2008

IP-Mapping a RFID-Integrated Shelf Replenishment Information System for the Retail Industry to Assess Information Quality

Cleopatra Bardaki
Athens University of Economics and Business, Greece, cleobar@aueb.gr

Katerina Pramatari
Athens University of Economics and Business, Greece, k.pramatari@aueb.gr

Georgios Doukidis
Athens University of Economics and Business (AUEB), gjd@aueb.gr

IP-MAPPING A RFID-INTEGRATED SHELF REPLENISHMENT INFORMATION SYSTEM FOR THE RETAIL INDUSTRY TO ASSESS INFORMATION QUALITY

Bardaki, Cleopatra, Athens University of Economics and Business, Evelpidon Street 47, 11362 Athens, GR, cleobar@aueb.gr

Pramatari, Katerina, Athens University of Economics and Business, Evelpidon Street 47, 11362 Athens, GR, k.pramatari@aueb.gr

Doukidis, Georgios, Athens University of Economics and Business, Evelpidon Street 47, 11362 Athens, GR, gjd@aueb.gr

Abstract

Motivated by the problem of out-of-shelf (OOS) in retail industry and the emergence of RFID (Radio Frequency Identification) technology, this paper investigates the impact that the adoption of RFID has on the quality of information utilized during the shelf replenishment process. A RFID-integrated information system (IS) with three alternative implementation scenarios is proposed to enhance the shelf replenishment process. The impact of the three alternative solutions on the quality of the IS information input and output is examined in terms of accuracy, timeliness and completeness. The quality of the IS information input and output will be assessed by developing the Information Product Maps (Ballou et al. 1998, Shankaranarayan et al. 2003) of the alternative implementations of the RFID-integrated shelf replenishment IS and utilizing the methodology introduced by the fundamental study of Ballou, Wang, Pazer and Tayi (1998). The contribution of this study is reflected on the research approach of using this methodology, not applied until now, based on the available literature.

Keywords: Information quality, IP-Map, RFID, Out-Of-Shelf

1 INTRODUCTION

In the last decades, the supply chain environment has changed; the rapid change in consumer characteristics, the consumer heightened expectations, the proliferation of products and the decreasing product life cycles call for more responsive retail chains to consumer demands. The fact that consumers find empty shelves (out-of-stock cases) at an extent of 8.3% worldwide while shopping (Gruen et al. 2002), is considered to be a major problem for retailers and suppliers, since they face a great loss of revenue (about 4%) each year.

The term out-of-stock (OOS) is used to describe the situation where a consumer does not find the product he wishes to purchase on the shelf of a retail outlet, during a shopping trip. OOS is used in the pertinent literature to describe two cases: the product is not in the store or in the warehouse; or the product is not on the shelf (out-of-shelf (Pramatari 2007, Pramatari and Miliotis 2007)), but it is in the store, not placed in the right position on the shelf where the consumer can find it (perhaps it is in the backroom or delivery facilities).

According to the Gruen et al. (2002) and Vuyk (2003) studies, almost half (47%) of the OOS cases are attributed to bad store ordering practices and one fourth (25%) to shelf restocking (shelf replenishment) problems. Until now, most researchers have focused on the extent and causes of the OOS (Campo et al 2002, Collachio et al. 2003, Gruen et al. 2003) and the improvement of the store replenishment process through information sharing between the trading partners in the retail supply chain. However this research, identifying the limited studies concerning the processes within the retail store (Wong 2006) focuses on the “final few meters” of the retail supply chain i.e., the retail store and, in particular, on how the OOS problem (product is not on the shelf i.e., out-of-shelf situation) can be improved through a more efficient and effective shelf replenishment process. For the rest of this paper, the term OOS describes the case, where the product is not available on the allocated shelf, but it is in the store i.e., out-of-shelf.

Apparently, when information concerning the position, the quantity and the status of product stock in the retail store is available anytime, then product visibility in the retail store becomes a fact and is the key to enhance the shelf replenishment process and eventually handle the persistent OOS problem. RFID (Radio Frequency Identification) technology supports product visibility across the extended supply chains (Verisign 2004) by its advanced information-captured capabilities: unique object identification, automatic object identification requiring neither direct human contact nor line of sight and continuous, accurate and real time information on the position and the status of objects. Nowadays, many in the retail sector are already looking to the business case of RFID as the “next generation of barcode” through its capability to enable a broad spectrum of supply chain applications ranging from upstream warehouse and distribution management down to retail-outlet operations, including efficient inventory management, shelf management, promotions management and innovative consumer services, as well as applications spanning the whole supply chain, such as product traceability (Ghisi et al. 2001, Kambil and Brooks 2002, Pentilla et al. 2004, Sarma 2002). Although RFID technology is still emerging, RFID adoption is pushed by major retailers which are already executing a number of pilot applications.

