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RFID Technology Enhancing Supply Chain Competence and E-Business: An Opportunity or a Threat?

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Abstract: Radio Frequency Identification (RFID), which uses radio waves to identify objects, was discovered in 1930s for military purposes and it transformed into commercial uses in 1980s in the United States. In this paper, we explore the research domains in RFID technology, innovation and diffusion theory, and supply chain management within the existing literature for exploring whether RFID enhances supply chain competence and e-business. This paper also forms a preliminary study base for researchers who may wish to carry on future research in this area.

Keywords: Emerging Technologies, RFID, supply chain.

I. Introduction

Radio Frequency Identification (RFID) is a term for technologies that makes use of radio waves to automatically identify people or objects [48], [25]. It was discovered in 1935 by Scottish physicist Sir Robert Alexander Watson-Watt [36] mainly for military use. It only started to become popular in commercial sector around 1980s, particular in automobile industry such as Ford, GM, Chrysler, and Toyota, with the RFID tags produced by Allen-Bradley in 1984 [45]. In this paper, we explore whether RFID would enhance the supply chain management system, and, whether it is an opportunity or a threat. We explored a number of different research domains (including RFID technology, supply chain management and diffusion theory) within the existing literature. According to Bourner (1996), there are a number of good reasons for spending time and effort on a review of the literature. Some of these reasons taken for this paper are: *to increase breadth of knowledge within a subject area*, and *to provide the intellectual context for one's own work, enabling the positioning of a project relative to other work* [10]. Hence, we organize this paper into seven sections. In the next section, it brings forth RFID fundamentals including the characteristics of RFID and a comparison between RFID and bar coding. In Section 3, we discuss how RFID technology fits in with the Theory of Technological Innovation Diffusion. In Section 4, we present how RFID improves the supply chain management and e-Business. In Section 5, we cover the current applications of RFID in Asia, particularly in China. In Section 6, the disadvantages and problems of RFID will be outlined. The conclusions and the future research areas of RFID in supply chain management will be presented in the final section.

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II. RFID Fundamentals

II.1 The Development and Characteristics of RFID

RFID is a wireless tracking technology that allows a reader to activate a transponder on a radio frequency tag attached to, or embedded in, an item, allowing the reader to remotely read and/or write data to the RFID tag [48], [25]. RFID utilizes a semiconductor (microchip) in a tag or label to store data. Data is transmitted from, or written to the tag or label, when it is exposed to radio waves of the correct frequency and with the correct communications protocols from an RFID reader. Tags can be either *active* (using a battery to broadcast a locating signal) or *passive* (using power from the RFID reader for location). Because the tag sends an electronic signal, it can transmit information when buried under several layers of products and shipping material, through concrete walls or even under water [6].

RFID has its roots dating back to WWII when British planes had surface mounted transponders installed so that radar could detect their planes from those belonging to the enemy [8]. After the 1950s, development went a little quiet until the 1960s when in the first commercial use of RFID, electronic article surveillance was used to counter theft, In the 1970s, inventors, companies, academic institutions and government all continued developing RFID applications and the opportunities afforded by the technology began to be realized. The latest generation of RFID allows the dozens of individual objects within a group to be uniquely identified at

