Research article

RFID and its benefits: a multiple case analysis

Yahia Zare Mehrjerdi

Department of Industrial Engineering, Yazd University, Yazd, Iran

Abstract

Purpose – The purpose of this paper is to identify the key benefits of the radio frequency identification (RFID) on various industries and supply chains (SCs) all around the world. In this research, author has looked into different case studies and identified a list of benefits that RFID has brought to various industries. The clear benefits of RFID are: automation; transparency; asset management; velocity; insight; traceability; security; reliability; and capability. To understand RF, fundamental key points are identified and reviewed. Some applications of RFID in SCs are briefly reviewed and ten cases of RFID are discussed.

Design/methodology/approach – The paper identifies key benefits of RFID using case studies approach. For this purpose, ten cases are reviewed from the entire industry, and then key benefits of RFID are determined.

Findings – To make business systems functional and successfully operational, manufacturers can use RFID solutions to reduce operating costs through decreasing the labor costs, claims, and returns. This will help them to increase the operating income. They also can reduce working capital by enabling reductions in inventory and lowering the inventory write-off from the return goods and those items that are un-saleable at the end. It is the collection of such strategies that can bring higher level of profitability and productivity to the business.

Originality/value – Owing to the fact that a better management of production system is related to the full understanding of the technologies implemented and the system under consideration, the paper provides some background to the RFID technology and its benefits for various industries.

Keywords RFID tags and applications, Supply chain management, RFID benefits, Profitability, Productivity, Case studies

Paper type Research paper

1. Introduction

Radio frequency identification (RFID) has been identified as one of the ten greatest contributory technologies of the twenty-first century. This technology has found a rapidly growing market, with global sales expected to top $7 billion by year 2008 (Chao *et al.*, 2007). Companies lined up to use RFID and employing experts to improve the efficiency of their operations in order to gain competitive advantages over time. Ford uses RFID tags at several of its facilities to track work-in process and improve production control. For example, at its Essex engine plant in Windsor, Ontario, tags carry all the instructions needed to assemble an engine and collect all the test data accumulated during manufacturing to be used in product tracking and quality control (Srivastava, 2004).

Automatic identification and data acquisition had made large contributions to many companies bottom line. RFID is one of the most wanted technologies in the today's large successful enterprises like Wal-Mart, Dell, automobile part makers, food stores, computer stores, and bookstores. The hope is that operating costs will decrease and data acquisition and reporting on products will get sufficiently accurate. More organizations from manufacturers to government agencies, retailers to healthcare providers are introducing RFID technologies into their supply chains (SCs), for asset tracking and on time management, and for the security and regulatory purposes. However, as companies explore these significant advantages through pilot programs, the impacts of RFID technologies on the company wide network must be considered.

Wal-Mart has asked its large suppliers to begin tagging all shipments starting from January 1, 2005. It is important to note that Wal-Mart with its enormous purchasing power can force not only its suppliers to tag the shipments, to its warehouses all around the USA, but makes it customary for all the shipments all around the world. US Department of Defense is another big player with the influential voice that can have its words play big in the tagging and RFID business. It is important for business and social science researchers to understand RFID, because it is likely to have a profound impact on how firms compete globally, especially in terms of SC management (SCM). About 97 percent of pallets sent to Iraq have been shipped with RFID tags (Barlas, 2005). The largest area of adoption has been in the retail industry (IDTechEx, 2006), and approximately 1,500 RFID patents have been issued since 1997 (Read, 2005). This technology can save billion of dollars for the world businesses specially the first world countries that are ready to use that.

Widespread adoption of RFID offers attractive avenues to reduce cost through greater coordination between marketing and manufacturing across SCs. For instance, RFID could improve SC efficiency through real-time tracking, safety monitoring, and overall warehouse operations, which leads to increases in sales volumes and improving profitability for suppliers and retailers (Bose and Pal, 2005). The magnitude of benefit depends on the level of tagging pallet/case/item and the area of application in the SC.

The purpose of this article is to examine the benefits of RFID that various researchers have faced with in different industries worldwide. Section 2 discusses RFID technology, in general. RFID applications are discussed in Section 3. Section 4 describes the research methodology. Sections 5 reviews ten case studies looking for the benefits of RFID in different industry as RFID has been implemented and discussed by prominent researchers. Section 6 lists key benefits of RFID in a tableau format along with the description of each benefit item. Managerial implementation is discussed in Section 7. Future works is the topic of Section 8. Author's conclusion is given in Section 9.

2. RFID technology

With the use of RFID technology and electromagnetic waves, users can send and receive data with no contacts occurring between interrogators and tags. RFID tags can hold more information than data carrier systems such as bar code system. Savi Technology has developed sensor-based security seals called SensorTag ST-646 for securing ocean shipping containers. This tag can detect both tampering and potential theft, as well as spoilage or damage of goods. The information is collected in real time (Chao, 2007).

There are four types of tags in industry that are known as:
1 passive tags;
2 active tags;
3 semi-passive tags; and
4 semi-active tags.

Passive tags get their energy from a remote RFID reader. An active tag uses a battery for both the chip and the transmission of data on the antenna. Semi-passive tags use a small onboard battery to power the chip. Semi-active tags use the battery for powering the antenna but the chip relies on the RF energy from the reader (Potter, 2005). The life of active tags are limited while of passive tags are unlimited. Active tags are heavier than the passive tags and more costly as well.

RFID systems work at a number of different frequencies including 125 KHz, 13.56 MHz, 2.45 GHz, and 5.8 GHz and for ultra-high frequency (UHF) 860-950 MHz. Low-frequency tags work along 120-140 KHz frequencies while high-frequency tags work along the 13.56 MHz RFs. UHF tags work along the 850-900 MHz. Low-frequency tags are less expensive and use less power compared to other kinds of tags. High- and ultra-high tags have better ranges and transfer data faster (Table I).

The RFID reader acts as a transmitter/receiver. The reader transmits an electromagnetic field that "wakes up" the tag and provides the power required for the tag to operate. The tag cost can be broken down into following components:
- chip cost;
- inlay/substance with antenna cost;
- assembly cost; and
- licensing cost.

Chips cost is about $0.25-$0.35 while inlay cost ranges from $0.02 to $0.10 and assembly from 0.02 to 0.04. In comparison with the price of one chip being estimated to reach $0.05 in year 2004, it is still very high (Chao, 2007). There exists few ways in helping to reduce costs significantly:
- utilization of a universal RFID tag that can be used for many applications;
- capable of handling multiple applications;
- reducing the cost of packaging antenna to the chip; and
- automatic handling versus manual.

