Study of RFID implementation for product control in a warehouse

Rui Pedro Moreira Flor Henriques Machado

Abstract

Cost is one of the main competitiveness factors in today's markets and, to that effect, controlling inventory and warehouse operations may play an important part in a company's financial balance. In order to increase the visibility and control of products whose monitoring is considered vital but insufficient, the logistics section at Imprensa Nacional-Casa da Moeda (INCM) is looking to introduce radiofrequency identification (RFID) technology in its warehouse, but only if that option is viable.

This essay seeks to study the feasibility of implementing a RFID system that should identify and track all products that go through the company's warehouse. With that end in mind, this study presents relevant concepts related to warehouse management, logistics, information systems and RFID, detailing this technology's core operational features. Several similar studies were also analyzed and the company's current situation was reviewed under the light of their results.

From the literature review and various meetings with the company's managers a simple RFID system was designed. However, according to the literature and despite the expected opportunities presented by RFID, its implementation may not be as feasible as desired, requiring big efforts in trial and error.

This study concludes that the shortage of related studies and the technology's unpredictable behaviour in real scenarios are factors that can negatively influence RFID's real potential for creating value in warehouse operations. If companies are looking to implement this technology, it's urgent to better understand how it behaves in real world scenarios.

Keywords: RFID, warehouse management, information systems, product visibility, product monitoring

1. Introduction

In a world where cost is the decisive factor in many strategic decisions, the implementation of a technology that holds the potential to generate savings might secure a company's future. With this in mind, warehouse management and logistics can play an important role, one that only recently started to gain real attention. The effectiveness of warehouse management can be

increased through the use of information technologies, which help secure faster, safer and cheaper warehouse operations, while maintaining or even increasing service levels. An example of this is the use of RFID, a wireless automatic identification and data capture technology that needs no human input. This technology greatly increases a company's capability to monitor and track entities, providing real time access to tagged items' localization and identification. Knowing this, the Portuguese mint and official printing office regarded RFID as a possible solution to one of their problems, and sought to ascertain the feasibility of using it to increase the visibility, security and control over certain types of products within their warehouse. As such, in order to help the company make an informed decision, this essay seeks to understand if the implementation of RFID technology is as feasible as desired.

To reach the proposed goal, conclusions were drawn from numerous meetings with the company's managers and the analysis of several studies that dwelled into similar undertakings. After gathering the required information and establishing the advantages and disadvantages of RFID, in general and also in this particular case, this paper goes on to propose a RFID system to be used as a reference, should an implementation ever take place.

2. Literature Review

2.1. Information technologies and systems

Information technologies (IT) can be seen as technology based resources, which include hardware, software, and peripheral and communication systems (Alshawi, 2001). IT allow the reduction or even the elimination of human intervention in a process, the quick and easy transfer of data over long distances and a better management of information (Davenport & Short, 2003).

The concept of Information Systems (IS) is broader than that of IT – they encompass a whole range of business processes that support the gathering of information from suppliers, which requires human interaction. As such, IS are based around IT resources and can be taken as a set of hardware, software, people and information exchange procedures which are required to process data. (Alshawi, 2001).

2.2. Logistics Management

According to Harrison & van Hoek (2005), logistics is a cross-functional subject that draws on contributions from marketing, finance, operations and corporate strategy. The Council of Supply Chain Management Professionals defines it as "the process of planning, implementing and controlling procedures for the efficient and effective transportation and storage of goods including services, and related information from the point of origin to the point of consumption for the purpose of conforming to customer requirements". The same organization sees logistics management as an integrating function which coordinates and optimizes all logistics activities,

planning and implementing the efficient and effective forward and reverse flow of goods, services and related information, and also integrates these activities with other functions, like marketing or manufacturing (CSCMP, 2013).

