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AN RFID SIMULATION FOR THE SUPPLY CHAIN MANAGEMENT OF THE UK DENTAL INDUSTRY

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ABSTRACT

This paper documents an RFID simulation for the supply chain management in the dental industry in the UK. The paper starts with a preliminary analysis of the UK dental product industry followed by a literature review on topics of IT and Logistics and Technological innovation. A case study from UK dental industry is selected for the study and a supply chain analysis conducted in order to discover the business processes and problems. A proposed solution with RFID technology to the encountered problems is simulated and then compared with the current supply chain system and metrics calculated for comparison and justification of the introduction of the RFID technology.

Keywords: *JIT, Supply Chain Systems, RFID, Dental Industry*

1. INTRODUCTION

The UK dental product industry includes both supplies and equipment. The focus of this study is supplies (referred to as "dental products") and the materials used to produce them. Demand for dental products and materials in the UK (at the manufacturers' level) reached $8.8 billion in 2007 based on growth of 5.8 percent per year from 2002 [1]. In the previous five years (1997-2002), annual gains set a 6.2 percent pace. During the mid-to-late 1990s, and into 2000, the dental product industry experienced favourable gains due to a slew of consumer product innovations, such as tartar control toothpaste, whitening toothpaste and over-the-counter (OTC) whitening products. Value gains decelerated in 2002 and 2003, a result of the recessionary climate. During this time, many dental patients postponed optional treatment plans, pursuing less expensive alternatives. In 2004 robust gains were due to improving economic conditions and the release of pent-up demand. Nevertheless, demand growth --while still very respectable --decelerated in 2005, 2006 and 2007, despite an aging population and the popularity of cosmetic procedures. Market maturity of consumer products such as toothpaste and denture items helped keep demand growth below the pre-recession pace. (Datamonitor, 2008)

In 2007, the global market for dental products totalled $32 billion, with demand levels and product mix differing widely depending on each country's economic strength and its level of development [1]. The requirement for dental products rises commensurately with dental expenditures, the number and type of dental procedures, and growth in certain demographic segments. In 2007, developed areas of the world (e.g., the United States, Canada, Western Europe, Japan and Australia) dominated the dental product market, and this will continue to be the case for the next decade. These areas generally maintain the highest per capita dental care expenditures in the world. Due to high levels of dental service expenditures and a lower incidence of tooth decay, dental care in developed areas will continue to shift towards preventive and aesthetic enhancing procedures [2]. Moreover, as health care continues to improve, life expectancies will continue to rise in developed countries. Lower incidences of tooth decay and longer living individuals will boost dental care requirements. In addition, in many cases, older segments of the population are well positioned to pay for the required procedures because they control sizable amounts of discretionary income [1].

The UK dental market space has witnessed aggressive growth rates, with strong inventory focus to enhance market penetration and presence. On the other hand, penetration of RFID tags to enhance inventory systems across the globe is low as compared to other industries. This forms the background for our research study with focus on enhancing efficiency with usage of online platforms and RFID in the UK dental sector. Therefore the main question is: How to enhance the distribution

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network in the UK dental industry with an effective RFID supply chain solution?

2. LITERATURE REVIEW

2.1 RFID Impact On Supply Chain Management

Previous work on RFID impacts in the supply chain can be classified in three main groups: conceptual papers, simulation papers and field studies. Among the conceptual papers describes some critical trends and implications of applying RFID to supply chain management detailing its benefits as well as the impediments to implementation [3]. With respect to supply chain strategy suggest that RFID may facilitate the development of emerging supply chain configuration by acting as an enabler of a build-to-order supply chain management strategy. More broadly consider RFID as a technology that enables "smarter supply and demand chain" facilitating collaboration practices such as collaborative planning, forecasting and replenishment. Many mathematical and simulation models have been used to assess the impact of RFID on supply chain performance [4]. For instance, manufacturer-retailer supply chain environments, the potential benefits of RFID in inventory reduction and service level improvement. The author also investigates the improvement of inventory replenishment decision considering some specific aspects of RFID enabled supply chain such as the increase in "information visibility". Glassberg et al., [5] propose six models of cost-benefit analysis for RFID applications in different logistics activities in the printing industry. The relationship between inventory inaccuracy and performance in a retail supply chain, and the way RFID may improve efficiencies by reducing supply chain costs and out of stock levels. Among articles with empirical results from field studies, Lockamy & McCormack [6] examines RFID applications in the retail supply chain based on the early Metro group pilots in Germany, suggesting that IT innovations (including RFID) in combination with the new marketing concept of "future stores" have contributed to a sales increase of about 23% compared to the preceding year while "reducing out of stock by 9 to 14% and store space by about 11%".

