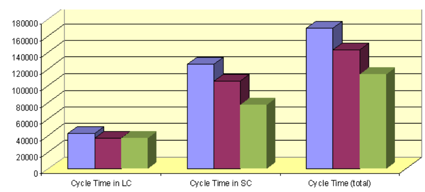

Figure 4: Cycle time.

In Figure 4 we can see that cycle times decrease in both RFID scenarios. This is due to shorter processing times enabled by RFID. LC cycle time decreases by 13% in both RFID scenarios. SC cycle time decre-

Table 1: Impacts of RFID on processes.

Building	Change	Where or when	Numerical values	RFID scenarios
LC	Suppression of bar code reading	At the entrance of LC	Suppression of all computer input duration	1 & 2
	Suppression of bar code reading	Upon loading a pallet on a pallet truck to be stored	$Loading\ duration - 5sec$	1 & 2
	Suppression of bar code reading	Upon unloading a pallet from a pallet truck to be stored	$Unloading\ duration - 5sec$	1 & 2
	Suppression of 2 bar code readings	Upon loading a pallet on a pallet truck to be picked	$Loading\ duration - 2 \times 5sec$	1 & 2
	Suppression of a part of process of preparing	In the preparing area	$Preparing\ duration - 60sec$	1 & 2
SC	Suppression of computer input process	At the entrance of SC	Suppression of the process duration	1 & 2
			Suppression of a human resource	1
			Reallocation of a human resource	2
	Suppression of cutting of bar codes in packaging process	During unpacking process	$Unpacking\ duration - 20sec \times number\ of\ items$	1 & 2
	Suppression of bar code reading	At the exit of SC	$Computer\ input\ duration - 5sec \times number\ of\ items$	1 & 2
	Suppression of bar code reading	Upon loading a pallet on a pallet truck to be loaded in a shipping truck	$Loading\ duration - 5sec$	1 & 2
	Suppression of bar code reading	Upon unloading a pallet on a pallet truck to be loaded in a shipping truck	$Loading\ duration - 5sec$	1 & 2

ases by 16% in the first RFID scenario and by 39% in the second. Note that the use of RFID changes the ratio between cycle times in LC and SC, indeed, SC cycle time is more improved than LC cycle time. Rethinking the number of respective resources in LC and SC may be necessary and may, enhance the effect of RFID by using the same total number of resources.

4.3.4 Rate of Late Orders

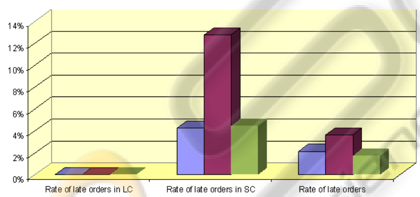

Figure 5: Rate of late orders.

Figure 5 shows that there is no late orders in the LC in all scenarios, while on the contrary, rate of late orders in the SC increases from 4% in the baseline scenario to 13% in the 1st RFID scenario and returns to 4% in the 2nd RFID scenario. The increase of late orders rate is certainly not desirable, but is due to increase of yield (see Section about yield). We can still notice that the second RFID scenario has equal performance in terms of rate of late orders, with a higher yield than the baseline scenario. The total rate of late orders follows the same pattern as in the SC, with smaller amplitudes (2%, 4% and 2% for baseline, first and second RFID scenarios respectively). Notice that late orders in the SC can still be fulfilled on time compared to the overall objective of 5 days. This explains why, the total rate of late orders is smaller than SC one, in this case.

To conclude about results, for this system, and with the chosen set of initial conditions, RFID enables higher performance in terms of yield and cycle time. But rate of late orders is deteriorated or remains unchanged with RFID. Even though performances of the second RFID scenario, on the chosen indicators, are higher than those of the first RFID scenario, we should keep in mind that, in the first scenario, a human resource is released and can be used in other activities.

5 CONCLUSIONS AND FUTURE WORK

In this paper we addressed the issue of RFID introduction in a CTO environment. We developed a simulation model which is based on a real system, and we assumed that RFID use can shorten processing times and free some resources that can be reallocated. RFID impact was estimated on different performance indicators. Simulation results are yield increase by 2%, cycle time decrease by 33% and rate of late orders decrease by 21%.

(Cai et al., 2009) say that *there is a gap between application and research in supply chain performance measurement and improvement*. Therefore, this study

Table 2: Table of results.

Measure category	Measure	Baseline Scenario	RFID 1st Scenario	RFID 2nd Scenario	Difference between baseline and RFID 1st Scenario	Difference between baseline and RFID 2nd Scenario
Yield	Yield of LC	1574	1575	1575	0%	0%
	Yield of SC	1491	1505	1558	1%	4%
	Total yield	1491	1505	1558	1%	4%
Resource Utilization	LC Employees	77%	64%	64%	-17%	-17%
	Computer Input employees at SC entrance	55%	-	-	-	-
	SC Unpacking Employees	72%	71%	72%	-1%	0%
	SC Assemblers	84%	85%	76%	1%	-10%
	Computer Input employees at SC exit	47%	43%	45%	-9%	-5%
Cycle Time	Cycle Time in LC	42403	36725	36722	-13%	-13%
	Cycle Time in SC	125357	104963	76906	-16%	-39%
	Cycle Time (total)	168890	142325	113789	-16%	-33%
Late Orders	# of late orders in LC	0	0	0	-	-
	# of late orders in SC	61	189	68	210%	11%
	# of late orders (total)	30	52	24	76%	-18%
Rate of Late Orders	Rate of late orders in LC	0%	0%	0%	-	-
	Rate of late orders in SC	4%	13%	4%	199%	5%
	Rate of late orders	2%	4%	2%	70%	-21%

gives an estimation of the impact of introducing RFID in a real system.

As mentioned in Section 2, the objectives of the study are much larger than results presented in this paper. Therefore, the study can be further extended, on the one hand, regarding RFID, and on the other hand, to address other issues such as resource allocation, activity reorganization and system performance under different conditions (high demand, new types of products...).

We saw, in this study, that RFID allows processing time reduction, because of rapid tags reading. Nevertheless, we implicitly supposed that the manufacturer prints the same number of tags no matter if they are RFID or bar code ones. In the real system on which this study is based, bar codes are already printed on items packaging before being received by the manufacturer. In addition, the latter prints a bar code tag for each received lot of items during receiving process and a bar code tag for each order during preparing process. If an RFID technology is adopted, the manufacturer will print all RFID tags by himself. Tags for lots of items and for orders will probably be printed during the same processes as the current case. By contrast, tags on items are not compulsory but may significantly increase flows visibility. Hence, if the manufacturer decides to keep items tagging, the task may be operated before storage or after destocking. We believe that this choice would influence system performance in terms of cycle time and resource utilization. For this reason, it can be interesting to investigate this issue.

Another issue related to RFID is the Return On Investment (ROI). Since cost and financial benefits are key performance indicators in most industrial cases, we plan to investigate this problem.

Few years ago, the manufacturer had an activity of assembling which has been delocalized to another country now. Therefore, there is some vacant space in the SC building, and the manufacturer would like to know if it will be effective to relocate logistic activity in the same building as CTO activity. A scenario of one building should be soon developed in the simulation model. By comparison to the baseline scenario, some processes will be modified, essentially, orders preparing, shipping to the SC and computer input at the entrance of SC.

In addition, the manufacturer wishes to measure impact of processing new types of products. Obviously, some numerical values in the model will be changed for this scenario (processing times, repairing rate, orders' number of items...), and some processes may also be modified.

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