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RFID Technology for Supply Chain Optimization: Inventory Management Applications and Privacy Issues

CAPSTONE REPORT

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Abstract

for

RFID TECHNOLOGY FOR SUPPLY CHAIN OPTIMIZATION: INVENTORY MANAGEMENT APPLICATIONS AND PRIVACY ISSUES

This study explores the benefits and liabilities of using radio frequency identification (RFID) technology in supply chain management operations to support optimization as suggested by Byrnes (2004). Through content analysis, a review of RFID technology benefits is centered on goals relative to the optimization of logistics activities, specifically related to inventory management (Frazelle, 2002). The examination of liabilities focuses on the privacy framework described as the principles of Fair Information Practices (FIP) (FTC, 1998).

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CHAPTER I – PURPOSE OF THE STUDY

Brief Purpose

The term Supply Chain refers to "the network of organizations that are involved, through upstream and downstream linkages, in the different processes and activities that produce value in the form of products and services in the eyes of the ultimate consumer" (Christopher, 1998, p. 15). A simplified example of a supply chain in the retail industry is shown in Figure 1 (Harrison & van Hoek, 2002). The existence of supply chains infers that businesses rely on the contribution and interaction of others in the end-to-end processes supporting their manufacturing and distribution activities (Dudek, 2004). Supply Chain Management (SCM), then, is the effort to optimize these contributions and interactions (Vis & Roodbergen, 2002).

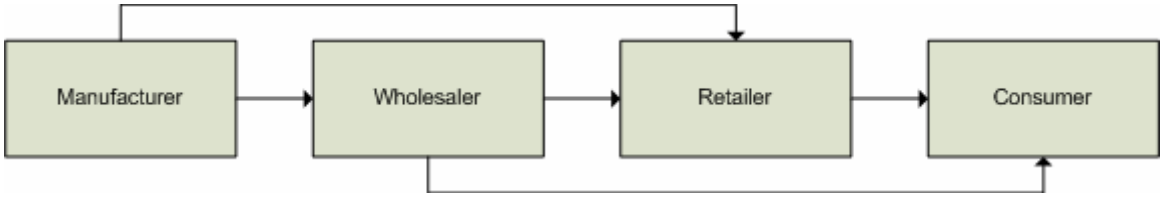

Figure 1 – Retail Supply Chain

Logistics, according to Vogt et al (2002), is a component of SCM. It refers to the management of goods, services, and information between points of origin and points of consumption in the supply chain (Vogt, J., Pienaar, W., de Wit, P., 2002). Among the activities encompassed by SCM logistics are the management and physical control of inventory (Frazelle, 2002).

Radio Frequency Identification (RFID) refers to data collection and identification systems that combine the use of radio and microchip technologies to locate objects (Finkenzeller, K., 2003). The assumption underlying this study is that RFID technology may enable some organizations to better meet their supply chain optimization goals (Byrnes, 2004).

The purpose of this study is to explore the benefits and liabilities of the use of RFID technology in SCM operations as a way to support the objectives of supply chain optimization suggested by Byrnes (2004). Discussion of RFID technology benefits is centered on goals relative to the optimization of logistics activities, specifically related to inventory management (Frazelle, 2002). The examination of liabilities associated with RFID technology deployment focuses on the privacy framework described as the principles of Fair Information Practices (FIP) (FTC, 1998).

The research method chosen for this study is literature review (Creswell, 1994; Leedy & Ormrod, 2001). Literature in the areas of supply chain management, logistics, RFID technology, and inventory management published since 2000 is selected for review. Additionally, literature addressing privacy principles published from 1974 to 2004 is selected. Content Analysis (Leedy & Ormrod, 2001; CSU Writing Center, 2004) is chosen as the strategy to analyze the selected literature and is performed in two phases. Phase one identifies supply chain strategies involving the use of RFID technology that support the optimization goals defined by Brynes (2004), relative to inventory management techniques as described by Frazelle (2002). Phase two identifies privacy-related issues within the context of the FIP (FTC, 1998) associated with the use of RFID technology.

The results of the review and analysis of the literature are used to develop lists that (1) identify strategies for SCM optimization consistent with Brynes' (2004) views, (2) identify RFID

technology applications aligned with Frazelle's (2002) strategies for inventory management, and (3) identify privacy issues linked to the use of RFID technology for inventory control in SCM.

These lists are then integrated to provide a summarization of supply chain strategies and RFID applications, along with RFID liabilities (in terms of privacy issues), presented in the form of two tables. The tables are designed for use by supply chain and logistics managers who hope to investigate the opportunities for RFID applications in supply chain optimization while understanding the privacy-related concerns. In addition, the tables should be of interest to others who wish to gain a broader understanding of privacy issues related to RFID technology implementation.

Full Purpose

The fundamental objective of Supply Chain Management is "to create or enhance value provided to the end-customer" (Stank, Keller, & Daugherty, 2001, p. 2). More specific goals may be to improve customer service, reduce costs, and improve cash utilization (Hakanson, 1999). Byrnes (2004) observes that many companies focus their SCM optimization efforts on improving existing processes. He suggests that those efforts would be better directed toward developing analytical applications that improve overall supply chain coordination.

According to Frazelle (2002), inventory management is one of the logistics activities that is targeted by SCM optimization efforts. He describes the objective of inventory management as the optimization of inventory levels, achieved by maintaining the least amount of inventory necessary to meet service level requirements. Frazelle (2002) emphasizes the importance of inventory management in SCM by pointing out that inventory availability is the most important factor driving customer service levels while at the same time representing the riskiest and most expensive component of supply chain logistics. He notes that the challenge "is to increase the

financial return on inventory while simultaneously increasing customer service levels" (p. 91). Frazelle (2002, p. 92) cites five approaches that may help businesses to achieve this elusive goal:

1. Improve forecast accuracy
2. Reduce cycle times
3. Lower purchase order/setup costs
4. Improve inventory visibility
5. Lower inventory carrying costs

The purpose of this study is to identify the benefits that RFID technology may bring to supply chain optimization efforts, specifically those benefits aligned with the goals described by Byrnes (2004) and related to Frazelle's (2002) five strategies for inventory management, along with the liabilities related to privacy issues that the use RFID technology may expose.

RFID is an example of an Automatic Identification and Data Collection (AIDC) technology (Frazelle, 2002). AIDC systems share common elements: (1) an object to be identified, such as a pallet or carton, (2) an identifier (ID), such as a label or tag, that is affixed to the aforementioned object, and (3) a device to read the ID and transmit information about it to some other system (Hill & Cameron, 2003). Bar code and magnetic stripe systems are common types of AIDC technologies used to track inventory (Frazelle, 2002).