3. RFID applications

RFID technology is applied to various areas such as pharmaceutical industry, heath care, logistics, retail, and security to name a few. Among these areas, the RFID technology has been used increasingly in SCM of logistics (Singh, 2003) for the efficient management of short shelf life goods (Karkkainen, 2003), container transport (Hengst and Sol, 2002), and automated delivery tracking system (Song *et al.*, 2005). RFID could be used to ensure quality control during production. To classify some application areas of RFID, an open ended list of that is:
- agriculture;
- airline industry;
- animal identification;
- health applications;
- traffic light control;
- equipment tracking;
- food industry;
- livestock;
- manufacturing industries;
- material management;
- parking cars;
- pets identification;
- pharmaceutical industry;
- railways;
- retail industry;
- RFID as a speed passes tool; and
- SC coupled with RFID.

A number of these application areas are discussed in more details below:
1 Song *et al.* (2005) presented a method for extending the application areas of RFID in the construction sites intending to determine the precise location of tagged materials. For this purpose, the performance experienced with a commercially available RFID system is compared with the theoretical performance derived from an analytical discrete framework. The problem of managing and tracking equipment has always been considered as a serious problem in construction sites.
2 The potential benefits to RFID technology in the food industry are enormous. Because each chip is unique to the specific box it is in, tracking the whereabouts of

Table I Tag frequencies used by different countries

Frequencies	Tags application areas
125-134 KHz	USA, Canada, Japan, Europe
13.56 MHz	USA, Canada, Japan, Europe
433.05-434.79 MHz	In most of the USA and Europe and under consideration in Japan
865-868 MHz	Europe
866-869 and 923-969 MHz	South Korea
902-928 MHz	USA
952-954 MHz	Japan (for passive tag after 2005)
2,400-2,500 and 5.725-5.875 GHz	USA, Canada, Japan, Europe

products becomes much simpler. If a manufacturer recalls a batch of products, the RFID tags for the containers affected can be flagged electronically. Eventually, grocery retailers will not be able to sell recalled products because the register will not allow it (Hall and Hampl, 2004). Looking further into the future, we can see other sort of RFID capability as such as: homes – equipped with "smart appliances" – will also be linked to the network. Refrigerators will inform homeowners that the milk is expired; the microwave will alert the consumer that the product about to be warmed was recalled 6 h earlier by the manufacturer. Even the pantry, if equipped, could print a grocery list based on current inventory (Hall and Hampl, 2004). Wentworth (2003) conducted a study aimed at inexpensive, disposable RFID biosensor tags used on food products for history checking and contamination and inventory control.

3 Connolly (2007) and Jansen and Krabs (1999) discussed the potential of RFID tags for "smart packaging", "automatic checkout", "smart appliances", "smart recycling", and marketing/promotional opportunities. He has pointed that this type of technology could improve security, productivity, inventory control, traceability, and result in capital and operational savings.

4 In May 2002, Massachusetts General Hospital installed its first trial of the iRIS RFID system, which was developed by Mobile Aspects. The purpose of iRIS was to manage inventory and access to medical supplies and surgical parts throughout the hospital. By the end of 2002, Massachusetts General Hospital had installed six iRIS units in its operating rooms. According to the RFID journal, with the assistance of iRIS over $500,000 worth of equipment and supplies were tracked. Additionally, iRIS has been integrated into the hospital's scheduling and billing system. As a result of the success of iRIS at the Massachusetts General Hospital, similar systems have been installed at the hospital of the University of Pennsylvania, the University of Pittsburgh Medical Center, and the Carolinas Medical Center (Crayton, 2004).

5 In the healthcare industry, RFID can help to improve patient safety (Koshy, 2005). Medical errors are the fifth to eighth leading cause of death in the USA (Kohn and Henderson, 2004). Recently, nurses are tracked as a way to ensure the proper personnel can be located for any emergency. Searches can be done by group, thereby identifying all appropriately trained nurses in the proximate area. Also in healthcare, infants are tagged in the nursery for protection. Seniors are tagged in assisted living centers to identify wandering. And, using active tag wristbands, patients can be automatically identified without disturbing them and for more accurate procedures and medications.

6 Bottani and Rizzi (2008) have described "Economical assessment of the impact of RFID technology and EPC system on the fast-moving consumer goods supply chain". They described a research that aims to quantitatively assess the impact of RFID technology and electronic product code (EPC) systems on the main processes of the fast-moving consumer goods SC. A three-tier SC that is composed of manufacturers, distributors, and retailers is examined, and the results of the feasibility study show that RFID and EPC implementation is still not profitable for all of the tiers in the chain.

7 Wang *et al.* (2008) simulated the impact of an RFID system on the inventory replenishment of the thin film transistor liquid crystal display (LCD) SC in Taiwan, and examined global operations and logistics through a case study of a well-known LCD monitor manufacturer. The results of the experiment show that an RFID-enabled pull-based SC can be effectively achieved with a 6.19 percent decrease in the total inventory cost and a 7.60 percent increase in the inventory turnover rate.

8 Wen (2008) has proposed a dynamic and automatic traffic light control expert system (DATLCES) for solving the road congestion problem. The framework is comprised of six sub-models coded in Arena to be simulated to help analyzing the problem. This DATLCES is composed of seven elements, as such as: an RFID reader, an active RFID tag, a personal digital assistant, a wireless network, a database, a knowledge base, and a back end server.

9 De Kok *et al.* (2008) have discussed "A break-even analysis of RFID technology for inventory sensitive to shrinkage" through adapting inventory policy by including both the shrinkage fraction and the impact of RFID technology. By comparing the situation with and without RFID in terms of costs, an exact analytical expression is derived for the break-even price of an RFID tag. The authors reveal that these break-even prices are highly related to the value of the items that are lost, the shrinkage fraction, and the remaining shrinkage after the implementation of RFID. A simple rough-cut approximation to determine the maximum amount of money a manager should be willing to invest in RFID technology is presented and evaluated.

10 Once RFID tags infiltrate the market, the retail industry will be revolutionized. Transceivers will be equipped to read multiple products simultaneously, allowing for shopping carts to be pushed through a device that seamlessly recognizes all items being purchased. Self-checkout will be commonplace, and cashless transactions will become regular practice.

Besides of retailers like Wal-Mart and outlet stores, there are many other companies that have already started using the RFID technology. We may learn from big industry users such as Wal-Mart, Deloitte Global Technology Innovation Centers, Target Corporation, The Boeing Company, US Navy, Michelin, Americas R&D Corporation, Delta Airlines, United Postal Service, Sonic Software, Tyco Safety Products, and DHL Worldwide Networks to mention some.

4. Research methodology

Research to identify the list of key benefits on RFID in SCM and other industrial areas is scarce. This is a step towards identifying such benefits. To find out what these benefits are, published articles on the RFID topic, as well as the success factors of related technology are studied and then a list of appropriate benefits, in different forms, are determined. Briefly then, this research attempts to study and identify the impacts of RFID on the SC, inventory control, and healthcare

to mention a few. To date, most of the research conducted on the RFID has been focused on the description of its real life applications in various settings. The number of researches conducted on its benefit finding and theoretical framework is limited.

