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RFID-enabled Inventory Control Optimization: A Proof of Concept in a Small-to-Medium Retailer

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Keywords

RFID, business process, simulation, proof of concept

Disciplines

Business Administration, Management, and Operations | E-Commerce | Management Information Systems | Operations Research, Systems Engineering and Industrial Engineering | Physical Sciences and Mathematics

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Abstract

This study examines the impact of radio-frequency identification (RFID) technology on the inventory control practices of a small-to-medium retailer using a proof of concept (PoC) approach. The exploratory study was conducted using a single case study of a hardware retailer stocking 5000 product lines provided by 110 active suppliers. To analyze the present mode of operation, procedural documents, semi-structured interviews and a participant observation was conducted. The basis for the proof of concept was a future mode of operation using a quasi-experimental design. Results indicate that in a small-to-medium retail environment, RFID technology could act as a loss prevention mechanism, an enabler for locating misplaced stock, and make a significant contribution to the overall improvement of the delivery process.

1. Introduction

Radio-frequency identification (RFID), which is defined as a wireless automatic identification and data capture (AIDC) technology [1], is increasingly considered by many scholars as the "missing link" in the supply chain management [2, 3]. For example, the technology could allow the identification of any tagged item in real-time in a given supply chain with minimum human intervention [4-7]. When integrating into a firm's business processes [5], the RFID technology allows "any tagged entity to become a mobile, intelligent, communicating component of the organization's overall information infrastructure" (p. 88), thus improving supply chain information flow [8, 9] and supply chain efficiency [3]. A basic RFID system is composed of a tag containing a microprocessor, a reader and its antennas, and a computer equipped with a middleware program, in which business rules are configured to automate some decisions [10]. Despite the high potential of the technology as an enabler of the supply chain transformation, the current adoption rate is still fairly low mainly because many technological and business questions are still to be answered. In order to reduce this knowledge gap, this study draws on the current RFID agenda [5] to answer the following questions: What is the impact of RFID on loss prevention? What is the impact of RFID technology on the delivery process in a small-to-medium retailer store? How can RFID help to locate misplaced stock? How may the RFID reading rate be influenced by the physical characteristics of items? More precisely, the objective of this paper is to document the results of a proof of concept (PoC) that examines the impact of RFID on inventory control. The PoC consists of RFID simulations and re-engineered business processes that demonstrate whether the RFID technology can operate within the small-to-medium retail industry and illustrates the anticipated impact of RFID on business operations.

Section 2 presents related works. In section 3, the methodology used in this study, including all simulation of RFID enabled scenarios are presented. Finally, section 4 presents the discussion and conclusion.

2. Background and context of the study

The current study uses the proof of concept approach to assess the feasibility of RFID technology in a small-to-medium retail store. Most early studies on the feasibility of RFID technology have mostly been conducted using this approach or pilots projects (e.g. [11-13]). A proof of concept is used to illustrate whether a proposed system or application is likely to operate or function as expected [14]. Using, data from "Wal-Mart RFID-enabled stores" over a period of 29 weeks, the conclusion was reached that RFID-enabled stores were 63% more efficient in replenishing out-of-stocks than stores without RFID, thus leading to a reduction of out-of-stocks by 16% over that 29 week period [12]. In a more recent study, [15] examined data collected over a period of 23 weeks from eight test stores equipped with a new "RFID-based perpetual inventory adjustment tool" and a corresponding set of eight control stores (without RFID), and found that

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"RFID is making a difference. Understated perpetual inventory inaccuracy declined by about 13% in the test stores, relative to control stores, with no additional labour. Furthermore, manual adjustments declined in the test stores" (p. 55). Finally, the outcome of a study by [11], who used a PoC in a laboratory setting, was that process optimization can be achieved when the RFID technology is integrated in intra- and inter-organizational information systems applications. All these studies have been largely conducted in large firms, but very few of them are concerned with RFID adoption within small-to-medium firms.

