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Using System Dynamics to Assess the Impact of RFID Technology on Retail Operations

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ABSTRACT: The application of item-level Radio Frequency Identification (RFID) technology in retail supply chains creates cost savings and promises large potential benefits from revenue growth. However, the economic assessment of the impact on improved store operations, labor utilization, and increased sales is still not fully explored. We propose to use System Dynamics as a structural modeling and simulation approach to integrate conventional return on investment evaluations. Building on previous research about RFID technology in retail supply chains, we developed a model based on the case exploration of a leading Italian apparel retailer. Simulations show that RFID implementations are profitable whenever they contribute to increase sales, especially when a fashion retailer is focused on clerk-assisted sales strategies. Sales growth results from the dynamic and integrated impacts of RFID technology on better inventory control, faster inventory turnover, and longer time available for store personnel to assist consumers as an effect of more efficient backroom operations.

KEYWORDS: Radio frequency identification, Supply chain management, Retail operations, Fashion industry

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1. Introduction

RFID technology has remarkable potential impacts on retail supply chain (SC) operations. By remotely reading the electronic product code and other pieces of information on a tag and making data available to information systems across the SC, RFID technology primarily claims to enable better inventory control, stock out reduction, labor cost savings, reduced shrinkage, and lower transaction errors.

However, despite several pilot mandates and industrial deployments in retail industries, there is still a limited understanding of the business value of RFID technology (Whitaker et al. 2007; Lee and Özer 2007; Delen et al. 2007) and, in particular, of item-level RFID tagging.

While the benefits that SCs gain from automational effects on operational processes and from information visibility on managerial processes are quantifiable (Visich et al. 2009), several components of item-level RFID implementation at the shop floor seem to require a larger investigation. In particular, RFID tagging at the item-level promises to bring the maximum benefits to retailers (Gaukler et al. 2007) for the inherent ability to enhance shop floor productivity, promote sales, and improve business performance in general.

Numerous studies are available to support cost-benefits analysis (Özelkan and Galambosi 2008), the exploration of the process driven value of RFID investments across supply chain stakeholders (Becker et al. 2010), and the optimal configuration of RFID systems within a supply chain network to impact on deployment strategies (Chang et al. 2010). However, little research is available to specifically evaluate the economic impact of item-level RFID-enabled retail store operations on sales and revenue performance. Mainly, there are two reasons for this. Firstly, the contribution of RFID to sales growth is dynamically influenced by a number of interrelated aspects, so that it is difficult to account for separate benefits from individual functions of RFID.

Therefore, it is more useful to look at retail store operations as a complex system that demands complex analysis methodologies. Secondly, sales performance strongly depends on specific SC organizations and retail strategies. It is highly recommended that evaluation frameworks and general business cases are built into company-based case studies (Tzeng et al. 2008).

To overcome these issues, first we propose to use System Dynamics (SD) (Forrester 1961; Sterman 2000) as a modeling method and simulation tool to refine ex-ante estimates. This approach has been selected since conventional financial methods, such as capital budgeting with discounted cash flow analysis (CFA), do not inherently include into the analysis any feedback relationships between system variables. On the contrary, SD is primarily aimed at investigating the structure of such cause and effect connections and how they evolve over time. Specifically, SD is used here to understand the extent to which RFID technology might impact on the complex relationships between retail operations, inventory management and sales performance, and to provide CFA with accurate inputs.

Following that, we build the model based on the case-project to deploy item-level RFID technology in the retail stores of a leading Italian Apparel and Fashion (A&F) retailer: Miroglio Fashion S.r.l. This is part of a larger supply chain reengineering effort that the company started in 2007. The project gives the chance to illustrate the integrated effects of RFID on sales performance, inventory and sales force utilization. Also, we show how the new technology might affect retail business growth depending on the fashion retail sales strategy. In the end, we use this case study to prove that SD is a practical and predictable method to assist the task of evaluating both cost and revenue benefits that can be achieved out of RFID implementation in retail stores.

The case study is presented as follows. The next section provides a review of relevant research. Section 3 illustrates the research methodology of this paper. Sections 4 and 5 present the case study environment and the SD model with associated simulations and results, respectively.

Section 6 discusses findings, highlights research limitations and future directions. Finally, conclusions are summarized in Section 7.

2. Relevant Research in Assessing the Value of RFID

As part of a vast amount of literature on RFID technology adoption and application (Ngai et al. 2008; Curtin et al. 2007), the portion of research specifically related to the problem of assessing the economic impact of RFID technology can be subsumed into two main management areas.

The first area of research is inherent with understanding the roots of RFID-enabled cost efficiency in retail SCs. This can in turn be broken down into a few streams of studies. Some researchers explore the strategic and operational value of RFID to reduce cost and improve service performance of inter-organizational SCs (Ju 2008) through enhanced information sharing, increased asset utilization, and higher visibility (Tzeng et al. 2008; Ustundag 2009; Lee 2009). Another stream of research is more focused on quantitative methods to measure economic benefits pertaining to several components of the RFID value proposition (Prater and Frazier 2005; Doerr et al. 2006, Delen et al. 2007; Lee 2009; Kumar, Kadow and Lamkin 2011) and to give return on investment (ROI) evaluation models (Lee and Lee 2010). Within this stream, some works are specifically related to fast retail (Bottani and Rizzi 2008) and fashion businesses (Moon and Ngai 2008, Koh et al.2006). In particular, Bottani et al. (2009) examine a fashion SC composed of a distribution center and a retail store in order to assess the profitability of an RFID investment and provide guidelines for its implementation in the A&F industry. As a derivative course, several contributions come from pilots and field experiences to determine the effectiveness of RFID application and creation of cost savings. Key examples are Wal-Mart's and METRO Group's experiences (Hardgrave et al. 2008; Ton et al. 2005); some cases report on pilots in the A&F retail industry, such as Prada, Benetton, Marks & Spencer and Kaufhof

companies (Loebbecke and Huyskens 2006; Loebbecke 2008). With specific regard to Galeria Kaufhof, Thiesse et al. (2009) illustrate RFID applications at the intersection between store logistics and customer service, analyze physical in-store processes, theorize about the effects that RFID may have on the business processes, and develop a conceptual model to explain the different cause-and-effect chains between RFID investments and their impact on the business performance. Gaukler et al. (2007) provide a long list of reports and academic papers on RFID trials in the retail industry.

Most models and case-based studies testify that RFID technology has an impact on profitability through revenue growth rather than through cost reduction (Mithas et al. 2008; Tzeng et al. 2008). This is why Whitaker et al. (2007) state that there is the need to assess the impact of RFID on sales and revenues. For this purpose, the second area of management research we reviewed explores the impact of RFID on retail store operations and on the revenue stream. In fact, it seems that item-level RFID technology contributes to revenue growth because of its inherent intelligent ability to improve sales and capture the customer's needs (Lo et al., Hong and Jeng 2008). For example, Koschat (2008) demonstrates that the higher the level of store inventory, the more the consumer demand. In particular, A&F consumers perceive large quantities of items displayed on shelves as an indication of novelty and a major motivation for shopping.

Therefore, item-level RFID tags can contribute to sales growth because of their capacity to improve inventory management and on-shelf availability. For instance, some business studies on pilots (Bauer et al. 2008) report that revenues from RFID-enabled improvement of store inventory can increase between 5 percent and 10 percent.

However, claims that RFID investments contribute not just to cost savings but also to revenue expansion are not yet completely substantiated with detailed model-based analysis in order to enable the integration between CFA and the dynamics of the complex relationships that exist

among a number of business variables affected by the RFID technology impact (Lee and Özer 2007).

To overcome this gap, here we propose a case-based model to understand the extent to which item-level RFID technology provides value through sales growth and cost efficiency in fast fashion trades (Rust et al. 2002). In particular this case study serves to build a model for simulating the complex relationships between the variables affecting the retail business performance, and to provide CFA with pertinent input data.