The use of RFID technology has given rise to concerns about privacy (Bacheldor, 2004). Privacy issues have been addressed in the context of information systems and technology by governmental and non-governmental organizations. In 1973, in response to the growing use of government databases to maintain information on individuals, the U.S. Department of Housing, Education, and Welfare (HEW) issued the Principles of Fair Information Practices (FIP) (Laurant, 2004). Congress reacted by passing the Privacy Act of 1974, which adopted the FIP

principles (Privacy Act of 1974). Those principles are: notice, choice, access, security, and enforcement (FTC, 1998). The Organization for Economic Co-operation and Development (OECD) elaborates on the FIP principles in Guidelines Governing the Protection of Privacy and Transborder Data Flows of Personal Data (Laurant, 2004). Today, RFID technology, because of its ability to track objects, and thus potentially also track people, is raising new concerns (White, 2003). As of this writing, no new state or federal legislation specifically addressing the use of RFID technology has been passed, although California SB1834, which would impose conditions on the use of RFID tags on consumer goods, is currently pending (OPP, 2004).

This study focuses on the use of RFID technology to optimize inventory management (Frazelle, 2002) in support of the supply chain optimization goals described by Byrnes (2004). Byrnes writes that companies use RFID technology to (1) optimize production-oriented supply chain activities and (2) develop analytical or business intelligence applications that improve overall supply chain coordination. He proposes that optimization efforts focused on production-oriented activities, such as reducing labor in shipping and receiving operations, is the least effective of the two approaches. Rather, Brynes (2004) suggests that the key to successful RFID implementations is to focus first on analytical applications. These applications would selectively target specific areas to improve supply chain coordination, visibility, and responsiveness. Unlike a production-oriented approach that tries to make existing supply chain processes more efficient, Brynes (2004) says that the goal of the analytical approach is to uncover ways to use RFID technology to create new and more effective supply chain processes. He suggests, for example, that RFID might be used to better align inventory levels with demand for short-lifecycle products, thereby minimizing markdowns and out-of-stock conditions.

According to Frazelle (2002), logistics optimization challenges are characterized by a common problem: there is an objective function that needs to be minimized or maximized, and there are constraints that make it difficult to achieve that objective. Frazelle (2002, p. 15) describes this problem mathematically in the following example:

Minimize:

Total logistics costs = Inventory carrying costs + Response time costs + Lost sales costs

Constraints:

1. Inventory availability > Customer service inventory target (expressed as fill rate)

2. Response time < Customer service response time target

The challenges here are many, and inventory is a central element. For example, a lower fill rate equals lower inventory carrying costs, but means increased lost sales costs, while lowering response time reduces lost sales costs but creates greater response time costs. While Byrnes (2004) cites the creation of analytical resources as the most compelling reason to deploy RFID technology, Frazelle (2002) asserts that it is just these analytical resources, required to solve this kind of complex logistical problem, that are lacking in most organizations.

The research method chosen for this study is literature review (Creswell, 1994; Leedy & Ormrod, 2001). Literature from scholarly and trade journals in the areas of SCM, retail supply chains, logistics, and inventory management published since 2000 is selected to for review. Additionally, literature from journals, privacy and consumer advocate organization reports, government sources and popular media addressing privacy issues and principles published from 1974 to 2004 is selected. Content for analysis is selected from the results of the review based on the existence of general concepts related to the use of RFID technology to achieve the goals described by Byrnes (2004) and the inventory management strategies proposed by Frazelle

(2002). Additional content is selected for analysis based on the existence of general concepts related to privacy concerns surrounding the use of RFID technology, specifically those framed by the FIP (FTC, 1998).

Conceptual content analysis (CSU Writing Center, 2004) is chosen as a way to analyze the selected literature. This strategy involves an eight step process wherein the parameters of the analysis are defined, the data are systematically analyzed for the presence of concepts, and outcomes are derived from inferences made about the analysis results. The analysis is conducted in two phases. The first phase identifies SCM optimization practices and uses of RFID technology aligned with Brynes' (2004) views and supporting Frazelle's (2002) strategies for inventory management. The second phase identifies privacy concerns in the context of the FIP (FTC, 1998) related to the use of RFID technology.

Results of the data analysis are presented in the form of three lists. List 1 identifies logistics optimization strategies in supply chains that are focused on the analytical and business intelligence goals as presented by Byrnes (2004). List 2 identifies applications of RFID technology intended to achieve the inventory management objectives described by Frazelle (2002). List 3 identifies privacy concerns associated with the use of RFID technology for inventory management in retail supply chains.

Demands on supply chain design and performance are increasing and the ability of current systems to provide the visibility required to optimize supply chains is strained (Sarma, 2004). Many companies are making the achievement of real-time visibility into their supply chains a strategic goal. According to Violino (2002), RFID technology may prove to be an effective tool to help them achieve this goal. Final outcomes of this study are presented in the form of two tables. Based on an integration of the three lists that resulted from the data analysis,

Table 1 identifies supply chain optimization strategies and RFID-based applications for inventory-related logistics operations that support those strategies. Table 1 can be a resource for supply chain and logistics managers tasked with understanding how RFID technology can help their companies achieve their supply chain optimization goals. RFID technology projects have not been without controversy (Ulfelder, 2003). As retail-oriented RFID projects have become more common, numerous issues privacy-related concerns have been raised (Murray, 2003; Ulfelder, 2003). Logistics managers and others studying RFID technology will find Table 2, identifying privacy concerns linked to the use of RFID in supply chain management and their relationship to the principles of FIP (FTC, 1998), valuable in helping them understand where the issues lie. These two outcomes may also be a useful resource for non-technologists such as privacy and consumer advocates, and consumers themselves, who would like to gain an understanding of how RFID technology is being used in supply chain optimization projects.

Limitations to the Research

AIDC systems have been in use since 1933 when patents were issued in Switzerland for a system that used optical sensors for package sorting (Hill, 2003). RFID technology has roots in the earliest research on electromagnetic energy by Faraday, Maxwell, and Hertz (Landt, 2001). Experimental RFID systems appeared in the 1930s and 1940s, and by the 1950s early relatives of today's RFID systems were used in long-range identification systems for aircraft (Landt, 2001). RFID systems have been used in support of logistics activities since 1984 (Hill, 2004). This date sets the early limit on the collection of literature related to RFID in the context of SCM. RFID technology and SCM practices continue to evolve; therefore, literature on RFID published up to the date this study (November, 2004) was conducted is included.

Businesses have been looking for ways to use technology to improve their processes for decades. Bar codes, for example, have been in widespread use since the 1970s (Hill, 2003; Fuller, 2004). Internally focused efforts to improve operational efficiencies that do not extend beyond the factory or warehouse walls are not likely to provoke concern among privacy advocates. As a technology to optimize these internal efforts, RFID, is relatively benign. However, as a technology to radically remake supply chain and logistics processes by creating visibility outside the warehouse walls, which is what Byrnes (2004) argues can be its most effective use, RFID enters a new dimension, exposing practitioners to privacy related liabilities. Byrnes' (2004) framing of these analytical, as opposed to operational, goals for RFID implementations guides this study's selection of literature addressing RFID benefits. While Byrnes (2004) speaks conceptually about the potential for supply chain improvement by focusing RFID technology on analytical, or business intelligence, projects, the collection of literature for this review is guided by Frazelle's (2002) more narrow focus on supply chain optimizations that come from improving inventory-related logistics processes.

While there are undoubtedly a multitude of factors to consider when evaluating the risks or liabilities related to RFID or any other technology implementation, this study focuses only on privacy-related liabilities associated with RFID use in the supply chain. This study was designed with this limitation because of the unique tracking characteristics of RFID technology and the resultant implications for personal privacy.

