WAVETREND TECHNOLOGIES: MARKETING ANALYSIS

MAJOR QUALIFYING PROJECT
SUBMITTED TO THE FACULTY OF THE MANAGEMENT DEPARTMENT
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Executive Summary

This major qualifying project is a market analysis for Wavetrend Technologies, Inc. Wavetrend is a world leader in the deployment of comprehensive track-and-trace solutions providing real-time visibility of assets, people and modes of transportation. They also provide unprecedented visibility and uncompromising intelligence for mission critical environments. (Wavetrend, 2007) The content of this project entails projections and validation of opportunities to enter markets within specific industries. These projections and validations are based upon market research heavily focused on low penetration rates of competition as well as high return on investment and a detailed description of the technology infrastructure that is currently being leveraged within each segment.

Wavetrend is the second largest installed base of active RFID tags in the world second to Savi Technology, Inc., and is presently a provider of various real-time tracking applications within the aviation, construction, defense, healthcare, and transportation industries. As a market leader, Wavetrend is interested in expanding their customer base by improving their current technology and possibly leveraging other identification technologies to fulfill unmet needs. This project recommends implementation of RFID technology in areas where there is minimal competition with indication of profitability. ABI Research, a leading group of technology analysts, forecasted that the global RFID industry will be valued at $9.7 billion by the year 2013, equaling roughly a 15% compound annual growth rate over the next five years. ABI Research provides strategic insights to more than 500 industry-leading organizations globally.

Our recommendations were to pursue opportunities within the aviation and healthcare industries. These recommendations are supported by a great deal of market research gathered from a variety of primary and secondary sources. Our major primary source was a survey we distributed to a number of Wavetrend’s current customers. The results from the survey provided us with information regarding how these customers are currently leveraging RFID technology. The survey also provided implications as to what the decision-drivers are for the adoption of RFID technology. This enabled us to better understand the reasons why different companies in different industries use location technologies to fulfill various needs. Our secondary sources included various RFID periodicals, several academic publications in the WPI database, Yahoo! Finance, and ABI Research which was previously mentioned.

Within the aviation and healthcare industries, our recommendations are similar but are slightly varied because of the magnitude of the application within the selected industries. In the aviation industry we suggest for Wavetrend to pursue opportunities focusing on the tracking and monitoring of valuable parts and mobile assets. This given application can be implemented within warehouses to regulate inventory size. To date only 1% of airports utilize RFID for this application which suggests opportunities for Wavetrend to profit from. In the healthcare industry, less than 5% of hospitals are using RFID for asset tracking and asset management. Both industries rely on a barcode infrastructure resulting in the loss of valuable assets due to lower accuracy levels (70% - 75%) because of human error. Conversely, RFID proves to be 99.5% accurate which is attributed to its automated feature.

Our MQP team believes that if Wavetrend properly executes our recommendations they will incur profits, increase their market share within each industry, furthermore upholding their brand name as a market leader. Chapters 1 – 5 will bring you through the introduction, background, methodology, results, and implications of our project respectively.

Table of Contents

Executive Summary…..2

Chapter 1 – Introduction…..3

Chapter 2 – Background…..8
Sec. 2.1 – History of Wavetrend…..8
Sec. 2.2 – History of RFID…..11
Sec. 2.3 – Industry Analysis…..16
Sec. 2.4 – Customer Analysis…..18
Sec. 2.5 – Industry Analysts…..21
Sec. 2.6 – Chapter Summary…..23

Chapter 3 – Methodology…..24
Sec. 3.1 – Selecting Industries…..26
Sec. 3.2 – Researching Segments…..28
Sec. 3.3 – Validating Segments…..28
Sec. 3.4 – Lead-User Survey Development…..29

Chapter 4 – Research Results…..35
Sec. 4.1 – Cost of RFID…..36
Sec. 4.2 – Aviation Industry…..38
Sec. 4.3 – Healthcare Industry…..44
Sec. 4.4 – Industries not Pursued…..55
Sec. 4.5 – Survey Results…..58
Sec. 4.6 – RFID in Biomedical Engineering…..66
Sec. 4.7 – Chapter Summary…..87

Chapter 5 – Implications and Conclusion…..89
Sec. 5.1 – Interpretation of Decision Drivers…..89
Sec. 5.2 – Industry Implication…..91
Sec. 5.3 – Limitations…..93
Sec. 5.4 – Lead-User Survey Implications…..95
Sec. 5.5 – Future Projects…..96

Table of Figures…..98

Tables of Appendixes…..99

Sources Sited…..102

Chapter 1 - Introduction

This project identifies new market opportunities for Wavetrend Technology Inc. Wavetrend is a leading producer of RFID (Radio-Frequency Identification Device) technology. RFID technology is an automated identification system used to track goods and assets, and can be implemented in products, animals, or humans (for the purpose of tracking and locating).

Wavetrend is currently involved in five major market segments:

- Aviation – Tracking of baggage, tools, and equipment as well as pre-flight checks of on-board safety equipment
- Construction – Tracking and monitoring of time and attendance for management
- National Defense – Tracking the position of soldiers in mission-critical environments, equipment and machinery, as well as access control to sensitive areas
- Healthcare – Monitoring patient location, emergency location of critical personnel, and visibility of portable assets (i.e. laptops, cardiac monitors, and gurneys)
- Transportation – Tracking of containers, fleet management

Throughout all five market segments, the applications are similar; the tracking and monitoring of valuable goods and assets. This project renders a detailed analysis of RFID and its capabilities and an analysis of some of the industries for which they provide benefits such as secured tracking of valued assets. While exploring the benefits of RIFD, we analyzed competition within the markets of the industries that we have chosen to observe. Examining Wavetrend and their competitors shows us how these companies currently service these markets. Our examination of the players in the markets will provide us with information that indicates if there is substantial room to compete with others in the market. While acknowledging competition and current barriers to a more widespread use, our examination in particular markets provides evidence that companies are benefiting from its use whether it be increased efficiency or cutting overheard cost. With RFID still on the rise to more conventional use, we show what particular drivers show

We examined both national and international markets for trends that support what our research is trying to reveal. In examining the trends of competition in these markets, the overall benefits of the technology, and other encouraging facts about the industry we can give insight as to how identification technology can be applied to these markets that may grow in profitability. For example, the information communication technology industry has increased by 13.2% from 2006 to 2007. Industries with steady growth rates, such as information communication technology, could possibly adopt identification technology quicker if the benefits outweigh the costs of the innovative identification infrastructure.

Many businesses and organizations adopt identification technology to generate measurable achievements such as financial gains, market share, customers, and purchases. These indicators often are reflected in the income statement. The following are some of these indicators:

- Increased customer base
- Increased customer and channel sales by volume and growth percentage
- Increased profitability in existing markets
- Diversified services to existing customers

Before your reach these measurable benchmark, it's important though to understand the influencing factors that drive RFID in a market which is another issue addressed in the project. These factors can be measured using several non-financial market indicators as well. These indicators are important since they often shed light on underlying conditions and circumstances facing the company that are not easily seen within the financial indicators. Chapters 2 and 4 touch on these factors discussing what these drivers could potentially be and what we have actually found to be the influencing factors of RFID respectively.

From this analysis, we form several conclusions for Wavetrend on potential markets for entrance. With the purpose of the project stated, the following chapter will deliver further insight into the key elements of the project. Chapter 2 will provide a better understanding of location identification technology, the location identification industry, Wavetrend's position in markets, and our methods for the project. Chapter 3 entails the methods used to carry out our industry and market analysis. Chapter 4 summarizes the results we obtain from our methods to carrying out a market analysis. Finally Chapter 5 will provide our implications to the project and a conclusion.

Chapter 2 – Background

Chapter 2 deals with the history of Wavetrend, a background of their RFID solutions, and the industries that they serve. Also included are their product lines and some of their partners and competitors. The chapter also covers the history of RFID and its progression into modern day. Other components to this chapter are steps to completing a competitor analysis, industry analysis, and example organization that regularly conducts industry analysis for RFID technology.

Section 2.1 - History of Wavetrend

Wavetrend Technologies Ltd., formerly known as Automated Identification Technologies, was founded in 1999. Headquartered in the United Kingdom, Wavetrend is a provider of long range active RFID technology. They offer a comprehensive range of tags, readers, peripherals and supporting software through their global network of accredited channel partners. These partners are supported by Wavetrend to design, develop, and deliver solutions based on Wavetrend's product offerings. Projects have been deployed successfully across multiple market sectors (Wavetrend, 2007). In 2008, Wavetrend was considered to have the second largest installed base company of active RFID tags in the world, following only Savi Technology (Wavetrend, 2007). Savi is a technology and information services company founded in 1989 that provides real-time supply chain management and security solutions for defense, public sector and commercial markets worldwide. Since 1999, Wavtrend has received over $22 million dollars from outside investors, to expand their technology and product line (Wavetrend, 2007).

Section 2.1.1 – Active RFID Products

In a highly competitive field such as RFID technology, Wavetrend distinguishes itself from its competition through its five separate product lines: Tags, Readers, Antennas, Interface, and Software. They provide products between 25%-50% less than competitive offerings, while still maintaining competitive margins. Wavetrend is able to achieve, on average, 75% more battery life from their tags then their competitors. Tag information is transmitted by means of intelligent firmware utilizing cleverly designed hardware which delivers ultra-low power consumption. (Wavetrend Technologies 1, 2007) Wavetrend's readers provide a low-cost reader infrastructure. Conveniently, Wavetrend readers are Wi-Fi and Ethernet compatible allowing RFID benefits through existing infrastructure. (Wavetrend Technologies 1, 2007) Wavetrend's technology, specifically antennas and software development, provide developers and system integrators a full-featured interface for integration of active RFID data into existing applications.

Section 2.1.2 – Industries Served & Solutions

Wavetrend's Active RFID products offer a comprehensive range of solutions designed to improve the management of people, assets and logistics for better business performance. With the introduction of its GlobalEyes product offering introduced in 2008, Wavetrend has integrated its active RFID capability into a system with greater capability. GlobalEyes is a fully integrated global tracking system, utilizing multiple communications and tracking technologies. These modes include active RFID, GPRS, SATCOM, GPS, GSM, and Zigbee. (Wavetrend Technologies 2, 2007) Saleem Miyan, President and CEO of Wavetrend, stated upon the release of GlobalEyes that Wavetrend was already working on multiple projects around the world where GlobalEyes was offering unparalleled reliability in ensuring that the assets, containers, or vehicles being tracked were completely visible and manageable remotely through the system. Rather than relying on one source technology, it provides an overlapping solution that assures visibility that our customers demand while at the same time providing an appropriate complementary range of technologies to deliver visibility in the harshest and most difficult of environments. (ST Media Group International, 2008)

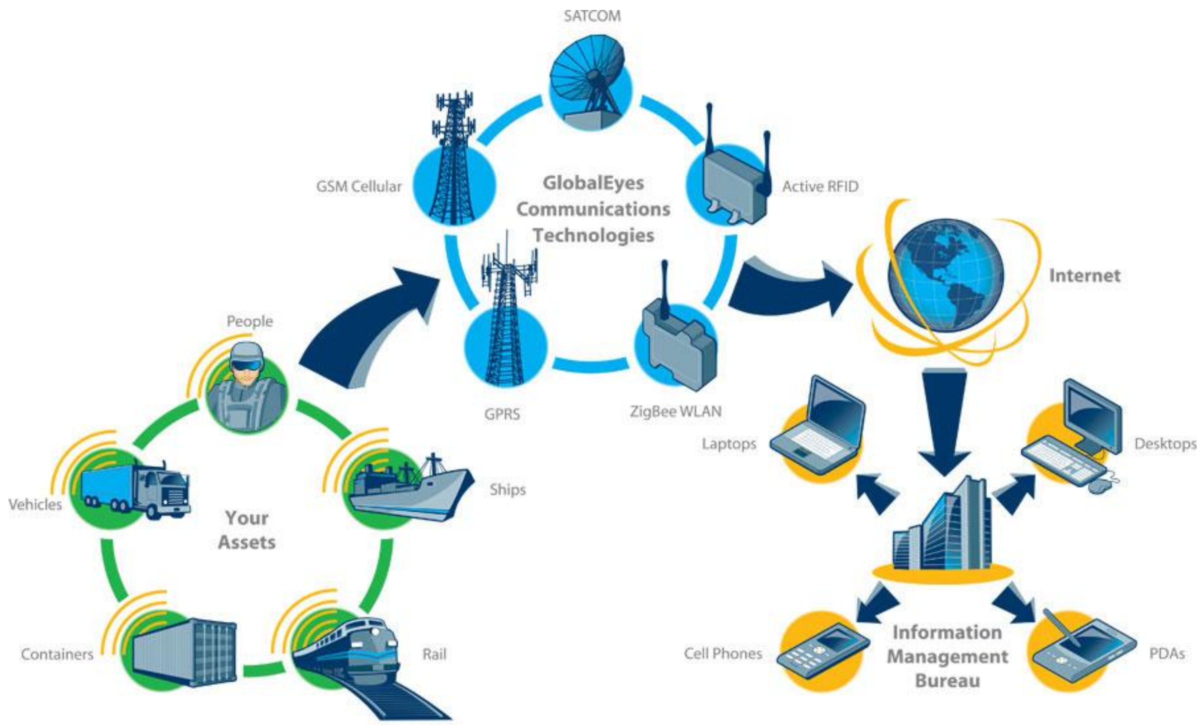


Figure 1: Tracking Assets

Figure 1 above roughly illustrates how Wavetrend's customers use their RFID every day to track and monitor their valuable assets. An asset, such as a ship, is assigned an ID microchip. This microchip sends a wireless signal to either an active RFID reader, GPS satellite, or a cellular tower. When the signal is retrieved, management is able to identify both current and past locations of their ship. Then the location can be sent to computers, cell phones, or PDA's via the Internet. This technology is also often used to monitor and track productivity and location of their employees.

Section 2.1.3 – Product Lines

Wavetrend has two different product lines that use slightly different types of technology. Their first line of products is known as L-Series tags. L-Series tags use fixed data lengths and structures and can also operate at five different transmit intervals. The L-Series readers detect and decode RF transmitted signals from the Wavetrend family of tags. The second line of products is known as W-Series tags. These tags operate at variable data lengths and structures and have the ability to operate on seventeen transmit intervals. W-Series tags also have an improved battery life and often receive three times more data throughput.

Section 2.1.4 – Partners & Competitors

Being the second largest producer of active RFID technology in the world, Wavetrend has built partnerships with some of the leading hardware and software companies in the world. Such partnerships include IBM, which offers a complete skill set for a customer driven supply chain solution enabled by RFID technology. Another partner is Microsoft, with which Wavetrend can offer customers active RFID solutions to manage data and process at the enterprise level through RFID infrastructure compatible with Microsoft's BizTalk Server. (Wavetrend Technologies, 2008) Hewlett-Packard, another partner of Wavetrend, introduced a new service that enables customers to reduce property loss, increase security, and improve audit controls in the data center with RFID technology. (RFID Product News, 2008) However despite its strong partnership base, Wavetrend also faces stiff competition.

Wavetrend is currently an industry leader, however, that does not mean they don't feel pressure from competitors. Some competitors include the market leader Savi, as well as RFCode, Identec, WhereNet, and Axcess. It is our goal to expand this technology into new, untapped markets to help Wavetrend become the market leader.

Section 2.2 – History of RFID

For most of history, little was known about the theories of electricity, magnetism, and optics with relation to mathematics. However throughout the two centuries leading up to the 1800's there was an increase of observational knowledge related to mathematics. There were many scholarly publications on the theory of electromagnetics during this time that sparked insights. Yet nothing compared to when, in 1896, the first successful demonstration of radiotelegraphy across the Atlantic took place, after which the world would not be the same. (Landt, 2005)

Section 2.2.1 – Intro the 20^th Century

The achievement of modern continuous wave (CM) radio generation and transmission of radio signals manifested the beginning of modern radio communication, where all aspects of radio are controlled. Radio signals echoing off radio waves could detect and locate an object by the reflection of the radio waves which correlates to determining position and speed of an object. In practice during World War II, the work in radar was a significant development as the military quickly became fond of these scientific principles. One form of RFID is the combination of radio broadcast technology and radar (Landt, 2005), therefore it is not unexpected that the convergence of these two radio disciplines support the notion that radar was the technological precursor to RFID (Landt, 2005). One of the major drivers for continued work on radar technology was the demise of the Titanic in 1912. Scientists saw tremendous value in a system that would allow a seaborne vessel to detect unseen objects at a distance, thus preventing a disaster. (Shepard, 2005) It was World War II that finally led to the creation of radar. Paranoia grew among opposing countries over the ability to detect an invading country's position, particularly at night or in foggy conditions.

By the time the war began in 1939, most of the countries involved in the war had developed functional radar systems. An early, if not the first, work exploring RFID was the landmark paper by Harry Stockman, "Communication by Means of Reflective Power," published in 1948. (Shepard, 2005) In this work Stockman conveyed that considerable research and development had to be done before the remaining basic problems in reflected power communication could be solved, and the field of useful application explored. (Landt, 2005) These other developments, though not known at the time, consisted of transistors, integrated circuits, microprocessors, development of communication networks, and changing of ways of doing business. The success of RFID application was lingering and it wasn't for another 30 years before technology caught up with Stockman's theory of required developments (Robert, 2008)

Section 2.2.2 – RFID in the Making

During the 1950s, there was a theoretical exploration of RFID techniques with a number of pioneering research and scientific papers being published (Roberts, 2006). This was an era in which exploration of RFID techniques following technical developments in radio and radar in the 1930's and 1940's began to surface. There had been several technological advancements at the time related to RFID that were readily being explored, an example of which being long range transponder systems of "Identification, Friend, or Foe" (IFF) for aircraft. Radio transmission systems with modulated passive responders were a vast breakthrough of the 1950s. As history illustrates that the RFID explosion occurred during the 1970s, it also strongly illustrates that RFID's reality began to ignite in the 1960s. During this decade, various inventors and researchers developed prototype systems. Some active companies partaking in commercial activities developed Electronic Article Surveillance (EAS) equipment, which could only be detected in the presence or absence of a tag in order to counteract the theft of merchandise. (Landt, 2005) During this same time, modern computers came into existence. The integrated circuit arrived, lasers were born, and digital data networks were perfected. (Shepard, 2005) These creations could be made inexpensively and most importantly provide effective antitheft measures.

The explosion of RFID development was underway. Testing of RFID began to accelerate and early adoption of RFID implementation was on the move. In 1973, Mario Cardullo got approval from the U.S. Patent Office for the first RFID tag. During the 1970s, Los Alamos Scientific Laboratory in northern New Mexico had become the focal point for research that led to the development of modern RFID systems. Developers, inventors, companies, academic institutions, and government laboratories were actually working on RFID while notable advancements were being realized, such as practical, completely passive tags. Large companies began to develop their own RFID technology. An example was Raytheon's Raytag in 1973 and RCA and Fairchild Semiconductor's Electronic Identification System (EIS) in 1975. (Shepard, 2005) The Port Authority of New York and New Jersey, a bi-state port district that runs most of the regional transportation infrastructure, including the bridges, tunnels, airports, and seaports within the New York-New Jersey Port District, was also testing systems. These systems, built by General Electric, Westinghouse, Philips, and Glenayre, experienced some success but were limited due to the fact that it was not ready for major usage. At this time intended applications were for animal tracking, vehicle tracking, and factory automation. As the late 1970s approached, tag technology had improved with reduction in size and improvements in functionality. (Shepard, 2005)

Section 2.2.3 – Implementation and Application

Commercial applications of RFID had become mainstream during the 1980's. (Robert, 2008) It was during this decade where RFID would be implemented fully as a result of interests that varied from one part of the world to the other. (Robert, 2008) Interests associated with the United States veered in the direction of transportation, personnel access, and to a smaller degree, animals. As for Europe, the greatest interests were for short range systems for animals and also for various industrial and business applications.

One key aspect to the rapid expansion of RFID was the invention of the personal computer (PC), which allowed both convenient and economical collection and management of data from RFID systems. As of the late 1980s, tests of RFID for collecting tools had been going on for many years, and the first commercial application began in Europe during 1987 in Norway. This was followed in the U.S. by the Dallas North Turnpike in 1989. In 1990, several regional toll agencies formed the E-Z Pass Interagency Group (IAG) to develop a regionally compatible electronic toll collection system. This model of using a single tag and single billing account per vehicle gives access to specific bridges and highways. Automated tolling can eliminate the inconvenience of requiring exact change as well as cash in general. It can also prevent traffic jams at peak commuting times because cars do not have to slow down through these tolls. (Want, 2006) Tolling and rail applications are also appearing in many areas around the globe.