3. Methodology

The research study documented in this paper involves a case examining a single small-to-medium retailer. A case study method has been employed as it is ideal for investigating contemporary events and is able to take into account a wide variety of evidence [16]. For this study data have been gathered through the collection of procedural documents, semi-structured interviews and a participant observation. This paper presents the data collected from the semi-structured interviews conducted with employees of the organization, as well as revealing the business process flows (through flowcharts) of the organization in order to determine whether RFID is a feasible automated data capture technology for small-to-medium retailers. An observational study was also conducted over a period of two weeks in 2007. A daily diary was kept by the participant and this data was analyzed together with full-length transcripts. A single small-to-medium hardware retailer is focused on in this paper in order to analyze and present inventory control practices.

3.1. Research design

As the main objective of the overall study is to improve our understanding of RFID impacts in the context of a small-to-medium retailer, the research design is clearly an exploratory research initiative. A case study method has been conducted as it is ideal for investigating contemporary events and is able to take into account a wide variety of evidence [16].

3.2. Research sites

The organization examined in this study is located on the south coast of New South Wales, approximately 128 kilometers from the centre of Sydney. The company employs ten staff including casuals and is classified as a small-to-medium hardware retailer. The current proprietors have operated the business since 2003. The premises of the retailer measures approximately 2000 square meters, with about 550 square meters of this area making up the internal shop floor. The shop floor is composed of four sheds, each with independent access. There are two small internal offices, one designed to deal with customer purchasing and point-of-sale (POS) transactions while the other is used by managers and bookkeepers for ordering, accounting and other administrative practices. The external perimeter of the organization is surrounded by an eight foot high barbed wire fence.

The retailer currently possesses between $300,000 to $400,000 worth of inventory which is kept on the premises. The inventory held by the organization is estimated to consist of 5000 product lines, which are provided by 110 active suppliers. Products and other inventory are stored or displayed before purchase inside the store or outside within the confines of the premises. Items and stock within the store are positioned based on the type of product as well as the supplier. Most items kept inside the store are also shelved on racks that measure 2.1m in height. The shop floor is divided into five separate areas that include general hardware, timber, gardening, cement and building supplies. Products stored outside are generally unaffected by environmental and weather conditions such as landscaping supplies, cement blocks, treated pine sleepers and sheets of steel reinforcing. Stock is usually delivered to the store packaged at pallet, crate, carton or item level.

The retailer provides many services to its customers primarily through the selling of hardware and other building related supplies. The organization provides a delivery service to its customers if they purchase products that are too large to be transported or products that they wish to be delivered on a certain day. Products are delivered to customers in one of the three vehicles the organization owns. A flat top truck is used for steel deliveries, a tip truck is used for landscaping supplies and a utility vehicle is used for general deliveries. The organization also has a front-end loader that it uses to load landscaping supplies on vehicles. The organization offers accounts for customers that purchase products frequently.

The retailer currently has limited Information Technology (IT) infrastructure and does not utilize a server, as the current operations of the business do not require a large volume storage device. The organization utilizes two desktop computers in their administration office that are primarily used to manage customer accounts through the software package MYOB Premier Version 10. At the end of each month, the organization uses the MYOB software to generate invoices which are sent out to account holding customers, requesting that they pay for the items they have purchased. The organization has another desktop computer which is used by employees to search a program that acts as an index of paint colors provided by different paint suppliers. All computers within the organization are able to access the Internet.

3.3. Data collection

For this study data have been gathered through the collection of procedural documents, semi-structured interviews and a participant observation. This paper presents the data collected from the semi-structured interviews conducted with employees of the organization, as well as revealing the business process flows (through flowcharts) of the organization in order to determine whether RFID is a feasible automated data capture technology for small-to-medium retailers. An observational study was also conducted over a period of two weeks in 2007. A daily diary was kept by the participant and this data was analyzed together with full-length transcripts. A single small-to-medium hardware retailer is focused on in this paper in order to analyze and present inventory control practices.