The most notable is Radio Frequency Identification, or RFID. RFID tags are essentially barcodes on steroids. Whereas barcodes only identify the product, RFID tags can tell what the product is, where it has been, when it expires, whatever information someone wishes to program it with. RFID technology is going to generate mountains of data about the location of pallets, cases, cartons, totes and individual products in the supply chain [7]. It's going to produce oceans of information about when and where merchandise is manufactured, picked, packed, and shipped. It's going to create rivers of numbers telling retailers about the expiration dates of their perishable items—numbers that will have to be stored, transmitted in real-time and shared with warehouse management, inventory management, financial and other enterprise systems. In other words, it is going to have a really big impact [7]. Another benefit of RFIDs is that, unlike barcodes, RFID tags can be read automatically by electronic readers. Imagine a truck carrying a container full of widgets entering a shipping terminal in China. If the container is equipped with an RFID tag, and the terminal has an RFID sensor network, that container's whereabouts can be automatically sent to Widget Co. without the truck ever slowing down. It has the potential to add a substantial amount of visibility into the extended supply chain. Right now the two biggest hurdles to widespread RFID adoption are the cost of building the infrastructure and the lack of agreed-upon industry standards [7].

RFID (Radio-Frequency Identification) technology has been considered as "the next revolution in supply chain" since it allows the tracking of each object or product in real time in the supply chain (SC). However, while RFID seems to offer a unique potential to supply chain management (SCM) improvements over existing automatic identification and data capture (AIDC) technologies, some scepticism remains in the community of potential adopters since there is no clear indication of the model to follow when assessing the impacts and benefits of an RFID enabled SC [7]. In particular, return on investment (ROI) is uncertain if one attempts to assess both cost reductions and value creation at the individual organisation level and at a collective level (i.e. including all the SC members). This difficulty adds to the challenge for RFID adoption which requires interorganizational cooperation among a network of firms to be involved in implementing this technology in a business-to-business electronic commerce (B-to-B e-commerce) context [8].

Considered as a wireless AIDC technology, RFID not only refers to the tag containing a chip, but also to an antenna for sending and receiving data, an interrogator, also called reader, and its antennas to communicate through radio frequency with the tag, and finally, a middleware that manages, filters, aggregates and routes the data captured. All these elements are essential to constitute a "basic" RFID system. This RFID infrastructure is generally integrated with enterprises systems (e.g. WMS:

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warehouse management system, enterprise resource planning: ERP) where specific applications are hosted and may be coupled with other technologies such as global positioning system (GPS). RFID has been the topic of interest in various fields of research related to the technology itself, innovation management and potential trajectories for RFID adoption, implementation in an inter organisational context, CRM (customer relationship management), PLM (product lifecycle management) integrating reverse SC activities, and an increasing number of papers in SCM. However, today's RFID adoption is still limited due to barriers such as (i) technology current weaknesses (e.g. read rate, data reliability, high rate of new hardware and software introduction [8], lack of unified standards for interoperability), (ii) relatively high costs related to hardware, software customization, systems configuration and integration , and training, (iii) security issues (i.e. data access, privacy and legislation), and (iv) lack of expertise (i.e. specialized skills required for RFID implementation).

Among the conceptual papers, describes some critical trends and implications of applying RFID to SCM, detailing its benefits as well as the impediments to implementation. With respect to SC strategy, suggest that RFID may facilitate the development of emerging SC configuration by acting as an enabler of a build-to-order SCM strategy [8]. More broadly, consider RFID as a technology that enables "smarter supply and demand chain" facilitating collaboration practices such as CPFR (collaborative planning, forecasting and replenishment). Many mathematical and simulation models have been used to assess the impact of RFID on SC performance. For instance, demonstrate, in manufacturer-retailer SC environments, the potential benefits of RFID in inventory reduction and service level improvement. Hilty (2005) presents a model of the benefits of "item level RFID" to two SC members. The author also investigates the improvement of inventory replenishment decision considering some specific aspects of RFID enabled SC such as the increase in "information visibility". Hilty [9] propose six models of cost-benefit analysis for RFID applications in different logistics activities in the printing industry. By simulating a "three echelon SC", Hilty [9] examine the relationship between inventory inaccuracy and performance in a retail SC, and the way RFID may improve efficiencies by reducing SC costs and out of stock levels. Among articles with empirical results from field studies, Wu [10] examines RFID applications in the retail SC based on the early Metro group pilots in Germany, suggesting that IT innovations (including RFID) in combination with the new marketing concept of "future stores" have contributed to a sales increase of about 23% compared to the preceding year while "reducing out of stock by 9 to 14% and store space by about 11%". Wu [10] present a study commissioned by Wal-Mart where they examine the influence of RFID on potential improvements such as the reduction of out of stocks. While preliminary results indicate that RFID reduced out of stocks by 16% during the period of their study (i.e. a period of six months in 24 Wal-Mart stores), the authors suggest that these impacts should be considered with caution until "the RFID effect" can be better isolated. By looking at the business process level Wu [10] explore the impacts of RFID in a retail SC, and shows the emergence of "intelligent processes" and RFID enabled B-to-B e-commerce.