Motivated by the perennial OOS problem in the retail industry, as well as the emergence of RFID technology, this paper first proposes a RFID-integrated information system (IS) to enhance the shelf replenishment process and thus improve products’ availability. The RFID system captures the products movements in the store and provides the IS with the necessary information input. Next, the IS provides the system users with the Out-Of-Shelf and Out-Of-Stock cases and Out-Of-shelf duration i.e. the time a shelf is empty of products. Three alternative implementation scenarios (Base, Medium and Full) of the RFID system characterized by the application level of tag (pallet/case/item level), the location of the tag readers and the implementation cost provide the IS with information input of different level of detail and different level of quality.

However, this research is dominated by the concept of information quality with the ultimate purpose to examine the impact that the adoption of RFID technology has on the quality of information utilized during the shelf replenishment process. The effect of the three alternative implementation scenarios of the RFID system on the quality of the IS information input and output is examined, in terms of accuracy, timeliness and completeness information quality dimensions. The research approach is mainly based on the concept of Information-Product Maps (Ballou et al. 1998, Shankaranarayan et al. 2003), a modelling method to capture all the stages the information output (product) will go through within the RFID-integrated shelf replenishment IS until it is delivered to the users (information consumers).

The following two sections present first the current and the proposed RFID-improved shelf replenishment process, in order to introduce the readers smoothly to the research question and research approach coming afterwards. Continuing, some preliminary results are provided and the final section presents the conclusions along with the contribution of this research and ideas for further research.

2 THE CURRENT SHELF REPLENISHMENT PROCESS

To map out the shelf replenishment process within retail stores, identify its weaknesses and provide with the state-of the-art practices, three case studies were conducted at a major Greek, Cypriot and Irish retailer using: (a) *semi-structured interviews* with the store manager, the backroom manager, store employees and the IT manager from company headquarters and (b) *direct-observation* of the products delivery in the store and the replenishment of the shelves, following the case study research guidelines of Stake (1995) and Yin (1994).

Shelf replenishment process in the retail industry is defined either as:

- the process of refilling the shelves with goods from the backroom of the retail outlet, as customers keep removing the products from the shelves (Bardaki & Pramatari 2006), or
- the process of restocking and maintaining inventory in the shelf according to a predefined shelf allocation by moving products from the backroom of the retail store (Wong 2006).

Whether the replenishment process starts from the shelf or the backroom (i.e. physical observation of products in the backroom or the shelves, respectively), Wong and McFarlane (2004) differentiate between a “pull” policy in which physical observation on product shelf level provides the basis for replenishment from the backroom to the shelf but in a “push” policy, the physical observation is on the products in the backroom. Within these two main policies, there may be variations in the length and types of operations, types of staffs involved, replenishment quantities and so on. However, to limit the scope of this research, the focus is on the “pull” replenishment process. Besides, the “pull” is the predominant approach and it is also applied by the Greek, the Cypriot and the Irish retailer.

Shelf replenishment takes place, at least, every morning for the store’s entire product assortment, before the opening of the retail store. During the day, the shelves are physically observed and refilled again periodically twice a day, depending on the products’ sales volume, the size of the store (small, medium, large); the promotion actions; the day of the week, etc. After the retail outlet is restocked from the central warehouse/distribution center or directly from the suppliers, all the products are not automatically transferred to the retail shelves. The shelf replenishment process is almost identical at the three retailers, except for some differences mentioned below, and can be generally analyzed in the following tasks:

- A truck with products arrives and backroom clerks unload the pallets/cases/items from the truck and transport them in the backroom.
- Backroom clerks verify manually (i.e. scan with barcode hand-held readers) that the products match the ship list (Cypriot case) or skip this task and accept the shipment as it is (Greek case). Then, the store’s on-hand inventory record in the retailer’s ERP system is updated (the Irish retailer uses an electronic invoice). The decision to verify or not usually depends on the quantity and the value of the products received. Retailers usually make an exception to the “blind” method of

receiving products when dealing with high-value items, such as health and beauty care products, over the counter drugs, cigarettes and magazines (Alexander et al. 2002).

- Backroom staff stores the goods on the backroom shelves. Alternatively, in case the received products are not supposed to be stocked in the backroom of the retail outlet, the products are directly transferred to the sales floor to refill the shelves.
- Store's employees, responsible for the shelves replenishment, print out the full product assortment or are equipped with hand-held barcode scanners (Greek case) or wireless hand-held PDAs (Cypriot case). Every store department is usually appointed a different employee in charge of the shelves replenishment.
- Shelf replenishment staff physically observes (inspects) the products availability on the shelves of their responsibility. In case of a product being out-of-shelf or a product reaching its minimum availability on the shelf, the staff marks on the print-out the required product quantity; or records manually the product quantity on the hand-held barcode scanner or the wireless PDA. Finally, a shelf replenishment list is produced.
- With this shelf replenishment list, the store employees locate and physically observe the availability of each out-of-shelf product of the list in the backroom. In case wireless PDAs are used (Cypriot case), the shelf replenishment list has been transferred wirelessly to the backroom.
- If a product of the shelf replenishment list is unavailable (out-of-stock) in the backroom, it will be concluded in the next store order. For each product of the shelf replenishment list that is available in the backroom, backroom personnel fill the replenishment wagons, according to the products quantities, and push them into the sales floor. Store staff finds the location of the products shelves, refills the shelves and then pushes the wagons back into the backroom.

