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Quantifying RFID-enabled Traceability For The Food Industry: A Case Study

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Abstract

With the competitive differentiators of supply chain operation's efficiency, food differentiation with credence attributes, quality enhancement and food safety, the concept of "traceability as strategy and mandatory initiative" has replaced that of "traceability as a cost of a business or as a voluntary responsibility". This implies that the introduction of a traceability system should be perceived and positioned as a catalyst for better business practices in terms of legal compliance, safety and quality assurance, risk prevention, efficient recalls/withdrawals and consumer's trust. However, despite these benefits, a traceability system is also investment worthy. Hence, the value of investment in a traceability system constitutes a matter of considerable concern and debate for both practitioners and academics alike; meaning that it is essential to recognize the extent to which the potential benefits gained by a traceability system outweigh the value of investment in such an initiative. As a result, this paper presents a cost-benefit evaluation applied in a frozen food company regarding the pilot deployment of a RFID-based traceability system.

Keywords: *RFID, Traceability, Cost-Benefit Analysis*

1 MOTIVATION

Public and industry concerns over food safety have grown considerably over the last decade. Food safety has traditionally been viewed as a "cost of business" (Littlefield, 2006) and, as a result, perceived and positioned as the voluntary responsibility of companies. However, this perception is changing as stricter legislation and industry standards are entered into force and require that companies not only adopt a strategy of minimal compliance, but also treat such strategy as a catalyst for better business practices.

Despite all the legal requirements and industry standards deployed to ensure optimum quality, serious outbreaks of food diseases (e.g. BSE or Mad Cow Disease, Dioxin contamination of animal feeds, Listeria) did occur where contaminated products had already reached consumers. To meet such ethical aspect, the withdrawal/recall of the inappropriate products from the market and the notification of authorities have become top of mind for the food companies. Furthermore, such food deficiencies have raised doubts in the consumer's mind and created a lack of trust and confidence in products put on the market. Consumers are getting more and more worried about what they eat – whether the food comes from a sustainable source and produced through eco-friendly methods, and whether production, transportation, and storage conditions can guarantee food safety. Betraying the consumers' confidence may lead, in the long term and the worst case, to damage a company and its brand image and lead it to economic collapse (ECR Europe, 2004).

Under the pressures of legal compliance, safety and quality assurance, risk prevention, efficient recalls/withdrawals and consumer's right to know, the introduction of a traceability system is not only an uppermost, but in some food chains, a mandatory initiative. Hence, deploying a traceability system can bring about significant improvements in three main dimensions (Golan et al., 2003):

- capturing efficiency gains through improved supply-side management

- achieving marketing/ competitive advantage by differentiating foods with credence attributes
- improving food safety and quality control by facilitating firms in identifying and resolving food safety or quality problems

Empowered by the possibility to automatically identify unique product instances through new technologies, such as RFID, a traceability system promises to meet the above requirements even more effectively. However, as with all novel technologies, it takes time to make “things work”. As a result, in view of the pre-mature level of RFID implementation, it is imperative to understand the significance of justifying the investment in a RFID-enabled traceability system and its implications for organisational performance. Therefore, this chapter describes work undertaken for a company that deals with frozen food regarding the requirements’ analysis, development and pilot implementation of a RFID-enabled traceability system. Based on the experience gained, several considerations are presented that could provide valuable feedback to other organisations interested in moving to a RFID-enabled traceability scheme.

2 THE RFID TECHNOLOGY

Radio Frequency Identification (RFID) is a technology that uses radio waves to automatically identify objects. The identification is done by storing a serial number, and perhaps other information, on a microchip that is attached to an antenna. This bundle is called an RFID tag. The antenna enables the chip to transmit the identification information to a reader. The reader converts the radio waves reflected back from the RFID tag into digital information that can be passed on to an enterprise information system (Kelepouris et al., 2007). RFID has been extensively used for a diversity of applications ranging from access control systems to airport baggage handling, livestock management systems, automated toll collection systems, theft-prevention systems, electronic payment systems, and automated production systems (Agarwal, 2001; Hou & Huang, 2006; Kelly & Erickson, 2005; Smith & Konsynski, 2003). Nevertheless, what has made this technology extremely popular nowadays is the application of RFID for the identification of consumer products and supply chain management.

