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Improving sales turnover in fashion retailing by means of an RFID-based replenishment policy

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Abstract.

In this paper, we aim to provide evidence of the capability to generate an increase in sales turnover by implementing an RFID-based system able to improve the shelf replenishment operations, reducing stock-out situations in fashion retailing.

To assess the increase in sales turnover, we developed a pilot project involving a store of a major fashion firm located in northern Italy. RFID technology was used to generate daily a list of models that turned out to be available in the backroom, but not on the shelves (referred to as "scandals"), to drive employees in the replenishment process. By subsequently monitoring the consumer's purchase, we estimated the contribution of RFID technology to the store turnover.

We found that increasing the availability of products (and of scandals in particular) on the shelves leads to a significant increase in the sales volume. Moreover, the availability of those products on the shelves stimulates the customers to ask for different sizes or colours of the items exposed, generating further potential for sales increase.

The results of this study may encourage fashion retailers to invest in RFID technology, whose cost often appears as high, since the increase in turnover can significantly contribute to recover the initial investment required. Also, since we carried out an in-field implementation, targeting a real scenario of the fashion industry, our results are realistic, solid and reliable. Fashion retailers can look at them as a concrete possibility to improve their business by adopting RFID technology.

Keywords: RFID, fashion industry, turnover increase, pilot study, shelf replenishment

1. Introduction

Radio Frequency Identification (RFID) is a wireless technology, used to tag, recognize, track and trace automatically the movement of an item, by using transmitted radio signal (Jones et al., 2005).

RFID is increasingly deployed for product tagging throughout the supply chain, in the light of the numerous benefits it can bring to the supply chain players. For

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instance, by applying RFID tags at item-level, each product can be easily tracked and information about its state and location can be shared real time within the whole supply chain (Prater et al., 2005). This brings significant improvements to the logistics processes, in terms, for instance, of better inventory control, stock-out reduction, labour savings, reduced shrinkage and transaction errors (De Marco et al., 2011).

In fashion retailing, the value of RFID technology is particularly relevant, because its implementation has the potential to solve some problems that are unique to that industry (IDTechEx, 2005a). Specific features of the fashion supply chain, which make this business environment particularly challenging, are short product lifecycle, high volatility and low predictability of the demand, often coupled with a high purchasing impulse of customers (Christopher et al., 2004). In such a context, delivering new products to the customer quickly in response to market changes is crucial. Similarly, identifying the customer's needs quickly and correctly is a main leverage to gain competitive advantage. Moreover, fashion retailers experience significant economic losses in the case of out-of-stock (Garrido Azevedo & Carvalho, 2012). To this extent, the deployment of RFID technology can bring significant benefits to the fashion retailers, by enhancing process automation and labour efficiency, as well as by improving the accuracy of logistics activities (Agarwal, 2001; Prater et al., 2005). Moreover, the availability of RFID data can open new business opportunities and strategies (Krotov, 2008; Bertolini et al., 2009). For example, at the point of sale (POS) level, RFID technology can help identify the demand trends and build a probabilistic demand pattern, thus counteracting the high degree of demand uncertainty (Zhu et al., 2012). Furthermore, sales transactions can take place instantly, avoiding long payment queues. The unpredictable behaviour of fashion shoppers could also be studied in greater detail, exploiting, for example, RFID-based customer cards able to record the behaviour of each customer (Moon et al., 2008).

A study conducted by Bertolini et al. (2012) at an Italian fashion brand showed that the implementation of RFID technology at a distribution centre and at a retail store served by that distribution centre could improve the shipping process, the inventory and shelf replenishment activities, at the same time reducing the time required for receiving and sell-in operations. In addition, some RFID readers with a near field antenna positioned in every fitting room allowed collecting try-ons data, whose availability, in the case coupled with complementary data, opens new possibilities for stylists and marketing managers. According to the same authors, RFID has also the potential to increase the sales volume of fashion items. Indeed, by means of RFID item-level tagging at the retail store and of a tailored software application, an employee could immediately inform the interested customer about the availability of the garments he/she is looking for and that do not seem to be available at the store shelves. This led to an increase in the number of items sold of about 0.52%. Moreover, replenishment operations could be improved, since RFID reads allow to identify those items which are stored in the backroom but are not available on the shop floor. The RFID-enabled replenishment process led to a further 4.91% increase in the sales volume, taking into account the fashion items whose dwell time on the shelf, before the sale, was lower than a week. Similar results are proposed by Gaukler (2010). This author found, in particular, that more than 80% of the benefits generated by RFID deployment are directly linked to preventing avoidable out-of-stocks *via* improvements to the backroom-to-shelf replenishment process.

The examples above suggest that fashion retailers can reach a considerable increase in the sales volume by exploiting RFID technology to optimally manage their inventory, thus reducing the occurrence of stock-out situations. In the fashion industry, the increase in the sales volume obtained by reducing stock-out occurrence can be particularly relevant: estimates by American Apparel indicate that sales volume typically increases by 15% to 25% when Stock Keeping Units (SKUs) are available on the shop floor (Zhu et al., 2012). An increase in the sales volume, and therefore in the store turnover, could be an important incentive to the deployment of technologies, such as RFID, whose implementation cost is often regarded as difficult to recover. Please note that, in this work, by SKUs we mean a specific combination of model, colour and size that can (or cannot) be available on the shop floor in different quantities of items (or garments). Also, by model we mean the style or design of a particular product, and models can be grouped in classes due to the similarities of their styles or designs.