3.3.1. Interviews-interviewees. Insights into the current inventory control practices at the small-to-medium retailer are based on semi-structured interviews carried out on four employees of the organization. The roles and duties of these employees are documented in Table 1.

Table 1. Employee roles and duties

ID	Job Title	Duties
1	Proprietor/ Manager	Stock replenishment, capital purchasing, staff management, delivery scheduling, customer service
2	Proprietor/ Part-Time Manager	Stock replenishment, staff management, delivery scheduling, delivery truck driver, customer service
3	Store Manager	Stock control and replenishment (for some of the stock), customer service, staff management, shop maintenance
4	Delivery Truck Driver	Stock delivery, stock control and replenishment (for some of the stock), customer service

As can be seen from Table 1, employees of the organization have minimal job specialization, which reinforces [17] observations of small businesses. The proprietor/manager and proprietor/part-time manager are responsible for the overall running of the business whereas the store manager is specifically responsible for shop maintenance and management. The delivery truck driver is primarily responsible for making outbound deliveries. The store manager and delivery truck driver are answerable to both of the proprietor/managers.

3.3.2. Interview questions and the inventory cycle. Inventory control as defined by [18] involves “coordinating the purchasing, manufacturing and distribution functions to meet marketing needs”. Coordinating these functions requires many discrete activities including ordering stock or materials and shelving or putting it in the correct position so that customers have access to it. In this section, the inventory control process has been broken down so that the inventory practices of the small-to-medium retailer can be explored in greater detail. Figure 1 illustrates the inventory cycle. It should be noted that the inventory flow cycle is focused on the flow of raw materials to their finished state, while this inventory control cycle has been developed based on a retailer that sells finished goods (p. 21) [19].

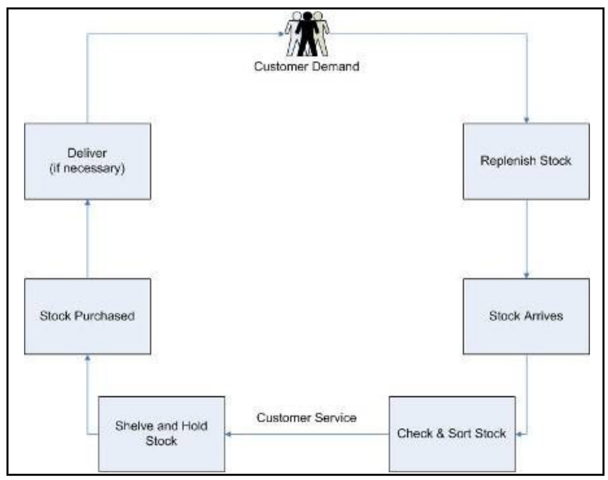

Figure 1. The Inventory Cycle

As can be seen in Figure 1, customer demand triggers the ordering or re-ordering of stock. Stock then arrives at the retailer, where it is checked and sorted before being shelved in the correct position. Stock is then purchased by a customer and delivered by the retailer if necessary.

The inventory cycle demonstrated in Figure 1 was considered when developing questions for the semi-structured interviews. The majority of the questions asked related to the six different processes that were identified in the inventory control cycle. There were a total of twenty-eight questions included in the original semi-structured interview protocol but additional probing sub-questions were asked where the respondent was able to expand their response due to their knowledge of operations. The questions covered the background of the company case, the role of the employee in the organization, questions related to the current mode of operation to gauge the current inventory control practices and set-up, and more speculative questions regarding the transition of the organization from a manual-based system to barcode and/or RFID. For instance the proprietor was asked:

1. Can you describe the process that you use to check that orders have been delivered with the correct contents?
2. Do you keep any sort of record of how much stock you carry, either in physical or electronic form?
3. How would you describe the theft prevention measures in your workplace?
4. What triggers your organization to reorder or order stock?
5. Are there any issues affecting your adoption of automated data capture technology?
6. Do you think that RFID could be used within your business to improve inventory control?

