ASSESSING INFORMATION QUALITY IN A RFID-INTEGRATED SHELF REPLENISHMENT DECISION SUPPORT SYSTEM FOR THE RETAIL INDUSTRY

(Research-in-Progress)
(IQ Assessment, Cost/Benefit Analysis of IQ and IQ improvement)

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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 and consequently on the products' shelf availability. A RFID-integrated decision support system (DSS) with three alternative implementation scenarios is proposed to enhance the shelf replenishment process. On one hand, the impact of the three alternative solutions on the quality of the DSS information input is examined in terms of accuracy, timeliness and completeness. On the other hand, the effect of the three alternative deployment scenarios of the RFID-integrated DSS on the OOS problem is assessed through measuring the number of OOS occurrences after utilizing the DSS. The quality of the DSS information input and the products' shelf availability are assessed for each implementation scenario by executing the DSS with input data of test cases. Test cases are generated via the business process modeling used to develop the RFID-integrated DSS and the respective input data of the DSS during the test cases are based on case studies findings and also real data from the retailer, e.g. point-of-sales data, in order to reflect each possible event during the shelf replenishment process. An example of assessing the impact of RFID technology on the quality of DSS information input is given to present the research approach of executing DSS with input data of test cases. A cost-benefit analysis of the alternative solutions of the RFID-integrated DSS will be conducted to select that solution that provides the DSS with satisfying quality of information input and also improves the products' shelf availability at an affordable cost. The contribution of this study is reflected on the research approach of using a DSS to assess information quality and executing it with input data of test cases based on real data and case studies.

Key Words: Information Quality, RFID, Out-of-Shelf, Shelf Replenishment, DSS

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 [16], 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 [36, 37]), 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. [16] and Vuyk [43] 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 [8, 10, 16, 43] and the improvement of the store replenishment process through information sharing between the trading partners in the retail supply chain [5, 37]. However this research, identifying the limited studies concerning the processes within the retail store [48, 49], 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 [42] 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 [15, 22, 34, 38]. 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 decision support system (DSS) to enhance the shelf replenishment process and thus improve products' availability. The RFID system captures the products movements in the store and provides the DSS with the necessary information input. Next, the DSS provides the system users (retail store's staff) with shelf replenishment alerts and shelf replenishment lists of the products quantities that need to be shelf replenished. 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 DSS 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 and consequently on products' shelf availability (out-of-shelf problem). On one hand, the impact of the three alternative implementation scenarios of the RFID system on the quality of the DSS information input is examined, in terms of accuracy, timeliness and completeness information quality dimensions. On the other hand, the effect of the three alternative deployment scenarios of the RFID-integrated DSS on the OOS problem is assessed through measuring the number of OOS occurrences after utilizing the DSS.

During this research, the quality of the DSS information input and the products' shelf availability are assessed for each implementation scenario by executing the DSS with input data of events (test cases) that can possibly occur during the shelf replenishment process. Test cases are generated via the business process modeling used to develop the RFID-integrated DSS, based on the principles of model-based software testing [30]. The respective information input of the DSS during the test cases is provided based on case studies findings and also real data coming from the retailer, e.g. point-of-sales data, in order to reflect the real shelf replenishment process. An indicative example of assessing the impact of RFID technology on the quality of DSS information input is given to introduce into the research approach of executing DSS with input data of test cases. This simple example shows that there is a RFID deployment scenario (the Full RFID scenario) that is accompanied with the most satisfying level of information quality. However, this solution is the most expensive. Thus, the user can compromise with another solution (the Medium RFID scenario) that provides almost the same level of information quality at a more affordable cost. Then, a cost-benefit analysis of the alternative implementations of the RFID-integrated DSS will be conducted to select that solution that provides the DSS with satisfying quality of information input and also improves the products' shelf availability at an affordable cost.

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, preliminary results through an example of applying the research approach to assess the impact of RFID technology on the quality of DSS information input are given. The final section presents the conclusions along with the contribution of this research and ideas for further research.