Privacy issues related to information systems date at least as far back as the 1960s when the U.S. federal government expanded its use of information technology to maintain databases of individuals' personal information. (EPIC, 2003). The Privacy Act (1974) was the first federal legislation to address these concerns (Berman & Bruening). The date of this legislation sets the

early limit on the collection of literature related to privacy issues in the context of information technology. As technology evolves, so do issues surrounding its use and its impacts on privacy. As with literature discussing RFID technology in the supply chain, literature published in the area of RFID privacy concerns is included up to the date of this study. This literature is further limited by its applicability to the principles of fair information practices outlined by Laurant (2004) and the U.S. Federal Trade Commission (FTC, 1998).

The subject of supply chain management is extremely broad, covering diverse disciplines such as inventory forecasting, replenishment planning, sourcing, purchasing and payment, transportation, and warehouse management (Frazelle, 2002). RFID technology may have applications in all of these disciplines. Privacy issues, however, are commonly understood to relate to individuals. Therefore, this study focuses on RFID-related privacy issues in retail logistics, and specifically inventory management, where the end-point in the supply chain is the individual consumer.

This study uses a qualitative design and content analysis strategy (Leedy & Ormrod, 2001; CSU Writing Center, 2004) with the aim of identifying patterns and themes (Leedy & Ormrod, 2001, p. 155) in the use of RFID technology in supply chain optimization efforts, along with associated privacy issues. Results of the data analysis are presented to supply chain managers and privacy advocates first in the form of a set of three lists and then in the form of two integrated tables. Through this presentation, this researcher anticipates that emphasis can be placed on the benefits and liabilities of applying RFID technology to improve supply chain performance (Byrnes, 2004) through the optimization of logistics activities, specifically those related to inventory management (Frazelle, 2002).

Definition of Terms

AIDC – Automatic Identification and Data Collection. This term refers to systems that automate the identification and collection of information about goods in process (White, 2003). Examples of AIDC systems include magnetic stripe card technologies, bar code technologies, and radio frequency identification technologies (Frazelle, 2002). The Association for Automatic Identification and Mobility (Technologies) states that the two primary goals of AIDC systems are to minimize errors in the data identification and collection process and to speed process through-put.

Bar code – a machine-readable tag or symbol containing binary codes represented, traditionally, by a field of bars and gaps (Finkenzeller, 2003). Two-dimensional bar codes use symbologies that encode data both horizontally and vertically, allowing significantly more information to be represented (Ross, 1995).

Benefit – in the context of this study, a positive outcome in terms of supply chain goals described by Byrnes (2004) and inventory management approaches defined by Frazelle (2002) resulting from the deployment of RFID technology.

Distribution – the processes involved with the outbound component of a supply chain. These processes include: those related to negotiating, buying and selling product; tasks associated with physically storing, handling, and transporting product; and activities required to support the preceding processes, such as information processing, financing, and promotional activities (Vogt, 2002).

Inventory – raw materials, work in process, finished goods, and supplies used in the production of finished goods (Vitasek, 2003).

Inventory management – activities, such as forecasting, order quantity engineering, service level analysis, replenishment planning, and inventory deployment, whose objective is the optimization of inventory levels, achieved by maintaining the least amount of inventory necessary to meet service level requirements (Frazelle, 2002).

Inventory control – activities, such as receiving, put away, storage, order picking, and shipping, performed with the objective of optimize inventory handling and warehousing costs by minimizing labor, equipment, and facilities costs while meeting delivery and accuracy requirements (Frazelle, 2002).

Issue – in the context of this study, a potential infringement on the privacy principles outlined in the Fair Information Principles (FTC, 1998) resulting from the use of RFID technology.

Logistics – the process of planning, implementing, and controlling the efficient and effective flow and storage of goods, services, and related information from point-of-origin to point-of-consumption for the purpose of confirming to customer requirements (CLM, 2001).

Magnetic stripe – a magnetically encoded label, typically affixed to a card or badge, containing data, read by sliding or swiping the card through a reader (Hill, 2003).

Privacy - although the word "privacy" is frequently used in ordinary, philosophical, legal, and political discussions, there is not a single, concise meaning or definition of the term (Privacy, 2002). Three types of privacy are commonly described: physical, informational, and decisional. "Physical privacy is a restriction on the ability of others to experience a person through one or more of the five senses; informational privacy is a restriction on facts about the person that are unknown or unknowable; and decisional privacy is the exclusion of others from decisions, such as health care decisions or marital decisions, made by the person and his group of intimates." (Online Ethics Center Glossary).

Retailer – a business that takes ownership of products and sells them to final customers (Votasek, 2003).

RFID – Radio Frequency Identification systems are data collection and identification systems that combine the use of radio and microchip technologies to locate and track objects (Finkenzeller, K., 2003).

Supply chain - "the network of organizations that are involved, through upstream and downstream linkages, in the different processes and activities that produce value in the form of products and services in the eyes of the ultimate consumer" (Christopher, 1998, p. 15).

Supply chain management - the planning and management of all activities involved in sourcing and procurement, conversion, and logistics (CLM, 2001).

Problem Area and Significance

Businesses today are allocating significant resources to supply chain management optimization initiatives ("Boost Expected in Supply Chain Spending", 2004). While there are many drivers, those most central to the purpose of this study include: (1) today's global supply chains are increasingly complex dynamic systems that require new techniques for effective management (Sarma, 2004); (2) competition in the market place is intense and businesses see supply chain optimization as an opportunity to create differentiation (Fox, 1999); and (3) customers are growing ever more sophisticated with increasing expectations of product availability and selection (Sarma, 2004).

In 2003, Forrester Research estimated that over the next five years, $35 billion would be spent in the U.S. on supply chain management (Surmacz, 2003). Over one half of the twenty-six $1 billion-plus manufacturers indicated that their supply chain budgets would increase (Surmacz, 2003). The goals for SCM improvement cited by the respondents in the Forrester research study included improvements in operational efficiency, improved customer service, and reduced time to market (Surmacz, 2003).

A 2004 survey by Yankee Group suggests that RFID initiatives will represent a sizeable portion of SCM spending. They project RFID spending of $4 billion over four years, with expected savings of $200 to $400 billion (Surmacz, 2004). A March, 2004 survey of 200 companies by Aberdeen found that 6% had RFID projects in place or underway, but another 5% planned to launch RFID project within three months, 11% within six months, 34% within one year, and 39% within two years (Violino, 2004). Mirroring some of the same issues cited by respondents in the Forrester research study, the Aberdeen respondents identified improvements in inventory information, tracking and management of assets, responsiveness, and customer

service as the key benefits they expected to achieve with their RFID projects (Violino, 2004). Clearly, businesses today are allocating significant resources to supply chain management improvement and many believe that RFID initiatives will further their optimization goals.

