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16. Abstract

Radio frequency identification (RFID) transmits the identity of an object or a person wirelessly. It is grouped under the broad category of automatic identification technologies with corresponding standards and established protocols. RFID is suitable for applications in different industries and has penetrated into several aspects of our lives. The versatile features and benefits of RFID technology have proven that RFID can be widely applied in the field of transportation to improve driving safety, reduce vehicle collisions, and even help reduce vehicle emissions. Generally speaking, the applications of RFID in transportation are still limited and are not scanned and summarized well. This paper aims to conduct an extensive literature review to identify the existing and potential applications of RFID and its research opportunities and needs in transportation. Existing applications in transportation fields have been identified such as safety, operation - including Intelligent Transportation System (ITS) and Vehicle Infrastructure Integration (VII), security, policy, etc. Obstacles that possibly frustrate the wide and in-depth applications of RFID in the transportation area are in the aspects of technology, cost, policy, and privacy. RFID is one of the most forceful technologies that will affect a variety of aspects in transportation including ITS. It is believed that RFID-based technologies can be extensively exploited to improve transportation safety and security, increase the efficiency of the transportation system, ultimately save costs, and, therefore, improve the quality of human lives.

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RFID Applications in Transportation Operation and Intelligent Transportation System (ITS)

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ABSTRACT

Radio frequency identification (RFID) transmits the identity of an object or a person wirelessly. It is grouped under the broad category of automatic identification technologies with corresponding standards and established protocols. RFID is suitable for applications in different industries and has penetrated into several aspects of our lives. The versatile features and benefits of RFID technology have proven that RFID can be widely applied in the field of transportation to improve driving safety, reduce vehicle collisions, and even help reduce vehicle emissions. Generally speaking, the applications of RFID in transportation are still limited and are not scanned and summarized well. This paper aims to conduct an extensive literature review to identify the existing and potential applications of RFID and its research opportunities and needs in transportation. Existing applications in transportation fields have been identified such as safety, operation - including Intelligent Transportation System (ITS) and Vehicle Infrastructure Integration (VII), security, policy, etc. Obstacles that possibly frustrate the wide and in-depth applications of RFID in the transportation area are in the aspects of technology, cost, policy, and privacy. RFID is one of the most forceful technologies that will affect a variety of aspects in transportation including ITS. It is believed that RFID-based technologies can be extensively exploited to improve transportation safety and security, increase the efficiency of the transportation system, ultimately save costs, and, therefore, improve the quality of human lives.

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Mention of trade names or commercial products does not constitute endorsement or recommendation for use. Trade and manufacturers' names appear herein solely because they are considered essential to the object of this report.

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EXECUTIVE SUMMARY

Radio frequency identification (RFID) was first developed in England, during World War II, in order to distinguish enemy airplanes from allied airplanes. To track nuclear materials, the U.S. government and LANL (Los Alamos National Laboratory) began developing the RFID technology system in the1970s. Later, in 1973, the United States had its first RFID patent which consisted of both the memory rewritable tags for active type and the intelligent door system with passive tags.

A basic RFID system is composed of tags and readers. The RFID tag is an object that stores data, information and is attached to products. RFID reader, also known as the transmitter, is a device that can receive and interpret the information from the tags. RFID reader transmits this information to a RFID host computer with the proper software. By transmitting the identity of an object or a person wirelessly, RFID now is widely applied in different industries and has penetrated into several aspects of our lives such as the supply chain, postal, automatic online payment, health care, agriculture, construction and facilities management, and others. Applications of RFID in these industries will all be stated before the discussion of RFID's current connection with transportation and the future utilization in this report.

Transportation is a crucial industry that affects the national economy and livelihood of the people. The versatile features and benefits of RFID technology have proven that RFID can be widely applied in the field of transportation to improve driving safety, reduce vehicle collisions, and even help reduce vehicle emissions. However, there are only very limited RFID applications in transportation, including the trucking weight monitor, toll way electronic control system, tire pressure detect system, etc..

Generally speaking, applications of RFID in transportation are still limited and are not scanned and summarized well. This paper aims to conduct an extensive literature review to identify existing and potential applications of RFID and its research opportunities and needs in transportation. Existing applications in transportation fields have been identified such as safety, operation including Intelligent Transportation System (ITS) and Vehicle Infrastructure Integration (VII), security, policy, etc. Obstacles that possibly frustrate the wide and in-depth applications of RFID in the transportation area are in the aspects of technology, cost, policy, and

privacy. RFID is one of the most forceful technologies that will affect a variety of aspects in transportation including ITS. It is believed that RFID-based technologies can be extensively exploited to improve transportation safety and security, increase the efficiency of the transportation system, ultimately save costs, and, therefore, improve the quality of human lives.

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ABBREVIATIONS

RFID:	Radio Frequency Identification
ITS:	Intelligent Transportation System
VII:	Vehicle Infrastructure Integration
LANL:	Los Alamos National Laboratory
UHF:	Ultra High Frequency
ISO:	The International Organization for Standardization
EPC:	Electronic Product Code
GTAG:	The Global Tag
MIT:	Massachusetts Institute of Technology
HP:	Hewlett-Packard
DOD:	The Department of Defense
NFC:	Near Field Communication
USDA:	United States Department of Agriculture
APHIS:	Animal and Plant Health Inspection Service
EM:	Electro Magnetic
EVI:	Electronic Vehicle Identification
VIN:	Vehicle Identification Number
AEI:	Automatic Equipment Identification
AVI:	Automated Vehicle Identification
VII:	Vehicle Infrastructure Integration
ETC:	Electronic toll collection
SWUTC:	Southwest Region University Center

CHAPTER 1

INTRODUCTION

1.1 Background of Research

Radio frequency identification (RFID) is a generic term describing a system that transmits the identity of an object or a person (in the form of a unique serial number) by using radio waves wirelessly. It is grouped under the broad category of automatic identification technologies (1), with corresponding standards and established protocols. RFID is suitable for applications in different industries and has penetrated into many aspects of our lives. Initially, it was used to identify enemy airplanes during World War II (2, 3), and has, since then, been widely used in the supply chain, inventory tracking and management, libraries, agriculture, medical affairs, and many other fields (4, 5, 6, 7, 8). IDTechEx forecasts a $5.29 billion RFID market in 2008, which is more than 7.3% to the $4.93 billion in 2007 (9).

Transportation is a crucial industry that affects the national economy and livelihood of the people. The versatile features and benefits of RFID technology have proven that RFID can be widely applied in the field of transportation to improve driving safety, reduce vehicle collisions, and even help reduce vehicle emissions. However, there are only very limited RFID applications in transportation, including the trucking weight monitor (10), toll way electronic control system (11, 12), tire pressure detect system, etc. (11, 13). These applications act as the tip of the iceberg with their narrow scope in the transportation system. To address this issue, the Transportation Research Board organized the "Research Opportunities in Radio Frequency Identification (RFID) Transportation Applications Conference" on October 17-18, 2006, in Washington, D.C. The conference focused on the transportation applications in RFID technology and discussed the research blueprint of RFID application in transportation operations, pavement management, policies, etc.

The company "Eyes for Transport" compared the surveys on RFID applications in transportation and logistics in 2005 and 2006. The surveys indicated that a great percentage of companies have adopted or are currently using RFID solutions, despite the percentage's dive from 28% to 23% (14). Retail and manufacturing are still the second biggest RFID users. But, since the end of 2006, the adoption of RFID has been stalled. Another survey shows 60% of industrial companies have no activity to even research on RFID and 60% of the companies that have already installed RFID have no further plans to increase RFID investment (15).