As mentioned by Lambert et al [11] "measures and metrics are needed to test and reveal the viability of strategies without which a clear direction for improvement and realization of goals would be highly difficult" This is certainly true for evaluating the viability of RFID-enabled SC scenarios. With respect to previous work on the impact of RFID in SC contexts, multiple KPIs are used ,such as "level of inventory (reduction) ,service level (improvement), (out-of) stock level, storage space (minimum), handling costs, process improvement (automation, cancellation), etc." These studies certainly provide valuable information on the impacts of RFID in SC, but do not offer an overall framework to evaluate impacts at the SC level. Some guidelines can, however, be found in a recent review made by Lambert et al [11] suggesting that the literature "prescribe two approaches to managing inter-company connectedness. One is based on transactional efficiency and the other is based on relationship management" insisting on the fact that these two approaches are not mutually exclusive. These authors also identified five SCM frameworks that recognize the need to implement business processes. Among these, they selected and compared the SC Operation Reference Model (SCOR) and the Global Supply Chain Forum (GSCF) framework which include business processes that could be used by management to achieve cross functional integration (i.e. activities across corporate functions) and cross organizational integration (i.e. connections with customers and suppliers).

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2.2 RFID Impacting And Integration With Supply Chain Management

Ever since retailers equipped their cash registers with bar code scanners, we've been promised a brave new world of supply chain management. Stores would automatically track the flow of goods and electronically transmit precise replenishment orders [12]. Suppliers would synchronize their production schedules to real-time demand data. Fewer goods would sit around in warehouses; fewer customers would find products out of stock. It's a great vision, and one that may still come to pass. But to get there, retailers will have to clean up their act. In an in-depth study of 35 leading retailers, we were dismayed to discover that the data at the heart of supply chain management are often wildly inaccurate. The executives at one company with a reputation for expert data handling estimated that their data were "99% accurate." Physical audits, however, showed that inventory levels were way off the mark for two-thirds of the stores' stock-keeping units, or SKUs. Mullins [13] estimates that those errors reduced the company's overall profits by 10% through unnecessary inventory carrying costs and lost sales from out-of-stock items, or stockouts [12].

Even when a store's inventory information is technically correct, it may still suffer from bad data because employees routinely put products in the wrong places. Another well-regarded retail chain found that 16% of its in-stock SKUs were reported as stockouts when customers asked for them at the help desk. In fact, however, the items were available; they had just been misplaced in a storage area or on the selling floor. Mullins [13] estimates that the problem of "phantom stockouts" cut this company's profitability by a whopping 25%. Why are the data so inaccurate? Some of the problem can be traced to human nature. Think about how clerks behave at cash registers. If a customer is buying peach, orange, and strawberry yogurts at the same price, the clerk often swipes one of the yogurts—say, peach—three times. As a result, the store's inventory system says the peach yogurts are down by three and the others are unchanged. Managers routinely exacerbate this problem by tracking checkout clerks' speed but not their accuracy. Indeed, most stores adopted scanners primarily to save on labour costs, not to gain better data [14].

Some of the blame must also go to retailers' distribution centres. When one retailer audited every item on hand at a new store, it found that the inventory system had the wrong quantities for 29% of the SKUs, with an average deviation from actual supplies of 25%. The pickers in the company's distribution centre had simply been sloppy in assembling the store's mix of SKUs. Here again, management practices exacerbated the problem [14]. We found that error rates on items received directly from manufacturers were substantially lower than on items received through company distribution centres. Why? To minimize paperwork and auditing expenses on goods transferred within the company, the retailer had discouraged store managers from getting credit from distribution centres for items shipped in error that cost less than a certain amount. As a result, the managers weren't motivated to carefully check the accuracy of deliveries from the distribution centres. Since they could receive credit for manufacturers' errors, however, they checked those shipments meticulously [14].