Yin (1994, 2003) pointed that a case study is an "empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially where the boundaries between the phenomenon and context are not clearly evidenced". Case studies are a valuable tool for examining a contemporary phenomenon, especially one that is not clearly understood, asking how and why questions, and capturing the context (TZeng et al., 2008).

In addition to that, the research questions that researcher is taking into consideration are of exploratory type and just wants to identify and analyze key variables related to the expected benefits of RFID profitability. Furthermore, researcher found that it is appropriate to use a qualitative method of enquiry that would allow collecting detailed and may be unstructured information in an appropriate way. Qualitative methods have been productively applied where there is a need to describe and explain the phenomenon under study and have been used for examining organizational adoption of various information technologies (Cook and Kumar, 1998).

5. Case studies

The cases studied here are:
1. RFID and innovative retail services: the consumer perspective (Theotokis et al., 2008).
2. Comparison of benefits of radio frequency identification implications for business strategic performance in the US and Korean retailers (Kim et al., 2008).
3. Sushi restaurant management (Ngai et al., 2008a).
4. Radio frequency identification: supply chain impact and implementation challenges (Li and Visich, 2006).
5. Dow Corning Corp. (available at: www.averydennison.com).
6. Factors creating a new demand for RFID technology (Vermesanl et al., 2007).
7. Highlighting the financial savings from RFID technology into equipment tracking in healthcare industry (available at: www.supplyinsight.com).
8. RFID vs bar code.
9. Hospital management (Fisher and Monahan, 2008).
10. Designing a prototype real time smart sensor array for measuring the soil temperature and soil moisture using odd components (Vellidis et al., 2008).

Each of these cases are reviewed in such a way that the researcher and reader can get the most out of the case while key RFID benefits are being extracted truly. For this reason, some cases are described in more details and others are described less.

5.1 Case 1
Although benefits are important for customers, they tend to see the problems that RFID technology creates (Ohkubo et al., 2005). It is obvious that the key to a successful RFID-enabled customer-service application is to consider the equation from the consumer's point of view (Eckfeldt, 2005). Therefore, understanding the consumers' attitude towards RFID technology and its applications in retailing is of significant importance in the RFID research field.

Through a use of workshop/focus group and a survey of 650 shoppers of five major retail chains in Greece, Theotokis et al. (2008) have determined a list of ideas for services. These ideas are: self-checkout, traceability information, trolley reader, shelf tags, dynamic promotion, and dynamic pricing. The objective of this research was set by researchers to measure customer attitude towards the RFID-enabled services and to provide a theoretical framework for implementing and evaluating such services. For this purpose, data were collected for the survey through the method of personal interviews with customers in supermarkets. A close-ended questionnaire with nine-point Likert scale questions was used by the researchers.

5.2 Case 2
In an article entitled "Comparison of benefits of radio frequency identification: implications for business strategic performance in the US and Korean retailers", Kim et al. (2008) have designed a study to explore a model for comparing the benefits of RFID technology on SCM by focusing on retail industry. For this purpose, a model was estimated to examine the structural relationships among technological infrastructure, RFID benefits, and business strategic performance in the USA ($n = 70$) and Korean samples ($n = 87$) (Kim et al., 2008). The results of this study showed that technological infrastructure was required to improve inventory management, store operation and demand management, and leading to business strategic performance. Researchers had come to this conclusion that hardware/software application was significantly related to the RFID benefit of inventory management for US retailers, whereas, it was related to the benefits of efficient store operation and demand management for Korean retailers. On the other hand, business strategic performance was significantly determined by RFID benefit factors (e.g. inventory management and demand management) for US retailers and Korean retailers. The managerial implication for business-to-business strategic performance in the US and Korean retail industries was discussed from a retailer's perspective. Following are those hypotheses developed and assessed by Kim et al. (2008):

H1. The higher technological infrastructure, the greater is the RFID benefits (e.g. inventory management, store operation, and demand management) for SCM as perceived by US retailers (H1a) and as perceived by Korean retailers (H1b).

H2. The RFID benefits (e.g. inventory management, store operation, and demand management) for SCM will influence business strategic performance in the US retailers (H2a) and Korean retailers (H2b).

H3. There will be difference in the effects of technological infrastructure on the RFID benefits between US retailers and Korean retailers (H3a); and there will be difference in the effect of RFID benefits on the business strategic performance between US retailers and Korean retailers (H3b).

5.3 Case 3
Ngai et al. (2008a) have described the design and development of an RFID-based sushi management system in a conveyor-belt sushi restaurant to enhance operational efficiency. The system is designed to help the restaurant achieve better inventory control, responsive replenishment,

and food safety control, and to improve its quality of service (Ngai *et al.*, 2008a). The study demonstrates the significance and benefits of using RFID technology in the food industry, and the lessons that are learned from this effort should help the academic and practical literature further on the subject, especially in the area of RFID systems development:

1   Managerial perspective:
    • strengthening food quality and safety control;
    • enabling responsive replenishment;
    • improving dining experience and service satisfaction; and
    • reducing out-of-stock situations.
2   Application perspective:
    • tracking the availability of sushi on the belt;
    • providing useful food content information to diners; and
    • food and refrigerator temperature control.
3   Technological perspective:
    • proven technology adopted in food industry;
    • responsive multiple tag real-time read/write capabilities;
    • long read range without specified sight requirement; and
    • normal functioning even in a restaurant with dimmed lighting or harsh environment.

Owing to the fact that one of the most important parameters of quality control of food is the temperature, it is feasible to consider applying RFID to control and monitor the temperature of the refrigerator that stores the sushi raw materials to further strengthen food safety control. Therefore, to increase the quality of the food using RFID tags with embedded temperature sensors would make a real-time monitoring of the situation possible. On the other hand, people are very conscious of food safety. Traceability has become a keyword with regard to food, particularly when a number of food safety incidents happen in a country in the world.

5.4 Case 4

Li and Visich (2006) compiled a list of 39 benefits across the SC. Upon the examination of Li and Visich's list and other RFID overview papers, Tajima (2007) has identified 15 distinct types of benefits by minimizing overlap and excluding secondary benefits. Subramani (2004) has conducted a study on the application of the exploitation–exploration perspective to determine the patterns of information technology (IT) use for understanding the diverse outcomes of IT applications. When used for exploitation, IT aims to improve operational efficiencies of existing processes through increased standardization, streamlining, tighter process control, and reduced manual intervention. On the other hand, when used for exploration, IT aims to discover novel ways for creating value or solving old problems through data analysis and pattern recognition. Based on the work of Subramani, the use of RFID for process automation is the same as the use of IT for exploitation in terms of the objective and how to achieve it. Hence, the following proposition theorizes one way for RFID to create a competitive advantage based on the exploitation-exploration perspective:

P1.   The use of RFID for exploitation improves the firm's competitive advantage through increased SC efficiencies.