Some of these areas include Australia, China, Philippines, Argentina, Brazil, Mexico, Canada, Japan, Malaysia, Thailand, South Africa, and South Korea. (Landt, 2005)

Section 2.2.4 – Transition into the 21st Century

Other advances continued to surge into the industry such as the first multi-application card used in different business segments. The term 'multi-application card' is used differently by different groups of people. Historically, marketing segments see the card in terms of selling features. IT segments have viewed the card according to the technologies used by the card, and operations segments traditionally view the number of processes the card supports. Now a multi-functional single tag could be used for electronic toll collection, parking lot access, and campus access. (Hendry, 2007) Research and development continued to soar during the 1990s with the expanding functionality of RFID. RFID emergence was becoming standardized and widely deployed. (Robert, 2008) The 21st century explored the smallest microwave tags built utilizing two components: Complementary metal-oxide-semiconductor (CMOS) integrated circuit and antenna. Tags could now be built as adhesive labels, applied with ease to windshields and objects to be monitored. The use of RFID for electronic toll collection had expanded in the U.S. to 3,500 lines of traffic by 2001. The size of tags then simply became limited to the constraints of the antenna. (Landt, 2005)

The impact of RFID is acclaimed regularly in mainstream media and the growing interest of telematics, article tracking, and mobile commerce will bring RFID even closer to the consumer. RFID has become a part of everyday life. (Robert, 2008) Nonetheless, the equipment required to accommodate newer applications and services call for necessary advancements beyond "traditional" RFID technology. The next generation of short-range communication systems between roadsides and vehicles are presently being standardized and are based on wireless LAN techniques. Supply chain management and article tracking are RFID application areas that have grown significantly due to the incorporation of microwave iodes in silicon on the same die as the tag circuitry. This allows a reduction in the size of circuitry, reduction in cost of tags, increased functionality, and increased reliability. (Landt, 2005)

The pace of development in RFID continues to hasten. Though the full potential relies on advancements in other areas as well as development of application software, development of privacy policies and considerations of other legal aspects need to be considered. The developments of supporting infrastructure to design, install, and maintain RFID systems are also essential to RFID's development. With the need for these advancements, an increasing number of engineers are involved in the development and application of RFID and this trend will more than likely continue. At a present glance however, the lack of technical and business people trained in RFID is impeding the growth of the industry. But looking back provides researchers with inspiration so we can lead RFID technology research into the future.

Section 2.3 – Industry Analysis

The next section of the chapter focuses on industry analysis. It includes the implications of these processes and will have a set of guidelines for these analyses.

Section 2.3.1 – Industry Identification

When conducting an industry analysis, the first step to be completed is identifying which industry a particular company is a part of. One must know just how an industry is defined. Michael Porter, in his book Competitive Advantage, refers to an industry as, "a market in which similar or closely related products are sold to buyers." (Porter, 1985) However, this does not mean that the boundaries of these markets are easily recognized. In one of his other books, Competitive Strategy, Porter recognizes that there are many scopes through which an industry can be viewed, stating, "…the proper definition of a company's industry or industries has become an endlessly debated subject." (Porter, 1985)

While all this may be true, in order to complete an industry analysis, one must determine to the best of their ability what industry a company is part of. As stated by Porter, this analysis can be very difficult because of the many questions that surround the specific industry. "In many instances, an industry can be reasonably defined in more than one way. Do makers of facsimile machines compete with each other…Is competition primarily between products, companies, or networks of alliance partners?...The use of too narrow a definition can lead to strategic myopia and cause executives to overlook important opportunities or threats". (Kluyver, 2009) Given that there may be many ways to define any industry, all include at least product, customers, geography, and technology as major factors in that definition. There are certainly other aspects to industry, such as size and growth, but product, customers, geography, and technology are staples of an industry

Section 2.3.2 – Market/Trend Analysis

Once the industry is established, the next step is to start evaluating the markets and trends within industries. For the purpose of this project the team has chosen to break down industries using several different analytical tools. These tools were a market/trend analysis and a customer analysis.

Performing a market trend consists of examining, "actual and potential size of the market, market and segment growth, market and segment profitability, the underlying cost structure and trends, current and emerging distribution systems, the importance of regulatory issues, and technological changes". (Kluyver, 2009) Information regarding the size of the market as well as key players can be found through journal articles, reports, electronic sources, case studies, and interviews that are all used throughout Chapters 3 and 4 and can be referenced in the bibliography section. For example, we utilize electronic sources such as Yahoo! Finance which is a useful source for financial text. Another tool to utilize for a thorough market overview may be ABI Research. Also, reports from companies pushing RFID may be able to help enlighten us on how some customers were able to improve regulatory compliance mentioned earlier with federal Sarbanes-Oxley reporting requirements and also the Joint

Commission on Accreditation of Healthcare. (AT&T, 2007) All of these mentioned tools are extremely useful in discovering market players and market drivers which are records that will help us choose particular industries. A good market analysis is needed so a company can weigh the pros and cons of entering or remaining in a market. For this project, markets crowded with competitors will take up less focus while those that may be significantly lacking in competition will be more heavily analyzed. elude

Section 2.4 - Customer Analysis

In addition to formulating a good business strategy, a customer analysis helps to access customer segments. This helpful tool will allow Wavetrend to identify and target the most promising and profitable customers. The customer base is one of the most important resources of a company and understanding the customers is critical to the success of Wavetrend. In performing a customer analysis it is important to: (1) identify Wavetrend's targeted customers, (2) convey the needs of these customers, and finally (3) show how Wavetrend's products and services satisfy these needs. We took these components of a customer analysis from Growthink, Inc., a provider of professional advisory services for startups, small and medium-sized enterprises, middle market organizations, and Fortune 2000 companies pursuing growth.

2.4.1 - Identifying Customers

In this analysis we first define which customers Wavetrend is serving. This part requires specificity and should divert from inadequate or generalized customer focus. As previously stated, the first thing we looked into was different industries, selected on their previous and expected future successes. With one of the goals of Wavetrend being to implement identification technology to new market segments, they shouldn't limit themselves to just national segments but also international segments as well. Thereafter narrowing down industries of focus, we will then look at which companies within these industries are doing the best among its competition. (Growthink, Inc., 2009)

Once the plan has clearly identified and defined the company's target customers, it is necessary to explain the characteristics of these customers. These characteristics can be broken down in many ways. In regards to Wavetrend and their approach, there are questions that we can ask in order to clarify these characteristics. Is this customer base growing or decreasing? Questions such as this will assist Wavetrend in planning who to approach and how to approach them. Glancing into the growth or decrease in this customer base also helped decide whether or not it is feasible to even consider these customers. (Growthink, Inc., 2009)

Along with these topics to consider in detailing the demographics of Wavetrend's customers, the average revenues/incomes of these customers must also be considered. Taking these matters into account helps to determine whether or not these desired customers can afford the products and services provided by Wavetrend. If customers cannot meet the expense of utilizing what Wavetrend has to offer, then this shows that Wavetrend must do some reevaluation of their pricing and or reevaluation of their target customers. It should be normal to expect disagreements and objections when dealing with customers therefore it is important for Wavetrend to find out what customers might find objectionable about their products and services. Though customers may not directly tell you these concerns, you can gain insight by paying close attention to what they ask you. Also important to ask is why they have not tried the products and services of Wavetrend and listing objectionable claims to refute their answers. (Growthink, Inc., 2009)

2.4.2 - Convey Customer Needs

After clearly defining targeted customers and their demographics, the plan must detail the needs of these customers. This step can take the form of past actions such as researching what percent of these customers have purchased similar products in the past. In observing this Wavetrend can gain more insight as to what customers are looking to achieve from identification technology and make considerable implications that their products and services can enhance customer business and replace other existing technologies. Another aspect to expressing the understanding of customer needs is detailing the drivers for customer decision-making. Though it is not always easy to figure out what factors affect the customer's decision-making, there are various clues to look for. One clue we will specifically look for is whether or not the customer has valuable assets that are worth tracking by analyzing each potential customers business. (Growthink, Inc., 2009)

Section 2.4.3 – Satisfying Customer Need

At this point we are equipped with the knowledge of a targeted consumer base for RFID technology and know what needs need to be conveyed in order for customers to draw to RFID technology. Since we have targeted a customer base and know what needs have to be satisfied, we must then show how Wavetrend can satisfy these needs. For this to happen will must explore the market players that are already competing. Making note as to how competitors who service similar location solutions will provide insight as to how Wavetrend can take advantage of similar customers.

Section 2.4.4 - Understanding the Decision Drivers– Purchasing Criteria & Influences

One last, but far from least, critical step in the customer analysis is showing an understanding of the decision drivers with respect to influences and rationale. Understanding rationale invoked in adoption decisions may prove useful in explaining many superficial implementations which fail to deliver adoption benefits and lead to unexpected IT diffusion patterns. We are aware that there are many factors with underlying rationale taken into consideration when deciding to adopt RFID. These factors are:

(1) <u>Technological Factors</u> such as perceived costs and benefits are facilitators and inhibitors of adoption intent on RFID. Perceived innovation characteristics such as complexity, compatibility, costs and communicability can be identified as important adoption predictors

(2) External Environmental Factors such as standard convergence (data, software/hardware and legal standards), perceived stakeholder privacy, and perceived consumer readiness are also viewed as important environmental influences in regards to RFID adoption.

(3) Inter-organizational Pressure Factors such as competitive pressure, industry pressure, regulatory pressure, inter-business association pressures, and pressure from focal institution powerhouses are also suggested influences of RFID implementation.

(4) Organizational Readiness Factors, meaning factors conveying availability of financial and technological resources (people, technology, expertise) of a firm. In relation to factors of External Environment, top management presence and support is a key factor for organization RFID initiatives. Other Organizational Readiness Factors include IS infrastructure and capabilities along with financial readiness. (Sharma, Citurs, & Konsynski, 2007)

Section 2.5 – Industry Analysts

Many companies have examined the location identification industry, especially the market for RFID technology. Examining how these companies execute an industry analysis will give our project group a better idea of how our industry analysis should be carried out. We chose to look at ABI Research's Annual RFID End-User Survey,

Section 2.5.1 – ABI Research

ABI Research was founded in 1990 to assist manufacturers of wireless semiconductor components in understanding and entering new markets. Later during the 90s, ABI Research expanded its analytical coverage to a broader base of manufacturers and service companies, such as Wavetrend, participating in the technology market revolution. To further validate ABI Research as a firm worthy to follow in terms of researching and reporting on industries, the opinions and strategic insights that their analysts provide appear in the major media sources of the world and in hundreds of industry-specific trade publications both online and in print. (Allied Business Intelligence, 2009) With ABI Research being a valid source in pointing out key market issues needed to be tackled in a successful analysis, we based a lot of our reported market criteria in chapter 4 of the suggestions from ABI. (Allied Business Intelligence, Inc., 2009) Below are some examples of market issues which ABI Research Service cover:

(A) RFID Technology Global Spectrum (low – high – ultrahigh frequencies)
(B) Hybrid RFID-Legacy Systems (GPS, Cellular, Wi-Fi, Barcode, ZigBee)
(C) Passive & Active RFID
(D) Infrastructure and Services

Though ABI Research covers numerous other market issues, the ones presented above are related the most to our project. Unfortunately the ABI information we were provided with by Wavetrend were not actual results from their reports. However the criterion which they reported on is what we used to report on. The market areas that ABI Research chose to explore are very important to our project because it set guidelines as to what information to investigate. To help illustrate the meaning of ABI Research procedures to our project we will start by giving instances as to where these issues were covered in different parts of the project. In all of their industry reports they report what types of frequency, on the RFID technology global spectrum, are commonly used in markets depending on usage in the industries. In our project, we are to be researching markets that utilize ultrahigh frequency because asset tracking requires real-time location systems (RTLS) to correlate with Wavetrend's products and services that provide RTLS for high-valued assets, a very important concept in our project. In terms of RFID legacy systems, we learned that there are many types of location technologies out there that are currently being leveraged. So for example, in order to further our knowledge about competition in regards to other technologies possibly servicing areas where Wavetrend could, we presented these other technologies in our lead-user survey asking which is seen as more profitable and which technology can be utilized in more ways than others.

ABI also covers the different types of RFID which are active tags. Wavetrend is a company that penetrates markets where valued items need to be traced in which active tags can service that task.

Passive tags encompass the ability to better identify objects. Though these two tags serve similar in which they both are identification enabled, they need to be specified when reporting them in our project because Wavetrend services active solutions. Reporting the passive solutions is important to keep in mind because it may open horizons to new markets for Wavetrend to penetrate. The final market issue I will cover obove that is relevant to our project is covering infrastructure. RFID is not a very widely spread technology and is still in its growing stage, therefore implementing it will mostly require a change in or first time installation of a new infrastructure. This is a very costly process and is a big reason for its sluggish adoption. Additionally, if there is already a widespread infrastructure as we have learned, companies without RFID are hesitant to adopt because of the slim convergence across industries. These are only a few of the marketing issues which we adopt from ABI Research, however we are simply trying to convey why ABI Research was important to our project. (Allied Business Intelligence, 2009)

2.6 Summary

We've devoted this chapter to explaining these methods a in depth for several reasons. Information about Wavetrend was conveyed to create an understanding of the company for which this project is being conducted. The background on RFID is stated to relay to the reader a basic understand of RFID, its beginnings and future outlook. Sections 2.3 through 2.5 are the research techniques that our team will be using throughout the entirety of this project. Each of the sections was designed as a way to educate our team in learning about the tactics, through research, that would be necessary to complete a research strategy. Derived from this chapter is the methodology which will be in Chapter 3.

Chapter 3 – Methodology

This chapter discusses the procedure we used in developing and executing our industry analysis for Wavetrend Inc. Section 3.1 will explain the first step of this industry analysis: how we decided which industries to examine. Section 3.2 will introduce our method for choosing segments within these industries, and section 3.3 will introduce our method of creating and implementing a survey of lead users. Prior to engaging in selecting the industries, we completed method chart which was centered on four building blocks:

1. ISSUES that needed to be addressed preceding the selection of industries.
2. KEY QUESTIONS that needed to be asked in order to broaden our scope of the issues that we later address.
3. Relevant DATA REQUIRED in gathering information that will lead to answering our posed questions.
4. METHODOLOGY which is the plan of action in completing the project.

As our research persisted overtime, our methods to research became modified in some aspects. However the methodology chart, suggested by our advisor, set us on a excellent path exposing us to considerations we had to take into perspective in order to obtain useful information. With the chart completed, we were able to begin looking for specific information that would help address the issues which we began with. See Figure 2 for our methodology chart.

Figure 2: Example Methods Chart

Issues	Key Questions	Data Required	Methodology
Existing location technologies and the markets they serve.	1. Which existing technology has grown the most recently? 2. Are there possibilities for using developing technologies to enhance current location technologies?	Sources that reveal how different locations technology products are used. Also documentation that reveals possibilities of integration of RFID and existing technologies	Researching various types of location technologies and acknowledge similarities and dissimilarities in applications. Tools used would be ABI Research, Business Week, Marketresearch.com
Establishing a customer need and demand in markets	1. Within each industry, what specific assets are valued enough to track with location technology? 2. How can we convey financial returns? Other benefits beside financial return?	Documents that reveal instances where RFID technology could help in cutting cost, increasing efficiency, heightened security of assets. Also future applications to appeal to adopters or possible adopters	We administered a survey/ questionnaire contacting system integrators and end-users to in different industries get diversified feedback on location technology and its uses.. We also continued observe practical situations where RFID could have made useful through news articles, reports, and journals.
RFID market Inhibitors	1. What are the possible barriers to entry? 2. What are the barriers to adoption?	We need to know what the major disadvantages of RFID technology are. These may be cost, reoccurring inefficiency, drastic change infrastructure, unforeseen promising returns.	Since RFID is still a growing technology we researched various organizations that have successfully implemented RFID technology in their facilities. RFID is still a growing technology, and so we noted any instance where they may have mentioned or suggested reasons why they hadn't done it early. We will then present these different reasons in chapter 4 results.
Influencing decision drivers of RFID	1. Internal environment pressures 2. Inter-organization pressures 3. Inter-organizational pressures 4. Technology pressure	Journals, reports, case studies, etc. suggesting why they decided to push for adoption of RFID. Other data would be other organizations that have done studies and have provide educated suggestions as to what other factors are driving RFID	Research organizations that have had to identify the key decision drivers for adoption of RFID. Based off our research we can then relay any similarities with what we found both in our own research and research done by others for a more thorough perspective.

Section 3.1 – Selecting Industries

Selecting an industry to analyze requires creating a logical framework that can take into account the different aspects of each industry. To reiterate what was mentioned earlier in Section 2.3.1 Industry Identification, the product, customers, geography, and technology are staples of an industry. We utilized a few different sources to select each industry and to later gather necessary information about each industry. The information we gathered alludes to these sources were industry reports from ABI Research and RFID journal. In terms of collecting financial data about the industries, we utilized "Yahoo! Finance", the top financial news and research website in the United States.

The sources that we initially used to identify viable industries were online news & information websites such as *RFID Journal* and *RFID News* which are oriented specifically toward RFID application. Another fundamental research tool that we employed was ABI Research provided to us by Wavetrend. ABI Research publishes market research and technology intelligence on the wireless and electronic industries as well as other industries. Within ABI Research reports, we used the industries presented in Section 4 (page 5) of ABI's 2007 Annual RFID End-User Survey as a starting point, listing the possible industries for RFID technology as those shown in Figure 3. Section 4.2 introduced a graph showing the percentage of respondents within each market that either "…are using, piloting/evaluating, and/or planning to install RFID. (Liard & Wheelock, 2007)

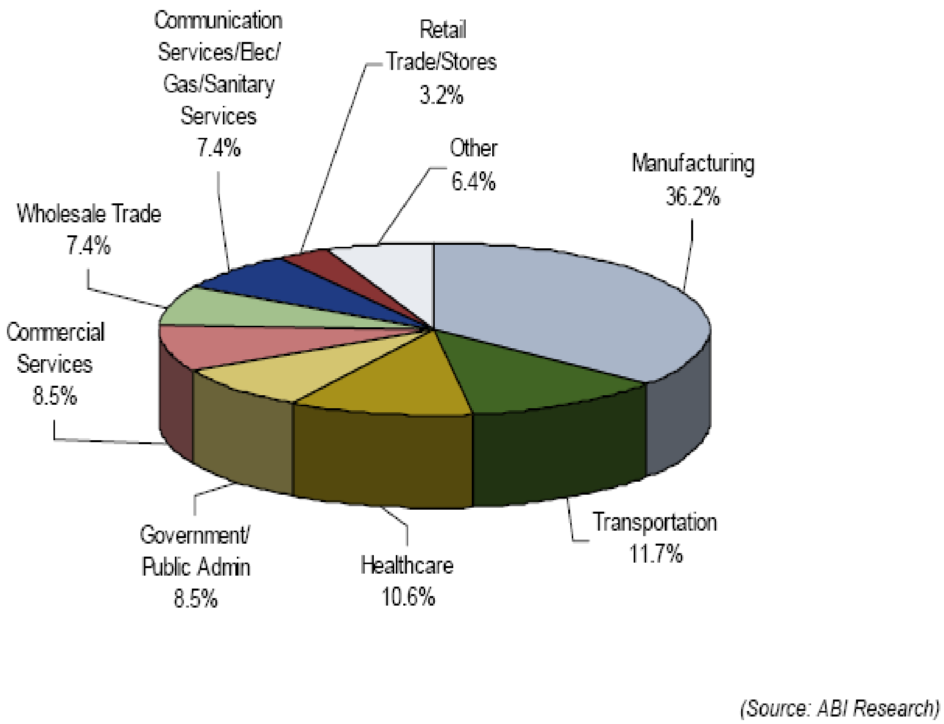


Figure 3: Percentage of Respondents for ABI's End-User Survey Segmented by Primary Vertical Market

Many of the industries which we began to investigate such as healthcare, manufacturing, retail trade/stores, transportation, stemmed from the industries found in the graph of Figure 1.

In order to decide which of these industries we would further research, we examined what was currently being done by other location technology companies in each industry. This initial research allowed us to see which industries would be best to continue researching. In order to verify and select a few specific industries, we presented what we had found to our sponsor. Since he had many years of experience in location technology and its marketing, his input was critical in deciding which industries we would examine.

Section 3.2 - Researching Segments

In order to uncover potential industry segments of entry, we used RFID Journal and listed potential applications of RFID within each industry. RFID Journal was more useful in uncovering potential industry segments, rather than analyzing each industry as a whole. Nonetheless, it was still a valuable tool to verify the credible information provided by the ABI Research report. In order to choose specific industry segments, we searched phrases like "RFID in healthcare" or "aviation industry implements RFID". Our focus was to use key words such as "RFID" and the industry of choice e.g. "Retail." What we discovered through these searches were articles describing how RFID technology was currently being leveraged in the different segments of each industry. These articles highlighted different industry segments and different business applications of RFID. The applications explained by these articles included: asset tracking, supply chain management, payment systems, and security & access control (RFID Journal, 2005).