However, generally speaking, there lacks a comprehensive literature review on RFID application in transportation. This motivates our project and this paper, which aims to identify the existing and potential applications of RFID and its research opportunities and challenges in areas of transportation through extensive literature review.

1.2 Research Objective

This research is intended to conduct an extensive literature review to identify the existing and potential applications of RFID and its research opportunities and needs in transportation. To this end, the following research objectives developed:

- Review the existing documents about the history and standards of RFID.
- Summarize the applications of RFID in diversified industries with focus on transportation.
- Point out obstacles and challenges for RFID Deploying in transportation.
- Present future potential applications and research opportunities of RFID in the area of transportation..

1.3 Outline of Report

This report is organized in the following order. Chapter Two provides an extensive review of the RFID Applications. Chapter Three summarizes the applications of RFID in other fields. Chapter Four focuses on the discussion of existing applications in transportation. Chapter Five gives out the obstacles and challenges for RFID Deploying in transportation. Chapter Six presents future potential applications and research opportunities of RFID in the area of transportation. Chapter Seven includes conclusions and recommendations.

CHAPTER 2

LITERATURE REVIEW

This chapter provides a review of existing research and applications with focus on the history and standards of RFID studies. First, an overview of RFID concept and working principle is presented. Then, a summary of RFID history is described in details. In addition, current existing and purposed standards are reviewed.

2.1 RFID Concept and Working Principle

A basic RFID system is composed of tags and readers. RFID tag is an object that stores data, information and is attached to products. RFID tags are typically categorized as *passive* and *active* tags (*3, 16, 17*). *Passive* tags do not need any power sources; they are powered by an antenna which receives electromagnetic waves from the reader. Passive tags have an unlimited life time unless damaged (*18, 19*). *Active* tags are self-contained and have their own power sources. What distinguishes an active tag from a passive tag is that the active tag has the ability to send and receive signals to and from the RFID reader (*5, 18, 20*). RFID reader, also known as the transmitter, is a device that can receive and interpret the information from the tags (*19*). RFID reader transmits this information to the RFID host computer with the proper software (*17*). Figure 1 shows the working principal of a RFID system.

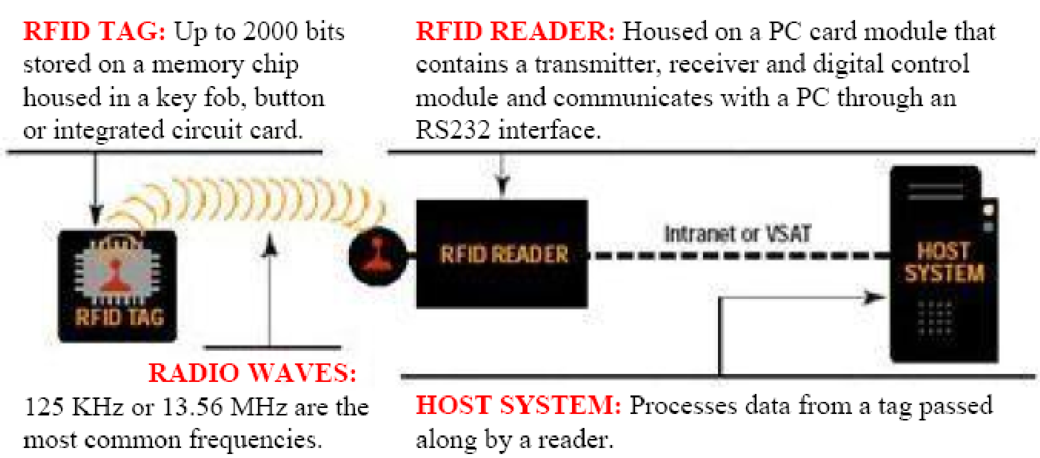

Figure 1 RFID operation principle (Modified from source: *21*).

2.2 RFID History

During World War II, the British developed the first RFID system in order to distinguish enemy airplanes from allied airplanes. The U.S. government and LANL (Los Alamos National Laboratory) began developing the RFID technology system in the 1970s to track nuclear materials. After that, LANL also developed a passive tag to track cows under Ultra High Frequency (UHF) radio waves (2). The first RFID patent in the U.S. was both the memory rewritable tags for active type and intelligent door system with passive tags in 1973 (2). The first RFID deployment in transportation operations management was in 1984, which consisted of tags attached to chassis carriers to serve as "license plates" (20). Since high frequency (13.56MHz) systems started to be commercialized in the mid 1980's, the applications have broadened from tracking reusable assets to different areas including - gate access control, payment system, and contactless smart card (2).

In the early 1990s, UHF RFID, which can offer a longer working range and faster data transfer, was initiated. In the beginning, this technology was not widely used due to its high price for operation. As a result, between the years of 1999 and 2003, researchers put much effort into lowering the price. They eventually developed more efficient technology by changing the RFID chip from a mobile database to a simple RFID tag with a series number that can be read faster and more accurately (2). There have been many patents regarding RFID such as Electronic Identification System, Electronic License Plate for Motor Vehicles, Animal Tracking and Monitoring System and many more (3, 16). The RFID standard and protocol have also been explored based on new criteria (16). Important events of RFID are shown in Table 1.

Table 1 History of RFID

Decades	Events
1940 - 1950	Radar refined and used major World War II development effort RFID invented in 1948
1950 - 1960	Early explorations of RFID technology, laboratory experiments
1960 - 1970	Development of the theory of RFID Start of applications field trials
1970 - 1980	Explosion of RFID development Tests of RFID accelerate Very early adopter implementations of RFID
1980 - 1990	Commercial applications of RFID enter mainstream
1990 - 2000	Emergence of standards RFID widely deployed RFID becomes a part of everyday life

Source: (*3*)

2.3 RFID Standards

Standardization is a critical part of RFID technology. Existing and purposed standards are mainly focused on air interface protocols, data content and applications. Before 1999, the International Organization for Standardization (ISO) was in charge of creating and setting RFID standards. They have created ISO 11784 for tracking cattle with RFID; ISO 11785 for interface protocol; ISO 14443 for smart cards in payment system; ISO 15693 for vicinity cards; and ISO 18000 series for automatic identification and item management (16). The Auto-ID center was set up in 1999 to develop an Electronic Product Code (EPC) and a low cost RFID system for goods tracking. The Auto-ID center rejected the Global Tag (GTAG) with ISO's UHF protocol and created its own UHF protocol to cut the extra cost due to complexity protocol (16).

In 2003, the Auto-ID Center was divided into two parts. One became Auto-ID labs at Massachusetts Institute of Technology (MIT) for more research on EPC technologies. The other one became EPCglobalTM to commercialize EPC.

The Auto-ID Center categorizes RFID tags to six classes listed in Table 2. Each class has more capability than the next one and is backward compatible. In the first-generation protocol that only specifies the first two classes, end users have to purchase multiprotocol readers to read Class 0 and Class 1 tags, which increased the initial cost of setting up a RFID system. To solve this problem, EPC Global began developing a second-generation RFID protocol named Gen 2 that could work for several classes under UHF band (16).