P2.   The use of RFID for exploration improves the firm's competitive advantage through increased innovation capability.

Based on the IT theory of sustaining, the first mover advantages by remaining ahead of the learning curve, the following propositions are developed on how RFID may sustain a competitive advantage in the long run:

P3.   The long-term use of RFID for exploitation improves the firm's short-term competitive advantage through "learning to adjust".

P4.   The long-term use of RFID for exploration improves the firm's long-term competitive advantage through "learning to transform".

5.5 Case 5

Dow Corning Corp., Midland, Michigan, a global leader in silicon-based technology, has an internal group that explores new alternatives in automatic identification "RFID has been used by the group's radar screen for more than six years (www.averydennison.com)". To improve its internal materials handling processes, Dow Corning wanted to exploit the benefits of RFID, including:

• *Rapid reading.* "Each of our bar-coded labels typically has a material number, batch number, quantity and other details". "Being able to instead use an RFID system to read all of those labels quickly and at one time is a major advantage".
• *Permissible paths for materials flow.* If materials go outside prescribed paths in the plant, an RFID system can issue alerts.
• *Container visibility.* RFID can provide high visibility into key processing factors, such as the accumulated refrigeration time for a container, allowing users to determine which containers are out of specification.
• *Transparency.* In this industry, with the use of traditional ID technology, an operator has to scan a piece of paper that tells them which order they are working with, then go to the drum and scan each of the different indicators on a drum. But, today, that RFID tag is linked to back end data, once the operator scans the tag, he knows everything about what is in that drum, because it is a unique identifier and it relates back to the database. That is one of the greatest things about RFID.

5.6 Case 6

There are a number of factors listed below creating a new demand for RFID technology (Vermesanl *et al.*, 2007):

1   Strong demand for tracking, locating, and monitoring of objects with a focus on increased security, safety, cost savings, and customer satisfaction. These requirements are the result of increased competition, the threat of terrorism and disease, an increasing healthcare system for elderly people, and the demand for more information and services.
2   Reduction in cost and size of RFID tags and systems.
3   The availability of open RFID standards (ISO 18000, EPC Global and IEEE 802.15.4).
4   New product developments based on emerging sensor networks and communication technologies such as Zigbee, UWB, Wibree, etc.

In the future, the RFID technology should be transparent to the end-user, which will concentrate mainly on how to use RFID, identify their target application with a clear objective and a defined medium that has to be tagged and monitored. The technology road map will address the bandwidth options, integration, memory size, sensor integration, etc. with a clear vision that the RFID technology will act more as an enabler and less as a constraint.

5.7 Case 7

RFID, with numerous advantages over bar codes, encompasses many benefits that include its unique capability to share information with business partners, allowing collaboration on inventory management, planning, forecasting, and replenishment (Trailblazer System, 2004; Vijayaraman and Osyk, 2006). Retailers believe that there are some potential for building SC relationships (Angeles, 2005; Arnold and Bures, 2003). With the use of RFID tags, there are some potential for improving visibility of inventory that is really of significant value to the business owner. Retail businesses are always concern about a good balance between supply and demand. RFID can improve demand management, customization, and automatic replenishment of out-of-stock goods while reducing inventory and distribution costs (Bose and Pal, 2005).

To date, RFID technology is still developing, standards are still converging, and costs are still being brought down in order to attach tags to individual customer products. However, the bar code system is deeply entrenched and will not be replaced any time soon (Wu *et al.*, 2006). RFID is another supporting tool for automating processes and improves the operation management. It can bring powers to the decision-making team by providing on time information. This technology is more sophisticated than the bar code. This is because of the following facts:

- it will be embedded and read with no requirement for line of sight;
- tags can be reprogrammed easily;
- capable of working in suitable and harsh environments;
- ready to carry 96 bits of information – compare with 16 bits for bar code;
- fraud controlling increases;
- cloning become non-existence;
- improves antitheft protection;
- better SC efficiency;
- cost saving;
- profit enhancement;
- better SC and inventory management;
- reducing counterfeiting;
- tracking work-in progress;
- reducing administrative errors;
- reducing rework; and
- better management of warrantee claims.

Once above factors are available to users it can be seen that why stock handling, traceability, and warranty also improves. Please notice that the fourth property of RFID tag gives it more power to be considered as a read or read/write device only. Table II compares RFID and bar code on key dimensions as such as read rate, line of sight, human capital, read/write capability, durability, security, and event triggering.

Table II Comparison of RFID and bar code based upon some characteristics

Read rate	Many tags can be read simultaneously – high productivity	Read one tag at a time and manually
Line of sight	Not required	Certainly required
Human capital	Once system is designed and set up then it is completely automated and do not need too much human help	Needs human capital to scan each tag
Read/write capability	Ability to read, write, modify, and update	Read ability only
Durability	High – it can be used in harsh environments	Low – it cannot used when it is dirty or greasy
Security	High	Low
Event triggering	Capable to trigger certain events	Not capable of triggering events

5.8 Case 8

Highlighting the financial savings from RFID technology into equipment tracking in healthcare industry (available at: www.supplyinsight.com):

- Not being able to locate the equipment, hospitals buy extra or replacement devices for availability, which causes high annual spending and many devices are left unutilized or under utilized.
- Using RFID to manage these devices increases the utilization rate, cuts annual spending, allows divestment of under-utilized assets, and improves confidence that equipment is always available when needed.
- With RFID equipment tracking in place, expensive medical devices can be quickly brought into control by alerts based on location and notification when a device leaves a predefined area.
- Equipment management with RFID can eliminate inefficient, long manual searches for assets that need maintenance or need to be returned to central processing units, and can maintain up-to-date equipment status.
- With a decrease in patient wait time, there is improved in patient care, more employee satisfaction for nurses, technicians, doctors, etc. lower per-patient cost of service delivery, effective work flow, and operational efficiency with support staff always at hand.

Some of the key benefits of RFID applications in healthcare business are: reducing time to find assets, improving the level of responsiveness, decreasing the staff waiting and idle time, increasing the utilization level by lowering asset investment required, reducing shrinkage/lost, and increasing efficiency. Other benefits of RFID can be stated as: fast response to critical events and safety improvement both in the areas of blood product management and pharmaceuticals inventory.

5.9 Case 9

The social and organizational factors that contribute to the success or failure of RFID systems in hospitals must be further analyzed. The implications of RFID systems, such as privacy concerns and work intensification for nursing and other hospital staff, should be taken into account from the outset, especially during the design and implementation of the

technology. What is known about the subject (Fisher and Monahan, 2008):

1 Information technologies, such as RFID-based systems, are being routinely integrated into hospital infrastructure in order to increase the efficiency and effectiveness of healthcare delivery.