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, two case studies were conducted at a major Greek and Cypriot retailer using: (a) semi-structured interviews with the store manager, store employees and the IT manager from company headquarters and (b) direct-observation of the shelf replenishment, following the case study research guidelines of Stake [40] and Yin [50].

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 [6].
- or as 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 [49].

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 [48] 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 policy" is the predominant approach and, as expected, is applied by both the Greek and the Cypriot 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 two retailers, except for some differences mentioned below, and can be generally analyzed in the following tasks:

- A truck with products arrives.
- 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 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 [1].
- 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 and refills the shelves.
- Store staff 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 in the backroom and, as a result, from many out-of-shelf cases occurring.

RFID-Enabled 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 supply chain and for this research's purposes, specifically, 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.

RFID technology can offer product (items/cases/pallets) visibility at each and every point across the extended supply chains [42] since it provides unique product identification along with continuous, accurate and real time information on the position and the status of products. Radio Frequency Identification (RFID) is a generic technology concept that refers to the use of radio waves to identify objects [3]. 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 [2]. Finkenzeller [14] provides a general overview of RFID technology while Sarma [38] describes the specific technology for supply chain management.

A large number of papers, white papers and industry reports, published recently, are mostly qualitative studies providing business cases for RFID deployment [1, 2, 19, 20, 48, 51]. Research on the impact of RFID on supply chain operations using analytical quantitative approaches is still at an early stage [11, 28, 23]. H. Lee [25] 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.

Therefore, this research comes to propose a RFID-integrated decision support system (DSS) 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 events taking place in the store during the shelf replenishment process (e.g. shelf refilling, products entering the sales floor from the backroom, products delivered to the backroom from the distribution center, etc.) filters them and transforms them to provide the DSS with information input. The RFID-derived information input of the DSS consists of: backroom on-hand stock (level of product's available inventory in the backroom), shelf on-hand stock (level of product's available inventory on the shelf), sales (recorded sales at the checkout of the retail outlet) and shelf replenishment history (time and products quantities of each shelf replenishment has taken place). Next, the DSS utilizes the RFID-delivered information input, uses a decision-making algorithm and provides the system users (retail store's staff) with information output in the form of shelf replenishment alerts and shelf replenishment lists. The shelf replenishment alert is a message delivered to the PDAs, mobile phones or beepers, etc. of the store's staff and identifies the products that need to be shelf replenished. Respectively, the shelf replenishment list includes the products quantities for shelf refilling. The business algorithm of the DSS also takes into consideration other factors, such as product category, sales volume, shelf space allocation, promotion actions, etc., to finally provide the time and the quantity of the shelf replenishment. The main goal of this paper is not the decision-making algorithm, so no further details about the decision logic will be provided.

When employing the RFID technology to enhance the shelf replenishment process, many different implementation possibilities of the RFID system are offered with their respective requirements in cost and infrastructure. Each alternative solution provides the DSS 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 DSS takes different information input depending on the next three evident and relevant implementation scenarios of the supporting RFID system (see Table 1): Base, Medium and Full RFID scenario.

- 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 DSS to update automatically the backroom on-hand stock. 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 DSS to record the time of the shelf replenishment, the shelf replenishment list and update automatically the backroom and the shelf on-hand stock. If the RFID reader identifies cases returning into the backroom from the sales floor, the backroom and the shelf on-hand stock are also updated the previous way.

At this scenario, 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 DSS takes the necessary sales information from historical Point-Of-Sales (POS) data stored in the ERP system of the retail store. Also, the DSS estimates the alteration of the shelf stock during the daily store operation, as consumers purchase the products, utilizing the recorded shelf replenishment history (time and quantity) and the historical POS data.

- 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-enhanced shelf replenishment process is not different from the base scenario except for the monitoring of the shelves. When products are entering or being removed from the shelves, the RFID reader at shelves captures this event and reads each item. The RFID system aggregates, filters the tag reads and delivers the information to the DSS to update automatically the shelf on-hand stock. Thus, the DSS does not have to estimate the alteration of the shelf stock anymore, since the shelves are in real-time, continuously monitored.