It's not just you. It really is getting harder to outpace the other guys. Mullins [13] recent research finds that since the middle of the 1990s, which marked the mainstream adoption of the internet and commercial enterprise software, competition within the U.S. economy has accelerated to unprecedented levels. There are a number of possible reasons for this quickening, including M&A activity, the opening up of global markets, and companies' continuing R&D efforts [14]. However, Mullins [13] found that a central catalyst in this shift is the massive increase in the power of IT investments. To better understand when and where IT confers competitive advantage in today's economy, we studied all publicly traded U.S. companies in all industries from the 1960s through 2005, looking at relevant performance indicators from each (including sales, earnings, profitability, and market capitalization) and found some striking patterns: Since the mid-1990s, a new competitive dynamic has emerged—greater gaps between the leaders and laggards in an industry, more concentrated and winner-take-all markets, and more churn among rivals in a sector [15]. Strikingly, this pattern closely matches the turbulent "creative destruction" mode of capitalism that was first predicted over 60 years ago by economist Joseph Schumpeter. This accelerated competition has coincided with a sharp increase in the quantity and quality of IT investments, as more organizations have moved to bolster (or altogether replace) their existing operating models using the internet and enterprise software. Tellingly, the changes in competitive dynamics are most apparent in precisely those sectors that have spent the most on information technology, even when we controlled for other factors [15]. This pattern is a familiar one in markets for digitized products like computer software and music. Those industries have long been dominated by both a winner-take-all dynamic

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and high turbulence, as each group of dominant innovators is threatened by succeeding waves of innovation. Consider how quickly Google supplanted Yahoo, which supplanted AltaVista and others that created the search engine market from nothing [15]. Or the relative speed with which new recording artists can dominate sales in a category. Most industries have historically been fairly immune from this kind of Schumpeterian competition. However, our findings show that the internet and enterprise IT are now accelerating competition within traditional industries in the broader U.S. economy. Why? Not because more products are becoming digital but because more processes are: Just as a digital photo or a web-search algorithm can be endlessly replicated quickly and accurately by copying the underlying bits, a company's unique business processes can now be propagated with much higher fidelity across the organization by embedding it in enterprise information technology [15]. As a result, an innovator with a better way of doing things can scale up with unprecedented speed to dominate an industry. In response, a rival can roll out further process innovations throughout its product lines and geographic markets to recapture market share. Winners can win big and fast, but not necessarily for very long. CVS, Cisco, and Otis Elevator are among the many companies we've observed gaining a market edge by competing on technology-enabled processes—carefully examining their working methods, revamping them in interesting ways, and using readily available enterprise software and networking technologies to spread these process changes to far-flung locations so they're executed the same way every time [15].

Given the costs of enterprise IT and the risks inherent in deploying it poorly, it's especially important that the change projects you select capitalize on IT's strengths. Consider the following hypothetical example of a company that did just that [16]. A U.K. furniture maker sells both standard and custom pieces out of its 100 showrooms nationwide. Because salespeople in each of the showrooms have very little direct interaction with or information about the company's three factories, they all quote long lead times for custom furniture, just to be on the safe side. To rectify this situation, the company develops software to integrate the activities of manufacturing and sales, and tests it at one location. Now salespeople can enter the specifications of a custom order and instantly receive an accurate delivery date. The company also decides to use the software to manage customer deliveries. The delivery team for the test showroom is required to call back to the dispatch centre immediately after leaving a customer's house. That enables the centre to contact the customer to verify his or her satisfaction and address any concerns. The software tracks delivery times and satisfaction levels and finds the former is decreasing while the latter ticks upward. Recognizing its success, the company quickly embeds the new process in its enterprise software and rolls it out to the other 99 locations. Because customers value these process innovations, the company's market share grows nationwide [16].

Successful IT-enabled business process improvements like this one generally have a number of important characteristics [16]:

- They cover a wide span. The new ways of working apply across a very large swath of a company—in this case, all stores, factories, and delivery teams.
- They produce results immediately. As soon as the new enterprise system goes live, so do the process changes it enables.
- They are precise, rather than general guidelines, suggesting highly scripted instructions for business activities (furniture order taking and delivery).
- They are consistent—executed the same way everywhere, every time. Every furniture store uses the same method to quote lead times, and deliveries are closed out the same way day after day.
- They make monitoring easy. Activities and events can be observed and tracked in real time, providing unprecedented opportunities for testing and feedback.
- They build in enforceability. The designers of a new process that's embedded in IT can have great confidence that it will be executed as intended. It is often simply impossible to execute the process the old way, and even when backsliding is possible it can be recognized and addressed. The furniture company could easily use the data collected during the delivery process to determine if all teams were calling in properly [16].