2 RFID systems can be used in hospitals to locate equipment, verify the identity of patients during medical procedures, and collect data on staff workflow to find inefficiencies in current hospital operations, but little empirical evidence exists on how to implement the systems effectively.

3 RFID systems do not adapt easily to hospital settings because the infrastructure of hospitals – in terms of space, equipment, personnel, and patients – is much more complicated than factory or warehouse settings.

4 Most of the literature focuses on the technical efficacy of RFID systems, not on the social and organizational effects of such systems.

5 A conceptual framework is developed for analyzing the host of social and organizational factors that contribute to the success or failure of RFID systems in hospitals.

6 Hospitals implementing RFID systems tend to experience two types of constraint:
   • the mal-adaptation of the technological system to the hospital setting; and
   • the organizational challenges for hospitals to utilize the system.

7 RFID systems introduce a key ethical concern regarding privacy because of the surveillance potential of the technology. The extent to which surveillance becomes a reality is dependent upon the policies and practices developed in each hospital setting.

8 Specific recommendations are detailed to mitigate negative organizational effects of RFID implementation in hospitals.

5.10 Case 10

Vellidis *et al.* (2008) designed a prototype real-time smart sensor array for measuring the soil temperature and soil moisture using odd components. This tool was used to schedule irrigation in cotton farm (Figure 1). This new item is comprised of a centrally located receiver connected to a laptop computer and multiple sensor nodes installed and

Figure 1 Schedule irrigation in cotton farm using RFID and sensor

Source: Vellidis *et al.* (2007)

located in the field. The sensor nodes were consisted of sensors, a specially designed circuit board, and an RFID tag which transmits data to the receiver. This type of smart sensor can offer real potential for reliably monitoring spatially variable soil water status in crop fields. Since the cost of designing this tool is relatively low, one can install a large number of soil moisture sensors to adequately represent the inherent soil variability present in fields. Vellidis *et al.* (2008) described this sensor in more detail and how it was used in a cotton field for verification purposes.

6. Summary of benefits

Table III summarizes the benefits of RFID based upon ten case studies already being reported in the literature. These cases are spread among various industries, such as: health care industries, retail industries, restaurant management, and SCM.

7. Managerial implications

The key managerial implications emerged from this research are:

- RFID as a collaborative tool for better management of a SC is a necessity tool in today's management modeling of the situations.
- All managers and working groups talk about RFID and its benefits but often not sure about its tremendous power in industries as such as health care, food industry, pharmaceutical, and systems with SC.
- The real belief among the experts is that customers are the real beneficiary of this technology once it is being implemented in the system.
- From one industry to another, the degree of RFID use varies. As it is reported, food industry has developed good RFID-based systems for better management making traceability of the products easy and possible.
- Pharmaceutical industries are developing sound systems to make the traceability of drug possible because of big fraud often occurs in this healthy block of business.
- Effective deployment of RFID has a potential to quickly provide accurate and reliable data that exceeds the bar coding or manual capabilities available today. This can have major impact, particularly in high volume and high-speed manufacturing operations, where speed, accuracy, and timeliness are critical for throughput and performance.
- Lowering required inventory levels and associated carrying cost expenses by optimizing inventory levels and reducing safety stock.
- Manufacturers can reduce obsolete inventory write-downs through better planning and visibility and lower inventory shrinkage by keeping better track of goods helping to eliminate losses and theft.
- An immediate impact of RFID is freeing up labor to perform things and more value-added tasks.
- Improving revenue opportunities, reducing out-of-stocks and improving promotional execution by having the right inventory available to match demand.
- Meeting new customer mandates and regulatory compliance.
- Improving customer experience and satisfaction by improving timeliness, quality, and availability.

Table III A summary of RFID benefits

1	Read rate	Read rate – high throughput. Multiple tags can be read simultaneously
2	Line of sight	Not required. Items can be oriented in any direction as long as it is in the read range and direct line of sight is never required
3	Human capital	Once up and running, system is completely automated
4	Read/write capability	More than just reading. Ability to read, to write, to modify, and update
5	Durability	Durability is high. Much better protected and can even be internally attached so it can be read through very harsh environments
6	Security	Security is relatively high. Difficult to replicate. Data can be encrypted; password protected, or includes a "kill" feature to remove data permanently, so information stored is much more secure
7	Event triggering	It can be used to trigger certain events (like door openings, alarm, etc.)
8	Self checkout	Scan all the products and pay without queuing behind a cashier
9	Traceability information	Electronic tags or displays that provide information about the history of products
10	Trolley reader	A reader on the trolley in order to scan the products I want to buy and "read" their prices
11	Self tags	Electronic tags on shelves that show clearly and dynamically accurate product prices
12	Dynamic promotion	Get informed dynamically through a display for pertinent promotions when buying a product
13	Dynamic pricing	Have different prices for the same product but for different expiring dates or based on other unique product characteristics (for fresh food specially)
14	Reduced shrinkage	Misplacement, spoilage, shoplifting, and organized retail crimes
15	Increased data accuracy	Accurate information has great potential to improve the quality of management decisions
16	Faster exception management	RFID can automate some aspects of exception management, such as invoice reconciliation, shipment data adjustment, and the sending of alerts
17	Improved information sharing	Data sharing, such as exchanging electronic bills, could be automated with the use of RFID and automation would consequently reduce the manual tracking of paper trails
18	Production tracking	RFID could enable tracking of raw materials, work-in-process inventory, finished products, and even assembly status during production
19	Quality control	RFID could be used to ensure quality control during production
20	Supply and production continuity	By improving material tracking through the manufacturing process, RFID could ensure continuity in production and supply availability
21	Space utilization	RFID could provide flexible space allocation by reducing product incompatibility problems
22	Asset management	Better tracking of reusable assets consequently leads to better asset utilization, better shipment consolidation, reduces fuel expenditure for trucking, improved reverse logistics, and lower capital costs
23	Reduced stock-outs	By increasing accuracy in finished good inventories, RFID could help reduce stock-outs and subsequently reduce lost sales
24	Customer service	RFID could help improve customer service in several ways. At gap, the use of RFID freed staff from counting inventory and dealing with stock-outs, and hence, increased staff availability for customer assistance
25	After sales service	RFID could efficiently respond to recalls by isolating bad batches of goods and improve warranty processing and returns handling by efficiently retrieving information such as warranty details, service history, and goods authentication
26	Increase SC efficiency	Improves the firm's competitive advantage through increased SC efficiencies
27	Increased innovation capability	Exploration improves the firm's competitive advantage through increased innovation capability
28	Short-term competitive advantage	The long-term use of RFID for exploitation improves the firm's short-term competitive advantage through "learning to adjust"
29	Long-term competitive advantage	The long-term use of RFID for exploration improves the firm's long-term competitive advantage through "learning to transform"
30	Rapid reading	Being able to instead use an RFID system to read all of those labels quickly and at one time is a major advantage"
31	Permissible paths for materials flow	If materials go outside prescribed paths in the plant, an RFID system can issue alerts
32	Container visibility	RFID can provide high visibility into key processing factors, such as the accumulated refrigeration time for a container, allowing users to determine which containers are out of spec
33	Transparency	"RFID tag is linked to back end data. Once the operator scans the tag, he knows everything about what's in that, because it is a unique identifier and it relates back to the database. That's one of the greatest things about RFID"
34	Improving revenue	Improving revenue opportunities, reducing out-of-stocks and improving promotional execution by having the right inventory available to match demand. Meeting new customer mandates and regulatory compliance. Improving customer experience and satisfaction by improving timeliness, quality, and availability
35	Financial savings	Not being able to locate the equipment, hospitals buy extra or replacement devices for availability, which causes high annual spending and many devices are left unutilized or under utilized
36	Utilization rate	Using RFID to manage these devices increases the utilization rate, cuts annual spending, allows divestment of under-utilized assets, and improves confidence that equipment will always be available when needed