- 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-enhanced shelf replenishment process is not different from the medium 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 DSS to update automatically the sales. Thus, the DSS does not need the POS data of the ERP system to estimate the sales, during the daily operation of the store.

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: The implementation parameters of the three deployment scenarios of the RFID system

However, since this paper presents a research study in progress, it must be said that the above implementation scenarios of the RFID system are not the only scenarios that are going to be assessed.

RESEARCH QUESTION & APPROACH

Apart from the development of a RFID-integrated decision support system (DSS), in order to improve the shelf replenishment process and thus address effectively the OOS (out-of-shelf) problem, the scope of this research is much broader (see Figure 1). The main research idea involves information quality with the ultimate purpose to examine the impact of RFID technology has on the quality of information utilized during the shelf replenishment process and consequently on products' shelf availability.

On one hand, the impact of RFID technology on the quality of the DSS information input is examined, in terms of these information quality dimensions: *accuracy*, *timeliness* and *completeness* (see first part of figure 1, on the left of DSS). It has long been recognized that information quality is a multi-dimensional concept [4, 35, 44] and many studies have identified and discussed lists of information quality dimensions [41, 44, 46, 45, 47, 27, 29, 13, 18, 12]. We consider the information quality dimensions as provided by the seminal work of Wang and Strong [44], 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 [44] 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. [39] 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.

On the other hand, the impact of RFID technology on the products' shelf availability (OOS problem) is assessed through the OOS-related benefits the DSS provides to its users (information output consumers [41, 44]) (see third part of figure 1, on the right of DSS). But, benefits are often intangible and difficult to measure [21]; so, a subjective approach is used to measure the OOS-related benefits as perceived by the users [33]. For the context of this study the number of OOS occurrences has been selected to evaluate how beneficial the RFID-integrated DSS is for the users.

In addition, the impact of the three alternative implementation scenarios of the RFID system is assessed; one of the alternative deployment scenarios of the RFID system will be found to provide the DSS with satisfying quality of information input and to improve satisfyingly the products' shelf availability at a cost the users can afford.

Summarizing the research scope, illustrated in Figure 1, the next key research questions follow directly:

- How does the adoption of RFID technology affect the quality of the information input in a Shelf Replenishment Decision Support System (DSS)?
- How does the adoption of RFID technology affect the products' shelf availability through the Shelf Replenishment DSS?

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

1. Different implementations of the RFID system provide the DSS with information input of different level of quality in terms of accuracy, timeliness and completeness.
2. There is an implementation of the RFID system that provides the DSS with information input of satisfying level of quality in terms of accuracy, timeliness and completeness at an affordable cost.
3. Different implementations of the RFID system affect differently the products' shelf availability through the DSS.

4. There is an implementation of the RFID system that improves satisfyingly the products' shelf availability through the DSS at an affordable cost.