2.3. Warehouse Management

Warehouse and inventory management is a vital piece in logistics management (Awuah-Gyawu *et al.,* 2015). Hompel & Schmidt (2006) describe warehouse management as the art of operating a warehouse in an efficient manner, with a good logistics performance and minimized costs. Van den Berg (2007) goes beyond and states that warehouse management is the continuous attempt to operate a warehouse and improve its processes and organizational structure, as well as collaborating with partners within the supply chain. A continuous activity is also defended by Tompkins & Smith (1998), who see the maximization of the use of a warehouse's resources while simultaneously satisfying the customers' needs as the main goal for a warehouse manager. With this in mind, Awuah-Gyawu *et al*. (2015) state that information technology can increase warehouse management efficiency, allowing faster, safer and cheaper operations.

2.4. RFID

The main idea behind Radio Frequency Identification (RFID) technology is marking items with tags. The tags emit messages through radio waves that can be read by specialized RFID readers, and most of these tags contain an identification number (a client number or a stock keeping unit code, for example). Upon capturing a tag's message, a reader retrieves information about the identification number from a database and acts upon it accordingly (Weinstein, 2005). By associating an electronic entity to an object, RFID-based systems allow the continuous identification and tracking of all tagged items in real time (Penttilä *et al.,* 2006). Hassan & Chatterjee (2006) propose a classification of RFID systems based on four dimensions: usage, physical, frequency and data.

2.4.1. Usage

RFID systems can belong to one of two categories: monitoring or authorization. The former determines the whereabouts and/or measures certain variables of all tagged items, and the tags are inseparable from the entities they are tagging. The latter forms an additional complement to traditional authorizing entities, through the embedding of tags in keys, passes or access cards, for example.

2.4.2. Physical

The physical dimension includes tags, readers and their respective subcomponents.

2.4.2.1. RFID Tags

RFID tags exist in a number of different configurations, shapes and sizes, all serving different purposes and suited to perform in different conditions and climates. Tags can either gain electric power through an inductive field generated by a reader (passive tags) or they can be internally powered with batteries (active tags). The latter are generally larger and more expensive than passive tags, but they are also more sophisticated and can be read at longer distances. Memoryless tags can only indicate their presence to a reader when within reach of its inductive field, but others have memory capabilities. Memory is important because it allows tags to store more information other than an identification number, like measurements or localization.

2.4.2.2. RFID Readers

RFID readers are interrogative devices that which capture data sent by the tags. Unlike most data gathering methods, they require no human intervention to work. Readers can create linear or circular electromagnetic fields to activate passive tags' responses. Linear readers generate a focused field used for a greater range, but the tags' antennas must be in a specific orientation to receive the signal. Circular readers create a non-directional inductive field that allows the interrogation of all tags, regardless of their antennas' orientation, but the range at which tags are activated is shorter.

2.4.3. Frequency

RFID is based in wireless communication through radio waves and operates in specific frequency bands that range from low frequencies to microwaves. However, most systems operate within the ultra-high frequency (UHF) band (Ramakrishnan & Deavours, 2006).Higher frequencies represent allow greater read ranges and data exchange speeds, but aren't recommended for use with fluids or in moist environments. Additionally, metal also has a negative impact on RFID performance, and that impact is felt the strongest in higher frequencies. Table 1, adapted from Ward *et al.* (2006) and Chawla & Ha (2007), summarizes the frequencies used by RFID systems.

Table 1 – Frequencies used by RFID systems

Frequency Bands	Frequency Range	Reading Range	Common Uses	Multi-tag Reading	Tag Size	Performance Near Water & Metal
Low (LF)	30 – 300 kHz	50 centimeters	Animal identification and tracking	Slower	Bigger	Better
High (HF)	3-30 MHz	1 meter	Security; acess cards	↓	↓	↓
Ultra High (UHF)	300 MHz – 3 GHz	4-5 meters	Logistics			
Microwave	2 – 30 GHz	1 meter	Toll booths for moving vehicles; production lines	Faster	Smaller	Worse

Frequency can be a source of global incompatibilities. RFID makers must abide by different rules created by regional agencies that control the frequency spectrum used within their respective areas of jurisdiction. This results in complex and expensive processes for RFID makers who seek to produce reliable readers that can work properly regardless of their geographical location (Hassan & Chatterjee, 2006).