In interorganizational systems (IOS) literature various models have been developed to identify adoption drivers. Most of the prior studies have used diffusion of innovation theory, which investigate innovation attributes along with the organizational innovativeness literature that examines characteristics of organizations in their adoption and diffusion decisions. The lens of

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institutional theory has also been used to predict institutional pressures as drivers of IOS based interorganizational linkages [17]. However, an integrative adoption and diffusion model incorporating drivers from multiple theoretical perspectives and combining different adoption rationales with testable predictive power is still needed. In addition, not fully yet explored external environment factors may influence the adoption and diffusion of new technologies because of their unique features and characteristics. An important consideration in the adoption of new technology is the motivation or rationale behind its adoption. Although it would seem that an organization's adoption decision is driven by well thought out internal and external assessments with a clear objective to improve performance there may be other factors such as conforming to external pressures from the organizational field to gain legitimacy which may drive adoption [18]. This is true even more when there is technological uncertainty induced by network externalities and mutual interdependencies among adopters. In case of adoption of interorganizational systems (IOS) such as EDI or ebusiness that integrate organizations, pressures from dominant partners (customers/suppliers) are likely to be significant. While identifying factors that drive RFID technology adoption it is also important to explore the effects of the underlying motivations or rationale behind adoption, which may shed light on how the technology is subsequently integrated and used by organizations. For example, we may find that in situations where rationale for adoption is conforming to institutional environment pressures there might be a very superficial adoption to satisfy legitimacy needs (which may be reflected in low minimal levels of early integration of the technology). Similarly if the decision to adopt is motivated by strategic and efficiency gains to improve organizational performance we may find evidence of a significant effort undertaken to integrate the technology with existing systems within and across organizations (Rogers, 1983).
RFID (Radio Frequency Identification) is a means of automatic identification of objects using radio signals and provides improved data collection and handling through greater accuracy, speeds and visibility. Basic identification data is carried in transponders known as tags read by transceivers that decode and transmit data to attached computers for processing where it can be associated with database information such as product, business processes and organization data. It is expected that RFID technology will provide real time information in tracking products and also opportunities for creating rich product profiles resulting in organizational cost savings in theft prevention, inventory management and quality control as well as indirect benefits such as better business customer management, partner collaboration, and altered processes from strategic insight. In addition several recent applications of RFID technology projects have shifted in focus from goods identification and tracking to complete systems integration initiatives [18].

Business adoption of RFID is relatively new and therefore as with most new information technologies its true potential both independent and in conjunction with other technologies is not yet fully understood. Its adoption considerations and the consideration's weights for internal organizational stakeholders and across the SC are important [19]. RFID can be viewed both as an internal as well as an interorganizational tool. Hence, relative strength differences may exist among adoption drivers depending upon anticipated uses of RFID (internal to the organization and/or between organizations). However, we believe that internal organizational use adoption drivers would be a subset of inter-organizational level drivers [19]. RFID combined with information management systems can create effective IOS capable of providing visibility across SCs and delivering direct and indirect benefits to participating SC partners. While direct IOS adoption benefits are quantifiable, some indirect benefits may only be realized through improved collaboration between SC partners and the transformation of business processes that result in competitive advantage gains. This research note focuses on manufacturer/retailer SCs and specifically on factors that drive the adoption and expected integration of RFID's by the manufacturers, retailers, distributors and vendors/consultants. The likelihood of direct and indirect benefits for both manufacturers and retailers from RFID adoption is high and the case for benefits although unequal resulting from collaborative RFID adoption efforts is very strong according to IBM Consulting. Hence, in this study focusing on manufacturers and retailers in SCs seems appropriate. When RFID information is used across SCs with inventory management systems it becomes an interorganizational tool with greater potential benefits derived from increased SC partner participation and commitment and subsequent refinements of organizational processes [17]. RFID technology has also been successfully integrated with E-commerce Solutions, Rathore and Valverde [20] have been successful in the integration of RFID and E-commerce applications,

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this has an impact on the supply chain as E-commerce integration with Supply Chain systems is possible mainly because of RFID technology.

3. RESEARCH METHODOLOGY

The study used the case study methodology. The selected case study is dental distribution company located in Newcastle UK. A supply chain analysis was conducted in order to identify the main business processes required for the supply chain management functions. Problems with the business processes were identified with the use interviews and direct observation techniques.

An RFID solution was proposed based on the analysis and a simulation of the proposed solution was produced with the help of the "RFID Enabled Supply Chain simulator" from Microsoft [21].

After the simulation, we have taken the collected lead times from the case study and compared then with the results of the simulation. These results were the base to justify the benefits of having the proposed RFID solution.