The advanced data capture capabilities of RFID technology coupled with unique product identification and real-time information coming from different data sources, such as environmental sensors, define a new and rich information environment that opens up new horizons for efficient management of supply chain processes and decision support. As such, RFID can potentially empower a broad spectrum of applications, ranging from upstream warehouse and distribution management down to retail-outlet operations, including shelf management, promotions management and innovative consumer services, as well as applications spanning the whole supply chain, such as product traceability (Pramatari et al. 2005). Despite the broad spectrum of applications, RFID implementations currently take place internally within a company, mainly with the objective to automate warehouse management processes or store operations in the first run. As an outlook to the future, a recent industry report (GCI 2005) identifies certain application areas (specifically store operations, distribution operations, direct-store-delivery, promotion/event execution, total inventory management and shrink management) as the major opportunities for the deployment of RFID technology in the short and mid-term. These application areas have been selected based on their performance versus the ratio of expected benefits over associated costs, including process transformation difficulties. The same report identifies further opportunities in several “track and trace” activities (such as anti-counterfeiting, product diversion, recalls/ reverse logistics, fresh/ code-dated product management, cold chain monitoring, and legal compliance), although it is noted that ‘more work is required to understand its potential applications and benefits in these areas’ (GCI 2005).

Leading companies in the global market have already made moves towards the application of RFID technology for monitoring product flow in their supply chain. Wal-Mart, the biggest retail chain in the United States, has mandated its biggest 100 suppliers to apply RFID tags to each pallet arriving in its central warehouse in Texas by January 2006. Respectively, the U.S. Department of Defense has already issued a mandate requesting from its suppliers to apply RFID tags to all parts delivered to U.S. Army by January 2007 (Shutzberg, 2004). Metro, a big retail chain in Europe, has implemented a store (called "the future store") that operates using RFID tags applied in each product. Metro has optimized many internal processes of the store utilizing the RFID technology and provides its customers with innovative services such as semi-automatic checkout, smart trolley, which carries a TFT display and provides the customer with information about the products on the shelves and the trolley. Furthermore, future store gives Metro the opportunity to assess the benefits of RFID in a real case, measuring the impact of RFID deployment on stock reduction, increased availability and other issues of supply chain management (Hamner, 2005). RFID technology has already been adopted by some suppliers at product level. Gillette is the most striking example, having already applied RFID tags in some razor products.

3 THE CONTEXT

3.1 The case: a frozen food company

The case concerns a leading food company in Greece (more than 30% of market share) and one of the largest in Europe. Its brands are recognized by millions, reaching consumers in 30 countries whilst expanding across the world map. Its success is based first and foremost on its respect for the consumer, and its tireless daily efforts to supply the best possible value in the form of healthy, quality products. The company is now comprised of four divisions: Dairy and Drinks; Bakery and Confectionery; Foodservices and Entertainment; and Frozen Foods.

The Frozen Foods Division is involved in the production and processing of frozen vegetables and foods in Greece and abroad. The range of the Division's products is constantly developing. It is active in the production of frozen vegetables, pre-cooked meals, mixtures of frozen vegetables, and more recently, fresh salads. Over its 35 years on the market, it has always been innovative and generated new products.

Realising the RFID's potential for improvements in different aspects of a warehouse, the company decided to participate in a project partly funded by the General Secretariat for Research & Technology, Ministry of Development of the Hellenic Republic regarding the requirements' analysis, development and pilot implementation of a RFID-enabled traceability system within the central warehouse.

3.2 The Warehouse and its operations

The company has a central warehouse that stocks frozen vegetables and comprises a production unit where vegetables are packaged in bags. This paragraph includes the description of the as-is operations within the central warehouse and aims at understanding the relationships between various activities and identifying operations that are troublesome and can be improved by the deployment of RFID. This is accomplished by interviewing and visually examining the operations that includes queues, bottlenecks, and human errors, and as a result, gain insight into the problems that are expected to be improved by the RFID deployment.

The raw materials constitute the domestic fresh vegetable (e.g. green beans, peas) or the imported frozen vegetable. The incoming fresh product is frozen immediately and packaged in large containers with a content of various kilos. Respectively, the imported frozen vegetable that arrives in the factory from approved suppliers of abroad is packaged directly in large containers. Consequently, the semi-finished product derives either from the freezing and packaging in large containers of domestic fresh vegetable or the packaging in large containers of imported frozen vegetable. The large containers are then stored in a chamber for semi-finished products until there is a need for putting into consumer packaging. Packaging follows a rolling and controlled program based to the sales target. Then the semi-finished product passes on a belt to mechanical equipment that bags it and puts it in a sachet/pouch. Workers are stacking the sachets in cases and, finally, palletizing the cases. Consequently, the finished product derives from the packaging in sachets, cases and pallets of the semi-finished product.

