THESIS

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A MODEL FOR THE IMPLEMENTATION OF A RADIO
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WAREHOUSE ENVIRONMENT

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MICHELLE RENEE RYAN

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of the requirements for the

MS degree in PACKAGING

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A MODEL FOR THE IMPLEMENTATION OF A RADIO FREQUENCY IDENTIFICATION SYSTEM INTO A WAREHOUSE ENVIRONMENT

By

Michelle Renée Ryan

A THESIS

Submitted to
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ABSTRACT

A MODEL FOR THE IMPLEMENTATION OF A RADIO FREQUENCY IDENTIFICATION SYSTEM INTO A WAREHOUSE ENVIRONMENT

By

Michelle Renée Ryan

As competition in business continues to rise, companies are becoming increasingly interested in achieving a competitive advantage. A competitive advantage can provide companies with success within the marketplace.

Many companies are examining the supply chain in order to identify opportunities for improvement. Traditionally, components of the chain operate independently, resulting in lack of communication. The value-based chain, however, views components holistically and focuses on increased communication flow.

Communication can be improved by increasing Information Technology (IT) capabilities. One type of IT is Automatic Identification and Data Collection (AIDC). AIDC can improve the speed and accuracy of operations within the supply chain. An AIDC technology that is gaining popularity is called Radio Frequency Identification (RFID).

This research proposes a Model that offers companies an unbiased method, in the form of decision trees, that can be used as a tool to help companies decide if RFID technology is a viable solution for their warehousing operations. Suggestions for utilizing RFID in the warehouse are provided based on how packaging is tracked through the warehouse. Benefits and issues to consider are also given for each suggestion.

DEDICATION

TO MY PARENTS, THERESA & ERIC,
KELLY & MATT, AND BRANDON.
I LOVE YOU ALL!

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There were many people that contributed to the completion of this thesis and I am thankful to have the chance to acknowledge them.

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INTRODUCTION

In today's volatile market, companies must constantly strive to improve in every aspect of their operations. Competition continues to rise with each passing day. Businesses have become more knowledgeable and technologically advanced over the past few years, increasing the need to "keep up" with the competition. Companies that become complacent will end up losing valuable customers which may lead to an insurmountable financial disaster. Achieving a competitive advantage provides companies with reassurance that they will be able to possess a significant share within the marketplace.

Successful managers realize the importance of customer satisfaction. If the customers are happy, the business can continue to grow. Many companies are reevaluating their own strategies by paying more attention to their customers' perspective. Jeff Holmes, Vice President of Industry Marketing for Manugistics, Inc., states, there is an "...escalating need for companies to be much more efficient in how they do their business, how they serve their customers. They need to create bottom-line efficiency-to get the cost out-and they have to change their organization structure to support that" (Harrington 1999). As businesses explore different options to enhance their overall efficiency, a key component is getting the most attention: the supply chain. Jim Shepherd, Vice President of Research at Advanced Manufacturing Research (AMR), points out, "success now depends on the ability to meet customer demands for delivery, quantities, and options. Companies are scrambling to improve supply chain performance just to remain competitive." (Harrington 1999).

Many companies have realized that supply chain management plays a key role in obtaining a competitive advantage. According to Rick Balsgen, vice president of the supply chain for Nabisco, Inc.,

> "The opportunities in supply chain management are second to none, and there's never been a time that's been more exciting and with a higher degree of optimism across the spectrum of supply chain management than today. Many of us are finding that we are moving from a liability to be managed to a competitive weapon in the marketplace, and that there is a lot more value the logistics supply chain can deliver than ever before" (Johnson 2000).

United States companies are recognizing this value; there has been great interest in the power and potential that supply chain management can provide (Quinn 1998). Due to the fact that the supply chain affects profits, market share, and customer satisfaction, many CEO's across the country are increasing their efforts to improve their supply chain processes and are attempting to emulate a "world-class" supply chain model.

A review of the literature reveals several common elements that exist in supply chains characterized as world class. They include: collaboration with external partners such as vendors; intragration between all logistics-related functions within the company such as transportation, distribution, warehousing, sourcing, and manufacturing; a holistic approach to management that views the supply chain as a single entity rather than individual components; and integration of the customer's needs and requirements (Quinn 1998; Markland et al. 1998; Parks 1998; Anderson et al. 1997). These elements work cooperatively to optimize material and information flow throughout the supply chain. This, in turn, results in greater efficiency and accuracy, characterized by a reduction in inventory, an increase in the visibility of goods, and greater labor productivity.

Information Technology

A key factor in maximizing the competitive advantage of a supply chain is the use of information technology. Managing the flow of information can be as crucial as managing the flow of products in a successful supply chain. According to Lance LaCross, Movex product director,

> "Information can be used as a competitive tool to connect and communicate all the way from suppliers to the end customers. The more information you can get within the supply chain, and the more tools you have to optimize the exchange of that information, the more competitive you can be" (Deveau 1999).

Many companies agree that increased information technology has shown major improvements in supply chain management. Author Peter J. Metz (1998), states, "no other factor has had as much to do with the development of supply chain management as the advance in key technologies: information, manufacturing, and transportation. The competitive urge has inspired us to implement these technology advances swiftly." In an effective supply chain, an increase in the flow of information can result in a decrease in inventory, and improved productivity and customer service. "The more we know about our products, inventory, and their movement," states Rick Bushnell, president of Quad II, a consulting firm, "the less uncertainty we have" (Trebilcock 2000). Knowledge about particular goods within a supply chain can help upper management make wiser decisions regarding the amount of inventory they utilize or store. Bushnell adds, "when we're certain about the movement and location of goods, we don't need to have as much product in the pipeline." (Trebilcock 2000).

Incorporation of information technology into the supply chain aids in the collection and processing of data in order to increase the speed and accuracy of the information flow. The knowledge and effective use of technology has been a competitive differentiator among companies for some time (Quinn 1999). Technology can provide increased product visibility, such as the identification, location, and quantity of goods, which can help companies predict more accurately what and when they will need to order or deliver. Dan Sholler, an analyst at the Meta Group, says, "using this information, (companies) can cut down on waste from overproduction; lost revenue from underproduction and late deliveries; and storage costs involved in making or getting items too early" (Holt 1998).

Automatic data collection (ADC), a type of information technology, is at the heart of a supply chain management and execution system (Trebilcock 2000). Different forms of ADC include barcodes, Radio Frequency Identification (RFID), smart cards, voice recognition, and biometrics. These technologies collect information and transmit/receive them to and from a relevant software system for processing. The data may include, for example, inventory levels, quantity of orders picked in an allotted time frame, or location of product in transit.

RFID

Radio frequency identification is a type of ADC that utilizes the radio frequency portion of the electromagnetic spectrum in order to communicate data. It is a system that has the ability to automatically identify and track objects often without line-of-sight, such as a barcode system requires. The individual components within an RFID system include a tag, reader, and host computer. Tags are information vessels that can transmit and/or receive data, readers emit frequencies in order to detect and/or send data to tags, and a computer device decodes and interprets the information contained within tags.

RFID can offer many advantages to a supply chain logistics system. Rich Krueger, Director of RFID Business Development for Motorola, points out, "It gives you much more detailed and fine demarcation points in the overall logistics pipe" (Hickey 1999). "RFID is very exciting," states Larry Sur, founder of ilogistics.com. "Depending on the application, it can provide a solution to a number of different problems." (Burnell 2000).

RFID Implementation into the Supply Chain

Many supply chain processes can be enhanced using RFID technology. This study specifically focuses on the application of RFID technology within a grocery and consumer goods supply chain. From the receipt of raw materials to the delivery to the end-consumer, RFID can be implemented into a variety of activities in order to provide a competitive advantage.

Due to the higher cost of an RFID system, applying the technology to each step in the supply chain can become very expensive. Therefore, companies should investigate their own practices in order to determine which functions and logistical activities will benefit the most from it.

One of the challenges of implementing RFID into an existing system is deciding the most effective way to utilize the hardware to achieve the desired results. The location where the information is acquired is also an important factor to consider when implementing the system. Depending on the information a company wishes to extract, tags can be placed on either full pallet loads or individual cases, and readers can be handheld or mounted in fixed positions on forklifts or over bay doors. This research explores the concerns and eventual outcomes between the placement of tags on pallets versus the placement of tags on individual cases within the warehouse. Deciding which method is best suited for an individual company requires a thorough investigation of the functions within the warehouse and a complete understanding of RFID technology.

The objective of this research is to analyze current warehousing operations and propose possible improvements to the systems by implementing RFID technology. Utilizing the most advantageous placement of RFID equipment will prove to increase efficiency and lower current warehousing costs.

The remainder of this thesis is comprised of a Background section, Literature Review section, Methodology section, Model section, and Conclusion section. In the Background section, a detailed description of the supply chain and supply chain management will be provided, as well as a thorough discussion of information technologies, including, most specifically, RFID. The purpose of the Literature Review section is to lend support to the statements and ideas produced in this thesis by asserting the valuable opinions of business and technology experts and revealing relevant statistical data. In the Methodology section, the course of action used to validate the model is explained. The Model section presents the research in the form of decision trees and then offers suggestions of how to implement RFID into a warehouse based on the outcome of those trees. The value of an RFID system and the evidence gathered from this study will be discussed in the Conclusion section.

CHAPTER ONE
BACKGROUND

Supply Chain

A supply chain incorporates all the processes involved in transferring materials and subsequent information from a beginning point to an end point. The definition applied by Markland et al. (1995), states,

> "The supply chain is the connected series of value activities that is concerned with the planning, coordinating, and controlling of materials, parts, and finished products from suppliers to the final customer."