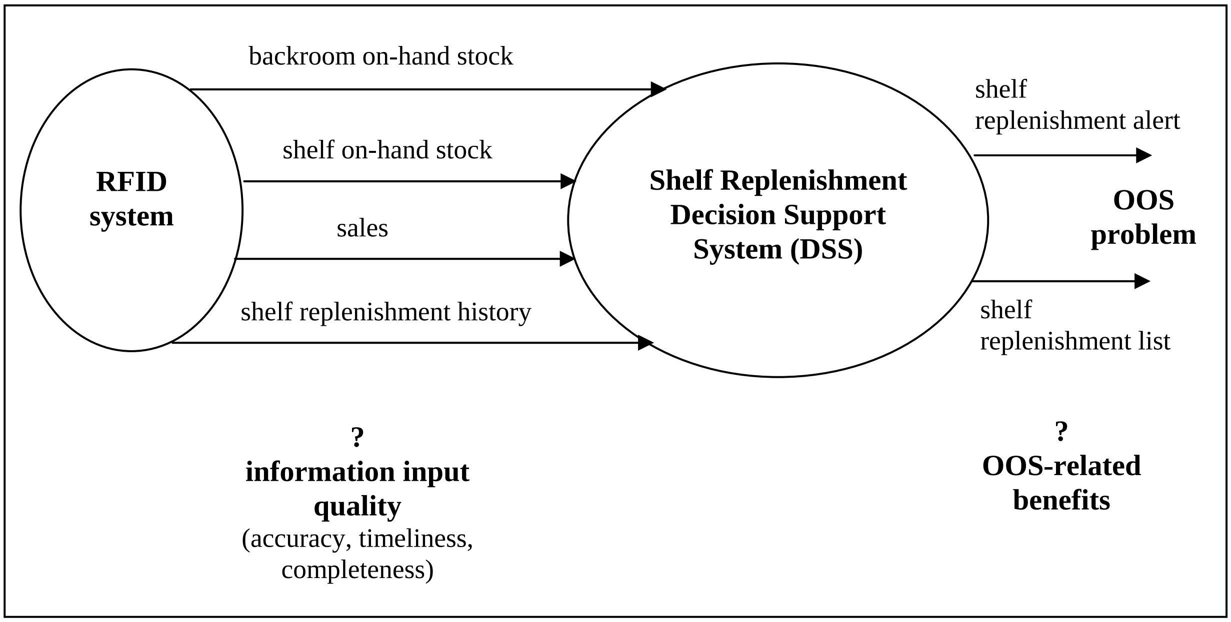

Figure 1: The Research Scope

To confirm the research propositions described above, the quality of the DSS information input and the products' shelf availability affected by the DSS could be assessed via a field experiment. However, it is not possible to conduct a field experiment for each implementation of the RFID system; therefore, the research approach is based on the principles of software testing [31, 32]. Software testing always consists of observing a sample of executions (test cases) and giving a verdict over them. But, testing faces two challenges: how to identify the test cases (test selection) in a systematic way and how many of them to take into consideration (test adequacy) [7]. All the test cases (events) that can possibly occur during the shelf replenishment process will be generated based on the principles of model-based software testing [30], meaning that the test cases will be derived via the business process modeling used to define and develop the RFID-integrated DSS. Thus, the test cases reflecting the complete operating profile of the DSS will be chosen systematically. Case studies findings and also actual data provided by the retailer (point-of-sales data, backroom on-hand stock, shelf replenishment times and quantities) will provide the respective DSS information input data of the test cases. The next section presents an indicative example of applying the above research approach to assess the impact of RFID technology on the quality of DSS information input by executing DSS with input data of test cases. Finally, a cost-benefit analysis of the alternative implementations of the RFID-integrated DSS will be conducted to select that solution that provides the DSS with satisfying quality of information input and also improves the products' shelf availability at an affordable cost.

PRELIMINARY RESULTS: ASSESSING THE IMPACT OF RFID ON THE QUALITY OF THE DSS INFORMATION INPUT

This example refers to the daily operation of a retail outlet involving the shelf replenishment process and demonstrates the research approach of this study to assess the impact of the three alternative implementation scenarios of the RFID system on the accuracy, timeliness and completeness quality dimensions of the DSS information input. In the same example, the current shelf replenishment process, i.e., the no RFID scenario, is also taken in consideration to compare the quality of the information input provided to the DSS with that provided during the RFID scenarios.

Before the description of the example, the metrics of the selected information quality dimensions should be provided, according to the context of the study:

- Accuracy [4, 44] 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 [44] 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. DSS, 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 DSS - time of RFID event capturing) + (time data enters the RFID system - time of real event)

- Completeness [44] 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 [24] as function of the empty fields of a record:

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

The records of the DSS information input, for the needs of this example, are supposed to be consisted of these record fields: backroom on-hand stock record = (product barcode, Product EPC, expiration date), shelf on-hand stock record = (product barcode, Product EPC, expiration date) and sales = (product barcode, Product EPC). 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.