According to Brynes (2004), however, seeking production gains by applying RFID technology to improve existing supply chain processes may be shortsighted. In contrast to RFID projects focused on analytical or business intelligence goals, those focused on production-oriented goals have the following drawbacks:

- Entry costs are high because of the need for comprehensive deployment of tagging and readers, and for modifying existing software applications.
- Opportunity costs are high if low-cost, high-return analytical applications of RFID technology are deferred.
- Production-oriented RFID applications mostly involve mid-level operations and IT managers whose focus is likely to be on reducing the cost of existing processes, not on potentially greater value producing activities like developing new business processes and organizational relationships.
- Once RFID technology has been widely deployed in production-oriented applications, production processes may become harder to change.

Byrnes (2004) suggests that RFID projects designed to build analytical capabilities rather than operational efficiencies are the better first step because:

- Entry costs can be lower than production-focused projects because a very specific component or sub-component of the supply chain can be targeted and RFID technology only selectively deployed.

- Costs and benefits of the project can be better aligned by focusing RFID technology on high-return areas within the supply chain.
- The process of developing analytical RFID applications involves marketing, merchandising and other business managers, bringing perspective and insight beyond the production-oriented viewpoints of operational and IT managers.
- Information derived from analytical RFID applications can be streamlined into the organization without having to modify large scale production software systems.

In the context of supply chain management, logistics refers to the management of goods, services, and information between points of origin and points of consumption in the supply chain (Vogt, J., Pienaar, W., de Wit, P., 2002). Logistics activities encompass the management of material flow through the supply chain, as well as the management of information flow to and from consumers and producers in the supply chain (Harrison & van Hoek, 2002). Retail businesses "are defined as those establishments that sell merchandise, generally without transformation, and attract customers using methods such as advertising, point-of-sale location, and display of merchandise." (NAICS). Distribution in retail businesses refers to logistics activities that focus on the flow of material and information between the retailer's distribution center(s) and its store locations (see Figure 2) (Harrison & van Hoek, 2002). The main objectives of retail distribution focus on the effective management of inventory and are: (1) to fill orders at the store as accurately and completely as possible, and (2) to do so at the lowest possible cost (Chappell, et. al., 2002a, p. 5).

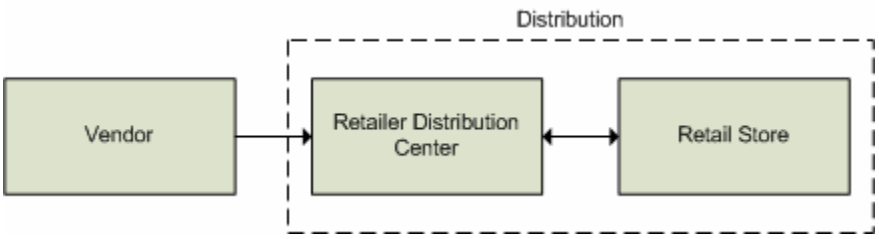

Figure 2 – Retail Distribution Supply Chain

An out of stock condition (stock-out) exists when there is demand that cannot be met by on-hand inventory (Frazelle, 2002). If retail distribution efforts could be optimized, stock-outs could be greatly reduced (Alexander, et al, 2002). However, in spite of significant investments in technology and process improvements, stock-out conditions continue to cost retailers profits (Alexander, et al, 2002). Distribution optimization efforts often rely on improving forecasting; unfortunately, forecasting is inherently uncertain (Harrison, 2002). According to Alexander (2002), the key to improved forecasting is better visibility, and RFID technology is ideally suited to enhance distribution chain visibility.

This study examines privacy issues related to the use of RFID technology. There is no single, concise definition of the term privacy. According to White (2003, p.7) privacy has been defined in several ways. Definitions have included:

- A right involving personal control over disclosure of information:
    - A person's right to information about herself, ranging from their address to health and financial records;
    - Confidentiality, a right to protect "secrets";
    - Anonymity, a right to conduct transactions without identifying oneself.
- Certain rights pertaining to personal safety and security:

  - A right to bar intrusion into personal space, both in private and, as the *Nader* case demonstrates, in public as well;
  - A right to guard against the misuse or appropriation of personal information, as for example in the case of identity theft.
- Perhaps the broadest definition equates personal information with property, granting personal information the same property rights accorded physical property.

The "Right to Privacy" does not appear explicitly in the U.S. Constitution or the Bill or Rights. It is commonly accepted that the modern legal concept of Privacy was established by Warren and Brandeis in their essay "The Right to Privacy", published in 1890 (Privacy, 2002). Warren and Brandeis expressed the principle of privacy as "the right to be let alone" (Warren & Brandeis, 1890, p. 193). In the years following, "the public and both state and federal courts were endorsing and expanding the right to privacy." (Privacy, 2002, p.4), and the Court inferred privacy rights in the First, Third, Fourth, Fifth, and Ninth Amendments (OTA, 1997). In the 1965 *Griswold v. Connecticut* case, the Supreme Court finally articulated a "Constitutional Right to Privacy" (Privacy, 2002, p.5). In Justice William O. Douglas' opinion, he described "a right protecting one's individual interest in independence in making certain important and personal decisions about one's family, life, and lifestyle." that emanated from the Constitution (Privacy, 2002, p.5). Later cases, including 1973's *Roe v. Wade* built upon this "right to privacy" (Privacy, 2002, p. 5).

In the time since Warren and Brandeis' paper, new technologies have continually challenged the prevailing notions of privacy (Privacy, 2002p. 13). Their own "The Right to Privacy" was motivated by the expanding communication technology of the day: widely

distributed newspapers and mass reproduced photographs (Privacy, 2002 p. 13). There have been numerous clashed between new technologies and privacy since then. Telephones, for example, bring with them concerns about wiretaps, telemarketers, and caller ID (Privacy, 2002, p. 13). Now, RFID technology and the unique capability it brings to systems to identify, locate, and track objects (and people?) in real time in the real world, has raised privacy concerns to a new level (White, 2003).

The intersection of the potential benefit of RFID technology for supply chain improvement and its equal potential for causing harm to privacy "rights" creates a rich environment for research and study. As revealed in this section of this paper, there has been a great deal of discussion surrounding privacy issues in our increasingly electronic and connected world. And there is much discussion and research examining the use of RFID technology for a multiple of applications. This researcher hopes to outline a very small intersection of these two forces, perhaps presenting a framework for additional and more exhaustive study.

CHAPTER II – REVIEW OF REFERENCES

Alexander, K., Birkhofer, G., Gramling, K., Kleinberger, H., Leng, S., Moogimane, D., Woods, M. (2002, June 1). ***Focus on Retail: Applying Auto-ID to Improve Product Availability at the Retail Shelf.*** **Cambridge: Auto-ID Center Massachusetts Institute of Technology.** Retrieved October 11, 2004 from http://www.autoidlabs.com/whitepapers/IBM-AUTOID-BC-001.pdf

The Auto-ID Center, now known as Auto-ID Labs (Auto-ID), was founded in 1999 with the goal of developing technologies and standards to enable a transparent global network of objects. Auto-ID Labs is a group of research universities, among them MIT, supported by funds from industry, governments, and EAN.UCC (a standards organization sponsored by European Article Numbering, International and the Uniform Code Council). Auto-ID has published several white papers that describe the capabilities of RFID technology and its potential for revolutionizing supply chain, logistics, and inventory management practices. Their *Focus on Retail: Applying Auto-ID to Improve Product Availability at the Retail Shelf,* highlights applications and a business case for the use of RFID technology in retail supply chains. The paper describes several "pain-points" in conventional retail inventory management and suggests solutions incorporating the use of RFID systems. These proposed solutions promise to do more than simply automate existing processes. Rather, Auto-ID presents strategies and techniques that create new paradigms in inventory management. These strategies and techniques are analyzed and represented in the outcomes of this study.