The interview transcripts were analyzed using a qualitative approach and the findings were presented using a modular narrative style based on the steps in the inventory control cycle. The following sections summarize the findings of the semi-structured interviews.

3.3.3. Participant observation. A participant observation requires the researcher to become a direct participant in the social process being studied by becoming a member of an organization. The participant observation was carried out over a two week period with the intention of recording observations relating to the inventory control practices used within the small-to-medium retailer. This study utilizes an overt participant observation as members of the organization were already aware of the researcher's presence due to interviews being carried out at an earlier date. The overt approach was perceived to have had minimal influence on the behavior of the organization's members as they were informed that the purpose of the study was to examine inventory control practices of the retailer, not their personal behaviors. During the participant observation annotations and issues were documented through the use of a diary. Field notes were recorded during each day, and were formalized at the end of the day.

3.3.4. Procedural documentation. The small-to-medium retailer's procedural documents were used to complement the semi-structured interviews and participant observation. Documentary secondary data, such as an organization's communications, notes, and other policy and procedural documents have been examined.

Table 2. The four RFID-enabled scenarios

	RFID-enabled loss prevention simulation	Delivery portal simulation	Tag environment simulation	RFID-enabled- locating misplaced stock simulation
Aim	To determine whether RFID can be used to promote loss prevention, by identifying tagged items that customers exit the store with	To create an RFID portal in order to accurately identify items and products as they leave the loading dock of the retail store	To test if the environment in which a tag is placed has an effect on its readability	To accurately identify an RFID tagged item or items that have been moved from within the range of one antenna to within the range of another antenna
Significance	To demonstrate how RFID can be used as a loss prevention mechanism and help prevent or reduce theft within the organisation	To demonstrate how RFID can be used to track and identify items that have been either delivered to the store or are being delivered to customers from the store	To test the technical feasible an RFID based system in a small-to-medium hardware store	To demonstrate the effectiveness of RFID in identifying and locating items that have been misplaced
Apparatus	-Symbol XR440 fixed RFID reader -Symbol AN400 High Performance Area Antenna -Stock (products) -Passive RFID tags	-Symbol XR440 fixed RFID reader -Symbol AN400 High Performance Area Antennas -Stock (products) -Delivery trucks -Pallets -Passive RFID tags	-Symbol MC9090-G -Mobile computer -Stock (products) -Passive RFID tags	-Symbol XR440 fixed RFID reader -Symbol AN400 High Performance Area Antenna -Stock (products) -Passive RFID tags

Official documents, like procedural documents can be treated as unproblematic statements of how things are or were (p. 104) [20]. The procedural documents have been used as evidence to support the determination of the inventory control practices of the small-to-medium retailer. The interviews conducted, participant observation and the collection of procedural documents were combined to develop the business process flows of the organization. A narrative presentation is used to bring together participant observational data and interviewee responses.

3.4. Simulation of RFID-enabled scenarios

Eight simulations have been developed which are aimed at examining different aspects of inventory control and known RFID issues that have been documented in the literature. However, within the scope of this paper, we'll only present and discuss four RFID-enabled scenarios (Table 2): (i) RFID-enabled loss prevention, (ii) RFID-enabled delivery portal, (iii) RFID tag environment simulation and (iv) RFID-enabled locating misplaced stock.

The results of the simulations are documented qualitatively, discussing read rates as well as any other technical issues experienced in the following section.

3.4.1. RFID enabled-loss prevention simulation-method. A fixed RFID reader with one and then two antennas will be placed above or around the entry/exit of the store with the aim of identifying any tagged item or product that passes through the entry/exit. Items that have been tagged with RFID labels will be moved past the reader in order to determine if the tag is interrogated and identified successfully. The tagged product will be concealed by the participant carrying it so the effect of this can be gauged. Multiple items will also be carried out by the participant to test if the reader identifies multiple tagged items.