3. Methodology

As part of a large project initiated by the case-company late in 2007 and aimed at reengineering the SC around the implementation of item-level RFID technologies, our research group was challenged to investigate the strategic impact on store operations and to provide a viable method to assess the benefits on both revenue and cost streams.

To this end, we took a SD model and simulation phased methodology, as described by Lyneis (1998). SD is a modeling and computer-based simulation approach to help understand complex systems (Sterman 2000). SD allow for graphically diagramming a system of feedback causal loops between interrelated accumulation stocks, flow rates, and auxiliaries variables, to define various linear and nonlinear mathematical relations, and to have commercial software packages do the discrete-step computational effort of solving the differential set of equations over a preset time frame (Sterman 2000). As an output to computer simulation, the curve lines of all variables are plotted on the time axis. Model testing is based on historical data and sensitivity analyses. SD lets understand the overall dynamics of the system, the influence of the various variables to the problem at issue, to support decision making, and test policies through simulations of various case-scenarios. SD has been largely used in production and operations management to explore

inventory capacity and instability (Croson and Donohue 2005; Anderson et al. 2005, White 1999), as well as to investigate the effects of new technologies on business strategies (Winch 1997; Lyneis 1998; Pardue et al. 1999; Disney, Naim and Potter 2004).

In accordance with Lyneis' approach, we first worked on understanding, structuring, and analyzing the system with regard to distribution, store operations, and sales issues. This was done through the gathering of detailed information and process flow data, process mapping, interviews with logistics managers, marketing executives, and salespersons, as well as through direct observation of warehouse, shipping and retail store operations.

Based on system thinking (Forrester 1961), a first-hand conceptual causal loop diagram was developed with the active and knowledgeable participation of the company's personnel. Following that, a numerical SD model was worked out. In compliance with SD principles and practice, the case model was developed to include stock variables, flows and feedback loops that tackle store inventory management, store labor utilization, and customer demand. Specifically, the model grounds on a few select reference previous works. On the one hand, it is founded on the "Stock Management Structure" model by Sterman (2000). This model replicates a supply line integrated with stock control balancing feedback loops, comprising both desired and actual adjustment quantities and review periods.

On the other hand, the model goes behind the standard practice in SD, rather than other approaches, to consider customer demand as an endogenous variable affected by the performance of the supply line itself (Akkermans and Dellaert 2005; Gonçalves et al. 2005; Ashayeri and Lemmes 2006). For instance, Gonçalves et al. (2005) demonstrate that SC instability and customer demand, though often analyzed separately, interact with product availability: product shortages cause lower demand, which in turn leads to reduced production, prolonging stock outs that depress demand even more, as a destabilizing reinforcing feedback loop, so that demand

ends to be endogenously affected from within the SC system.

The mathematical equations underpinning the stock & flow diagram were then developed. After that, the model was tested through curve fitting of historical data, robustness appraisal in relation to extreme values, and analysis of model sensitivity associated to random exogenous variables.

After testing, many simulation runs were performed under several scenarios to investigate the effects of RFID deployment on inventory, labor usage, and sales growth. Case-scenario simulations also served to provide inputs for CFA and ROI assessment.

Finally, we analyzed results and made recommendations.

4. Case-Study

4.1. The Fast Fashion Industry

The mass A&F market is a buyer-driven SC, where retailers seek to capture the consumers' mood of the moment. It typically exhibits products with short life-cycles, seasonality, highly volatile demand, and impulse purchasing attitudes in a global context. Thus, mass apparel retailers are fashion-followers that exploit the market by bringing new products to their stores as frequently as possible. A large variety of clothes must be designed as late as possible so as to include the ultimate fashion trends. They must also be made available as quickly as possible in order to serve customer satisfaction, and in sufficient quantities to assure sales, avoid stock outs, and grant prompt replenishment of successful items (Christopher et al. 2004).

This is the context that has spawned the emerging domain of the agile SC and the philosophy of the quick response, as a set of policies and practices to increase the speed and flexibility of reactions to market shifts (Lowson et al. 1999; Masson et al. 2007).

Key international competitors in the mass quick fashion market are Zara-Inditex, H&M-Hennes&Mauritz, The Gap, Benetton, Miroglio, Mango, and a few minor ones.

The innovative business system of most players comprises in-house creative design capabilities, centralized distribution, and frequent shipments to well-located and attractive stores (Ghemawat and Nueno 2006). Indeed, retail shops are crucial points of communication and advertising: they are targeted to give customers a unique shopping experience through variety and novelty of products, to stimulate brand loyalty, and foster the retailer's identity and brand equity versus market competitors.

The inherent dynamic characteristics of this market, such as demand volatility, flexibility and speed, make the mass A&F business most relevant and pertinent as proof of SD validity as a supporting method to assess the benefits of RFID technology.

4.2. Miroglio Fast Fashion

Miroglio Fashion S.r.l., Fast Fashion Division (Miroglio) is a global retailer headquartered in Alba, Italy, which designs, manufactures, and sells women's garments and accessories through Motivi, Oltre, and Fiorella Rubino brand chains. At the end of the year 2008, it produced 20 million clothing items and operated more than 1,680 stores globally (in actual fact, this work is limited to just the total of the 850 brand stores located in Italy).

As part of the two fall/winter and spring/summer seasons, each brand chain presents several collections, which are in turn split into a variety of themes, or looks, differing in design, fabrics and colors. A centralized distribution center (DC) located close to the headquarters collects from multiple manufacturers and packs items to serve all retail stores around the world (Cagliano 2010).

To assure novelty and stimulate frequent consumer visits, a new theme is shipped to Miroglio stores every two weeks and interior display reconfigured. In addition, to enhance fidelity to the brand, store managers and sales assistants are committed to deliver experienced and personalized advice to customers. In the opinion of the corporate managers, the clerk-assisted sales strategy

has the role of differentiating from competitors, which are more based on self-purchasing and visual merchandising (Mittelstaedt and Stassen 1990), and has the added advantage of involving salespersons in the process of improving product quality. Therefore, it is important that the shop personnel is dedicated to assisting customers, and that very little time is spent on backroom tasks and other operations that are not directly aimed at selling products.

4.3. Miroglio's Current Store Operations

Following is a summary description of inventory control, receiving, and other store operations. As far as inventory management is concerned, the initial quantity and variety of items to fill the store inventory at the beginning of each theme period (nine per season) are determined centrally by the marketing department, based on demand planning, while successive best-selling item replenishments are assured up to twice a day. Store managers are responsible for defining the reorder point and place the replenishment order based on personal experience, sales past performance and forecast, as well as projected store window displays. The reorder quantity is checked out, and perhaps adjusted, by the central marketing department based on store location and visitor frequency statistics. Orders enter the DC queuing system that optimizes the number and size of shipments based on the tradeoff between time and cost of transportation. Whenever a product goes out-of-stock, after checking out the availability at other nearby brand stores, an urgent order can be placed, which will be sent out in the shortest period of time.

At present, unit loads received in the store backroom are soon checked against the respective bill of lading. Then, whenever sales staff are available, items are picked out of boxes, individual barcodes are scanned, and magnetic-acoustic security tags are applied. A portion of items is soon displayed on shelves, while the remaining is stored in the backroom. Typically, 70 percent of store inventory is displayed on the shop floor. All salespersons share backroom duties to facilitate picking based on customer demand. At check out, items are scanned for payment transaction and

security tags are removed. Unsold items, which are approximately 10 percent of total production, are returned at the end of the seasonal eight-week long period of promotional sale, after removing antitheft magnetic tags and creating a barcode-scanned list of lading.

Following is a summary table of the main tasks with associated parameters, as recorded by the company's internal auditors of both the Sales & Marketing and the Logistics departments, over a four-year period of time since 2005 (Table 1).

Table 1 – Current store operations records

4.4. RFID-Enabled Store Operations

As anticipated, this paper is aimed at presenting the project of introducing RFID technology into Miroglio SC, with specific focus on assessing the benefits that can come out from more efficient shop operations, and, in particular, on understanding the sources of sales growth.