Table 2 Auto-ID Center RFID Tag Standards

Class	**Tags**
Class 0	A read-only, factory programmed tag
Class 1	A passive, read-only, backscatter, write-once-read-many (WORM) tag
Class 2	A passive backscatter field programmable tag with user memory, encryption,
Class 3	A semi-passive backscatter tag with user memory and encryption; essentially, a Class 2
Class 4	An active tag that uses a built-in battery to run the microchip's circuitry and power a
Class 5	An active tag that can communicate with other Class 5 tags and/or other device

Source: (*16*)

In Table 3, features between Class 1 Gen1 and Class 1 Gen2 are summarized in six categories: (1) read speed; (2) write speed; (3) tag sorting protocol; (4) multiple reader operation; (5) security; and (6) extensibility. Features for each category are further classified based on the generation. From Table 3, it is seen that Gen2 can provide faster, more flexible read speed; higher reliability in tag counting; enhanced security, etc (22). In addition, if end users are using RFID facilities based on EPC Class 0 and Class 1 or both from ISO, it can be easily upgraded. Today, the EPC Gen2 standard is widely used in the field of transportation (16).

Table 3 Comparison of EPC Class 1 Gen 2 and Gen1 Features & Performance

Features	**Class 1 Gen 2**	**Class 1 Gen 1**
Read Speed	• Up to 800 tags/sec (US FCC) • Up to 450 tags/sec (EU ETSI) • Read adaptable to RF noise in environment	• Up to 230 tags/sec (US FCC) • Up to 115 tags/sec (EU ETSI)
Write Speed	• 5 tags/second minimum • Rewriteable many times	• 3 tags/second • Rewriteable many times
Tag sorting protocol	• "Q" protocol: a random number algorithm with 2 persistent symmetric states	• Binary tree algorithm with • persistent sleep/wake states
Multiple reader operation	• Frequency hopping • Listen-before-talk • Dense reader modes • Four reader "session", allowing parallel communication by multiple	• Frequency hopping • Listen-before-talk
Security	• 32-bit lock and kill passwords • Option for "handle"-	• 8-bit kill password with • lockout after incorrect queries
Extensibility	• Up to 512 bit item ID • Unlimited user memory • Anticipate Class 2 & 3	• Up to 96 bit item ID

Source: (*22*)

CHAPTER 3

RFID APPLICATIONS IN OTHER FIELDS

As stated in the previous chapters, the research objective of this report is to conduct an extensive literature review to identify the existing and potential applications of RFID and its research opportunities and needs in transportation. To this end, this chapter is intended to summarize the application of RFID in the following seven parts:

3.1 Supply Chain

Wal-Mart is a pioneer that uses RFID technology in its supply chain management system, which helps in inventory and asset management. First, Wal-Mart assigns different numbers for each bundle or category of products and inputs them into a passive or active tag. Secondly, when these products arrive at the different stores, antennas or readers located at the picking store will read and collect relevant information. Then, this information will be sent to the operations and merchandising center as well as the suppliers to report that the products have arrived (18). In general, RFID chips can be used to track products grouped in various hierarchies: (1) individual items or single packages containing multiple items for consumer purchase; (2) cartons or cases of multiple items; (3) pallets of multiple cartons or cases; and (4) loads of multiple pallets. The products at each of these levels may be assigned an RFID label that is associated with information pertaining to at least one adjacent hierarchical level (23). This system can provide real-time information including location, delivery time, and the number of products for the inventory and supply system (5). Target, Hewlett-Packard (HP), Intel, AT&T, and other companies also use RFID technology. Some of them even set up their own RFID management and development labs to create their own RFID solutions (24, 25, 26).

In the mean time, the Department of Defense (DOD) also spends over $115 billion every year for its RFID solutions. They use RFID to integrate and share synchronizing data as well as informing every aspect in its supply chain (4).

3.2 Postal

Package transportation is another potential use of RFID technology (27). In less than ten years, over a trillion postal items were tagged each year, making RFID for the postal and courier service the second largest application of RFID in the world after the retail supply chain. After using RFID labels by DHL (a global postal company founded by Dalsey, Hillblom, and Lynn), an innovation is now proved executable.

The new postal RFID system, which is anticipated to replace the existing barcode system, aims to reduce costs, errors, and human interventions. RFID technology provides a comprehensive electronic system with the potential to maximize mail packaging process capabilities while minimizing logistics cost. Real-time information automation is now possible with the existing system.

3.3 Automatic Online Payment

The success of toll collection programs has spurred interests from payment providers such as American Express, Visa, and MasterCard, who have launched pilot programs to examine RFID-based payments in the U.S. (28). Sony and Phillips are leading the way to implement radio frequency (RF) wireless payment systems, called Near Field Communication (NFC). These systems will enable RFID communications among PCs, handheld computers, and other electronic devices. The consumers will log on to their personal online portals by swiping their intelligent cards through a specific RFID reader plugged into the USB port on the computer. Consumers may shop and pay online, download any kind of receipt to their PC, and then transmit them, with the help of NFC technology, to an RFID tag in their mobile phones (13).

3.4 Health Care

Applications of RFID to Healthcare have many benefits and the best is yet to come. The health care system is a huge market place for RFID technology. For example, in pharmaceutical application, by using RFID, one can identify counterfeit medication, altered dosage, and even an expired date for the proper medication (29, 30). As a result, RFID can save lives, and, it can prevent the illegal activity of some companies.

Also, RFID can be used in clinical trials where the dosage of medication and number of times the medication is taken is very important since it can affect the results in clinical trials or even affect the life of the subject.

Another application of RFID in the health care system is to track medical equipment and products, medical records of patients, and newborn babies with RFID wristbands (29, 30). For example, if a patient suffers from Alzheimer or loss of memory or if the patient has diabetes and experiences a diabetic coma, the RFID technology is able to give proper information to the health care practitioner in order to provide proper care by scanning his or her wristband that contains RFID chip. By placing RFID wristbands on newborns the healthcare practitioners are able to avoid confusion or mistaken records in regard to the babies. As a result, it will increase quality of care.

In October 2004, US Food and Drug Administration (FDA) approved the first RFID tag used on humans (31). In this system, a passive tag contains the patient's essential biometric and medical information and is implanted under the skin; therefore, doctors are able to find the patient's medical history more quickly and accurately through reading the information. RFID can also improve the efficiency of the health care system together with the medical record system (31). Sanacorp is a famous German pharmaceutical wholesaler that uses RFID for picking and dispatching its medicals supplies (18, 32, 33, 34).

3.5 Agriculture

The break out of Mad Cow Disease in the U.K. and the discovery of Mad Cow Disease in the U.S. created tremendous interests in RFID technology for tracking livestock and cattle on the global scale. The goal is to provide a better, safer, and higher quality of food supply chain from producer to consumer domestically or internationally. By adopting RFID technology in the food supply chain and agriculture, the government is able to track all the potential contaminated food and prevent further spread of any kinds of diseases (7).