In order to compare segments, we looked at four criteria: return on investment of currently implemented systems, current penetration rate of RFID into the segment, specifications of current infrastructures implemented, and competitors already leveraging the segment. The segments with the greatest examples of return on investment, lowest penetration rates, least number of quality competitors, and descriptive articles about the infrastructure used in the segment were graded highest. After choosing several industries and compiling data in each of the four categories supporting why we felt the industry should be examined, we presented this information to our sponsor. Since he has had several years of experience in the industry, his input was extremely useful in deciding which industries to examine.

Section 3.3 – Validating Segments

To effectively convey value to potential users of RFID technology, it is imperative that you prove this value on some sort of standard. This standard is met by focusing on:

- Return on investment from implementing the location technology. There are a variety of reasons why RFID adoption has been slow and one of them is because the payback period has typically been less immediately visible than what most companies prefer. Therefore presenting cases where end users of RFID have had substantial final returns will be very powerful in pitching to Wavetrend. ROI was at first measured on cost savings equaling the cost to install the RFID system. Any savings thereafter is considered bank.

- Penetration rate of companies deploying RFID in chosen industries. Prior to carrying out the methodology, we were advised to focus more of our efforts on targeting an industry that did not have too many players and an industry that had room to gain market share. An industry that isn't already mature with competitors leaves optimism for those trying to get in on the action within the industry.

- Knowing competitors involved in the chosen industry is also an important for anyone trying to compete in an industry. Awareness of successful competitors provides insight as to what elements are necessary for success. These elements may include a particular type of location technology being used besides RFID, or the distinction between using passive or active systems, or incorporating RFID with Wi-Fi certified systems for the location technology to work.

- Knowing the current infrastructure being utilized that is serving the need that RFID has the potential to serve can be an element that adds value to RFID. By comparing the advantages and disadvantages of RFID and opposing location technologies, you can pose the potential benefits that RFID has over these opposing technologies. For example, in comparison to barcode, RFID bears advantages such as automated data collection, read/write capability, unique identification of each tagged item, superior read range, increased read rate, and it doesn't require a direct line-of-sight to tags.

Section 3.4 - Lead-User Survey Development

We surveyed a group of Wavetrend's current customers to determine how they leverage RFID technology. We also wanted to determine what the driving factors for adoption were and if they varied from industry to industry. We chose an online survey, using surveymonkey.com, in order to better understand the needs of customers who currently use RFID technology in their daily operations. This was in an attempt to better understand the reasons why different companies, in different industries, use location technologies to fulfill various needs. We were planning on using the recorded results as a validation technique for our industry analysis. However, the number of responses we received made it quite difficult to do so. This will be discussed in greater detail later in the chapter.

Section 3.4.1 – Survey Objectives

In order to verify our secondary data research, we decided to collect primary data by executing a survey of Wavetrend's customers. Many of these customers provide Wavetrend's location technology to a wide range of end-users. Surveying these distributors would allow us to use their expertise in the industry as an additional source for our industry and segment selections. The first step we took was to define the goals of our survey, which were:

- to create a clear, concise, and easy survey from the survey-taker's perspective
- to create questions that will qualify the survey-taker
- to create questions that will provide us with the most information in the little time that we had to work with. Some of the objectives of the question were:

  (A) To attain a multi-perspective view or persuasion on RFID and other location technologies and their profitability. Having these perspectives present in our minds will help us draw conclusions as to which technology is being leveraged more or is thought to be leveraged more in the future. These opinions may be helpful to Wavetrend because it deals with opposing technologies that have features different from Wavetrend’s products. If the survey is supporting other technologies then we can recommend Wavetrend to look into adding features of these opposing technologies.

  (B) To include room for respondents to express what they feel are the reasons that hinder adoption of RFID technology. With this information handy we can use it to find out reasons why companies aren't adopting RFID faster. For example, we anticipated cost as being one of the hindering reasons. We allow respondents to express what is the most expensive feature (Hardware, Software, and Services/ Maintenance) when implementing an RFID system. Perhaps we can then advise to Wavetrend what customers would like to see more affordable especially with Technology cost being a major factor.

(C) To get an idea which industries are being served by end-users and system integrators. We also wanted to find out which industries are bringing more profits to the business of the respondents. Our intentions behind asking this information was to observe any trends in the responses we got. If there is a trend or tendency towards specific industry we assume that a majority of profits are from these industries. A trend that is present will be conveyed to Wavetrend with inclination to approach these industries if they already have no.

Section 3.4.2 – Key Survey Resources

Don Dillman – "Surveys: The Tailored Design Method"

As a guideline to reach these goals listed in section 3.4.1, we used the tailored design method, which is described in the book "Internet, Mail, and Mix Mode Surveys" by Don Dillman. The method was designed to improve response rates of the survey and to increase the quality of the feedback received through survey responses. We tried to incorporate as many details of the tailored method as possible. Dillman claims that the proper implementation of the tailor design method could increase your response rate by up to 70%. (Dillman, 2009) The tailor method was designed to do two things: Increase the response rates for a survey and increase the quality of the feedback you receive.

In order to increase response rates, the concept of the social exchange theory is discussed in detail. The social exchange theory is one that describes why people do things for other people. (Dillman, 2009) A majority of this section discussed the incentives used in past surveys to subsequently increase response rates. For example, one surveyor decided to pay one dollar to each person who participated in the survey. As a result his response rates were drastically better than his control experiment, the survey without the monetary incentive. In our project we promised to share the results of the survey with the parties who participated. After reviewing the questions we felt like many system integrators would see value in receiving the results. According to the social exchange theory appropriate usage of such incentives can greatly increase response rates.

Dillman's tailored design method also describes how to design individual questions, as well as set a series of guidelines regarding how to design the layout of the survey. It has been proved that both question and layout design are directly related to the quality of information obtained through surveying techniques (Dillman, 2009). Dillman also incorporates a series of rules that minimize the total survey error. Our group used many of these techniques when designing our survey and cover letter.

Section 3.4.2 - Implementation

To gain another perspective of what opportunities are available for location technologies, we decided to execute a survey of Wavetrend's customers, many of which are companies that provide location technology to a wide range of end-users. The survey was another means to supporting our selection of industries and segments. However, due to the fact that development of this survey took several attempts, it was not executed to the full list of Wavetrend customers, and results were not gathered before the rest of our research was completed. Furthermore, in developing the questionnaire, we first composed a cover letter which effectively conveyed why the survey was important, why it will help the company of the respondent, and an incentive for completing the survey. The incentive we provided was to share an aggregate summary of the results. The survey was sent out to 30 customers of Wavetrend, both end-users and system integrators, who were selected by our sponsor. They were contacted through email and on the cover letter was a link directing them to the survey which was directed through Survey Monkey, a web-based survey administrator.

Section 3.4.3 –Survey Questions

We created a ten-question survey in order to not take up too much time from the survey-takers. The first question we asked simply qualified the survey-taker as either an end-user of Wavetrend's products or a system integrator.

Questions 2, 5, and 6 were designed to discover which industries these system integrators were currently selling to. For example, question 2 asks: "Which industry do you feel currently presents the best opportunity for technologies such as RFID or GPS in the next few years?" By identifying which industries have the most potential, as well as which are spending the most and purchasing the most location technologies, we would be able to rank the industries according to the survey responses.

Question 3 asks the survey-taker to rank the profitability of several different types of location technologies. This question was designed to discover which technologies are preferred by end-users, and therefore help us suggest to Wavetrend which technologies should be implemented in the next few years.

Questions 4 and 7 ask about the reasons end-users decide to either implement location technologies or not implement them. These questions were designed to generate responses that would allow us to specify to Wavetrend what it really is that affects purchasing decisions of end-users. Question 8 is a simple question designed to discover basically how the company heard about RFID technology.

Question 9 asks the survey-taker to "Please rank the following from 1 being the largest expense to 3 being the smallest expense when implementing an RFID system." The responses available to be ranked are: hardware, software, and services/maintenance. This question is designed to verify which of these attributes of an RFID system is the most expensive.

Question 10 simply asks, "How long did it take to reach the break-even on your investment of RFID technology?" The purpose of this question is to discover the length of time it takes these customers to make a return on their investment. The cover letter to the survey and actual survey questions in their actual format can be observed in Appendix A and B in the Table of Appendixes after chapter 5.

Chapter 4 –Results

This chapter describes the results of our research efforts to determine feasible markets within industries that could support RFID adoption. The two markets that we selected are asset tracking and maintenance for both aviation and healthcare industries. Some other industries that we obtained data while researching were agriculture, biotech, financial, and cold-chain. In many cases for these industries, organizations have saved significant dollar amounts in ensuring security for their high-valued asset and right-sizing their inventory due to increase visibility of their high-valued assets. We were also exposed to the competitive aspect of RFID within these industries. In the forthcoming sections of this results chapter, we present the benefits for different organizations in the use of RFID which is supported by the return on investment and the rate at which competitors are entering these markets which we are suggest Wavetrend pursuit. As you read you will also be exposed to competitors who are taking advantage of these available markets and also experiencing financial rewards from it.

Figure 4: Snapshot Industry Data

Industry	Application	Penetration Rate	Current Infrastructure	RFID Barriers to Entry
Aviation	(1) Airline Parts Maintenance & Tracking (2) Mobile Asset Management	Only 1% of airports are using RFID for asset tracking and management	Barcode	(1) high technology cost, (2) unsure Payback Periods, (3) lacking RFID industry standard
Healthcare	(1) Medical Device & High-Value Asset Tracking (2) Inventory Management	Less than 5% of hospitals are using RFID for asset tracking and management	(1) Barcode (2) RFID-Based Tracking, (3) Wi-Fi-Based RFID Tracking	(1) maximizing benefits is a daunting task, (2) lacking RFID industry standard (3) unclear industry standard

Section 4.1 – Cost of RFID

As far as the cost of implementing an RFID system like this goes there are several costs that must be accounted for. In any system there are software, hardware, and service costs to be incurred. Because each hospital has different needs to be met there is no standard as far as how much it costs to fit a hospital with this technology. However, prices for individual tags, readers, antennae, host computer systems, middleware and several other key components to the system are readily available in Figure 5.

Section 4.1.1 – Cost of Components

Figure 5: RFID elements of cost

Components	Price Range	Special Considerations
Tags	40 Cents	• Cost is recurring • Mounting accessories or specialized packaging can double the tag cost • Printer/encoder and label applicator costs $5,000 to $25,000
Readers and Antennae	$1,500 to $5,000	• Additional antennae cost $500 or more • Handheld readers cost $1,500 and up
Host Computer System	$1,000+ to $100,000+	• Not necessary unless new middleware or new applications cannot run on existing system
Middleware	$25,000 to $100,000	• Cost is often per site/location • A reader appliance with built-in middleware can cost significantly less ($8,000 to $10,000) • Middleware can also be a built-in feature of the software application
Host Applications	Varies	• RFID-enabled version of your existing application software may be available for an upgrade fee
Installation and Tuning	Varies	• Depends on site conditions, existing infrastructure, and set-up and project requirements
Integration and Business Process Reengineering	$0 to $1 million+	• Basic integration can be provided in the RFID-enabled version of existing application software • Full integration can take years and offer long-term payoff
Support and Maintenance	20% to 25% of overall project cost	• Includes training and replacement cost of failing equipment • Cost is recurring yearly

Generally speaking, the application requirement is the primary driver for the selection of a particular type of tag. Two types of costs are associated with tags: acquisition cost and preparation cost. Note that some of these costs may be recurring, so careful planning and negotiation can bring volume discounts, thus lowering tag costs. In acquisition costs, significant volumes can yield discounts of 20% to 30%. Preparation costs are related costs, for example, mounting tags on a metal surface or a container filled with liquid may require special mounting accessories so that the tag can be read properly by a reader. These costs can range anywhere from 5,000 to 25,000 as shown in Figure 8. (Moradpour, 2009)

Reader range, multi-frequency handling capability (agile readers), and antennae capability affect reader costs. Some manufacturers combine the host computer functionality and a reader in one package to create a reader appliance. Reader prices, with one or two external antennae, vary from $1,500 to more than $5,000 for readers used in rugged industrial environments. Additional antennae can cost $500 or more. Handheld readers typically combine the antenna and the reader in one package, costing more than $1,500. (Moradpour, 2009)

The host computers typically run the RFID middleware software-responsible for collecting, filtering, and routing RFID tag data-and other applications such as warehouse management and inventory control. Depending on the type of application a host computer system infrastructure can run anywhere from a few thousand dollars to hundreds of thousands of dollars. The cost of standalone RFID middleware can be anywhere from $25,000 to $100,000 and up, and includes a site license (e.g. for a single plant or warehouse location). A reader appliance, on the other hand, could provide similar functionality at a cost of $8,000 to $10,000 per appliance. The cost of application software depends on the application. (Moradpour, 2009)

The on-going support and maintenance of the new infrastructure and re-evaluation of existing processes to maximize the usage of newly available data represent additional costs as well. For example, a software support and service agreement can cost 15% of software license costs on an annual basis. Physical equipment can depreciate or fail altogether and need replacement. Various existing processes may need to be re-engineered to take advantage of the real-time data collected by an RFID system. Costs may also be incurred by training different stakeholders in using these new processes. A good rule of thumb is to assign somewhere between 20 to 25% of the total project cost to annual support and maintenance costs. (Moradpour, 2009).

One last but very important idea in the scope of pricing RFID is to consider the size of the hospitals and airports that RFID is being implemented in. Small hospitals, consisting of around 250 licensed beds, typically cost around $250,000. Medium sized hospitals, consisting of around 300 – 500 licensed beds, cost around $300,000 - $500,000. Finally, large hospitals that typically have over 500 licensed beds and can cost from $550,000 - $1M. For airports, the total cost for implementation is $1 M for big airports. For medium sized airports, the cost to for implementation is $350,000. (AeroAssist, 2008)

Section 4.2 – Aviation Industry
Airline Parts Maintenance and Tracking/ Mobile Asset Management

One of the goals of this project was to implement Wavetrend's identification technology in an industry which they are not currently serving and one that could benefit from identification technology validated by our research. Rooting from the methods explained in Chapter 3 methodology, we have concluded that the Aviation industry may benefit from identification technology, through the introduction of the technology into their business or through an upgrade of their existing systems. However, we determined before, that in order to do this we would conduct a customer analysis which required us to identify customers, convey customer need, and survey customers and prospects. In order to identify the aviation industry as a viable enough for Wavetrend, we took note of the rising gas prices which resulted in decreased travel. Cutting flights and grounding airplanes cause a loss in income for airlines such as Delta who in 2008 lost $8.9 billion compared to a profit of $1.6 billion in 2007. However we saw this as an opportunity for airlines to begin to save money by cutting costs. Our view for airports and airlines is an application of a fully operational system enabling the automated identification and tracking of on-site high-importance valuables such as airline parts, maintenance tools, and mobile assets.

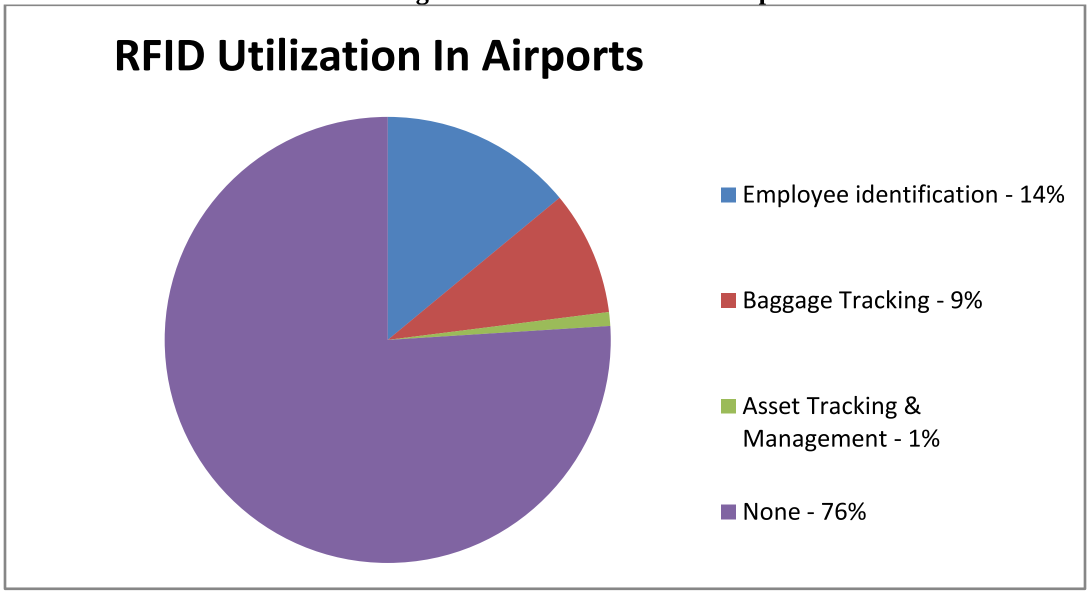
Section 4.2.1 – Infrastructure in Aviation: Current & Future

The current infrastructure used for automated identification for valuables like these is Barcode. A frequently asked question is "when is RFID of better use than Barcodes." The answer is that they are two different technologies which can have different applications. RFID offers advantages over traditional barcodes for example since it does not require line-of-sight scanning, has high throughput, and is a lot more accurate in its read rate (75-80% for barcode and 99.5% for RFID). Other advantages are RFID's read/write capability. RFID utilizes less human capital, where barcodes need laborers to use them and scan each tag. In terms of security, RFID has benefits when compared to barcode since RFID data can be encrypted, password protected, or include a "kill" feature to permanently remove data, making stored information much more secure. RFID is also capable of triggering certain events such as alarms and door openings.

Section 4.2.2 – Penetration Rates in Aviation

The penetration rate in this case is the extension of the influence of location technology on airports in the areas that we are focused on. A survey administered by aviation technology supplier SITA says current RFID applications within the aviation industry are primarily limited to baggage handling and identification. Only 14% of airports are using RFID for employee identification, 9% use if for baggage tracking and just 1% for asset tracking and management. (Friedlos, 2006)

Figure 6: RFID utilization in airports



(Friedlos, 2006)

These penetration rates for airports provide evidence for Wavetrend in implementing their systems as long they can successfully convey customer need and a significant ROI. The attractive statistic found in Figure 5 is that only 1% of airports are utilizing RFID for asset tracking which is one of our themed applications for RFID. We are focusing Wavetrend's location technology on; (1) airline parts maintenance and tracking and (2) and mobile assets management. There is room for penetration because of the low volume in competition for this aspect.

Section 4.2.3 – Return on Investment in Aviation

Mentioned below are some instances of RFID being deployed in airports similarly to the ones reported in section 4.1.3. Airports both nationally and internationally deploy RFID in similar and different ways. These installations are often times on different scales in terms of applications therefore expenditure on the technology can range.

Lyngsoe Systems, a Jutland based software manufacturer and systems integrator of logistics solutions, acquired an order to supply a trolley management system based on radio frequency identification (RFID) technology to Dubai International Airport. The system cost $250,000 to implement, and intends to cut overhead costs in labor, increased productivity and efficient use of resources. The trolley management system will comprise an RFID tag mounted on each trolley, and 60 RFID readers placed throughout the airport area. Initially 4,000 trolleys will be equipped with tags. The system provides the airport with an automatic, real-time tracking and overview of trolley location, and via a connection to the airport's flight information system, will predict where and when the trolleys are needed. (Absolute IT, 2006) Dubai International Airport is one of the very few airports seeking to deploy RFID for asset tracking as opposed to baggage handling. Savings are yet to be determined.

Next we present McCarran International Airport in Las Vegas, NV who announced a contract with Matrics, Inc. to supply RFID tags and readers for use in tracking passenger bags. Though the focus of our research wasn't towards bag tracking, this gives a perspective of the range that costs of RFID systems can stretch. The Carlyle Group, one of the world's largest equity groups, reported that the value of the contract along with the infrastructure approximated $25 million and is one of the largest single orders ever placed for RFID technology and the largest for security application. This cost however is a rare case because baggage handling entails cross infrastructures with different airlines as opposed to strictly in house facility usage. Each tag has the capability for each separate airline to write their own code when the tag is printed. The Dubai International Airport is a more typical example of how much airports have to compensate to install RFID systems. To recollect on airports deploying RFID, only 1% of airports are utilizing RFID for asset tracking and management. (Carlyle Group, 2003)

Intermec Inc. has been selected to provide the RFID system for the Hong Kong International Airport (HKIA) in Hong Kong. A total of HK$50 million has been initially invested for the infrastructure. Operating around the clock and managing an average of 110,000 pieces of luggage for departing, arriving and transfer passengers each day, HKIA's baggage handling system is among the most sophisticated in the industry. (Airport Authority Hong Kong, 2008) The airport has big potential long-term savings –estimated at over HK$ 200million a year after full implementation which takes 5-6 years. Payback on the investment will come in 2-3 years thereafter. (Alien Technology Corporation, 2008)

Figure 7: Aviation Cost – Benefit Comparison Chart

Competitor	Hospital	Items Tagged	Cost	Savings
Lyngsoe Systems	Dubai International Airport	4,000 tugs, trolleys, trailers, and forklifts	$250,000	Pilot trial still in progress. Cost savings yet to be calculated
Matrics, Inc.	McCarran International Airport	70,000 bags per day	$25 M	$200 M/ yr. after full implementation (5-6 yrs.)
Intermec Inc.	Hong Kong International Airport	110, 000 bags per day	$50 M	Long-term savings estimated at over $30 M/ Yr.