(*continued*)

37	Equipment management	Equipment management with RFID can eliminate inefficient, long manual searches for assets that need maintenance or need to be returned to central processing units, and can maintain up-to date equipment status
38	Employees satisfaction	With a decrease in patient wait time, there is improved patient care, more employee satisfaction for nurses, technicians, doctors, etc. lower per-patient cost of service delivery, effective work flow, and operational efficiency with support staff always at hand
39	Risk management	Most importantly, the risk of liability is reduced with better control of equipment usage
40	Automatic identification	Enables automatic identification of items and people without scanning individual labels or cards
41	Loss prevention	Using RFID to management perishable goods and drugs would help management to prevent losses
42	Faster response to critical events	With the use of RFID, faster response to critical events would become possible
43	Increase quality level	Producing and management of quality goods under RFID systems is highly possible
44	Increase efficiency and effectiveness	Systems engaged with RFID can increase the level of its efficiency and effectiveness in the long run
45	Increase productivity	Once effectiveness and efficiency of a system increases then it come its productivity
46	Responsive	Responsive multiple tag real-time read/write capabilities
47	Long read range	Long read range without specified sight requirement
48	Real-time data	Make real-time data acquisition possible
49	Continuous improvement	Owing to the fact that real-time data acquisition is possible hence continuous improvement will be the outcome
50	Mix of tools	Most organizations find they need a mix of tags and readers from multiple manufacturers. Care should be taken in being flexible to expand implementation without being locked into a single vendor's products
51	Automation	Reducing manual processes through automated scanning and data entry improves productivity, allowing resources to be reallocated to higher value activities
52	Integrity	Improving the integrity of real-time SC information with increased authentication and security and tracking capabilities reducing errors, shrinkage, and counterfeiting while improving customer satisfaction – information is only valuable if it is correct
53	Velocity	Reducing workflow issues by minimizing the time spent finding and tracking needed assets, in turn increasing product flow and handling speeds
54	Insight	Providing the real-time information needed to make faster, better, and more informed decisions and the ability to be more responsive to the customer
55	Capability	Providing new applications and quality to meet SC partner demands and enhance customer experiences
56	Receiving of raw materials	RFID portals at dock doors and points of ingress allow instant verification of the entire contents of a shipment by reading an RFID-tagged case, container or pallet. The content's status and information is updated and automatically communicated to the factory's WMS/ERP system at the point of entry. Proof of receipt and accounts payable processing can all be automated, improving accounts payable productivity and reducing payment inquiries and disputes
57	Tracking work-in-process	RFID-tagged raw material and sub-assembly parts are routed and tracked throughout work stations along the assembly line and the entire production process. RFID automates the validation of sequence and components and speeds build times. If an issue is found, accurate tracking can help to reduce quality issues and errors
58	Tracking history	RFID can track the history of the production and finished goods which are important information for shipping and possible recalls
59	Shipping	RFID helps to eliminate shipping delays by increasing staging accuracy and ensuring that the right shipment is on the right outbound truck. RFID allows "certifying" the shipment. Establishing agreements with trading partners to leverage RFID data as "proof of delivery" can speed the processing of accounts receivable invoicing and significantly reduce disputes, claims or returns
60	Inventory and net fixed asset optimization	Depending upon investments in automation and MES, RFID could be used in varying scales, either locally or across the entire facility to provide visibility into incoming raw materials, work-in process, production sequencing, packaging, palletizing, and warehousing operations, as well as final shipping to the next destination in the SC
61	Compliance	Customers are mandating that items shipped to them be tracked and secured. RFID helps meet these new compliance programs to meet customer mandates
62	Counterfeit prevention	In pharmaceutical manufacturing, it is important to track the entire life cycle of raw materials, production, and shipment. RFID can help to assure that only properly tagged and uniquely identified and tracked items are introduced into the SC and sold and distributed
63	Improving production asset visibility	Helping to track the maintenance and reduce related issues. Reducing claims and returns by assuring the right goods are sent where they should be
64	Put away	Finding the right location (from receiving to storage) can be automated, assuring that the right items are placed in the right location. Perishable goods and priorities can be more accurately and intelligently managed
65	Cross-docking	RFID can help improve just-in-time management of inventory, helping to drive process improvements, productivity, visibility, and accuracy. This enables the immediate transporting of goods – from inbound trucks and receiving to shipping and customer transport
66	Picking and packing	RFID can increase the accuracy of the picking process, ensuring that the right goods are picked from the right locations and packaged in the proper way. This increases productivity, provides for better management of priorities and minimizes errors

(continued)

67	Yard management	RFID enhances scheduling and trailer utilization efficiency, ensuring that the right trailers arrive at the right location at the right time, minimizing idle time for the trailer assets and reducing receiving and shipping wait time
68	Back room operations	To gather information and track inventory, unattended, fixed readers, reader portals, and handheld and vehicle-mounted RFID readers provide real-time information from RFID-tagged boxes, cases, containers, and pallets that move through critical points of retail distribution – from receiving and shipping to the retail store backroom
69	Back-office application empowerment	The use of RFID tags and automated scanning further enables applications, such as advanced shipping notices and proof-of-delivery, to speed up the entire transaction process, eliminating errors, reducing the labor hours associated with reconciling back room inventory and processing returns or credit claims due to supplier error shipping
70	Reliability	Reliably, monitoring can be improved by using RFID into the system
71	Collaborative tool	RFID as a collaborative tool for better management of an SC is a necessity tool in today's management modeling of the situations
72	Store operations	RFID-tagged items allow intense item-level tracking, reducing shrinkage on the store floor. It helps to speed restocking, improve returns processing, improve inventory control, as well as streamline seasonal and promotional sales
73	Improved customer satisfaction	RFID enables retailers to better manage inventory and assure that items are in stock, merchandised properly, and provided for sale
74	Reducing labor costs and improving productivity	An immediate impact of RFID is freeing up labor to perform things and more value-added tasks. Effective deployment of RFID has a potential to quickly provide accurate and reliable data that exceeds the bar coding or manual capabilities available today. This can have major impact, particularly in high volume and high-speed manufacturing operations, where speed, accuracy, and timeliness are critical for throughput and performance
75	Improving production asset visibility	Improving production asset visibility helps to track their location and reduce maintenance issues. Reducing claims and returns by assuring the right goods are sent where they should be
76	Improving revenue	Improving revenue opportunities, reducing out-of-stocks, and improving promotional execution by having the right inventory available to match demand. Meeting new customer mandates and regulatory compliance. Improving customer experience and satisfaction by improving timeliness, quality, and availability
77	Customer satisfaction	Increase customer satisfaction by ensuring that the right goods reach the right customer at the right time
78	Reducing labor	Reduce labor required for almost all primary warehouse worker functions including receiving, put-away, inventory, and pick/pack/ship and transportation management
79	Improving product promotions	Improving product displays and promotions helps to validate proper placement to sponsoring vendors, assuring promotional placement