A disposable garment-care RFID tag was selected (passive ultrahigh frequency EPC global standard UHF Class2 Gen2). Hand held readers, with reading distance of up to two meters and simultaneity of 250 items, are used to support the store staff in goods receiving and treatment, picking, inventory taking, item positioning, and dressing of shop windows. Finally, information corners and theft prevention portals are included.

With this configuration, a few aspects of store operations will change tremendously: incoming cases will not need to be opened for manual counting and items will be promptly made available for display because price labeling will be replaced by information corners. In addition, antitheft magnetic tagging will no more be required. Moreover, RFID will allow for real-time inventory control and support the store managers in the process of placing appropriate replenishment orders. Quarterly inventory taking and returnable item packing time will fall close to a few minutes. Therefore, the store personnel will be able to give more exclusive customer care.

5. Modeling and Simulations

Below is a description of the main phases we undertook to develop the SD model, namely the causal loop diagram and the numerical SD model built using Vensim® DSS software tool.

5.1. Causal Loop Diagram

Before dealing with the main feedback loops, one important assumption of our SD model needs to be discussed, namely the relationship between the available time to assist customers and sales. A survey carried out among the 850 Italian stores revealed that there is the perception in the store managers' minds that the more time spent by salespersons to assist customers is an important drive to increased sales. This is probably due to the fact that staff assisted sales are a relevant component of Miroglio strategy**.** Such a conviction can be considered as moderately suitable since a statistical analysis of historical time series of data collected by the company revealed a slight positive correlation between the time dedicated to assist customers and sales (Figure 1). This finding suggested to us that it would have been worth while exploring the relationship through the modeling study.

Figure 1 – Correlation between staff time available to assist customers and sales

Figure 2 illustrates the feedback loops that impact most on the final SD case model. The loops are extracted from the total diagram.

Loop #1 is a representation of the balancing feedback effect of sales on store inventory. The more the level of store inventory, the more the time spent by staff to treat items (e.g. labeling, counting, etc.), with consequent reduced time available to help customers and associated negative impact on sales. If the sales rate goes down, fewer orders will be placed with a subsequent lower rate of incoming items and decreased inventory growth rate.

Loop #2 describes the balancing impact of order rate on store inventory. As a matter of fact, the

order rate is determined by both the sales forecast, through the reorder point, and the current level of inventory. If the level of inventory increases fewer items will be ordered per unit of time, if the reorder point remains equal. As a consequence, fewer items will enter the store resulting in a store inventory level decrease.

The feedback structure presented in Figure 2 also includes two other reinforcing loops. Loop #3a and Loop #3b act in similar ways. As the store inventory goes up, less time will be available to assist customers, so that sales will decrease, with a subsequent reduced rate of outgoing item and, therefore, inventory growth.

Finally, let us remember that the 'assisted sales index' has been defined to quantitatively represent the impact on sales of the time spent by staff on customer care. It will be discussed in depth in a later section.

Figure 2 – Main feedback loops interacting in the store operations system

5.2. SD Model

The model is an illustration of the average behavior of the real system: the large variety of garments, size and colors is reduced to one sample item and the variety of points of sales is limited to one sample store. The model makes use of average values reported in Table 1. Below are the illustration (Figure 3) and the description of the most relevant parts of the model. The full list of equations is available in the Appendix.

Figure 3 – Portion of the SD model of Miroglio's fast fashion store operations

The developed SD model is a representation of a variable reorder quantity and variable review period stock control policy under uncertain demand.

It can be broadly described as structured into two stock & flow sections, namely orders and

inventory, and a system of interconnecting variables mainly related to staff usage and sales demand. The top portion of the diagram depicts the order adjustment process: the accumulation of orders is increased by the incoming order rate and decreased by the order fulfillment rate. The rate of orders received at the DC is determined according to Equation 5.1.

order rate = MAX(0, (reorder point – store inventory – items en route) / day) [Items/Day] (5.1)

It is important to remark that order rate refers to replenishment orders of sold items. This kind of orders differentiates from other types of orders, namely the two-week central orders and the new-season orders. The first ones are related to new themes that Miroglio ships to stores every two weeks during a season. The second ones are associated with new themes delivered to stores before the launch of the season.

As a consequence, 'items en route' during a season are the summation of both '2-week items central order rate' and the 'order fulfillment rate', multiplied by the time.

The reorder point is initialized at the beginning of the season and then adjusted all the way through the season by both store managers and the central marketing department based on sales forecast. This has been modeled with a 14-day simple exponential smoothing (Silver et al.1998); the selected smoothing period is consistent with the period of time that a theme is displayed and allows for eliminating stochastic noise. Here is the associated equation:

*sales forecast = SMOOTH(sales*day , 14)* [Items] (5.2)

The portion of the stock & flow diagram that models the store inventory makes use of a dummy incoming buffer ('items on shipper's buffer') with the purpose of eliminating, as in real-case, Saturday afternoons' and Sundays' shipments so that Friday shipments are simulated to arrive early the next week. The 'incoming items rate' variable refers to those items entering the store and promptly displayed for sale. Because of limited space, items of new themes arriving before the beginning of a season are partly stocked in the backroom ('new theme's items') and

progressively displayed on shelf (‘display actual rate’). The store inventory level is initiated at the beginning of a season and then increased by both ‘incoming items rate’ and ‘display actual rate’. Inventory is reduced by both items sold in the course of the season (the ‘sales’ variable) and items returned at the finish date of the promotion period (‘returnable items’).

It is also worth remarking that the variable ‘inventory level check’ returns a binary value indicating the time when the level of store inventory is lower than the reorder point and, therefore, a replenishment order needs to be placed. Even if such variable is not strictly essential for the model, it is introduced here for the sake of model testing (Section 5.3).

The bottom-right side of Figure 3 is related to measuring the effects of the various feedbacks on the added-value time the store staff can spend on assisting sales. This time equals the total available productive working hours minus the time required to receive inventory and treat items for shelf display, dress shop windows, and prepare returnable items. The complete definition is given in Equation 5.3.

staff assisted sales time = store opening time – (shop window dressing time + incoming items’ treatment time + returnable items process time + item count time + price labeling time) [Day] (5.3)

Store opening time is determined by adding the product of full-time employees and full-time working hours to the product of part-time employees and part-time working hours. The resulting quantity is then divided by the number of hours per day.

The ‘sales’ variable is an important element. It describes the demand and is used to quantify the impact of a longer staff assisted sales time enabled by the introduction of RFID technology. Sales result from summation of two factors, as per the following equation:

$$sales = time\ index + assisted\ \ sales\ index \qquad \text{[Items/Day]} \qquad (5.4)$$

The ‘time index’ variable allows for including weekly estimated sales based on previous sales records. It is computed as:

$$time\ index = weekly\ sales * sales\ index \qquad \text{[Items/Day]} \quad (5.5)$$

where ‘weekly sales’ is a fourth-order polynomial curve line model that reasonably fits past series of sales data (Figure 4), and the ‘sales index’ (Table 1) lets distribute sales for every week and day along a season. It is worth remarking that the ‘weekly sales’ variable is a representation of the typical seasonality as a trend, rather than as total values.

Figure 4 – Scatter plot and fourth-order polynomial fitted curve line of weekly sales

The ‘assisted sales index’ indicates the influence of assisted sales time on sales performance, according to the following equation:

$$\text{assisted sales index} = \text{time index} * \frac{(\text{staff assisted sales time} - \text{average staff assisted sales time})}{\text{average staff assisted sales time}} * \text{assisted sales factor}$$

[Items/Day] (5.6)

The ‘time index’ variable is multiplied by the percent variation of staff-assisted sales time in comparison to the average daily assisted sales time at each time step of the simulation, and by the ‘assisted sales factor’. The latter is a constant parameter that can be set from 0 to 1, as to represent the influence of staff assistance on purchasing effectiveness and sales growth.

Miroglio has assumed that its current value for ‘assisted sales factor’ is worth on average 0.5, based on statistics that half of transactions are actually completely assisted. With a nil ‘assisted sales factor’ the system would fall in the polynomial demand model.