Section 4.2.4 – Aviation Competition and their Methods

There are current competitors already exploring the benefits of RFID implementation into the aviation industry. In view of airline parts maintenance and tracking, Boeing and Airbus have teamed up to set international standards for maintenance and tracking using RFID. Motorola RFID solutions are servicing Boeing while Siemens RFID systems are servicing Airbus. These two systems both operate on a 13.56 MHz range due to standards of the Air Transport Association (ATA). This range can also be used for RFID tagging worldwide so it makes sense for global manufacturers such as Boeing and Airbus to use this frequency. Boeings Labor requirement was dramatically reduced from 4 workers to 1. Inventory accuracy and visibility were both dramatically improved and Boeing was able to recoup their investment in 6 months, based upon the savings in labor costs alone and is looking to roll out the technology to additional facilities, as well as test RFID to track tools and supplies in some of its other plants. (O'Connor, 2008)

Looking further internationally, Lyngsoe Systems has won an order to supply a trolley management system based on RFID technology to Dubai International airport. The order was secured in collaboration with Wanzl, which are the suppliers of the trolleys. The trolley management system is comprised of RFID tags mounted on each of the 4,000 trolleys, and there is 60 readers placed in different areas of the airport. The system provides the airport with an automatic, real-time tracking and overview of trolley location, and via a connection to the airport's flight information system, will predict where and when the trolleys are needed. About 50% of the Lyngsoe's revenues are generated from solutions utilizing RFID technology for data capture in supply chains. (Danish Company 2007)

Section 4.2.5 – Key Barriers of Entry

Some key barriers to RFID adoption stem from previously high technology costs. Payback periods have typically been too long. Companies are waiting for RFID technology to drop in price, thus making it a more affordable investment. This means that new technologies need to demonstrate compelling business cases and short paybacks on investments. Companies are skeptical if the costs cannot be offset by the promised benefits. An additional barrier to RFID technology investment stems from the view that applicable standards are lacking. (Reiner, 2005)

Section 4.2.6 – Aviation Summary

RFID is a major part of technological breakthroughs in the aviation industry. The handling of airplane parts over the years has been a highly inaccurate and costly process, both for the airlines that fly the aircraft and for their manufacturers. Consider that the world's airlines have an estimated $45 billion in spare parts. However, this sizeable investment actually works against the airlines' financial and operational health, as much of the spares inventory is not cataloged and unnecessary. This has lead the world’s leading aircraft manufacturers to turn to RFID parts labeling.

As mentioned earlier on, IATA has constructed a business case that trolley tracking will provide quick ROI for airlines, often in the 12 to 24 month range, and even shorter if RFID trolley tracking investments are combined with an overall RFID strategy involving baggage handling, ULD tracking, and surveillance of parts and safety equipment. This shows that RFID implementation for mobile assets tracking can cut costs significantly. In addition to that, findings from the business case found that better tracking with RFID can reduce spare parts inventory by about $5 billion. If this can be expressed effectively to prospective customers of Wavetrend, this could very well lead to multiple bids from customers. Mobile assets such as trolleys and carts have a price range of $600 - $1000. Major airlines have up to 50,000 of these mobile assets spread around the world, and are often stolen or lost. We can recollect LSG Sky Chefs experienced a significant financial lost during one three month period reaching up to$1.5M. With secured tracking of these costly items, inventory can be reduced by 10%-15% saving airports and airliners figures reaching $7.5M. The evidence is clear and validated and RFID implementation into the aviation industry can be worth it.

Section 4.3 – Healthcare Industry

Asset Tracking and Maintenance; Patient Safety; Inventory Management; and Business Process Improvement

The health-care industry does not have a history of investing in information technology. However with intensifying operating costs, the sector is now looking to technology—particularly RFID—to improve inefficiencies that might impact the end result. RFID holds the promise of addressing key business problems by enabling staff to automatically identify the location of assets and patients, and track inventory. This could help reduce the over-procurement and under-utilization of equipment, optimize personnel's time and increase caregiver job satisfaction, as well as improve patient safety. In addition, data from RFID systems that track assets and people could be used to improve business processes—from housekeeping to equipment maintenance, record-keeping and billing. In some cases, RFID is well served by the fact that IT budgets in most hospitals aren't very large. That means these institutions haven't spent a lot of money putting into place competing automatic identification technologies that would need to be integrated with or replaced by RFID. One place where most hospitals have spent IT dollars is on Wi-Fi infrastructures, which they may be able to leverage for RFID-based applications.

Provided below are examples of how some medical centers are exploiting the technology to their advantage today. The following content explains the major applications of RFID in a hospital setting, including asset tracking and maintenance; patient tracking and safety; inventory management; and business process improvement. The objective is to gain insight into the various technology options; costs and return on investment; and implementation challenges.

Section 4.3.1 – Healthcare Industry Infrastructure: Current & Future

The technologies used in current applications include both UHF and HF RFID. As RFID technology continues to grow there have been more cases of successful application of RFID through pilots. Wi-Fi based location systems is also a popular solution when implementing a tracking system because most hospitals already have a Wi-Fi system in use. However, Wi-Fi networks can be slowed down severely by adding hundreds of tags, and the tracking quality is mediocre compared RFID-based location systems.

Section 4.3.2 Healthcare Industry Penetration Rates

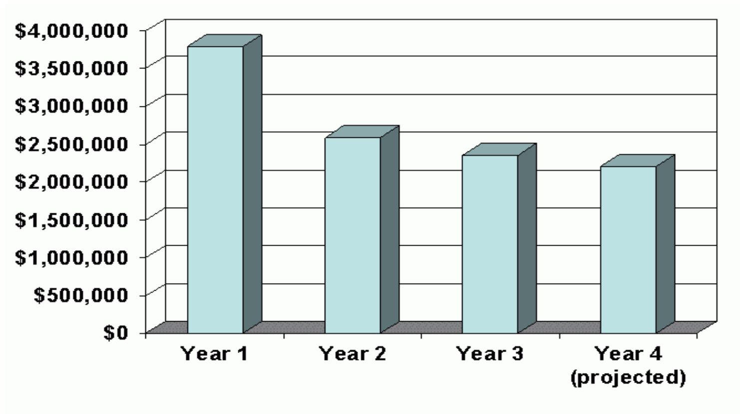


Figure 8: Savings by an Early Adopter (Mun, 2006)

While less than 5% of hospitals have currently deployed this type of asset tracking technology, it is expected to increase over the next several years. According to ABI Research, RFID systems for asset tracking and real-time location in healthcare will experience a compound annual growth rate of 49% over the next five years, reaching $155 million by 2011. (Hospitals Turn to RFID, 2009) ABI Research quoted analyst Sara Shah as saying that less than 5 percent of North American health care facilities are equipped with RTLSs, so the market is truly up for grabs. These penetration rates for airports give optimism for Wavetrend in implementing their systems as long they can successfully convey customer need and a significant ROI. We are focusing Wavetrend's location technology on, (1) medical device and asset tracking, (2) inventory management, and (3) patient tracking and safety; there is room for penetration because of the low volume in competition for this aspect.

For a variety of reasons, adoption of RFID technology by the healthcare industry has been sluggish because payback is less immediately visible than what most companies prefer. Although the costs are decreasing making it a more affordable investment many companies are reluctant to invest in a technology not yet widely adopted. Maximizing RFID benefits also requires modifying existing business processes, a daunting task that usually entails changes in technology investment strategies. Without clear RFID standards and data ownership policies, investment in RFID has been a difficult proposition. (Reiner, 2005) EPC Global, however, is working to create the EPC which will provide significantly more data capabilities for the 96-bit EPC tags. The EPC will enable more information to be captured than the current Universal Product Code (UPC) which can only contain 12 bits of information.

Section 4.3.3 –Return on Investment in Healthcare

<u>Medical Device and Asset Tracking/Maintenance</u>

RFID has strong application potential with medical device companies. The FDA requires medical device companies to be able to identify each unit by serial number. Medical device companies need better control of implants on consignment with hospitals because returns can occur more than 50 percent of the time. RFID technology that improves visibility into returns could enable faster redeployment since the company would know sooner when an unused product could be returned. Surgical instruments and other devices must be properly cleaned and packaged between uses. Tags on the instruments and readers on the sterilization chambers and storage cabinets can validate proper cleaning and help locate needed instruments. Since medical devices are often mounted on portable carts, smart tags placed on the devices and readers installed in the doorways can enable personnel to quickly l locate a crucial piece of equipment and immediately determine its fitness for use. (Reiner, 2005)

Lahey Clinic, an academic medical center with 450 affiliated doctors and 327 licensed beds, (medium sized hospital), has two major campuses with a combined 1.2 million square feet. Staff uses thousands of mobile or portable devices, some of which are routinely transferred between the campuses. The management team performed an ROI analysis focused on chronically hard-to-locate items, including IV pumps, wheelchairs, stretchers and pulse oximeters. Jeff Doran, Senior Vice

President of Operations, said “pumps were our biggest frustration…nurses tended to hoard them, putting them in corners or in closets because they felt that was the only way to be sure of having them when needed.” In 2006 the clinic deployed the RFID system at its two major campuses and tagged 3,500 items. Illustrated in the next paragraph is the overall savings and costs for both asset and inventory management in Lahey Clinic.

The management team conservatively estimated that Lahey Clinic could immediately save $270,000 by being able to track those devices and to right-size their inventory. The analysis also projected savings of $76,000 from equipment losses prevented and $31,000 from better transport processes. Doran also pointed out that they have eliminated $45,000 off saved annual planned maintenance and safety checks for high value items such as IV pumps because they had fewer of them. This comes to a total of $422,000 in savings every year that they have the RFID system in deployment. For a medium sized hospital, ranging from 450 to 700 licensed beds, it typically costs $300,000 - $500,000 to install RFID systems. (Page, 2007) If we high-ball the cost of implementing this system at $500,000, we can see that 84% of the cost in implementing the system is covered within the first year. By the second year of implementation the hospital began to reap benefits of cost cutting and saving. This example clinic not only saved a significant amount of dollar figures, but also tagged thousands of items, optimized their resources internally saving man-hours to locate equipment, and enhanced JCAHO compliance. (GE Healthcare, 2007).

The UMass Memorial Medical Center in Worcester, MA, another medium-sized hospital with 325 licensed beds, is tagging boxes containing stents and balloons for the use in the catheterization lab department procedure room with RFID solutions provided by WaveMark Inc. Here the overall savings for both asset tracking and inventory management is illustrated. The catheterization lab, where doctors perform 7,000 procedures every year, has shelves with built in RFID readers. The UMass Memorial lab’s stents and balloons can cost up to $3,000 each. And each of its cardiovascular pacemakers, which also bear RFID tags on their packaging, are worth up to $30,000. Raul Navarro, supply chain manager, said "Running out of any of the devices, which come from at least a half-dozen vendors and in several sizes (to suit patients' needs and physicians' individual preferences), is unacceptable." A missing medical device for an emergency (or scheduled) procedure can result in unsightly situation. Kim Carter, a top administrator at the lab, said the WaveMark system has helped her bring consigned and paid stock down to $100,000, from about $400,000. (Baard, 2008) Here we see savings amounting to $300,000. Again with the cost of installing RFID high-balling at $500,000, it would take 2 years to not only fully recover what they spent RFID system integration, but also to begin their saving on the investment. This is an attractive statistic for Wavetrend to present to its customers as UMass Memorial reports an ROI of 200 to 300 percent with positive returns in less than six months. (Dr. Crounse, 2005)

Tracking mobile, high value medical equipment is a priority in healthcare systems. According to a 2004 article in Health Facilities Management, hospitals can spend over $4,000 per bed annually on misplaced equipment. A more extreme case of misplaced supplies was at the Heart Hospital where Mark Valentine, president of the hospital, noted that the facility forfeits about $2 million a year in stolen or misplaced supplies. (Godinez, 2007) During a 12 month stretch starting in February 2005, 11 of the U.K.'s National Health Services hospitals reported thefts of diagnostic equipment worth at least $17,000 each. (Ranger, 2006) With RFID technology, it is possible to view real-time locations of these high-value mobile assets. Doctors and nurses can spend less time searching for equipment, and materials managers can reduce the amount of unnecessary ordering.

Blood transfusion errors have long been a concern of healthcare professionals with mistakes in blood tracking making news around the world, even resulting in death. Between 1996 and 2005 five patients in the UK died as a result of being given the wrong blood. There has been a number of blood tracking pilots carried out throughout Europe in the past few year. For example the Amsterdam study estimated in blood tracking alone the technology could save an average-sized hospital $550,000 annually through more efficient use of bloodstocks. Shanaz Sohal, the project manager of the IM&T Department at Mayday Healthcare NHS Trust in London, spoke on the active tracking of the blood bags saying " Previously we didn't know what happened to that blood and where it's gone from the time it left the issue fridge to when it got to the patient on the ward." To ensure the complete traceability of the blood it is necessary to track the entire journey of the blood. Implications are less blood wastage, elimination of delayed blood arrival to wards, elimination of unaccounted for bags of blood, and assisted fating process. (Boyes, 2008)

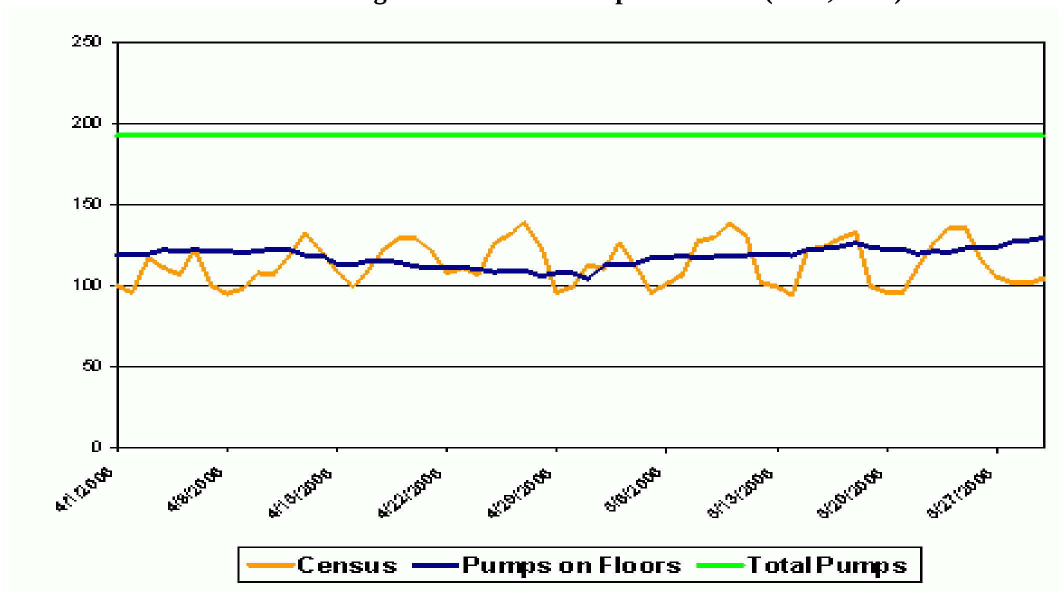
Inventory Management

Large amounts of inventory typically can be found in hospital operating rooms. Lack of visibility in the supply chain joined with the unauthorized purchase of certain items often results in the abundance of “unofficial” inventory that could be reduced by properly managing the materiel ordering process. RFID technology can provide an accurate report of both official and unofficial inventory levels. Proper diagnosis of the problem will drive the implementation of corrective solutions. Hospitals could move to the next generation of supply chain management by having their suppliers manage product ordering and inventory levels. A shift in how hospital supplies are ordered could significantly drive down hospital inventory levels.

Exemplified above is the ability to downsize inventory due to more accurate tracking of assets. Lahey Clinic was able to immediately save $270,000 by being able to track those devices that they needed and eliminate the overabundant inventory. Also at Lahey they were able to immediately save $45,000 right off the bat on annual planned maintenance and safety checks for assets simply because there were fewer of them on stock. (GE Healthcare, 2007) In addition, large medical facilities report that hardware such as wheelchairs and IV pumps go missing at an alarming and expensive rate. Dr. John Halamaka, a leading IT professional in medical care, while helping implement RFID technology at Beth Israel Medical Deaconess Hospital in Boston, MA stated in 2008 “At this point, I think our system could save close to $400,000 per year in hardware costs, and improve the work flow of doctors, nurses and other care givers.” (Hendrickson, 2004) The ability to track inventory and make sure it is at the right size is a big convenience for administrators. Take Kim Carter for example who is an administrator at the Umass Memorial Medical Center in Worcester, MA. Carter quoted in a Boston Globe article back in June 2008, “I can put my finger on our inventory figures at any moment, like this” Carter said, with a snap of a finger. Umass Memorial Medical Center downsized their cash tied up in inventory to $100,000 down from $400,000. (Baard, 2008)

In an April 2007 article in RFID Journal, Wayne Memorial hospital was reported to use active UHF FRID tags to track about 1,300 medical devices such as infusion pumps, diagnostic, computers on wheels, wheelchairs and other equipment. The location system enabled Wayne Memorial to save about $303,000 on infusion pumps. The hospital studied its infusion pump utilization during the two-month period between February and March, and found it was using only about 50 to 60 percent of all its infusion pumps throughout the hospital. "We tracked the utilization pumps because Wayne is going to replace all the pumps in May of this year," Kane says. Once the hospital determined it wasn't fully utilizing all the infusion pumps it had on hand, it decided to order fewer replacements. Instead of the more than 300 pumps it initially planned to buy, it now will purchase only about 250 pumps. This will save it nearly $276,000, plus an additional $27,000 in operating costs for those added pumps summing up at a significant figure $303,000. Kane further note that is more than it costs to install the system. (Bacheldor, 2007) In tracking their wheelchairs, Wayne Memorial has been able to decrease the wait time for these mobile assets to 5 minutes down from 20 minutes.

Figure 9: Infusion Pump Utilization (Mun, 2006)



Brigham and Women's Hospital in Boston, another medium sized hospital with 316 licensed beds, is working with Andover, MA's Radianse Inc. to track the precise locations of thousands of devices, using active RFID tags, which are programmable and can be tracked to within a few feet, anywhere in the hospital. They too experienced rewards on their investment as they tagged 4,000 different assets on their premises. Prior to deploying RFID, they incurred losses adding up to $300,000 from misplaced items. Here, we high-balled the cost for implementation for assurance and a better scope as to how long it will take to see returns. This hospital too saw savings within a 2-year span. (Baard, 2008)

Beth Israel Deaconess Medical Center in Boston, MA is doing similar work with combination WiFi-and-RFID tags from PanGo Intelligent Wireless, based in Framingham. This hospital was reported in this project because they tagged over 8,000 medical devices. They are also a very large hospital with 747 licensed beds which we have not seen yet in this chapter. They were able to save $600,000 annually after RFID installation. (Malykhina, 2006) As mentioned before, the general highest cost for large hospitals can reach $1M. After 2 years, we can estimate that they began to save money after the investment. (Baard, 2008)

Section 4.3.4 – Healthcare Competition and their Methods

There are current competitors already exploring the benefits of RFID implementation into the healthcare industry. For instance, Beth Israel Deaconess Medical Center in Boston, MA is doing similar work with combination WiFi-and-RFID tags from PanGo Intelligent Wireless, based in Framingham. They actually were actually able to pay for the system in less than a year Massachusetts General Hospital in Boston, MA is working with Tagsys, which has offices in Cambridge, to match patients with the right blood bags using RFID tags and a reader the hospital helped to build. (Baard, 2008) WaveMark Inc. has been servicing Umass Memorial Medical Center in Worcester, MA in downsizing overstocked and underutilized inventory.