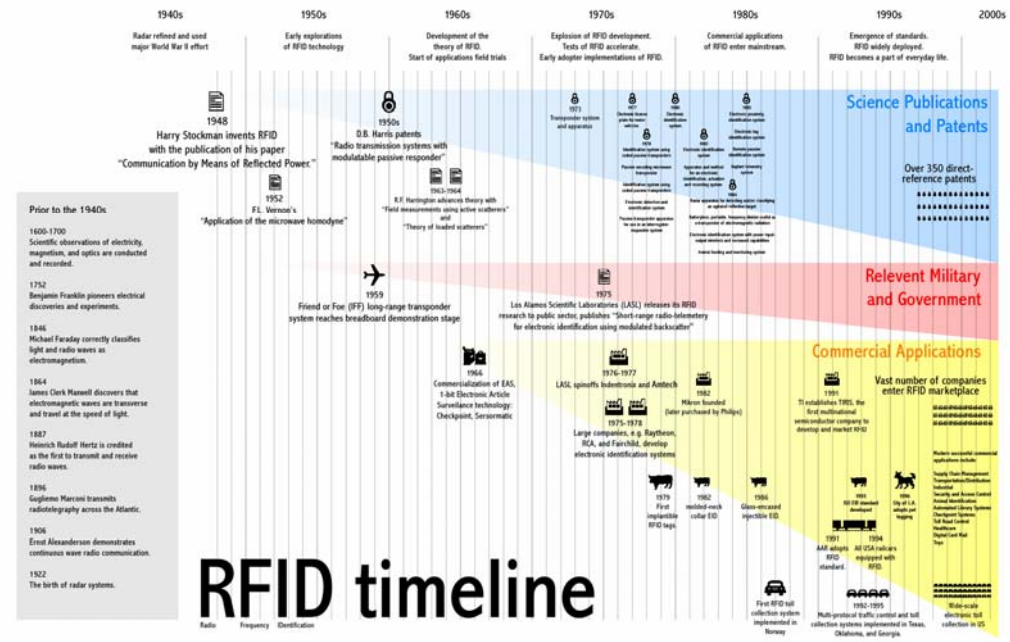

FIGURE 1. RFID Timeline
(Source: Interaction Design Institute Ivrea 2002 [24])

	Bar Coding	RFID
Reading capability	Optical-line of sight required.	Wireless – line of sight not necessary (some environmental exceptions).
Reading speed	Bar coding can read a single label per scan.	RFID can read multiple tags in a single pass.
Durability	Labels tend to be damaged in harsh processes. Etching directly onto part has increased durability.	Tags are more durable than bar code labels, can be used during and after most harsh environments.
Amount of information	A 1D bar code can store 20 alphanumeric characters, while a 2D bar code can store roughly 2,000 characters.	RFID tags are capable of storing several thousand characters, or several kilobytes, of information.
Flexibility of information	To update information, a bar code label must be replaced with a new bar code label.	To update information, many RFID tags can have their memories updated with new information through wireless communication.
Security	2D bar codes provide encryption capability.	RFID tags have manufacturer installed identification codes that cannot be changed, thus making counterfeiting difficult.
Cost per label or tag	Bar code labels typically cost less than $0.01.	RFID tags cost from $0.25-$0.50, up to $250.
Standards	Bar coding is standardized and widely accepted.	RFID lacks complete standardization, especially in the global environment
State of infrastructure	The infrastructure to support bar codes is in wide existence.	The infrastructure to support RFID is minimal. Users would have to invest in additional equipment to support RFID.

TABLE 1. *Summary of Differences between Bar Coding and RFID*
(Source: Robert W. Baird & Co. Incorporated 2004 [38])

the same time. However, until recently, RFID, which allows the tracking of individual items, has not been feasible for many commercial applications given its high cost and technological limits. Today, companies such as Alien

Technology and Matrices are developing RFID components (e.g., tags, readers, etc.) at a much lower cost than was formerly possible, creating a wider opportunity for RFID. Figure 1 gives the timeline of RFID [24].

II.2. RFID Attributes – A Comparison vs Bar coding

As bar coding is the most established automatic identification technology and RFID can be considered the most promising. Conceptually, bar coding and RFID are similar: both are intended to provide rapid and reliable item identification and tracking information. RFID is similar in theory to bar code identification systems. Both technologies establish object identification via scanning and facilitate data collection. However, RFID offers vast improvements over bar coding. The advantages of RFID over bar code technology are summarized in Table 1.

RFID technology is "essentially a new and vastly improved barcode [33]." It has been considered a replacement for barcodes. However, it is much more than an "improved barcode," not only because it does have high storage capacity and ability for reprogramming, but also because of its miniature size and the accompanying tracking ability. We evaluate their suitability in the different application types.

Authentication applications

RFID technology is far more suitable than bar coding for authentication type applications due to the relative ease of copying and forging bar codes. In contrast, RFID technology is considered to be almost impossible to counterfeit or copy, which makes it a valid technology for authentication purposes.

Tracking applications

In most tracking applications, bar codes will currently provide the best payback for investment. It helps to alleviate the problems of manual data handling with relatively low costs [19]. The installed base of bar code readers is extensive, as it is by far the most popular automatic identification technology [18]. However, if the deliveries are likely to require excessive handling and poor environmental conditions, RFID is a viable option as the identification technology [11] [26] [31]. The use of RFID greatly increases the needed investments, and thus easily reduces the number of tracking points in the system, as even the cheapest RFID readers with limited functionality cost around one thousand Euro [47].

Process effectiveness applications

At the moment bar code based applications are widely used in the short shelf life supply chain. Bar code scanning reduces errors associated with manual data handling, and produces visibility to aid supply chain management [19]. Also, the introduction of new bar coding standards that enable adding the sell-by dates to the codes have helped in retaining the integrity of stock rotation and hence help solve the spoilage problem [43]. However, there are problems associated with bar code data collection. The reading of bar codes invariably requires manual handling in the supply chain. Either the packages with bar codes or the reading devices are handled manually in order to read the codes [11] [13] [26] [31]. This makes data capture difficult, especially in the retail store environment where large amounts of goods are handled in facilities not designed for effective logistics [17]. Readability of bar codes is, occasionally, problematic due to dirt and bending; resulting in reduced accuracy of reading rates, particularly in successive handling situations and in difficult environments [35] [31]. However, RFID tags with sensor functions can monitor physical conditions, like temperature and humidity and to register if the product has suffered any knocks. The greatest cost efficiency can be achieved with recyclable transport containers, as the same investments in transponders can be continuously utilized [2].