2.4.4. Data

The automatic data capture presented by RFID technology allows for more visibility and easier tracking of products. This data should then be automatically interpreted and transformed into business semantics before it can be integrated into management applications (Wang & Liu, 2005). Data processing is made by software known as middleware. Its primary objectives include filtering, converting, correcting and transmitting the data captured by the readers to companies' information systems.

Multi-tag coordination is also a relevant dimension of RFID data, due to the fact that many readers are able to read several tags simultaneously. All tags within a reader's range respond to the received signal, and complications can arise if their responses collide in the communication channel (Hassan & Chatterjee, 2006; Chen *et al.,* 2010).

2.5. Relevant studies

2.5.1. RFID Implementation

The implementation of RFID in an industrial setting is a subject breached by several authors. Niederman *et al.* (2007) stated that RFID allows the possibility of identifying process bottlenecks, decreasing order picking time, prioritizing deliveries and organizing packaging and transport operations in a more efficient manner, all thanks to real time product tracking and monitoring. Weinstein (2005) analyzed the implementation of a passive RFID system by the United States Navy and concluded that the use of RFID resulted in better precision and speed in localizing products, more visibility and greater efficiency in loading operations. By installing a RFID system in the Institute of Automation of the Chinese Academy of Sciences' warehouse, Liu *et al.* (2006) managed a decrease in operational errors and associated costs, as well as an increase in work speed.

However, RFID implementation is not without its challenges. Despite being called the barcode of the future, one of RFID's main problems is its reliability. It's quite difficult to read all tags with 100% precision in real world scenarios, and the case is of special importance in settings where tags are applied to each item in the warehouse (Wang *et al.,* 2007; Mylyy, 2007). The presence of water and metal in the surrounding environment can also be a negative factor, contributing to multipath fading and diminishing the tags' and readers' efficiency by altering their antennas' resonating frequencies (Ramakrishnan & Deavours, 2006).

2.5.2. RFID System Design

In contrast to the existence of several studies regarding RFID implementation, studies which tackle RFID system design are scarce. The lack of appropriate studies, the insufficient understanding of radiofrequency fields' unpredictable behaviour and the fact that any experimental test results aren't necessarily applicable to different scenarios are some of the main challenges posed to those tasked with designing a system based on RFID technology. Without a better perception of RFID's performance in real-world scenarios, all entities interested in this technology must test each possible configuration in a trial and error basis (Cha & Kim, 2005; Ramakrishnan & Deavours, 2006).

The design of a RFID system is a complex task, especially because radiofrequency fields are extremely sensitive to the environment in which they propagate. In real-world scenarios, numerous factors can be critical to the success of a RFID solution: tag reading range and rate (radiofrequency fields' complex nature are associated to difficulties in determining range and rate with precision), surrounding environment (especially when in the presence of metal and water), orientation and placement (antenna orientation contributes heavily to tag reading success or failure), and reliability in the presence of multiple readers and tags, which decreases as the number of tags to be read simultaneously increases (Cha & Kim, 2005; Penttilä *et al.,* 2006; Fan *et al.,* 2007; Wang *et al.,* 2007).

3. Imprensa Nacional-Casa da Moeda

IMCN is the Portuguese mint and official printing office. The company is responsible for producing, among other things, personal documents for the citizens of Portugal, like passports or identity cards. These personal documents are the relevant subject in this study, as it seeks to ascertain the feasibility of implementing a RFID system in INCM's warehouse. The system should be able to identify and track all personal documents going in and/or coming out of the warehouse, as their monitoring is essential to the company's managers.