The case studies revealed that the current shelf replenishment process is a time-consuming and labour-costly procedure that suffers mainly from low receiving accuracy of the products delivered to the backroom; poor visibility of the stock available on the shelf or in the backroom and, as a result, from many out-of-shelf cases occurring. More importantly, the case studies pointed out the places in the store where RFID readers should be placed in order to monitor all the possible movements of inventory (products) and thus make significant steps towards a more accurate picture of inventory in the store. The next section shows how the utilized RFID infrastructure and its respective cost suggest alternative implementation scenarios of a RFID-integrated shelf replenishment process.

3 THE RFID-INTEGRATED SHELF REPLENISHMENT PROCESS

As the case studies have shown, there is an information gap concerning the position and the quantity of product stock in the retail store. Thus, product visibility is necessary to enhance the shelf replenishment process and eventually handle the persistent OOS (out-of-shelf) problem.

Radio Frequency Identification (RFID) is a generic technology concept that refers to the use of radio waves to identify objects (Auto-ID Center 2002). The core of RFID technology is the RFID transponder (tag) – a tiny computer chip with an antenna. Consumer good suppliers attach these tags to logistic units (palettes, cases, cartons and hanger-good shipments) and, in some cases, to individual items. Logistic units and individual items are identified by the Electronic Product Code (EPC). An RFID reader is used to identify the EPC stored on the RFID tag. The antenna enables the microchip to transmit the object information to the reader, which transforms it to a format understandable by computers (Angelles 2005). Finkenzeller (1999) provides a general overview of RFID technology while Sarma (2002) describes the specific technology for supply chain management. Empowered by the capability to identify uniquely and automatically provide continuous, accurate and real time information on the position and the status of product instances, RFID offers a great improvement opportunity to the shelf replenishment process.

There is a large number of white papers and industry reports that either focus on the technical aspects of RFID technology or are qualitative studies providing business cases for RFID deployment

(Alexander et al. 2002, Angelles 2005, Jones et al. 2004, Jones et al. 2005, Yossi 2004, Chow et al. 2007). Only few academic papers (Joshi 2000, Karkkainen 2003, Hou 2006, Gaukler 2004, Fleisch and Tellkamp 2003) try to give a model-based quantitative assessment of the impact of RFID on supply chain operations. H. Lee (2007) underlines the challenge of offering concrete assessment of the true scale effect of RFID technology. For RFID's potential to be realized, RFID-enabled software systems are needed to improve the supply chain operations and assess quantitatively the true scale of RFID benefits. The literature review revealed no RFID-enabled information system with the purpose to enhance the shelf replenishment process in the retail industry and consequently handle the OOS problem.

This research proposes a RFID-integrated information system (IS) to improve the efficiency and effectiveness of the shelf replenishment process, in order to address effectively the OOS problem and thus improve products' availability. The RFID system captures the inventory movement events taking place in the store (e.g. shelf restocking, product removal of the shelf, order delivery, etc.), filters them and transforms them to provide the IS with data input. Also, the Point-Of-Sales (POS) data and the products information (e.g. product category, price) are provided to the IS from the retailer's ERP system. The RFID system-derived inventory movement events data are combined with the ERP-derived data to provide the IS with information input in the form of: backroom inventory, shelf inventory and store inventory. Next, the IS provides the system users (store's staff, supplier's salesmen) with information output in the form of: Out-Of-Shelf and Out-Of-Stock cases and Out-Of-shelf duration i.e. the time a shelf is empty of products.

However, many different implementation possibilities of the RFID system are provided with their respective requirements in terms of cost and infrastructure. Each alternative solution provides the IS with information input of different level of detail and different level of quality; has its own value proposition and can be characterized by the *application level of tag* (pallet/case/item level), the *location of the tag readers* and the *implementation cost*. According to the aforementioned implementation parameters, the RFID-integrated shelf replenishment IS takes different information input depending on the next three evident and relevant implementation scenarios of the supporting RFID system (Table 1): Base, Medium and Full RFID scenario.

Implementation Parameters	Base RFID scenario	Medium RFID scenario	Full RFID scenario
Tag readers location	backroom entrance backroom to sales floor entrance	backroom entrance backroom to sales floor entrance sales floor shelves	backroom entrance backroom to sales floor entrance sales floor shelves check out
Tag application level	case	case, item	case, item
Implementation cost	low	medium	high

Table 1: Three deployment scenarios of the RFID system

- Base RFID scenario (The RFID tags are applied on cases of products. The tag readers are fixed on the backroom entrance and on the backroom to sales floor entrance.)