- Improving product displays and promotions helps to validate proper placement to sponsoring vendors, assuring promotional placement.

8. Future works

Despite the numerous opportunities for RFID, it seems that there is still a long way to go before its extensive global application is achieved. There are many challenges that need to be overcome and a host of problems to be solved to expedite the widespread implementation of RFID (Ngai *et al.*, 2008b). A short list of studies and researches that can be done in relation to RFID-based systems for various organizations are provided below:

1. Tracking and tracing capabilities:
   - Tracking and tracing of critical items used in the products.
   - Degree of importance of security and privacy issues for an organization and its real impact on the adoption of RFID technology.
   - Privacy and security issues of RFID – in relation to highly sensitive issues as such as data acquisition on minorities and gender issues.
2. Critical success factors (CSF) and performance:
   - Studying the CSF of RFID adoption.
   - Studying the performance of RFID technology in whole organization.
   - RFID strategies that are suitable, acceptable, and manageable for the organization.

3. RFID management:
   - Finding a new management way for managing this new RFID technology.
   - Creation of a business model for an organization to adopt an RFID-based system.
   - The bar code vs RFID studies for various industry to determine whether that sector is apt to use RFID.
   - What rules and guidelines a company should follow to get a full readiness for implementing RFID and to be a continuous RFID user.
4. RFID impacts:
   - RFID impacts on cost management in SC systems (manufacturing SC, health SC, etc.)
   - RFID impacts on flow management of products in SC systems.
   - RFID impacts on serviceability and customer satisfaction.
   - RFID impacts on companies' bottom line.
   - Studying the impacts of RFID-based systems on companies and organizations.
   - Studying the impacts of RFID-based systems on various processes, functions, departments, and subsidiary of the organization.
   - Psychological impacts of RFID utilization on employees in general and customers in particular.
   - The RFID true impacts on people health.
5. RFID integration:
   - Integrating RFID systems with quality assurance systems.

- Integrating RFID systems with ERP systems.
- Integrating RFID systems with decision support systems.
- Integrating RFID systems preventive maintenance systems.
- Integrating RFID systems with inventory management systems.
- On time and online assembly line scheduling using RFID-based system.
- RFID implementation in robotic systems.
- Quality systems developments with RFID-based systems.
- RFID-based systems with expert systems in mind for better decision-making purposes.
- The integration of RFID, internet, expert systems, and decision support systems for making online and on time decisions.

9. Discussion and conclusion

RFID is part of a new generation of IT known as "contact-less communication" and the foundation of the "silent business" and "internet of things". RFID may reduce costs and improve efficiency, but it may also cause security and privacy problems. Despite RFID adoption challenges and corresponding low adoption rates, Sheffi (2004) argued that RFID will follow the adoption path of other disruptive technologies, such as television, automobile, and refrigeration toward wide adoption. The most cutting edge technology for SC integrity and traceability is the RFID system (Kumar and Budin, 2006). Recent advances in RFID have enabled its early adoption in many commercial applications, such as SCM, logistics, and transportation. RFID technology is a supporting tool for automating processes and improving operations management. The fact is that it can bring more power to the decision-making team by providing on time information. This sophisticated technology is more useful to the management for one or more of the following facts:

- better SC and inventory management;
- reducing counterfeiting and fraud controlling;
- tracking work-in progress;
- reducing administrative errors;
- reducing rework;
- better management of warrantee claims;
- capable of working in suitable and harsh environments;
- better SC efficiency;
- cost saving; and
- profit enhancement.

Manufacturers can use RFID solutions to reduce operating costs through decreasing the labor costs, claims, and returns. This will help them to increase the operating income. They also can reduce the working capital by enabling reductions in inventory and lowering the inventory write-off from the return goods and those items that are un-saleable at the end. Main benefits of RFID can be categorized as follows:

- improving the speed and accuracy for tracking pallets, cartons, and containers;
- helping to reduce stock levels;
- helping to reduce operating costs;
- improving the management of inventory;
- improving efficiencies in work-in process reporting; and
- improving inventory visibility to feed JIT systems.

In this research, author has looked into different case studies and from there he has identified a list of benefits that RFID has brought with itself to various industries. Some benefits of RFID are those listed below:

- Automation – reducing manual processes through automated scanning and data entry improves productivity, allowing resources to be reallocated to higher value activities.
- Integrity – improving the integrity of real-time SC information with increased authentication and security and tracking capabilities reducing errors, shrinkage, and counterfeiting while improving customer satisfaction – information is only valuable if it is correct.
- Velocity – reducing workflow issues by minimizing the time spent finding and tracking needed assets, in turn increasing product flow and handling speeds.
- Insight – providing the real-time information needed to make faster, better, and more informed decisions and the ability to be more responsive to the customer.
- Capability – providing new applications and quality to meet SC partner demands and enhance customer experiences.

With its tremendous benefits as are explored in this article, this author agrees with other researchers (Reyes *et al.*, 200; Chen *et al.*, 2008) that RFID will fit most industries in the coming futures.

References

Angeles, R. (2005), "RFID technologies: supply-chain applications and implementation issues", *Information Systems Management*, Vol. 22 No. 1, pp. 51-65.

Arnold, J. and Bures, C. (2003), "Revisiting retail challenge", *Industrial Engineer*, Vol. 35 No. 12, pp. 38-41.

Barlas, D. (2005), "DoD RFID updates", Line56, February 10, available at: www.line56.com/articles/default.asp?ArticleID=6339

Bose, I. and Pal, R. (2005), "Auto-ID: managing anything, anywhere, anytime in the supply chain", *Communications of the ACM*, Vol. 48 No. 8, pp. 101-6.

Bottani, E. and Rizzi, A. (2008), "Economical assessment of the impact of RFID technology and EPC system on the fast moving consumer goods supply chain", *International Journal of Production Economics*, Vol. 112 No. 2.