In addition, a binary ‘RFID’ input variable was included: a 0 value meaning that the model replicates current store conditions, while a 1 value for the RFID variable determines a reduction of the time required to perform backroom operations, thus consenting to spend a longer time on

taking care of customers. In particular, the model considers the potential of RFID technology to automate and reduce the time required to perform the operations listed in Table 1.

We run simulations with Euler integration, 0.5 time step, a time horizon consistent with seasonal duration of 182 workdays, steady and unvaried exogenous conditions, and replenishment orders placed up to day 165, just before the beginning of the sale period. Other assumptions are included in Table 1.

5.3. Model Testing

Before running predictive simulations on future state scenarios that would envisage the introduction of RFID, the model was first tested to measure the ability of simulated results to fit the curve lines of past series of data associated to the as-is scenario without RFID technology. The testing activity, considered as an ex-ante evaluation of the validity and predictability of the model, was run through curve fitting of the simulated behavior, robustness tests, and sensitivity analyses (Sterman 2000).

Model output fitting to real data was checked by focusing on the main variables: ‘sales’, ‘store inventory’, and ‘actual shipment rate’ (replenishment shipments). Figure 5 compares the trends of as-is versus simulated sales when the ‘assisted sales factor’ variable is set equal to 0 (Figure 5.a) and equal to 1 (Figure 5.b). As it can be noticed, the curve of simulated outcomes well approximates that of historical ones. Only in the last ten weeks of the season do as-is values oscillate more than simulated ones: this is probably due to the peculiar appealing characteristics of single themes that are put on the market fortnightly, an aspect that was not considered by our model. Similar results were obtained for the other investigated quantities, thus allowing us to conclude that the developed SD model is able to effectively reproduce the actual behavior of the system at issue.

Figure 5.a – Actual and simulated sales when the 'assisted sales factor' equals 0

Figure 5.b – Actual and simulated sales when the 'assisted sales factor' equals1

Model robustness and sensitivity analysis were supported by the specific validation tool offered by Vensim® DSS. Multivariate sensitivity analyses were performed by defining input variables as uniform distributed and launching 200 simulation runs for each analysis.

As a first step, 'assisted sales factor' and 'sales' were assumed as random input variables. In particular, it has been considered that when the level of store inventory is lower than the reorder point, that is the binary variable 'inventory level check' is activated, there is more probability of facing a stock out, negatively influencing sales. Thus, a decrease in sales from 30 percent to 90 percent has been assumed in those time steps when 'inventory level check' equals 1.

Figure 6.a shows the probability distribution of the 'store inventory' variable and Figure 6.b the probability distribution of the 'incoming items rate' variable as the percent of reduced sales varies.

Figure 6.a – Probability distribution of store inventory level

Figure 6.b – Probability distribution of the incoming items rate

Both variables show very similar trends associated with different confidence levels (50 percent, 75 percent, 95 percent, and 100 percent).

For the purpose of further proving robustness, it is also worth observing the probability distribution of sales (Figure 7). First, we realize that sales values never fall negative. Second, the apparent oscillation by the end of the season is not an indication of poor robustness of the model,

but rather this is due to the fluctuating market demand during the eight-week long promotional period.

Figure 7 – Probability distribution of sales

In addition, sensitivity analyses were also performed under sales growth. In this case, when the 'inventory level check' variable is nil, sales are increased up to 70 percent. The combination of both sales increase and sales decrease case-scenarios allows for testing the model under highly oscillating demand.

Then, inventory level effects on sales were removed and the variables 'items per case' and 'salesperson utilization' were defined as random values. Finally, previously defined variations to sales were combined to the case of scarce sale staff, in order to understand the store behavior predicted by the model under extreme conditions of both highly variable demand and few salespersons available.

The most relevant stock and flow variables were not found to be sensitive to changes in input quantities.

5.4. Simulation results

Simulations indicate that, with the introduction of RFID technology in Miroglio Fashion stores and under the current 'assisted sales factor' assumed equal to 0.5, staff time available for customer care grows up to 2.5 percent as a result of reduced time spent by store personnel on backroom operations (Table 2). Such extra time can be used to facilitate sales. Also, if the 'assisted sales factor' increases, the inventory turnover becomes quicker as an associated effect of increased sales rate. This in turn contributes to time-based competitive advantage.

Table 2 – Comparison of time spent on store operations between current status and with RFID technology

The combination of the ‘assisted sales factor’ with RFID directly results in increased sales volumes, as shown in Figure 8. The model estimates seasonal cumulative sales to rise up to about 2.5 percent, being the ‘assisted sales factor’ constant and equal to 0.5, as per the interconnecting dynamic feedback effects of augmented assisted sales time, better inventory control, reduced stock-outs and faster inventory turnover. It can be realized that, as the ‘assisted sales factor’ goes up, cumulative sales increase almost linearly. Moreover, the derivatives of curves show that as ‘assisted sales factor’ increases, the benefits on sales of introducing RFID technology become more important.

On the other hand, in the case-scenario of a nil ‘assisted sales factor’, e.g. when visual merchandising and self-purchasing strategy are adopted, implementing RFID does not contribute directly to sales growth, but only gives opportunities to save labor cost because of shorter backroom operations.

Figure 8 – Growth of sales as a function of the ‘assisted sales factor’, in both current and RFID case-scenarios

The quicker inventory turnover induced by a greater ‘assisted sales factor’ also permits to reach a lower level of store inventory with desired increased business efficiency.

To this end, Figure 9 shows the inventory level either without or with RFID adoption under different values assigned to the ‘assisted sales factor’. Without RFID (Figure 9.a), on average, as ‘assisted sales factor’ increases the inventory level decreases.

This benefit is even more relevant when RFID technology is adopted. In fact, the difference between the curve line with ‘assisted sales factor’ equal to 1 and the other ones is even greater than without RFID (Figure 9.b).

Figure 9.a –Inventory level as a function of the ‘assisted sales factor’, in the current case-scenario

Figure 9.b –Inventory level as a function of the 'assisted sales factor', in the RFID case-scenario

These results are based on the assumption that the extra time made available by RFID technology is spent to serve a greater number of consumers, which can be expected to come shopping in periods of good economy. Moreover, the longer time available for assisting customers may effectively be used only when sales strategy is strongly based on staff assisted sales, like in the case of Miroglio Fashion.

On the contrary, when either demand is not large enough, which usually happens in periods of stagnating economy, or sales are not assisted, the time saved in background operations may only lead to create cost savings due to store personnel reduction.

5.5. Cash flow analyses

To complete the process of quantifying the economic benefits of item-level RFID, SD simulation outcomes served as inputs to CFA to evaluate the return on RFID investment achieved by a retailer focused on salespersons-assisted sales strategy such as Miroglio.

To this end, different market scenarios were considered under either stagnating or boosting economy conditions. With stagnating economy, a steady trend of undiminished current sales is assumed over the cash flow period so that only personnel cost savings are created.

With booming economy, which is modeled through a greater 'sales index' variable, the availability of RFID technology would replace the need for additional workforce to fill the increased demand. Also, as shown in Figure 9.b, with an increased 'sales index' associated to a boosting economy, the average inventory reduces due to a greater sales rate and a shorter inventory turnover so that no extra storage space is required than the one currently available at the stores.

For each of the two scenarios, three-year and five-year net present values (NPVs) and internal rates of return (IRRs) were compared. The discounted pay-back period (DPP) was also computed. We evaluated the discount rate by using the Weighted Average Cost of Capital (WACC) method based on current Miroglio's economic performance. Two situations were analyzed: on the one hand, the company's investment in RFID technology was assumed to be completely funded by equity, on the other hand, 65 percent debt leverage was considered, according to the standard Miroglio's investment policy.

The following additional assumptions were considered for CFA: a € 21,500 investment to equip each individual store with RFID technology; a gross profit per item equal to 75 percent of sale price, turned into 37.5 percent during the promotional period; a cautious cost estimate of 14€cents per disposable tag.

Cash streams did not take into account maintenance and operations costs of RFID middleware. In addition, the effect of taxes was not considered.