Information management applications

Currently, in license plate applications bar coding is the most cost efficient technology. When storing read-only information directly on the identifiers, two-dimensional bar codes are often the best alternative due to the amount of information that can be incorporated and the relatively low price. In applications with requirements for read-write capabilities RFID is, of course, preferable.

Even though there are differences between bar code and RFID standards, technology can overcome this and now some stand-alone devices can read from barcode and write to RFID tags [23][7].

III. Theory of Technological Innovation Diffusion

III.1 RFID and e-Technology

The use of e-technology as a means to enhance supply chain competence has been widely espoused. A brief listing of these technologies ranges from those that have existed for decades to some very recent innovations, and encompasses many of the following:

- the personal computer;
- electronic data interchange (EDI) among carriers, shippers and customers;
- bar-coding and scanning;
- advance ship notices (ASNs);
- shipment and package tracking systems;
- satellite global positioning systems (GPS) and geographic information systems (GIS);
- software agents, HTML, JAVA, XML, object-oriented programming and semantic webs;
- the Internet, intranets and extranets;

- Web-enabled relational databases, data warehouses and data marts;
- decision support systems;
- electronic signature technology;
- wireless technology; and
- Enterprise Resource Planning systems (ERP).

Application / Technology	Authentication	Tracking	Automation	Information Management
Bar code		X	X	X
RFID	X	X	X	X
OCR			X	
Biometrics	X			
Vision recognition			X	
Magnetic ink	X		(X)	
Smart cards	X			X
Contact memory			(X)	X
Magnetic stripe	X			X
Bluetooth	(X)	(X)	(X)	(X)
GPS		X		
GSM cell location		X		

TABLE 2. Different Identification Technologies Classified By Application Types
(Source: Kärkkäinen, Ala-Risk and Kiianlinna 2001 [27])

Various technologies used to track and automatically identify (ID) people, products, and other objects in order to enhance the supply chain management are:

- Barcodes
- Optical Character Recognition (OCR) Systems
- Biometrics
- Voice recognition and ID systems
- Fingerprint ID systems
- Smart cards
- Memory cards
- Microprocessor cards

RFID combines features of several of these technologies. Like barcodes, RFID is used to identify and track objects. As with OCR and biometrics, RFID enables automatic ID and verification. RFID also can be used like smart cards, memory card, and microprocessor cards to store information and provide interactive data processing.

The most important strength of RFID technology is that when using RFID tags, no line of sight is needed with the identifier in order to identify the object. Products can be identified effortlessly, during processing and without additional handling. Tags can be read through non-metallic materials, and about 60 tags can be read simultaneously [11] [26]. Also, most RFID tags are durable and resistant to temperature and other environmental factors [15]. More detailed descriptions of the technologies can be found in Table 2 [27].

III.2 Rogers' Technological Innovation Diffusion Theory

Rogers (1983) explains *diffusion* as: the process by which an innovation is communicated through certain communication channels over time among the members of a social system [40]. He breaks the adoption process down into five stages: awareness, interest, evaluation, trial, and adoption. The distribution of adopters of an innovation can be approximated by a normal distribution of the time of adoption. Using the mean and standard deviation of this distribution as a method of segmentation results in five adopter categories: (1) innovators, (2) early adopters, (3) early majority, (4) late majority, and (5) laggards [40] [41].

(1) *Innovators* are the first 2.5 percent of the individuals in a system to adopt an innovation. While an innovator may not be respected by the other members of a social system, the innovator plays a gate keeping role in the flow of new ideas into a system.
(2) *Early Adopters* are the next 13.5 percent of the individuals in a system to adopt an innovation. The early adopter decreases uncertainty about a new idea by adopting it, and then conveying a subjective evaluation of the innovation to near-peers through interpersonal networks.
(3) *Early Majority* is the next 34 percent of the individuals in a system to adopt an innovation. The early majority follow with deliberate willingness in adopting innovations, but seldom lead.
(4) *Late Majority* is the next 34 percent of the individuals in a system to adopt an innovation. The late majority adopt new ideas just after the average member of a system.
(5) *Laggards* are the last 16 percent of the individuals in a system to adopt an innovation. Laggards tend to be suspicious of innovations and change agents. From the laggard's viewpoint, their resources are limited and they must be certain that a new idea will not fail before they can adopt [39].