The availability of SKUs on the shop floor, as mentioned, could be ensured only by means of adequate replenishment operations. To this extent, De Horatius & Ton (2009) pointed out that non-optimal product availability on the store shelves is due to three main factors, i.e. poor assortment, inadequate inventory planning and poor execution of the replenishment process. Similarly, Gruen et al. (2002) estimated that 25% of all stock-out situations observed in retailing are caused by inefficiencies in shelf replenishment operations, which lead to a lack of products on the shop floor even though the same product is available in the store backroom. This brings back to the importance of the replenishment process and its correct management, in order to reduce the occurrence of stock-out situations and stimulate the customers to purchase. RFID technology can be used to detect discrepancies between the inventory available on the shelf to satisfy the customer's demand and the backroom inventory. Related to this latter point, one of the biggest problems that retailers face concerns the inaccuracy of inventory records; inaccuracy can lead to wrong decisions in managing inventories, thus generating either excessive costs or stock-out situations (Hardgrave et al., 2009a). During a study conducted in the fresh food supply chain, Bertolini et al. (2013) observed that, thanks to the improved inventory accuracy and shelf management and to the reduction of stock-out situations, RFID technology could bring an increase in the sales turnover of about 1.75%. Although this implementation is specific to the food industry, it can be argued that RFID technology has potentials to improve inventory accuracy in different contexts. Looking at the fashion industry, a study by Hardgrave et al. (2009b) demonstrated that the implementation of RFID technology improved inventory accuracy at Bloomingdale's by more than 27%. Fashion retailers obviously take advantage of the higher accuracy of their inventory records, by improving the efficiency of stock control and shop floor management; those activities are particularly critical to that industry, because of the short life cycle of products and the complex assortment requirements (Moon et al., 2008).

A further relevant problem for fashion retailers is the need to display numerous products, of different styles, colours and sizes, in a limited space, such as the store shelves. Some studies in literature suggest that RFID could be useful to deal also with this problem. For example, using a simulation model, Condea et al. (2011) demonstrated that significant benefits can be achieved combining RFID technology with the most suitable shelf space allocation decisions and with a flexible replenishment process, which should be adapted continuously by the inventory management system to meet the customer's demand. Moreover, with respect to the replenishment issues, Hardgrave et al. (2005) carried out a study in 12 retail stores of the Wal Mart distribution channel. Although their work did not target the fashion industry, they showed that RFID can bring significant benefits in the replenishment operations, by generating automatic picking lists for shelf replenishment, on the basis of the items sold. The implementation resulted in an increased accuracy of the picking process and in significant time savings, by reducing manual scanning of empty shelves to detect possible missed products. Overall, the authors observed a decrease in stock-out situations of about 16%. A similar process could be implemented also in the fashion industry, to improve the accuracy of replenishment operations.

As already mentioned, a decrease in stock-out situations can significantly affect the sales volume of the fashion retailers. IDTechEx (2005b) explained that GAP, the US apparel company, increased its sales by 2% by reducing stock-out, using RFID technology. Similarly, a pilot project, involving 280 American Apparel fashion stores, ascribed to the implementation of RFID technology an increase in sales volume of the retail stores up to 15% (RFID Journal, December 12th, 2008). De Marco et al. (2011), through a simulation model, observed that the introduction of RFID technology in the Miroglio Fashion retail channel increased the personnel's time available for customer care significantly, up to 2.5%, thanks to the corresponding decrease in the time spent by the employees in backroom operations. Although the authors did not carry out a pilot implementation, their results suggest that retail stores adopting a sales-person-assisted strategy could benefit from an increased turnover as a result of the increased time available for customer care.

Overall, the studies reviewed indicate that RFID technology has the potential to increase the turnover of the fashion industry, thanks to improvements in the replenishment operations and the increase in product availability on the store shelves. In line with this premise, this study aims to provide a quantitative assessment of the RFID impact on the turnover of the fashion industry, with a particular attention to the sales volume generated by optimizing the shelf replenishment process. The quantitative evaluation is obtained starting from real data, collected in-field as the result of a pilot implementation, involving a store of a famous fashion firm located in northern Italy. To be more precise, this study presents a quasi-experimental design – namely a pre-test/post-test design without a control group, as illustrated in Shadish et al. (2002). This approach was chosen because our field experiment failed the true test of an experimental manipulation, i.e. random assignment to groups, due to practical reasons.

The remainder of the paper is organized as follows. In the next section, we describe the pilot implementation, the research methodology, the data collected from the in-field measurements and their subsequent elaborations. In Section 3, we present the detailed results of this study. Finally, in Section 4, we discuss the main findings and highlight research limitations and future research directions.

2. Experimental design and methodology

2.1. Background and objectives

The research proposed in this paper is the last step of an experimental campaign started by the RFID Lab of the University of Parma (Italy) in 2012, in collaboration with an important Italian company operating in the fashion industry (we will refer to it as "fashion retail store" hereinafter, due to secrecy reasons). The campaign began with the implementation of RFID technology in the fashion retail store.

A preliminary analysis, carried out in late 2012, focused on the benefits that RFID could bring to the different logistics operations and store activities, and compared the original (manual) processes with the new (RFID-enabled) ones. This analysis highlighted that RFID technology could bring significant improvements in receiving, replenishment, inventory, check-out and return flows management, thanks to the capability to reduce the time required for manual operations, and to ensure a quick and accurate acquisition of information about the status and location of each item. During that step of the research, a software application, called *RSA dashboard*, was also developed, to help calculate and monitor some specific key performance indicators of the retail store processes. The dashboard also allowed monitoring the stock availability and the trend of the sales in time. Furthermore, the dashboard highlighted the SKUs that were out-of-stock; by knowing the sales rate of those items, the loss of sales due to the occurrence of stock-out situations could be estimated.

In the second step of the research, which is described in this paper, the focus was on assessing how RFID technology can improve the replenishment operations, by means of accurate data about the fashion items and their location in the store. Specifically, the objective of the analysis was to exploit this technology to facilitate and speed up the identification of those SKUs that were unavailable on the store shelf, but were stocked in the backroom, and, therefore, could be replenished. The implementation of the RFID-enabled replenishment process targeted a specific set of SKUs referred to as "scandals". By scandal, we mean a SKU with a significant sales volume, and whose stock level, at a given time, is found to be very low (i.e., null or equal to one item) on the shop floor and greater than zero in the backroom. If detected, such SKUs should be prioritized during replenishment operations.