Byrnes, J. (2004, May 3). Are You Aiming Too Low With RFID? ***Harvard Business School Working Knowledge.*** Retrieved September 14, 2004 from http://www.hbsworkingknowledge.hbs.edu/item.jhtml?id=4107&t=operations

Jonathan Byrnes earned a doctorate from Harvard Business School in 1980. He is a Senior Lecturer at MIT, teaching graduate courses at the MIT Center for Transportation & Logistics. He serves on the Executive Committee of the Harvard Alumni Association Board of Directors and is the chairman and founder of Swift Rivers, a technology company providing business intelligence solutions. Dr. Byrnes writes *The Bottom Line*, a monthly column focusing on innovative approaches for profit growth, for Harvard Business School Working Knowledge (HBSWK) (http://hbswk.hbs.edu).

Dr. Byrnes's HBSWK article, *Are You Aiming Too Low With RFID?*, challenges conventional wisdom regarding the use of RFID technology in supply chain improvement initiatives. He makes a compelling case for first focusing RFID projects on increasing analytical capabilities rather than seeking to improve operational efficiencies. Byrnes likens the latter approach to "paving the cowpaths", that is, trying to do the same thing only better. He argues instead that RFID technology should be used to help businesses do *different* things. This distinction is used as a guideline (described in Limitations) to focus this study on supply chain optimization efforts that go beyond production-oriented objectives.

Creswell, J. (1994). *Research Design: Qualitative & Quantitative Approaches.* Thousand Oaks: SAGE Publications.

John W. Creswell, a professor of Educational Psychology at the University of Nebraska's College of Education & Human Sciences, has authored numerous texts and articles on research methods and design. He was the recipient of the Teachers College 1998 Distinguished Teaching Award and was Visiting Scholar on Qualitative Research, School of Education, Centers for Postsecondary and Higher Education, at the University of Michigan in 1997. His *Research*

Design: Qualitative & Quantitative Approaches provides a thorough description of qualitative research designs including the literature review methodology employed in this study.

CSU Writing Center (2004). http://writing.colostate.edu/references/research/content/

Writing@CSU is an online writer's resource hosted by the Colorado State University Writing Project (http://www.csuwritingproject.org), a National Writing Project (http://www.nwp.org) site. Writing@CSU offers writing guides, tutorials, demonstrations, and other writing resources for students and teachers. A number of Writing Guides cover various research writing topics including statistics, surveys, experimental methods, case studies, and content analysis. The content analysis guide, edited by Mike Palmquist of CSU's English Department, offers succinct explanations of conceptual and relational content analysis strategies. The conceptual content analysis used in this study follows the detailed, eight step plan found in this writing guide.

Frazelle, E. (2002). *Supply Chain Strategy: The Logistics of Supply Chain Management.* New York: McGraw-Hill.

Edward Frazelle, Ph.D. is the founder of The Logistics Institute at Georgia Institute of Technology and the former president of the International Material Management Society. He is president and CEO of Logistics Resources International (LRI), a logistics-focused consultancy. Dr. Frazelle is the author of seven books and numerous articles on the field of logistics. His achievements include the Council of Logistics Management's Doctoral Research Grant, the Warehousing Education and Research Council's Burr Hupp Fellowship, the Material Handling Institute's MHEF Fellowship, the Institute of Industrial Engineer's Armstrong Award, and Kodak's Educational Grant Award.

Dr. Frazelle's *Supply Chain Strategy* outlines the fundamental principles and best practices of logistics and supply chain management. Following the logistics master planning methodology developed at LRI, *Supply Chain Strategy* outlines three phases of the logistics optimization process: investigating logistics performance and practices; innovating logistics practices and systems; and implementing logistics systems. This systems oriented approach to logistics problem solving serves as a foundation for the logistics optimization strategies, specifically those related to inventory management, underlying the problem area addressed by this study. Frazelle covers inventory management in detail and establishes the critical role that good inventory management practice plays in building supply chain excellence. This premise along with Frazelle's summarization of key inventory management strategies are used to narrow the focus of this study within the broader field of supply chain management and serve as limitations to the examination of the use of RFID technology in logistics practice.

Laurant, C., Farrall, K. (2004, July 9). ***Comments of the Electronic Privacy Information Center to the Federal Trade Commission. RFID Workshop Comment P049106.*** Retrieved September 26, 2004 from http://www.epic.org/privacy/rfid/ftc-comts-070904.pdf

The Electronic Privacy Center (EPIC) is a public interest research organization dedicated to raising awareness of privacy and civil liberty issues associated with emerging electronic technologies. EPIC's web site (www.epic.org) is a rich source of current news, resources, and policy content related to electronic privacy.

On June 21, 2004, the U.S. Federal Trade Commission (FTC) held a workshop on RFID applications and implications for consumers. Cedric Laurant and Kenneth Farrall submitted EPIC's comments to the workshop on July 9, 2004. Their comments include an overview of RFID technology and its privacy implications, as well as a position statement on the use of RFID

technology in consumer products and recommendations to the FTC. Laurant and Farrall discuss RFID technology in the context of the Principles of Fair Information Practice (FIP) which are codified in the Privacy Act of 1974. This contextual framing guides the limitations for evaluating privacy concerns associated with RFID chosen in this study.

Leedy, P., Ormrod, J. (2001). *Practical Research: Planning and Design* (7th ed.). Upper Saddle River: Prentice-Hall.

Paul Leedy and Jeanne Ellis' *Practical Research: Planning and Design* is a widely used textbook on basic research methodology. First published in 1974 and now in its 8th edition, this text walks the reader through all phases of the research design process, with useful exercises and descriptions of practical applications. The authors discuss in detail the attributes, benefits, and applicability of both qualitative and quantitative research design methods. Specific qualitative research strategies, including the general content analysis approach used in this study, are well treated.

U.S. Federal Trade Commission (FTC) (1998, June). *Privacy Online: A Report to Congress.* Retrieved September 28, 2004 from http://www.ftc.gov/reports/privacy3/toc.htm

In 1998, as use of the Internet and the World Wide Web was growing exponentially, the Federal Trade Commission (FTC) provided to the U.S. Congress an assessment of the effectiveness of self-regulation as a mechanism to protect consumer privacy in these new mediums. As part of that report, the authors traced a history of governmental privacy policy and chronicled the evolution of the Principles of Fair Information Practices (FIP). The report discusses these principles in the context of the Internet, a context that did not exist when the

principles were first articulated in 1973. This discussion, focusing on *electronic* privacy, serves as a useful framework for establishing the limitations of this study's examination of privacy concerns associated with RFID technology.