GE Healthcare supplied Lahey Clinic, a multi-specialty group practicing in Burlington, MA mentioned earlier, with a RFID tracking system to track high-value medical devices to help reduce equipment loss, better transport processes, right-size inventory, and reduce the cost of maintenance and safety checks for medical devices. (GE Healthcare, 2007) The scenario mentioned earlier in which RFID technology was implemented into the Heart Hospital in Dallas, TX was backed by Mobile Aspects Inc. with their active tags. (Godinez, 2007) Priyanka Gouthaman, an industry analyst with consulting company Frost & Sullivan, said vendors such as 3M, McKesson and Siemens send active RFID signals over wireless hospital networks based on the 802.11 standard, a common platform for health care communications. Gouthaman further quoted, “This enables hospitals to leverage existing infrastructure, thereby reducing the total cost of the investment.” (Joch, 2008) AeroScout, Inc., a leading provider of Wi-Fi-based Active RFID solutions, supplied RFID technology at the new digital General Hospital in Lagos de Moreno, Jalisco, Mexico to help meet patient care challenges and asset tracking of medical devices. (Health News Team, 2009)

Figure 10: Healthcare Cost – Benefit Comparison Chart

Competitor	Hospital	Hospital Size	Items Tagged	Cost	Savings
General Electrics	Lahey Clinic: Andover, MA Burlington, MA	327 licensed beds	3,500 hospital assets	$300,000 - $500,000	$422,000 / Yr.
WaveMark, Inc.	The UMass Memorial Center, Massachusetts	325 licensed beds	> 3,000 in 7-room cardiac cath lab	$300,000 - $500,000	$300,000 / Yr. An ROI of 200 to 300 percent with positive returns in less than six months
RadarFind Corporation	Wayne Memorial Hospital, Georgia	98 licensed beds	1,300 hospital assets	< $303,000	$303,000 / Yr.
Radiance Inc.	Brigham and Women's Hospital, Massachusetts	316 licensed beds	4,000 medical devices	$300,000 - $500,000	$300,000 in lost or misplaced devices
Mobile Aspects, Inc.	Heart Hospital, TX	68 licensed beds	10 high-tech drug-coated stent storage cabinets	$4,000,000	$2,000,000 / Yr. in lost or misplaced supplies.
PanGo Intelligent Wirelss	Beth Israel Medical Deaconess Hospital, MA	747 licensed beds	8,000 medical devices	$600,000 - $800,000	$600,000 / Yr. in lost or misplaced equipment (Malykhina, 2006)

Section 4.3.6 – Healthcare Summary

Although healthcare companies are slowly adopting RFID, usage is expected to accelerate when RFID technology prices drop and companies become more confident in the applications. RFID's strong functionality can improve a company's operational efficiency by reducing labor and enhancing product visibility, thus reducing overall inventory levels. Patient safety and product tracking requirements will be the driving factors that will necessitate the adoption of RFID technology. Hospitals already have strong RFID applications which include asset and medical device tracking to promote patient safety and increase operational efficiency. In addition, some hospitals that have not yet adopted bar code technology can use RFID technology to jumpstart their competition in maintaining better asset visibility while reducing inventory levels.

Despite the various barriers to entry, one of the most important ones was the worry of RFID interfering with the function of medical devices. Active RFID tags have an intrinsic power source and do not need to be powered by an RFID reader allowing readers for active RFID tags to operate at lower power than passive RFID tag readers and hence reducing their potential to cause electromagnetic interference. Nonetheless, with medical products being very expensive and human error always being an issue in misplacing these devices, there is room and need for the technology with its benefits of maintaining better asset visibility while reducing inventory levels. More importantly these devices that have been presented either save lives or make human life a lot easier for those who need them. These are types of assets that need to be traced at all times because of the service they do to man kind

Within this report of the healthcare industry, there are countless developments where RFID has successfully become a niche in the healthcare industry despite the barriers to entry. Hospitals and other healthcare groups have saved significant dollar figures and have gained their vendors a greater customer base which Wavetrend can successfully compete in with the low penetration rate of less than 5% of healthcare facilities in North America with RFID solutions. Lahey Clinic for example was able to immediately save $270,000 by being able to track those devices and to right-size their inventory. This facility also projected savings of $76,000 from equipment losses prevented and $31,000 from better transport processes. To top things off, Lahey Clinic, with the help of RFID, eliminated $45,000 off saved annual planned maintenance and safety checks for high value. High-valued items such as cardiac stents individually cost about $3,000. However there are items such as cardiovascular pacemakers that cost around 10 times more than that of stents equaling $30,000. UMass Similar to Lahey Clinic, healthcare facilities like UMass Memorial Medical Center, Beth Israel Deaconess Medical Hospital, and Wayne Memorial all have committed to RFID and have had rewarding outcomes from the decision through asset tracking and management which draws a parallel to a reduced inventory stock. With the savings and better management from medical device and asset tracking there will be improved work flow among doctors, nurses and other care givers.

Section 4.4 – Industries Not Pursued

During the course of our research we encountered many industries that could very well reap benefits from RFID technology. Part of our methodology process was to research as many industries in the beginning so that we can have a respectable list of industries to consider and thereafter make a decision on two industries to pursue. The other industries in this list, mentioned early in this chapter, were agriculture, biotech, financial, and cold-chain.

Section 4.4.1 – Agriculture Industry

The agriculture industry was another we reviewed while conducting our research. While this industry did not possess the financial statistics that we were searching for we did come across recent scholarly articles that supported entry into this sector. The research explained that the use of RFID in the feed management of cattle can reduce feeding expenses by as much as 10%, yet less than 20% of ranchers use any sort of on site software. As of 2007 only 9% of dairy cattle were tagged, proving that there was certainly an area that may be taken advantage of. Other information we uncovered involved tracking of individual packages of meat. Only one company worldwide uses this tactic, Metro Group of Germany. The team found that a recent recall of meat products cost one company upwards of $20 million. For these reasons we presented the agriculture industry as one with potential for investment to Wavetrend.

The two uses explained above are very different. The RFID tag used for tracking live cattle would require several different things that the retail tag would not. For one, tags used outdoors are exposed to varying weather conditions. “The transponders in the tags typically operate at low frequency (125 to 134.2 kHz)” (RFIDjournal.com, “Cattle-tagging technology). However, newer technologies are arriving that are helping to make tracking even easier. For tracking packaged meat products, Metro Group has decided to use an Ultra High Frequency EPC Gen2 tag with Impinj interrogators and antennae.

Section 4.4.2 – Cold-Chain Tracking

Cold-Chain tracking is an application of RFID technology that is used to track and monitor temperature variations within multiple distribution chains. Often times, temperatures within a shipping container can vary as much as 35% from pallet to pallet. As one could assume, this results in substantial freight loss of perishable goods as well as the loss of vaccines and pharmaceuticals. Since vaccines don't change their appearance as a result of temperature variations it makes it difficult to tell if a vaccine has been exposed to extreme high or low temperatures. In addition to tracking temperature changes, cold chain technology has also been adapted to monitor whether or not a package has been opened in transport and also identify who opened it. Optional additions such as shock sensors, and humidity monitors are also available from some companies. Regulations, such as the ones below, have played a large role in the adoption of RFID technology within supply chain management of pharmaceuticals.

One of the greatest benefits of Cold-Chain monitoring is the ability to know, in real time, whether your products have spoiled. Many companies provide real time phone, text, and web based responses to both the shipper and the receiver of the goods (Avante International Technology, Inc., 2009). This results in saving both time and money, which will be discussed further in the return on investment section of this section.

The way RFID is being used is relatively uniform throughout each industry. The concept of an internal "Zoner tag", as Avente refers to it, records the temperature and transmits it to an exterior "Relayor reader." Many companies claim that they are able to monitor temperature variations with +/- 0.5^0C. This information is then stored and backed up in a database for future records. If there are any extreme warnings/notifications that need to be sent, they are sent in real time. (Avante International, Inc., 2009) Each company seems to leverage a slightly different form of RFID technology to fulfill the same need. One similarity between each application is that they use a form of Active RFID. For example, Sensitech uses an Active tag that operates at 915 MHz in order to send temperature readings to interrogators within warehouses, retail locations, or distribution centers. (Sensitech, Inc., 2008)

Section 4.4.3 – Banking/Financial Institutions Industry

Like most large organizations, the employees at large financial institutions rely on laptop computers to maximize efficiency. However, maintaining security for high-value assets that enter and leave the building every day proved extremely challenging. Employees are lined-up outside the front door of these corporate facilities every morning. From assistants to senior vice presidents, all are required to take his or her place in line for individual check-in and laptop serialization checks—a highly inefficient process that involved approaching the security desk with one's ID card and laptop. New security gates utilizing RFID access control cards coded to each individual have proven to be a major step forward for employee check-in. Financial companies replace their data center equipment fairly frequently, so there could be a substantial demand for tagged equipment. Large banks spend millions of dollars each year upgrading their equipment. By using RFID instead of bar code scanning to track IT assets and perform regular quarterly inventories audits required by the Sarbanes-Oxley Act, banks can cut 80% to 90% of the labor and time by automating the entire inventory process, from ordering and receiving through removal and destruction. With application of RFID, these institutions can experience cost-efficient asset management, error-free performance and accuracy (100% read rates), and increase level of security.

Though there are many appealing benefits the scope as to how the benefits will outweigh the cost are a lot more reachable in pursuit of industries such as aviation and healthcare which we chose. At some point with widespread convergence of the technology, RFID in bank/financial institutions will flourish

Section 4.5 – Survey Results

As discussed in chapter 3, we surveyed a group of Wavetrend's current customers to determine how they leverage RFID technology. We also wanted to determine what the driving factors for adoption were and if they varied from industry to industry. We chose an online survey, using surveymonkey.com, in order to better understand the needs of customers who currently use RFID technology in their daily operations. This was in an attempt to better understand the reasons why different companies, in different industries, use location technologies to fulfill various needs. We were planning on using the recorded results as a validation technique for our industry analysis. However, the number of responses we received made it quite difficult to do so. This will be discussed in greater detail later in the chapter.

Section 4.5.1 – Recorded Lead – User Survey Results

Question 1 A critical part of this project was the primary data collected during the lead-user survey. Unfortunately, due to time constraints and other setbacks, we were not able to gain as many responses from our survey as we had hoped. We received six responses from system integrators that are customers of Wavetrend.

In Question 2, each of these 6 respondents answered question 2 by selecting which of the industries they felt would present the best opportunity for location technologies in the next few years. Two respondents selected "Defense" and two selected "Other." Both Industrial goods and utilities received one selection a piece, making it difficult to consider. Due to the small response numbers, not much can be interpreted from this other than the fact that at least two of these system integrating companies feel that the defense industry is going to hold great opportunities for location technologies.

Question 3 asked the respondents to rank each of the technologies (GPS, Active RFID, Passive RFID, Satellite, Cellular, Mesh, and Bar-coding) by current profitability for the company. Since each respondent could select up to five technologies to rank, there is actually a decent amount that can be interpreted from the responses. The only technology that was selected by every respondent was bar-coding. This verifies the fact that bar-coding is still the most widely used tracking system. However, bar-coding did not receive any votes as the most profitable technology. Four of the six respondents selected RFID (3 active, 1 passive) technology as their most profitable, and each of these technologies was selected by five of the six respondents.

Question 4 ranked the importance of: monetary savings, improving efficiency, and cost of system when implementing a location technology system. As expected, monetary savings has the highest rating average, as return on investment is usually the reason end-users decide to purchase a location system.

Question 5 asks the respondents: "To which of the following industries do the majority of your current customers belong to?" Each respondent was allotted three selections. The industries selected more than twice were: Industrial Goods (5), and Services (3).

Question 6 asks a similar question, but asks which industries are most profitable. In the responses to question 6, only Industrial Goods (5) is selected more than twice. This suggests that industrial goods is the most popular industry, but this may also be skewed by the fact that it is one of the least specific industries, and therefore acts as somewhat of a catchall when it comes to responses.

Question 7 is intended to discover why end-users decide not to adopt a location technology system, according to these system integrators. The most hindering reason to adoption is definitely cost, according to the results. Unawareness of benefits and unwillingness to change are closely ranked as second and third respectively, while security issues and regulatory restrictions are the least hindering reasons to adoption.

Question 8 asks the respondents: "Which of the following were the most influential in deciding to switch to RFID products and services?" Five of the six respondents identified professional sources (consultants, analysts, system integrators) as the most influential source for switching to RFID products.

Question 9 asks the respondents to rank hardware, software, and services/maintenance by cost when implementing an RFID system. Software (database, infrastructure, etc.) is selected to be the most expensive factor by half of the respondents. Hardware is selected as the next expensive factor by 3 respondents, and services/maintenance is selected as the least expensive factor by 4 respondents.

Question 10 asks the respondents how long it took them before they broke even on their investment in RFID technology. Out of the 5 who responded to this question, one respondent answered that they reached the break even on their investment within 6 months; two other respondents answered they broke even within 12 months; one other respondent answered they broke even within 2 years; and the last respondent answered it took them more than 2 years to break even on their investment.

Question 11, an open-ended question that ended the survey, was responded to by 3 respondents. This question asked "What suggestions would you have for Wavetrend's next generation of products?" One of these responses simply asks for "stable and reliable products." Another of the responses is much more specific, asking for a specific feature that could be added to Wavetrend's next product. "We are specialized in Access control and human track/trace: Door controllers controlling more doors on one controller."

Figure 11: Survey Results

Question	# of Respondents	Data Summary
1. Is your company and end user or system integrator of Wavetrend's product?	6	100% of the respondents were system integrators of Wavetrend's products.
2. Which industry do you feel currently presents the best opportunity for technologies (such as RFID or GPS) in the next few years?	6	33% chose Defense, 33% chose other, 16% chose industrial goods and 16% chose utilities
3. In your view, please rank the profitability of the following technologies for your company (1= the most profitable, 2= 2nd most profitable, etc.).	6	50% of respondents chose active RFID as the most profitable. 50% chose passive RFID as the 2nd most profitable. Barcoding averaged the 3rd most profitable while responses for cellular, satellite, GPS, and Mesh technoligies were mixed.
4. On a scale of 1-5, 1 being not important at all, 5 being very important, how would your rate the importance of each category below?	6	Monetary Savings responses averaged 3.67. Improving efficiency averaged 3.33. Cost of system averaged 3.17.
5. To which of the following industries do the majority of your current customers belong to (select up to 3)?	6	83.3% selected industrial goods, 50% selected services, 33.3% selected technology, 33.3% selected government, and healthcare, aerospace, consumer goods, and other were selected by 16.7% of respondents.
6. Which of these industries are your most profitable (select up to 3)?	6	83.3% chose industrial goods, 33.3% chose healthcare, 33.3% chose government, and aerospace, consumer goods, services, technology, and other were chosen by 16.7% of respondents
7. Please rank each of the reasons below from 1 being the most hindering reason for the adoption of RFID technology to 5 being the least hindering reason.	6	Unawareness of the benefits of RFID was viewed as the most hindering by 33% of respondents. Cost was chosen by 50% as the second most. Security issues and regulatory issues were viewed as the least hindering, while responses to unwillingness to change were scattered.
8. Which of the following were the most influential in deciding to switch to RFID products and services? (choose only one)	6	83.3% of respondents selected "Professional Sources (consultants, analysts, system integrators, etc)". 16.7% selected "Media sources (magazines, newletters, etc)". No one selected "Wavetrend's own sources".
9. Please rank the following from 1 being the largest expense to 3 being the smallest expense when implementing an RFID system.	6	50% of respondents selected software as the largest expense, while 33.3% chose hardware and 16.7% chose services/maintenance. Services/maintenance was selected as the least expensive by 66.7% of respondents.
10. How long did it take to reach the break even on your investment of RFID technology?	5	20% of respondents broke even within 6 months, 40% within one year, 20% within 2 years, and 20% took longer than 2 years. One subject elected to skip this question.
11. What suggestions would you have for Wavetrend's next generation of products?	3	Respondent 1: "stable and reliable products." Respondent 2: "Door controllers (under stations) controlling more doors on 1 controller)." This individual worked for a company that specialized in Access Control and Human Track/Trace. Respondent 3: said he would rather convey suggestions through email.

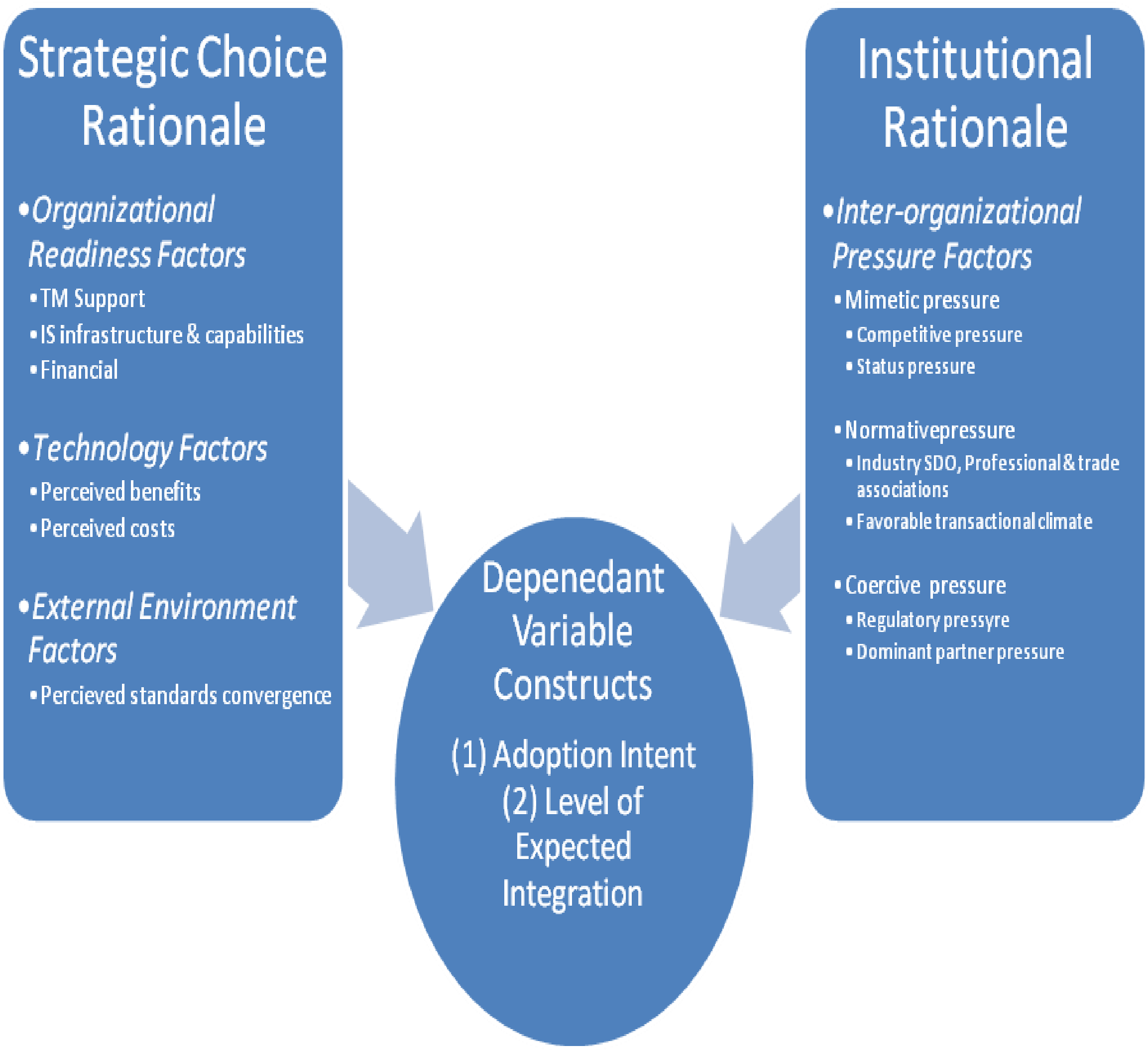
Section 4.5.2 – Research Results on Decision-Drivers

Although it would seem that an organization's adoption decision is driven by well thought out internal and external assessments with a clear objective to improve performance, there may be other influencing factors such as conforming to external pressures to gain legality which may drive adoption. While identifying factors that drive RFID technology adoption, we came across an underlying mix of motivations and rationale behind adoption. The relevance of stating these different aspects of decision drivers for RFID shows that there usually isn't just one motivation but often multiple motivations that spark widespread adoption of a technology. What also makes the information presented below valuable is that it reflects data from a study that consisted of interviews and news reports. The study was carried out by individuals out of Emory Unversity and Eastern Connecticut State.

The study develops an integrative conceptual RFID adoption model and presents testable hypotheses at different rationales and motive levels. The model incorporates different rationales for adoption and integration of interorganizational systems (IOS). Though the study was done in a more formal and thorough manner, many of the conclusions about decision drivers from our research are backed the findings in the research of the testable hypothesis mentioned in the previous paragraph is centered around the idea that there are four typues of adoption influence. These influences are categorized as technological, interorganizational-pressure, organizational-readiness, and external-environments factors. These categories are chosen to help further define the strengths of two dependent variables proposed in the study which are (A) adoption intent, and (B) level of expected integration.

This mix of influencing factors that push the adoption of RFID technology can be broadly classified under two umbrellas in organizational perspective theories: (1) "Rationalistic" Strategic Choice Perspective, with an emphasis on improving efficiency and organizational performance, encompasses the technological, organizational-readiness, and external-environment factors and (2) an Institutional Perspective with an emphasis on maintaining legitimacy, encompasses inter-organizational pressure factors. Factors in the "Rationalistic" Strategic Choice Perspective which is soon explained, have been suggested as adoption and integration drivers from strategic choice perspectives. Factors in the Institutional Perspective, also further elaborated on below, have been are proposed as predictors of adoption intent and expected integration. (Sharma, Citurs, & Konsynski, 2006) See Figure 8 for overall illustration on how these perspectives intertwine.