Currently, all personal documents are placed inside their own envelope, and placed into plastic boxes that can carry between 400 and 1000 envelopes each, depending on the type of document. These boxes can be piled up on a small pallet truck (four or five boxes, maximum) or inside a wheeled metal cage, which can carry up to 32 full boxes. The documents are then dispatched from the Production area, arriving at an intermediate security area called "Entre-Portas", where a warehouse operator uses a barcode reader to input the delivery into the company's information system. The barcode comes in a sheet of paper along with the envelopes, and is the only way the company can track its production. Once this check-in is done, the documents are taken into the warehouse.

Personal documents are kept close to the dispatching area, which functions in a similar way to a cross-docking area, and they usually are kept there for short periods of time – most often it's a matter of minutes between their arrival at the warehouse and their shipment to the outside

world. However, although boxes of envelopes can keep arriving at the warehouse throughout the day, all of the day's production leaves the warehouse in a single shipment, and that amounts to tens of thousands of documents.

4. Feasibility of RFID Implementation

Since a sheet of paper with a barcode is considered insufficient in terms of monitoring – and even in terms of security measures – the company is looking to implement RFID technology in order to allow an instantaneous identification and tracking of every envelope that goes through the warehouse at any given moment. The warehouse management staff are looking for a system which eliminates the need for the barcode reader and reduces warehouse operators' interventions in the process, freeing them to other important tasks. The RFID system should automatically input all of the envelopes directly into the information system without any need for human input.

Given RFID's capabilities, namely wireless identification and the readers' capacity for detecting multiple tags at once, at first glance it seems the technology is well suited to the company's requirements. However, as was stated in section 2.5.2, RFID's performance can be difficult to predict. As a consequence, RFID systems are usually designed in a conservative way that can guarantee consistent – but not optimal – results. After drawing on conclusions from numerous meetings with INCM collaborators and the various studies reviewed, a conservative system was suggested that could theoretically fulfil the company's needs. Despite this, no guarantees on success were given, as the company needs to test possible configurations on a trial and error basis.

The suggested system, as summarized in figure 1, seeks to place readers next to every door the documents go through along their path from Production to exit. In red, the core readers, and in blue complementary readers that could be added as a security precaution. This way, the company would always know in which area of the warehouse every document was and the chances for reader area overlapping would be minimal. Since the warehouse deals with thousands of documents each day and the only purpose of the tags is to identify each document, a system based on passive RFID tags seems to be the wisest choice. Adding to that, the UHF frequency band looks as the most promising option, since it maximizes reading rates and ranges.

Two main difficulties are set against the implementation of RFID technology in the INCM warehouse, however. The first one has to do with the amount of items to be tagged. The cost of tagging several thousands of items each day, even using unsophisticated passive tags, would be significant. Tags would also be too close to each other to allow effective identification, and many would disappear from the reader's scope, shadowed by other better placed tags. Adding to that, no studies were found that delved into reader capacity for identifying such a sheer number of tags at once.The second problem is related to the environment. The warehouse has significant portions of metal and the documents themselves travel inside metal cages (UHF

frequencies are among those most affected by metal). As such, some alternatives can be pointed out. Tagging only the plastic boxes instead of each individual envelope could be a viable option, greatly reducing the amount of tags required, but the control and visibility gains (compared to the current situation) seem too small. A second option would be to arrange a different transportation method. Instead of plastic boxes and metal cages, the company could use more RFID-friendly materials. However, the plastic boxes and metal cages are used because they belong to the postal service, the main transporter for all documents. As these boxes and cages are used throughout the country in other companies that deal with the postal services, negotiating a different transport method might not be possible. Another alternative presents itself in the form of RFID tunnel readers, which look like x-ray machines used in airports. Tunnel reader makers claim their readers can identify up to ten thousand tags in a short period of time. However, this option doesn't seem viable once one takes into consideration the size of the machine and the warehouse's dimensions. Hallways and passages are narrow, with just enough room for a forklift to pass, so introducing tunnel readers would be an impractical solution.