2.2. Analysis of the replenishment processes

The implementation of RFID technology in the fashion retail store brought with it a whole re-engineering of the replenishment processes. Before implementing the technology, in fact, the replenishment activities were based on: (i) number and models of items sold every day; and (ii) the identification of an out-of-stock (OOS) event of a model of products (in fact, we considered a model to be OOS if it is available on the shop floor in less than two items). At a greater detail, the pre-RFID replenishment process was as follows:

i. in the morning of every working day, before the store opening time, the store employees performed replenishment operations on the basis of the sales of the previous working day and of the amount of garments available in stock. The store information system (named POSWEB) recorded every combination of model/colour/size sold on the previous working day, and this list of SKUs sold was used for replenishment purposes on a daily basis;
ii. in addition to the previous point, whenever a store associate identified an OOS event (again, a model available in less than two items) in the shop floor for one or more models, he/she was responsible for looking in the backroom for some items belonging to that model and, if possible, replenish them in "real time". The choice of which SKU replenish of a given model was made by, or in accordance with, the store manager.

These processes, however, presented some major weaknesses. Due to internal guidelines of the company, in fact, only two different sizes for each combination of model/colour could be exposed on the shop floor at the same time, so as to maximize the number of different models shown to the customers and available for sale. That is to say that, if a specific model (e.g., model 1) is available in 3 different colours, a maximum of 6 different SKUs, i.e. combinations of model, colour and size, could be exposed in the shop floor simultaneously. Therefore, the list of items sold every day was just a draft for replenishment operations that needed to be compared with the sales floor and the backroom availabilities. Unfortunately, however, the pre-RFID system could not monitor the stock positions in the sales floor and in the backroom separately, but it rather measured the overall inventory of the store.

Therefore, as the size of the shop floor is not so large, every sales assistant is responsible for replenishing certain models during off-peak periods. This activity took, on average, 10 man-hours every working day (i.e. approx. 5 people working from 8 to 10 a.m.), and was therefore very time consuming. Indeed, due to requirements of the human resource department, 10 man-hours per opening day was the maximum time allocated to replenishment processes. One of the main goals of reengineering this process was to automate it and, potentially, reduce OOS. As it was commonly perceived by store associates, in fact, the replenishment processes was often interrupted by opening times at the shop and, therefore, not completed correctly.

For this reason, this practice often resulted in the lack of some products on the shelf, because of the high number of models and variants composing a fashion collection and of the limited space available on the shelf. This kind of mistake was only detected and corrected by the identification of an OOS event (see point ii), but some OOS events happened anyway, especially during rush periods. As an example, a model available in the backroom and not available on the store shelves would not be replenished, because of its null sales, unless some store associate would notice its OOS position and ask the store manager to replace it.

For all these reasons, the pre-RFID replenishment policy did not allow managing scandals adequately. The first option considered was to reengineer this process without eliminating barcode technology. However, analysing the problem with managers from the fashion retail store, we realised that the need to scan the barcodes of every item moved from the backroom to the shop floor, or *vice versa*, was simply not feasible, due to the increased amount of labour requested.

Therefore, we decided to implement RFID to reengineer the replenishment activities. In fact, combining sales data with RFID data related to the stock available allows identifying and replenishing scandals more easily. The final goal of the implementation of RFID was to demonstrate that the RFID-enabled replenishment generates an increase in the sales turnover, by reducing the occurrence of stock-out situations and stimulating the consumer to purchase.

2.3. Hardware and software apparatus

The fashion retail store analysed consists of two main areas: the shop floor, where items are located on the shelves, and the backroom, where products are kept in stock.

Given the aim of the analysis carried out in this paper, the accuracy of the inventory data is particularly relevant. Indeed, to design an effective replenishment process, it is essential to precisely identify which items are available either on the shop floor or in the backroom, and which items are moved from the backroom to the shop floor (and *vice versa*). Similarly, the availability of accurate POS data is crucial to determine which products are sold and should be prioritized in replenishment activities because of their high sales volume. Also, accurate POS data allow identifying those purchases that can right be ascribed to an effective replenishment strategy, resulting in a turnover increase compared to the original situation.

With the purpose of ensuring a high level of data accuracy, RFID technology was implemented in several processes of the retail store. More precisely, to facilitate data acquisition during receiving operation and return flow management, an RFID cage was installed in the store backroom, equipped with an antenna on each side. The antennas were able to automatically, and real-time, update the inventory data by identifying the products that were put in the cage for inbound and outbound activities. A replenishment gate, installed between the shop floor and the warehouse, recorded any change in the product location (i.e., from the shop floor to the backroom and *vice versa*). The gate was equipped with two antennas, able to read the tag of the items moved, and a monitor, where the information associated to the crossing items was displayed. In Fig. 1 we propose a representation of the store areas considered in the study and of the corresponding reading equipment.

To identify possible errors in inventory data and items position, periodical inventory counts were conducted separately in the store and in the backroom, using two RFID handheld readers. Errors detected were realigned to the actual situation.

A particular metal bin, equipped with two RFID antennas, was placed near the cash counter to track sales and update the stock data. Specifically, when a product is sold, the shop assistant should put the corresponding tag in the bin. By this operation, the tag will be excluded from any subsequent process and, although it is still in the store, it will no longer be read (for example, during inventory counts operations).

Finally, the aggregation and processing of the RFID reads was carried out by means of the *RSA dashboard*, which was made available to the store employees. The dashboard included five modules, such as Traceability, Historical EPC, Availability, Inventory and Replenishment. Those modules track any event occurring at the store. Moreover, the dashboard included five specific shortcuts for the analysis of the scandals, which were used during the implementation.

2.4. *Preliminary activities*

We spent the first part of the project in testing the reliability of the experimental apparatus, so as to ensure that the data collected during the experimental campaigns would have been correct and accurate.