When products are delivered to or leaving the backroom of the retail store, the RFID tag reader at the backroom entrance captures this event and reads each case tag. The RFID system aggregates, filters the tag reads and delivers the information to the IS to update automatically the backroom inventory. Respectively, when products are entering the sales floor from the backroom, the RFID reader at the backroom to sales floor entrance captures this event and reads each case. The RFID system aggregates, filters the tag reads and delivers the information to the IS to record the time of the shelf replenishment and update automatically the backroom and the shelf inventory. If the RFID reader identifies cases returning into the backroom from the sales floor, the backroom and the shelf inventory are also updated the previous way. Since the products are tagged only at case level and there are no tag readers fixed on the shelves or the checkout, the shelf replenishment IS takes the POS data from the retailer's ERP system to estimate the alteration of the shelf and the stock inventory during the daily store operation, as consumers purchase the products.

- Medium RFID scenario (The RFID tags are applied on cases and items of products. The tag readers are fixed on the backroom entrance, on the backroom to sales floor entrance and on the sales floor shelves.)

The RFID system does not function differently from the base scenario except for the monitoring of the shelves. The RFID reader scans the shelves and counts the products on them. The RFID system aggregates, filters the tag reads and delivers the information to the IS to update automatically the shelf inventory.

- Full RFID scenario (The RFID tags are applied on cases and items of products. The tag readers are fixed on the backroom entrance, on the backroom to sales floor entrance, on the sales floor shelves and on the checkout.)

The RFID system does not function differently from the base scenario except for the monitoring of the sales. When consumers purchase the products, the RFID reader at the checkout captures this event and reads each item. The RFID system aggregates, filters the tag reads and delivers the information to the IS to update automatically the store inventory.

4 RESEARCH QUESTION & APPROACH

The scope of this research (Figure 1) is much broader than the development of a RFID-integrated information system to support the shelf replenishment process in order to address effectively the OOS (out-of-shelf) problem. The main research idea involves information quality with the ultimate purpose to examine the impact that RFID technology has on the quality of information utilized during the shelf replenishment process.

The impact of alternative implementations of RFID technology on the quality of the IS information input and output is examined, in terms of these information quality dimensions: *accuracy*, *timeliness* and *completeness*. It has long been recognized that information quality is a multi-dimensional concept (Ballou & Pazer 1985, Pipino et al. 2002, Wang and Strong 1996) and many studies have identified and discussed lists of information quality dimensions (Strong et al. 1997, Wang and Strong 1996, Wang et al. 1998, Wang 1998, Wolstenholme et al. 1993, Lillrank 1997, Miller 1996, English 1999). We consider the information quality dimensions as provided by the seminal work of Wang and Strong (1996), where quality attributes were collected from data consumers instead of being defined theoretically or based on researchers' experience. As information quality has best been defined (Wang and Strong 1996) as "fitness for use", the dimensions should be chosen based on the context of the study and the relevant tasks. Therefore, the dimensions accuracy, timeliness and completeness were chosen as the most relevant to this research context because they are directly connected to the advanced information-captured capabilities of RFID technology. Besides, Selitto et al. (2007) have recently examined the scholarly literature of studies concerning RFID-derived benefits in retail supply chain and concluded that the improved information value associated with RFID-derived benefits is embodied in the quality dimensions timeliness, accuracy and completeness.

Summarizing the research scope, illustrated in Figure 1, the next key research question follows directly: How do alternative implementations of the RFID technology affect the quality of the information input and output in a Shelf Replenishment Information System?

Given this research scope and this research question, the research propositions which we seek to confirm in this study are as follows:

- Alternative implementations of the RFID system provide IS with information input of different level of quality, in terms of accuracy, timeliness and completeness at different cost.
- Alternative implementations of the RFID-integrated IS provide with information output of different level of quality, in terms of accuracy, timeliness and completeness at different cost.