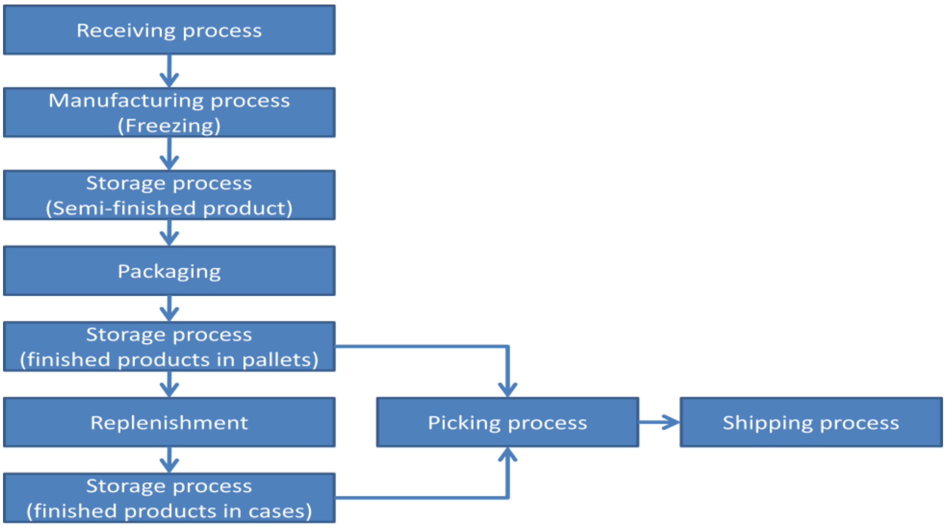

Figure 1: The most important processes that take place within the central warehouse

3.2.1 Receiving Process

A container carrying fresh vegetable arrives and stops at the assigned docks outside the warehouse. The products on the bed of the container are unloaded in a conveyor, which triggers the production line.

3.2.2 Manufacturing Process

The freezing process is seasonal, based on a harvest that starts in May. By the end of December the last vegetables have been picked, processed and stored as semi-finished products. The actual process of freezing a food item varies somewhat depending on what is to be frozen. Peas are the most common frozen vegetable. The pea process is typical for many vegetables. A typical process for a frozen entrée involves the following steps:

- Cultivating the peas
- Picking and washing
- Blanching
- Sorting
- Inspection
- From the oven to the freezer

3.2.3 Quality Controls

Frozen foods must be carefully inspected both before and after freezing to ensure quality. When vegetables arrive at the processing plant, they are given a quick overall inspection for general quality. The peas are inspected visually again as in step five, above, to make sure that only the appropriate quality peas go on to the packaging and freezing step. Laboratory workers also test the peas for bacteria and foreign matter, pulling random samples from the production line at various points.

3.2.4 Packaging Process

The frozen vegetable passes on a belt to mechanical equipment that bags it and puts it in a case. Then, workers that are dressed in cold-weather gear for protection are palletizing the cases. The pallets are stored in a warehouse cooled to between 0- -20° F (-17.8- -28.9° C). They remain there up to their demand from the customer.

3.2.5 Storage Process

Although having a Warehouse Management System (WMS) in place, the process of storage of semi-finished products depends heavily on quality variation and FIFO. It is impractical to have predetermined fixed positions because of the characteristics of the particular products. As a result, the assignment of the semi-finished products to storage locations is based on a haphazard fashion, indicating that products are not stored in designated fixed locations (random storage scheme). The system considers only the production and the expiration date of the products. The produced goods enter the warehouse reserved by the quality control and they are released automatically by the system in a certain number of days after the production date. The finished product is stored in two chambers: one that consists of pallets of finished products and one that consists of cases of finished products.

3.2.6 Picking Process

Whenever an order is requested, the list of picking is generated. An operator of an indoor forklift truck picks up the corresponding products from the designated locations by using the WMS and by perception. This policy of marshalling products for delivery is chosen because of being easily employed and for order integrity to be maintained. The multiple orders are picked consecutively and are accumulated applying a first-come-first-served (FCFS) logic that combines orders as they arrive until the maximum cubic and weight capacity of a container has been reached.