In the initial part of this simulation a fixed reader was set up with one antenna which was positioned above the entry/exit, 2.1 metres off the ground.

The antenna was orientated at a 45 degree angle, sloping inwards towards the interior of the store. The participant walked towards the entry/exit with an RFID tagged item held 1.5 meters off the ground. Five different items of stock were used in this simulation, each being RFID tagged in a different configuration. Two of the items had tags wrapped around them so the tag was overlapping itself, one item had its tag wrapped around it but was not overlapping, another item was labelled with a tag that was folded in half and the final item had a tag applied to it in a general flat configuration. The tagged items were passed through the RFID monitored entry/exit individually in plain view of the reader, then concealed under the jumper of the participant and finally all items were passed through the entry/exit simultaneously in a plastic basket.

Exhibit 1. An RFID armed entry/exit

The results revealed that items which had RFID tags wrapped around them and were overlapping could not be detected by the reader when passed through the entry/exit. It was also found that concealing items had an effect on whether they would read or not with a single concealed product being identified compared to the three tagged items which were identified when they were passed through the entry/exit in plain sight. Table 3 summarises the results of the simulation (✔ = read successfully, ✖ = not able to be read).

Once this simulation was carried out another antenna was attached to the fixed reader and a small portal was created to see whether it was more accurate to identify tagged products from side-on than from above. Figure 2 illustrates the configuration of the portal.

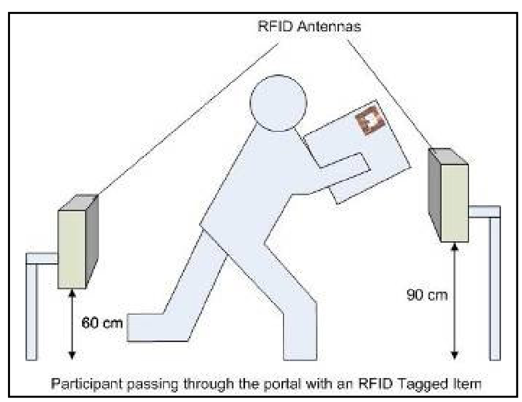

Figure 2. Configuration of the loss prevention portal

The participant once again walked through the doorway with items held 1.5 metres from the ground.

The items that had RFID tags wrapped around so they overlapped were still not able to be read in this variation of the simulation, but three tagged items that had been concealed were identified compared to the one item identified in the previous variation. The range of the antennas was also tested with items being passed through the portal held above (1.8 metres from the ground) and below them (30 centimetres from the ground). The three tagged items that were identified initially were also read when they were passed above and below the antennas at the entry/exit to the store.

The results of this simulation revealed that RFID experienced poor to average read rates when implemented for loss prevention. It is perceived that if RFID was applied in the small-to-medium retailer for loss prevention purposes, theft may be reduced but the reliability of the technology could not be guaranteed; unless orientation issues are resolved and read rates are improved.

Table 3. Loss prevention simulation results

Item or product	Tag orientation	Identified individually	Identified when concealed	Identified with multiple items in plastic basket
250 ml Lime Sulphur Insecticide Concentrate (in plastic bottle)	Wrapped around item, tag overlapping	✗	✗	✗
250 ml Cabothane Clear Finish (in metal can)	Wrapped around item, tag overlapping	✗	✗	✗
150mm Diecast Door Pull (in plastic/cardboard packaging)	Folded in half and applied to the item	✓	✗	✓
Wooden Hammer Handle	Wrapped around item tag not overlapping	✓	✗	✓
2kg 100mm x3.75mm Bright Bullet Head Nails (in plastic container)	Flat	✓	✓	✓

3.4.2. RFID-enabled delivery portal simulation-method. This simulation involves RFID tagged items being placed on a pallet then onto a delivery vehicle at the loading dock of the hardware store. A portal will be created at the loading dock, equipped with two antennas originating from an RFID reader which will be used to identify the products and stock that are moving in and out of the premises.