Figure 42: RFID Adoption Rationales



(Sharma, Citurs, & Konsynski, 2007)

"Rationalistic" Strategic Choice Perspective

Technological factors, within the confines of the "Rationalistic" Strategic Choice Perspective, often selected as facilitators and inhibitors of adoption are **(a)** perceived benefits and **(b)** perceived costs. (Sharma, Citurs, & Konsynski, 2006)

a) Perceived benefits have consistently been found to be an important predictor of adoption intent. RFID technology is likely to bring operational savings resulting from increased internal efficiency of the organization whereas indirect benefits refer to opportunities and gains resulting from RFID's impact on business processes and relationships. Issue

b) Perceived costs are also an influencing factor. Higher costs lead to lower intent to adopt. The less expensive the innovation, the more likely it will be adopted, but innovation costs relative to innovation benefits are more meaningful. Perceived costs will have a significant negative relationship with adoption intent but a significant positive relationship with level of expected integration. (Sharma, Citurs, & Konsynski, 2009)

External environment factors, within the confines of the "Rationalistic" Strategic Choice Perspective, often viewed as important environmental influences on a firm's RFID adoption decision are **(a)** perceived standard convergence and **(b)** perceived stakeholder privacy. (Sharma, Citurs, & Konsynski, 2006)

a) Perceived Standard convergence is the degree of consistency of standards between the partner organizations within an industry (vertical) and across industries (horizontal). With RFID adoption, it is important to achieve interoperability between SC partners and to move towards open standards for leveraging cross industry benefits. It is proposed that higher perceived standard convergence would be favorable for adoption as it would result in more transactions using RFID within and across industries, thus greater benefits at possibly lower costs.

b) Perceived privacy is the extent to which individuals and organizations believe they have control over information about them being communicated to others. In context of RFID, due to its pervasive nature, it is suggested that beliefs of privacy of consumers and/or organizations would foster its adoption while lack of would inhibit. Perceived privacy for both consumers and organizational stakeholders will have a significant positive relationship with adoption intent and level of expected integration. (Sharma, Citurs, & Konsynski, 2006)

Organizational readiness factors, within the confines of the "Rationalistic" Strategic Choice Perspective, often proposed as important attributes to influence on a firm's RFID adoption decision is **(a)** top management support, **(b)** IS infrastructure and capabilities, and **(c)** financial readiness. (Sharma, Citurs, & Konsynski, 2006)

a) TM support been shown to be an important IOS adoption predictor [18]. With RFID, where strategic benefit may be realized through improved partner coordination and business process reengineering, signals need to be sent within and between firms about commitment and importance of the RFID initiative. Long term strategic vision and direction from TM is critical to RFID adoption and integration in and between firms.

b) The presence of a good IS infrastructure (hardware, software, and expertise) is quite similar to possessing technological resources that can enhance adoption facilitation. Technological resources readiness refers to a firm possessing appropriate technology infrastructure, people and expertise to support easy adoption. The presence of appropriate resources reduces costs and efforts in integrate RFID technology with existing systems compared to purchasing or developing new systems and training employees in new skill sets.

c) Financial readiness refers to having enough financial resources available to pay for adopting a new technology, including new systems' learning and integration costs. The presence of financial resources to cover associated RFID costs would increase the likelihood of adoption. (Sharma, Citurs, & Konsynski, 2006)

Institutional Perspective

<u>Inter-organizational factors</u>, within the confines of the Institutional Perspective, often selected as facilitators and inhibitors of adoption are **(a)** coercive pressures, **(b)** normative pressures, and **(c)** mimetic pressures. (Sharma, Citurs, & Konsynski, 2006)

a) Coercive pressures are defined as formal/informal pressures, which result from organizations that the focal firm is dependent for resources and is analogous to the resource dependence argument. Coercive pressures on organizations may stem from many different sources such as regulatory bodies, resource dominant organizations and parent corporations. Dominant organizations within the SC and in the institutional environment could pressure dependent organizations to adopt programs, policies, and technologies that are favorable to them.

b) Normative pressures occur in relational channels among network members when norms are shared during consensus building thus potentially increasing a norm's influence. Communication among SC partners and among members of professional bodies and industry trade associations concerning benefits and best practices related to innovations would result in shared beliefs and persuade organizations to adopt technologies. With RFID, a technology with network effects and dependencies, this scenario is highly likely given that trade/professional association memberships and business association memberships between SC partners are important factors in norm sharing

c) Mimetic pressures result from organizations response to uncertainty. In uncertain conditions, with no clear course of action unavailable, organization leaders tend to mimic/copy actions of perceived successful organizations. Mimetic pressures are driven by industry bandwagon effects (following successful competitors) or driven by status (following prominent organizations). With RFID adoption, technology uncertainty may exist due to differences in firms that are strongly influenced to mimic firms considered industry leaders or competitors who are considered to have successfully adopted. (Sharma, Citurs, & Konsynski, 2006)

Section 4.6 – RFID in Biomedical Engineering

This section of the MQP project focuses on the future of RFID systems for biomedical applications. It discusses current technology, restrictions and applications and also illustrates possible future development for the technology. This report gives the reader an idea of what research has been done to date and draws some conclusions about where further development is needed. You will also be familiarized with what the field of biomedical engineering encompasses along with what purpose it serves. This section also gives a definitive description as to what a biomedical engineer is and what they do in practice of their profession along with the specialized areas in which they may choose to do research.

Section 4.6.1 – The Field of Biomedical Engineering

In our day, many of the problems confronting health professionals are of tremendous interest to engineers because they involve the design and practical application of medical devices and systems and processes that are fundamental to engineering practice. These medically related design problems can range from very complex large-scale constructs. One example may be the design and implementation of automated medical laboratories specialized for particular studies, or multiphase screening facilities (medical laboratories that permit many clinical tests to be conducted), and hospital information systems. Other medically derived design problems may be the creation of relatively small and simple devices such as electrodes and biosensors that may be used to monitor the activity of specific physiologic processes in either a research or clinical setting. Therefore the American healthcare system encompasses many problems that present challenges to certain members of the engineering profession called biomedical engineers. (Bronzino, 2000)

Section 4.6.2 – The Biomedical Engineer

A Biomedical Engineer uses traditional engineering expertise to analyze and solve problems in biology and medicine, providing an overall enhancement of health care. Biomedical engineers choose the field to be of service to people, to partake in the thrill of working with living systems, and to apply advanced technology to the complex problems of medical care. The biomedical engineer works with other health care professionals including physicians, nurses, therapists and technicians. Biomedical engineers may be called upon in a wide range of activities such as to design instruments, devices, and software. Also to bring together knowledge from many technical sources to develop new procedures or to conduct research needed to solve clinical problems. (Biomedical Engineering Society, 2009)

Section 4.6.3 – Disciplines of Biomedical Engineering

In this field there is continual change and creation of new areas due to rapid advancement in technology. Here are some of the well established discipline areas within the field of biomedical engineering:

- Biosensors & Bioinstrumentation: the application of electronics and measurement techniques to develop devices used in diagnosis and treatment of disease.
- Biomaterials: integrates engineering fundamentals in materials science with principles of cell biology, chemistry and physiology to aid in the design and development of materials used in the production of medical devices
- Biomechanics: involves the application of engineering mechanics to the study of biological tissues and physiological systems.
- Tissue Engineering: integrates the principles and methods of engineering with the fundamentals of life sciences towards the development of biological substitutes to restore, maintain or improve tissue/organ function.
- Clinical Engineering: the design and development of clinically related facilities, devices, systems, and procedures.
- Biomedical Imaging: involves the application of quantitative science and engineering to detect and visualize biological processes.
- Rehabilitation Engineering: a growing discipline area where the design and development of therapeutic ad rehabilitation devices and procedures.

Section 4.6.4 – Medical Devices in Biomedical Engineering

As medical professionals are faced with newer challenges in healthcare, there is a continuous arising need for medical devices to be designed and built. A medical device, according to the Food and Drug Administration (FDA), is a diagnosis, cure, mitigation, treatment or prevention of disease or condition that (1) affects the structure and function of the body, (2) does not achieve intended use through chemical reaction, and (3) is not metabolized. The FDA recognizes three classes of medical devices based on the level of control necessary to assure safety and effectiveness of the device.

FDA Medical Device Classes

Class I – General Controls: These devices are subject to the least regulatory control. They present minimal potential for harm to the user and are often simpler in design than Class II or Class III devices. Class I devices are subject to "General Controls" as are Class II and Class III devices. Examples of Class I devices include elastic bandages, examination gloves, and hand-held surgical instruments.

Class II – Special Controls: These devices are those for which general controls alone are insufficient to assure safety and effectiveness, and existing methods are available to provide such assurances. In addition to complying with general controls, Class II devices are also subject to special controls. Devices in Class II are typically non-invasive and include powered wheelchairs, infusion pumps, and surgical drapes.

Class III – Premarket Approval: This class is the most stringent regulatory category of devices. These devices are those for which insufficient information exists to assure safety and effectiveness solely through general or special controls. These devices are usually those that support or sustain human life, are of substantial importance in preventing impairment of human health, or which present a potential, unreasonable risk of illness or injury. Premarket approval is the required process of scientific review to ensure the safety and effectiveness of Class III devices. However not all Class III devices require an approved premarket approval application to be marketed. These Class III devices require a premarket approval and are items such as replacement heart valves, silicone gel-filled breast implants, implanted cerebral stimulators, implantable pacemaker. (U.S. Food and Drug Administration, 2009)

Section 4.6.5 - RFID Application to Biomedical Devices

In brief review of RFID technology, an RFID system consists of two main components: a tag (transponder) and a reader (interrogator). Tags are placed on objects, people or animals and directly or indirectly contain information about the object, person or animal. The reader, either activated manually or automatically, uses RF energy to interrogate the tag and read the information it contains, or write data to the tag. Given that RF energy can pass through solid objects, RFID does not require a line-of-sight communication that is a direct, clear transmission path between a tag and its reader. The information obtained from the tag, such as the object's physical location, can then be transferred to a host data management system. For example, an RFID tag that is attached to a patient, an ECG machine, or an infusion pump communicates with the RFID reader through radio waves. Radio waves have a range of possible frequencies. The RFID systems use frequency ranges that have been reserved specifically for industrial, scientific or medical applications (ISM) or for short range devices (SRD). In order to prevent errors due to interference the frequency band is divided into four different groups (LF, HF, UHF and Microwave). (Dr. Oduncu, 2008)

RFID provides the capability for remote and real-time tracking of medical devices and assets which are always expensive and sophisticated. Like the ECG machine or IV infusion pump, mobile devices are oftentimes lost or hoarded away somewhere in the hospital and staff are left spending valuable time searching for them. RFID is able to locate the devices at all time and this helps the better utilization of the devices. The FDA received reports from Universal Hospital Services that the national average utilization of mobile equipment is only 45% and from HCPro Healthcare Marketplace saying that hospitals lose nearly $1 million every year in medical equipment thefts alone. (Ph.D Mun, 2006) Though there is an understandable need for RFID implementation, it is important to ensure that it is addressing a clear business and/or clinical need. The following section focuses on devices that are created by biomedical engineers in order to resolve healthcare needs. For each device there is a description of the device, the healthcare issue it helps to resolve, and the issues tied in with them in regards to healthcare facilities and the need for tracking using RFID technology.

Biomedical Devices & RFID Application in Healthcare Facilities

1. INFUSION PUMPS

Infusion Pumps are electronically controlled devices that deliver constant and precise amounts of fluid, blood, medication, or nutrients over a specified time period. This is a major technological advance in infusion therapy because fluids can be administered in ways that would be impractically expensive or unreliable (orally) if performed manually by nursing staff. In such cases, the fluids can be delivered into the patient's blood stream through the vein using a needle or catheter connected to a reservoir of the fluid. Although many therapies can be delivered safely and effectively via gravity drip systems, others require the highly precise and constant flow rate offered by electronic infusion devices.

Figure 53: Outlook Safety Infusion System with DoseScan and DoseGuard by BRAUN Technologies

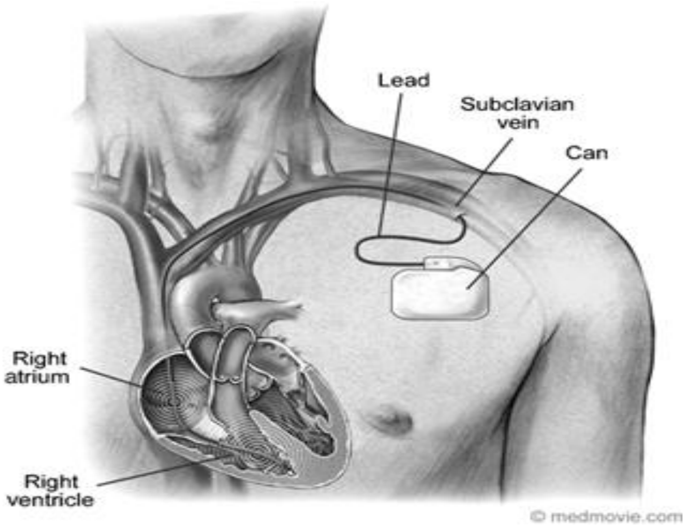
For example, intraarterial infusion usually requires positive pressure pumps because the back pressure is higher in arteries than in veins. Volumetric or syringe pumps are the most common. The useful advantages of this device have healthcare facilities paying up to $2500 per unit. (Street, 2008)

Wayne Memorial Hospital in Goldsboro, NC is an excellent example of a healthcare facility realizing the benefits of RFID technology and putting them to good use track devices such as an infusion pump. Wayne Memorial Hospital has saved about $303,000 in infusion pump expenses alone due to RFID systems. The hospital studied its infusion pump utilization during the two-month period between February and March of 2007, and found it was using only about 50 to 60 percent of all its infusion pumps throughout the hospital. The reason why those chose infusion pumps for the study was because they were going to replace the infusion pumps in May that year. Once the hospital determined it wasn't fully utilizing all the infusion pumps it had on hand, it decided to order 250 pumps down from 300 pumps it originally planned to purchase. This saved them nearly $276,000, plus an additional $27,000 in operating costs for the added pumps totaling $303,000. (Bacheldor, 2007)

Lahey Clinic in Burlington, MA was also able to save money by using RFID to tag 3,500 medical devices, with the ability to find any item from any networked computer. Jeff Doran, Senior VP of Operations at Lahey Clinic presented an analysis by clinic staff showing that using RFID to right-size asset inventory of infusion pumps and other critical devices would by itself save enough money to justify the investment. Lahey was able to save $270,000 immediately b tracking devices and right-sizing inventory. They also projected and additional $76,000 in savings from loss of equipment and saved $45,000 in annual planned maintenance costs. (GE Healthcare, 2007) In support of tracking infusion pumps in healthcare facilities, Emory Healthcare which is Georgia’s largest healthcare system utilizing 3 different sites, deployed RFID systems to track the location of 2,400 infusion pumps both on and off the premises. (O'Connor, 2007)

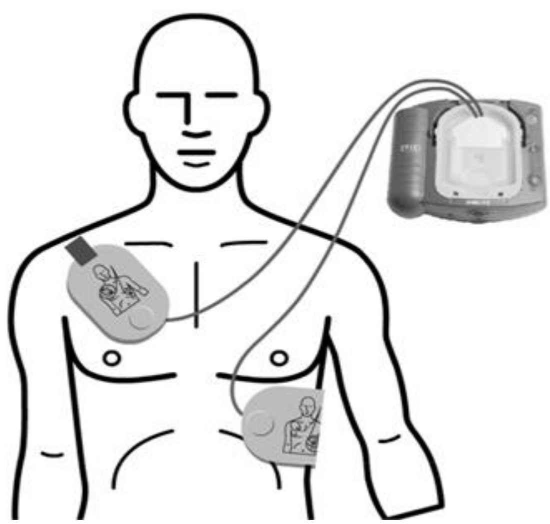
2. DEFIBRILLATORS

Figure 14: An implantable cardioverter defibrillator (Roth, 2008)



An *Internal Defibrillator* resembles a pacemaker, but its circuitry is similar to that in an AED. The battery, capacitor, and electronics are enclosed in a metal case (titanium or stainless steel), which is implanted under the skin in the chest with two leads passing through the vein to the heart. (Roth, 2008)

Figure 15: An automated external defibrillator (AED)



An *External Defibrillator* works by applying a shock through electrodes on the surface of the body. A typical AED is shown in Fig. 3. Each electrode has an area of at least 50 cm^2 and is attached to the skin by a self-adhesive pad. A conducting gel should always be placed between the skin and the electrode to reduce the skin resistance. The device works by charging a capacitor to a high voltage; the current passes the electrodes through the entire torso with only a fraction with only a fraction of it reaching the heart. (Roth, 2008) This device is used to delivers an electric shock to a heart that is in ventricular fibrillation. Ventricular fibrillation is a lethal malfunction of the heart (heart attack).

Similar to other instance mentioned earlier, defibrillators have a need to be tracked with RFID technology in healthcare facilities. For example, Florida Hospital, located in Orlando, FL deployed RFID-assisted inventory tracking and patient-care system that it believes will lower its inventory spending while also improving the lifecycle tracking of medical devices, as well as post-operative patient care. The hospital conducted an evaluation of the integrated system in its electrophysiology department where various medical device implants e.g. pacemakers, defibrillators, and catheters. The electrophysiology department's goal of the pilot not only succeeded in reducing its device and equipment inventory by $30,000 - $40,000, but exceeded their benchmark and posted savings of $65,000 at the conclusion of the trial. These significant dollar figure savings provided Sam Braga, the hospital's supply chain manager, with the confidence to purchase some devices in bulk instead of in small quantities equating to savings of $85,000. The Florida Hospital was able to save $150,000 just through the pilot run. (O'Connor M. C., 2008) Similar to the Florida Hospital, the Heart Hospital Baylor Plano deployed RFID technology to keep tabs on the whereabouts of their defibrillators along with other medical devices as well such as stents and pacemakers. Mark valentine, president of the hospital, expressed that RFID in this case is a very worthy technology to invest in as he noted that the Heart Hospital forfeits about $2 million a year in lost or misplaced. (Godinez, 2007)

3. STENTS

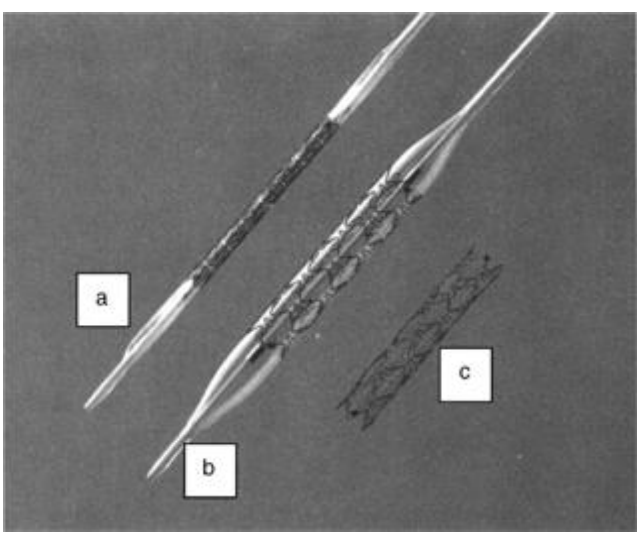


Figure 16: (a) A PTCA catheter and stent. Stent and balloon in collapsed configuration for insertion and placement into coronary artery. (b) Inflated balloon causing stent to expand. (c) Expanded stent after collapse of balloon and removal of catheter. (Goldsberg, 2008)

Stents are used to open a blocked, constricted coronary artery instead of bypassing the blockage with a graft. Under local anesthesia, a steerable balloon catheter containing a stent mounted to the balloon (Fig. 4a) is inserted into the patient's femoral artery and guided to the constricted coronary artery under fluoroscopy. Once in position, the balloon is inflated to compress and flatten the plaque against the arterial wall, creating a larger opening for blood to flow through the coronary artery. During balloon inflation, the stent is expanded to a larger diameter Fig. 4b, which is maintained after deflation of the balloon. The catheter is removed, and the expanded stent (Fig. 4c) is left in place to maintain a larger opening and prevent restenosis (narrowing of a blood vessel leading to restricted blood flow) of the coronary artery. (Goldsberg, 2008)