3.2.7 Shipping Process

Before being transported, the products for one truck are lumped together at a provisional position. At that time, an operator gives them a compliance check. After that, a truck arrives at the designated docks and all products are to be loaded on the bed of the truck. Then, the truck departs for its destination.

3.2.8 Recall Process

Product recall can be discriminated in three stages according to the level of its sprawl inside the supply chain:

a. Tracking the product is inside the factory warehouse
b. Tracking in intermediate stages of the supply chain (associates' warehouses, major distributor etc.)
c. Tracking the product at the buyer's level, the consumer has already purchased the degrated product, which is the most expensive scenario.

In Vivartia orders can concern big customers or even smaller, therefore there are two types of distribution:

a. Distribution orders, the distribution lorry can be constituted from more than one orders.
b. Big – distributor orders

Orders and shipments to big customers are in multiples of pallet and since each pallet is constituted by boxes of one unique LOT NUMBER, there is some kind of visibility across the supply chain for these products. Consequently there is not any particular problem in the detection and retraction of degraded products that concerns this category of customers. The main problem is presented to the small customers where there is no information with regard to whom the products end up. Before the installation of the new IS the standard procedure was to allocate additional personnel that would visit all the distribution points, check all the boxes without exception that belong in a particular product type in order to find out and return in the factory only those that belong in the "suspect" lot. As one can realize a lot of extra amount of time, people was necessary in order to complete a product recall making these procedure very expensive.

4 ALTERNATIVE RFID IMPLEMENTATIONS

Alternative RFID implementation scenarios result also from the recognition of problems for complete traceability. The implemented scenario is essential to satisfy and improve, consequently, most from these problems. Through the interviews that were conducted, the problems that occur in the frozen products factory are the following:

- Need for automatic tracing of production background
- it requires computerisation of files of agronomists and food technologists
- Need for more efficient localisation and collection of pallets of semi – ready product
- they are stored without precise recording of their place
- Need for automation of process of storage and substitution of ready product
- Need for precise tracking in level of box at their distribution in intermediary
    - big-distributor
    - retailer

At equivalence, the proposed application scenarios of technology RFID are the following:

1. Electronic recording of information for detection of problems (tracing)

- Lot number relates a concrete lot with the production background (tests from agronomists & food technologists)

2. Monitoring of products in the semi – products warehouse (internal traceability)

- Efficient localisation and collection of orders using FIFO

3. In-bound, out-bound in the warehouse (internal traceability)

- Automation of processes

4. Localisation (tracking) parcels at the distribution

- To intermediary big-distributor or retailer
- Lot number relates parcels with dispatch locations

From the above alternative scenarios, based mostly on the different implementation costs, in the problems that are presented for traceability in box – level and through an extensive discussion with all participating, it was decided to materialize the first and fourth scenario. The detail description of the final scenario that it incorporates these two is presented in the following paragraph. Through this description it will become obvious that this choice achieves to a high level of traceability in level of box and therefore justifies the implementation cost.

5 RFID SCENARIO

When the industrialization of vegetables is finished, the food technologist performs sample tests (microbiological, natural and chemical) and according to their results it defines the product quality. The results of these controls will be recorded henceforth electronically, in order to be able to affiliate the lot number of the semi – ready product with the files of the food technologists' in relation to each of the test stages of the semi – ready product. The semi – ready product then is stored in the semi – ready warehouse. When, however it is packed in bags, the change of state from semi – ready to ready product will be recorded. This means that the lot number of the semi – ready product will be related to the lot number of the ready product. At this point it will be also performed tagging in level of box. Afterwards, RFID readers will be placed in the shipping areas. Then during the loading the overall bill of goods, the EPCID of boxes and shipping gate will be recorded. Through the interconnection of the RFID system with Aberon Warehouse Management System, that maintains all the data related to the orders and routes, it would be able to relate the lot number of the ready product with the dispatch locations. Finally, the system, will provide the possibility for two types of reports: a) tracing, that will give the possibility recovering the data of qualitative control by providing a specific product lot number and b) tracking, that will give the possibility of recovering the current place of products of a specific lot number.