4. IMPLEMENTATIO AND RESULTS

4.1 Case study

The dental distribution company selected for the study is currently using bar codes as it main technology automatic identification and data capture technologies.

A set of interviews were conducted and information recorded for further analysis. We used a purposive (Judgemental) sample for this part of the research. In-depth interviews for data collection were used with key decision makers (KDM's) in the dental distribution company to gain view as much insight as possible. The sample size was arranged for 20. A summary of the detected problems for each of the processes in the supply chain management is included in table 1.

Table 1 Dental Equipment Manufacturer-Hospital Supply Chain Problem Analysis

Processes	*Description*	*Specific Opportunities*
Receiving	Handling of products that arrive at the warehouse	Automate the verification activities - Manage the flow of damaged goods
Put-away	Moving and placing products in their specific storage location	- Improve temporary storage - Reduce manual intervention
Picking	Retrieving the products from their storage location to consolidate customer	Automate the location of products and picking
Shipping	Checking, packing and loading in the transportation unit	Automate the verification activities

After an analysis of the problems, a simulation of the supply chain processes of the company with RFID was implemented and details documented in section 4.2

4.2 Simulation and results

We have implemented a RFID simulation using the "RFID Enabled Supply Chain simulator" from Microsoft (Microsoft, 2009).

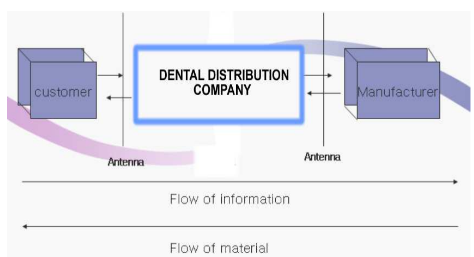

Figure 1 Supply Chain Model For Metro Dental Hospital

The Dental Distribution Company has a simple Supply Chain. They receive orders from customers, buy the products at the Manufacturers or Suppliers and ship it to the Customers (Figure 1).

At this point in the simulation, we started with the flow of Information as shown in Figure 1.

The first step was to create an order from the customer as shown in figure 1.

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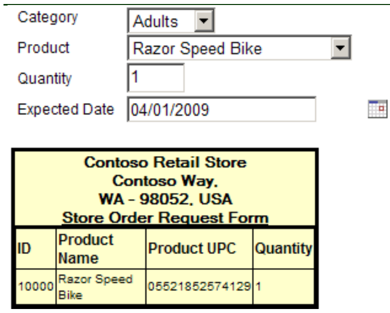

Figure 2 Create An Order

In the simulation, the customer has ordered an item called "Razor Speed Bike". The next step was to check the item availability. As the item was not available for shipping, we needed to buy the item from the manufacturer or a supplier. For this reason, we created a purchase order in the simulator. This purchase order was then sent to the manufacturer/supplier. According to the expected delivery from our manufacturer/supplier, we can then plan our own shipping. At this point RFID can be very important as we would be able to know exactly when the product enters our Warehouse and leaves after it is shipped to the customer (Figure 3).

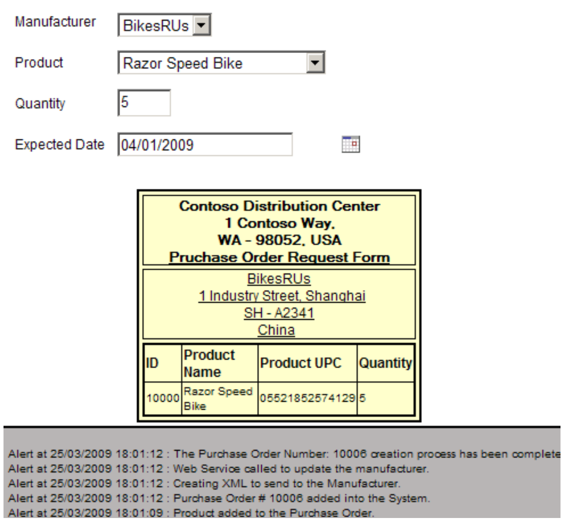

Figure 3 Purchase Order For Simulation

In this simulation we have simulated the use of 2 main antennas:

- One for the Good-in: Incoming goods from the Manufacturer or Supplier and
- Goods-Out: Items send to customers.

The simulation followed the following flow of material:

Figure 4 Flow Of Material For Simulation

In the simulation, a truck has just arrived with our goods and they are about to enter our warehouse.

There are two options:

- The tags were already provided by the Supplier or
- We need to control the goods before storage. We will put our own tags in the products.

We opted to simulate by putting into the products our own tags as this is how the Warehouse process for the Dental Distribution Company we used this study works with its present identification technology (bar codes). With bar codes, the case study controls the incoming goods.

