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What to expect? Inconveniences and reasons for failure in RFID pilots

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Abstract

RFID technologies and applications are expected to turn logistics operations upside down, once the cost limitations are overcome, generating enormous benefits in aspects like inventory control, traceability or supply chain integration. However, the first implementation steps of RFID may instead result in a series of problems and operational deficiencies in the distribution centre, not only related to costs or information management, but also to the design and reliability of the system itself. We analyse here the problems that had to be faced when implementing a RFID pilot in a Spanish dairy product producer, and measure them using the appropriate metrics.

Keywords: RFID, logistics, shipping, performance, metrics.

1 Introduction

Even though its expansion has not been as revolutionary as initially expected, the introduction of radio frequency identification (RFID) in logistics operations is an ongoing trend. Adding the real-time component to barcode product identification, RFID is now, despite the high cost of its implementation, one of the main technological tools available for speeding up the supply chain and reducing the occurrence of errors. As a result, RFID technologies and their application in supply chain management have represented one of the main research objectives in the field over the last decade, as some recent review papers show (Chao et al, 2007; Ngai et al, 2008; Meyer et al, 2009).

As a result of this research, based on many tests, case studies and pilot implementations, the expected benefits of RFID in supply chain management have been identified and largely discussed. Authors mention improvements in customer service and customer targeting (Hingley et al, 2007), improved traceability (Kelepouris et al, 2007) or the achievement of an error-free environment (Turcu et al, 2007). Lefebvre et al (2006) establish their focus on the distribution centre, identifying potential benefits in reception (handling of products that arrive at the warehouse), put-away (moving and placing products in their specific storage location), picking (retrieving the products from their storage location to consolidate customer orders), and shipping (checking, packing and loading in the transportation unit), as well as stressing RFID's potential to automate verification activities, which turns it into a powerful tool to eliminate human errors. Tzeng et al (2008) include also higher-level benefits, including improvements in communications among staff members, utilization of assets, optimization of processes, visibility of data, development of new services and identification of new business opportunities.

What are the problems then? Cost in the first place, which still makes it difficult to make ends meet and obtain reasonable returns on investment. Some authors have started to comment on the introduction (and subsequent cost assumption) of RFID forced by retailers on manufacturers (Michael and McCathie, 2005) or the different scenarios generated by coerced adoption versus free-will adoption of RFID (Matta and Moberg, 2006). But there are also additional issues to take into account when contemplating the introduction of RFID in the supply chain. Curtin et al (2007) mention issues like the technical integration with other applications, the costs and risks associated with becoming dependent on RFID, or the difficulties of taking advantage of voluminous data collection and using it for real-time decision making.

Spekman and Sweeney (2006) consider it critical to get the infrastructure right first and be sure of 100 percent read success, and recommend companies to provide clear answers to these questions before taking the RFID step: Will the cost of integration with current systems be prohibitive? Will the coding requirements and data management problems be excessive? Will implementation seriously disrupt current business practices? Will the effort required to implement these systems detract from the company's core business? Will the system have the same reliability and up-time as current infrastructure? Michael and McCathie (2005) are concerned about the need for accuracy, reliability, security, need to withstand harsh environments, cost of technology including software and equipment upgrades, introduction forced by retailers on manufacturers, lack of standards and interoperability, interference and reading considerations, and privacy.

Other authors comment directly on the potential disadvantages of RFID systems in the supply chain, which include both operational (standards, interoperability, costs, forward compatibility, lack of familiarity and lack of standards) and technical (interference, security and accuracy) barriers (Asif and Mandviwalla, 2005). Even when the right type of RFID technology is chosen, companies can expect to suffer a variety of technical problems, including false reads and failure to read at all, and require all kinds of IT infrastructure reengineering and integration (Angeles, 2005). Apart from the cost inherent to the installation of RFID systems, aspects like privacy issues, the need for data storing and management, the integration of RFID into existing databases and applications and within business processes and relationships with suppliers and distributors, the lack of ability for companies to make effective use of the data captured through RFID or the provision of training for all involved personnel can expect to represent barriers and additional costs incorporated into the system (Lazar and Moss, 2005; Hingley et al, 2007).