With stagnating demand, RFID enables store personnel reduction only. The cash flow comprised initial RFID investment, the cost of disposable tags, and reduced cost of human resources. Personnel cost savings were evaluated by multiplying the cost per hour of individuals by the total amount of hours saved in a month timeframe because of the reduced time spent on backroom operations. This case-scenario leads to a DPP slightly longer than three years (Table 3). Calculations were performed under Miroglio's current value for 'assisted sales factor' (0.5 value) since an increased 'assisted sales factor' would not lead to augmented sales due to market stagnating conditions.

Table 3 – Return on investment under the stagnating economy scenario

Also, the three-year IRR is lower than the cost of capital. Thus, if the RFID technology became

obsolete within three years, the investment should not be pursued.

When the economy boosts, the decreased time spent on backroom operations can be used to raise sales. However, in order to ensure that Miroglio stores are actually able to transform this time into more sales and don't need to reduce personnel, we estimated an extra five year advertisement and promotional investment of € 10,500,000 to attract the required additional demand and reach the envisaged market share increase. The figure is based on the company's budgeted estimates by the marketing department, which indicated that this was a level of effort similar to a previous five-year plan to increase the market share so that the augmented expected sales would be in the order of 2 to 5 percent, as per Figure 8.

The resulting enlargement of the company's market share has been quantified by considering that raised sales may be captured by an increase in the 'assisted sales factor'. Therefore, cash flow analyses have been performed by setting the 'assisted sales factor' equal to 0.7, 0.8, and 1 respectively. The first two values represent a medium market share growth, while the third one a strong expansion. Besides the marketing investment, the cash stream also includes initial investment in RFID technology, increased sales revenues, and costs of tags. Table 4 details the results got for this scenario.

Table 4 – Return on investment under the boosting economy scenario

The best investment return is achieved when the 'assisted sales factor' equals 1, in line with a large market share increase, with a DPP lasting less than two years.

On the other hand, with a medium market share growth, the investment is not profitable within a three-year time frame.

6. Discussion

RFID technology allows for automating and reducing the time required to perform various backroom operations, and, in turn, for releasing extra time the store personnel can effectively use to assist customers as a source of potential sales and revenues increase.

The case study suggests that retailers focused on salesperson-assisted sales strategies could invest in item-level RFID technology in periods of boosting economy as a promising way to be better able to face the market growth and spend the time saved from backroom operations in taking care of a greater number of customers, thus achieving a higher return on the RFID investment.

The integration between SD and CFA adopted in this case-based model can be easily applied to similar retailers, as a tool to provide with strategic insights for implementing item-level RFID intelligence. Also, it can be profitably adopted to evaluate both operational and economic benefits given by innovation in all those industries whose behavior is determined by extreme dynamism and interconnected feedback effects among relevant variables.

Though, the approach suggested in this paper poses some limitations. First, some restrictions in the applicability of the model are inherent with its assumptions, such as ignoring the storage costs, any potential RFID technology breakdown-related expenditures, and staff training costs. Second, the method disregards potential additional impacts on store operations and sales strategy, such as perpetual inventory and in-store location, theft prevention, check-out automation, interactions with salespeople's productivity, and various innovative marketing technologies, such as dynamic pricing. Then, it only takes into consideration product identification aspects, while ignoring possible implications on customer identification and relationship management. Finally, the present work is limited to assessing the benefits of store operations only, without including the impacts on the DC and manufacturing echelons of the SC, as well as additional soft variables

involved in the process reengineering. These elements may gainfully be included in future research, to part of which our research group is currently committed.

It is also worth remarking that economic benefits largely vary as a function of the retailer technological gap because the lower the current automation, the higher the economic return from RFID deployment. Moreover, the model does not confront with inter-organizational SC issues. Thus, it is valuable for the retailers that obtain the maximum advantage from in-store implementation of RFID, rather than other SC players (Bottani and Rizzi 2008).

As a conclusive note, some limitations are inherent with the predictive nature of the proposed SD decision support model, which would need an ex-post validation based on the underlying RFID deployment experience before its reliability and validity can be assumed to be total.

7. Summary

With reference to the case of a fast fashion retailer, this paper proposes to use System Dynamics as a structural modeling and simulation method to assist in the process of assessing the economic impact of item-level RFID technology on retail operations. SD proves to be a valuable empirical approach because of its capability to take into account the complex interrelated feedback effects of a multiplicity of variables involved in the system performance.

In particular, it is revealed that RFID technology does not only reduce operational costs, but also has large potentials to provide benefits on the revenue stream because the maximum advantages can be achieved in terms of sales growth. This is most relevant when the retailer makes use of store personnel to assist customers. In this context, RFID technology can be used as a driver of competitive advantage and a lever for market share growth. The proposed approach may also be accommodated for application to other complex and highly volatile industries.

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Appendix

"2-week items central order":=GET XLS DATA('file.xls', 'sheet', 'cell', 'cell'); Units: Items/Day

actual shipment rate=(items in route/day); Units: Items/Day

arrival of new season's themes=500 * PULSE TRAIN(163, 0.5, 5, 181); Units: Items/Day

day=1; Units: Day

display actual rate=IF THEN ELSE(PULSE TRAIN(5.2, 1.8, 7, 181), 0, new season's items/day); Units: Items/Day

"full-time employees"=IF THEN ELSE(PULSE TRAIN(4.5, 2.5, 7, 181) , 2 , 2 * RANDOM UNIFORM(0.65, 0.7, 0.01)); Units: employee

"full-time working hours"=1*9.5; Units: Hour/employee

hours per day=9.5; Units: Hour/Day

incoming items rate= IF THEN ELSE(PULSE TRAIN(5.2, 1.8, 7, 181), 0, (items on shipper's buffer/day)); Units: Items/Day

incoming items treatment rate=IF THEN ELSE(RFId = 0, (salespersons utilization*RANDOM UNIFORM(95, 105, 1)) , salespersons utilization*RANDOM UNIFORM(650, 700, 10)); Units: Items/Hour

incoming items' treatment time=((incoming items rate + display actual rate) * day / incoming items treatment rate) / hours per day; Units: Day

initial inventory coverage=2150; Units: Items

intial store inventory=2200; Units: Items

inventory adjustment=SMOOTH(sales *day ,14); Units: Items

item count rate=IF THEN ELSE(RFId =0, (salespersons utilization*RANDOM UNIFORM(300, 350, 1))* (PULSE(63, 1) + PULSE(126, 1)), (salespersons utilization *RANDOM UNIFORM (750, 870, 10)) * (PULSE(63, 1) + PULSE(126, 1))); Units: Items / Hour

item count time=IF THEN ELSE(item count rate = 0, 0, (store inventory / item count rate) / hours per day); Units: Day

items in route= DELAY FIXED (order fulfillment rate*day + "2-week items central order" * day , (0.5*RANDOM UNIFORM(1.4, 1.7, 0.1 + 0.5* RANDOM UNIFORM(1.9 , 2.4, 0.1))), 0); Units: Items

items on shipper's buffer= INTEG (actual shipment rate-incoming items rate,0); Units: Items

items per case=45; Units: Items

new season's items= INTEG (new themes' incoming rate-display actual rate, 0); Units: Items

new themes' incoming rate=arrival of new season's themes; Units: Items/Day

order fulfillment rate=(MAX (0, INTEGER(orders/items per case) * items per case/day)) * PULSE TRAIN(0, 5, 7, 181); Units: Items/Day

order rate=MAX(0, (reorder point-store inventory-items in route) / day); Units: Items/Day

orders= INTEG (order rate-order fulfillment rate, 0); Units: Items

outgoing items= INTEG (outgoing items rate, 0); Units: Items

outgoing items rate=sales + returnable items; Units: Items/Day

"part-time employees"=IF THEN ELSE(PULSE TRAIN(4.5, 2.5, 7, 181) , 3, 3* RANDOM

UNIFORM(0.65, 0.7, 0.01)); Units: employee

"part-time working hours"=0.5*9.5; Units: Hour/employee

price labeling rate=IF THEN ELSE(RFId =0, (salespersons utilization* RANDOM UNIFORM(140, 160, 1)) * PULSE(145, 1) , (salespersons utilization*RANDOM UNIFORM(750, 800, 10)) * PULSE(145, 1)); Units: Items/Hour