This example takes place one day of the week in a retail outlet, where shelf replenishment happens periodically twice a day. It involves one product with product shelf space equal to 30 items. When the day begins, the product's backroom on-hand stock is 10 items, the shelf on-hand stock is equal to 10 product items and the product sales are zero. During the example, the following events take place at specific time moments:

- At 7.30 a.m., 5 product cases (each case contains 20 items) are delivered to the backroom of the retail store. The RFID system captures the event and the backroom on-hand stock in the DSS is automatically updated for all the RFID scenarios.
- At 7.45 a.m., a replenishment wagon with a product case (20 items) enters the sales floor from the backroom. The RFID system captures the event and the backroom and the shelf on-hand stock in the DSS are automatically updated for all the RFID scenarios.
- At 7.55 a.m, the 20 product items refill the shelf. The RFID system captures the event and the shelf on-hand stock in the DSS is automatically updated for the medium and full RFID scenarios.
- At 8.25 a.m., a customer removes 10 product items from the shelf. The RFID system captures the event and the shelf on-hand stock in the DSS is automatically updated for the medium and full RFID scenarios.
- At 8.35 a.m., a replenishment wagon with half a product case (10 items) enters the sales floor from the backroom. The RFID system captures the event and the backroom and the shelf on-hand stock in

the DSS are automatically updated for the medium and full RFID scenarios.

- At 8.40 a.m. the same customer purchases the 10 products and passes the checkout. The RFID system captures the event and the sales in the DSS are automatically updated only for the full RFID scenario.

Concluding, all the above events are captured by the RFID system only for the full scenario. The customer sales are not captivated in case of the medium or the base scenario, so POS data from the retailer's ERP system are used. Also, the shelves monitoring and the subsequent updating of the shelf on-hand stock are not supported by the base scenario. Finally, since this paper presents a research in progress, this example does not include all the events that can possibly take place during the shelf replenishment process i.e. the complete operating profile. Thus, the quality assessment of the DSS information input does not cover the complete test cases profile of the DSS.

Table 2 in appendix illustrates how the values of the DSS information input change (if so) after each of the above events happens, according to the implementation of the RFID system that provides the DSS with this information input. The same table also contains the information input of the DSS when no RFID system is utilized and the replenishment operates only with the barcode of the products. Table 2 assists in producing the next table. Table 3 in appendix assesses the values of the selected quality dimensions of the DSS information input after each event, for the three deployment scenarios of the RFID system and the no RFID scenario.

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 and consequently on products' shelf availability.

Also inspired from the emergence of RFID technology and its advanced information-captured capabilities, this research begins with the introduction of a RFID-integrated decision support system (DSS) to enhance the shelf replenishment process and thus improve products' shelf availability. The DSS accepts RFID-derived information input to provide the users with shelf replenishment alerts and shelf replenishment lists. 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 DSS with information input of different level of detail and different level of quality. On one hand, the impact of the three alternative implementation scenarios of the RFID system on the quality of the DSS information input is examined, in terms of the quality attributes accuracy, timeliness and completeness. On the other hand, the effect of the three alternative implementation scenarios of the RFID system on the products' shelf availability (OOS problem) is assessed through measuring the number of OOS occurrences after utilizing the RFID-integrated DSS.

To serve this research's purposes, the quality of the DSS RFID-derived information input and the products' shelf availability affected by the DSS are assessed for each implementation scenario by executing the DSS with input data of test cases. Test cases are identified via the business process modeling used to describe formally and develop the RFID-integrated DSS; the respective information input of the test cases, provided to the DSS, comes from case studies findings and also real data from the retailer, e.g. point-of-sales data, in order to reflect all the events that can possibly occur during the shelf replenishment process. An indicative example of assessing the impact of RFID technology on the quality of DSS information input is given to introduce into the research approach of executing DSS with input data of test cases. This simple example shows that there is a RFID deployment scenario (the Full RFID scenario) that is accompanied with the most satisfying level of information quality. However, this solution is the most expensive. Thus, the user can compromise with another solution (the Medium RFID scenario) that provides almost the same level of information quality at a more affordable cost. After the information quality and the products' shelf availability assessment, a cost-benefit analysis of the alternative implementations of the RFID-integrated DSS is the next step of the research approach to select that solution that provides the DSS with satisfying quality of information input and also improves the products' shelf availability at an affordable cost. 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 identification of all the test cases of the RFID-enabled DSS in order to assess the quality of the DSS RFID-derived information input and the impact of the RFID-integrated DSS on the products' shelf availability.