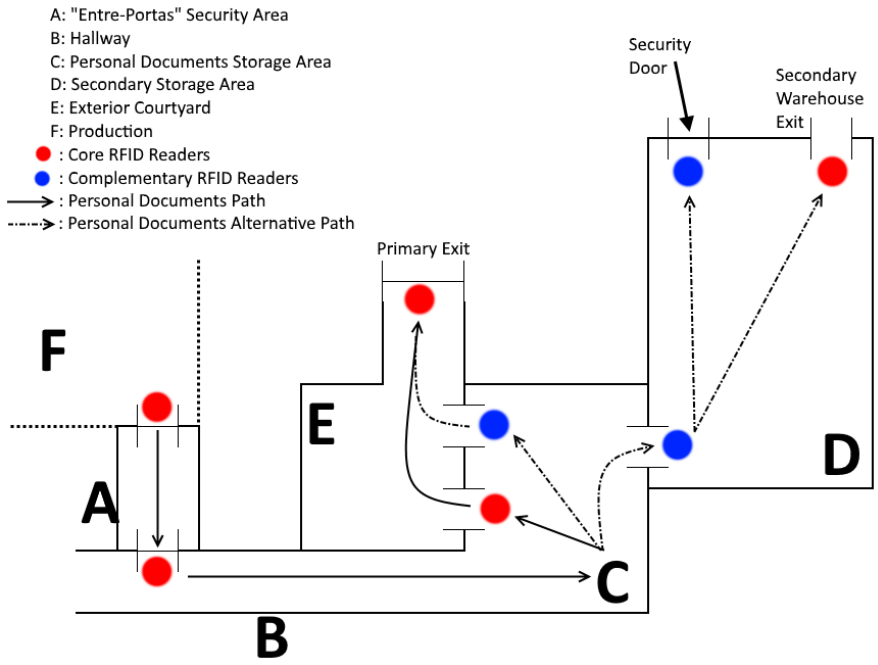

Figure 1 – Suggested RFID System

5. Conclusions

INCM is the Portuguese company responsible for producing personal documents, like passports and identity cards. Currently, these documents' monitoring is considered insufficient and the company is looking to RFID technology as a way of increasing their control and visibility within their warehouse. However, before making any decision a feasibility study should be done. This is the main motivation behind this study: assessing the feasibility of implementing a RFID system and designing a suggestion should that implementation ever happen.

At first glance RFID's core features make it a solid option, considering INCM's requirements. It's a wireless data capture technology with no need for human intervention and capability to identify and track multiple items simultaneously and in real time. As studied by several authors, the technology improves warehouse operations efficiency, paves the way for a decrease in operational errors and associated costs, and allows for better and faster item tracking. However, RFID implementation still faces some attrition due to doubts regarding its tag reading reliability and performance near water and metal.

The lack of related studies and the still poor understanding of how radiofrequency fields behave in real-world scenarios is another challenge one must face when designing a RFID system. Nonetheless, a system was suggested and it entailed the use of passive UHF tags and readers. However, due to the abundant presence of metal in the warehouse and the sheer amount of tags to be read simultaneously, the task of identifying all documents that go through the warehouse seems to be too ambitious for the time being. In essence, RFID might not be as viable an option as it initially seemed to be. However, if companies are interested in adopting this technology, further studies related to understanding the yet unpredictable behaviour of radiofrequency are the key to make more informed decisions.

References

Alshawi, S. (2001). Logistics in the Internet age: towards a holistic information and processes picture. *Logistics Information Management*, *14*(4), 235-242.

Awuah-Gyawu, M., Adzimah, E. D., & Brako, S. (2015, September). Assessing The Effects Of Information Technology (ICT) On The Performance Of Warehouse And Inventory Operations (The Case Of Unilever Ghana Limited). *International Journal of Innovative Research and Studies, Volume 4, Issue 9*.