In the simulation, the products passed the RFID reader. Before passing the RFID reader, the products had the following information included in figure 5.

Manufacturer: BikesRUs
1 Industry Street, Shanghai, Shanghai-A2341 China.

Item Description	Qty Ord.	Qty Recv.	Variance
Razor Speed Bike	5	0	0

EPC Number	Description	Product Name		Discovery Time
urn:epc:tag:sscc-64:4.055443.8	Pallet			0
urn:epc:tag:sgtin-64:3.552185.257412.2	Case	Razor Speed Bike		0
urn:epc:tag:sgtin-64:1.552185.257412.2		Razor Speed Bike		0
urn:epc:tag:sgtin-64:3.552185.257412.3	Case	Razor Speed Bike		0
urn:epc:tag:sgtin-64:1.552185.257412.3		Razor Speed Bike		0
urn:epc:tag:sgtin-64:3.552185.257412.4	Case	Razor Speed Bike		0
urn:epc:tag:sgtin-64:1.552185.257412.4		Razor Speed Bike		0
urn:epc:tag:sgtin-64:3.552185.257412.5	Case	Razor Speed Bike		0
urn:epc:tag:sgtin-64:1.552185.257412.5		Razor Speed Bike		0
urn:epc:tag:sgtin-64:3.552185.257412.6	Case	Razor Speed Bike		0
urn:epc:tag:sgtin-64:1.552185.257412.6		Razor Speed Bike		0

Figure 5 Products Before Passing The RFID Reader

After passing the RFID reader the information was immediately updated in the simulation as we can see in the figure below (Figure 6). There was some processing going in the background. This means that our back-end (ERP System) was updated:

- It has updated the order status

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- Tag observations were added to the system

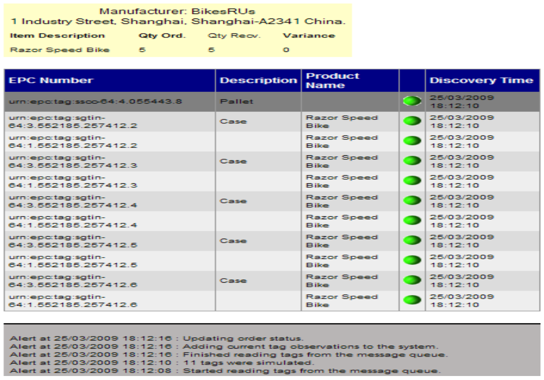

Figure 6 Products after passing the RFID reader

The current barcode readers are manual. This means that the operator has to go with a barcode reader to the product and valid the bar-code. That can cause errors and takes time. With the RFID architecture this is done in a few seconds.

On average this operation takes up to one minute at the moment so we estimate that the gains would be of about 90%. We could see clearly that this operation only took a few seconds in the simulation.

The next step of the simulation was to pick up the good and create a package – the store palletization process.

First the operator printed a new pallet tag and started the palletization process. Figure 7 shows items before they passed the RFID sensor.

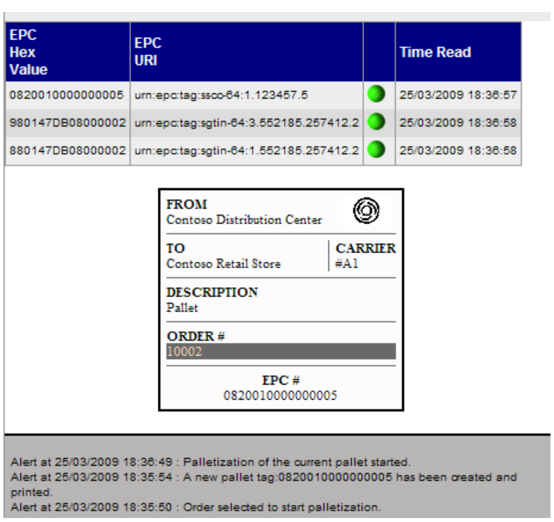

Figure 7 Palletization process

After the new case passed the tag reader, it updated the backend system and displayed the results document in figure 8.