To test the RFID delivery portal, a flat top truck is reversed into the loading bay of the organisation. Seven products that are commonly delivered to or by the organisation are RFID tagged, including a wooden pallet which the items are placed on. The truck is reversed in and out of the loading bay on five occasions and the read rates are recorded each time.

Exhibit 2. Tagged RFID products on pallet (top); the flat top truck being reversed into the loading dock (middle); the utility vehicle in the RFID portal (bottom)

Three of the tagged items including a piece of treated pine, a roll of foam joint and the pallet are successfully interrogated on each of the five times the truck is reversed.

A tagged piece of treated pine is also identified on the first and the last time the vehicle is backed into the loading dock.

The other three items on the truck are unable to be identified at all, most likely due to the back tray of the truck, sitting higher than the antenna (all the RFID tagged products on the truck were situated above the antenna).

Another vehicle, a utility that is used by the organisation to deliver products is then employed in the simulation with the same products and pallet being placed in the vehicle's tray. The tray of this vehicle is at a more suitable height for the RFID antennas, as it sits 80 centimetres off the ground. Exhibit 2 demonstrates the RFID portal with the utility vehicle reversed into the loading dock.

Ten products composed of varying materials were RFID tagged and attempted to be read by the mobile RFID reader. The compositions of the ten items tagged varied greatly with some of them being made or packaged from metal, plastic, cardboard, paper, wood and stone. Some of the items such as the container of nails and the bag of cement were also dusty and dirty. The mobile RFID reader was used to make six attempts to read data from all of the tagged products individually. Table 5 reveals the results of the six attempts for each product (✔ = read successfully, ✗ = not able to be read).

As can be seen in Table 5 all items could be read by the mobile reader, but objects made of metal took around 5 or 6 attempts to be read successfully. It should also be noted that dirty and dusty products were interrogated successfully by the reader on every attempt.

Table 4. Read rates of RFID tagged items on the utility vehicle

Attempt	*Treated Pine Timber 2.1mx70x35mm*	*Treated Pine Timber 1.3mx70x35mm*	*General Purpose Cement 20kg*	*Aluminium Angle 50x50x3mm x1m*	*Foam Joint 75x10mmx 25m*	*Masonite 900x600x 4.8mm*	*Wooden Pallet 600mmx1m*
1	✔	✔	✗	✗	✔	✔	✔
2	✔	✔	✔	✔	✔	✔	✔
3	✔	✔	✔	✗	✔	✔	✔
4	✔	✔	✔	✔	✔	✔	✔
5	✗	✔	✔	✔	✔	✗	✔

The read rates experienced when products were placed on the utility were far superior to those experienced when the flat top truck was employed, with read rates ranging from 71% to 100% of all items and products tagged. Table 4 reveals the read rates of the tagged items and products on the utility vehicle (✔ = read successfully, ✗ = not able to be read). This simulation illustrated that if an RFID portal was constructed appropriately by considering the conditions and vehicle used by the small-to-medium retailer it could effectively monitor stock being delivered to the business and stock being delivered to customers of the business.

3.4.3. RFID tag environment simulation-method. This simulation involves trying to identify RFID tagged products of various compositions using the mobile RFID reader. Items composed of wood, metal, plastic, stone and those containing liquids were tagged and attempted to be read. Items left outside and exposed to the elements were also tagged and attempted to be read, along with other items that are stored in dirty manufacturing type environments.

In order to further test the effect the environment had on the readability of tags, four items that were regularly kept outside were RFID tagged. These items included a treated pine sleeper, a stone paver, a bale of sugar cane mulch wrapped in plastic and a 6 metre length galvanised pipe (Exhibit 3).

Exhibit 3 An RFID tagged treated pine sleeper (top); An RFID tagged pipe (bottom)

After being tagged with RFID labels these items were left outside for five nights. It rained quite heavily over the time the items were left outside and upon examining the products and RFID tags after the fifth night had elapsed, they were saturated.