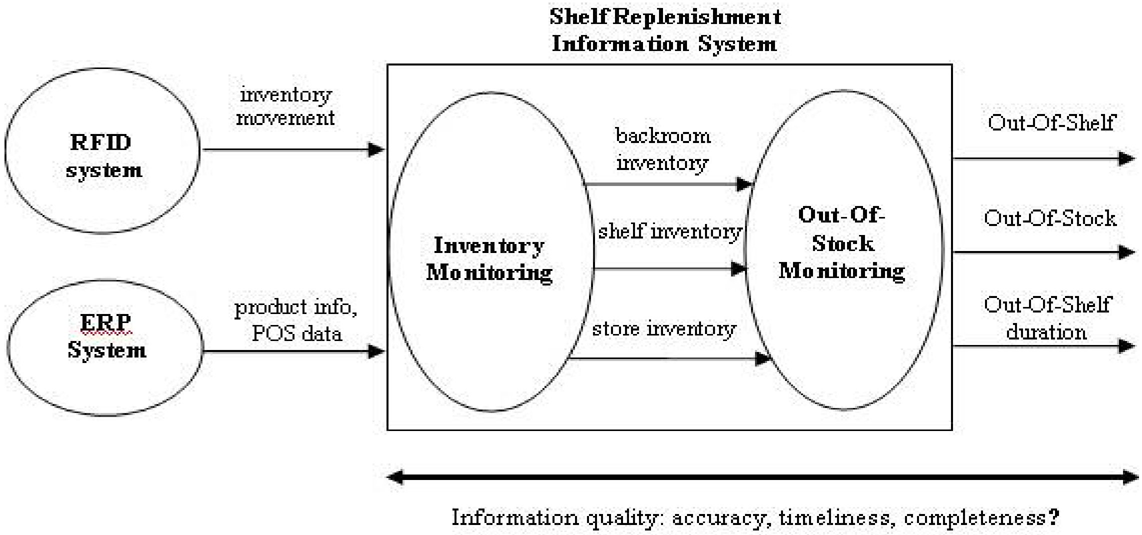

Figure 1. The Research Scope

To confirm the research propositions described above, the research approach consists of the following steps and their sub-steps:

A) Define and describe the current business process (see section 2):
- three case studies of two years (Stake 1995, Yin 1994): Greek, Cypriot and Irish retailer
- three rounds of semi-structured interviews with the stakeholders (store manager and staff, IT and Logistics manager, supplier's salesmen)
- direct observation of the products delivery and the replenishment of the shelves in the store
- modeling the current business process systematically via Business Process Modeling Notation (BPMN)
- validating the current business process model via interviews with the stakeholders

B) Design and develop the RFID integrated shelf replenishment IS (see section 3)
- proposing alternative implementations of the RFID system
- modeling the alternative implementations of the RFID-integrated shelf replenishment IS via BPMN and Unified Modeling Language (Use Cases)
- implementation of a prototype

C) Information Quality (IQ) Assessment of the RFID-integrated shelf replenishment IS
- survey among the stakeholders to assess (qualitatively) the IQ of the current IS supporting the retailer store (Lee et al. 2002)
- selecting the IQ dimensions: accuracy, timeliness, completeness
- defining the metrics of the IQ dimensions (Ballou and Pazer 1985, Laudon 1986, Wang and Strong, 1996)
- developing the Information Product Map (Ballou et al. 1998, Shankaranarayanan et al. 2003) of the current IS that the retailer uses to monitor the store inventory.
- developing the IP-Maps of the alternative implementations of the RFID-integrated shelf replenishment IS
- validate the IP-Maps through semi-structured interviews with the stakeholders
- Conducting a field experiment in the retail store to assess (quantitatively) (Ballou et al. 1998) in practice (i) the quality of the information input provided by the RFID system and (ii) the quality of the information output of the RFID-integrated IS.
- survey among the stakeholders to assess (qualitatively) the IQ of the new RFID-integrated IS (Lee et al. 2002)

Tasks A and B have almost finished and some of the results have already been presented in sections 2 and 3 to assist the reader to comprehend the main research question that seeks for answers during task C. Since this paper presents a research study in progress, the next section presents some preliminary results of task C.

5 PRELIMINARY RESULTS

The dimensions of the information have already been selected and their metrics are provided, according to the context of the study:

- Accuracy (Ballou et al. 1985, Wang and Strong 1996) is defined as "the extent to which data are correct, reliable, and certified free of error" and is measured as:

Accuracy = 1 - (# uncorrect data/ # data)

- Timeliness (Wang and Strong 1996) coincides with the age of data, that is often described by currency:

Currency depends on when the information is delivered to the customer, i.e. IS, when the data is obtained (i.e. when the RFID reader captures the event) and how old the data unit is when received (age). Age is the time difference between the real world event and when data enters the RFID system. Thus,

Currency = (Delivery time to IS - time of RFID event capturing) + (time data enters the RFID system - time of real event)

- Completeness (Wang and Strong 1996) is defined as "the extent to which data are of sufficient breadth, depth, and scope for the task at hand" and is measured according to the record completeness (Laudon 1986) as function of the empty fields of a record:

Completeness = 1 - (# empty fields / # record fields)

The records of the IS information input consist of these record fields: backroom inventory record = (product barcode, product EPC, expiration date), shelf inventory record = (product barcode, product EPC, expiration date) and store inventory record = (product barcode, product EPC, expiration date). The expiration date information is kept, in order to have a more accurate picture of the "physic" stock status in the store e.g. if a product item has passed its expiration date, it should not be included in the available stock even though its physical presence in the store.