In the pilot implementation, the fashion items arrived at the retail stores equipped with the RFID tags. Indeed, the tags, that are associated to a unique EPC code (in turn, linked to a specific item and to the corresponding SKU), were printed and encoded at the distribution centre. This latter also took care of applying them to the finished goods monitored during this study (see section 2.5) before shipping them to the retail store. Thanks to this tagging process, the receiving activities of the store can be fully automated, by simply placing the products received inside the RFID cage. This latter, by reading the RFID tags, verifies the correctness of the delivery, by comparing the items received with those expected, and updates the corresponding inventory data. After some modifications to the antennas' position and of some preliminary tests, aimed at identifying the optimal products arrangement in order to facilitate reads, the accuracy of the RFID cage reached 100%. This means that the cage, in its optimal setting, was able to read the whole sample of items placed inside it. The accuracy level was verified by means of some manual controls, where an employee compared the tags read by the cage with the number of items actually placed inside the RFID cage.

Conversely, some more difficulties were encountered when testing the replenishment gate, which took about one month and a half to be optimized. More precisely, to evaluate the reliability of the RFID gate, reading data of the crossing items were compared with the data resulting from periodical RFID inventory counts, carried out on

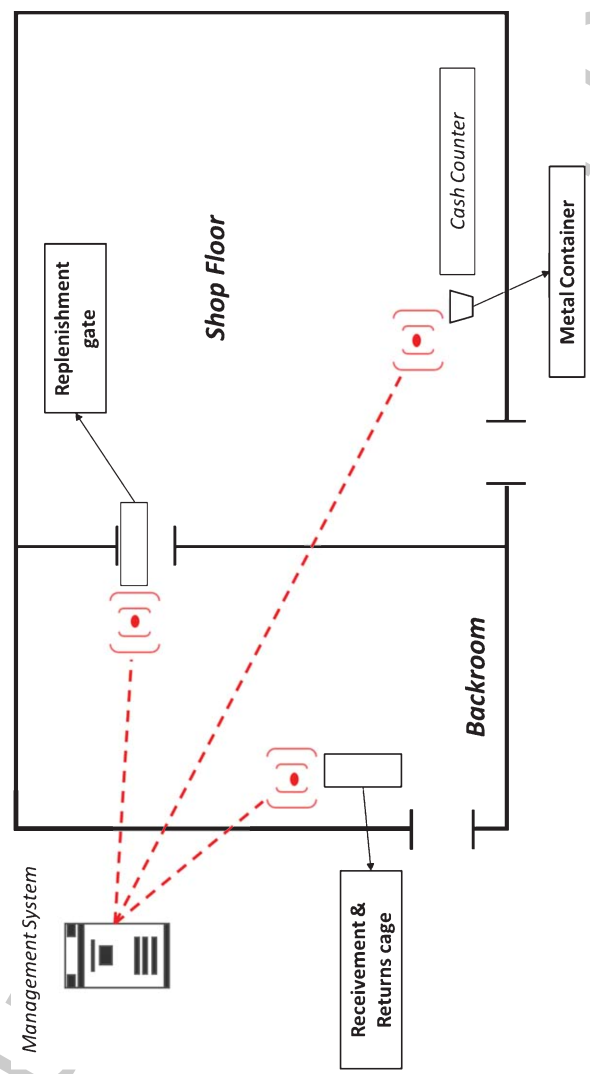

Fig. 1. Scheme of the store areas and reading points.

the whole collection available at the retail store. If the stock position of an item (i.e., either the shop floor or the backroom) was found to be different in two subsequent inventory counts, we verified whether the gate had detected the item movement from the backroom to the shop floor or *vice versa*. In the case this observation was missed, and therefore the item position recorded on the information system was incorrect, we used the information resulting from the inventory counts to update the inventory data. During the test, we observed that weekly inventory counts, coupled with the attention of the shop assistants while crossing the gate with replenished items, led to a significant accuracy in data updating. The detailed outcomes are reported in Section 3.1.

The choice of using a metal bin equipped with RFID antennas (that will be referred to as “RFID bin”, for simplicity) to record the sales data is the result of different solutions that have been tested during the implementation. Compared to other equipment that was tested during the project (i.e. an antenna with a tag-holder cage and an antenna equipped with a buzzer bleeping whenever a tag was read), the RFID bin immediately showed a significantly higher reading accuracy. Moreover, its higher capacity could be very important during sales and festivity periods, when the sales volume increases and numerous tags are put in the RFID bin when items are sold. The detailed results of the tests carried out on the check-out process are proposed in Section 3.2.

At the end of these preliminary activities, we were almost sure that subsequent analyses would have been based on solid RFID data, collected using a reliable system.

2.5. Data collection

The experimental phase began with the identification of the product classes to be monitored during the analysis. Indeed, analysing the whole set of items sold at the retail store could have been either unfeasible from a practical perspective or meaningless in terms of the number of scandals. Therefore, the application of the new replenishment policy was limited to the SKUs belonging to the most sold product classes of the store. By analysing the historical sales data of the Autumn/Winter collections, we identified five clothing classes, labelled 01, 02, 08 (coats) and 34, 36 (knitting items, i.e. the class of knitwear products).

The data collection started in September 2013. For the first two weeks, SKUs of the Autumn/Winter collection were exposed on the store shelf in rotation, in order to identify the most sold models, which should be managed with priority in the replenishment activities.

From September 23rd (Week 39) until November 17th (Week 46), excluding the weekends, the store employees carried out replenishment activities according to the new procedure of scandals management, on the basis of the observations available on the RSA dashboard. The reason why weekends were excluded from the analysis is that, although the store is opened during the weekends, store activities are particularly intense; therefore, the store’s managers preferred not to introduce an experimental replenishment procedure in those days. Indeed, during the weekends, the store is visited by numerous customers (as it is expected); hence, during the day, store employees should, primarily, assist consumers, and, despite the high sales, cannot carry out replenishment operations regularly. Accurate replenishment operations are actually performed on Monday morning. In this moment, it is likely that there will be very numerous items to replenish, because of the high sales of the weekend. According to this explanation, the sales observed on Monday were primarily ascribed to the replenishment operations carried out in the same day, early in the morning.