This however did not have any effect on the readability of tags, with all items being successfully identified in all six of the scans except for the metal item (the 6 metre length of galvanised pipe) which was only interrogated successfully on the sixth attempt.

To compare the robustness of RFID tags and barcodes, a cardboard box with a barcode imprinted on it in ink was also left outside over the same period as the RFID tagged items. Like the RFID tags and products the cardboard box was saturated after the fifth night outside. The barcode on the box was able to be scanned successfully, but when the researcher applied some friction to the barcode it was damaged. Once the barcode was damaged it could not be identified by the barcode reader. Unlike the barcode the RFID tags were not affected or damaged by friction in this simulation.

Table 5. Read rates of the environment simulation

Item	*Attempt*					
	1	*2*	*3*	*4*	*5*	*6*
Flat Sheet of Metal 300mm x 900mm x0.5mm	✗	✗	✗	✗	✓	✗
3/8 inch Mudguard Washer	✗	✗	✗	✗	✗	✓
Electrical Tape	✓	✓	✓	✓	✓	✓
Sleeve Bolt Anchors 12mm x 9mm (in cardboard box)	✓	✓	✓	✓	✓	✓
76mm Zinc Eyebolt (in plastic/cardboard packaging)	✓	✓	✓	✓	✓	✓
Wooden Hammer Handle	✓	✓	✓	✓	✓	✓
Methylated Spirits 1 Litre (in plastic bottle)	✓	✓	✓	✓	✓	✓
Stone Paver	✓	✓	✓	✓	✓	✓
5kg Galvanised Flathead Nails 65mmx 2.8mm, (in plastic container) -**Dusty and Dirty**	✓	✓	✓	✓	✓	✓
4kg White cement (in plastic bag) -**Dirty and Dusty**	✓	✓	✓	✓	✓	✓

This simulation revealed that the readability of RFID tags was not affected when applied to products of varying compositions, except for products composed of metal which resulted in these products only being identified in about one out of six attempts. It was also revealed that RFID tags were able to function after being stored outdoors and exposed to the elements over five nights. To further test the robustness of RFID tags it is recommended that they are exposed to the same environmental conditions for longer periods of time in a future study.

3.4.4. RFID-enabled- locating misplaced stock simulation-method. An RFID tagged product will be positioned so that it can be read by an antenna attached to a fixed RFID reader. Once data have been read from the tagged item it will then be moved around the shop to another location so it is within range of another antenna. The results of this simulation will focus on the 'tag reads' at each of the antennas. After one tagged item has been tested the read rates of multiple items will be observed.

A fixed RFID reader was set up with two antennas situated 10 metres apart. RFID tagged items were initially positioned in front of an antenna then put on a trolley and moved outside the range of the antenna and into the range of a second antenna to simulate stock being misplaced within the retailer. Exhibit 4 shows RFID tagged products that have been moved past an antenna on a trolley.

Exhibit 4. RFID tagged cartons of nails within the read range of an antenna

A plastic 5 kilogram carton of galvanised bullet head nails was RFID tagged and moved from the read range of the first antenna to within the read range of the second antenna which resulted in it being detected by both antennas. Once a single RFID tagged carton was tested more were introduced to further examine the accuracy of the antennas. Table 6 illustrates the results of this simulation. It should be noted that in the table, tags which were identified by both antennas (at the first antenna prior to being 'misplaced' and or the second antenna after being 'misplaced') were recorded as being read successfully (✓ = read successfully, ✗ = not able to be read).