Cha, J. R., & Kim, J. H. (2005, July). Novel anti-collision algorithms for fast object identification in RFID system. In *11th International Conference on Parallel and Distributed Systems (ICPADS'05)* (Vol. 2, pp. 63-67). IEEE.

Chawla, V., & Ha, D. S. (2007). An overview of passive RFID. *IEEE Communications Magazine*, *45*(9), 11-17.

Chen, Y. H., Horng, S. J., Run, R. S., Lai, J. L., Chen, R. J., Chen, W. C., ... & Takao, T. (2010). A novel anti-collision algorithm in RFID systems for identifying passive tags. *IEEE Transactions on Industrial Informatics*, *6*(1), 105-121.

CSCMP (2013, August).SUPPLY CHAIN MANAGEMENT TERMS and GLOSSARY, pp.1–222.

Davenport, T. H., & Short, J. E. (2003). Information technology and business process redesign. *Operations management: critical perspectives on business and management*, *1*, 97. Accessed on November 15th2016 at the following address: http://sloanreview.mit.edu/article/the-new-industrial-engineering-information-technology-and-business-process-redesign/

Fan, Z., Qiao, S., Huang-Fu, J. T., & Ran, L. X. (2007). Signal descriptions and formulations for long range UHF RFID readers. *Progress In Electromagnetics Research*, *71*, 109-127.

Harrison, A., & van Hoek, R. I. (2005). *Logistics management and strategy*. Pearson Education.

Hassan, T., & Chatterjee, S. (2006, January).A taxonomy for RFID. In *System Sciences, 2006.HICSS'06.Proceedings of the 39th Annual Hawaii International Conference on* (Vol. 8, pp. 184b-184b).IEEE.

Hompel, M., & Schmidt, T. (2006). Warehouse management: automation and organization of warehouse and order picking systems. Springer Science & Business Media.

Liu, G., Yu, W., & Liu, Y. (2006, October).Resource management with RFID technology in automatic warehouse system. In *Intelligent Robots and Systems, 2006 IEEE/RSJ International Conference on* (pp. 3706-3711). IEEE.

Mylyy, O. (2007). RFID data management, aggregation and filtering. In *Proceedings of the 31st International Conference on Very Large Data Bases Seminar on RFID Technology* (pp. 6-154).

Niederman, F., Mathieu, R. G., Morley, R., & Kwon, I. W. (2007).Examining RFID applications in supply chain management.*Communications of the ACM*, *50*(7), 92-101.

Penttilä, K., Keskilammi, M., Sydänheimo, L., & Kivikoski, M. (2006). Radio frequency technology for automated manufacturing and logistics control. Part 2: RFID antenna utilisation in industrial applications. *The International Journal of Advanced Manufacturing Technology*, *31*(1-2), 116-124.

Ramakrishnan, K. M., & Deavours, D. D. (2006). Performance benchmarks for passive UHF RFID tags. *MMB 2006*.

Tompkins, J. A., & Smith, J. D. (1998). *The warehouse management handbook*. Tompkins press.

Van den Berg, J. P. (2007). *Integral Warehouse Management*. Lulu.com.

Wang, F., & Liu, P. (2005, August). Temporal management of RFID data. In *Proceedings of the 31st international conference on Very large data bases*(pp. 1128-1139). VLDB Endowment.

Wang, L., Norman, B. A., & Rajgopal, J. (2007). Placement of multiple RFID reader antennas to maximise portal read accuracy. *International Journal of Radio Frequency Identification Technology and Applications*, *1*(3), 260-277.

Ward, M., Van Kranenburg, R., & Backhouse, G. (2006). RFID: Frequency, standards, adoption and innovation. *JISC Technology and Standards Watch*, *5*.

Weinstein, R. (2005). RFID: a technical overview and its application to the enterprise. *IT Professional* 7, 3 (May 2005), 27-33. DOI=http://dx.doi.org/10.1109/MITP.2005.69.