United States Department of Agriculture (USDA) approved RFID tagging system for the national animal identification program (2, 8). Each live stock is identified with an unique identification number that can help the livestock industry trace and destroy animals that are infected with diseases such as the Mad Cow Disease. Tracking of Foot and Mouth Disease, Pseudo-Rabies Disease, and Porcine Reproductive and Respiratory Syndrome in pigs is being run by the USDA's Animal and Plant Health Inspection Service (APHIS). USDA has recommended visual tags for livestock; e.g., ear tags with RFID technology,(8). In the state of California the implementation of RFID technology to almondand pistachio farms has helped nut producers speed up the loading process by 60%. The other profit has been to improve data base collection and tracking products. Also, the information stored in RFID tags allows staff to prioritize loads as they arrive at their processing warehouse. For example, the load that arrives at a higher temperature will be unloaded first,

3.6 Construction and Facilities Management

The Construction Industry Institute identified a number of potential application areas for RFID technology in its 2000 reviews (35), including component tracking, inventory management and equipment monitoring. In the UK, various government-supported projects involve the use of RFID in manufacturing, asset tracking and maintenance within the construction sector (36). In 2006, Robert Wing indicated that the potential of RFID tagging technology in the construction and management of facilities is assessed in terms of value chains (37) which follow the lifecycle of a building from raw materials through to the management of the completed facility. During this lifetime serving, the most important benefits include: direct and automated surveillance maintenance programmers by a ‘click’ on a PC or PDA; inventory control; control of having the right equipment at the right place, and reduction of data entry errors in ‘production’ and maintenance (38).

3.7 Others

The tags and readers used in RFID systems have begun to replace both Electro Magnetic (EM) or Radio Frequency (RF) theft detection targets and barcodes in libraries (39). RFID technology helps libraries track book inventory status, identify books for renting and selling, and provide information regarding the renting or selling date. In addition, the new version of the U.S passport will have an embedded RFID tag that contains information for personal identification to avoid unauthorized use. Such passports will speed up border crossing and enhance the deployment of a more secure driver's license (40), which was mandated by the Real ID Act of 2005 and may well include a contactless chip—even a RFID tag (13, 40). As the world's largest RFID project, the Chinese government spent six billion dollars for its national ID card with 300 million cards being delivered before 2008 Beijing Olympics (9).

CHAPTER 4

EXISTING RFID APPLICATIONS IN TRANSPORTATION

This RFID technology is not only widely used in fields as described in the previous section, but also in areas of transportation. The following sections will review and discuss RFID applications in transportation based on these categories:

- Identification
- Security
- Safety
- Operation.

4.1 Identification

One of the basic usages of RFID in transportation is the Electronic License Plate (41, 42), which is an electronically tagged number plate that is read by a computer system through the readers. One of the leaders in Electronic Vehicle Identification (EVI) is the e-Plate (41). Most e-Plates do not look different from standard number plates now, except for the built-in active RFID tags. However, some e-Plates are tagged on the windscreen, either front or rear. They are operating at the frequency of 868MHz or 915MHz, with long effective ranges. The active tag used in e-Plate transmits the vehicle ID periodically, and the very low power readers are supplied by mains, battery or solar energy. The e-plate of a vehicle could replace the registration mark or the vehicle identification number (VIN) (43).

Experiment results show that the secure and free-maintenance e-Plate helps vehicles to be positively identified with up to 99.98% accuracy and within 100 meters of the reader at any time, any speed, individually or in dense traffic, and under all weather conditions with a guaranteed life of up to ten years (43). The e-Plate could also be theft resistant to prevent its removal from vehicles. The first RFID deployment for transportation identification management was in 1984, with tags attached to chassis carriers serving as "license plates" (20).

4.2 Security

The U.S. Department of Transportation office of hazardous materials safety, has enhanced tracking and monitoring for hazardous materials during their delivery times. For example, RFID systems are deployed in the railway system (11, 44, 45, 46). A RFID tag, also known as an Automatic Equipment Identification (AEI) tag in this system, contains necessary information attached to the container of hazardous material, and the information can be retrieved by a special reader in a distance to every freight railcar, which delivers hazardous materials in the U.S and Canada. Railways use this tag to confirm train content and identify freight cars loading specific goods. This RFID tracking application can provide inventory status, report unauthorized control, and pinpoint item location, etc (11, 47).

RFID has also been used in Secure Electronic Network for Travelers Rapid Inspection in U.S.-Mexico and U.S.-Canada borders (11, 48). For example, in the U.S.-Mexico border, vehicles with a RFID transponder and travelers with an I-94 permit with a RFID chip can cross the border quickly using a special lane with RFID readers (11, 49). In October 2006, a new RFID monitoring system was deployed and used in Manchester Airport, U.K. Passengers were issued RFID tags during check-in so that the security department could track and monitor passenger flow and thus airport security improved (13, 50).

4.3 Safety

Seaports deal with a tremendous amount of containers and goods, and areas around sea ports become traffic distributors with excessive trucks entering and exiting from these areas. To ensure the safety of truck drivers and loads, many ports use RFID transponder technology along with “weight-in motion” and weight detector for weight station bypass (10). Readers, located at the roadside, search, receive, and query a signal from a RFID in-vehicle transponder for vehicle identification information, which then returns data to a computer located in the weigh inspection station. Once the height, weight, and driver credentials are verified, the computer sends a signal back to the truck indicating that the truck can bypass the system and exit the port area (10).

Tire manufacturer, Michelin, has begun using RFID tags to check tire pressure and tire conditions. They attach a RFID transponder or a passive RFID tag containing tire information into their tire products along with a temperature and pressure sensor. It is very easy for mechanics with readers to interpret data to make sure a tire should be maintained or replaced. In the "e-Tire" system, each truck has a RFID tag on its bumper that contains its tires' low-pressure information associated with the e-Tire ID. The data is then sent to a data center and the operators use this system to check the status of low pressure (11, 13, 51)

4.4 Operation

RFID technology has been implemented in transportation including the Automated Vehicle Identification (AVI) system, the Vehicle Infrastructure Integration (VII) System, and the Intelligent Transportation System (ITS) (52). ITS has 16 subcategories, in which RFID technology has been used in electronic payment and pricing subcategories, toll collection, and parking fee payment system, etc. (11, 53).

Electronic toll collection (ETC) supports the collection of payment at toll plazas using automated systems to increase the operational efficiency and convenience of toll collection. Systems typically consist of vehicle-mounted transponders identified by readers located in dedicated and/or mixed-use lanes at toll plazas (53). In 2005, Texas Department of Transportation (TxDOT) selected TransCore's eGo(R) Plus RFID technology for use in the area's Central Texas Turnpike Program (12). The purpose of this program is to add capacity and reduce congestion in the toll way of the region. Each tag is equipped with a unique tag number in order to prevent duplication. When vehicles enter the reading area, sensors or readers detect and receive signals through the information implanted in the tags and make sure the vehicle can drive through the gate barrier (11, 12).

Another successful application in transportation operation is "Automated Baggage Handling Systems" at the Las Vegas Airport (11, 48). In addition, Delta Airlines is the first US carrier to test RFID baggage handling (48). Today, automated baggage handling systems altogether play a critical role in the airport operation. A barcode-based system is used to trace passenger's baggage. The problem with this system is that it needs a laser line to read the bar code, and if the bar code itself becomes damaged or misplaced, it cannot be scanned and read. As a result, only 80-90% percent of luggage can be read and tracked accurately (54). However, the RFID based system does not need any laser line to scan and read. No matter where the tag is, readers can receive signal from the RFID tag attached to luggage. Therefore, RFID technology can reduce the rate of losing luggage, allowing ramp work to be performed quickly and accurately (54, 55).