It should be noted, however, that the issue of collecting data only on weekdays (excluding the weekends from the analysis) does not seem to be a threat from the scientific perspective. The only reason why this could be a concern is if there was the possibility that the results would be reversed or nullified if data from the weekends were included. However, both the authors and the staff from the fashion retail store believe that it is more likely that the results would be strengthened, rather than weakened, if the weekends were included in the study. The rationale behind this opinion can be found in Hardgrave et al. (2011; 2013): as these studies report, in fact, RFID-enabled visibility is more effective in reducing out-of-stocks occurrence and inventory record inaccuracy, respectively, for SKUs with higher sales velocity and higher sales volume. With the higher sales velocity and volume on weekends, it is reasonable to expect the experimental intervention in the current research to be more effective in improving the performance of replenishment activities.

In the new replenishment procedure, scandals were detected by combining sales and inventory data, available thanks to the RFID technology. More precisely, by identifying those models (i.e. sets of SKUs with different sizes and colours but belonging to the same model) whose inventory level in the backroom is higher than zero, while the number of items on the shelves is almost null, the RFID system generated daily a list of ten scandals to replenish. Models with the same stock level on the shelf were prioritized in the list based on their sales volume.

As already mentioned, inventory data were derived by combining RFID reads made by the cage used during receiving operations, the RFID bin and the replenishment gate. To correct possible misalignments between RFID reads and physical inventory, employees carried out weekly (or twice a week) manual inventory counts, to monitor the stock level of the clothes examined on the shop floor, and to realign it in the case of errors. Handheld RFID readers were used to this extent. The realignment rules were as follows:

1. If the reader detects, on the shop floor, an EPC associated with an item whose location should have been the backroom, the corresponding information is updated in the store information system, allocating the EPC to the shop floor. The rationale for this realignment is that the RFID gate could miss some items while they cross it; therefore, this procedure is expected to solve possible reading errors of the replenishment gate;

2. Conversely, in the case the reader does not detect an EPC on the shop floor, and the EPC is expected to be in that area, the latest available information about the item's position is maintained in the store information system. In this case, the reading error could be either due to the replenishment gate (that did not detect an item that moved from the shop floor to the backroom) or to a missed read during an inventory count on the shop floor. This latter, however, seems to be more probable, due to the wide number of items on the shop floor, which probably generates hidden or overlapped tags. Consequently, the item is assumed to be on the shelf, and this is why the latest available information about the item's position is maintained in the store information system.

As mentioned, the RFID system generated a list of models to replenish daily on the shop floor, while it does not indicate the specific SKU. The choice of indicating the models (and not SKUs) in the list was made in accordance to the store manager, with the purpose of keeping the replenishment procedure followed by the employees almost unchanged. Indeed, before the RFID implementation, the identification of the items to be replenished was carried out based on the sales volume of the different models (and not on the single SKUs). Once the model to be replenished is detected, thanks to the replenishment list, the choice of the specific SKU (i.e., size and colour of the model), as well as of the number of items for each SKU, to be displayed on the store shelves is left to the store manager, who is expected to have a sufficient experience to identify the most appealing SKUs. Indeed, due to the limited shelf space, it mostly happens that a model is not exposed on the shop floor in all its variants (i.e., colours and sizes).

Similarly, the number of models (10) included in the list was defined together with the store managers. Such number could seem limited, compared to the number of items replenished daily in the store (more than 350 items/day, on average). As a matter of fact, the replenishment list should be regarded as a support to the employees, to help them in the replenishment operations, by indicating some selected models that should be replenished with priority, because of the high sales and the limited stock available in the store.

Store employees downloaded and printed this list daily, exploiting an application on the RSA dashboard. This application automatically generates a query with predefined parameters (i.e., for example, the classes monitored, the minimum number of items available on the shelves, etc.). The scandals list was then used to drive employees in the replenishment operations. It should be mentioned, however, that each list included only the models to be replenished, while did not define the related variants (e.g., colour and size) nor the number of items to restore; these choices were left to the store manager.

In Fig. 2, we propose an example of scandals list. The first two columns list the names of the models to replenish and the correspondent classes (in the example, the model names are omitted, for confidentiality). Then, the list indicates the stock level available on the shop floor and in the backroom and the number of items sold. Looking

Query	*Filter*	*Quantity*		
Model	Classes	Shop floor	Backroom	Sales
Mod1	34	0	3	4
Mod2	36	0	4	0
Mod3	36	1	4	5
Mod4	34	1	3	5
Mod5	36	1	42	4
Mod6	34	1	5	4
Mod7	34	1	6	3
Mod8	34	1	5	3
Mod9	34	1	3	3
Mod10	36	1	9	2

Fig. 2. Example of a scandals list.

at Fig. 2, it can be seen that model “Mod1” (of class 34) should be replenished with priority, since it is unavailable on the shop floor (“Shop floor = 0”) while its stock in the backroom is three items. The second model to replenish is “Mod2” (of class 36): for that model, the stock level in the backroom is higher than that of “Mod1”, but the number of items sold from the beginning of the season is lower (0 vs. 4).

To compute the turnover increase due to the RFID-based replenishment procedure, we needed to identify those sales that could be associated with the new practice. To this extent, we assumed that a sale could be *directly linked* to the replenishment procedure if it occurred within one week from the item replenishment on the shelf. Moreover, additional sales could be *induced* by the new replenishment process. First of all, it should be specified that, although the replenishment list only includes models, during replenishment the store employees read the RFID tag of each item replenished, to record the fact that these specific SKUs have been displayed on the store shelves. Therefore, the full set of data (model/size/colour) is actually available in the store information system. Let us suppose that the replenishment list proposes Mod1 to be replenished (as per the example in Fig. 2). The store manager will indicate the size and colour of this model to be displayed on the store shelves (e.g., size = small and colour = pink). By reading the RFID tag of the item replenished, the store employee records the full set of data (i.e., model = Mod1, size = small and colour = pink). If the retail store sells this item within a given time interval since the replenishment, a *direct sale* is recorded. Implicitly, we assume that this sale can be directly linked to the RFID-based replenishment procedure, which led to display Mod1 on the store shelves. Obviously, in the case a model is replenished (in a given colour and size) thanks to the RFID-based procedure, some sales of a different colour or size of the same model could also be generated. Specifically, if the retail store sells a different item of the same model (e.g. model = Mod1, size = large or colour = green), within a given time interval since the replenishment, an *induced sale* is recorded. In this case, it is assumed that the sale of this item was due to the fact that the customer saw Mod1 (in a given size and colour) on the store shelves and was stimulated to ask for a different variant and finally purchased it. A more precise definition of *induced* sales is proposed in Section 3.3.