The conclusion that can be drawn from all this is that RFID is merely an enabler, and where implementation seems to progress well is when firms move beyond simple compliance in logistics and extend the use of RFID into other areas of their operations (Spekman and Sweeney, 2006). Based on this knowledge, we present here the description and evaluation of a pilot project for RFID implementation in the shipping area of a Spanish dairy producer. And we will not concentrate on the potential benefits of a full-scale RFID system, but rather on the negative effects that RFID can bring, at least during the first stages after its implementation, due to difficulties in architecture design and to the still unresolved reliability flaws. In the next sections we describe the pilot project, the incidents identified, the failures in the system architecture and the evaluation of the indicators that we proposed to assess the performance of the system.

2 General description of the pilot

The pilot project that we present here as a case study was implemented in a dairy product plant in Córdoba, in the south of Spain. The objective was to control shipments from the dairy plant in order to increase performance and reduce the occurrence of errors, but also to position the company in the supply chain as a leading partner in the introduction of technology.

The first decision was to apply the RFID tagging only to those milk shipments corresponding to a particular brand, and to tag pallets instead of individual items due to cost reasons. In total, during the pilot test, around 85 orders, each of which contained around 20 pallets, were processed and tagged. We used passive tags in the UHF band, with a frequency range that in Spain was originally assigned to military communications, and was assigned to RFID applications only after the end of 2007. The tagged pallets were to be sent to a specific loading dock for shipment, where the scanner with RFID sensors was placed. The RFID system was controlled by an interface application, specifically developed for this pilot project. This application received information from the warehouse management system (WMS) application, which was in charge of controlling the automatic warehouse and shipments from the dairy plant. This system assigned pallets to orders using a FIFO policy, and controlled the movements of transelevators in the automatic warehouse and the automatic sending of assigned pallets to the shipping area.

Using the interface application, the shipment managers assigned the different orders to a shipping dock, and the interface application filtered the orders that had been assigned to the RFID dock and classified them as RFID orders. For each RFID order, it loaded the codes for each pallet the order included; later, these codes had to be detected by the RFID scanner during truck loading. Pallets that were already loaded in the truck were to be marked on the load order list, and once all pallet codes on the load order had been marked, the order was eliminated from the list of orders to be completed.

The entry detection module consisted of two photoelectric sensors in parallel, used to identify not only the passing of a pallet load, but also the direction it followed. Also, in addition to RFID antennas, warning lights were installed in the scanner arch, controlled by the middleware equipment. These lights glowed green when a pallet was correct and red when it was incorrect, accompanied by an audible signal to indicate that the pallet had been detected. Correct identification of a pallet meant that the scanned pallet had a code that was included in the order being loaded; incorrect identification of a pallet meant that the pallet code was not part of the order. Logically, loading pallets with no RFID tag from the RFID dock did not result in any interaction with the system.

Tagging pallets with RFID was carried out using an automatic RFID printer, which was installed in the pallet access to the shipment holding area. This tag generator, which was also run by the interface application, received the signal to tag a pallet when the system detected that the pallet was assigned to the RFID dock. Finally, the RFID module itself consisted of the RFID reader and the antennas connected to it. It read the information contained in the RFID tags and transmitted it to the middleware for processing. Figure 1 shows a description of the RFID arch with the antennas, sensors and visual warnings, and Figure 2 depicts the system architecture.