Every company has its own unique supply chain and, therefore, each maintains a slightly different definition of what a supply chain incorporates. Recently, there has been a great emphasis placed on the importance of adding value to the traditional, product focused elements.

The traditional model of the supply chain incorporates three major components: the supplier network, the manufacturing unit, and the customer network (Markland et al. 1995) (Figure 1). The supplier network refers to the group of suppliers, or vendors, that are responsible for providing goods and services to an organization. The manufacturing unit is a series of steps performed by the organization to transform the raw materials from the supplier into finished products. The finished products are distributed to the end customer, such as a distribution center or wholesaler, also referred to as the customer network.

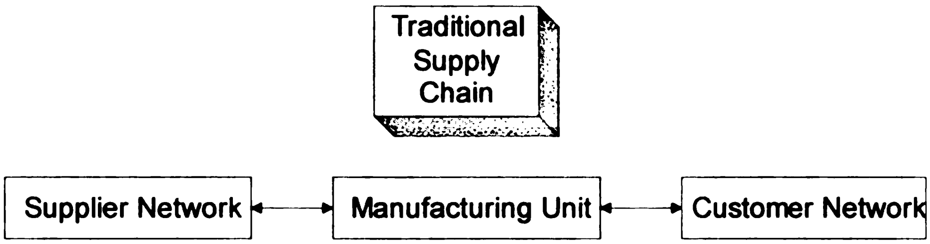

Figure 1: Components of Traditional Supply Chain

The traditional supply chain approach includes many additional elements that can significantly impact the efficiency of the supply chain, but are not considered to be primary components. Two of these elements that require further consideration are packaging and transportation. Both play a role in each component of the supply chain, as illustrated in Figure 2.

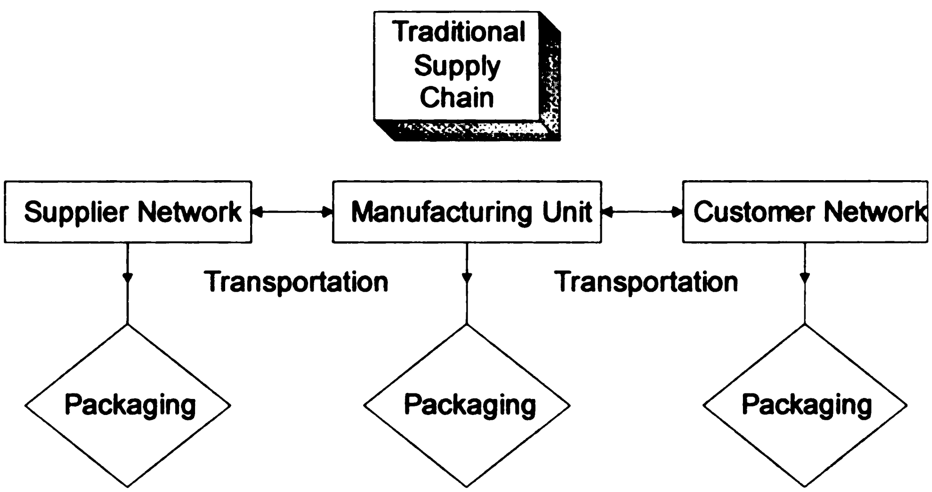

Figure 2: Relationship of Packaging and Transportation to Traditional Supply Chain

The importance of packaging to the supply chain is often overlooked, or at least underestimated, in an organization (Bowersox and Closs 1996). This is unfortunate, since the cost and productivity of a supply chain can either be positively or negatively affected by the packaging of a product. The extent to which it affects the supply chain is determined by the overall cost as well as its ability to successfully accomplish the four main functions of a package: containment, protection, utility, and communication (Abbott 1989). These four functions apply to any type of packaging, whether it is crates used at the supplier, pallets used at the manufacturer, or corrugated cases used at the customer level. Each component utilizes the most effective packaging system for their needs, in an attempt to achieve these basic functions at the lowest possible cost.

A fundamental relationship exists between the packaging of a product and the distribution, or transportation, of a product. Transport of goods occurs from the supplier to the manufacturing plant, and also from the manufacturing plant to the retailer, which can expose the package to unfavorable conditions such as shock, vibration, extreme environments, and mishandling. Not only must a package survive this abuse to protect its contents, but it must also communicate its identity, destination, and other relevant information for appropriate handling and delivery.

The transportation and delivery of goods must be accomplished accurately and in a reasonable time frame in order to positively impact the supply chain. Obviously, delivering the wrong goods to the wrong customer at the wrong time will result in harmful consequences to the company, however, an increase in speed and accuracy can increase productivity and ensure customer satisfaction.

The traditional view of the supply chain has received much criticism due to the linear interaction between the three major components: suppliers, manufacturers, and customers. Within a company, these components are often managed separately, which may lead to miscommunication or minimal information exchange. Robert Olsen, of Tompkins Associates states,

> "In a traditional flow, each step in the chain works independently of the others. Other than information passed on about an order, each organization is oblivious to the activities of all others in the supply chain. The reaction of the system is hindered. Product is not delivered in a timely manner, stock buildups occur, production capacity is wasted, and costs rise" ("Ready, set, plan" 1999).

As mentioned by Olsen, several complications can result from inadequate communication between supply chain components. Using the grocery industry as an example, consider the problems that could arise if a manufacturer of animal crackers decided to change its primary packaging from a tall, thin plastic container to a wider, stand-up flexible pouch but did not communicate this change to the warehouse or the store. Also, because the pouches now had the ability to lie flat during transport, modification could also be made to the secondary packaging, or the case. The warehouse personnel might not recognize this case, however, after the initial confusion, would be able to determine its appropriate storage location. Since the storage racks would be constructed using the previous, larger case dimensions, the entire space would not be utilized, resulting in extra space that cannot be used unless the racking is altered. When the case finally reaches the store, the store employee would not recognize it immediately. Since the shelving would have been designed for the previous container dimensions, only one of the wider pouches could fit in the space allotted instead of two containers. The product would not receive adequate merchandising space allocation and thus may result in a reduction in sales unless the shelves are adjusted. Packaging modification may seem trivial, but if changes are not effectively communicated, substantial difficulties can result for all the components of the supply chain.

Increased awareness of the consequences that can arise from disassociated components of the supply chain is causing companies to reject this traditional approach. Communication flow throughout the chain is extremely important to its overall efficiency, and the way to achieve this is through total integration of all supply chain elements. Frohlich and Westbrook (2001) found that the more integration with suppliers and customers, the higher the improvement in performance. Coordination of activities across the supply chain adds value for the customer as well as increasing profitability of every link in the chain (Anderson et al 1997). Adding value to the traditional supply chain results in a new, innovative, customer-centric model, described as a value-based chain.

A value-based chain is more complex, parallel, and relationship-oriented than the traditional supply chain model. It not only views components holistically, the value-based chain focuses on increased communication flow throughout the chain. It incorporates such activities as sharing information (collaboration) with suppliers and customers, increased information technology, and offers more personalized services for customers. The greater the amount of value in a supply chain, the greater the competitive advantage the business will have. Rick Blasgen, Vice President of the supply chain for Nabisco, Inc., describes the effect of the value-based chain on customer satisfaction by stating,

> "If your inventory accuracy isn't what it should be, you have inefficiencies, and you don't have the relationships with your customer;

think about the effect you're going to have on a customer that is going to be so much more demanding for customer-specific personalized service than ever before. You'll get one or two chances at best to deliver that type of service and the minute you fail that person is going to your competitor" (Johnson 2000).

A world-class supply chain model embodies the additional complexity of the value chain that has been ignored by the traditional model. It involves the interaction of many different areas, in different locations, utilizing the same product in different ways.

Significant increases in competition among businesses today has driven many companies to take notice of their practices and pursue initiatives to discover a way to improve overall efficiency. Attention falls on the supply chain, due to its substantial importance to business operations. "Business has accelerated to such velocity that, in many industries, a company's fortunes can rise and fall on its ability to monitor and manage the supply chain" ("Visible assets" 2000). Graham C. Stevens (1989) stated that "the design and operation of an effective supply chain is of fundamental importance to every company."

Managing the supply chain is crucial, considering that nearly $3.4 trillion dollars are spent on supply chain operations globally (Nelson 2001). "Much of that cost is wasted because companies fail to recognize potential savings in trucking, inventory control, order fulfillment, packaging, material handling, data management, distribution, and more" (Nelson 2001). In fact, a study by consultants at A.T. Kearney revealed that inefficiencies in the supply chain can waste as much as 25% of an organization's operating costs (Quinn 1998).

The ability of a supply chain to either "make or break" a company is evidenced by the fact that there is a tremendous amount of wasted effort that does not add value to the final product.

> "Basically, the supply chain costs much more than it should. It takes much longer than necessary to move goods. And to make matters even worse, the supply chain as it now stands is not a good deliverer of customer satisfaction" ("Ready, set, plan" 1999).

Evidence of the waste inherent in the supply chain is substantiated by Jim Allred of Eskay Corporation in a statement referring to one company's supply chain: "We found that each product was touched 37 times before it was shipped. And of those 37 touches, 29, or nearly 80%, were touches that added no value" ("Ready, set, plan" 1999). Productivity increases when non-value-added steps are diminished, thus resulting in a significant financial gain for the company.