U.S. Federal Trade Commission (FTC) (2004, June 21). *Radio Frequency Identification: Applications and Implications for Consumers: An FTC Workshop.* Retrieved September 28, 2004 from http://www.ftc.gov/bcp/workshops/rfid/transcript.pdf

The Federal Trade Commission (FTC) is concerned with, among other things, consumer privacy. The FTC has taken notice of RFID technology and its potential for compromising consumer privacy and data security. On June 21, 2004 the FTC held a public workshop on RFID applications and its implications for consumers. There were several presenters at the workshop and a number of panel discussions involving authorities in the areas of RFID technology and consumer privacy. The transcript of this workshop provides background on a wide range of RFID applications, consumer concerns, and policy issues. Among the themes that emerged at the workshop were that much education about the capabilities and limitations of RFID technology is needed, and that the threat of overly harsh regulation in response to unfounded fears should be guarded against. Cedric Laurant, policy counsel with the Electronic Privacy Information Center (EPIC), who would later co-author EPIC's official comments, recommendations, and RFID policy statement to the FTC, participated in one of the panels and discussed RFID technology as it relates to privacy principles. Laurant's comments are helpful in developing the limitations that guide this study's focus on liabilities associated with RFID technology in supply chain management.

CHAPTER III – METHOD

A qualitative approach to research design is often chosen when the research task is to describe and understand a phenomenon in a real-world setting (Leedy & Ormrod, 2001, p. 101, p. 147). This study uses a qualitative approach to explore issues related to the use of RFID technology in supply chain operations, through collection and analysis of selected literature. Peshkin (as cited in Leedy & Ormrod, 2001, p. 148) writes that qualitative designs can be used to describe, interpret, verify, and evaluate the nature of a research problem. A qualitative approach is appropriate, then, to describe the benefits of using RFID technology in logistics optimization activities, and the privacy-related issues that might arise. A literature review, described by Leedy & Ormrod (2001, p. 70) as useful in describing "theoretical perspectives and previous research findings related to the problem at hand", is used in this study to collect a body of material related to RFID technology and privacy concerns for content analysis.

Leedy & Ormrod (2001, p. 155) write that "content analysis is a detailed and systematic examination of the contents of a particular body of material for the purpose of identifying patterns, themes, or biases". Conceptual content analysis is a content analysis strategy that seeks to establish "the existence and frequency of concepts" (CSU Writing Center, 2004). The objective of this study is to examine patterns of use of RFID technology in SCM and themes related to resulting privacy concerns. The concepts related to these patterns and themes are described in the literature selected through the literature review. Conceptual content analysis, as defined on the CSU Writing Center website, edited by Michael Palmquist, is used in this study as the data analysis strategy to identify and describe these patterns and themes.

Literature Collection and Selection

The search strategy for this literature review was executed using online library catalogs from University of Oregon and Portland State University. These resources provided access to their respective catalogs as well as several full text online research indexes: Business Sources Premier, Academic Search Premier, Computer Source, and Inspec. Additionally, Internet search engines by Google and A9 were used. A number of texts were accessed at the Portland State University library. The remaining sources were accessed as full text via the aforementioned online research indexes and search engines.

The following keywords were used, alone and in various combinations, to identify an initial set of literature: RFID, supply chain, logistics, distribution, inventory, management, AIDC, bar code, privacy. Internet searches on these terms often yielded articles and papers at sites which were themselves searched using internal search mechanisms, yielding additional sources. The results of these searches yielded additional terms and phrases such as “privacy act” and “fair information practices” that were used in subsequent searches. Bibliographic references from the search results were also examined and used to identify additional documents.

The search strategy identified documents from several sources. Foundational business management texts on supply chain and logistics management, including Frazelle (2002), Harrison (2002), and Vogt (2002) were located using the University of Oregon and Portland State University online library catalogs. The research index and Internet searches yielded a wide range of articles, reports, and white papers from a number of supply chain and logistics management trade journals, including *Logistics Management*, *Supply Chain Management Review*, *Materials Handling Management*, *Journal of Business Logistics*, and *Inside Supply*

Management. Numerous articles from popular IT and RFID magazines, including *eWeek*, *Network World*, *Information Week*, *CIO*, and *RFID Journal*, were identified.

A number of management, supply chain, technology, government, and privacy-related web sites also yielded articles and papers, including Center for Democracy & Technology (www.cdt.org), Harvard Business School Working Knowledge (www.hbsworkingknowledge.hbs.edu), the Massachusetts Institute of Technology Auto-ID Center (www.autoidlabs.org), Electronic Privacy Information Center (www.epic.org), Federal Trade Commission (www.ftc.gov), and Achieving Supply Chain Excellence through Technology (ASCET) (www.ascet.com).

Literature was selected for inclusion based on the limitations described earlier in this paper and the presence of concepts related to the focus areas of the study: (1) the use RFID technology in inventory management practices in supply chains, consistent with the inventory management optimization strategies described by Frazelle (2002) and aligned with Byrnes' (2004) goals for analytical improvement, and (2) privacy-related issues framed by the principles of FIP (FTC, 1998) and associated with the use of RFID in the aforementioned context.

Data Analysis

The collected literature was subjected to conceptual content analysis (CSU Writing Center, 2004) as described above. This data analysis strategy is useful when the research goal is to establish the presence of concepts within a body of literature and to make inferences about the presence of those concepts (CSU Writing Center, 2004). It is used here to analyze the literature with the goal being to understand how RFID technology is being applied to manage inventory, how those applications support supply chain optimization strategies, and how the technology is creating privacy-related concerns.

The CSU Writing Center (2004) outlines eight steps in the conceptual content analysis process. In step one, the level of analysis is determined. The terminology associated with the topics of study in this paper is diverse. The texts selected for analysis in this study were therefore scanned for sections of text related to the underlying themes, rather than occurrences of specific words. Key themes (framed as questions) included: (1) what strategies for supply chain optimization are being employed, (2) how is RFID technology being used to optimize inventory management in supply chains, (3) what are the benefits, or expected benefits, of using RFID technology for this purpose, and, (4) what privacy-related concerns are emerging as a result of this use.

In step two, the number of concepts to code for is established. The identification of concepts was allowed to evolve from an initial scan framed by the key themes listed in step 1 (framed as questions) underlying this study. As the CSU Writing Center (2004) suggests, this approach allowed specific concepts to be identified and incorporated into the analysis.

Step three establishes whether concepts are coded for existence or frequency. This study is based on a selection of texts that discuss the themes and patterns that are the focus of the key questions described above. This literature is not a closed set of all such discussions and cannot be used to make inferences based on the frequency at which coded concepts appear. Coding is therefore done for existence rather than frequency.

Step four sets the level of generalization. Because of the thematic nature of this analysis, the concepts are coded generally, based on the meaning and context of the text, as opposed to selection based on specific words or phrases.

In step five, coding rules are determined. Again, concepts for coding were allowed to emerge from the texts by scanning for general themes, as identified in step two. Selections from

the texts are organized according to these themes and not by specific word or phrase-based rule sets.

The sixth step sets the process for handling irrelevant information. In this analysis, concepts not relevant to the study's purpose (to explore the benefits and liabilities of the use of RFID technology in SCM) are discarded.

Step seven is the coding of the texts. In this study, selections of text from the literature were coded by reading through material and noting occurrences of the relevant concepts. The noted text was then electronically cataloged for later analysis.