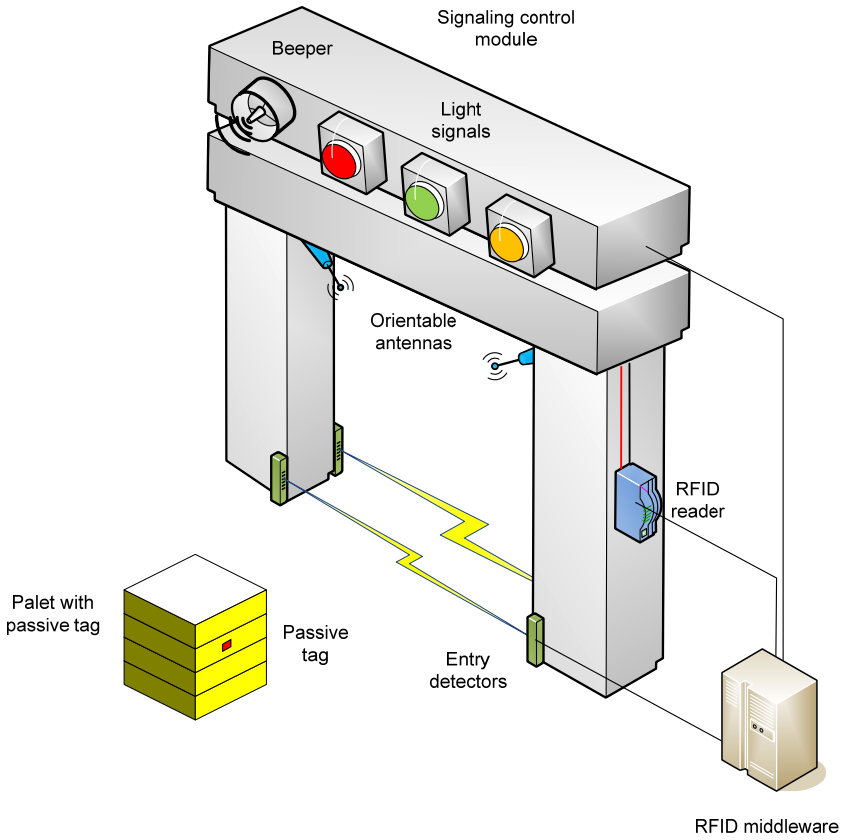

Figure 1: Configuration of the RFID arch.

The orders that leave the plant are usually loaded in trucks by the truckers themselves. In these cases, the producer's shipment personnel are obliged, once the order is loaded, to verify that the pallets loaded in the truck correspond to those listed in the order. To help the shipment personnel with the load check, a PDA was habilitated with an application connected with the interface application. This way, the PDA showed the list of pallet codes corresponding to the order that was being loaded in that moment, and as the scanner detected the pallets passing through, they were also automatically marked off the list.

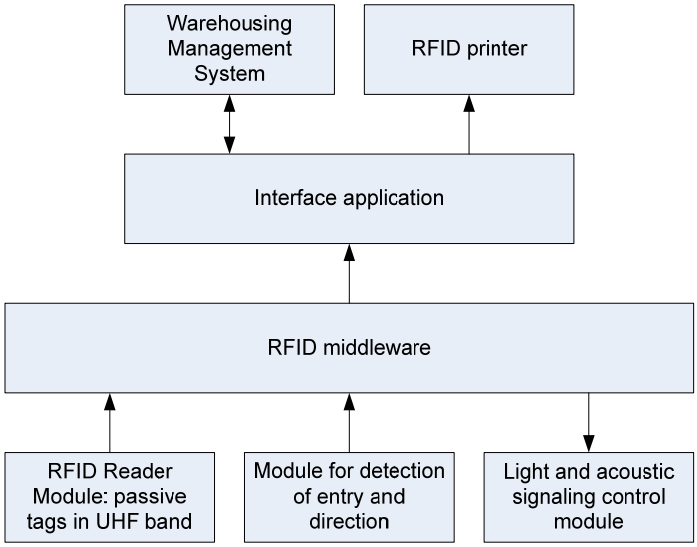

Figure 2: Architecture of the applications set up in the RFID pilot project.

3 Incidents registered during the pilot experience

In general, the pilot experience was positive, given that most of the tests that were carried out resulted in the pallets being tagged correctly and detected when loaded in the trucks, and the scanner arch gave the correct signals. In turn, the interface system interacted with the WMS database as anticipated by loading RFID orders and pallet codes, and gave proper verification that the orders were being completed.

However, a number of incidents with the normal system function were identified during the pilot period. In some cases, the cause of the problem has been located, and required only a few adjustments in order to be resolved. For other cases, however, the cause of the incidents is unclear, and will require a more in-depth analysis. It is important to highlight that in many cases these incidents only affected a small number of pallets, that is, a low percentage of the total pallets included in each RFID order, although only a low number of orders were completely incident-free during the pilot experience, due to different causes each time. The following sections list and describe the most important incidents - those that affected normal system functioning - which were detected during the pilot experience.