With respect to the computation of the turnover increase, it should be mentioned that our assessment takes into account only those scandals that were immediately replenished. By "immediately", we mean that items were replenished as soon as they appeared on the scandals list, i.e. in the next replenishment operation. Typically, replenishment operations are carried out early in the morning (before the store opening); therefore, to be included in the analysis, items should be replenished in the same day where the scandals list was generated.

In practical cases, it could happen that not all scandals are immediately replenished, either because of a lack of space on the store shelves, or because the store employees neglected or forgot them. Whenever, in the next replenishment, one SKU was, for instance, omitted, the sales due to this SKU were not considered in the analysis. Similarly, sales of items that were replenished later (e.g., the day after the generation of the scandals list) were not considered in the analysis.

The new replenishment procedure was implemented for eight weeks at the retail store. Sales data were elaborated weekly, to evaluate the turnover increase. In this regard, it is worth mentioning that the turnover increase actually indicates an increase in the number of items sold (i.e., it reflects a sales increase), while the economic value is not assessed in this study. Numerical results related to the sales increase are reported in Section 3.3.

3. Results

3.1. Reengineered replenishment process

Between May 17th, 2013, and June 30th, 2013, we collected the reading data of the replenishment gate, to assess the performances of the replenishment process. More precisely, we compared the inventory data stored in the store information system, based on the item movements recorded from the backroom to the shop floor, with the actual stock level, to detect possible reading errors or missing reads. By this comparison we derived an estimate of the reading accuracy of the gate. We also evaluated possible improvements in the accuracy of the gate by adding periodic inventory counts, to update the inventory data.

During the whole observation period, the gate recorded 22,084 crossing items, and missed 326 items (1.45% of the total number of items crossing). The gate reading accuracy, therefore, initially accounted for 98.55%. To increase this percentage, we coupled RFID reads with periodic inventory counts to detect missing records of crossing items and realign the inventory data. We observed that 140 of the 326 unread tags (0.625% of the total number of items) remained undetected until the items were sold, i.e. when they were finally read at the cash counter. These items, indeed, according to the store information system, turned out to be still available in the backroom; however, they were actually exposed on the shop floor, or, at least, they had crossed the replenishment gate to be brought directly at the cash counter. Therefore, inventory counts did not help identify the exact location of this percentage of items. Consequently, we can affirm that the reliability of the replenishment gate can grow up to 99.375% by associating periodical inventory counts to the replenishment gate reads.

Finally, during the eight weeks of data collection, we also recorded the average time spent for replenishment processes, which resulted in an average value of less than 7 man-hours per working day, and a maximum value of around 9 man-hours recorded on Friday the 27th of September. This testifies that the newly reengineered replenishment process allows to maintain the labour below 10 man-hours and therefore to complete the process according to the company requirements.

3.2. Reengineered check-out process

To assess the reliability of the RFID bin located near the cash counter, in Table 1 we show and compare the results of the reading accuracy test carried out on each equipment originally proposed to record sales information (i.e., antenna with cage, antenna with buzzer and RFID bin). The table reports the date of the check-out process, the reader type, the total number of items sold in the day, the number of tags unread and corresponding percentage. The tags unread were detected by means of manual checks, comparing all the tags physically present in the reading device at the end of the day with those that turned out to be read, and thus recorded as sold, in the information system. Data related to the first two solutions (i.e., antenna with cage and antenna with buzzer) are aggregated in Table 1 because those solutions have been tested simultaneously. More precisely, the store employees put the tags of items sold indifferently in one or other device, and both were checked at the end of the day. The number of "unread tags" in Table 1 is obtained as the total amount of tags not read by the cage-equipped antennas nor by the buzzer-equipped ones.

From the data in Table 1, it is evident that the reading accuracy is significantly higher when using the RFID bin for check-out (percentage of tags unread = 0.0%), compared to the remaining solutions. Therefore, it can be right assumed that the RFID bin was able to detect each tag put inside it during the check-out, so that, with this solution, POS data were always accurate and updated.

3.3. Turnover increase

After this preliminary evaluation of the reading accuracy of the RFID apparatus, we focused on the main objective of our analysis, i.e. the increase in sales turnover as a result of the implementation of the scandals replenishment process. Results are presented separately for the SKUs belonging to classes 01, 02, 08 (Table 2) and 34, 36 (Table 3), so as to assess the contribution of the new replenishment process for each product category.

Table 1
Reading accuracy of check out device

Date	Reader	Total sold items (Tagged)	Unread tags	Percentage of unread tags
22/09/2013	Antenna with cage/buzzer	463	0	0,00%
23/09/2013	Antenna with cage/buzzer	193	2	1,03%
24/09/2013	Antenna with cage/buzzer	191	9	4,50%
25/09/2013	Antenna with cage/buzzer	173	2	1,14%
26/09/2013	Antenna with cage/buzzer	127	2	1,55%
27/09/2013	Antenna with cage/buzzer	301	3	0,99%
28/09/2013	Antenna with cage/buzzer	472	1	0,21%
29/09/2013	Antenna with cage/buzzer	350	4	1,13%
30/09/2013	Antenna with cage/buzzer	197	0	0,00%
01/10/2013	Antenna with cage/buzzer	131	0	0,00%
02/10/2013	Antenna with cage/buzzer	206	12	5,50%
03/10/2013	Antenna with cage/buzzer	211	2	0,94%
04/10/2013	Antenna with cage/buzzer	336	1	0,30%
05/10/2013	Antenna with cage/buzzer	472	0	0,00%
01/11/2013	Antenna with cage/buzzer	321	3	0,93%
01/11/2013	RFID bin	774	0	0,00%
02/11/2013	RFID bin	1003	0	0,00%
03/11/2013	RFID bin	795	0	0,00%