price labeling time=IF THEN ELSE(price labeling rate = 0, 0, (store inventory/price labeling rate) / hours per day); Units: Day

reorder point= ACTVE INITIAL ((initial inventory coverage + inventory adjustment)*PULSE(0, 165), initial inventory coverage); Units: Items

retunable items time=IF THEN ELSE(returnable item rate = 0, 0, (returnable items*day / returnable item rate) /hours per day); Units: Day

returnable item rate= IF THEN ELSE(RFId =0, (salespersons utilization*RANDOM UNIFORM(180, 200, 1)) * PULSE(179, 1) , (salespersons utilization*RANDOM UNIFORM(750, 800, 10)) * PULSE(179, 1)); Units: Items/Hour

returnable items= RANDOM UNIFORM(700, 800, 10) *PULSE(179, 1); Units: Items/Day

RFId= 1; Units: Dmnl [0,1,1]

sales:=GET XLS DATA('file_motivi.xls ' , 'vendite' , 'A', 'C1'); Units: Items/Day

salespersons utilization= 0.7; Units: Dmnl

shop window dressing rate= IF THEN ELSE(RFId = 0, (RANDOM UNIFORM(2, 2.5, 0.1)/salespersons utilization)* PULSE TRAIN(14, 0.5, 14, 181) , RANDOM UNIFORM(1.5, 2, 0.5) * PULSE TRAIN(14, 0.5, 14, 181)); Units: Hour

show window time= IF THEN ELSE(shop window dressing rate = 0, 0, shop window dressing rate / hours per day); Units: Day

"staff-assisted sales time"= MAX(0, store opening time - (show window time + incoming items'

treatment time + retunable items time + item count time + price labeling time)); Units: Day

stock out= IF THEN ELSE(reorder point-store inventory>= 0, 1, 0); Units: Dmnl

store inventory = A FUNCTION OF(display actual rate, incoming items rate, initial store inventory, outgoing items rate); Units: Items

store inventory= INTEG (MAX(0, incoming items rate+display actual rate-outgoing items rate), initial store inventory); Units: Items

store opening time= IF THEN ELSE(PULSE TRAIN(0, 0.5, 1.5, 181) , 0.8* ((("full-time employees"*"full-time working hours") +("part-time employees"*"part-time working hours")) /hours per day), ((("full-time employees"*"full-time working hours") + ("part-time employees"*"part-time working hours"))/hours per day)); Units: Day

Vitae

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Figure 1

Correlation coefficient ρ	p-Value
0.245	0.000

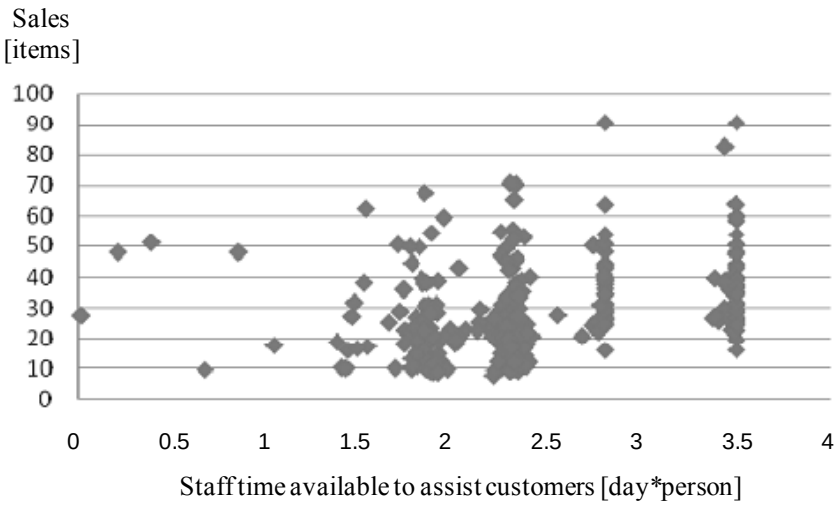

Figure 2

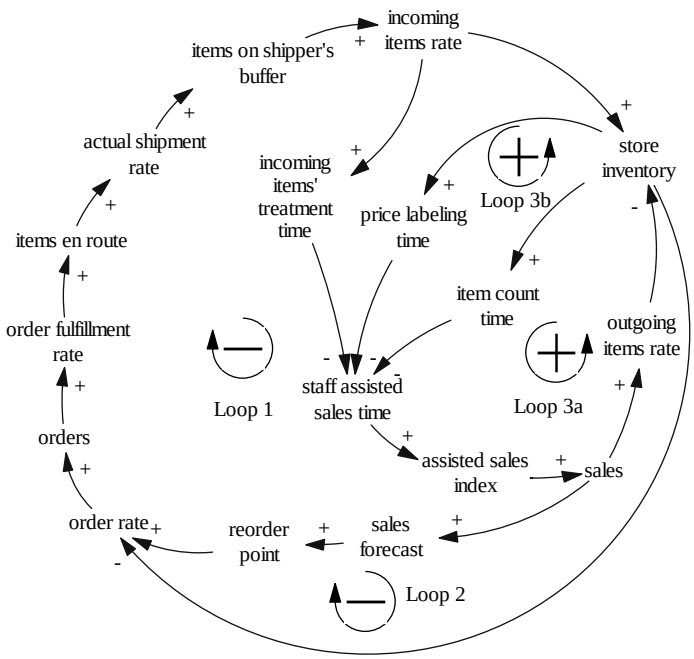
incoming items rate
items on shipper's buffer
actual shipment rate
items en route
order fulfillment rate
orders
order rate
reorder point
sales forecast
assisted sales index
sales
staff assisted sales time
item count time
price labeling time
incoming items' treatment time
store inventory
outgoing items rate
Loop 1
Loop 2
Loop 3a
Loop 3b