3.1 Pallet detection

Most times, the system generally detected the pallets correctly. However, there were occasional irregularities in the readings, normally associated to failure to detect the RFID tag, but which could be aggravated by the direction photoelectric sensors. For example, the RFID system occasionally failed to detect a passing pallet, and therefore the light and beeper signs did not operate. To rectify the situation, the pallet was unloaded from the truck to be loaded once again; but it was then detected by the sensors, which showed an error because a pallet that had not previously been detected was being unloaded from the truck. Sometimes, if the pallet was brought out again before it had completely passed the photoelectric detectors, it was finally identified by the RFID system, but then, when it was passed below the scanner arch once again to be loaded in the truck, the sensors detected it once again, but this time it

had already been identified, and the interface system had erased it from the list of pallets filling the current order. It was therefore registered as an unlisted pallet, and the sensor's red light lit up.

3.2 Tag position

Pallets used in the dairy plant are wooden 800x1200mm Europallets. When loading this type of pallet in a standard-sized truck with a container 2.5 m wide, the wide face can be loaded first, allowing for rows of two, or the narrow face can be loaded first, allowing for rows of three. This means that the pallet truck used to carry the pallets can pick them up either from the wide face or the narrow face. Given that the RFID tag is stuck to one of the wide sides of the pallet stack, when the tag passes under the scanner arch it will be facing the side, which is the best position for being scanned, if the pallet was picked up by the narrow side. If the pallet was picked up by the wide side, however, the tag will be facing forward or backward.

If the pallet was loaded with the tag facing forward, the scanner arch is usually able to read it, even though the failure rate increased considerably, as was thoroughly confirmed during the pilot experience. However, if the tag was facing backwards, it is touching the hand truck, which usually made it impossible to read, even though, in theory, the system had been designed to scan tags even in that case.

3.3 Database duplication

The interface application imported information on RFID orders from the WMS application's database. Specifically, it imported lists of pallet codes for the pallets to be loaded for each order. Next, once the sensors detect each pallet passing under, it was marked as loaded, but the entry in the database remained in order to keep track of the operations. Thus, the interface application’s database grew indefinitely as new orders were loaded. The ideal solution would be to have the RFID system read the pallet codes directly from the WMS database, but this would require to modify the WMS database, which is always something difficult to propose in the scope of a pilot implementation.

3.4 Discrete information scanning

The WMS systems updated order information from the interface application every five minutes; it captured the pallet codes that were assigned to the RFID dock, in order to send those pallets automatically to the dock. The problem lied in the fact that sometimes it divided orders in two when the order contained pallets with different products and the reading took place just when the corresponding number of pallets with some of the products had already been assigned to the RFID dock and the rest was still pending. In this case, the interface application identified the order as containing only those pallets that were already assigned, without adding the rest in the following reading. The result was that when the complete order was loaded, the scanner identified the pallets that were assigned before the reading as correct, and gave an error signal when the rest of the pallets were loaded. Furthermore, due to having readings every five minutes, there was a time lapse between the assignment of pallets to orders in the WMS system and their entry in the interface system. If an order had just been assigned in the WMS and the shipping staff immediately consulted the interface system to check whether the order had been registered correctly, the loading order did not appear as pending, and would not until the next programmed reading was carried out.

3.5 Real-time modifications

The configuration of the interface system only allowed real-time viewing of the loading progress for the orders, but it was not possible to undo or change the order in real time. This was caused by the fact that, once the order information had been downloaded from the WMS, the interface application functioned independently and no back-and-forth communications were possible in real time. This made shipment operations less flexible, although sometimes it was necessary to make last-minute modifications to orders. For example, if the load order contained 27 pallets, but when the truck arrived it could only carry 24 due to weight or volume limitations. In this case, 24 pallets were loaded and the other three were left for a future load order, either alone or grouped with other pallets belonging to the same customer's next order.

The delivery of incomplete orders is common in the company's logistics operations, but according to the information stored in the interface system, this order will be permanently registered as incomplete.