Other applications in areas of transportation include the automated parking management system in London (17, 42), the electronic pre-clearance of trucks (Pier Pass at ports of Los Angeles and Long Beach) (11, 56), and the pilot test of the applications of RFID in roadside guide signing through a Southwest Region University Center (SWUTC) project (57). It is generally agreed that applications of RFID in transportation have a promising future and the need for extensive research on the special requirements and challenges posed by the transportation systems is urgent.

CHAPTER 5

OBSTACLES AND CHALLENGES OF RFID DEPLOYING IN TRANSPORTATION

From literature review, we found that even though RFID technology has found its applications in some transportation related fields, it has not been widely adopted due to a number of obstacles. We summarize these into the following categories and will go into detail on each in this section:

- Technology obstacles
- Cost obstacles
- Policy obstacles
- Privacy obstacles.

5.1. Technology Obstacles

Major technology obstacles may include reading distance and rates, physical challenges, and human health.

5.1.1 Reading Distance and Rates

Most RFID applications in transportation are using the passive read-only tag. The disadvantage of such a setup is the short reading distance. It is normally about 31.5 feet, which is not enough to integrate into many ITS subsystems (53), given that most pole to pole or traffic light to traffic light distance is about 200 feet.

5.1.2 Physical Challenges

There are many physical challenges of RFID technology as we summarize here: (1) “Reader collision”, where multiple readers attempt to read the same tag at the same time. (2) “Tag collision”, where a reader receives reflected signals from multiple tags at the same time. (3) Signal interference where electromagnetic signals from different tags and readers interfere with each other and decrease the signal to noise ratio. (4) Possible inconsistent information received from the same tag. (5) Special materials (such as metal pipes) may block signal at radio frequency spectrum, which could affect the whole monitor or management system (48).

5.1.3 Human Health

There is a controversy that cell phone wireless signals, typically at very high frequency spectrum, may damage a sers' health and neural system and even cause cancer. Will RFID signals or electromagnetic waveform have similar effect to a users' health, especially with much higher power levels required for the readers? This question needs to be investigated to ensure the safety of the technology and wide adoption in our daily lives.

5.2 Cost Obstacles

Even though RFID costs are decreasing, it is nevertheless "too expensive" for the much wide deployment in transportation. While the unit price for a typical electronic tag may be 30 cents a piece or even cheaper (13), with the hundreds of millions of vehicles in a country, deploying RFID system along the countless length of roadway network will introduce a tremendously high total cost. In addition, sensors used to read these tags could cost well over $1,000 each.

Furthermore, the integration of RFID into existing transportation systems also needs a large amount of investment (48)

5.3 Policy obstacles

Support from the policy makers has a great influence on adapting or rejecting a technology. Therefore, RFID technology deploying in the field of transportation relies on related policy supports as well. Gifford proposed four policy and institutional issues including standard issues, privacy issues, a role for U.S. Department of Transportation (USDOT), and data ownership (58).

With standard issues, the major issue is how to choose a good standard for applications in order to protect users' privacy. Current available standards for RFID systems include those from ISO standards and EPC global standards initiated from RFID companies (22, 58, 59). The role of the USDOT is to ensure the proper collection of multiple RFID activities within its boundaries (58, 60).

The data ownership issues relate to who can store and use RFID data, and whether legislators regulate the use of them (58).

Specifically, the major policy obstacles are policy makers and executers, financial support, and uniform standard.

5.3.1 Policy Makers and Executers

Which department or committee should be authorized to make RFID related policies or regulations? Although the U.S. Congress and some states have passed a few regulations regarding RFID technology, there are, unfortunately, no special committees or departments to regulate the use of RFID in this field.

5.3.2 Financial Support

Any new technology requires financial support. Where is the budget coming from? In addition, RFID-related research and development in this industry also lack sufficient financial support though some state DOT such as TxDOT that has realized the need for such R&D effort and is considering using RFID technologies to support state right of way function (61).

5.3.3 Uniform Standard

There is no uniform standard of RFID in transportation that can ensure interoperability of RFID systems from different manufacturers. For example, in the freight container industry, there are three existing ISO standards available: ISO 6346, ISO 9897, and ISO 10374 (12, 62). Most current RFID applications in transportation are based on ISO 10347 protocol standards such as Texas e-Go toll way payment system and RFID crossing system along the U.S.- Mexico border in Arizona. They are, however, not applicable in the new ISO standard, ISO 18185, approved in the middle of April, 2007 (63).

5.4 Privacy Obstacles

Accordingly, just like other wireless technologies, RFID also has privacy issues because tags store identification information (13, 64, 42). Privacy protection is the main concern for legislators and citizens. One good example is the RFID tagged Coco-cola and shirt that have been used to track the consumers who bought the product by accident (65). RFID creates several major privacy concerns as described in the following parts:

5.4.1 Transaction security

If a reader operates in an identical standard and protocol as that of another, it can read the information and series number from the tag without the owner's consent. As a result, this identification information may be stolen by hackers and may cause clandestine tracking and counterfeit tagging (13, 40, 64). The progress is shown in Figure 2.

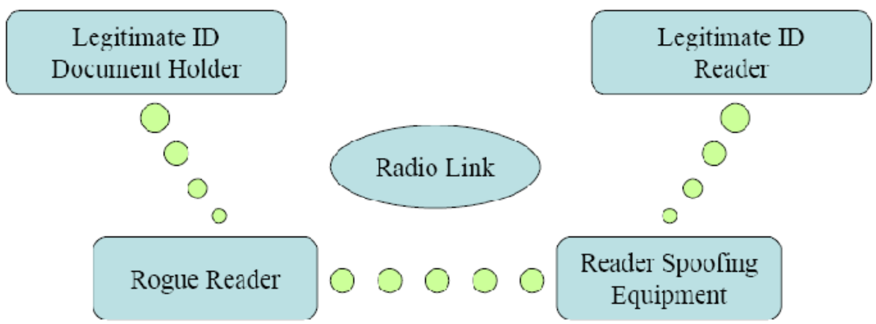

Figure 2 Real attacks in the context of building access (Modified from source: *64*)

Figures 2 tells how a rogue reader steals identification information through unauthorized reading and makes a fake copy to get access to a building.

5.4.2 Encryption password

Encryption password in RFID tag is not complicated and can be easily hacked. Based on our literature review, Class 1 Gen 1 RFID uses a simple 8-bit password to protect information, whereas, Class 1 Gen 2 RFID uses 32-bit password. In comparison to the smart card system, which has 128-bit encryption, RFID security is easier to be skimmed so information and data on the smart card may not beprotected well (27, 29, 41). For example, the 40-bit encryption of the Texas Instruments RFID transponders used in the Exxon / Mobile was once cracked by four students and two researchers (48).

5.4.3 Privacy protection accountability

People intend to believe that businesses have little incentive to protect consumer's privacy (13). It means that if the government will mandate RFID chips into new version passport and embed it into a driver's license based on Real ID Act, the government owns the data and needs to take responsibility and proactive measures to protect citizens' identification information (13, 56).

5.4.4 National level privacy regulations

Each country has its own RFID guideline regarding the RFID privacy protection. For example, in the U.S., the regulations of RFID are still on or below state level. North Dakota banned forced RFID implantation in humans in April 2007 (13). California also initiated some privacy legislations in 2004 and 2005 (40). Should the use of RFID, and generally of new technological devices, be regulated by the government, especially regarding issues regarding privacy and individual rights (48)?