Figure 3

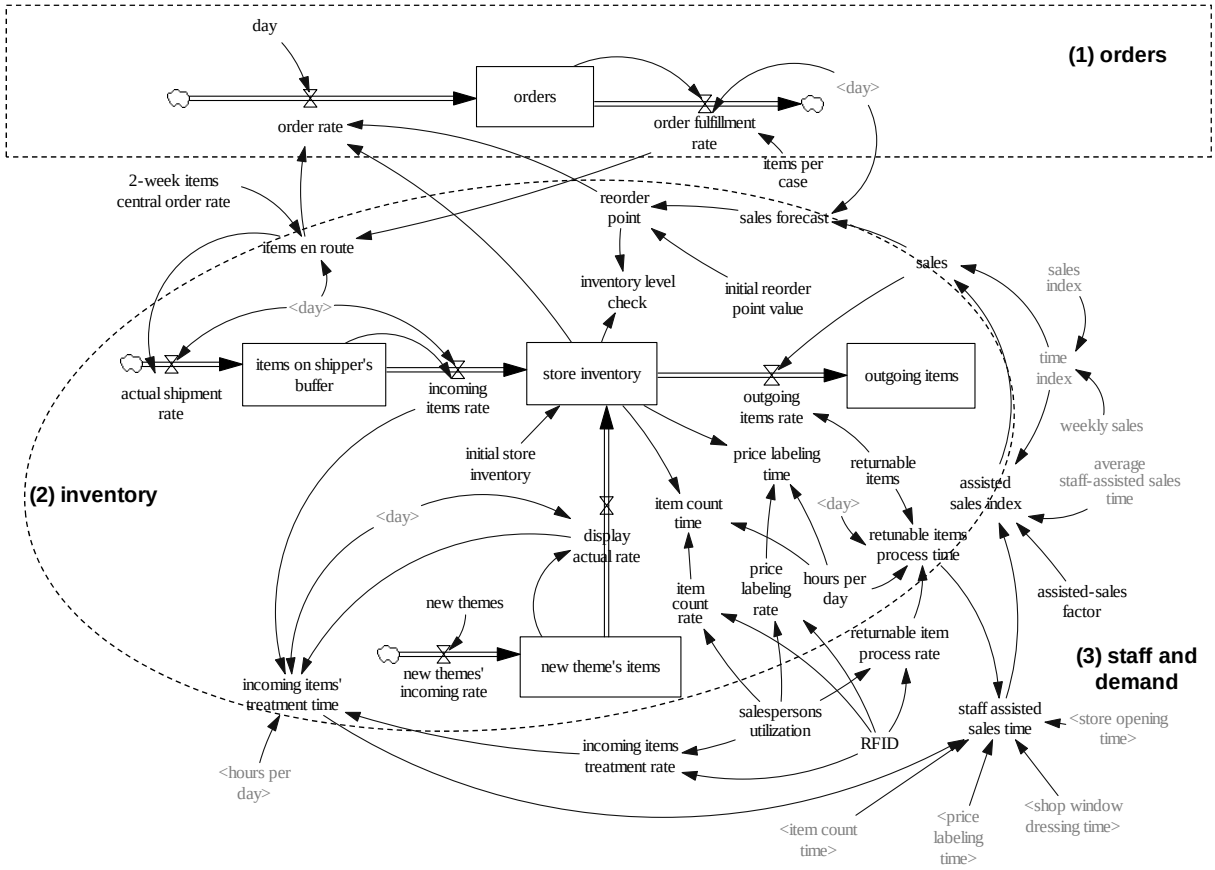
(1) orders
day
orders
order rate
order fulfillment rate
<day>
items per case
2-week items central order rate
items en route
reorder point
sales forecast
inventory level check
initial reorder point value
sales
sales index
time index
weekly sales
<day>
actual shipment rate
items on shipper's buffer
incoming items rate
store inventory
outgoing items
outgoing items rate
(2) inventory
initial store inventory
price labeling time
returnable items
assisted sales index
average staff-assisted sales time
<day>
item count time
<day>
retunable items process time
display actual rate
price labeling rate
hours per day
assisted-sales factor
new themes
item count rate
new themes' incoming rate
new theme's items
returnable item process rate
(3) staff and demand
incoming items' treatment time
salespersons utilization
staff assisted sales time
<store opening time>
incoming items treatment rate
RFID
<hours per day>
<item count time>
<price labeling time>
<shop window dressing time>

Figure 4

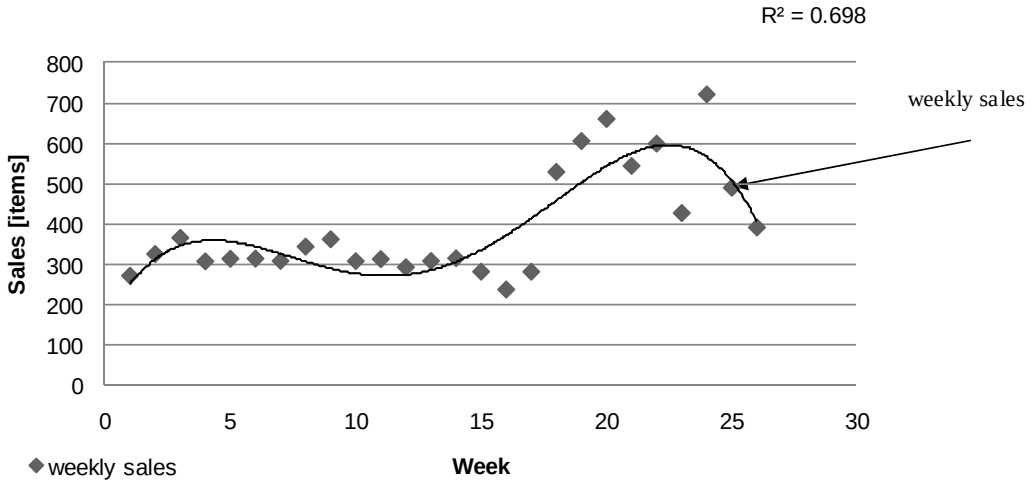
R² = 0.698
weekly sales
800
700
600
500
400
300
200
100
0
Sales [items]
0
5
10
15
20
25
30
Week
weekly sales

Figure 5a

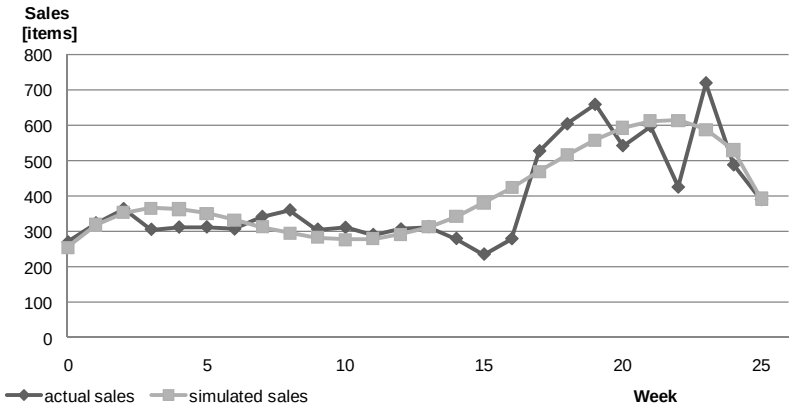
Sales
[items]
800
700
600
500
400
300
200
100
0
0
5
10
15
20
25
actual sales
simulated sales
Week

Figure 5b

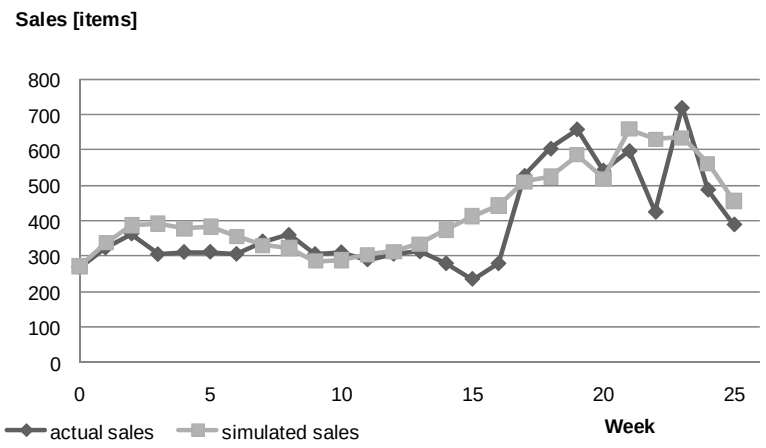
Sales [items]
800
700
600
500
400
300
200
100
0
0
5
10
15
20
25
Week
actual sales
simulated sales

Figure 6a

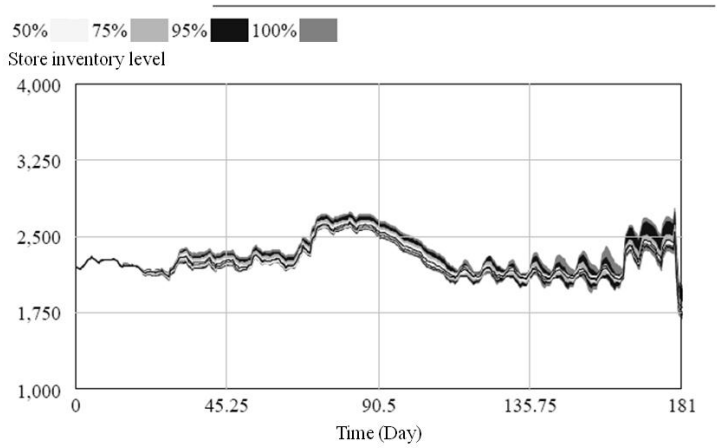
50%
75%
95%
100%
Store inventory level
4,000
3,250
2,500
1,750
1,000
0
45.25
90.5
135.75
181
Time (Day)