A similar situation arises if a pallet is already tagged and waiting in the shipping zone and is then found to be defective and cannot be shipped. In this case, the pallet is replaced with another one, the previous one is discarded, and the merchandise that is not damaged is recovered to be packed in a new pallet. However, the interface system has registered the old pallet's code as part of this order, and it was not possible to modify it and replace it with a new code. Therefore, when the new pallet is loaded the sensors will signal an error, and the order will be registered as incomplete because the substitute pallet's code was never loaded. In general, the possibility of interacting with the interface application to modify load orders in real time is absolutely necessary in order to maintain shipment flexibility once the implementation becomes definitive. In any case, as mentioned before, this problem would disappear if instead of duplicating the WMS's information, the interface application would simply read from the same database, which can be modified in real time.

3.6 PDA application

The PDA application was available for checking the shipping of the orders as they were loaded onto the trucks, but the slowness in the information update caused more delays than simply checking the loaded pallets visually. The reason why the PDA application was so slow was attributed to communication delays between the interface application and the PDA. In addition, the fact that only a few of the pallets in the shipment zone were tagged with RFID, combined with the fact that, instead of registering the RFID pallets that were incorrectly loaded, the PDA subtracted correctly loaded pallets from its list, meant that it was necessary to do a visual inspection of the load.

Besides, the PDA application should work in two directions. This way, it would be possible to work with the load order directly from the shipping zone, including the following functions, which are often used when sending shipments:

- Replace pallet codes with others in real time.
- Eliminate pallets from the load order if they cannot be loaded due to the vehicle's capacity being exceeded.
- Close an order that is still incomplete.
- Mark a load order as completed so as to create the delivery note.

3.7 Checking of load orders

As we mentioned previously, the interface application functions for each order by marking pallets that are scanned by the RFID sensors as loaded. When all the pallets in the order have been loaded, the order is marked as complete and eliminated from the list of pending load orders. This system works properly as long as the load does not have any anomalies. However, if there is an anomaly (a pallet that was not scanned by the sensors, a pallet code that was not on the list, an extra pallet, a missing pallet, etc.), there was no possibility to check what had gone wrong. It is essential to reconfigure the interface system in order to view the list of planned pallets and the list of pallets that had actually been scanned for each other, so that it would be immediately possible to tell what error or anomaly had occurred, and with respect to what pallet.

3.8 Creating the delivery note

The loading phase of an order is closed when the delivery note is created. This delivery note must be signed by the trucker transporting the merchandise and by a member of the company's shipping crew. One of the principal advantages of using the RFID to speed up shipping processes would be to automatically create the delivery note for a load order at the moment when the system detects that the load order has been completed. Even if it were possible to view in the PDA that loading of the order had been completed, it would still be necessary for the operator to go to the shipping control room to request

that the load order be marked as finished and the delivery note printed; this step could be eliminated by using the new technology.

4 RFID pilot metrics

Careful evaluation of logistics processes through the use of the appropriate metrics is essential to estimate the paybacks of RFID and decide on implementation. Apart from the generic metric systems applicable to the evaluation of supply chain performance (Chan and Qi ,2003; Gunasekaran et al, 2004; Bhagwat and Sharma, 2007; Muñuzuri et al, 2009), authors like Hou and Huang (2006) or Bendavid et al (2009) have developed indicator systems directly applicable to the evaluation of RFID performance, including aspects like IQC, shop-floor space, value-added manufacturing, picking efficiency, efficiency of stock checking, real-time inventory status, transportation efficiency, distribution accuracy, goods tracking, case recycling, sales tracking, reverse logistics, goods identification or sales forecasting. However, these metrics can only be applied when the company has a history of indicator recording that can be used for ex-ante and ex-post evaluations. In our case, however, the pilot experience had to be evaluated using a series of indicators that had to be specifically designed and recorded on the spot, given that the company was not measuring and recording them before. These indicators were mainly referred to the time required for shipping operations, as the duration of the pilot tests did not allow achieving significant variations in other inventory or customer service indicators. In any case, it is important to note that the introduction of RFID in companies must be carried out without stopping normal logistics operations, which in this case meant that the reliability flaws in the system had to be accounted for by visually checking all outbound shipments, which resulted in performance levels similar to the pre-RFID stage.