CHAPTER 6

FUTURE POTENTIAL APPLICATIONS AND RESEARCH OPPORTUNITIES IN TRASNPORTATION SYSTEMS

6.1 Future Potential Applications

Although it has been used in several fields including transportation, RFID technology needs to be explored in transportation systems more widely and extensively. As mentioned earlier, RFID have been integrated into transportation applications such as AVI, VII, and ITS (52).

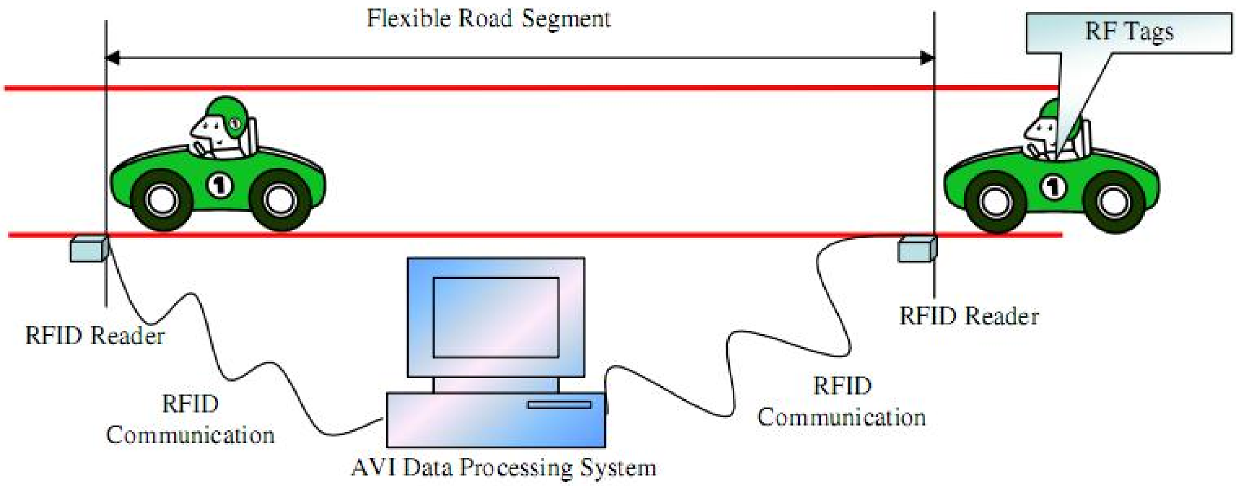

Figure 3 RFID based Automated Vehicle Identification (AVI) system (Source: *52*).

1. AVI uses wireless communication to determine the characteristics of the vehicle. Figure 3 shows the basic working principle of an AVI system. An AVI system includes probe vehicles, electronic tags, roadside antennas, roadside readers, and a central computing facility. The capability of communication is between vehicles and other vehicles, or between vehicles and the road-side. It alerts the driver of any obstacles that could create delay and congestion at freeways and highways. If it were based on RFID, this system would have been much more accurate (52, 66).

2. VII is an advanced vehicle to vehicle communication system and will help drivers keep a certain distance from other vehicles (52). RFID tags may be embedded into vehicles so that readers can detect signals and warn drivers if too close. This will contribute to both crash prevention and congestion relief through the well equipped vehicle-to-vehicle and vehicle-to-roadside communications (52).

3. RFID technology may improve driving safety efficiently if integrated into ITS system. Table 4 summarizes the research opportunities in ITS system, while Figure 4 shows the working principle of the Traffic Priority Control System and Intelligent Speed Control System in ITS.

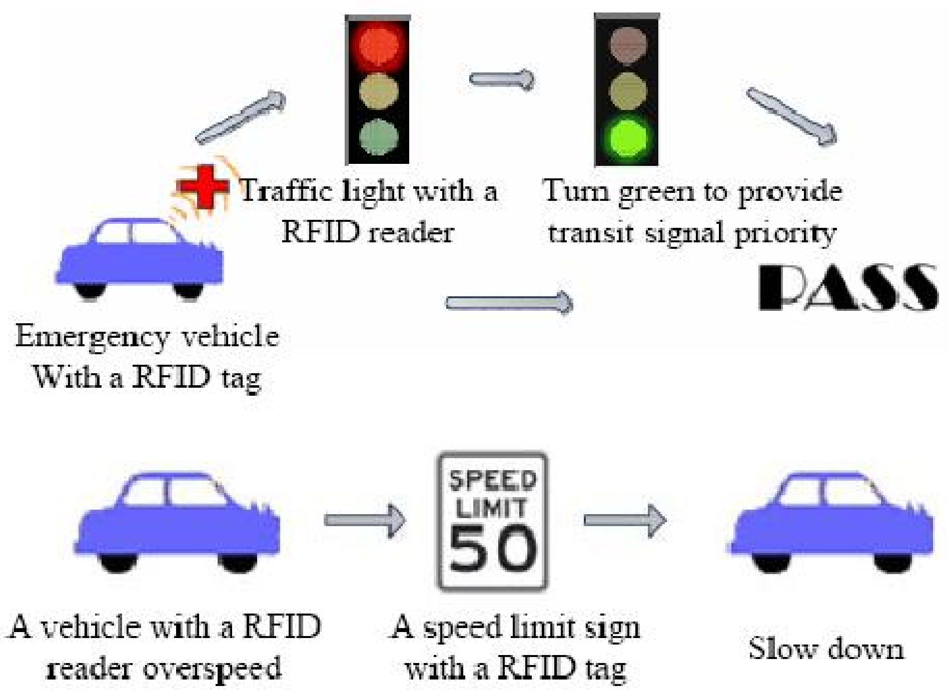

Figure 4 Traffic priority control system (top) and intelligent speed control system (bottom) based on RFID

4. RFID technology can also be deployed in other transportation operation systems such as mobile report and incident detection system, corridor management, dynamic route choice system, pre-trip route choice and route guidance system, etc. (52).

Donath purposed several potential applications requiring lane-level accuracy in urban locations including collision avoidance, enhancement of driver's situation awareness, traffic signal priority for emergency and transit vehicles, traffic signal violation warning, lane change warning, stop sign movement assistant, detection of approaching vehicles, congestion mitigation, congestion pricing, incident and work zone management, route vehicles off road or around incident lane by lane, load balancing across lanes, etc. (56). Table 4 summarizes the typical examples of potential RFID applications in ITS.

Table 4 Typical Examples of Potential RFID Applications in ITS

Category	Application
Collision Avoidance Systems • Advance lane change system • Road departure warning system • Forward and rear collision system • Intersection collision warning • Obstacle detection system	These applications use a variety of sensors to monitor the vehicle's surroundings and warn the driver of conditions that could lead to a collision. RFID integrated into this system would result in the reader's ability to receive signal from another vehicle that contains a RFID tag attachment. If the distance is too short, the reader returns the alert to the prior driver.
Driver Assistance System • Navigation guide sign • Intelligent speed control • Adaptive Cruise control • Drowsy Driver Warning	RFID technology can be used as a navigation guide sign. For example, a RFID tag located in a hospital tells your reader you are about to arrive at a hospital.
Collision Notification System • Advance / ACN	Collision notification system is designed to detect and report the location and severity of incidents to agencies and services responsible for coordinating appropriate emergency response actions.
Crash Prevention and Safety • Road geometry warning system • Highway-rail crossing system • Pedestrian safety • Bicycle warning • Animal warning	For example, the "Stop sign movement assistant" is a system that promotes the safety of drivers. When a vehicle reaches a stop sign, the reader receives a signal from a tag which has been attached in that stop sign and warns the driver to stop (56)
Arterial Management Systems • Surveillance • Traffic control • Parking management	RFID is useful in traffic surveillance system. Traffic control system can use RFID to provide transit signal priority for emergency vehicles (56)
Work Zone Warning System	Route vehicles off road or around incident lane by lane

6.2 Future Research Opportunities

Possible research issues in the future to prepare wider adoption of RFID technology into transportation systems are related to several essential issues, such as technology development, standards, policies, and privacy protection. The following list contains the visions from Donath (56), Gifford (58) and others.