Then, Figure 2 depicts the Information Product Map of the current IS that the retailer employs to monitor the store inventory and Figure 3 depicts the Information Product Map of the full implementation of the RFID-integrated Shelf replenishment IS.

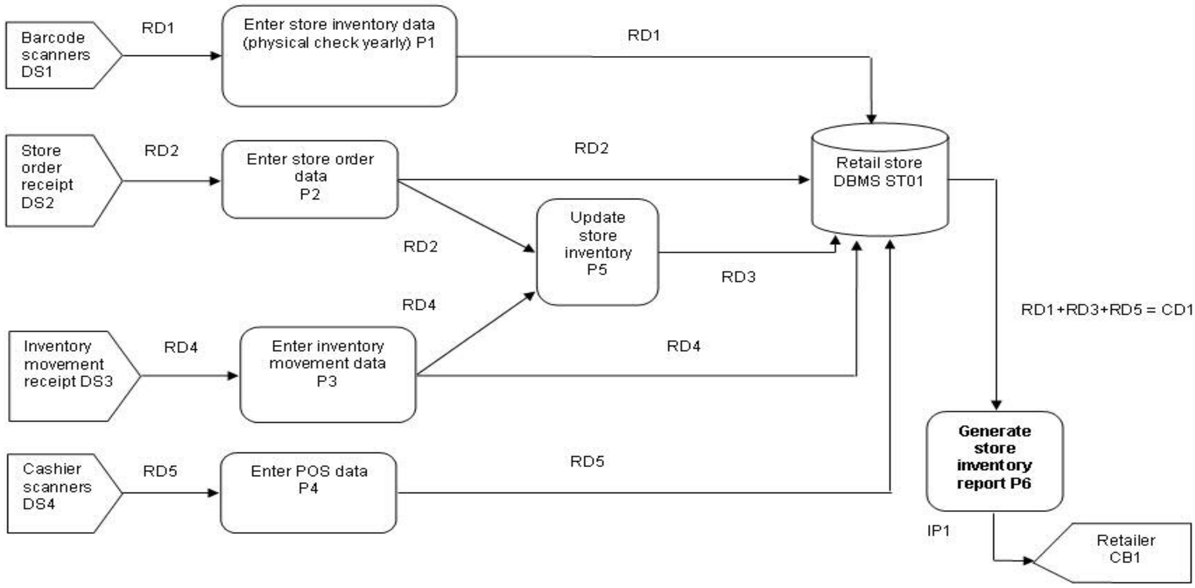

Figure 2. The IP-Map of the current IS the retailer employs to monitor the store inventory

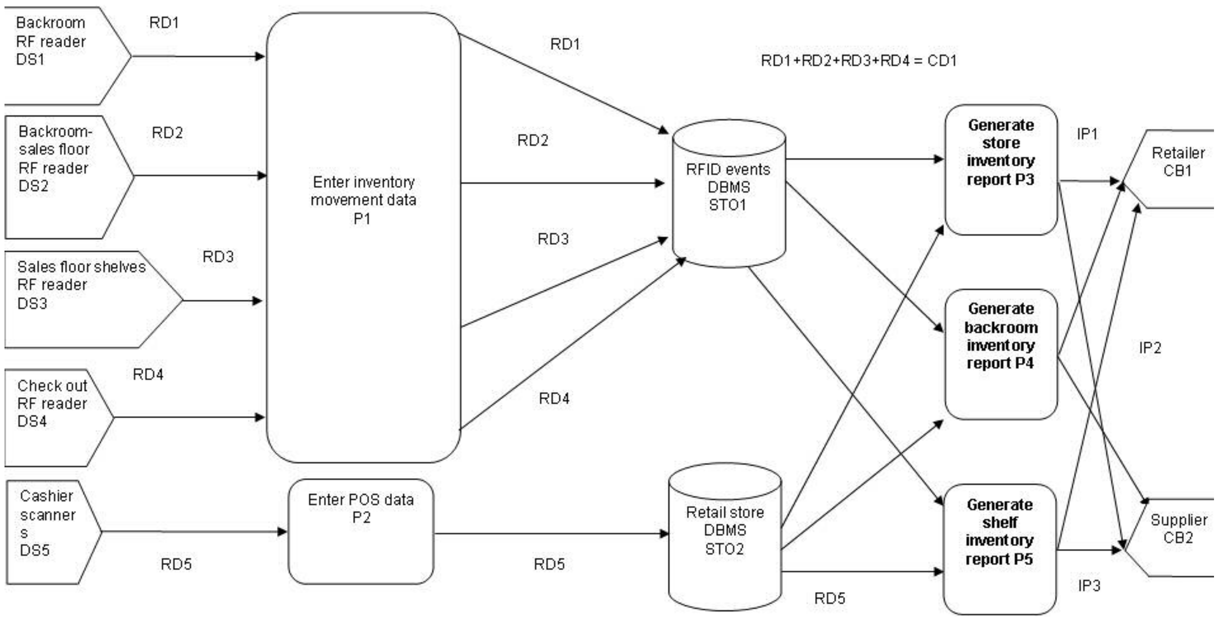

Figure 3. The IP-Map of the full implementation of the RFID-integrated shelf replenishment IS

6 DISCUSSION & CONCLUSIONS

This research focuses on the "final few meters" of the retail supply chain, i.e., the retail store. It is motivated by the problem of OOS (out-of-shelf) in retail industry, i.e., the temporary unavailability of items on retailers' shelves and investigates the impact that the adoption of RFID technology has on the quality of information utilized during the shelf replenishment process.