We will now describe the three main indicators that we used to evaluate the pilot, showing their variations due to the introduction of RFID. The fact that none of the three indicators showed improvements is evidently not to be expected in the long run after a full-scale implementation once the aforementioned problems have been solved, but rather an example of what companies can expect during the implementation stage, all throughout the transitory period until the RFID system is running smoothly and can be entirely relied upon.

4.1 Loading time

In the case of this dairy producer, this process requires about one minute per pallet, depending on the size of the truck and the number of pallets on the load order (the last pallets take less time to load than the first ones do, as they travel a shorter distance within the container). And, due to the introduction of RFID in the shipments, this time has been lengthened rather than shortened. This has been the case during the pilot experience, since on some occasions when the correct scanning signal did not go off when a pallet passed through the entryway, it was necessary to unload the pallet from the truck and reload it, thus delaying the process. This possibility of delay, if multiplied by the 20,000 pallets per month that are now sent out as shipments of the company's dairy products, could lead to a sizeable accumulated delay. In order to not increase the loading time per pallet, the definitive implementation would therefore need to guarantee correct scanning of pallets at the dock, regardless of the position of the tag and the travelling speed of the forklift.

4.2 Checking time

This process, which consists of a visual check that the loaded pallets belong to the load order and is carried out after completing loading, takes between one and two minutes, depending on the number of pallets in the order. This indicator could be significantly reduced by a definitive, error-free implementation of RFID, since the system itself would indicate in real time that the load order had been completed, and whether or not an incorrect pallet had been loaded. The dairy plant fills 1000 monthly load orders of around 20 pallets per order. Therefore, if the verification time is decreased, it could save an average 25 hours a month, during which shipping personnel who now devote part of their time to these checks could

carry out other duties. However, for the entire duration of the pilot, this checking time was not eliminated, due to the described reliability issues.

Thus, during the first months following the definitive implementation of RFID in the entire plant, it would be necessary to continue carrying out the process of checking the load, given the possibility that errors could occur in the pallet tagging process or the RFID scanning process. It would only be possible to eliminate the process completely when the system had proved to be totally error-free. And in any case, before eliminating this process, it would first be necessary to show that the benefits of eliminating the checking process would outweigh the risks caused by the errors that could arise. This would be done by a follow-up study in the first few months after implementation that would show what errors were detected during the checks in order to document their expected frequency in the event that visual load checking was to cease.

4.3 Order closing time

This process currently consumes about two minutes, and it is possible that it will not be substantially affected by the definitive implementation of RFID in the plant, as the trucker, at least in the initial stages of RFID functioning, would probably continue to check the delivery note before the shipping order could be closed. The only reduction in time that could be expected here could have to do with closing the order and generating the delivery note, in the event that the slip could be created automatically by the system once the load order had been finished. For the 1000 orders a month mentioned previously, this time reduction could amount to between 8 and 10 hours a month.

4.4 Other indicators

Apart from affecting internal logistics through the shipping time indicators, RFID technology would have significant impact on other links in the company's supply chain. Even though other higher-level indicators can also be used in the analysis, the most immediate impacts would be on customer service, referring to fewer delivery errors, and reducing inventory errors in the warehouse.

- Delivery errors: these errors, which are a habitual source for customer dissatisfaction in supply chains, are produced by delivering the wrong references within an order, or delivering incomplete or overfilled orders. The introduction of RFID should enable the company not only to keep real-time track of the percentage of erroneous orders delivered, but also, and this is more important, to achieve the traceability of this indicator, that is, to find out in each case what the source of the error was, once the RFID technology is implemented in the entire plant. Although implementing RFID should contribute to reducing delivery errors, given that they will make the shipping process more automatic, it would be necessary for the company to carry out an exhaustive follow-up of the associated indicators, in addition to providing historical pre-implementation data, in order to quantify this impact.
- Reduction in inventory errors: tagging all pallets with RFID before storing them in the warehouse and installing RFID sensors in the warehouse transelevators would allow for near real-time control of total warehouse inventory, which could also be compared against the inventory levels predicted by the WMS system, rapidly identifying any discrepancy.