Chao, C., Yang, J. and Jen, W. (2007), "Determining technology trends and forecasts of RFID by a historical review and bibliometric analysis from 1991 to 2005", *Technovation*, Vol. 27 No. 5.

Connolly, C. (2007), "Sensor trends in processing and packaging of foods and pharmaceuticals", *Sensor Review*, Vol. 27 No. 2.

Crayton, J. (2004), "Incorporating radio frequency identification technology into the health care sector", Infohealth Management Corp., available at: www.infohealth.net

De Kok, A.G., Van Donselaar, K.H. and Van Woensel, T. (2008), "Break even analysis of RFID technology for inventory sensitive to shrinkage", *International Journal of Production Economics*, Vol. 112 No. 2.

Eckfeldt, B. (2005), "What does RFID do for the consumer?", *Communications of the ACM*, Vol. 48 No. 9, pp. 77-9.

Fisher, J.A. and Monahan, T. (2008), "Tracking the social dimensions of RFID systems in hospitals", *International Journal of Medical Informatics*, Vol. 77, pp. 176-83.

Hall, R. and Hampl, J.S. (2004), "Radio frequency identification applications for dietetics professionals", *Journal of the American Dietetic Association*, Vol. 104, pp. 1521-2.

Hengst, M.D. and Sol, H.G. (2002), "The impact of electronic commerce on inter-organizational coordination: a framework from theory applied to the container-transport", *International Journal of Electronic Commerce*, Vol. 6 No. 4, pp. 74-91.

IDTechEx (2006), "RFID retail case studies", *IDTechEx Case Studies*, IDTechEx, Cambridge, MA.

Jansen, R. and Krabs, A. (1999), "Automatic identification in packaging: radio frequency identification in multiway systems", *Packaging Technology and Science*, Vol. 12 No. 5, pp. 229-34.

Karkkainen, M. (2003), "Increasing efficiency in the supply chain for short life goods using RFID tagging", *International Journal of Retail & Distribution Management*, Vol. 31 No. 10, pp. 529-36.

Kim, E.Y., Ko, E., Kim, H. and Koh, C.E. (2008), "Comparison of benefits of radio frequency identification: implications for business strategic performance in the US and Korean retailers", *Industrial Marketing Management*, Vol. 37 No. 7.

Kohn, C. and Henderson, C.W. (2004), "RFID-enabled medical equipment management programs to reduce costs", *Managed Care Weekly Digest*, Vol. 5, pp. 94-5.

Kumar, S. and Budin, J.P. (2006), "Prevention and management of product recalls in the processes food industry: a case study based on an exporter's perspective", *Technovation*, Vol. 26, pp. 739-50.

Li, S. and Visich, J.K. (2006), "Radio frequency identification: supply chain impact and implementation challenges", *International Journal of Integrated Supply Chain Management*, Vol. 2 No. 4, pp. 407-24.

Ngai, E.W.T., Suk, F.F.C. and Lo, S.Y.Y. (2008a), "Development of an RFID based sushi management system: the case of a conveyor belt sushi restaurant", *International Journal of Production Economics*, Vol. 112.

Ngai, E.W.T., Moon, K.K.L., Riggins, F.J. and Candace, Y.Y.I. (2008b), "RFID research: an academic literature review (1995-2005) and future research directions", *International Journal of Production Economics*, Vol. 112.

Ohkubo, M., Suzuki, K. and Kinoshita, S. (2005), "RFID privacy issues and technical challenges", *Communications of the ACM*, Vol. 48 No. 9, pp. 66-71.

Potter, B. (2005), "RFID: misunderstood or untrustworthy?", *Network Security*, No. 4, pp. 17-18.

Read, R. (2005), RFID monthly: an overview of RFID industry development.

Sheffi, Y. (2004), "RFID and the innovation cycle", *International Journal of Logistics Management*, Vol. 15 No. 1, pp. 1-10.

Singh, N. (2003), "Emerging technology to support supply chain management", *Communications of the ACM*, Vol. 46 No. 9, pp. 243-7.

Song, J., Haas, C.T., Caldas, C., Ergen, E. and Akinci, B. (2005), "Automating the task of tracking the delivery and receipt of fabricated pipe spools in industrial projects", *Automation in Construction, March*.

Srivastava, B. (2004), "Radio frequency ID technology: the next revolution in SCM", *Business Horizons*, Vol. 47 No. 6, pp. 60-8.

Subramani, M. (2004), "How do suppliers benefit from information technology use in supply chain relationships?", *MIS Quarterly*, Vol. 28 No. 1, pp. 45-73.

Tajima, M. (2007), "Strategic value of RFID in supply chain management", *Journal of Purchasing & Supply Management*, Vol. 13, pp. 261-73.

Theotokis, A., Pramatari, K. and Doukidis, G. (2008), RFID and innovative retail services: the consumer perspective.

Trailblazer System (2004), "Is your RFID EDI aware?", available at: www.trailblazersystems.com/rfid.asp (accessed August 20, 2006)

TZeng, S.-F, Chen, W.-H. and Pai, F.-Y. (2008), "Evaluating the business value of RFID evidence from five case studies", *International Journal of Production Economics*, Vol. 112.

Vellidis, G., Tucker, M., Kevin, C. and Bednarz, C. (2008), "A real-time wireless smart sensor array for scheduling irrigation", *Computers and Electronics in Agricultures*, Vol. 61 No. 1.

Vermesanl, O., Grosso, D., Dell'Ova, F. and Prior, C. (2007), "Emerging RFID technology roadmap", paper presented at EU RFID Forum 2007, Brussels, March 13-14.

Vijayaraman, B.S. and Osyk, B.A. (2006), "An empirical study of RFID implementation in the warehousing industry", *International Journal of Logistics Management*, Vol. 17 No. 1, pp. 6-20.

Wang, S.-J., Liu, S.-F. and Wang, W.-L. (2008), "The simulated impact of RFID enabled supply chain on pull-based inventory replenishment in TFT-LCD inventory", *International Journal of Production Economics*, Vol. 112.

Wen, W. (2008), "A dynamic and automatic traffic light control expert system for solving the road congestion problem", *Journal of Expert Systems and Applications*, Vol. 34, pp. 2370-81.

Wu, N.C., Nystrom, M.A., Lin, T.R. and Yu, H.C. (2006), "Challenges to global adoption", *Technovation*, Vol. 26, pp. 1317-23.

Yin, R.K. (1994), *Case Study Research: Design and Methods (Applied Social Research Methods)*, Sage, Thousand Oaks, CA.

Yin, R.K. (2003), *Case Study Research: Design and Methods*, Sage, Newbury Park, CA.

Corresponding author

Yahia Zare Mehrjerdi can be contacted at: Yazm2000@yahoo.com