To sum up the RFID implementation scenario for traceability is constituted by the following operations:

- Electronic recording of data of quality tests
    - Cross-correlation <u>lot number of semi – ready product</u> with the <u>files of food technologists</u> with regard to all test stages (microbiological, natural, chemical) of the semi – ready product
- Recording of state changes from semi – ready to ready product
    - Cross-correlation lot number of semi – ready product with lot number of ready product
- Recording of product shipments
    - Cross-correlation of lot number of ready product with dispatch locations
- Generation of reports:
    - Tracing
    - Tracking

The following figure summarises the implementation scenario.

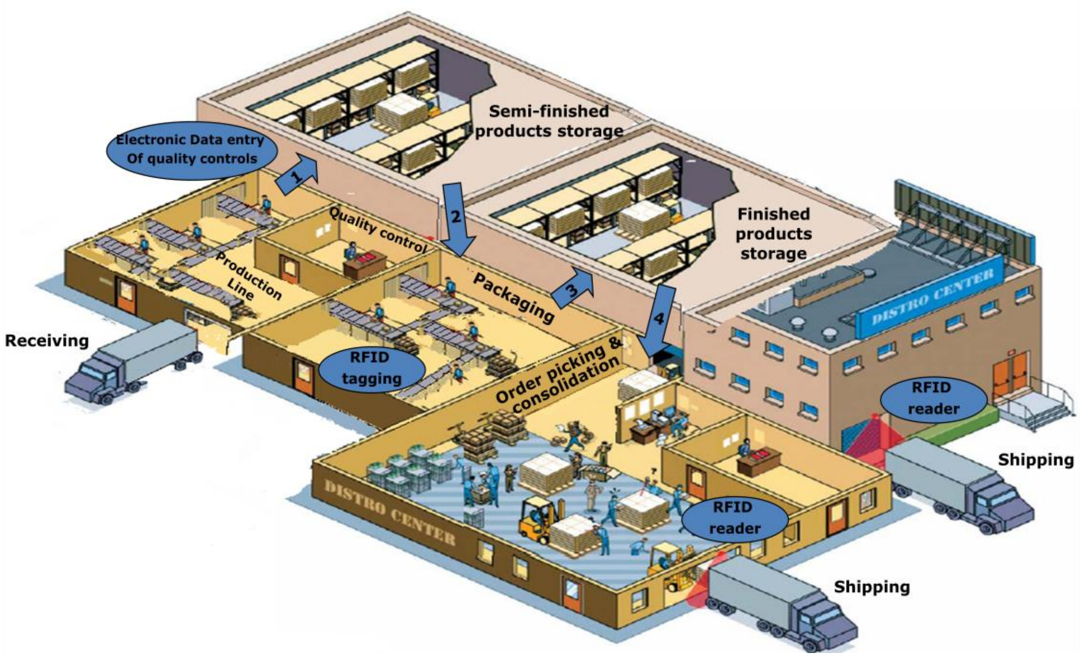

Figure 2: The chosen RFID implementation

6 COST-BENEFIT ANALYSIS

Reverse logistics refer to the management of the sub-products of production and consumption (waste, used packages) and the defective, ruined, used or hazardous for public health products that can't be sold and are predestined either for recycling either for destruction. They have two basic application fields: product recall, which concerns products which have been already placed to the market, and the collection of-no-use products or sub-products from some points of the production line (factories, warehouses, shops etc.). The main difference between these two fields is spotted in the amount of time that is needed to perform this action and the recurrence of it. Carrying back the products to the main factories has a significant cost that can be reduced by doing with the same distribution trucks.

In our case, a cost-benefit analysis was conducted in order to evaluate the recently installed IT system that is relying on the RFID technology. Mostly the interest focused on whether the new Information System produces more profitable results during a recall of a defective batch from a product and on the 30 % of the total market, which represents only the clients with direct distribution from the factory in Salonica. The analysis was based on two different scenarios according to the Information System that is being used each time and the information that it provides. In the first scenario it is hypothesized that there is no traceability system installed, in the second it refers to the current traceability system that exists in the factory.