Figure 6b

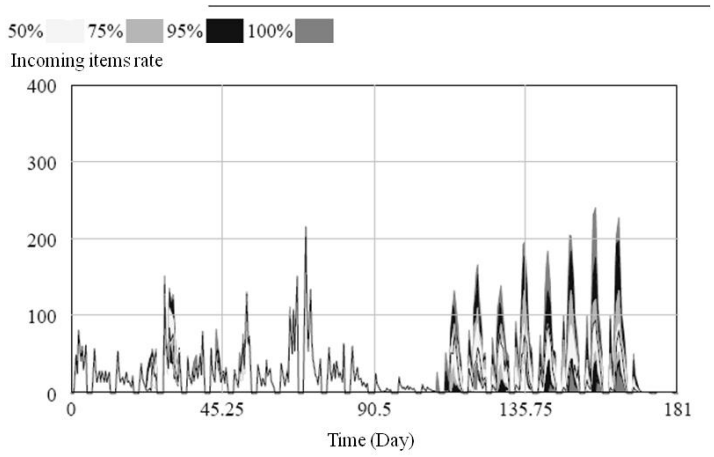
50%
75%
95%
100%
Incoming items rate
400
300
200
100
0
0
45.25
90.5
135.75
181
Time (Day)

Figure 7

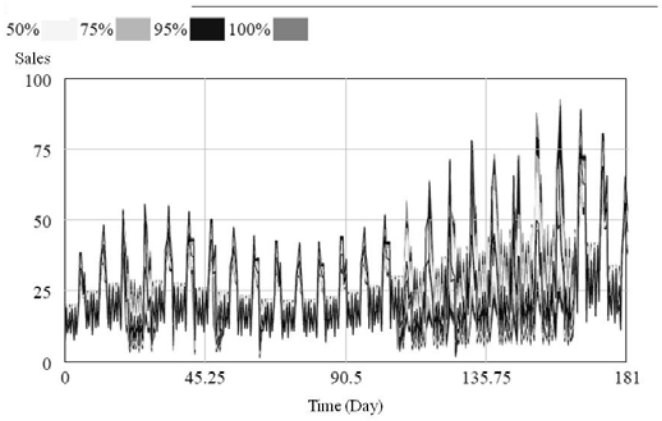

Figure 8

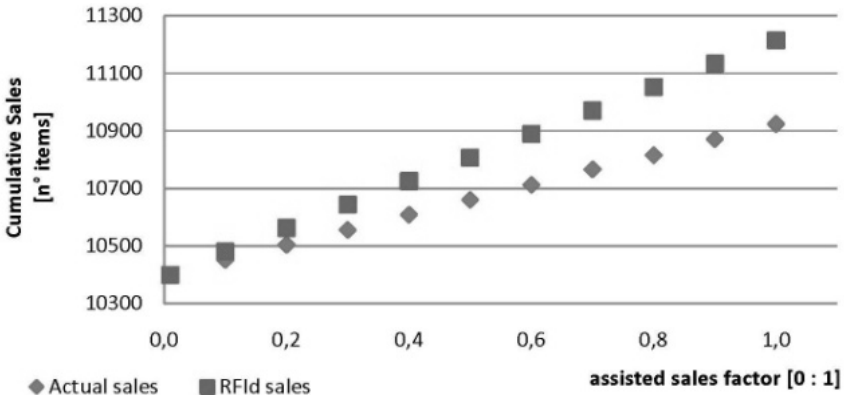
11300
11100
10900
10700
10500
10300
Cumulative Sales
[n° items]
0,0
0,2
0,4
0,6
0,8
1,0
assisted sales factor [0 : 1]
Actual sales
RFId sales

Figure 9a

Store Inventory
4,000
3,250
2,500
1,750
1,000
Items
0
45
91
136
181
Time (Day)
assisted sales factor = 0
assisted sales factor = 0.5
assisted sales factor = 1

Figure 9b

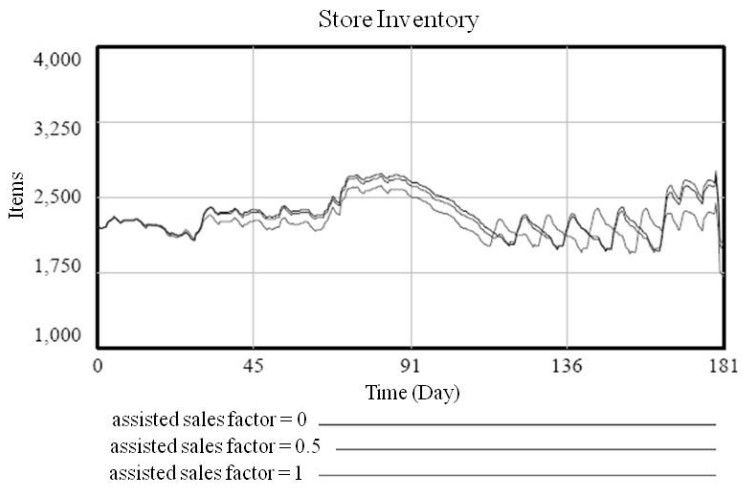
Store Inventory
4,000
3,250
2,500
1,750
1,000
Items
0
45
91
136
181
Time (Day)
assisted sales factor = 0
assisted sales factor = 0.5
assisted sales factor = 1

Table 1

Task description	Average record
Inventory receiving	100 items/hour
	25% of available staff involved
	All items managed within the day
Initial store inventory	2,200 items
Inventory taking	4 times a year
	170 items/person*hour
Price re-labeling for sale period	120 items/person*hour
Store opening time	9.5 hours/day
Full-time employees	2 persons
Part-time employees	3 persons
Salespersons utilization	70%
Shop window dressing time	2 times a month
	2 hours/shop window
Preparation of items to be returned	150 items/person*hour
	850 items (at the end of each season)
Items per case	45
Quantity of items shipped for each new theme	400
Shipment lead-time	1.5 days
Sales share index	35% half-a-day, Mon-Fri morning
	65% half-a-day, Mon-Fri afternoon
	50% half-a-day, week-end morning
	50% half-a-day, week-end afternoon
Preparation time at the DC	0.5 day

Table 2

	Current [hours]	**RFID**[hrs] factor 0.5	**Variation** [%]
Store personnel total working hours	8,901.13	8,901.13	0.00
Incoming items treatment time	162.85	25.26	-84.49
Inventory taking time	38.63	16.41	-57.52
Sale price relabeling time	38.14	7.69	-79.84
Shop window dressing time	38.38	21.66	-43.56
Returnable items process time	11.67	2.79	-76.09
Staff assisted sales time	8,612.10	8,827.95	2.51

Table 3

Assisted sales factor = 0.5						
Leverage	**Annual discount rate**	**Three year-NPV**	**Five year-NPV**	**Three year - IRR**	**Five year-IRR**	**DPP (months)**
100% equity	3.67%	- € 54,335	€ 5,921,685	2.63%	22.25%	37
35% equity-65% debt	3.83%	- € 78,146	€ 5,860,293			37

Table 4

Assisted sales factor = 0.7						
Leverage	**Annual discount rate**	**Three year-NPV**	**Five year-NPV**	**Three year - IRR**	**Five year-IRR**	**DPP (months)**
100% equity	3.67%	- € 6,307,516	€ 860,093	-28.44%	1.06%	59
35% equity-65% debt	3.83%	- € 6,325,667	€ 841,943			59
Assisted sales factor = 0.8						
Leverage	**Annual discount rate**	**Three year-NPV**	**Five year-NPV**	**Three year - IRR**	**Five year-IRR**	**DPP (months)**
100% equity	3.67%	- € 1,576,702	€ 8,922,477	-3.42%	20.50%	42
35% equity-65% debt	3.83%	- € 1,576,702	€ 8,893,347			42
Assisted sales factor = 1						
Leverage	**Annual discount rate**	**Three year-NPV**	**Five year-NPV**	**Three year - IRR**	**Five year-IRR**	**DPP (months)**
100% equity	3.67%	€ 8,082,450	€ 24,157,297	34.63%	52.88%	22
35% equity-65% debt	3.83%	€ 8,555,482	€ 24,005,465			22