6.2.1 Technology

Extend RFID reading distance and the speed of reading rate; improve the hardware and software for RFID system so that readers can interpret correctly and uniquely signal from multiple tags; RFID users need to know whether RFID rays can damage people's health.

6.2.2 Policies

Both the policy maker and/or special interest group, and standard are of concern. There are several useful research issues that include: (a) evaluate the potential impact of RFID use on the mobility of people and freight, and its impact on congestion (56, 58); (b) develop a training courses for RFID (8); (c) identify who should execute the law or regulations regarding the RFID in transportation; (d) explore the possibility of setting up a development union and a special committee in the U.S. Congress or USDOT. RFID technology has different standards and protocols for different applications fields (16). Therefore, it is necessary to develop performance and functional standards for applications in transportation (56). Additional research issues are: an analytical review of current RFID standards used in transportation (56, 58); a comprehensive comparison of different standards in transportation such as their adoption rate by companies, easiness to implement, flexibility and openness to adapt future advances; more detailed case studies; and recommending a uniform standard for applications in transportation; etc.

6.2.3 Privacy

The recommendations for research opportunities related to this include: reviewing of optimal RFID privacy protection plans in different countries (58); admissibility as evidence in court (56); improving encrypt methodology; setting up a special RFID privacy protection council (13); exploring the possibility of national level RFID privacy protection law.

6.2.4 Cost

Due to the price of RFID, Class 1 Gen 1 is still high (2). The research opportunities include: deploying RFID Class 1 Gen 2 as soon as possible; creating a new, cheaper generation of RFID; reducing tag and reader's prices; and decreasing the cost of the RFID system in general, etc.

CHAPTER 7

CONCLUSION AND SUMMARY

Recognized as one of the ten major technologies of this century, RFID will have a great impact on future industries including transportation. This paper provides the comprehensive literary reviews on RFID applications, with focus on the field of transportation. It summarizes different topics based on existing literatures. Existing RFID applications in transportation fields are identified including identification, security, safety, operation, etc. Obstacles that exist in technology are cost, policy, and privacy that have dampened wider applications of RFID in transportation area. RFID is one of the most forceful technologies that will affect the future including the transportation field. It is believed that RFID-based technologies can be extensively exploited to improve transportation safety and security, increase the efficiency of the transportation system, ultimately save costs, and improve our lives.

BIBLIOGRAPHY

1. What is RFID? RFID Journal. www.rfidjournal.com/article/articleview/1339/1/129/. Accessed July, 2008.
2. The History of RFID Technology. RFID Journal. www.rfidjournal.com/article/articleview/1338/1/129/. Accessed July, 2008.
3. Landt, Jeremy. Shrouds of Time the history of RFID. October, 1 2001. AIM Inc. Accessed July 2008. www.rfidconsultation.eu/docs/ficheiros/shrouds_of_time.pdf.
4. F.A. Radio Frequency Identification Technology in the Department of Defense Supply Chain —Now and Future. Presented at *Research Opportunities in Radio Frequency Identification (RFID) Transportation Applications Conference*, October 17-18, 2006.
5. Erdem, E. Application of RFID Technology for Quality Management in Production and Distribution of Frozen Food Products. Presented at *Research Opportunities in Radio Frequency Identification (RFID) Transportation Applications Conference*, October 17-18, 2006.
6. Hont, S. 2001. The Cutting Edge of RFID Technology and Applications for Manufacturing and Distribution, *Texas Instrument TIRIS* White Paper.
7. Can RFID protect the beef supply? RFID Journal. http://www.rfidjournal.com/article/view/722/1/1. Jan 5, 2003. Accessed July 2008.
8. U.S. Department of Agriculture Approves Digital Angel Livestock RFID Tagging System for National Animal Identification Program. *More RFID.* www.morerfid.com/details.php?subdetail=Report&action=details&report_id=1973&display=RFID/. Accessed July, 2008.
9. RFID in 2008 – Where is the Action? BNET. findarticles.com/p/articles/mi_hb5243/is_200803/ai_n25262268. March 2008. Accessed July 2008.
10. Conway, A. and C. M. Walton. State Enforcement Practices in Commercial Vehicle Security: Advanced Technology Use and Inter-Agency Cooperation. CD-ROM. Transportation Research Board of the National Academies, Washington, D.C.,

2007.
11. Kain, C. RFID Transportation Applications in Operations, Safety, and Security. Presented at Research Opportunities in Radio Frequency Identification (RFID) Transportation Applications Conference, October 17-18, 2006.
12. Texas Department of Transportation to instate RFID TxTag. Infowars. www.infowars.com/articles/bb/toll_roads_tx_tag.htm. September 19, 2005. Accessed July, 2008.
13. RFID *Privacy page.* EPIC. www.epic.org/privacy/rfid/. Accessed July, 2008.
14. RFID in Transportation & Logistics An analysis of eyefortransport's recent survey. *Eyesfortransport*, July, 2006.
15. RFID Adoption Stalls: Executive Summary. Computer Economics. February 2007. www.computereconomics.com/article.cfm?id=1203. Accessed July, 2008.
16. A Summary of RFID Standards. RFID Journal. www.rfidjournal.com/article/articleview/1335/1/129/. Accessed July, 2008.
17. RFID Applications in inventory control. DecisionCraft Analytics. www.decisioncraft.com/dmdirect/rfidapplications.htm. Accessed July, 2008.
18. Radio-frequency identification. Wikipedia. en.wikipedia.org/wiki/RFID. Accessed July, 2008.
19. Finkenzeller, K. RFID Handbook. John Wiley and Sons, 2003.
20. The basics of RFID technology. RFID Journal. www.rfidjournal.com/article/articleview/1337/1/129/. Accessed July, 2008.
21. RFID Module and Principle of working. July 19, 2008. ugpro143.blogspot.com/2008/07/rfid-module-and-principle-of-working.html. Accessed July, 2008.
22. EPCglobal Class1 Gen 2 RFID Specification. *Alien Technology* White Paper, 2005. www.ship2save.com/page_images/wp_alien_gen2.pdf. Accessed July, 2008.
23. Lindsay, J.D., and W. Reade. Cascading RFID Tags. November 2003. www.jefflindsay.com/rfid3.shtml. Accessed July, 2008.
24. HP Advances RFID Adoption with New Solution and Innovation Lab. Hewlett-Packard Development Company. www.hp.com/hpinfo/newsroom/press/2007/071004a.html. October 2007.

Accessed July, 2008.