Stents, like other medical devices mentioned, are high-valued assets and can cost healthcare groups a lot of money to maintain even if administered with great care and focus. In some cases, healthcare facilities deal with medicated stents that are to be used on particular patients. With this in mind it is very important for to know the status on their shelf life span and RFID is the perfect tool to do it. The Heart Hospital for example tagged 10 high-tech storage cabinets around the hospital that encased high-dollar items such as drug-coated stents costing $5,000 a piece, and other tools and devices that can cost several thousand dollars. Though the cabinets weren't cheap at all costing about $400,000 with all the scanners and network equipment installed, Mark Valentine who is the president of the hospital believes the technology would quickly pay for itself because of significant reduction in inventory. (Godinez, 2007)

UMass Memorial Medical Center in Worcester, MA also utilizes RFID technology to help keep track of their medical devices and to save lives as well. The medical center's lab balloons and stents cost up to $3000 each. Running out of any of these devices that come from different vendors in several sizes (to suit patients' needs and physicians individual preferences) can be very problematic and can make the difference between life and death. Similarly to other hospitals, many of the stents that doctors use are drug-coated and have limited shelf lives. Prior to the implementation of RFID, the supply chain coordinator of the hospital, Raul Navarro, relied on his own eyes to monitor the lab's shelves to ensure the devices were in stock and fresh which left plenty of room for human error. Nonetheless, with the help of the new technology the catheterization lab has reduced their inventory value to $100,000 down from $400,000 and administrators can put a number on the inventory figures at any moment. (Baard, 2008)

4. WHEELCHAIR

Figure 17: (a) Standard wheelchair, (b) Lightweight wheelchair, and (c) ultralight wheelchair. (Goldsberg, 2008)

Wheelchairs and other mobility aids, whether it be a walker or a prosthetic limb, give their users the independence in their everyday lives to work, play, and perform their activities of daily living. Properly prescribed mobility aids also assist in the safety of their users by reducing falls, and reducing fatigue and injuries to the upper extremities. The dramatic advancements in technology in the past decades have allowed mobility aids to be accessible to a far greater population of users, and have given users, even those with very limited functional mobility, the means to participate in whichever activities they please and also to perform their normal daily activities. The ultimate goal and outcome for a clinical assessment of mobility should drive toward a successful wheelchair, recommendation that enhances the quality of life expectations and their effectiveness as reported by the consumer. Quality of life is specific to and defined by each person and/or family receiving clinical services. The consumer, their family, and care givers, must be actively included in this process, as they will be most affected by the choice of the mobility aid. Also, people chose their mobility devices based on the features available that facilitate activities or address needs, and the clinician should be aware of the consumer preferences and the features of various devices. (Cooper, Wolf, Collins, Chavez, Karmarkar, & Cooper, 2008)

In our everyday lives we see individuals with limited mobility in wheelchairs going about their everyday activities. These activities can be sports, doing grocery shopping in supermarkets, and typical strolls through the parks. Well in hospital environments, wheelchairs are an essential mobile asset that helps both patients and professionals in their daily activities. However, wheelchairs like other mobile assets in hospitals go missing all the time because they are always in constant use and are in continual movement throughout the facility. Therefore hospitals are required to compensate for not knowing the precise whereabouts of their own property by purchasing or renting more items than would otherwise be necessary. So again shown is RFID technology being a cost-effective method for managing and important device. St. Trudo Regional Hospital in Sint Truiden, Belgium is an example healthcare group that utilized RFID for better utilization of patient care equipment. Before implementing the new asset tracking solution, staff often had to manually search the entire facility to locate needed equipment which wasted a substantial amount of time and reduced overall utilization of patient care equipment. Moreover, when the equipment was not readily available, the hospital often had to rent others incurring high expenses and delays. To resolve this issue the system is set up to alert hospital personnel when the number of wheelchairs available reaches a critically low level, or whenever a wheelchair is inactive for two hours so that it can be returned to the reception area. (International Hospital Equipment and Solutions , 2009)

In relevant to St. Trudo Regional Hospital's situation, Lahey Clinic mentioned above also deployed asset tracking systems to monitor their mobile assets like wheelchairs. When performing and ROI analysis they focused on hard-to-locate items in which wheelchairs were included. Jeff Doran, Sr. VP of Operations for Lahey Clinic, said "wheelchairs and stretchers are always easy for escorts to find. Patients spend less time waiting. We've been able to eliminate one-half FTE for equipment locating." Along with this reduction in FTE, the clinic was able to cut rental and replacement costs by significant figures. (GE Healthcare, 2007)

Section 4.6.6 – RFID and Biomedical Device Compatability

As we can see from cases presented in earlier sections, RFID technology is emerging within healthcare settings to improve patient care, patient safety and hospital efficiency. Currently the RFID technology is being used for asset management, patient care and inventory management in the healthcare industry. As multiple types of short-range wireless technologies are used simultaneously within close range in a dense wireless environment such as inside a hospital setting, the potential for interference among them and with medical devices becomes a concern. Therefore it is important we consider the possibility for electromagnetic interference (EMI) among these devices sharing the same frequencies.

Electromagnetic Interference and Electromagnetic Compatibility of Medical and RFID Devices

Electromagnetic interference (EMI) occurs when one or more electronic devices adversely interfere with the operation of another electronic device. Any radio frequency (RF) transmitting device such as a mobile phone or any other wireless device has the potential to electronically interfere with the operation of another electromagnetic device because of the physics governing radio waves: as electrons move, they create electromagnetic waves that spread through free space and potentially interact with each other. In healthcare facilities, EMI occurs when electromagnetic devices interfere with medical equipment, potentially causing equipment malfunction. Electromagnetic compatibility (EMC) is the opposite of EMI. EMC means that the device is compatible with (i.e., no interference caused by) its Electromagnetic (EM) environment and it does not emit levels of EM energy that cause EMI in other devices in the vicinity.

Medical devices can be susceptible to EMI if they confuse external EM signals for the physiological signals they are designed to sense (e.g. pacemaker inhibition due to misinterpretation of the external electrical signal sensed). If the medical device incorporates leads, the leads may act as antennae and detect external signals, or if the device has inadequate filtering to remove unwanted signals and enhance the desired signals, or both, the signal can enter the device and disrupt its normal operation. IEC Standard 60601-1-2 (EN 60601-1-2 in the European Union) sets out electromagnetic shielding standards for medical equipment. All medical equipment subject to EN 60601-1-2 must comply fully in order to be legally marketable in the European Union (EU). This 2007 standard sets immunity test level for critical devices at 10 V/m, and at 3 V/m for other equipment over the frequency range 80 MHz - 2.5 GHz. (Dr. Oduncu, 2008)

Reported Cases of Electromagnetic Interference to Medical Devices due to RFID Devices

A study conducted in Sweden by the International Anesthesia Research Society has tested the compatibility of different mobile phone technologies and WLAN (802.11b) with medical devices. Both laboratory test according to ANSI standards and clinical test have been performed. The study showed minimal interference between medical devices and WLAN communications. Some rare pieces of old equipment were affected by mobile phones broadcasting at full strength. However, a study conducted in USA has tested RFID readers and reported that they interfered with pacemakers at distances from 11.5 cm to 51.3 cm (134kHz – 77%, 13.56MHz – 24%, 915MHz – 5%).

In a study that simulated a dense wireless environment such as in a healthcare / hospital setting, investigators examined the scalability and coexistence of two wireless personal area networks, WPAN (Blueetooth and Zigbee) technologies and found that there were serious limitations in scalability and interference with multiple medical sensors (ECG monitoring). Although they did not study the RFID technology, but because the RFID shares the same frequency bands (915 MHz and 2450MHz), it is likely that similar findings of interference could happen between RFID and WPAN devices using the same frequencies

In the US, the Food and Drug Administration, Center for Devices and Radiological Health (CDRH) tested the electromagnetic compatibility between active implantable cardiac devices and Radio RFID readers. A total of 18 cardiac pacemakers and 19 Implantable Cardioverter Defibrillators (ICDs) were tested for immunity to Radio Frequency (RF) emissions generated by seven RFID readers. The seven RFID readers operated at one of the following frequencies: 134 kHz, 13.56 MHz or 915 MHz. The pacemaker (or ICD) was placed in a torso simulator which contains saline bath filled with 0.18% saline solution to mimic the electrical characteristics of human body. The output signal of the implantable device was observed on an oscilloscope during exposure to electromagnetic fields from the RFID readers. Any change in output signal was noted as a reaction from the pacemaker (or ICD). Reactions ranged from non-clinically significant events to the potentially harmful inappropriate tachyarrhythmia detection and delivery of therapy or complete inhibition of cardiac pacing. However all pacemakers and ICDs tested returned to normal operation once removed from RFID exposure.

Another very similar study conducted in Japan also tested the effect of EMI due to RFID devices for implantable cardiac pacemakers. They tested 10 RFID readers / writers operating at 125 kHz, 13.56 MHz (continuous wave) and at 950MHz and 2.45GHz (pulse modulated wave). They found that continuous wave from RFID antennae did not affect the operation of the pacemaker, but either moving the antennae or operating with pulse modulated wave affected 14% of the tested pacemaker operating modes. The maximum interference distance between the antennae and the pacemaker (minimum safe distance) was measured as 15cm. (Dr. Oduncu, 2008)

Management of EMI Issues within Healthcare Settings

Healthcare organizations should pay extra attention to situations where new and old equipment co-habit the same location and either move the older equipment to more shielded areas or force stricter EMI control measures. Many healthcare facilities have responded to the introduction of wireless devices by banning the use of devices such as mobile phones on their premises. However, evidence compiled by industry sources such as the Medicines and Healthcare products Regulatory Agency (MHRA) in the

United Kingdom shows that mitigating the EMI risk posed by wireless devices need not be expensive or time-consuming. Each healthcare organization should evaluate industry practices and recommended guidelines within the context of its own facility, since each healthcare facility has a unique electromagnetic environment composed of a heterogeneous mix of medical and wireless devices. (Dr. Oduncu, 2008)

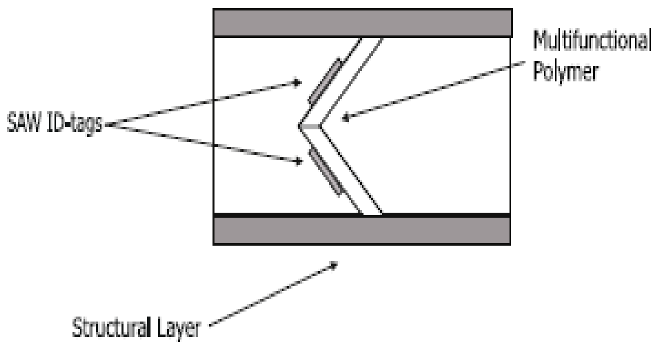
Section 4.6.7 - Future of RFID in Biomedical Applications

RFID in Biotelemetry

This section focuses on wireless transcutaneous RF communication in biomedical applications. It discusses current technology, restrictions and applications and also illustrates possible future development. The focus here is the application in biotelemetry where the system consists of a transmitter and a receiver with a transmission link in between. The transmitted information can either be a biopotential or a nonelectric value like arterial pressure, respiration, body temperature or pH value. It is understood that RFID is a technology that is analogous to the working principle of magnetic barcode systems. Unlike magnetic barcodes, passive RFID can be used in extreme climatic conditions—also the tags do not need to be within close proximity of the reader.

Efforts put forth in implementing RFID in biotelemetry are to exploit an exciting new development in making circuits on polymers without the need for battery power. This solution utilizes the principle of a surface acoustic wave (SAW) device on a polymer substrate. The SAW device, recognized for its versatility and efficiency in controlling and processing electrical signals, is a set of interdigitated conducting fingers on the polymer substrate. The fundamental property of the SAW device is its ability to act as a signal delay line. With an appropriate RF signal sent to the device, the fingers act as microantennas that pick up the signal emitting energy that is then converted into acoustic waves that travel across the surface of the polymer substrate.

Figure 18: Flexible polymer substrate



Being a flexible polymer, the surface acoustic waves cause stresses that can either contract or stretch the material of microstructures such as valves, pumps, and channels. So when the surface acoustic waves cause stresses in the polymer substrate, the resulting deflection can be of the order of microns, suggesting an ideal novel application would be a microvalve. Essentially, a small hole in the polymer substrate can be stretched to open wider or contracted by application of the RF signal on a SAW-on-polymer device. By sandwiching a number of these microvalves together, and by operating them in different phases, a peristaltic micropump could be created—this is very useful in cases where a fluid needs to be pushed through the orifice. The focus of these efforts is for an RF controllable microvalve that could ultimately be used for *in vivo* applications such as fertility control, drug delivery, flow cymetry, and DNA sequencing. A further possibility is for passive venous valves (such as in artificial heart valves) to use the polymer device for monitoring the open/shut status of the valve, rather than for actuation. A host of lucrative applications from valves for electronic fertility control to micropumps for nanoliter drug delivery become foreseeable. The basic structure of the Vgroove microvalve is shown in figure 6.

Future MEM Systems in Biotelemetry

MEM (microelectromechanical) systems of the future will require integration of active as well as passive devices. There are many types of devices produced for different tasks, for example *microchannels*, *micropumps*, and *microvalves*. These microfluidic structures are divided into two different categories: passive devices (without an actuator) and active devices (with an actuator). Passive microvalves get their activating energy from the surrounding fluid and flow in only one direction is possible.   On the other hand, the energy of active valves is externally supplied. The advantage to using active valves is that the control of very small sample volumes is possible, which is very important in biomedical, chemical, drug delivery and printing applications.

Possible Applications of RF-Controlled Microvalve

This section describes some of the main biomedical fields in which the RF-controlled microvalve may be applied, i.e (1) fertility control, (2) drug delivery, (3) flow cytometry and (4) DNA sequencing. Fertility Control – There are a variety of methods for conception control such as using the 'pill' or performing a vasectomy. But the choice of a suitable method is very difficult and the potential risks and benefits must be carefully analysed. For example there are many side effects to using the 'pill' and a vasectomy reversal has a high failure rate containing a painful surgical procedure with an inconvenient recovery time for the patient. To avoid these problems the microvalve described above could be used. It could be placed in the *vas deferens* of a male to make restored fertility possible and relatively easy. Within the first two weeks after insertion, the valve can be episodically switched on and off, reducing the backpressure during the early stages when the valve adheres to the walls of the *vas deferens* and to reduce any possible build up of proteins on the face of the valve. The insertion can be performed by a hypodermic needle.

Researchers are currently unable to insert the microvalve in the female ovarian duct because the ovarian duct has an inner surface which is coated with *microvilli* that are like microscopic fingers which help the *ova* to move along the duct in the correct direction. The ovarian duct is also very sensitive to foreign objects which tend to cause adhesion within the tube.

Drug Delivery – In many different cases it is very useful if drugs can be delivered at the right time and as close to the treatment area as possible, such as, for example, in the case of *diabetes mellitus*. To make this possible, drug delivery micropumps that can be implanted in the body are used to deliver small quantities of drug from a reservoir. These micropumps would avoid the strain on veins of weekly or daily injections. In this case, an RF-controlled microvalve could be integrated in an implanted drug delivery system and make it possible to set the correct drug dosage to be applied at the right time. Existing approaches either use an osmotic valve, which unfortunately provides a continuous feed, or have the disadvantage of battery power.

Flow Cytometry – The basis of flow cytometry is that specific optical characteristics (such as fluorescence or light scatter) can provide a measure of the specific physical or chemical properties of biological particles (such as size and DNA content). The principle of flow cytometry has been integrated into a micromachined silica flow chamber. In this instrument a collection of small particles is pumped through a specially designed transparent tube. A measurement is made when the particles pass the 'sensoring region'. This region is delimited by the illumination and collection regions which are provided by light source and optical detector assemblies. The RF-controlled microvalve could be integrated into a flow cytometry system to control the stream of particles, which would keep the biological cells of interest in a separate particle chamber for later investigations. It could also prevent a reverse flow of the cells out of this chamber.

DNA Sequencing – Present DNA sequencing methods employ electrophoresis and they are still quite slow and expensive. To speed up the sequencing process and reduce costs through miniaturization, one idea is to pull a strand of DNA through a tiny hole in a polymer material immersed in an ion solution. Variations of the ion current are detected, which correspond to the A, G, C or T bases in the DNA molecule. One key problem is that of poor signal-to-noise ratio (SNR) in the measured current. The proposed SAW-on-polymer devices provide a means to an adaptively modulate the diameter of the hole to optimize the SNR via use of lock-in amplifier techniques.

RF – Controlled Microvalve: A Fertility Control Modeling Study

The microvalve can be employed for fertility control or to replace a vasectomy. The main element of the valve is the multifunctional polymer actuator, which serves at the same time as a closure element of the microvalve. The wireless communication principle via ID tag is used as previously described. The ID tag is deposited on the surface of the polymer actuator. The corresponding reader/transmitter station is outside the human body. The valve is closed in the initial state if no RF signal is sent to the ID tag. In this state, infertility is set. If a sperm or *ovum* should pass through the microvalve, RF pulses are transmitted by the base station, which is located outside the body, to the valve. Because of the deformation of the actuator material, the microvalve opens and closes with a certain frequency. The intention of the study is to develop a device in which the orifice opens cyclically at a certain frequency. The lower the frequency, the more severe the demands on the RF power to the device. On the other hand there are fluid-dynamic restrictions on how high the frequency can be which were determined by the study

The decline of the oscillatory flow rate with frequency indicates that, despite the small tube diameter in the frequency range of interest, momentum plays a highly significant role in determining the flow that occurs in response to the applied pressure gradient. In the present context, what is determined here is the extent of forward flow for a given frequency of opening orifice, relative to the flow that would occur through the tube if the microvalve presented no obstruction of the tube occurs when the microvalve is open.

The fluid dynamic simulation has a typical low pass characteristic with a cutoff frequency fc of 30 Hz. The frequency range of interest here is between 10 and 100 Hz. In that particular range, the flow rate relative to that at 0 Hz is 90% for 10 Hz and 25% for 100 Hz. From the physiological point of view, the flow rate at 100 Hz is sufficient for sperm transport through the microvalve, whereas it is desirable to have a higher flow rate. The flow simulation shows that a material is needed which is able to oscillate in that frequency range. Oscillations at such low frequencies are achieved by a special arrangement and distances of electrodes on the surface of the SAW device and by the fact that the nanoparticle-embedded polymer is a highly damped material. Frequencies down to 100 Hz have been achieved at Penn State and work is ongoing for further reduction.

Key Decision Criteria for Entry into Markets:Safety and Reliability Issues

Figure 19: Maximum radiated power that is allowed to be sent through the human body at different frequency ranges

Frequency band (MHz)	Maximum isotropically radiated power
915–928	1 W
2400–2463	4 W
2463–2483.5	20 mW
5725–5875	1 W

There are many restrictions associated with RF technology that need to be considered. One of the main regulations is related to bandwidth and power dissipation. The relationship between the different frequency ranges and the maximum radiated power is shown in Figure 6. The Australian Communications and Media Authority (ACMA) releases licences for companies and strictly governs bandwidth and power emission. One of the main restrictions is on interference—devices must not cause interference to other radio communications services and must operate within the relevant ISM bands.

One of the fundamental concerns for RF *in vivo* applications is how the radiation affects the human body. Countless tests have been carried out researching a link between RF exposure and cancer. Hence a unit of measure called the specific absorption rate (SAR) has been developed. The SAR is the basic unit of measurement of RF fields between 1 MHz and 10 GHz, with a SAR of 4 W kg^{-1} needed to produce adverse health effects. It has also been claimed that RF exposure induces heating in the body, which is thought to affect male fertility. This is an area that needs to be investigated further. The maximum SAR is dependent on where in the body the device is placed so each application will have to verify the device is within these limits.

Open Questions and Future Work for RF-Controllable Microvalve

From the information provided we can see that there is a wide scope for the future development of an RF controllable microvalve. In new fields of research, there are many questions to be answered before any invention can be safely applied. Above all, in the field of fertility control it is important to make sure that the microvalve works correctly and efficiently to prevent problems which could endanger the patient. Considering the expansion of the actuator material, analysis should also be done if a particular shape of the microvalve has an influence on the displacement of the actuator material. It is not yet known whether there exist differences in displacement of different shapes of the valve. The aim is to find the 'optimum' shape which satisfies the requirements of displacement for application in the area of fertility control. Furthermore, it should be established which shape is the easiest to implant in the body in order to prevent complications in surgery and additional pain for the patient. Initially, these tests, together with tests for the functionality of the valve, can be undertaken in animals such as sheep or pigs.

Apart from that point of view, there is also room for electromechanical modeling of the actuator material of the valve. In particular, the gain of the antennas versus the suitable frequency ranges has to be carefully analyzed. The next step in research is to analyze the efficiency of the antenna, because the lower the RF frequency, the lower the gain of the antenna, which makes it difficult to deliver enough power to cause a certain amount of strain in the material. In this study we only considered a simple dipole antenna structure. Improved trade-offs between efficiency and antenna size may be achieved by use of other geometries such as fractal antennas. For a given frequency, suboptimal small antennas may be possible at the expense of increased external RF power—the limit to this trade-off will depend on the safety requirement for transcutaneous RF transmission for each given application. Given that the human *vas deferens* is of the order of 400 μm in diameter, male fertility control is a rather ambitious goal, as the whole integrated valve would have to fit into that diameter. Therefore our near-term goal will be to firstly target drug-delivery applications, where the size restriction can be greatly eased. Size requirement will impact on the lowest usable RF frequency, and in this program we will push valve size and antenna size down as far as we can go to find the limits.