Table 6. Products identified in the locating misplaced stock simulation

Number of cartons attempted to be Identified	Number of cartons of nails									
	1	2	3	4	5	6	7	8	9	10
1	✓									
3	✓	✓	✗							
5	✓	✓	✓	✓	✓					
8	✓	✓	✓	✗	✓	✗	✓	✓		
10	✓	✗	✓	✗	✓	✓	✓	✗	✓	✓

The results revealed read rates ranging from 67% to 100% for the five tests conducted in this simulation. When products were placed on the trolley and transported between antennas they were placed in a random configuration which meant that the RFID tags applied to them were not presented to the reader in the same arrangement for each of the tagged cartons of nails.

It was noted that tagged cartons that were not detected when moved between antennas, had tags orientated perpendicular to them or had tags that were applied to the opposite side of products. Figure 3 illustrates where RFID tags were applied on products that were not identified by the antennas.

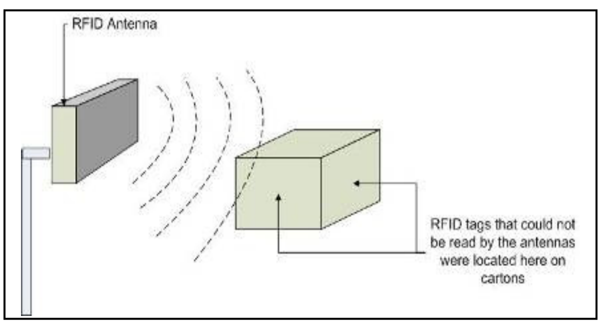

Figure 3. The position of RFID tags that were not identified

Apart from the orientation issues that were encountered, this simulation illustrated that RFID could be used within the small-to-medium retailer to monitor the positioning of products within the store. If RFID was employed in the store and appropriate backend software was developed it is highly likely that misplaced items that had been tagged within the store could be registered on the system, and found thereafter.

4. Discussion and conclusion

The simulations revealed that items with overlapping RFID tags wrapped around them could not be detected by the reader when they passed through the entry/exit. It was also found that concealing items had an effect on whether they would read or not with a single concealed product being identified, as compared to the three tagged items which were identified when passing through the entry/exit in plain sight. Moreover, the results showed that RFID experienced poor to average read rates when implemented for loss prevention. It is perceived that if RFID was applied in the small-to-medium retailer for loss prevention purposes, theft may be reduced but the reliability of the technology could not be guaranteed, unless orientation issues were resolved and the read rates improved. Also, if an RFID portal were constructed appropriately, taking into account the conditions and the vehicle used by the small-to-medium retailer, it could effectively monitor the stock being delivered to the business and the one delivered to the customers of the business. In addition, the study revealed that the readability of RFID tags was not affected when applied to products of varying compositions, except for metal products – which were identified only once on six attempts. Moreover, the RFID tags were able to function after being stored outdoors and exposed to the elements over five nights. These results provide strong support to previous studies on RFID technology [11, 12] and highlight the fact that RFID technology is mostly product driven, and therefore, the best performance of the system heavily depends on the type of product, the context of implementation, the level of tagging, etc.

Consequently, a scenario building, validation and demonstration of RFID-enabled process optimization is highly recommended prior to any large RFID technology deployment [13]. To our knowledge, this study is among the first studies to illustrate that RFID technology could be used within a small-to-medium retailer in real-life settings to monitor the positioning of products within the store, to help small-to-medium retailer prevent in-store stock losses, enhance delivery process and improve the process of locating misplaced stock within the store. Nevertheless, these findings are consistent with results of prior research by [15] at Wal-Mart stores, which are mainly large stores. Despite these encouraging results, further tests on the robustness of RFID tags should be conducted when they are exposed to the same environmental conditions for longer periods of time. Moreover, given that the more recent RFID tags have a tag reading accuracy of almost 100%, their use is highly recommended [21]. The study was conducted in a single store of a small-to-medium retailer situated almost at the last node of the retail supply chain, and therefore was not able to capture the network effects of RFID technology.

Therefore, further works need to be done to assess the impact of RFID technology at the supply chain level in a real-life setting and to develop different models of cost sharing between stakeholders involved in RFID-enabled projects.

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