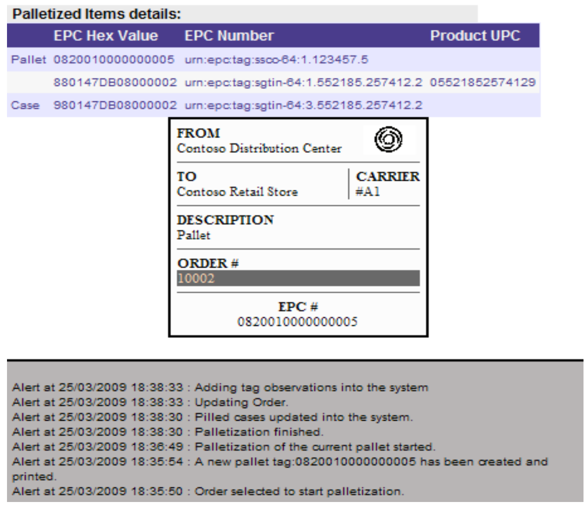

Figure 8 Palletized items details

According to the results of our simulation (see figure 8), the time it took between selecting an order to start palletization and its conclusion was less than three minutes. The current process with barcode readers can take up to 10 minutes for a single package as there are no conveyers and this a manual task done by warehouse operators.

The last process was to load the carrier.

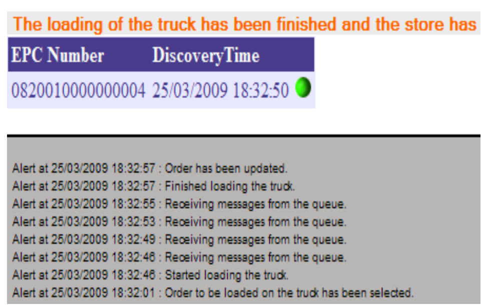

Figure 9 Loading the carrier

According to Figure 9, it took less than a minute to read the goods going into a truck. This process is not used currently in the company but we thought it might be very useful in order to improve warehouse inventory performance.

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Table 2 Simulation results

Dental Distributor Workflow	Current Process	RFID Process	Immediate Benefit
Goods-In Control	01:30	01:30	0%
Receive Goods	01:00	00:08	86%
Store Palletization	10:00	02:43	75%
Quality Control/Loading Truck	01:00	00:56	7%

Table 2 summarizes the results of the simulation and it compares them with the times that current processes in the supply chain are taking to execute. For the goods in control, the dental distribution company would still need to tag items with RFIDs instead of bar codes therefore we have considered this task as 'no gain'. For the receive goods process, the current process of barcode reading is manual therefore the discrepancy and benefit. For the store palletization process, this is currently manual - warehouse operator has a barcode reader but not an RFID technology that would automate this process. The quality control/loading truck process, before the goods are ready for truck loading they are controlled, this process is manual and takes proximally one minute/box. With the introducing of RFID Tags we believe the Quality Control process would be much improved.

In our case RFID's benefits offered by simulation could be reduction in process optimization in the whole Dental Distribution workflow - from the Goods-In up to the goods leave the Warehouse. If the several Suppliers include RFID technology then the benefits in the whole SCM process are even higher as we can expect a much improved Supply Chain Management.

5. CONCLUSIONS

To resume a set of recommendations to our original question: How to enhance the distribution network in the UK dental industry with an effective RFID supply chain solution? we suggest the following based on the study results:

- The use of RFID technology and the EPC Network that automates verification procedures during receiving and provides accurate information at a very high level of granularity (pallet, box); this information can then be shared among the whole supply chain. RFID and EPC. This will eliminate almost all paper-based documents generated in the traditional receiving process.
- RFID technology and the EPC Network enable electronic integration of all firms involved in the supply chain. This way, any actor in the supply chain can, at anytime, anywhere, can obtain continuously updated product information from the remote ONS via the local ONS. Product flows can be totally synchronized with information flows.
- Generate, automatically and in real time, all the information necessary for e-procurement, e-billing, e-forecasting, e-replenishment, from the local ONS and the EPS-IS and thereby enable intelligent management of B-to-B e-commerce processes.

There are several benefits of this solution for the supply chain of the analyzed industry. If the several Suppliers include RFID technology then the benefits in the whole SCM process are even higher as we can expect a much improved Supply Chain Management, Just-In-Time (JIT) analysis and plan E-commerce. Critical inventory such as stents will be closely monitored and expensive assets will be available at the right place and time.

Despite access to the "public", the hospital must remain a highly secure. Manual security systems are not capable of "enforcing" security. But RFID can provide a robust and automated security system.

Processes can be carried out simultaneously and automatically. For example, faulty deliveries can be quickly identified and efficiently pulled from the shelf. Dental clinics can monitor their inventory, saving time and staff-intensive counts. Supply of goods in store can be controlled more efficiently. Staff can have shelves stacked and reorder in plenty of time as they are always aware what is in the warehouse.

The proposed solution also helps to comply with regulations. EU regulation 178/2002 implies that all those involved in the supply chain must be able to

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guarantee complete traceability. Unique identity of RFID tagging allows this.

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