III.3 Applications of Rogers' Theory in RFID

The RFID industry is still at the growing stage. Technical standards and customer demand will hasten maturity of the industry, favourably impacting supply capacity and cost. Some actual implementations of RFID technology are being experienced within some organizations in the U.S. and Europe. Wal-Mart, for example, the world's largest retailer, has instructed its top 100 suppliers to place RFID tags on all its pallets and cases, though not on individual items, by January 2005. Over the next decade, it is likely that nearly every Fortune 500 and Global 1000 company will join the U.S. Department of Defense (DoD) and Wal-Mart in employing so-called automatic identification technology, making RFID an essential factor in almost any business [33].

Royal Philips Electronics and IBM have announced a major collaboration, which will see the joint development of RFID and smart card applications. The two companies hope that their combined reputation and market muscle will attract customers seeking to roll out their RFID projects using well-established suppliers [4].

Woolworths involvement with RFID technology came under the Home Office's 'Chipping of Goods' initiative [20].

Tesco is currently trialing tags on DVDs at its Sandhurst and Leicester stores. In this trial Tesco is testing smart shelf technology in collaboration with MeadWestvaco, an American packaging company and Entertainment UK (EUK), that keeps DVDs stocked in 2,500 retail stores in the UK [46].

In January 2003, Gillette became the first major manufacturer of consumer goods to place a giant order, 500 million, for RFID tags.

In U.K., Argos' involvement in the 'Chipping of Goods' initiative is mainly due to the fact that they are a retailer of high value products such as jewellery, electrical equipment and furniture. Since jewellery pieces are small and easy to convey, this was the chosen product to track for this nine-month trial, which aimed to reduce shrinkage. Up to 16 per cent of the products are returned and so an improvement in supply chain transparency was also sought [22].

Organizers of the 2006 football World Cup in Germany are to issue paper tickets incorporating smart tags. With more than 3.2 million tickets expected to be issued it will be the largest deployment so far of RFID technology at a sporting event [4].

The organizations cited above are the *Innovators* of applications in RFID, and meanwhile, the number of organizations preferred to be *Early Adopters* is increasing. Rogers identifies several additional characteristics dominant in the *Innovator* type:

- venturesome, desire for the rash, the daring, and the risky,
- control of substantial financial resources to absorb possible loss from an unprofitable innovation,
- the ability to understand and apply complex technical knowledge, and
- the ability to cope with a high degree of uncertainty about an innovation.

Early adopters frequently serve as opinion leaders who can persuade others to adopt the innovation by providing evaluative information [41]. From the perspective of theory development, knowledge about the characteristics of early adopters can help researchers develop richer theoretical models that explain adoption behaviours across a range of adopter types.

Recently statistics indicate that more than four-fifths of U.S. businesses plan to use the tracking technology at some point, with 69 percent looking at RFID as in 2005 [9]. This shows that U.S. companies adopt RFID technology at *Early Majority* category.

IV. RFID Emerging Applications—Supply Chain

IV.1 Supply Chain Historical Perspective

RFID technology can help suppliers eliminate delivery lag times, determine point of origin, track orders in the supply chain, and make inventories more visible (e.g., in a warehouse, in a shopping cart, on a battlefield). Technically, RFID has the capability to increase efficiencies in supply operations by minimizing the need for line-of-sight proximity between a scanner and an RFID tag. In fact, industry analysts are predicting that within a decade, RFID technology will have matured to a point where loaded shopping carts can be automatically read as a customer moves through the store checkout, without the need to unload or manually read tags.

According to Accenture (2004), a global management consulting, technology services and outsourcing company, an RFID open systems solution can increase inventory turns by 10 to 15 percent. Greater inventory turns facilitate capital resource optimization, increased margin procurement and significant reductions in obsolete inventory levels. Supply chain managers today must be better informed with accurate real-time data to stay competitive [1]. Other potential benefits of RFID technology in the supply chain management are listed in Table 3 [6].

Explanation of P, C, I symbols:
Tagging at various packaging levels (Pallet, Case, Item) in order of significance to achieve named benefits.