5 Possible solutions and related warnings

Different technical solutions can be implemented to overcome most of the inconveniences described in section 3, as, for example, the following:

- Tag position: standardize the pickup procedure for pallets, ensuring that the RFID tag is placed to one side.
- Discrete information scanning: include an additional field in the database of the interface application to indicate whether an order has been fully assigned to the corresponding dock or is still in process.

- Real-time modifications / PDA application: improve the interface and PDA software accordingly.
- Creating the delivery note: install a printer in the shipping area, to avoid the need to move back and forth between this area and the control room.

However, several of those inconveniences are not so easy to deal with, and may still be present for a long time after completing the full-scale implementation, like the following:

- Pallet detection: is related to the electronic reliability of RFID systems, which still do not guarantee 100% error-free readings.
- Database duplication: involves the full integration of the WMS and interface databases, which is not commercially available nowadays and requires extensive ad-hoc developments.
- Checking of load orders: technically, this issue may also be solved by improving the PDA software, but the visual double-check of loaded orders may still be required in medium term.

Thus, the technical and economic feasibility of a full-scale RFID implementation in this company remains unclear even after the results of the pilot have been thoroughly examined. Besides, the worst side of this scenario is that economic losses or logistics inefficiencies may only reveal themselves after the company has already undertaken large investments, upgrading the different databases and applications and possibly modifying some of its shipment processes.

6 Conclusions and future work

The benefits of RFID in the long run are well documented in the literature, covering most areas of supply chain management, where the availability of real-time information and the elimination of human errors are valuable assets. Besides, in the case of a dairy producer in Spain, the use of this innovative technology would place the company on the cutting edge on a national level. In addition to possible improvements that RFID may contribute to the company's internal logistics, the improvement of its technological status and the fact that its competitors would feel implicitly obliged to take the same step sooner or later are factors that should be taken into account. Besides, the competitive advantage that the company would enjoy as a pioneer in the introduction of RFID would place it in a privileged position before its customers. Having this technology available could lead some of them to adopt it, given the automation of logistic processes and the associated traceability that it provides. The nearly indisputable evidence that all supply chains will incorporate RFID sooner or later is an incentive for all companies to position themselves in that setting.

Undoubtedly, associated costs do exist that the company must evaluate before proceeding to implement RFID on a large scale. These costs refer to the cost of RFID tags on the one hand, and the annual payment of the license to use the corresponding RFID code on the other. While the second is a cost that does not seem likely to vary greatly over time, we can assume that the first will have a clear tendency to decrease as the technology extends and tag production volumes increase. Although pioneer companies would face relatively high costs in the use of this technology, it is true that they can expect progressive reductions over time in those costs. However, there are other inefficiencies and hidden costs that can accompany the introduction of RFID in the logistics processes of a company. The fact that this technology cannot prove yet to be 100% reliable might cause that, under certain circumstances, human errors might simply be replaced by RFID-caused errors. During the first stages of implementation, companies would have to keep doing the same, or sometimes even more, manual and visual work than before, incurring in additional costs and inefficiencies that also need to be taken into account. Also, the full integration between the existing and the new systems represent a relevant burden for pioneer companies. Processing times, data management, real-time operations, system architecture and information flows must be monitored closely in order to ensure that all configurations are correct, and that the new technology does not interfere or constrain in any way normal functioning in the supply chain.

The benefits of RFID might then well prevail in the long run, but what we could certainly verify with this pilot test is that the drawbacks of RFID implementation, also accounted for in the literature, are always

present. The trend towards the introduction of RFID will no doubt continue in the future, but companies must be aware that, like in the cases of ERPs or warehouse management, the overall costs (both in the system itself and in the subsequent inefficiencies suffered) might surpass the potential benefits, and that in the end automation might not always be the answer. The path to follow from here on implies the completion of full ex-ante and ex-post evaluations of RFID systems, identifying all the hidden costs and quantifying the amount of time required until the system achieves full efficiency.

References

Angeles, R. (2005) Rfid Technologies: Supply-Chain Applications and Implementation Issues. Information Systems Management, 22-1, 51 – 65.