The supply chain offers many areas for improvement, and companies are beginning to take notice. Rick Blasgen states, "Many of us are finding that we are moving from a liability to be managed to a competitive weapon in the marketplace, and that there is a lot more value the logistics supply chain can deliver than ever before" (Johnson 2000).

The management of the necessary elements of a supply chain is very important in order to develop an efficient and effective system. Modern supply chain management has evolved as a way to control the system and combine the separate elements into one holistic chain with a consistent flow of product and information.

Supply Chain Structure

Although there are various ways of viewing the supply chain and its corresponding management, the basic structure relating to the flow of goods is similar for every industry. Since the grocery industry is the main focus of this research, a fundamental description of the organization within a typical grocery supply chain is obligatory.

The key stages involved in the movement of goods and information within the grocery supply chain include acquisition of raw materials, manufacturing of raw materials into a final product, warehousing of final products, and transportation and distribution to the retailer. Related to these processes are additional activities that are specific to each function. Due to the importance of packaging, a general description of package movement throughout the supply chain should be noted.

The main processes involved in a supply chain can be demonstrated with the following example (refer to Figure 3). A farmer sells his crop, corn, to a vendor for a large cereal corporation, Cereal-Biz. The vendor sells the corn to Cereal-Biz and transfers it to the proper manufacturing plant (acquisition of raw materials). The corn would most likely be transported in some kind of bulk, containerized package, such as a rail car. The manufacturing plant uses the corn to create its final product, cereal (manufacturing). The cereal is first inserted into a pouch, then the pouch is inserted into a printed carton. A pre-determined quantity of cartons is then placed into a corrugated shipping case, which acts as the secondary package. The cases are loaded onto a pallet and possibly stretch wrapped for load stabilization. Pallets of cereal are loaded onto a trailer and shipped to a Cereal-Biz, or a public, warehouse. The cereal pallets are stored at the warehouse until a retailer places an order for a specific quantity. The cereal is then loaded onto a trailer and delivered to the store that requested it. The store receives the cereal, employees open the cases, stock the shelves, and ultimately, the cereal is bought by the consumer. The point at which the cereal is purchased by the consumer is considered the end of this supply chain.

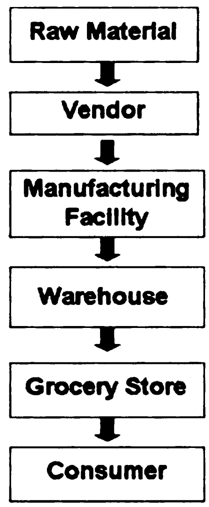

Figure 3: Overview of Grocery Supply Chain

Warehousing

Warehousing is the act of maintaining goods within a warehouse facility. It accepts an inbound flow of goods from manufacturing sites, stores them for a short period of time, and then releases them as an outbound shipment to the stores. It is the intermediate step in the supply chain between manufacturing and the sale of the product in the grocery store where the flow of goods is temporarily stopped.

The three main components, or resources, of warehousing are space, equipment, and people (Ackerman 1990) (Figure 4). The space within a warehouse must be sufficient to allow effective flow of goods and productive operations. "The physical structure must be capable of orderly, damage-free and timely staging of full goods" (Koss

1998). Space management must also consider the second component of warehousing: equipment. Equipment used in a warehouse includes all material handling devices such as forklifts, conveyors, racks, and also the hardware and software systems utilized to manage warehouse functions. The most critical component of warehousing is people (Ackerman 1990). Quality and efficiency of operations largely depends on the performance of warehouse personnel. "Adequately trained warehouse crews are essential for handling the continuing increase in packages, products and volumes within the set bounds of physical conditions" (Koss 1998). Capitalizing on these three components maximizes the success of warehousing functions.

The fundamental functions of warehousing are classified as movement and storage (Bowersox and Closs 1996) (Figure 4). Movement, or material handling, is emphasized and divided into three categories; storage is secondary and is divided into two categories (Bowersox and Closs 1996).

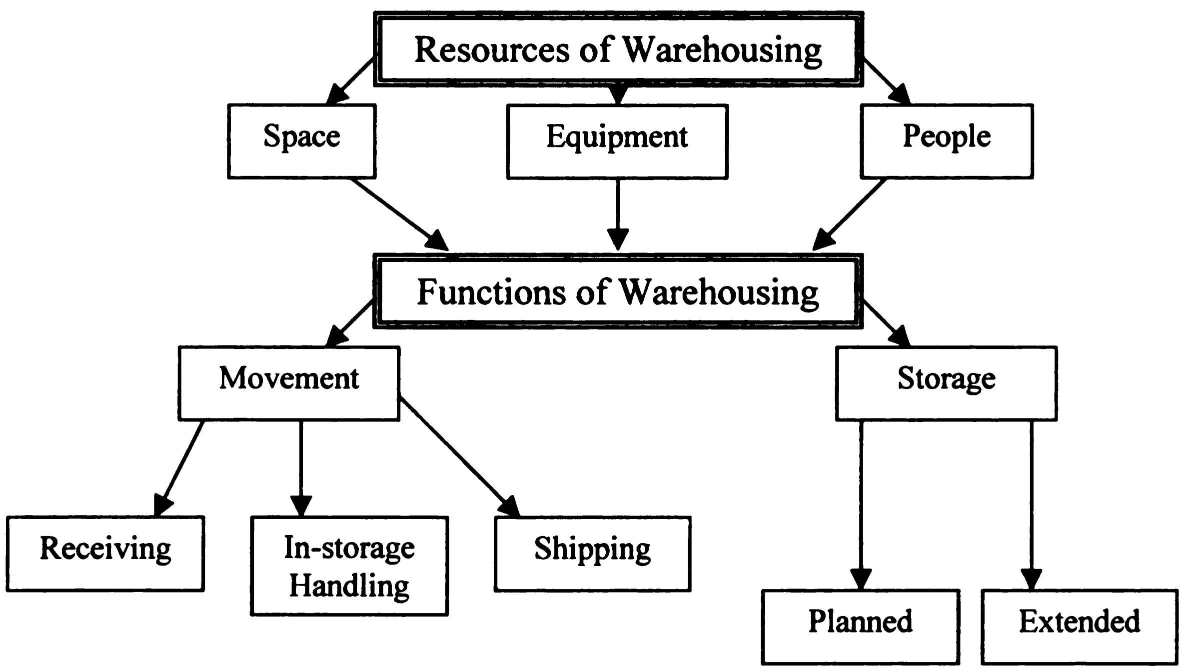

Figure 4: Outline of Warehousing

The three activities involved in movement are receiving, in-storage handling, and shipping (Figure 4). These three activities correspond to the handling of goods from arrival at the warehouse to the eventual shipment to the customer.

The activity of receiving takes place at the receiving bay doors of a warehouse dock and consists of a multitude of basic tasks. Employees begin by unloading the products from the trailer of a vendor's truck. Although products can be shipped using different methods depending on the distribution environment (i.e. floor loading or use of slip sheets) industrial use of wooden pallets is common and, therefore, will be the only method considered for this research. Pallets are unloaded using a forklift and placed at the warehouse dock. The products contained upon the pallet must be "checked in", or verified against documentation of the order, such as an advance shipping notice (ASN). Once all the goods have been accounted for, the receiving operation ends and in-storage handling begins.

In-storage handling is a general term referring to two separate activities, designated as put-away and order selection. Put-away, as its name implies, involves transporting pallet loads from the receiving dock and "putting them away" to their proper storage locations. This operation can be performed manually or automatically, depending on the capabilities of the warehouse. The identification of storage locations is also dependent on the technology employed by the warehouse. For instance, an employee can determine location based on previous knowledge of where the product is stored, or can automatically display the storage location on a handheld device through the use of barcodes. Once the goods have been stored appropriately, they should remain stationary until selected for an order.

Order selection, or picking, refers to the process of extracting individual products from storage and compiling them to fulfill a customer's order. Many different strategies exist for the picking operation. Implementing these strategies can provide optimum picking patterns and effective route determination. Each company must decide on the most beneficial strategy by considering the layout of the warehouse facility, the equipment owned, the capability of employees, and the level of automation in place. The properties of the specific products contained within an order must also be considered when picking. "We have to plan the picking route," explains Ann Neumann, Operational Product Manager of a grocery business, "so that fragile items, such as potato chips, are picked after heavier stuff" (Witt 1999). Picking of an order is complete when every product of a customer's order has been compiled; the goods are assembled onto pallets and transferred to the shipping dock for outbound shipment.

Shipping is the third activity involved in material handling, and is the last operation executed before an order is transported to the customer. It encompasses the verification of an order, the loading of goods onto the trailer, and the actual transport to a customer site. Employees verify that each item of an order is contained upon the pallets before they are loaded onto a trailer. The process of verification can differ based on technological capabilities of the warehouse. One system may require an employee to manually record the individual products, yet a more advanced system could utilize technology that is capable of automatically inputting data into a computer program, such as barcodes. Shipping provides the last opportunity to correct errors made by the previous operations before the items leave the facility and are transported to the customer. When the items on the pallets match the order documentation, they are loaded onto the trailer and sent to the customer.

The secondary function of warehousing, storage, is divided into two categories: planned and extended (Figure 4). Planned storage refers to goods stored for the basic replenishment of inventory, and extended storage refers to the excess inventory that is not required for normal warehouse operations (Bowersox et al 1996).