For each week of observation, we evaluated:

- the number of *replenished scandals*, i.e. those scandals immediately replenished following the list of scandals generated by the RSA dashboard;
- the *direct sales*, i.e. the number of items of the classes monitored that were sold during the week, after a replenishment performed the week before;
- the *induced sales*, i.e. the number of items for which a variant (i.e., a different colour or size) sold during the week was not on the shelves, although the model was available on the shop floor, after a scandal replenishment performed the week before;
- the *total sales due to RFID*, i.e. the sum of direct and induced sales;
- the *total sales of the week* for each class;
- the *turnover increase due to RFID for direct sales*, i.e. the ratio between the direct sales and the difference among the total sales of the week and the total sales due to RFID;
- the *turnover increase due to RFID for induced sales*, i.e. the ratio between the induced sales and the difference among the total sales of the week and the total sales due to RFID;
- the *total turnover increase due to RFID*, i.e. the sum of turnover increase due to direct sales and that due to induced sales.

Other pieces of information collected during the study (such as, for instance, the number of scandals reported, the number of items not restored for different problems, etc.) are omitted in the tables, because they are not directly relevant to our analysis.

Table 2
Turnover increase for product classes 01, 02 and 08 (coats)

Week	39	40	41	42	43	44	45	46	
Classes	01,02,08	01,02,08	01,02,08	01,02,08	01,02,08	01,02,08	01,02,08	01,02,08	Total
Replenished scandals	26	19	5	21	0	53	29	28	181
Direct sales	5	8	3	7	1	10	10	8	52
Induced sales	0	1	5	8	1	3	12	10	40
Total sales due to RFID	5	9	8	15	2	13	22	18	92
Total sales	112	160	181	152	134	127	107	123	1096
Turnover increase due to RFID - (direct sales)	4.67%	5.30%	1.73%	5.11%	0.76%	8.77%	11.76%	7.62%	5.18%
Turnover increase due to RFID – (induced sales)	0.00%	0.66%	2.89%	5.84%	0.76%	2.63%	14.12%	9.52%	3.98%
Total Turnover increase due to RFID	4.67%	5.96%	4.62%	10.95%	1.52%	11.40%	25.88%	17.14%	9.16%

Table 3
Turnover increase for product classes 34 and 36 (knitting items)

Week	39	40	41	42	43	44	45	46	
Classes	34,36	34,36	34,36	34,36	34,36	34,36	34,36	34,36	Total
Replenished scandals	60	83	65	81	57	43	56	57	502
Direct sales	7	15	9	5	6	6	9	6	63
Induced sales	1	0	3	2	0	2	2	1	11
Total sales due to RFID	8	15	12	7	6	8	11	7	74
Total sales	187	240	252	221	181	236	163	163	1643
Turnover increase due to RFID - (direct sales)	3.91%	6.67%	3.75%	2.34%	3.43%	2.63%	5.92%	3.58%	4.02%
Turnover increase due to RFID – (induced sales)	0.56%	0.00%	1.25%	0.93%	0.00%	0.88%	1.32%	0.64%	0.70%
Total Turnover increase due to RFID	4.47%	6.67%	5.00%	3.27%	3.43%	3.51%	7.24%	4.49%	4.72%

Looking at Table 3, it can be seen that for knitting items (classes 34 and 36), RFID technology could increase the sales turnover up to 4.72% overall, primarily as a result of the increase in direct sales (63 direct sales vs. 11 induced sales). For those items, indeed, the contribution of induced sales is limited, accounting for approx. 0.70% of the turnover. A different result was observed for coats (classes 01, 02 and 08).

With respect to Table 2, which refers to coats (classes 01, 02 and 08), a first consideration is that the sales (both direct and induced) of those items highlight more variability compared to the knitting items. The contribution of direct sales ranges from 0.76% in week 43 to 11.76% in week 45, while the contribution of indirect sales ranges from 0% in week 39 (corresponding to the implementation of the new replenishment procedure) to 14.12% in week 45. The variability of the results, in terms of the direct and induced sales, could be due to different aspects. First, most SKUs are, *per se*, subject to the month-to-month fluctuations in consumer's behaviour and purchasing decisions (Starr-Mccluer, 2000). Moreover, the kind of products considered introduces a further variability: for instance, poor weather conditions could increase the sales (Starr-Mccluer, 2000). This is also the reason why sales are particularly relevant in week 45, corresponding approx. to early November: probably, the worsening of the weather conditions at the beginning of November pushed customers to purchase coats. A further source of variability is represented by the fact that, once a customer has purchased a new coat, it is very unlikely that the same customer will purchase another coat in the same season, since this item is expected to be used for the whole season, and also for future seasons, in the light of the relatively high cost of that product. Those considerations probably do not hold for knitting items, for which the cost is lower and it is, therefore, more likely that a customer will purchase more than one item in the same season. Also, the purchasing impulse of customers can be less sensitive to the weather conditions. Consequently, the trend of sales is more stable and no peaks of request are observed (cf. Table 3).

Table 2 shows that, by means of the new scandals management procedure, the increase in the sales volume of those items could reach 9.16%, on average, considering the contribution of both the direct and induced sales overall. Moreover, the contribution of the induced sales was more relevant, compared to the knitting items. Indeed, almost 4% of the sales increase was due to purchases of models whose variants were not available on the shop floor, but, since the model was replenished, it drew the customers' attention, leading the customers to ask for different colours or sizes. This result could be explained, in turn, considering that purchasing a coat is probably a more though-out decision, where the customers tend to control their purchasing impulse and therefore can be interested in trying different models or colours.