Function / Activity	Potential Benefits	Manufacturing	Warehousing	Transportation	Store Operations
Demand Planning	Reduced out of stocks	C	C, P	P, C	C, I
	Decreased order lead time	C	C, P	P, C	C, I
	Sales driven replenishment	C	C, P	P, C	C, I
	Increased inventory turns	C	C, P	P, C	C
	Decreased safety stock	C	C, P	P, C	C
Item/Batch/Lot Tracking	Reduced sale of counterfeits	C, I	C, P, I	P, C, I	I, C
	Increased contract compliance	C	C, P	P, C	C
	Increased product quality	C, I	C, P	P, C	C
Security	Reduce theft	C, I	C, P, I	P, C, I	I, C
	Reduce chances for product tampering	C, I	C, P, I	P, C, I	I, C
Procurement & Material Storage	Reduced order lead time	C, I			
	Increased raw material availability	C, I			
	Higher capacity utilization	C, I			
Production	Higher capacity utilization	C, I			
	Reduced order cycle time	C, I			
	Increased quality	C, I			
Receiving	Decreased unloading times		P, C		P, C
	Increased accuracy of accepted shipments		P, C		P, C
Order Selection	Increased accuracy of orders		C, I, P		
	Increased order fill rate		C, I, P		
Exception Product Location	Fewer misplaced items		C, P, I		
	Decreased time to locate specific items		C, P, I		
Loss Prevention Asset Management	Reduced shrink		C, P, I		I, C
	Increased productivity of assets			P, C	
	Reduced loss of assets			P	
	Pricing based on actual use of assets			P	
Yard Management	Increased productivity of assets			P	
	Increased visibility of drop shipments			P	
Contract Compliance	Decreased exceptions management			P, C	
	Increased customer satisfaction			P, C	
Routing Checkout	Dynamic routing			P, C	
	Increased accuracy of checkout				I, C
	Increased checker productivity				I, C
Returns and Reverse Logistics	Increased accuracy of returns acceptance				I, C
	Increased accuracy of refund amounts				I, C
	More efficient recycling or disposal				I, C
Post-Sales Service	Increased warranty compliance				I, C
	Faster warranty and repairs processing				I, C

TABLE 3. RFID and the Supply Chain
(Source: [5])

IV.2 Driving Forces of RFID Applications in Supply Chain Management

RFID Technology and Information Flow

The supply chain is the flow of both information and material through a manufacturing company, from the supplier to the customer. Information flow broadcasts demand from the end customer to preceding organizations in the network. Information has to be accurate, timely and visible before it can replace inventory. It is the integration of transportation, distribution, ordering, and production. The information can access data interchange and data acquisition at the point of origin and point of sale through inter-company and intra-company. The smoother the information flow, the earlier information can be reached to the customers. It is important that systems be designed to enhance open and rapid communication and sharing of information across the supply chain and within the organization. The flow of information has been recognized alongside the importance of materials flows in the logistics channel. Information technology has been forwarded as a means of achieving competitive advantage, and as a valuable tool used to ensure that the logistics objective of providing target services at the least total cost is accomplished.

RFID enables the user to find, track, secure, and count items faster and with higher accuracy than with other competing technologies. RFID can dramatically increase the speed, efficiency, and accuracy of data collection by improving the linkage between management information systems directly to the various data points of the supply chain. This capability allows information to be collected, processed, shared and leveraged on a near real-time basis by virtually all members of a supply chain. It is believed that this increased communications speed will continue to enhance the management capabilities throughout the supply chain as they are adopted further. Figure 2 indicates the large number of touch points in a supply chain where RFID tagged pallets, cases and items aid in connecting the physical world with the information world. This does not just only apply to traditional distributions, i.e. from manufacturers to retailers. It can also adapt to the B2B e-business/e-commerce.

RFID is a means of capturing data about an object without the need of a human to read and recode the data. Radio frequency (RF) tracking is a current and highly beneficial technological advance that could lead to tremendous cost reduction in the future for all retailers. If the reader detects a large quantity of a certain product moving off the shelf, it automatically sends a signal to a nearby camera to take pictures and alert security to make sure that these items are not being stolen. This type of information should help stores reduce the amount of theft by not only the customers but also its employees.

Issue Pertaining to Process and Quality Control

RFID enables a number of process management and quality control innovations through real-time tracking.

Inventory expiration management

Products can be tagged for expedited processing when there are time-sensitive constraints. The technology is typically used to track assets at three levels — pallet, case/carton, and unit. Tagging at all three levels allows each to possess its own identity or to be associated with the others for tracking at various stages in the supply chain. With the associations made possible by RFID, when a pallet passes by a reader, for example, the RFID system can identify the pallet and check its location into the software system, while at the same time recognizing the corresponding cartons and units that it is carrying.

RFID's faster scanning process significantly increases inventory visibility, which enables better inventory management through more efficient staging and rapid cross docking. Improved inventory management increases inventory velocity and allows for incremental labor cost reductions. Further, as a result of the enhanced tracking, less safety stock is required.