The resources, functions, and activities of warehousing all contribute to the achievement of its overall objective, which is getting the right product to the right place at the right time. The successful achievement of this objective results in obtaining customer satisfaction, one of the top priorities of the company. As previously stated, a company is challenged with providing a high level of customer service while simultaneously decreasing costs in order to obtain a profit. By meeting its objective, warehousing offers significant value to the company in achieving these aspirations.

There are many goals that must be met in order for warehousing to achieve its objective. Research suggests that goals generally involve some, if not all, of the following: improved accuracy of information and outbound orders, faster communication, optimized use of space, quicker turn-around, lower labor costs, increase in on-time shipments, reduction in inventory, elimination of shrinkage, and increase in equipment utilization (Lenius, 1998; Mohrman 1999; Schmidt 2001; Schulz 2000). Meeting these goals increases the productivity of warehousing. Increased productivity results in getting the customer the right product at the right time while simultaneously reducing costs.

Reduction in inventory has been designated as the major goal of many warehouse managers due to the considerably high cost of carrying inventory. "One of a company's most significant investments after its people and facilities is its investment in inventory" (Margison 2000). Many costs are associated with maintaining an inventory that can be reduced through increased productivity.

The costs involved with storing inventory are referred to as inventory carrying costs. It is estimated that companies pay an annualized carrying cost based on all quantities on hand of roughly 25 to 30 percent (Stratman 2000). One type of carrying cost is the cost of capital investment of inventory. Money invested in sustaining on-hand inventory cannot then be utilized for other operations that could improve the company's performance. Taxes and insurance costs also contribute to inventory carrying costs. Inventory can be considered as property and be taxed accordingly in some locations. Insurance cost is based on estimated risk or exposure over time, thus, an item of higher value will require a greater investment in insurance than one of lesser value (Bowersox et al 1996). Another factor that increases carrying cost is the potential obsolescence or pilferage of inventory. Obsolescence refers to the deterioration of a product or the discontinuation of a particular item, and pilferage refers to the loss of products as a result of theft. The expense of maintaining the storage area (warehouse) is also a significant cost of inventory. Utilities such as electric and water, as well as the expense of purchasing and maintaining equipment are all elements of inventory carrying costs.

The significant cost involved with storing inventory heightens the need for its rapid turnover. Turnover refers to the quantity of goods that have been sold and restocked in a designated period of time. Idle inventory adds to a company's costs, while those products that are repeatedly being sold (those with a high turnover) increase profits.

Reducing inventory costs without sacrificing customer service is a balancing act in warehousing. Customer satisfaction is acquired when a warehouse maintains sufficient stock to fulfill the customer's request. The trend in business today is to "cut inventories and inventory costs to the bone - and then cut them some more - without inducing a stock-out at the store level" ("Trends in the grocery industry" 2001). A stock-out occurs when a warehouse depletes its inventory to a point where it cannot ship a particular item of a store's order. The store may lose sales of that product and, more drastically, lose the loyalty of the end consumer. The severity of these consequences can lead warehouses to carry surplus inventory despite the exorbitant costs. The goal "is to achieve the desired customer service with the minimum inventory commitment, consistent with the lowest cost" (Bowersox et al 1996).

With such a dynamic flow of goods, a company must be aware of its exact inventory at all times. Decisions made by various departments within the company are greatly affected by the accuracy of inventory levels. A salesperson, for example, must have access to the correct quantity of goods so he/she does not sell an amount to a customer that exceeds the amount actually stored in the warehouse. The inventory management system, or computer program that monitors inventory levels, must contain correct levels of inventory or lost sales and lower productivity will result. Jon Schreibfeder, of Effective Inventory Management, Inc., claims, "in order to receive all of the benefits from a good inventory management system, stock balances must be at least 97% accurate, *every day of the year*" (Schreibfeder 2000). In other words, if a company believes it has a quantity of 100 cans of green beans in the warehouse, there should be no less than 97, and no more than 103 (Schreibfeder 2000).

Two methods that many companies employ to examine their inventory levels are cycle counting and annual physical counts. Cycle counting refers to a manual count of a small percentage of inventory on a regular basis. The amount of inventory to be counted and the frequency of the counts is decided by management (Ackerman 1990). These auditors can be employees at the warehouse or externally contracted. The main objective of cycle counting is to compare current inventory levels with inventory records on a continual basis in order to identify and correct errors as soon as they are found.

Annual inventory counting employs the same objective as cycle counting, however, as it is performed only once a year, the entire warehouse inventory must be counted in one session. In order to complete this time-consuming and expensive process, a company can decide whether to count during regular business hours or close down the warehouse for a period of time. Counting inventory while simultaneously conducting business activities can lead to mistakes within both operations. However, closing the warehouse can result in tremendous financial losses in sales and productivity, not to mention the additional overtime expense for employees. Another issue for a company to consider when performing annual counts is the amount of time that the inventory level will remain accurate. Once inventory levels are corrected, how much time will pass before new errors are introduced? Errors can happen at any time and they might not be discovered until the next annual inventory count, which could result in relying on inaccurate information for a considerable length of time.

SUPPLY CHAIN INFORMATION

Information is vital to the success of the entire supply chain. Operations and activities within the chain rely on both internal and external information in order to perform their required functions. As previously noted, external information, or information provided from one unit within the chain to another, is the factor that differentiates the value-based supply chain from the traditional approach. This communication of information forward and backward throughout the chain is a necessary condition for competitive advantage (Markland et al. 1995).

Communication of information between members of a supply chain, i.e., vendors, manufacturing, warehousing, store, and consumer, is essential for each unit to maximize efficiency (refer to Figure 5). This is also referred to as "integration." Integration is the development of external partnerships between supply chain members. These partnerships allow for the exchange of valuable information, i.e. demand forecasts, production data and inventory data, which helps to eliminate the amount of "guesswork" involved in decision-making. According to John Burnell (2 1999),

> "In truly progressive supply chains, information flow is not one way. Information, in the form of forecasts and reports, is jointly created among trading partners, then continuously communicated and updated."

An example of the desire for information flow is as follows: a manufacturing plant that produces pretzels must have information regarding the raw materials (flour, salt, etc.) sent by the vendors in order to plan their production schedules. The warehouse managers, in turn, rely on information received from the pretzel manufacturer in order to effectively manage the flow of incoming products to storage and to outbound shipment to the customer. Each unit receives and supplies information which creates a bi-directional flow that increases the efficiency of the entire chain.

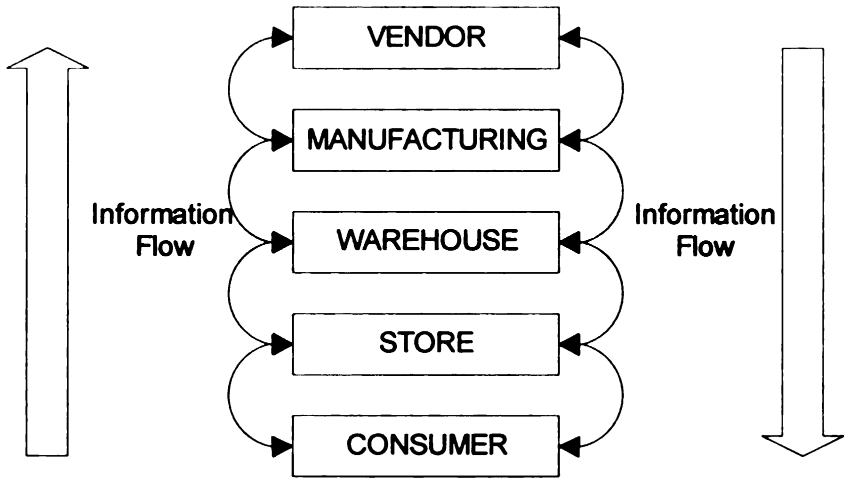

Figure 5: Flow of Information Through Members of a Supply Chain

The significance of information flow to the efficiency of the supply chain has been noted by many members in industry. Integration of supply chain members has provided benefits to Texas Instruments such as significant cost efficiencies, customer-service enhancements, and marketing advantages (Quinn 1998). Bob Trebilcock, Contributing Editor of Modern Materials Handling, states, "...in an effective supply chain, an increase in the flow of information can result in a decrease of inventory, and improved productivity and customer service" (Trebilcock 2000). These benefits provide the company with competitive leverage, and, according to Lew Pritchett, a retired Procter & Gamble executive, "success in the next century will depend on access to information, not access to capital" (Burnell 2 1999).

Additionally, integration can provide considerable time advantages. Julie England, Vice President of Texas Instruments' Semiconductor Group, claims that having partnerships with external members of the chain provides a critical time advantage in bringing new products to the market before competitors and delivering them on time at an acceptable cost (Quinn 1998). The effective management of time is another competitive advantage that can be a result of improved communication and more rapid information transfer. Dave Hubbard, Vice President of Global Supply Chain Management at Iomega Corp., explains,

> " 'The key battleground in this whole value-chain thing is the concept of time. From the supplier's supplier to the customer's customer, you want to make the cycle time as fast as possible because you have to improve quality, improve efficiency, improve productivity, improve cost, etc...If I can take time out of the chain and take out my redundant steps I can keep my price competitive, still make a good profit, and be at the forefront of the competition rather than always fighting based on price considerations. I have extra weapons I can fight with. I've got delivery, customer satisfaction, reduced obsolescence. The value chain is giving me more things to compete with than just price' " (Taninecz 2000).