4. Conclusions

4.1. Discussion of findings

Potential benefits that RFID technology can bring to the supply chain processes are particularly relevant for fashion retailing. The capability of RFID to improve inventory accuracy and optimize shelf replenishment operations, in particular, is of high relevance to the fashion industry. In this regard, this paper investigated the shelf replenishment process in a fashion retail store. A new RFID-based replenishment system was proposed, based on the identification of "scandals", i.e. those models whose sales volume is high but that are OOS (or available in less than 2 items) on the shop floor (although available in the backroom). Those models should be replenished with priority. The stock data of items were available thanks to the in-field implementation of the RFID technology, while the sales volume was already recorded by the store information system. Results of the in-field experimentation show that exploiting RFID data to identify the scandals and thus to drive the replenishment process can lead to a significant increase in the sales turnover of a fashion store. Obviously, improvements can be achieved only if this replenishment system is grounded on solid data; in this study, the experimental apparatus was previously tested to ensure reliability of the RFID reads and of the data collected.

Although the data collection was limited to some selected product categories, the results obtained allow concluding that the adoption of the new RFID-based replenishment procedure has the potential to significantly increase the sales volume of the fashion retail store considered. Obviously, the sales increase could be even more relevant if the new replenishment process was extended to other product categories or to other stores of the same fashion company. Specifically, the increase in the sales volume, as it emerges from our study, ranges overall from 4.72% for knitting items up to 9.16% for other clothing categories (e.g., coats). Such increase should be primarily ascribed to the fact that reliable RFID reads allow to real-time update inventory information both on the store shelf and in the backroom. As a second point, RFID offers the opportunity to track the sales volume, thus supporting the identification of the most profitable products.

Looking at the induced sales, it is easy to see that these latter are particularly relevant for SKUs belonging to the coats category (3.98%), while their contribution is lower for knitting items (0.47%). Such difference can be associated to the higher purchasing impulse of customers against knitwear items, compared to more expensive items such as coats. In other words, it is likely that a customer wishing to buy a coat will ask whether different sizes or colours are available. The same behaviour is less likely to be observed for customers that buy knitwear items: typically, those customers will make their purchase more impulsively, without asking whether the same model might be available in a different colour. Therefore, a more general conclusion from this study is that turnover increase due to induced sales has potential to be more significant for high value products, such as coats.

4.2. Limitations

We must remember that some limitations affected our experimental campaign. First, the new replenishment policy was not applied during the weekends. As mentioned, this choice was driven by a decision of the store's managers, motivated by the fact that those days are particularly critical to the fashion store; hence, store's managers preferred not to apply the new (experimental) procedures in such critical days. Applying this policy also on Saturday and Sunday, when the sales volume is higher, has potentials to generate a further increase in turnover. Evaluating this additional contribution can be the starting point for future research activities. To our knowledge, the encouraging results of this study led the store's managers to consider the application of the new replenishment procedures also in the weekends, so that the process is now implemented in all weekdays.

A similar consideration holds for the number of product classes examined in this study. Since this was a pilot implementation, the analysis was limited to five clothing classes, which could be RFID tagged at the distribution centre. Examining further classes could bring additional insights about the potential of RFID to increase the corresponding sales turnover.

Another issue was the improvement of the reading accuracy of the gate, which took more than a month to reach its optimal setting, because of some difficulties in detecting overlapping tags of items crossing the gate. Therefore, in future research, alternative solutions could be studied to solve this problem.

Finally, although benefits brought by RFID technology are evident from our outcomes, the cost of RFID implementation can be particularly high. In this regard, the increase in sales turnover can help recover the initial investment more quickly, especially in fashion industry, where the product value is relevant. However, this point was not investigated in detail in this study, since we limited the analysis to the number of items sold thanks to RFID, neglecting their economic value.

4.3. Suggestions for future developments

An interesting opportunity for future research is to investigate in greater detail some SKUs, for which we observed a strange situation during the implementation of the new replenishment policy. More precisely, a particular SKU drew our attention during the observation period. This was an overcoat model, never exposed on the shop floor (probably because of a commercial strategy of the retail store, that privileged different models), but available in the store backroom. The sales of that product, therefore, scored zero. Despite the null sales, after some weeks from the implementation of the RFID-based replenishment policy the product appeared in scandals list, because of the very high stock level in the backroom. We have previously mentioned that the list of scandals to be replenished prioritizes models with a limited number of items on the shop floor and a high sales volume. However, when products whose shelf availability was lower than two items had already been replenished, the RSA dashboard inserts in the replenishment list (which always consists of ten models) those models that are available in the backroom in large quantities but are not available on the shelves, regardless of the amount of sales. This is the reason why, after some weeks, the overcoat appeared in the scandals list. After replenishing it, and by analysing the POS data and the RFID reads of the replenishment gate, we found that the model captured the interest of customers. Indeed, several items were moved from the backroom to the shop floor, thus suggesting that customers appreciated the model and asked for different sizes and colours. Overall, six items of that model were sold within ten days from the replenishment. This particular case suggests that the potential benefits generated by the RFID-based replenishment management can be higher than those estimated in this study, involving also the opportunity to identify models whose sales potential is underestimated. In addition, the use of the new replenishment policy allowed also identifying a current limit of the commercial choice of the fashion company that never exposed the overcoat on the shop floor.

A second opportunity for future research is to compare, in greater detail, the performance of the RFID-based replenishment policy with the replenishment policy adopted by the retail store previously. As sketched earlier in the paper, before the implementation of the RFID technology, the store employees managed the replenishment activities on the basis of the data generated by the store information system (POSWEB). The next step of the experimental campaign could be to examine separately the impact on the sales turnover generated by the RFID-driven replenished policy and that generated by a more conventional replenishment policy, driven by the POSWEB data and simply aimed at reducing stock-out situations on the store shelves. To evaluate this difference, it could be useful to manage the replenishment operations of the retail store examined with the conventional policy based on POSWEB data, and to compare the list of items replenished with those identified as scandals and generated by the RSA dashboard. Such a comparison would allow identifying those models missed in the first list, but detected by the RFID system and suggested for replenishment.

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