Also inspired from the emergence of RFID technology and its advanced information-captured capabilities, this research begins with the introduction of a RFID-integrated information system (IS) to enhance the shelf replenishment process. The IS accepts RFID-derived information input to provide the users with Out-Of-Shelf and Out-Of-Stock cases and Out-Of-shelf duration i.e. the time a shelf is empty of products. Three alternative implementation scenarios (Base, Medium and Full) of the RFID system characterized by the application level of tag (pallet/case/item level), the location of the tag readers and the implementation cost provide the IS with information input of different level of detail and different level of quality. The impact of the three alternative implementation scenarios of the RFID system on the quality of the IS information input and output is examined, in terms of the quality attributes accuracy, timeliness and completeness.

To serve this research's purposes, the quality of the IS information input and output are assessed for each implementation scenario by developing the Information Product Maps of the alternative implementations of the RFID-integrated shelf replenishment IS and using the methodology introduced by the fundamental study of Ballou, Wang, Pazer and Tayi (1998). Since this paper presents a research-in-progress, the next steps of the study include the formal description of the RFID-enabled shelf replenishment process via business process modeling and the resulting IP-Maps of the alternative applications of the RFID-enabled IS in order to assess the quality of the IS information input and output.

This research contributes to the academic literature, as well as to industrial practice, with the development of a new RFID-enabled IS to support the shelf replenishment process in retail industry. Also, it provides a concrete quantitative assessment of the RFID impact on the information quality for the shelf replenishment process. In addition, this study assesses information quality in a new, among the available literature, business context, i.e. the retail industry. Moreover, the information quality assessment is not monolithic, but includes different implementations of the RFID system that affect information quality differently. Finally, the most important contribution of this study is reflected on the research approach adopted to assess information quality. Although the available literature provides mostly survey-based (Lee et al. 2002) information quality diagnostic tools, this research applies a methodology not applied until now, based on the available literature.

However, this research has the potential to be expanded by integrating another Auto-ID technology, e.g. 2-D barcodes with the shelf replenishment IS and comparing the implementation cost, as well as the impact on information quality, with those of the RFID-integrated IS.

References

Alexander, K., Birkhofer, G., Gramling, K., Kleinberger, H., Leng, S., Moogimane, D. and Woods, M. (2002). Focus on Retail: Applying Auto-ID to Improve Product Availability at the Retail Shelf. Auto-ID Center. White paper.

Angelles, R. (2005). RFID Technologies: Supply Chain Applications and Implementation Issues. Information Systems Management, 51-65.

Auto-ID Center (2002). Technology Guide. Auto-ID Center. White paper.

Ballou, D. P. and Pazer, H. L. (1985). Modeling data and process quality in multi-input, multi-output information systems. Management Science, 31(2), 150-162.

Ballou, D., Wang, R., Pazer, H. and Tayi, G. K. (1998). Modeling Information Manufacturing Systems to determine Information Product Quality. Management Science, 44(4), 462-484.

Bardaki, C. and Pramatari, K. (2006). Replenishment Processes in Retailing: before and after RFID. In Proceedings of the 5th ECR Academic Symposium, Sweden, Stockholm.

Campo, K., E. Gijsbrechts and P. Nisol (2002). Towards Understanding Consumer Response to Stock-Outs. Journal of Retailing, 76(2), 219-242.

Clark, T. H. and Lee, H.G. (2000). Performance interdependence and coordination in business-to-business electronic commerce and supply chain management. Information Technology and Management, 85-105.

Colacchio, F., Tikhonova, O. and Kisis, J. (2003) Consumer response to Out-Of-Stock: Decision Making process and influence factors. ECR Europe Berlin Conference.