The knowledge that increased information flow can lead to a competitive advantage has caused many companies to consider expanding their information technology capabilities. Information technology (IT) incorporates hardware and software components that collect and analyze data in order to manage the flow of information. IT offers quicker, more accurate management of information compared to the traditional manual methods. "Technological investments may be the route to improved competitiveness and increased revenue" (Schwartz 1997). The investment in technology helps to build value through better logistics services that are required by customers. Francis Quinn, Editor of Supply Chain Management Review, agrees, "The knowledge and effective use of technology has for some time been a competitive differentiator among companies" (Quinn 1999).

Many companies are realizing this; a survey of 200 North American manufacturers and distributors found that "75% of the companies plan to significantly increase their spending on supply chain technology to support their improvement initiatives and to attain competitive advantage" ("Survey spotlights..." 1998). The survey concentrated on supply chain systems and technologies, particularly information systems. According to the survey, "many companies believe that managing the flow of information in the supply chain may be as important as managing the flow of the products" ("Survey spotlights..." 1998).

The improvements gained by implementing appropriate information technology can be demonstrated in many supply chain operations. At the manufacturing level, technology can accelerate the production line and also support the control of Materials Requirements Planning (MRP) which can result in reduced costs and more efficient product flow (www.aimglobal.org). In warehousing applications, technology can eliminate many errors by replacing traditionally manual methods with automated ones, and it also aids in managing the incoming and outbound flow of good. In transportation, technology can provide greater visibility of goods, that is, the ability to monitor and track the movement of goods at any point in the supply chain.

> "By improving supply chain visibility in the transportation industry, shippers and carriers alike can improve the quality of their information. When quality of information improves, efficiency improves and that translates into money saved" (Schwartz 1997).

At the store level, technology can significantly improve errors caused by inaccurate manual ordering and incorrect pricing of goods. A reduction in these inaccuracies and errors by implementing technology results in an improvement in revenue for the company as well as increased customer satisfaction.

The challenge of implementing technology is to discover the most appropriate technology to meet the needs and requirements of the company. "To add value to the enterprise, IT must be applied intelligently and strategically to where it will do the most good" (Hollinger 2000). Bob Auray, President and CEO of USCO Logistics, agrees, "You need to carefully evaluate the fit of technology before investing in it" (Loudin 2000). Technologies differ in the benefits they offer to certain applications, therefore, choosing the most advantageous technology for an operation is crucial to its success.

As noted, IT is a broad term that encompasses a variety of hardware components and software applications utilized to manage information flow. Hardware components generally extract or collect the data while the software components process the data. Each component is a tool for collecting or analyzing information, but many forward-thinking companies are beginning to understand the value attained when they are integrated. "They transform the movement of product through the supply chain from a necessary cost of doing business into a competitive advantage in the battle to retain customers and expand market share" (Trebilcock 2000).

The most critical technological component required in warehousing is a computer network. Computers can be utilized for many repetitive and complex functions such as issuing bills of lading, retaining vast amounts of information regarding inventory, receiving and transmitting data through Electronic Data Interchange (EDI), and receiving information from automatic identification methods (Ackerman 1990). A computer is the link between the hardware and software components of information technology.

Hardware for the automatic collection of data is necessary in order to eliminate errors caused by manual data entry. Automatic Identification and Data Collection (AIDC) is "the worldwide industry term which describes the identification and/or direct collection of data into a computer system, programmable logic controller (PLC), or other microprocessor-controlled device without using a keyboard" (www.aimglobal.org 2002). Technologies of AIDC support two goals: to eliminate identification and/or data collection errors and to accelerate the throughput process (www.aimglobal.org). There are various forms of AIDC technology, including, but not limited to, barcodes, 2D (two dimensional) barcodes, Radio Frequency Identification (RFID), Card Technologies (including Magnetic Stripe and Smart Card), Voice and Vision Systems, Optical Character Recognition (OCR), and Biometrics (see Figure 6). Due to the focus of this thesis, the only AIDC technologies that will be discussed in detail are bar codes and RFID.

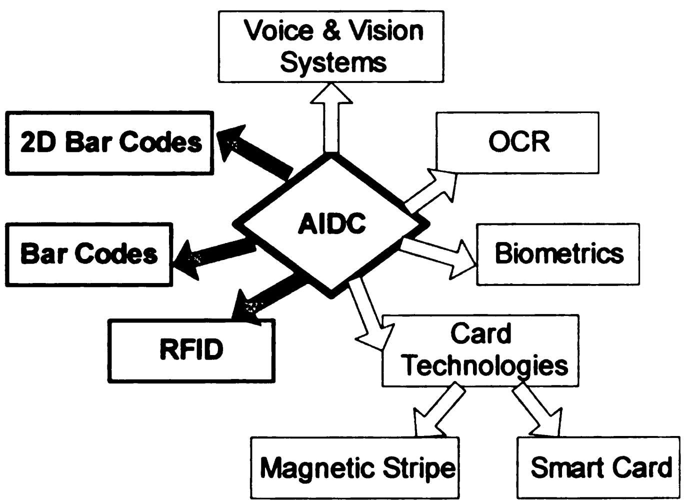

Figure 6: AIDC Technologies (only the items in bold type will be discussed in this document).

Bar Codes

Bar codes are one of the best known and most widely used AIDC technologies. Invented in the early 1950's, bar code technology is defined by AIM, a global trade organization that is the worldwide authority on AIDC, as technology that

> "encompasses the symbologies that encode data to be optically read, the printing technologies that produce machine-readable symbols, the scanners and decoders that capture visual images of the symbologies and convert them to computer-compatible digital data, and the verifiers that validate symbol quality" (www.aimglobal.org 2002).

A linear bar code is made up of a pattern of parallel dark bars and spaces which are graphical images of data characters and control characters (also referred to as bar code symbology). The amount of data a typical bar code can represent varies from 15 to 50 characters. The most familiar bar code is called UPC/EAN (Universal Product Code/European Article Number) which is used widely throughout the grocery industry, printed on almost every product that is stocked in the store (refer to Figure 7). The equivalent human-readable code appears below the encrypted design.

2 03489 34382 2

Figure 7: UPC/EAN Linear Barcode

This linear bar code is one out of 250 variations that have been designed over time, although industry only considers 10-12 linear bar codes as acceptable for use (www.aimglobal.org). Depending on the symbology used (specific examples aside from UPC/EAN include Code 128, Code 39, Code 93, and Interleaved 2 of 5), the bar code may encode only numeric data or all or part of the American National Standard Code for

Information Interchange (ASCII) character set by varying the width of the bars and spaces (www.aimglobal.org 2002). Industry specific requirements are the determining factor on which symbology must be used.

Bar codes can be produced in a variety of ways. The most common method is by printing the pattern on a separate label and applying it to the product. It can also be directly applied to the product by printing (www.aimglobal.org 2002).

The data is extracted from a bar code by scanning it with an electro-optical system. The system, casually referred to as a bar code scanner, operates by illuminating the symbol and measuring the reflected light. The light waveform data is then converted from analog to digital, in order to be processed by a decoder and eventually transmitted to the computer-based software system (www.aimglobal.org 2002).

The scanner itself can be either a handheld version or fixed mount version. Handheld scanners can be in the form of a contact wand, a charge-coupled device (CCD), or a laser. Fixed mount scanners incorporate either a moving-beam laser or "vision-based" technology. A grocery checkout is a common application of both fixed mount and handheld laser scanners. Overhead or side-mounted laser scanners can also be used in industrial applications. Vision based scanners are useful for high speed sorting operations.

2D Bar Codes

A second type of barcode, a two dimensional (2D) bar code, provides a means for incorporating a large amount of data in a very limited space (refer to Figure 8). The advantage they possess over linear bar codes is the vast amount of data they can store.

2D bar codes can store up to 7000 numeric or 4200 alpha-numeric characters (as compared to 50 stored in linear codes). The disadvantage is that 2D bar codes require the use of a specialized scanner.

Figure 8: 2D Matrix Bar Code

There are three types of 2D barcodes: stacked symbologies, matrix symbologies, or packet symbologies. Stacked symbologies are comprised of linear bar codes stacked on top of each other. Matrix symbologies consist of a pattern (or matrix) of dark and light elements including squares, circles, or hexagons. Packet symbologies refer to a collection of "randomly" arranged linear symbols on a page.

Radio Frequency Identification (RFID)

Radio Frequency Identification (RFID) is a type of automatic identification method that has acquired extensive interest in recent years.

An RFID system is based on data flow throughout an air interface, in other words, transmission of data by wireless communication. The system requires the collaboration of three components: a data carrier, a method of adding, retrieving, or changing the data, and an information system to manage the data. In RFID terminology, these components are referred to as a transponder (commonly known as a tag), a reader, and a host computer, respectively (see Figure 9). These components will be discussed in further detail, however, it is necessary to first gain an understanding of wireless data systems since they are vital to the operation of RFID technology.

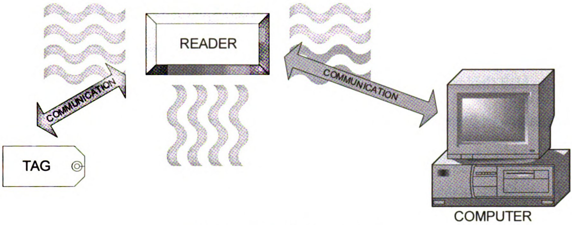

Figure 9: RFID Components

In an RFID system, data is communicated between a transponder and a reader through an air interface, also referred to as a "channel." The data is transmitted in a form called a "bit" which is represented by voltage or current levels imposed upon a radio frequency carrier waveform. Bit is an abbreviation for "binary data," which indicates a single element (0 or1) in a binary number (www.aimglobal.org 2002). The rate in which data (bits) are transferred, or streamed, between the transponder and reader is termed the "bit rate". The process of communicating information from tag to reader in the form of bits requires methods referred to as encoding and modulation.