Manufacturers can continuously track products offering verification and certification of product location, product handling, environmental conditions and processing procedures. And meanwhile, tracking a product's location, handling procedures, environmental conditions, and processing will enable quality control, improvement, and certification.

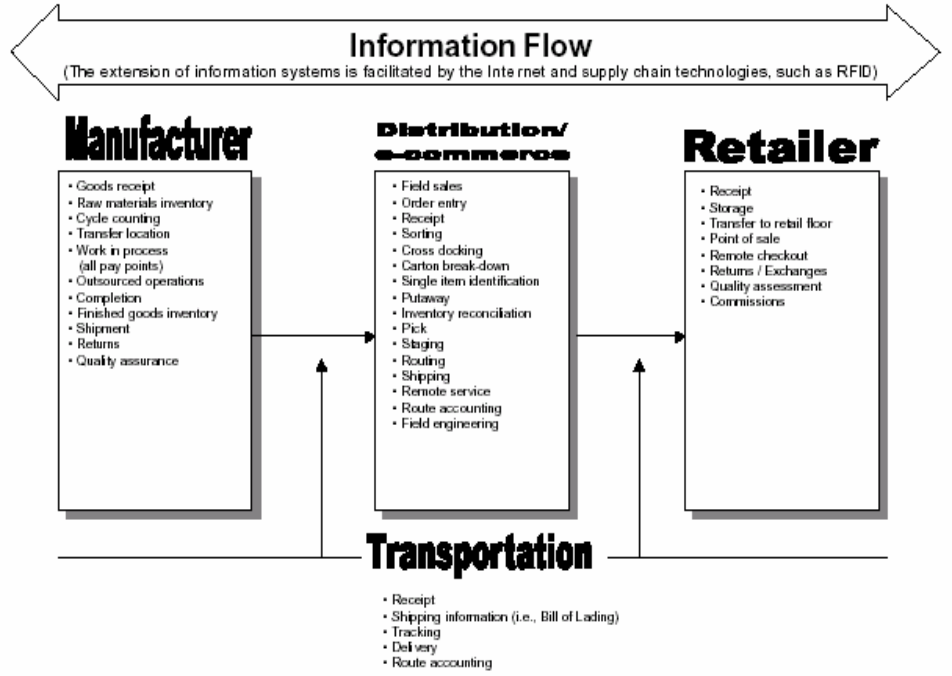

FIGURE 2. Potential RFID Touch-Points in the Supply Chain
(Source: Robert W. Baird & Co 2004 [38])

Employee management and monitoring

Quality improvement requires that line personnel improve product handling and processing. If products can be tracked through the production process, then personnel who handle the products can be better managed and supervised.

The increased reading capability reduces the need for manual intervention as RFID readers can automatically scan incoming shipments entering a distribution center or retail location. RFID's more robust scanning capability also reduces labor associated with pallet breakdown and cross docking activities. In addition, improved inventory accuracy also reduces the need for labor intensive physical counts.

Just in time manufacturing and delivery

Manufacturers can use RFID to work more closely with suppliers and customers to integrate production activities within the plant and to streamline interactions with other participants in the supply chain

As supply chain members receive better, faster and more accurate inventory information, they improve their forecasting and plan their operations more effectively. As a result, retailers have fewer stock outs, resulting in improved sales (retail sales are said to be reduced by nearly 4% each year from stock outs), while distribution centers save through increased shipping accuracy, which lowers returns and improves customer satisfaction.

Government Regulations and Certifications

Governments can play an important role in helping to foster the adoption of new technologies such as RFID. For example, in the U.S., Department of Defense (DoD) is seeking to use RFID to transform its supply chain. Department of Homeland Security is looking at RFID to secure the nation's ports and borders. Food & Drug Administration (FDA) is encouraging pharmaceutical companies to use RFID to reduce counterfeiting and secure the country's drug supply. Government concerns over food safety have increased dramatically and they are demanding improved supply chain visibility to increase safety and efficiency. This track will have experts to talk about various Government Regulations and how plants can maintain the integrity of their brands, control product from harm, better manage product recalls, comply with government regulations and gain supply chain efficiencies using RFID. For example, in European Community (EC) 178, Article 18 [16] is, the law of traceability, "The traceability of food, feed, food-producing animals, and any other substance intended to be, or expected to be, incorporated into a food or feed shall be established at all stages of production, processing and distribution."

Governments that fund RFID projects give local companies an edge while helping to promote technology that can benefit the society at large.

We have examined the U.S. and European government's roles on RFID. In the next section, we explore RFID in the Asia region.