The main problem of the cost – benefit analysis was to define what would be regarded as recall cost and how it could be measured with regard to the amount of money and time that is needed to recall a suspicious batch of a product. As mentioned in a product recall it is significant whether the product has already been placed in the market or not, in each case the measures are completely different. The current analysis considered the worst case scenario where the defective products have already been placed in the market in a large number of clients and therefore many additional costs were to be considered. First and above all is the transportation cost where the defective products are returned to the factory for destruction. This cost is considered as the product of the cost of each route with the number of routes that are required for a product recall, and is directly related to the propagation of the defective products. However, this cost can be greatly reduced if the recollection is done by the same distribution trucks when a new delivery is being conducted. During the recall procedure another cost is presented; the cost of examining all the products that have distributed to the market in order to reveal the defective ones. Nevertheless, this cost may be not taken into consideration if the examination is performed by employees of the clients. The most important costs, although, in a product recall is the lost sales cost; the company loses from the sale of the product, because during a recall period all the amount of that particular product is tied down until it is confirmed as safe for sale and the cost of the RFID tags that the product cases must have. Finally, a cost that is not directly associated with the recall product procedure, but of great importance is the initial set up cost for the introduction of the new technology in the company's IT. This cost calculated 1n 27000 € is distributed properly in a three year period (40%, 30%, 30%) according to the following table;

	1st year - 40%	2nd year - 30%	3rd yaer -30%
New IT	10800 €	8100 €	8100 €

Table 1 Distribution of the initial set up cost per year

In order to produce more accurate results the analysis categorized all the frozen products that the company produced into four major classes according to two important characteristics, volume and cost of production:

a. High production volume and low production cost

b. High production volume and high production cost

c. Low production volume and low production cost

d. Low production volume and high production cost

The following table describes on average the main characteristics of each category;

class	Production cost per item	Cases distributed / produced (per day)	RFID tags cost (per year)
a	≈2,50 €	≈500	≈20000 €
b	≈5,00 €	≈300	≈12000 €
c	≈1,40 €	≈20	≈850 €
d	≈4,90 €	≈25	≈1000 €

Table 2 classes characteristics

Moreover, the total year production of the company is calculated in 2500000 cases of products which produces on average a 375000 € cost for the RFID tags. However due to the fact that only the 30% of the market is being examined this cost is reduced to 111250 €. For more simplicity in the results, since the production rate in each class of product in a year period has little variance, it was supposed as fixed during the three year amortization period of the new IT system.

In order to have a more comprehensive aspect of the impact of the new IT system new metrics have been introduced;

a. Difference, which is measured from the total recall cost for each product before the new IT subtracting the total recall cost after the installation of the new IT with the RFID technology
b. Benefit, which is calculated as *Difference* product the number of times a recall procedure is being conducted for a product during a year
c. Profit, calculated subtracting from the total benefit the cost of the initial set up cost for the examined year and the RFID tags' cost, whereas the total benefit corresponds to the aggregation of the benefits of each separate class that occur in case of a product recall.

The mathematical analysis produced the following table that indicates the Difference for each product class;

Difference (per product class)			
Class 1	Class 2	Class 3	Class 4
19.764 €	**10.212 €**	**3.900 €**	**4.464 €**

Table 3 Difference

A vector is being produced which represents the total benefit;

$$19764 * x_1 + 10212 * x_2 + 3900 * x_3 + 4464 * x_4$$
$$x_1, x_2, x_3, x_4 \in Z$$

, whereas x_1 stands for the number of times a recall procedure is being conducted for class 1 products, x_2 stands for the number of times a recall procedure is being conducted for class 2 products etc. Finally, with the help of the above vector the profit can be calculated and determine the minimum range of times that product recall must take place in year time in order for the recently installed IT to be more profitable from the old one.

7 CONCLUSIONS

After mathematical analysis, the new installed Information System indicated a spectacular reduce in recall cost for all the product classes at about 90% from the initial cost. Analytical measures are represented in the following table;

Product class	Reduction rate
class 1	**90,3%**
class 2	**89,0%**
class 3	**92,0%**
class 4	**92,2%**

Table 4 Recall cost reduction rates due to new IS

Especially in order to make this more comprehensive the following figures indicates the actual recall costs for each class each time a recall of a product is being conducted;