Another question is whether the SAW device can exert the forces required to control flow against ultimately physiological pressure gradients. In the short term, the proposed device will simply be limited to a narrow range of applications, if higher pressure gradients prove problematic. In the longer term, new polymer substrate materials may emerge (e.g. nanotube – embedded polymer) that exhibit higher actuation strains. The aim of material simulations is to find a material which needs a very low energy level to cause a relatively high deformation. The frequency behaviour of the material could be calculated by a simulation of the valve. Together with a simulation of the different shapes of microvalves, we can optimize the microvalve set-up for fertility control. As a result of these simulations, a first model could be constructed following the required design specifications.

Section 4.7 – Summary

As discussed earlier, organizations adopt new technologies with different underlying rationales. Although the these industries are making a slow but gradual move towards major mplementation of RFID, usage is expected to accelerate once the price of RFID drop and companies become more comfortable with the shift towards the technology. RFID's benefits as we have seen can have an immense impact on the efficiency of hospitals and airports, reducing their inventory size which leads to cut costs. These two elements will be the driving force behind RFID's industry-wide deployment. Based on our findings, it is suggested that in the adoption of RFID technology, institutional pressures from organizations would be a stronger driver for adoption than strategic considerations. We make this conclusion based on knowing that integration requires substantial commitment of resources (time, money, effort). Greater integration would be more likely when adoption is voluntary, while keeping in mind performance and efficiency benefits, than when it is a response to pressures from organizations.

Therefore, for expected internal and external integration of RFID, we suggest that strategic rationale, with an emphasis on improving efficiency and organizational performance, may actually be the better predictor.

Our results from the industry research show that there is a need for RFID to trace high-valued assets which evidently cuts cost in many ways including stolen or misplaced items and by decreasing the amount of inventory needed to assure availability of resources. For early adopters of RFID in both the aviation and healthcare markets, there is evidence supporting that market penetration is available for Wavetrend. Wavetrend can present these cases to their potential customers showing them the substantial amount of return they can receive with implementing RFID technology.

What’s even more convincing is the incredibly low penetration rate of competitors. With less than 5% of hospitals deploying RFID and only 1% of airports utilizing RFID for asset tracking, these industries are ideal for the goal of this project which was to discover industries that have needs for location technology in tracking assets, while being able to show a feasible return on investment for customers, and a showing that the industry actually has room for penetration. When entering a market within an industry, were we told from the beginning of the project that learning about the customers who are players in the market would be vital. In regards to these instructions, we inspected some of the competition who have had success, and reported how they carried out their efforts which should be helpful to Wavetrend in strategically approaching these markets.

Chapter 5 – Implications and Conclusion

Our final chapter covering implications and conclusion provides the implications of our analysis and the conclusions that can be drawn from them. Section 5.1 will discuss how we interpreted the decision drivers, section 5.2 will discuss our conclusions about the aviation industry, section 5.3 will explain our conclusions about the healthcare industry, and section 5.4 will explain the conclusions drawn from our survey.

Section 5.1 – Interpretation of Decision Drivers

As discussed earlier, organizations adopt new technologies with different underlying rationales with influencing factors. This mix of influencing factors that push the adoption of RFID technology are classified under two umbrella organizational perspective theories which are "Rationalistic" Strategic Choice Perspective, with an emphasis on improving efficiency and organizational performance, encompasses the technological, organizational-readiness, and external-environment factors. The other organizational perspective theory was Institutional Perspective with an emphasis on maintaining legitimacy, encompasses inter-organizational pressure factors.

Based on our findings, it is suggested that in the adoption of RFID technology, institutional pressures from organizations would be a stronger driver for adoption than strategic considerations. We make this conclusion based on knowing that integration requires substantial commitment of resources (time, money, effort). Greater integration would be more likely when adoption is voluntary, while keeping in mind performance and efficiency benefits, than when it is a response to pressures from organizations. In correlation to this conclusion, both industries that were researched show organizations deploying RFID in which the primary milestones reached came from improving efficiency and organizational performance in regards to perceived benefits outweighing the perceived costs housed in the technology factors. Therefore, for expected internal and external integration of RFID, we suggest that strategic rationale, with an emphasis on improving efficiency and organizational performance, may actually be the better predictors rather than drivers at this stage for both industries. In organizations presented in the industries research, top management support was also present between partner organizations. This means that other businesses which they work directly with in their industry are also putting forth efforts to deploying RFID for the same causes. This top management support pressure is also deemed a better predictor rather than a driver.

With the costs and the benefits being addressed this leaves us to focus on institutional pressures from organizations which we deemed stronger fundamental decision driver in these industries. In this category, normative pressures, also decision drivers needed to be present to drive RFID, occur in relational channels among network members when norms are shared during consensus building thus potentially increasing a norm's influence. Communication among SC partners and among members of professional bodies and industry trade associations concerning benefits and best practices related to innovations would result in shared beliefs and persuade organizations to adopt technologies standard convergence would be one of the pressures that would have to be present to drive RFID.

Perceived standard convergence, explained earlier, is the degree of consistency of standards between the partner organizations within an industry (vertical) and across industries (horizontal). With RFID adoption, it is important to achieve interoperability between partners and to move towards open standards for leveraging cross industry benefits. For example, these missing pressures could be associated with both industries. In the aviation industries, if manufacturers of airplane parts such as Boeing and Airbus, would install RFID directly during assembly of the parts then it would allow for more airports to begin also using RFID for other applications besides tracking and maintenance of airplane parts.

To further support our conclusion of institutional pressure from organizations being fundamental decision drivers, we consider external competitive pressures. If we recall from the industries research, the penetration rates of competitors are very low. If the penetration rates of competitors indicate RFID usage within industries, this illustrates how the lack of pressure from competition truly drives whether or not organizations will turn to RFID for different applications. This idea correlates to mimetic pressures (competitive pressures) from organizations response to uncertainty. In uncertain conditions, with no clear course of action unavailable, organization leaders tend to mimic/copy actions of perceived successful organizations. Mimetic pressures, as mentioned in Chapter 4, are driven by industry bandwagon effects (following successful competitors) or driven by status (following prominent organizations). With RFID adoption, technology uncertainty may exist due to differences in firms that are strongly influenced to mimic firms considered industry leaders or competitors who are considered to have successfully adopted. In essence, leading competitors aren't utilizing RFID, then perhaps less successful companies will not explore RFID's uses until the successful ones demonstrate that its benefits are reachable.

Section 5.2 – Industry Implication

Healthcare Industry

Healthcare is predicted to be one the major growth areas for RFID. This paper describes some interesting applications with promising perspectives. It also presents an open source application and shows how it could be used to directly implement some of the use cases. However, it is worth noting that there are still some open problems to be solved before the healthcare community fully embraces the RFID technology. One must be sure that the deployment of radio frequency devices does not interfere with pacemakers, heart monitors or other electrical devices that are common in a hospital. Furthermore, the consequences and side-effects of radio waves on the exposed humans have to be clarified. When talking about pasting radio frequency tags on drug packages, there are concerns that exposure to electromagnetic energy could affect product quality.

Furthermore, any technology implementation in healthcare must deal with privacy and security issues. But RFID presents unique concerns because of the possibility of unintended wireless transmission of healthcare-related information. Unethical individuals could snoop on people and surreptitiously collect data on them without their approval or even without their knowledge. This could occur even after completion of healthcare services if RFID tags remain active. Hospital staff has to feel comfortable with the fact that they can be tracked and located every time. From these concerns, it should be clear that challenging cryptographic issues are raised in relation with wireless transmission and that there is a need for clear laws and recommendations about the tracking of goods and people.

In the healthcare sector, the penetration rate is also currently very small. However, it is expected that many hospitals will begin to use RFID technology within the next five years. In order for Wavetrend to fully take advantage of this opportunity, they need to attack this market as quickly as possible. Throughout section 4.2, there are several examples of the thousands of dollars that hospitals can save by tracking their most expensive assets, deterring losses and maintaining steady inventory levels. There are many examples of hospitals that have successfully began to use RFID technology explained in section 4.2, and these examples can be cited when explaining the benefits of RFID technology to potential customers.

Aviation Industry

The FAA formally approved the use of passive UHF RFID tags on individual airplane parts for commercial aircraft, which opens up a number of potential RFID-based applications for airlines, air-freight carriers, aircraft maintenance and repair centers, and airplane manufacturers. This paper touched on some of these topics: (1) Airline parts maintenance tracking, (2) Tool management, (3) Cargo container management, (4) Mobile asset management

Aviation is one of the key areas where RFID will bring huge savings to airlines, airports and other aviation partners. Airport baggage control is one of the most interesting areas where RFID may be applied, with proven trials in some airports around the world, and potential huge savings. Mishandled baggage is a worldwide problem generating high and increasing costs. RFID implementation and experiences are being widely sponsored at government level and there is a window of opportunity for being part of leading group in terms of applying RFID technology to airport baggage control. This is a technology that may be introduced gradually. Program actions identified by IATA may eliminate about 80% of mishandling bags (after the 20% solved by RFID alone through improvement of read rates and BSM). This is a strong incentive to airports and airlines to start evaluation "now" in order to stay competitive and not to be left behind in the application of this inevitable step towards a clear upgrade in passengers' satisfaction.

Within the aviation industry, mobile assets and spare parts tracking has the most potential to be tracked with RFID technology. Throughout the industry, location tracking could save over $7.5 million. Wavetrend could use these numbers, found in section 4.1 of this paper, to explain the advantages of RFID technology to potential customers within the industry. Due to the incredibly low percentage of airlines currently leveraging these technologies, Wavetrend will need to persuade potential customers by showing the vast return on investment of these systems.

Section 5.3 – Limitations

A major hindering factor of our project was the limitations for our data collection methods. Throughout the project our team ran into several areas which may have prevented some data from being fully recorded. In different stages of our work we encountered different types of problems. These issues will be address throughout this section of chapter 5.

There were two portions of data collected for this project, primary sources (the survey that we conducted) and secondary sources (the researched data that we compiled over the course of the year).

First to be addressed will be the setbacks seen during the primary data collection. The survey, while taking time to develop, was something that the team thought could yield significant results for the final project. Much time was spent in creating the questionnaire and cover letter that were distributed to the selected customer list chosen by our sponsor. However, here lies the problem for our group: we did not receive the number of responses that we had hoped for. Of the 25 customers who received the cover letter and survey link just 6 responded by completing the questionnaire. This was unfortunate for us because it made drawing conclusions from the survey very difficult. With only 6 responses it was very difficult to make inferences that were not very general. Had we been able to get a higher response rate we may have seen more trends within the data that could then be relayed to Wavetrend. Yet, this was not the case, showing how this aspect of the project limited our expected output.

Besides running into limitations in primary data collection we did sometimes run into problems with the secondary data collection. One of the main problems encountered here was the lack of availability of certain documents that could have improved our data. We saw many reports on various aspects of the RFID industry and competition that needed a subscription to be viewed. Had some of these sources been modest in cost we may have been able to work something out, however, many of these cost upwards of $1,000, far too expensive for our MQP team. Besides being unable to view these reports problems were relatively few. Occasionally a source would be unavailable to us at the campus library but we had several of those at our disposal, including the Boston Public Library's system, as one of our team members is from that area.

Overall, the main limitation of data collection to this project came from the survey. This section could have been far more beneficial to Wavetrend if the desired number of responses was reached. Other than this, the limitations of secondary data collection were minimal.

Section 5.4 –Lead-User Survey Implications

The lead user survey that we created in this project was not used to its full potential due to time constraints. Therefore, directly from the results there is little value for Wavetrend. Through the survey we were able to suggest that RFID technology is perceived as more profitable than GPS, satellite, cellular, mesh, and bar-coding. We were also able to suggest that the reason end-users do not adapt RFID technology is primarily based on cost.

The final question of the survey returned several comments about how Wavetrend should specifically modify their next generation of RFID technology. This could be very useful for Wavetrend if this survey were distributed to all of Wavetrend's customers, as it would return many specific ideas from these customers.

Overall, reading too much into the survey responses could cause a problem, as the survey was only a test receiving six responses. Only receiving six responses makes it quite difficult to analyze the results and draw conclusions that we could use to validate our market research. The point of any survey is to use the information gathered from a small targeted group to draw conclusions on a greater population. For example, in question three we ask our respondents to rank, in order, the profitability of multiple types of location technologies (RFID, GPS, Cellular, etc). Active RFID was the technology that most of the respondents chose. However, only three of Wavetrend's customers picked active RFID as the most profitable. Even though half of all respondents chose active RFID, statistically that information is skewed and cannot be used to draw conclusions about the entire population.

After re-evaluating the responses and perhaps modifying some of the questions or answers, this survey could be distributed to a larger audience to receive more responses. Receiving a minimum of twenty responses to this survey would allow for us to analyze and gain more from this survey.

Section 5.5 – Future Projects

Our market research methods were executed perfectly and were an overall success. We were able to collect substantial data pertaining to penetration rates, ROI, and current RFID applications. However, we would have used a slightly different method to gather information from Wavetrend's current customers.

After the execution of our survey we realized we could have done some things differently, which could have possibly obtained better results and response rates. In hind sight, we would have used phone interviews of lead users or sent the survey to more than thirty people to obtain information that would support and validate our market research. We considered phone interviews before we decided to use the survey, but we thought we wouldn't be able to talk to enough people to make the information we would obtain credible. If we did choose to use phone interviews we would have interviewed a minimum of six lead users. This would also allow us to get more detailed responses in regards to their personal experiences with RFID and other location technologies.

If we sent out our survey to the entire list of Wavetrend's customers, approximately 300 companies in total, we would have received many more responses. If the participation percentage remained uniform, we could have expected roughly 50 responses that we could have used in our market validation. However, Professor Gonsalves advised us that we should not send the survey to the entire list.

Ideally we would have combined the two techniques discussed above in order to obtain the most detailed responses. We could have sent the survey to 100 companies, and then interview 10-20 lead users. This would have made it difficult to perform statistical analysis, but would have provided us with a much greater number of responses to work with and to draw conclusions from.

Due to time constraints we were unable to contact companies within our chosen industries. We would have briefly conveyed the benefits of RFID technology and then determined why they have not yet adopted such a system. If more time was available we would develop another survey to better understand just that. This survey would be combined with phone interviews in the same method discussed above. The survey and interviews would allow us to better determine the feasibility of adoption within the given industry. For example, many companies do not like to change their daily operations. There is always some level of a learning curve associated with any corporate change. By contacting multiple companies within our given industries we would be able to determine if unwillingness to change is a uniform view throughout the industry. This would certainly hinder the adoption of a new RFID infrastructure.

Table of Figures

Figure 1: Tracking Assets……………………………………………………………………………………………………….10

Figure 2: Example Methods Chart…………………………………………………………………………………………..25

Figure 3: Percentage of Respondents for ABI's
End-User Survey, Segmented by Primary Vertical Market……………………………………………………...27

Figure 4: Snapshot of Industry Data…………………………………………………………………………………...**Error! Bookmark not defined.**3

Figure 5: RFID Elements of Cost…………………………………………………………………………………………34

Figure 6: RFID Utilization in Airports……………………………………………………………………………………398

Figure 7: Savings by an Early Adopter (Mun, 2006)……………………………………………………………………39

Figure 8: Infusion Pump Utilization (Mun, 2006)………………………………………………………………………43

Figure 9: Healthcare Cost - Benefit Comparison Chart………………………………………………………………...49

Figure 10: Survey Results……………………………………………………………………………………………………**Error! Bookmark not defined.**1

Figure 11: RFID Adoption Rationales……………………………………………………………………………………59

Figure 63: Outlook Safety Infusion System with DoseScan
and DoseGuard by BRAUN Technologies…………………………………………………………………...68

Figure 14: An implantable cardioverter defibrillator…………………………………………………………………70

Figure 15: An automated external defibrillator (AED)………………………………………………………………70

Figure 16: A PTCA catheter, stent, and balloon………………………………………………………………………71

Figure 17: (a) standard wheelchair, (b) lightweight wheelchair,
and (c) ultralight wheelchair……………………………………………………………………………………73

Figure 18: Flexible polymer substrate…………………………………………………………………………………..79

Figure 19: Maximum radiated power that is allowed to be sent
through the human body at different frequency ranges……………………………………………..83

Table of Appendixes

APPENDIX A:

Survey Cover Letter:

Dear (recipient name),

This survey is being sent to you on behalf of Wavetrend Technologies, Inc. The survey focuses on how Wavetrend's identification products have affected your company's business and also what new capabilities need to be offered by Wavetrend to satisfy your future needs.

In order to get the most constructive responses, we ask that the (Person in desired POSITION) be the one to complete the survey.

The questionnaire should only take about 10 minutes to complete. Your responses are voluntary and will be kept confidential. Your names are not on a mailing list nor will your responses be associated with your address. If you have any questions about this survey, please contact l Ed Gonsalves at 1-508-673-0697 or at Edward.gonsalves@wavetrend.net.

By taking a few minutes to share your thoughts and opinions you will be helping us in our efforts to improve Wavetrend's products and services for your business. We will share with you an aggregate summary of our results.

We hope you enjoy completing the questionnaire and look forward to receiving your responses.

Thank you,

Link to Survey
http://www.surveymonkey.com/MySurvey_EditorPage.aspx?sm=Pb06w%2fUBR35T3uQG5%2b52Xe3x8A%2f%2fKYEgeutQdDYAkws%3d

APPENDIX B:

Survey Questions and Format

1. **Is your company:**
   - ☐ An end-user of Wavetrend's products
   - ☐ A system integrator of Wavetrend's products to end-users

2. **Which industry do you feel currently presents the best opportunity for technologies (such as RFID or GPS) in the next few years?**
   - ☐ Healthcare
   - ☐ Aerospace
   - ☐ Financial
   - ☐ Consumer Goods
   - ☐ Industrial Goods
   - ☐ Services
   - ☐ Technology
   - ☐ Defense
   - ☐ Utilities
   - ☐ Other

3. **In your view, please rank the profitability of the following technologies for your company (1= the most profitable, 2= 2nd most profitable, etc.)**

	1	2	3	4	5
GPS	O	O	O	O	O
Active RFID	O	O	O	O	O
Passive RFID	O	O	O	O	O
Satellite	O	O	O	O	O
Cellular	O	O	O	O	O
Mesh	O	O	O	O	O
Barcode	O	O	O	O	O

4. **On a scale of 1-5, 1 being not important at all, 5 being very important, how would you rate the importance of each category below?**

	1	2	3	4	5
Monetary Savings	O	O	O	O	O
Improving Efficiency	O	O	O	O	O
Cost of System	O	O	O	O	O

5. **To which of the following industries do the majority of your current customers belong to? (select up to 3)**
   - ☐ Healthcare
   - ☐ Aerospace
   - ☐ Financial
   - ☐ Consumer Goods
   - ☐ Services
   - ☐ Technology
   - ☐ Defense
   - ☐ Utilities
   - ☐ Government

☐ Other

6. **Which of these industries are your most profitable? (select up to 3)**
   - ☐ Healthcare
   - ☐ Aerospace
   - ☐ Financial
   - ☐ Consumer Goods
   - ☐ Services
   - ☐ Technology
   - ☐ Defense
   - ☐ Utilities
   - ☐ Government
   - ☐ Other

7. **Please rank each of he reasons below from 1 being the most hindering reason for the adoption of RFID technology to 5 being the least hindering reason.**

	1	2	3	4	5
Cost	O	O	O	O	O
Unawareness of the benefits	O	O	O	O	O
Unwillingness to change	O	O	O	O	O
Security Issues	O	O	O	O	O
Regulatory Restrictions	O	O	O	O	O

8. **Which of the following were the most influential in deciding to switch to RFID products and services? (choose only one)**
   - ☐ Professional sources (consultants, analysts, system integrators, etc.)
   - ☐ Wavetrend's own sources (Wavetrend's marketing group, website, direct sales
   - ☐ Media sources (magazines, newsletters, etc.)

9. **Please rank the following, 1 being the largest expense to 3 being the smallest expense when implementing an RFID system.**

	1	2	3
Hardware (tags, readers, etc.)	O	O	O
Software (database, infrastructure, etc.)	O	O	O
Services/ Maintenance	O	O	O

10. **How long did it take to reach the break even on your investment of RFID technology?**
    - ☐ Within 6 months
    - ☐ Within 12 months
    - ☐ Within 2 years
    - ☐ More than 2 years
    - ☐ We have yet to break even

What suggestions would you have for Wavetrend's next generation of products?

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