V. RFID in Asia

V.1 Applications of RFID in Asia

In Asia, RFID applications primarily focus on logistics, with an emphasis on warehousing, shipping, maintenance of product quality and inventory management. Japan is currently researching two approaches to reducing the cost of chips and other Asian countries are expected to follow Japan's lead. Japan has already adopted RFID for a variety of purposes, including anti-theft devices, public transportation, and supply chain management. In their 2004 white paper on the status of information and communications in Japan, the Ministry of Internal Affairs and Communications (MIC) outlined a "u-Japan" policy to promote a "ubiquitous network society [30]."

RFID has been used in South Korea primarily for tracking livestock, public transportation fare payment, highway toll collection, and postal services. The South Korean government is supporting an RFID project at the Port of Busan. It is encouraging companies to invest in an RFID research park. It is also promoting RFID to satisfy growing demand for supply side applications in South Korea and globally in hopes of becoming a leading exporter of RFID technology. South Korean electronics firms such as Samsung and LG are heavily involved in developing RFID technology. Nevertheless, South Korea's RFID technology is currently years behind that of Japan, Europe, and the United States.

Despite Taiwan's experience in establishing supply chain models and the government's success in promoting e-business, the adoption of RFID technologies in Taiwan has been relatively slow. The government of Taiwan is beginning to assist in the development of an RFID industry and to promote the use of RFID technologies among leading industries.

The Singapore government has put up US$5.8 million to support the development of the RFID industry in the island republic, while the Chinese government has been encouraging the use of RFID for mass transit tickets and other applications to stimulate adoption. If history is any gauge, this government-industry partnership in Asia is likely to catapult the region to the forefront of RFID adoption.

V.2 Overview of RFID Adoption Drivers in China

China, as a key manufacturing center, will be directly affected by the RFID adoption. There are several driving forces to have RFID adopted in China. Chinese businesses began with a weak foundation in the intense world trade environment, similar to the many other companies that grew from developing countries. How were these Chinese businesses able to compete with foreign competitors armed with strong capital structures and efficient communication networks?

Firstly, as China becomes one of the world's main manufacturing centres, 'Made in China' is reshaping the world supply chain structure. Consequently, China logistics is playing a key role in world business that no manager can afford to ignore. Global manufacturers supply products to many nations, but no nation plays a bigger role than China. Well over 70 percent of the more than $200 billion worth of goods imported into the U.S. from the Pacific Rim each year comes from China [37].

Chinese government officials and heads of Chinese companies are placing an increased emphasis on the country's logistics infrastructure, which has not kept pace with the growth in manufacturing during the past decade. Because of the growth of China's logistics infrastructure has lagged, China's supply chains are highly fragmented.

China is the world manufacturing engine and the adoption of RFID in the factories and distribution centers of China is fundamental for RFID technology to deliver on its promise of product visibility throughout the global supply chain. China is also a powerful source of out-sourced manufacturing, and suppliers of RFID components, subsystems, firmware or integration services cannot afford to ignore this marketplace of suppliers.

Secondly, the Chinese government is closely watching the adoption of RFID by overseas companies, both to understand potential customer requirements and to learn best practices. The government is also acutely aware that Wal-Mart, with its RFID mandate, imports an estimated $12

billion to $20 billion (roughly 10 percent to 15 percent of overall US imports from china) per year directly from China.

Finally, experts suggest RFID might help China's retailers better compete against foreign rivals. They held several conferences on RFID within a couple of years. For example, the RFID China Summit 05, on March 10, 2005, was designed to present the latest news and key end-user case studies and pilots to help China-based decision-makers answer the questions about RFID they are struggling with. Shanghai and 44 other cities already use an RFID payment system for public transportation.

V.3 Opportunities of RFID Applications in China

RFID technology increases visibility and accountability in the supply chain. RFID will allow manufacturers, retailers, and suppliers to efficiently collect, manage, distribute, and store information on inventory, business processes, and security. Everyone recognizes China as a low-cost manufacturer and a huge potential market. In early 2004, China established a working group to draft and develop national standards for RFID tag technology. Some reports indicate the group is adhering to international standards, while others suggest the group is planning to go its own way.

The Chinese government starts to realise the importance of RFID. In addition to the focus in manufacturing, China is interested in anti-counterfeit solutions using RFID especially for the liquor and tobacco industries. Estimates show that more than six hundred million bottles of liquor and two billion cartons of cigarettes are consumed annually by the Chinese population. For the popular brands of liquor and tobacco, more than half are counterfeit items. To protect these industries, the need for anti-counterfeit solutions is compelling. RFID may be one of solutions to this issue.