Finally, step eight is the analysis of the data. Within the limits of interpretation and generalization imposed by the conceptual content analysis method (CSU Writing Center, 2004), this study presents the existence of the coded concepts in the selected text in the form of three lists: (1) supply chain optimization strategies, (2) inventory management applications using RFID technology, and (3) privacy concerns related to RFID systems presented as liabilities. The lists are then integrated to develop two tables. The first identifies the practices and benefits of using RFID technology for inventory management in supply chains. The second identifies privacy issues linked to the use of RFID in retail supply chains.

Data Presentation

The results of the two phases of conceptual analysis and the two final outcomes of this study are presented in Chapter IV – Analysis of Data. Phase one of the data analysis consists of two stages. The conceptual analysis of the selected literature identified logistics strategies related to Byrnes' (2004) goals for supply chain optimization. These strategies are presented in List 1. Applications of RFID technology in supply chains, specifically those associated with the

inventory management strategies outlined by Frazelle (2002), were also identified through this analysis, and are presented in List 2. These logistics strategies and RFID technology applications are integrated and presented in Table 1. This table describes the analytically-focused supply chain optimization strategies identified in List 1 and associates them with RFID technology applications, presented in List 2, that have been used to execute each of those strategies. Supply chain, logistics, inventory, and IT managers focused on optimization of supply chain activities should find these results useful as they seek to understand how and why RFID technology is being implemented.

Literature selected in the second phase of data analysis identified a set of issues related to privacy (White, 2003) and RFID technology. These are presented in List 3 and then aligned with the principles of FIP (FTC, 1998) in Table 2. This table summarizes each of the privacy issues identified by the data analysis and associates that issue with one or more of the FIP (FTC, 1998). Supply chain managers should find these results helpful in understanding how RFID technology is viewed as a privacy threat. This information may enable implementers of RFID technology to meet their supply chain optimization goals while avoiding problems posed by privacy challenges.

Privacy and consumer advocates with concerns about RFID technology should find the information presented in Tables 1 and 2 useful in clarifying how RFID is being used in supply chain optimization initiatives and what the objectives of those initiatives are.

CHAPTER IV – ANALYSIS OF DATA

Documents were selected and analyzed in two phases as described in the Limitations and Methods sections of this study. In the first phase, conceptual content analysis was performed in two stages on fifteen articles and five white papers to identify: (1) analytically-oriented supply chain strategies; and (2) RFID-based inventory management applications. The material was scanned for existence of text related to these framing questions:

1. What strategies for supply chain optimization are being employed?

2. How is RFID technology being used or planned to optimize inventory management in supply chains?

3. What are the benefits, or expected benefits, of using RFID technology for this purpose?

The results were organized into two lists. The first, presented below as List 1, identifies supply chain optimization strategies that are focused on analytical objectives. These strategies are consistent with Byrnes' (2004) view that companies are better served by directing SCM optimization strategies toward building analytical and business intelligence capabilities, as opposed to enhancing existing operational processes.

- Improve Supply Chain Visibility
- End-to-End Process Integration
- Eliminate Artificial Uncertainty and Reduce Natural Uncertainty
- Improve Supply Chain Measurement and Benchmarking Capabilities
- Enhance Collaboration with Trading Partners
- Optimize Reverse Logistics

List 1 – Supply Chain Optimization Strategies Consistent with Byrnes (2004)

The second list identifies inventory management applications involving the use of RFID technology. These RFID applications, presented as List 2 below, are aligned with Frazelle's (2002, p. 92) earlier stated objectives for inventory management: improve forecast accuracy, reduce cycle times, lower purchase order/setup costs, improve inventory visibility, and lower inventory carrying costs.

- Automatic Product Receiving
- Directed Putaway
- Automated Shipping Operations
- Smart Shelves
- Product Freshness Management
- Enhanced Point-of-Sale Processing
- Automatic Self-Checkout
- Anti-theft/Shrink Systems
- Returns/Warranty Authentication
- Product Recall Management
- Continuous/Real-Time On-Hand Inventory Counts
- Intelligent Products

List 2 – RFID-based Inventory Management Applications Consistent with Frazelle (2002)

The supply chain optimization strategies identified in List 1 and the RFID-based inventory management applications identified in List 2 were correlated to form a table that

indicates which RFID applications support each of the supply chain management strategies. These relationships are presented below in Table 1.

Strategy / Application	Improve Supply Chain Visibility	End-to-End Process Integration	Eliminate Uncertainty	Improve Measurement Capability	Enhance Collaboration	Optimize Reverse Logistics
Auto-Product Receive	✓		✓	✓		
Directed Putaway	✓		✓			
Automated Shipping	✓		✓	✓		✓
Smart Shelves	✓	✓	✓	✓	✓	
Product Freshness	✓		✓	✓		✓
Enhanced POS	✓			✓		
Auto Self-Checkout	✓					
Anti-Theft/Shrink	✓		✓			
Returns/Warranty	✓	✓			✓	✓
Product Recall	✓				✓	✓
Continuous Inventory	✓		✓	✓		
Intelligent Products	✓	✓	✓	✓	✓	✓

Table 1 – Supply Chain Strategies Correlated with RFID Applications

In phase two of the data analysis, sixteen articles were analyzed to identify privacy-related issues associated with the use of RFID technology. These issues fall within White's (2003) broad framework defining privacy, including disclosure, confidentiality, anonymity, personal safety, security and appropriation of personal information (p.7) and are presented below in List 3.

- Consumers may not be aware that their product or its packaging are

tagged

- Tags, even if disclosed, may be non-removable
- Consumers may not be aware of locations of readers
- Item-level tags may be used to establish an individual's presence at a specific place and time, or track a person's movements
- Tags may be read by those other than intended, i.e. hackers
- Combinations of tags could be used to uniquely identify individuals
- Tags and loyalty programs could be combined to embed personal identify information in tags
- Marketers may target individuals based on tagged items not necessarily purchased but merely carried into range of a reader
- There are no privacy regulations in place to guide RFID tag use

List 3 – Privacy Issues Associated with RFID Technology

As technology to enable large-scale collection and use of personal information has evolved, and awareness of the potential for misuse of that information has grown, a widely-accepted set of principles addressing fair information practices (FIP) has emerged (FTC, 1998). These principles: notice, choice, access, security, and enforcement form a blueprint for information practice codes that guide the collection and use of personal information. Each of the privacy-related issues associated with RFID technology identified in phase two of this study (List 3) was examined in the context of the FIP principles. These issues were then organized by the FIP principle or principles that are potentially threatened. This integration of RFID privacy issues and FIP principles is presented below as Table 2.