This research contributes to the academic literature, as well as to industrial practice, with the development of a new RFID-enabled decision support system to improve 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 [26] information quality diagnostic tools, this research uses the DSS to assess information quality and executes the DSS with input data of test cases chosen based on real data and case studies findings.

However, this research has the potential to be expanded by integrating another Auto-ID technology, e.g. 2-D barcodes with the shelf replenishment DSS and comparing the implementation cost, as well as the impact on information quality, with those of the RFID-integrated DSS. Also, if the research approach of assessing information quality by executing the DSS with input data of test cases is applied to other business contexts, then it could be suggested as a generic information quality assessment approach.

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APPENDIX

Event	no RFID scenario			Base RFID scenario			Medium RFID scenario			Full RFID scenario		
	backr. on-hand stock	shelf on-hand stock	sales	backr. on-hand stock	shelf on-hand stock	sales	backr. on-hand stock	shelf on-hand stock	sales	backr. on-hand stock	shelf on-hand stock	sales
Before the store opens	10	10	0	10	10	0	10	10	0	10	10	0
100 items (5 cases) are delivered to the backroom	110 (10+100)	10	0	110 (10+100)	10	0	110 (10+100)	10	0	110 (10+100)	10	0
20 items (1 case) enter the sales floor from the backroom entrance	110	10	0	90 (110-20)	30 (10+20)	0	90 (110-20)	30 (10+20)	0	90 (110-20)	30 (10+20)	0
20 items refill the shelf	110	10	0	90 (110-20)	30 (10+20)	0	90 (110-20)	30 (10+20)	0	90 (110-20)	30 (10+20)	0
Customer removes 10 items from the shelf	110	10	0	90 (110-20)	30 (10+20)	0	90 (110-20)	20 (30-10)	0	90 (110-20)	20 (30-10)	0
10 items (half case) enter the sales floor from the backroom entrance	110	10	0	90 (110-20)	30 (10+20)	0	80 (90-10)	20 (30-10)	0	80 (90-10)	20 (30-10)	0
Customer buys 10 items and passes the checkout.	110	10	10 (POS)	90 (110-20)	30 (10+20)	10 (POS)	80 (90-10)	20 (30-10)	10 (POS)	80 (90-10)	20 (30-10)	10

Table 2: Comparing the values of the DSS information input after each event, for the three deployment scenarios of the RFID system and the "no RFID" scenario.

Event	**no RFID scenario**			**Base RFID scenario**			**Medium RFID scenario**			**Full RFID scenario**		
	accur.	timel.	compl.	accur.	timel.	compl.	accur.	timel.	compl.	accur.	timel.	compl.
backroom on-hand stock												
100 items (5 cases) are delivered to the backroom	100%	100%	33% (1-2/3)	100%	100%	33% (1-2/3)	100%	100%	100%	100%	100%	100%
shelf on-hand stock												
20 items (1 case) enter the sales floor from the backroom entrance	0%	0%	0%	100%	100%	33% (1-2/3)	100%	100%	100%	100%	100%	100%
20 items refill the shelf	0%	0%	0%	0%	0%	0%	100%	100%	100%	100%	100%	100%
Customer removes 10 items from the shelf	0%	0%	0%	0%	0%	0%	100%	100%	100%	100%	100%	100%
backroom on-hand stock												
10 items (half case) enter the sales floor from the backroom entrance	0%	0%	0%	0%	0%	0%	100%	100%	100%	100%	100%	100%
Sales												
Customer buys 10 items and passes the checkout.	100% (POS)	100% (POS)	50% (1-1/2) (POS)	100%	100%	50% (1-1/2) (POS)	100%	100%	50% (1-1/2) (POS)	100%	100%	100%

Table 3: Assessing the quality of the DSS information input after each event, for the three deployment scenarios of the RFID system and the "no RFID" scenario.