Asif, Z. and Mandviwalla, M. (2005) Integrating the Supply Chain with RFID: An In-Depth Technical and Business Analysis. Communications of AIS, Volume 15, Article 24.

Bendavid, Y., Lefebvre, E., Lefebvre, L.A. and Fosso-Wamba, S. (2009) Key performance indicators for the evaluation of RFID-enabled B-to-B e-commerce applications: the case of a five-layer supply chain. Inf Syst E-Bus Manage, 7:1–20.

Bhagwat , R., Kumar Sharma, M., (2007), "Performance measurement of supply chain management: A balanced scorecard approach", Computers & Industrial Engineering, 53, 43–62.

Chan, F.T.S. and Qi, H .J. (2003) An innovative performance measurement method for supply chain management. Supply Chain Management, 8-23, 209-223.

Chao, C.C., Yang, J.M. and Jen, W.Y. (2007) Determining technology trends and forecasts of RFID by a historical review and bibliometric analysis from 1991 to 2005. Technovation 27 (2007) 268–279.

Curtin, J., Kauffman, R.J. and Riggins, F.J. (2007) Making the 'MOST' out of RFID technology: a research agenda for the study of the adoption, usage and impact of RFID. Inf Technol Manage (2007) 8:87–110.

Gunasekaran, A., Patel, C., McGaughey, R. E., (2004), "A framework for supply chain performance measurement" , International Journal of Production Economics, 87 - 3, 333-347

Hingley, M., Taylor, S. and Ellis, C. (2007) Radio frequency identification tagging: Supplier attitudes to implementation in the grocery retail sector. International Journal of Retail & Distribution Management, 35-10, 803-820.

Hou, J.L. and Huang, C.H. (2006) Quantitative performance evaluation of RFID applications in the supply chain of the printing industry. Industrial Management & Data Systems, 106-1, 96-120.

Kelepouris, T., Pramatari, K. and Doukidis, G. (2007) RFID-enabled traceability in the food supply chain. Industrial Management & Data Systems, 107-2, 183-200.

Lazar, L.D. and Moss, H.K. (2005) Radio frequency identification technology: an introduction. Proceedings of the 2005 Southern Association for Information Systems Conference, Savannah, 67-71.

Lefebvre, L.A., Lefebvre, E., Bendavida, Y., Fosso-Wamba, S. and Boeck, H. (2006) RFID as an Enabler of B-to-B e-Commerce and its Impact on Business Processes: A Pilot Study of a Supply Chain in the Retail Industry. Proceedings of the 39th Hawaii International Conference on System Sciences, 1-10.

Matta, V. and Moberg, C. (2006) The Development of a Research Agenda for RFID Adoption and Effectiveness in Supply Chains. Issues in Information Systems, Volume VII, No. 2, 246-251.

Meyer, G.G., Framling, K. and Holmstrom, J. (2009) Intelligent Products: A survey. Computers in Industry 60, 137–148.

Michael, K. and McCathie, L. (2005) The pros and cons of RFID in supply chain management. Proceedings of the International Conference on Mobile Business, Sydney, 11-13 July 2005, 623-629.

Muñuzuri, J., Beltrán, J., Rivas, M.A. and Onieva, L. (2009) Logistics management systems: an approach for the evaluation, integration and improvement of logistics processes. Int. J. Procurement Management, 2-4, 358-376.

Ngai, E.W.T., Moon, K.K.L., Riggins, F.J. and Yi, C.Y. (2008) RFID research: An academic literature review (1995–2005) and future research directions. Int. J. Production Economics 112, 510–520.

Spekman, R.E. and Sweeney, P.J. (2006) RFID: from concept to implementation. International Journal of Physical Distribution & Logistics Management, 36-10, 736-754.

Turcu, C., Cerlinca, M., Cerlinca, T., Prodan, R., Turcu, C., Giza, F. and Popal, V. (2007) An Integrated RFID-Based B2B System for Supply Chain Logistics and Warehousing. International Journal of Computers and Communications, 3-1, 90-98.

Tzeng, S.F., Chen, W.H., Pai, F.Y. (2008) Evaluating the Business Value of RFID: Evidence from Five Case Studies. Int. J. Production Economics 112 (2008) 601–613.