Chow H. K.H., Choy K. L. and Lee W. B. (2007). Integration of web-based and RFID technology in visualizing logistics operations – a case study. Supply Chain Management - An International Journal, 12, 221-234.
English, L. P. (1999). Improving data warehouse and business information quality: Methods for reducing costs and increasing profits. Wiley, New York, NY.
Finkenzeller K. (1999). RFID Handbook: Fundamentals and Applications in Contact-less Smart cards and Identification. John Wiley & Sons.
Fleisch, E. and Tellkamp C. (2003). The Impact of Inventory Inaccuracy on Retail Supply Chain Performance: A Simulation Study. International Journal of Production Economics, 95(3), 373-385.
Gaukler, G. (2004). RFID in the Retail Supply Chain: Benefits, Roll-out Strategies, and Cost Sharing Agreements, The Supply Chain Connection. Newsletter of the Stanford Global Supply Chain Management Forum, 10(2), 6-7.
Ghisi, F. and da Silva, A. (2001). The information technology on food supply chain management. In Proceedings of the International Conference on Management of Engineering and Technology, 1, 169.
Gruen, T.W., Corsten, D.S. and Bharadwaj, S. (2002). Retail Out-Of-Stocks: A Worldwide Examination of Extent, Causes and Consumer Responses. The Food Business Forum (CIES, FMI, GMA).
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.
Jones P., Clarke-Hill C., Shears P., Comfort D. and Hiller D. (2004). Radio frequency identification in the UK: opportunities and challenges. International Journal of Retail & Distribution Management, 32, 164-171.
Jones P., Clark-Hill C., Comfort D., Hillier D. and Shears P. (2005). Radio frequency identification and food retailing in the UK. British Food Journal, 107, 356-360.
Joshi, Y. (2000). Information Visibility and its Effect on Supply Chain Dynamics. Master degree thesis, MIT.
Kambil A. and Brks J.D. (2002). Auto-ID Across the Value Chain: From Dramatic Potential to Greater Efficiency and Profit. Auto-ID Center, White paper.
Karkkainen, M. (2003). Increasing efficiency in the supply chain for short shelf life goods using RFID tagging. International Journal of Retail & Distribution Management, 31, 529 - 536.
Laudon, K. C. (1986) Data Quality and due Process in large Interorganizational record systems. Communications of the ACM, 29(1), 4-11.
Lee H. L. (2007). Peering through a glass darkly. International Commerce Review, 7(1), 61-68.
Lee Y. M., Cheng F., Leung Y. T. (2004). Exploring the impact of RFID on Supply Chain Dynamics. In Proceedings of the Winter Simulation Conference.
Lee W. Y., Strong D. M., Kahn B. K., and Wang R. Y. (2002). Aimq: a methodology for information quality assessment. Information & Management, 40(2), 133-146.
Lillrank, P. (1997). The quality of information in business processes. Industrial Management, Working paper No. 10/1997/ 2nd revised edition. Helsinki University of Technology, Espoo.
Miller, H. (1996). The Multiple Dimensions of Information Quality. Information Systems Management, 13(2), 79-83.
Pipino, L., Lee, Y. W. and Wang. R. Y. (2002). Data quality assessment. Communications of the ACM, 45(4), 211-218.
Penttilä, K., Engels, D. and Kivikoski, M. (2004). Passive radio frequency identification in supply chain management. Int. J. Robotics Automation, 19, 143-152.
Pramatari, K. (2007). Collaborative supply chain practices and evolving technological approaches. Supply Chain Management: An International Journal, 12(3).
Pramatari, K. and Miliotis P. (2007). The impact of collaborative store ordering on shelf availability. Supply Chain Management: An International Journal, forthcoming, 2007.
Shankaranarayan, G., Ziad, M. And Wang, R. (2003). Managing Data Quality in Dynamic Decision Environments: An Information Product approach. Journal of Database Management, 14(4), 14-32.
Sarma S. (2002). Towards the 5¢ tag. Auto-ID Center. White paper.

Selitto, C., Burgess, S. and Hawking, P. (2007). Information quality attributes associated with RFID-derived benefits in the retail supply chain. International Journal of Retail and distribution Management, 35(1), 69-87.
Strong, D. M., Lee, Y. W. and Wang, R. Y. (1997). Data quality in context. Communications of the ACM, 40(5), 103-110.
Wang, R. Y. and Strong, D. M. (1996). Beyond Accuracy: What Data Quality means to Data Consumers. Journal of Management Information Systems, 12(4), 5-34.
Wang, R.Y. (1998). A product perspective on total data quality management. Communications of the ACM, 41(2).
Wang, R. Y., Lee, Y. W., Pipino, L. L. and Strong, D. M. (1998) Manage your information as a product. Sloan Management Review, 95-105.
Wolstenholme, E. F., Henderson, S. And Gavine, A. (1993) The evaluation of management information systems: A dynamic and holistic approach. John Wiley & Sons. Chichester.
Wong, C. Y. & McFarlane, D. (2004). The Impact of Auto-ID on Retail Shelf Replenishment Policies. Auto-ID Center. White paper.
Wong, C. Y. (2006). The impact of Information Quality on Shelf Replenishment Policies. Doctoral Dissertation, University of Cambridge.
Yossi, S. (2004). RFID and the Innovation Cycle. The International Journal of Logistics Management, 15, 1-10.