Encoding for channel communication begins with the input of raw data into a computer. The data bits distinguished in this way are added to other bits to serve a variety of syntactical, organizational, data identification, and error control purposes. This process is referred to as "source encoding". Attention must be given to the form in which the data is communicated, and thus, a restructuring of the bit stream is required to accommodate these needs (www.aimglobal.org 2002). This restructuring is called "channel encoding".

Once this process has occurred, the next step is to transfer the encoded data through the air space using a process called modulation. In order to transmit data effectively, it must be superimposed upon a rhythmically varying (sinusoidal) field or radio frequency carrier wave (www.aimglobal.org 2002). This is achieved by varying one of the primary features of an alternating sinusoidal source: its amplitude, frequency or phase, in accordance with the data carrying bit stream (www.aimglobal.org 2002). The methods used are referred to as amplitude shift keying (ASK), frequency shift keying (FSK), and phase shift keying (PSK). The choice of which method to utilize is determined by the RFID manufacturer. Each method has its own checking scheme and error rate (www.aimglobal.org 2002). A checking scheme is generally in the form of a "checksum" which refers to additional bits included in the tag's message that insure the reliability of the data transmission (Beigel 1999). The error rate depends on the accuracy of the data transmission and is reported as a percentage, such as a 2% error rate.

Thus, data is carried through the air interface at a designated radio frequency. The operating frequencies are allocated by the governments of a country. The authority for managing the radio frequency spectrum within the United States is partitioned between the National Telecommunications and Information Administration (NTIA) and the Federal Communications Commission (FCC). Policies made by NTIA and FCC establish the radio services that are allowed to operate in the United States in a given frequency band (www.ntia.org 2002). In other words, the spectrum is divided into bands which are assigned to different purposes (e.g. broadcasting, maritime mobile satellite, etc.) Three frequency ranges are generally distinguished for RFID systems in the US: 100-500kHz (low frequency), 10-15MHz (intermediate frequency), and 850-950MHz, 2.4-5.8 GHz (high frequency) (www.aimglobal.org 2002).

Since frequency allocations are managed by governments, other countries may not use the same RFID operating frequencies as the US. This can create problems with applications of RFID systems in certain countries. Due to increasing global interest in RFID technology, however, efforts in standardization are currently underway to resolve this issue.

The low, intermediate, and high frequency allocations for RFID systems differ in the capabilities that they provide. A high frequency carrier wave will produce a higher rate of data transfer than a low frequency carrier wave. Low frequencies offer the advantage of less environmental interference than high frequencies. The determination of operational frequency is specific to the application at hand.

RFID Components

As mentioned previously, an RFID system consists of three components: a tag, reader, and computer (refer to Figure 8). Each unit performs a specific operation within the communication exchange in order to provide the means to meet its objective: automatic identification.

The tag acts as the data carrier, which responds to a communicated request for the data it carries (www.aimglobal.org 2002). A tag is comprised of an antenna and an electronic circuit; it is affixed in some way to the object in question. Tags are manufactured in many shapes and sizes and possess different performance capabilities based on pre-programmed characteristics.

RFID tags require power in order to operate. They are generally classified according to how they derive their power; they can be either passive tags or active tags. A passive tag uses electromagnetic energy generated by the reader as its power source. They are lighter, smaller, and less expensive than active tags, and have a virtually unlimited useful life. The disadvantage is that they have a shorter read range than active tags and require a more powerful reader. Also, due to the limited power capabilities, they provide less data storage capacity and increased sensitivity to electromagnetically noisy environments (www.aimglobal.org 2002). However, due to their low cost and long operational lifetime, they are preferred over active tags in many applications.

An active tag differs from a passive tag in that it contains an on-board battery source that supplies its power. They are heavier than passive tags, more expensive, and a have a limited operational lifetime (although this could be up to 10 years). The benefit of active tags is that they provide a longer read range which makes them more functional for large-scale operations.

The applicability of a tag to certain operations depends largely on its memory capabilities. The type of memory programmed to a tag determines the amount of information that can be stored on it. Tags can incorporate a Read Only memory (R/O), Write Once/Read Many (WORM), or Read/Write memory (R/W).

Read Only memory is usually incorporated into passive tags. Specific information or data is written onto the tag, usually during its manufacture, and it cannot be altered. This tag is useful for identification of objects, in that the memory can store a specific code for the item, comparable to a license plate for a vehicle. In essence, it acts as an electronic bar code. A tag consisting of R/O memory is typically less expensive than one with R/W memory.

Write Once/Read Many memory differs from R/O tags because information can be written to the tag, although only one time. Once information has been written to the tag, it can be read many times, as in a R/O tag.

Read/Write memory provides certain benefits over R/O tags. The data it contains is not fixed; it allows the user to program additional information into the memory as the need arises. This characteristic is beneficial for work-in-process tracking, such that information can be written to the tag at various points of a product's lifecycle.

The second component of an RFID system is an interrogator, or reader. A reader is necessary to communicate with the tags and receive and transmit data. The reader generates an electromagnetic (interrogation) zone, and as a tag enters this zone, it can supply power to a passive tag, collect information by decoding the tag's transmitted signal, or send out a different signal in order to write additional information onto an R/W tag. The reader then conveys the data to the host computer for processing. Readers can be manufactured into a multitude of different shapes and sizes. Readers are usually handheld or fixed-mount (including portal readers).

A computer is the third component of an RFID system. Once the reader has gathered data from the RFID tags, it transmits that data to a host computer for further processing. The software incorporated in the computer is ultimately responsible for transforming the entered data into usable information. The success of the data collection method relies on the ability of the computer to effectively display the desired information.

RFID Performance

Evaluation of an RFID system is based upon its operational performance with respect to certain parameters. For logistical applications such as warehousing, the parameters of an RFID include communication range, amount of transmittable data, communication time, and speed of tag during communication (Dinnyés and Kulcsár 1999).

The communication range of an RFID system refers to the distance in which the reader can transmit or receive (communicate) data to the tag. Two types of communication are recognized: read range and write range. Read range refers to the distance in which the data contained within the tag can be read by the reader, and write range is the distance in which the reader can write data onto the tag. When a tag exits the communication range, it cannot be acknowledged by the reader. The size and shape of the tag greatly affect this range. Generally, a larger tag will boast a greater communication range than a smaller tag, given the larger size of its antenna. For example, Texas Instruments (TI) sells a "disk transponder" in two different sizes: 30mm and 85mm. TI's website (www.tiris.com 2002) displays the specifications for both tags; the 30mm disk has a read range of approximately 60cm, while the 85mm disk has a read range close to 150cm. The only difference between these two tags is their antenna size. The larger the disk, the larger the antenna, and therefore, the longer the read range.

Another factor that influences read range is the intensity of the reader's interrogation zone. Power output of a reader can be adjusted to maximize read range, however, the Federal Communications Commission (FCC) has regulations regarding the radiated emissions from such devices. For instance, in the frequency range of 13.553-13.567 MHz, the field strength emissions cannot exceed 10,000 mV/meter at 30 meters (www.fcc.gov). In the frequency range of 902-928 MHz, the field strength cannot exceed 500mV/meter at 3 meters (www.fcc.gov). In some cases, a tag and reader may have a very large read range, but the power output may be above FCC regulations. Since the power output must be compliant with FCC regulations, electromagnetic shielding may be necessary. Shielding reduces radio frequency emissions outside of the interrogation zone and may also help to eliminate additional electromagnetic "noise" that can interfere with the transmission of signals (Beigel 1999).

The orientation of the tag to the reader can also affect read range. There is an optimum orientation of the tag to the reader that will produce the greatest reading distance, and a lesser reading distance will result from sub-optimal orientation (Beigel 1999). Dinnyés and Kulcsár (1999) define an "ideal" orientation as

> "...having the operating environment ideal and the orientation of the coils in such a way that the DC's [Data Carrier] coil plane is parallel with the reader's coil plane and the coil centres of the RFID components are set at the same height ('ideal' orientation)."

Dinnyés and Kulcsár acknowledge the fact that maintaining an ideal orientation during dynamic communication is not realistic. Considering a tag in the form of a label, for instance, the tag might read accurately at 20cm from the reader in one orientation, but if rotated 90 degrees, it may not read at all.

If a read/write tag is used, the maximum distance from which it can be read may be considerably different from the distance at which it can be written to. A study conducted by the Defense Logistics Agency (DLA) which tested several tags and readers from a variety of vendors, discovered that the write distance was usually less than one inch, while the read distance was much greater (Harmon 2000). This difference must be accounted for when evaluating an RFID system.

The amount of transmittable data is another parameter of RFID performance. The amount of data that is transmitted between the tag and the reader affects both the time it takes to transmit the data as well as the accuracy of the transmission. In general, the more data that is transferred between the tag and the reader, the longer communication time that is needed (Dinnyés and Kulcsár 1999). By adding bits for error checking, the reliability of the message is improved, however, the extra length of the message increases the communication time needed.

Two additional performance parameters for RFID systems are the communication time and the speed at which a tag can enter the reader's interrogation zone and be read accurately. As mentioned above, the communication time is the amount of time necessary for the transmission of data between the tag and the reader. The tag must spend a sufficient amount of time in the reader's zone before it exits in order to be read effectively. There is a maximum velocity at which a tag can pass by the reader and transmit a complete message (Beigel 1999). The probability of reading a tag above this critical speed is close to zero (Beigel 1999). As mentioned above, the greater the amount of data to be transferred, the more slowly the tag will need to pass by the reader for an accurate read. Speed also depends upon the tag orientation, noise interference, and other factors (Beigel 1999).