Principle: Notice/Awareness • Privacy Issue: Consumers may not be aware that their product or its packaging are tagged, or of the locations of RFID readers • Privacy Issue: Item-level tags may be used to establish an individual's presence at a specific place and time, or track a person's movements
Principle: Choice/Consent • Privacy Issue: Tags, even if disclosed, may be non-removable • Privacy Issue: Combinations of tags could be used to uniquely identify individuals • Privacy Issue: Tags and loyalty programs could be combined to embed personal identify information in tags • Privacy Issue: Marketers may target individuals based on tagged items not necessarily
Principle: Access/Participation • Privacy Issue: Tags may be read by those other than intended, i.e. hackers • Privacy Issue: Tags and loyalty programs could be combined to embed personal identify information in tags
Principle: Integrity/Security • Privacy Issue: Tags may be read by those other than intended, i.e. hackers
Principle: Enforcement/Redress • Privacy Issue: There are no privacy regulations in place to guide RFID tag use

Table 2 – Fair Information Practice Principles and RFID Privacy Issues

CHAPTER V – CONCLUSIONS

Globalization, competition, and increasingly sophisticated and informed customers are creating ever greater supply chain challenges for today's businesses (Fox, 1999; Sarma, 2004). While achieving supply chain excellence in the face of these challenges is difficult, companies that lead in supply chain improvement may be able to build competitive advantage (Mulani, 2002). Dell and Wal-Mart, for example, have used pioneering supply chain models to dominate their markets (Mulani, 2002). Wal-Mart and others are now taking a hard look at using RFID technology to drive continued innovation in their supply chains (Byrne, 2004). Those companies may find their efforts best served by focusing RFID technology on analytical applications that have the potential to create entirely new supply chain opportunities rather than merely applying the technology to make existing processes more efficient (Byrnes, 2004).

This study looked at supply chain optimization strategies aligned with Byrnes' (2004) point of view, and more specifically at RFID-based applications for the inventory management-related activities reported by Frazelle (2002) as being central to supply chain improvement efforts. As suggested by the authors cited in this paper, in spite of their promise, RFID initiatives are not without challenges. While immature technology, high costs, and evolving standards present hurdles (Gardner, 2003), the most visible obstacles appear to be those related to RFID's implications for privacy and abuse of personal information (Bednarz, 2003). RFID attributes, including tags that can be extremely small and also updatable, along with other silent and potentially unobservable mechanisms, make RFID uniquely capable of collecting and using personal information in ways that conflict with commonly accepted principles of privacy and fair information practice (Laurant, 2004; White, 2003). In response, this study was designed to

examine the privacy-related issues that have come to light as public awareness of RFID technology applications in supply chain strategies and concerns over the potential impact on fair information practices have grown.

Although businesses will continue to look for ways to improve the efficiencies of their processes, and will use technology to create efficiencies whenever possible, Byrnes (2004) argues that supply chain optimization is not just about improving efficiency. Rather, he suggests that the greatest potential for supply chain optimization lies in using technologies like RFID to grow business intelligence and find new ways of doing things.

This study identified a number of supply chain strategies that are oriented towards Byrnes' (2004) bias for analytical and business intelligence objectives. As Frazelle (2002) observes, inventory management is a critical component of effective supply chain management. RFID technology, designed to tag and track objects, is, in the context of supply chain management, essentially an inventory management tool. Bar code technology, another inventory management tool, is virtually ubiquitous in supply chain logistics. Using RFID technology to replace bar code systems, however, would be merely "paving the cowpath" as Byrnes (2004) puts it. This study revealed several RFID applications for inventory management that go beyond the improvement of operational processes; these applications, including smart shelves, auto self-checkout, and intelligent products, presented in Table 1, leverage RFID's unique characteristics to create new ways to implement innovative supply chain strategies. An "intelligent product", for example, might dynamically adjust its expiration date based on changing environmental variables, dynamically re-price itself based on its age, location, or other lifecycle factors, or perhaps drive a dynamic picking process for stock rotation (Zaharudin, 2002). Applications of

this kind introduce opportunities to revolutionize, not just evolve, supply chain and logistics processes.

A common thread among the RFID applications presented in Table 1 was supply chain visibility. Better supply chain visibility can bring many benefits, including reduced inventory and safety stock levels, and fewer stock-outs (Violino, 2002a). By helping to identify the location and velocity of every product at every node in a supply chain, each of the RFID applications identified in Table 1 enhances supply chain visibility in some way. It appears that among all of the potential benefits of RFID technology for supply chain improvement, its strongest impact may come from its ability to improve visibility throughout the supply chain.

Although loosely defined, privacy is widely held to be a personal and constitutionally-protected "right" (Privacy, 2002; White, 2003). Control over one's personal information is an intrinsic component of the right to privacy (White, 2003). New and evolved information technologies have continually challenged prevailing notions of privacy and forced re-thinking of standards and principles for the preservation of privacy and the protection of personal information (Privacy, 2002). The first set of principles related to information practices was articulated by the U.S. Department of Housing in 1973 as the Principles of Fair Information Practices (FIP) (Laurant, 2004). These principles were later codified by Congress in the Privacy Act of 1974.

RFID technology, with attributes that make it a potentially easy target for abuse of information privacy rights, has become a lightning rod for concern by privacy advocates and consumer watchdog groups (Albright, 2003). Several privacy-related issues connected with RFID raised by these groups are identified in this study and related to the particular FIP principle(s) that they potentially impact.

The FIP principle of notice holds that consumers should be notified of an entity's information practices before any personal information is collected. Notice should include the identity of the entity collecting the data, disclosure of how the data will be used, the identity of potential recipients of the data, the nature of the data and how it will be collected, and what steps will be taken to insure the confidentiality and integrity of the data (FTC, 1998). Hidden RFID tags and/or readers, one of the privacy issues presented in List 3, are not consistent with this principle of notice.

Consumers should be given options to influence if or how information about themselves will be collected and used according to the FIP principle of choice (FTC, 1998). Non-removable RFID tags, unless governed by a "kill switch", do not allow consumers choice. Personally identifiable information should not be written to RFID tags without consumer consent.

According to the FIP principle of access, individuals should be able to access any data collected about them and contest that data's accuracy and completeness (FTC, 1998). If personal information from tags is readable by unknown or unintended parties, access is not possible. If tags contain personal information and consumers do not have the ability to read that information, access is not possible.

The FIP principle of integrity requires that collectors of consumer data ensure that the data is accurate and secure (FTC, 1998). If personal information contained in RFID tags can be read by unauthorized entities, that personal information is not secure.

There must be mechanisms in place to enforce the principles of fair information practices and establish means for redress (FTC, 1998). The immature state of RFID technology and the absence of regulations specific to RFID applications currently leave consumers with no protection or channel for redress.

This study identifies a number of privacy issues suggesting that RFID technology has the potential to be used in ways that run afoul of each of the fair information practice principles. The unique attributes of RFID technology, including updateable and very small tags, unseen and potentially ubiquitous readers, and non-line-of-sight communication, coupled with existing information technologies for collecting and correlating personal data, may represent for some a perfect convergence of technologies designed to abuse personal information and privacy.

For marketing, supply chain, logistics, and inventory managers tasked with helping their companies compete more effectively in today's complex global markets, RFID may appear an attractive tool for supply chain optimization. Tables 1 and 2 presented in this study may help them understand how innovative RFID applications for inventory management can support analytically oriented supply chain strategies, while casting light on potential privacy issues related to RFID's capability to infringe on fair information practice principles. For privacy advocates concerned about the use of RFID in consumer-oriented inventory applications, Table 2 presented in this study may be useful in helping to understand the positive aspects of the technology and the potential it presents for supply chain and logistics improvements.

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