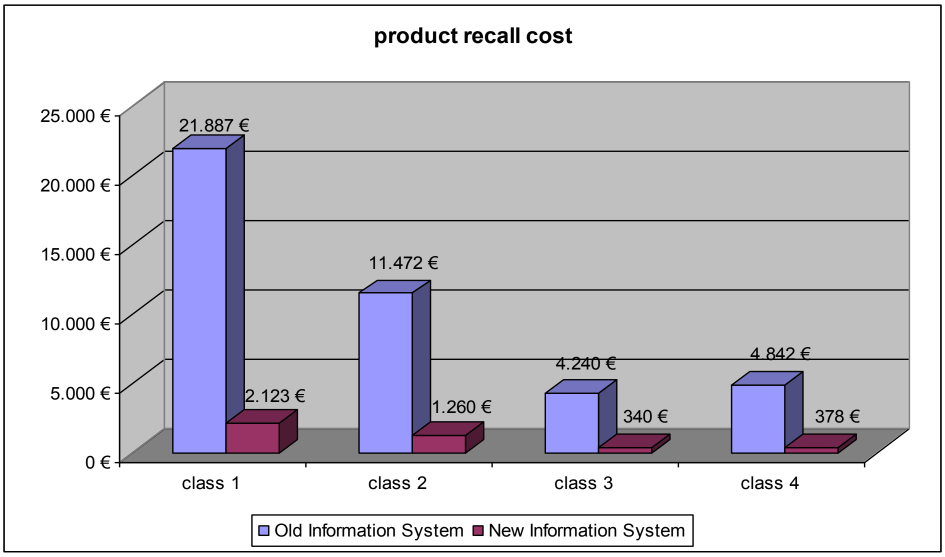

Figure 3 Total recall cost for each product class

This cost reduction is a consequence from the reduction of the number of possible locations that a defective product is located, that also is being dramatically reduced due to the visibility that the new IS provides.

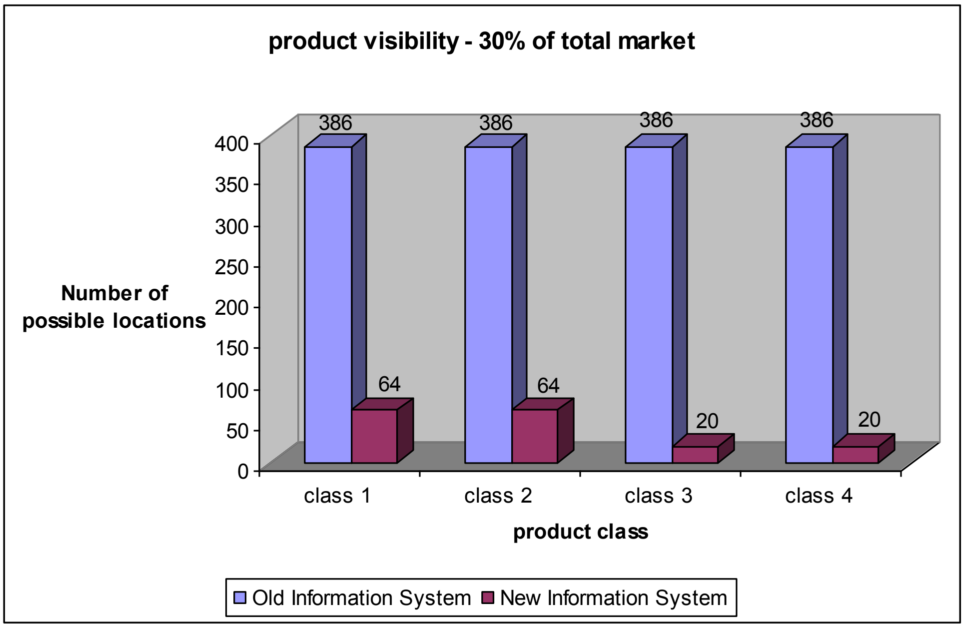

Figure 4 Possible locations of a defective product

As indicated in the above figure, when no information exists the company is obliged to check all of her clients whether they have any amount of the defective product or not. However, after the installation of the new system this number of possible locations is greatly reduced according to the volume of production. Especially, for products with low production volume the reduction is extremely high.

Reading again table 3, a very interesting assumption can be made; if the company was interested in applying the RFID technology to only specific products, then it would be more profitable to install it on products with high volume production rather than with low, because the recall cost of a product with high production volume is multiple times higher than the recall cost of a product with low production volume.

According to the present analysis, it is clear that the new traceability system that the company installed is cost – effective and profitable, especially when a number of product recalls are being conducted in a year's time. However, more research should be made whether it would even more profitable the use of RFID technology not only on the company's factory but also on the distribution trucks and even from the company's clients.

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