These performance parameters for RFID systems lead to the determination of objectives for certain applications. In warehousing applications, objectives of an RFID may include: communication with the tag as far as possible from the reader, communication at any orientation, transfer of data in the shortest amount of time, error-free transfer of data, and transfer of data with the velocity of the tag as high as possible. Identifying an RFID system that meets these objectives will not compromise any current warehousing activities.

In addition to the parameters stated above, there are other issues that may affect performance of an RFID system. These issues include the memory of the tag, anticollision properties, and processing of data.

The amount of memory contained within the tag should be sufficient for the specific application. The amount of memory required depends upon the number of unique codes necessary. This number should be kept to a minimum due to its tendency to slow the process of transmitting data. However, the number of unique codes should accommodate the needs of the system over an extended period of time (Beigel 1999).

Anticollision mechanisms are very important to the performance of RFID systems, especially in warehousing. Anticollision mechanisms are programmed into the RFID system to prevent more than one tag from being read by the reader at a time. When multiple tags enter a reader's interrogation zone, they will all respond to the reader by transmitting bits through radio frequency waves. These waveforms will become jumbled (collision) and the reader does not receive any data. An anticollision mechanism allows only one tag at a time to communicate with the reader; in essence, only one tag is "on" while the others are "off."

Another issue that may indirectly affect the performance of an RFID system is data processing. Processing of transmitted data into usable form should occur in "real time", or almost simultaneously with the tag passing through the reader's interrogation zone. "The decoded ID tag events must be stored, transmitted to a central location and recorded or displayed for analysis purposes" (Beigel 1999). If the information is not available in real time, the RFID system performance loses its value.

Warehouse Management System

After the computer collects data generated by the AIDC system, it must be processed and presented in a logical, organized fashion (refer to Figure 11). The software component of the system is responsible for synthesizing the data and manipulating it into relevant information that can be utilized by warehouse personnel. A type of software system employed by warehouses is called a Warehouse Management System, or WMS.

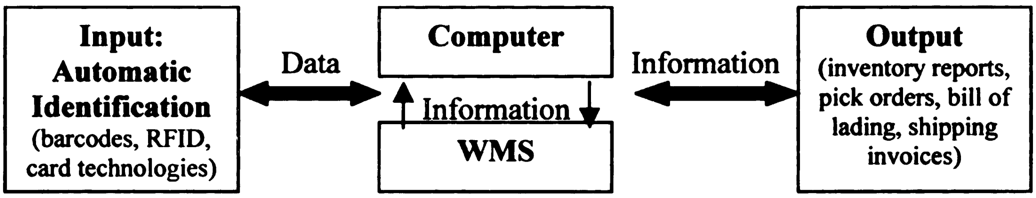

Figure 10: Relationship of Hardware to Software

A WMS system manages the data in order to provide efficient material and information flow through warehouse operations. For instance, data received through an automatic identification method, such as scanning a bar code on a case of goods upon arrival to the warehouse, is interpreted by the WMS which then utilizes this data to generate valuable information. This information can consist of inventory reports, determination of proper storage location, efficient pick routes for order selection, and shipping invoices. Many functions of the WMS have replaced traditional manual operations, resulting in more rapid and accurate information flow, and therefore, an increased competitive advantage.

The WMS is designed to meet specific requirements dictated by the warehouse managers. In the food industry, some of the general applications that a WMS should incorporate are: date tracking; support for high productivity and efficiency levels such as pick strategies; catch-weight capability for tracking and billing meat and dairy products; fail-safe regulatory compliance; and ability to support cross-docking (Navas 2, 1999).

Date tracking ability is very important to the grocery industry due to the considerable amount of perishable goods. Many perishable goods such as milk and lunch meat, have expiration dates or "sell-by" dates printed on the package. Other perishable goods, such as fresh fruit and vegetables, do not incorporate this feature and rely instead on inherent quality characteristics such as firmness or color. In either case, a consumer will typically purchase the products that are the freshest. This behavior of consumers exemplifies the value of fresh products, and therefore, retailers must continually stock fresh goods in order to maintain customer satisfaction. Date tracking enables the warehouse to keep track of when the products arrived and allows retrieval of products on a first-in-first-out (FIFO) basis. This ensures that the goods with the oldest dates are shipped to the retailer in a timely fashion to maintain their freshness.

CHAPTER TWO
LITERATURE REVIEW

In the Background chapter, the importance of implementing appropriate information technology to supply chain operations in order to gain a competitive edge was discussed. One emphasized technology was Radio Frequency Technology, or RFID. There has been great interest in RFID for applications that require or will benefit from faster, more accurate information than a current bar code system can provide. This Literature Review examines industry's need for improved information technology and provides examples of current applications of RFID and the benefits realized.

As competition continues to increase in the marketplace, companies must differentiate themselves with a key competitive weapon. According to a recent survey conducted by Forrester Research, three-quarters of the retailers surveyed claimed that the quality of logistics operations is a significant factor in competition (Konicki 2001). Professor Hau Lee at Stanford University states, "the battle for market supremacy will not be between enterprises but between supply chains" (Enslow 2001). According to Enslow (2001), that battle will result in the "fast and accurate beating the slow and imprecise."

For warehouse operations in particular, speed and accuracy are of considerable importance. With respect to warehouse managers, "success is not only getting the job done fast, but also in the most accurate manner possible" ("Trends in the grocery industry" 2001). "The need for effective and accurate management of warehouse processes is thus being seen more and more as a vital element in the continuing battle to remain competitive" (The Logistics Business 2001). The importance of warehousing is plainly stated by Chris Newton, Senior Analyst of supply chain strategies for AMR Research, "A warehouse is the last chance a company has to get an order right" (Douglas 2001).

Implementing Information Technology, or IT is one step that companies are taking to improve the speed and accuracy of their supply chain operations. A recent survey determined that 80% of CEOs (Chief Executive Officer) from 26 countries claim the role of technology is significant to the success of their companies, and 77% reported that their IT investment will increase over the next three years (Janoff 2001). Another study found that 60% of businesses expect to increase their IT budgets by an average of 27% over the next year (Johnson 2001).

Research conducted by Rogers et al. (1996) explored the relationship between IT and warehousing performance. They concluded that companies that used more warehousing information technologies had better performance in the areas of quality improvements, cycle time reductions, and productivity improvements than the low user group. Also, "there appears to be a realization that warehousing firms must invest in information technology to remain competitive" (Rogers et al. 1996).

To increase order accuracy as well as warehousing efficiency, one type of IT that companies rely on is a Warehouse Management System, or WMS. Investing in a WMS can help to organize workflow, make better use of storage space, eliminate paper-based procedures, and cut the time required to complete operations, all while keeping costs at a minimum (Douglas 2001). Other benefits of a WMS include higher inventory accuracy levels, reductions in labor cost due to efficient allocation of employees, reduced picking errors, and ultimately, more reliable service to customers (Gurin 2000).

However, a WMS will provide substantial benefits only if it receives precise, immediate data. An employee manually entering data into the WMS a half hour after receipt of inventory will not offer the same benefits of an automatic, real time data collection system. The following excerpt describes the advantages it can provide.

> "Real time data capture and keyless data entry can instantly ring up a retail purchase, accurately adjust in-store inventory, signal the warehouse for replenishment, initiate an order with the manufacturer, speed the flow of raw goods from suppliers to manufacturers, and follow the manufacturing process through to the delivery of the new product to its destination" (Trends in the grocery industry" 2001).

Radio Frequency (RF) data transmission, in conjunction with bar codes, is frequently used to capture and transmit information in order to save time and reduce errors. Jon Zaturn, Director of Distribution Operations for Dana Corporation, asserts, "RF devices give us a lot of power. They allow us to make real-time decisions based on a purchasing standpoint, customer-promise standpoint, and ordering standpoint" (Owen 2000). A new bar code system also allowed Bryan Foods to increase productivity within its distribution center, enabling it to "...receive, put-away, and pick and pack quicker, and with a greater accuracy" ("Trends in the grocery industry" 2001).

Having access to real time information is also crucial for the management of inventory within a warehouse. As mentioned in the Background chapter, inventory can account for up to 40% of the cost of doing business (Enslow 2001). Companies that reduce inventory levels "...can plug a cash drain that costs them hundreds of thousands of dollars annually" (Krizner 2001). The cost of inventory can be substantial if time is wasted in locating "lost" products or inventory data is inaccurate. Gino Nannini, Plant Manager for Peer Bearing Co., implemented a bar code inventory tracking system because his company was, "...tired of dealing with inventory errors" (Randall 1998).

The system improved traceability and eliminated errors for Peer Bearing, and, in fact, saved them almost three times the cost of implementation (Randall 1998). Both Bryan Foods ("The magic of barcodes" 2001) and Medis Health & Pharmaceutical Services Inc. (Aichlmayr 2001) have realized significant improvements in inventory management through the use of bar codes and WMS.

It is no secret that bar codes can provide considerable improvements in many supply chain applications; there have been many companies that have publicized their success using this system. There are, however, limitations to the use of bar codes such as the requirement for line-of-sight and print and legibility quality issues. As bar coding applications become increasingly common, companies are looking for an even faster, more accurate solution to supply them with a competitive edge: RFID.