25. Intel, Intel Mote Sensor Nets/RFID. www.intel.com/research/exploratory/motes.htm. Accessed July, 2008.
26. AT&T Intellectual Property**.** *AT&T Launches Trial of Managed, End-To-End, Hosted RFID Services*. www.corp.att.com/news/2005/09/13-1/. Accessed July, 2008.
27. Harrop, P., and G. Holland, RFID for Postal and Courier Services, 2008-2018. *IDTechEx* Report.
28. Moore, A.M., Replacing Cash with Convenience: The Promise of RFID Payments. *Bank Systems & Technology*. www.banktech.com/story/wireless/BNK20030902S0001/. Accessed July, 2008.
29. Hospitals Get Healthy Dose of RFID, *RFID Journal*, April 27, 2004.
30. RFID: The Next Generation of AIDC, *Zebra Technologies* Application White Paper, 2003.
31. Quinn, R. E., Jr., Radio Frequency ID Devices in Humans, CEJA Report 5-A-07. Presented at *Reference Committee on Amendments to Constitution and Bylaws*, May, 2007
32. Pharmaceutical Product Tampering News Media Factsheet, *HDMA*, April 2004.
33. Koh R., E.M. Schuster, I. Chackrabarti, and A. Bellman, Securing the Pharmaceutical Supply Chain, *Auto-ID Center* White Paper, June 1, 2003.
34. Ergen, E., and B. Akinci, Utilization of Radio-Frequency Identification Tags (RFID) for Transportation Infrastructure Management: Tracking Engineered-To-Order Elements and Materials throughout their Life-Cycles. CD-ROM. Transportation Research Board of the National Academies, Washington, D.C., 2007.
35. Lake, C., and E. Jaselskis, RFID Applications for Owners and Contractors, *Proc. Construction Industry Institute Annual Conf.*, Nashville, Tennessee, 7-24, 2000.
36. Bassi, R., SMARTTAG Project, Client Report to DTI, 213-911(a), The use of RFID technology in the off site manufacturing sector of construction, 2004. www.britichprecast.org/publications/off-site-tagging-final.doc. Accessed July, 2008.
37. Wing, Robert. RFID Applications in construction and Facilities Management. *ITcon* Vol. 11, Special Issue IT in Facility Management, pp.711-721, 2006.

www.itcon.org/cgi-bin/works/Show?2006_50. Accessed July, 2008.

38. Review of the current state of Radio Frequency Identification (RFID) Technology, its use and potential future use in Construction. July, 2006. www.akseli.tekes.fi/opencms/opencms/OhjelmaPortaali/ohjelmat/Sara/fi/Dokumenttiarkisto/Viestinta_ja_aktivointi/Esitysaineisto/Report_RFID_in_Construction.pdf. Accessed July 2008.
39. Boss, R. W., RFID Technology for Libraries. www.ala.org/ala/pla/plapubs/technotes/rfidtechnology.cfm. Accessed July, 2008
40. Juels, A., RFID Security and Privacy: A Research Survey, Journal of Selected Areas in Communication (J-SAC), 24(2), 381-395, February, 2006.
41. E-Plate. www.e-plate.com/. Accessed July, 2008.
42. O'Connor, C. Mary. Michelin Shrinks its eTire Pressure Monitor**.** RFID Journal. www.rfidjournal.com/article/articleprint/2950/-1/1/. Accessed July, 2008.
43. Identic Solutions. *Electronic License Plate.* www.identecsolutions.com/electroniclicenseplate.html. Accessed July, 2008.
44. GAO RFID Inc. *RFID Solutions for Railway Industry.* railway.gaorfid.com/. Accessed July, 2007.
45. Englert, B., Evaluating and improving the security of RFID tags in shipping containers. Presented at *Research Opportunities in Radio Frequency Identification (RFID) Transportation Applications Conference*, October 17-18, 2006.
46. Char, R., Improving Transportation Safety & Security Using RFID. Presented at *Research Opportunities in Radio Frequency Identification (RFID) Transportation Applications Conference*, October 17-18, 2006.
47. Hazardous Materials: Enhancing Rail Transportation Security for Toxic Inhalation Hazard Materials. *Docket* No. RSPA-2004-18730, RIN 2137-AE02, August 16, 2004.
48. Gifford, J., RFID Applications in Transportation Operations. Presented at *Research Opportunities in Radio Frequency Identification (RFID) Transportation Applications Conference*, October 17-18, 2006.
49. Harrison, R., Truck Transportation Security Processes in US-Mexico Trade.

Presented at *Research Opportunities in Radio Frequency Identification (RFID) Transportation Applications Conference*, October 17-18, 2006.

50. New RFID tech would track airport passengers. www.travelwirenews.com/cgi-script/csArticles/articles/000099/009913.htm. Accessed July, 2008.
51. Zeng, H., Application of RFID Technology to Loss Management in Pharmaceutical Distribution. Presented at *Research Opportunities in Radio Frequency Identification (RFID) Transportation Applications Conference*, October 17-18, 2006.
52. Qiao, F., and L. Yu, Potential Applications of Radio Frequency Identification (RFID) *Proceedings of The 4th International Conference on Cybernetics and Information Technologies, Systems and Applications: CITSA 2007, jointly with The 5th International Conference on Computing, Communications and Control Technologies: CCCT 2007, Orlando, Florida, USA, July 12-15, 2007.*
53. U.S. Department of Transportation. *ITS Applications Overview.* April 2008. www.itsoverview.its.dot.gov/. Accessed July, 2008.
54. Heacock, Philip. Smart Baggage Handling Systems Improve Airport Baggage Operations. www.groundsupportworldwide.com/online/article.jsp?id=1074 &siteSection=1/. Accessed July, 2008.
55. Gao RFID Inc. *RFID Solutions for ID Badges and Access Control.* accesscontrol.gaorfid.com/. Accessed July, 2008.
56. Donath, M., Future Directions in RFID Application and Research in Transportation. Presented at *Research Opportunities in Radio Frequency Identification (RFID) Transportation Applications Conference*, October 17-18, 2006.
57. Qiao, F., R. Fatholahzadeh, and L. Yu, Feasibility of Using RFID for Guide Signing, Research Report of Southwest Region University Transportation Center Project, Texas Southern University, 2008, In Preparing.
58. Gifford, J., Policy and Institutional Issues Breakout Report. Presented at *Research Opportunities in Radio Frequency Identification (RFID) Transportation Applications Conference*, October 17-18, 2006.
59. Fennig, C., and C. Karani, Understanding the Evolution: How Gen 2 Will Impact

You. *ODIN Technologies* White Paper, September 2005.

60. United States Department of Transportation *Standards Setting Needs for Freight Management*. Prepared for ISO TC204 ITS/TICS, May 15-17, 2002.
61. Feasibility and Applications of RFID Technologies to Support Right of Way Functions, Texas Department of Transportation (TxDOT) Research Project Statement, Project Number: TxDOT 09-6142, 2008.
62. Jackson, Randall. *RFID Industry Standards.* rfid.home.att.net/rfid-stds.htm. July 2005. Accessed July, 2008.
63. Bacheldor, B. *Savi. Technology Announces IP Licensing for Cargo E-seals.* www.rfidjournal.com/article/articleview/3287/1/1/. Accessed July, 2008.
64. Wiley, T., *Privacy in Radio Frequency Identity Documents*, *Texas Instruments* White Paper RFIDEDOC01, April, 2007.
65. EPC Global Inc. *EPCglobal Standards Overview*. www.epcglobalinc.org/standards/. Accessed July, 2008.
66. Frank, Randy. Making vehicles and highways intelligent. autoelectronics.com/mag/511AETF2.pdf. Accessed July, 2007.