VI. Threats of RFID Projects in Supply Chain

VI.1. Investment and Training Costs

Presently, RFID technology is expensive and the price of RFID tags has traditionally been a significant obstacle to its widespread deployment in Supply Chain Management. Cost is a factor that may hinder the widespread utilization of radio identification tags. Tags range in price from US$0.55 to $55 [28]. Currently the tag reader is possible to read 75 or more tags per second, it has been remarkably difficult to design systems that can read 100% of the cases on a pallet, let alone all of the individual cartons inside a case [21].

Another cost is the large investment for RFID implementation in the large scale IT infrastructure required to support the many suppliers. The cost of acquiring, installing, and maintaining an RFID system will be a major and determining factor in the deployment of RFID in the commercial sector. There appears to be great diversity and little quantitative information in the overall costs of acquiring, installing, supporting and maintaining an RFID system. RFID system cost is composed of tags, readers, and processing and supporting information technology hardware and software. Higher adoption rates will cause system costs to drop and encourage more RFID users. Middleware (the software that runs the operation) costs vary from US$25,000 to several thousand dollars [44]. Many expenses will be incurred – everything from the equipment to the management educating employees – without a real sense of what the benefits can be. Many expenses will be incurred – everything from the equipment to the management educating employees – without a real sense of what the benefits can be.

The cost of simple RFID tags is likely to fall to roughly US $0.05/unit in the next several years [42].

VI.2. Authentication and Security Issues

Authentication is a fundamental aspect of manufacturing and customer interface systems' security. Once a user account has been authenticated and can access an object, either the user rights that are assigned to the user or the permissions that are attached to the object determine the type of access granted. Therefore, authentication applications are usually applied in security critical situations, i.e. granting access rights to restricted locations or providing possibilities for accessing privileged information. Therefore security aspects are highly relevant when considering the best possible technology for authentication applications.

The impending ubiquity of RFID tags, however, also poses a potentially widespread threat to consumer privacy [29]. Most privacy and security concerns about RFID involve the use of RFID at the individual customer level, at or after the point of sale, rather than in supply and inventory tracking applications. Privacy advocates are worried that if RFID tags are placed in common items, the product may continue to be tracked even after being purchased by consumers [49].

According to Cohen (2003), recent improvements have allowed the creation of RF tags that have limited read/write capability. Once authentication protocols for read/write applications have been perfected, there will be a greater chance for creating more secure tags [14].

Jeff Woods, a Gartner research analyst who researched ongoing RFID projects for over six years foresees by 2007, at least 50% of RFID projects will fail - a lot of companies will burn through plenty of money testing the new technology [9],[34]. Reasons for failure may be due to

- many companies have unrealistic expectations on RFID
- sometimes bar codes work best
- ROI is elusive

However, Woods agrees with many industry analysts who said RFID can live up to its billing in about three to five years.

VII. Conclusions and Future Research

In this paper we have illustrated that RFID technology has relatively higher potential applications through the supply

chain procedure over the other identification technology on both the physical transport products from the manufacturers to retailers; and the B2B e-business. We also discover that RFID technology in supply chain management in the U.S, is at *Early Majority* category as suggested by Rogers' Innovation Diffusion model. Similar study in the Asia region is encouraged. The aim of this paper is to explore the opportunities and threats of the applications of RFID technology in supply chain management through the literature review of the research domains: REID technology and the supply chain management.

Asia is eventually going to take the lead in RFID innovation and adoption. In China, because the government now sees logistics infrastructure as a focal point of the country's strategic position in the global economy, it is likely that its government plays a significant role in the adoption of RFID, both in the promotion of standards and the launching of pilot programs.

As is common with emerging technologies, several challenges must be overcome for RFID to mature to its full potential: maturation of RFID technology, harmonization of standards for hardware/software, privacy and security concerns, and implementation cost barriers.

The overall success of RFID technology in the mass market mainly depends on chip prices. It is predicted that by 2006, tags will cost $0.05/piece [12]. RFID technology is not standardised. Current industry RFID standards are largely incomplete with respect to addressing a number of technology and application issues. "Barcodes have a good fifteen years left to run, but once RFID standards are fixed, it just needs some major retailers to drive supplier adoption, and the whole thing will quickly pick up critical mass [3].

The most straightforward approach for the protection of consumer privacy is to "kill" RFID tags before they are placed in the hands of consumers. A killed tag is truly dead, and can never be re-activated.

The Chinese government is beginning to take action to leverage RFID technology to benefit the country's overall logistics infrastructure and support key customers. Hence, there is a need and great interest for the research on applying RFID technology in supply chain management and e-business in China. We look forward to seeing whether RFID will enhance supply chain competence and e-business, whether this is an opportunity or a threat, in coming years. This paper should help establish the foundation of this research.

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