RFID

RFID has achieved considerable growth and recognition as a valuable automatic identification in the last few years. In fact, it has sustained an annual growth rate of 24%, which is higher than any other automatic identification technology (Venture Development Corporation 2001). Venture Development Corporation (VDC) reported that global shipments of RFID systems approximated $890 million in 2000, and are expected to reach $2.65 billion by 2005 (VDC 2001). In 2000, the RFID market was dominated by security/access control applications, however, by 2005, VDC expects that supply chain management applications will join others in holding the bulk of market revenues (VDC 2001).

History of RFID

The use of RFID dates back to the 1940's, during World War II, the British desired a method to distinguish between their own aircraft and the aircraft of the enemy. The system that was developed, termed "Identify: Friend or Foe" (IFF) consisted of placing a transponder onto a "friendly" aircraft which would generate an appropriate response to a radar interrogation signal (The Eagle's Nest 2001). Present day commercial and private aviation traffic control is still based on IFF concepts (Auto-ID Center 2002).

Throughout the 1960's and 1970's, RFID development was primarily a government-sponsored endeavor due to safety and security issues involving the use of nuclear materials (Auto-ID Center 2002). In the late 1970's, the public sector gained access to the technology that had been developed in government laboratories (The Eagle's Nest 2001). This acquisition of knowledge led to further investigation into alternate applications for RFID technology.

One of the first commercial uses of RFID technology in the late 1970's was tracking livestock in Europe (Auto-ID Center 2002). Throughout the 1980's, RFID was found useful for applications such as railroads, automatic toll collection, access control, and Remote Keyless Entry (RKE) (Emory University 2002). As technology advanced through the 1990's, tag performance continued to increase while size and cost of tags reduced dramatically. Today, RFID is receiving considerable attention due to new developments in technology that permit its use in a wide variety of applications, especially supply chain initiatives.

RFID in the Supply Chain

In the past few years, RFID has been expanding into new arenas such as tracking video cassettes in rental stores for inventory management (Intermec 2001), tracking animal tissue (meat) throughout processing to monitor pH levels and temperatures ("Beefing up with RFID" 1998), and tracking Returnable Produce Containers (RPCs) as they are transferred between supplier and manufacturer (Intermec 2001). The success of these applications has encouraged industry members to continue to strive for the end goal of their supply chain initiatives. Schmidt (2001) asserts,

> "...the ultimate goal is to put a [RFID] tag on virtually every manufactured item, each tracked by a network of millions of readers in factories, trucks, warehouses and homes, transforming huge supply chains into intelligent, self-managing entities."

The advantages over bar codes that companies expect to gain from implementing RFID include faster information retrieval, increased visibility into the supply chain, more information content, and less probability of theft (Hickey 1999). Rich Krueger, of Motorola, supports the usage of RFID, stating, "it gives you much more detailed and fine demarcation points in the overall logistics pipe" (Hickey 1999).

According to CIO Kevin Turner, Wal-Mart, a renowned leader in supply chain efficiency, has been considering and experimenting with RFID for over 12 years (Roberti 2002). Wal-Mart has identified some key areas that RFID can significantly benefit. One of these areas is reducing lost or misdirected products. According to Kevin O'Marah, Vice President of Global Supply Chain Strategies at AMR Research, supply chain losses can average 3 to 5 percent of total supply chain costs (Roberti 2002). Reducing these costs with RFID could "...add millions more to the bottom line of companies that implement the technology" (Roberti 2002).

Reducing shrinkage is another area in which RFID can contribute. A National Retail Security Survey discovered that almost 2 percent of total sales in the United States is lost every year due to shrinkage (Roberti 2002). Shrinkage encompasses employee theft, customer theft, vendor fraud, and administrative errors. RFID can reduce shrinkage by providing real-time information about product movement and alerting security systems of unauthorized product movement.

The third area that Wal-Mart has identified as benefiting from RFID is in reduced out-of-stocks. In the consumer products industry, out-of-stocks can average about 7 percent (Roberti 2002). RFID can provide more knowledge of product movement which can aid in forecasting and inventory issues, resulting in decreased out-of-stocks.

The perception of RFID providing a competitive advantage has resulted in the hesitancy of companies to disclose information regarding their experiences with RFID systems. Kevin Sharp (2 1999) clarifies this perception by stating, "the competitive advantage to be gained comes not from RFID technology itself but from the improvements to software systems and business processes that would be impossible without the RFID devices." Nevertheless, Chris Rezendes, an ADC market researcher at VDC, confirms, "there are no publicly available analyses of the economic impact of RFID on core, closed-loop supply chain applications and that is an impediment to the industry" (Sharp 2 1999). There are, however, some examples of RFID technology currently being utilized by a number of companies, although details are limited.

RFID Applications

The automotive industry has been a forerunner in the adoption of RFID technology. RFID tags are preferred over bar codes for use in many manufacturing plants to track Work-In-Process (WIP) (Navas 2 1999). The ability of RFID tags to withstand harsh conditions such as high temperatures, shock, and painting allow them to penetrate this market successfully. These achievements have paved the way for examination of new applications for RFID tags, such as remote access and security systems (Navas 2 1999).

General Motors, Ford, Daimler Chrysler, and Toyota are a few of the major automotive companies that have invested in RFID systems. Chevrolet Creative Services has implemented an RFID system from Texas Instruments to track the movement of crates into and out of its Wixom, Michigan warehouse (Texas Instruments 2001). Benefits that this system has provided Chevrolet are the elimination of human error, elimination of costly shipping charges, and greater speed and efficiency of shipping (Texas Instruments 2001).

Ford Motor Company, in collaboration with WhereNet, has implemented a real time locating system (RTLS) using RFID tags to locate and track inventory. Ford claims that the system is extremely accurate, with over 13 million transmissions without one missed communication (Maloney 2000). The system has also resulted in labor efficiencies, increased flexibility, and an estimated $500,000 savings compared to a wired system (Maloney 2000).

Toyota-South Africa has also invested in an Automatic Tracking System (ATS) using an RFID solution provided by Escort Memory Systems (EMS). The capabilities of the RFID tags have impressed Toyota-South Africa; they are continuing a second phase of the RFID project (Escort Memory Systems 2001).

Although the automotive companies have sought out RFID solutions independently, the Automotive Industry Action Group (AIAG), which includes representatives of General Motors, Ford, and Diamler Chrysler, has currently been pursuing an RFID standard for tires (Krizner 2001). This standard will enable the companies to attach an RFID tag to the inside of the tires. When the tag is read, a vast amount of information about the tire can be retrieved, including the time, date, and specific plant of tire manufacture. This information is crucial in the event of a tire recall.

RFID has also been successful in the airline industry for the identification and tracking of baggage. The amount of baggage that passes through a busy airport on any given day is alarming. Bar codes have been helpful in providing accurate transport of baggage, however, in prototype demonstrations at London Heathrow, San Francisco, Seattle, Houston, and Singapore, it has been shown that "...airports can gain up to a 25% greater throughput from their existing baggage systems by incorporating RFID technology" (Wilson 2001). In fact, the tag read performance exceeded 98%, substantially outperforming that of barcode systems (Wilson 2001).

There are many benefits to using RFID for baggage handling at airports: it can speed baggage processing at airports, baggage can be loaded faster onto the aircraft, and compensation claims for misplaced or stolen bags are decreased (Wilson 2001). This increase in accuracy can amount to a 90% savings over the current cost of reconnecting misplaced bags with their rightful owners (Nelms 1999).

Another area that has realized benefits from RFID is the parcel carrier industry. Although bar codes have traditionally worked well for carriers, limitations such as the line-of-sight requirement and damaged, unreadable labels have created the need for a new solution. LynxExpress is one parcel carrier that has achieved handling and shipping advantages due to RFID ("Money well spent" 2000). The new system increases the handling speed by 70%; it now has the capacity to handle up to 40,000 parcels an hour, compared to the previous system of only 3,000 parcels an hour ("Money well spent" 2000).

The grocery business is an example of one industry that has publicized its interest in RFID applications but continues to struggle with implementation issues. In the United Kingdom, J. Sainsbury, a leader in the grocery industry, conducted a trial using RFID tags to track and automatically record boxes, cartons, and pallets as they moved throughout the supply chain (Sharp 1 1999). The result of this trial proved to Sainbury that there was "much more value to be had from RFID than anyone could quanitify at the beginning" (Sharp 1 1999).

Sainsbury recently invested in RFID technology to track its returnable transit packaging (RTP) crates throughout its supply chain. A reusable RFID tag is embedded into a crate and read by portal antennas at certain points in the supply chain. Mark Gillot, Project Manager for Sainsbury, claimed that the RFID tags reduced the receiving function from 2 1/2 hours to 15 minutes (Falkman 2000). He also commented that inventory accuracy had improved and the speed of the distribution function had been increased (Falkman 2000). According to Gillot, "This is a level of control that is simply impossible to achieve with bar codes, manual data entry or any other system. And even better is the fact that it is totally automatic, enabling more efficient use of labor resources" (Falkman 2000).

Another company that has found success using RFID for tracking food products is another UK retailer, Marks & Spencer. Marks & Spencer used returnable plastic trays labeled with a bar code to track products throughout the supply chain. Although the bar code system was accurate and reliable, the bar codes had to be scanned manually and were continually ripped or torn (RFID Journal 2002). A re-examination of their identification methods led them to take a closer look at RFID as a replacement. A trial was conducted using RFID tags attached to trays which were then stacked onto dollies and read by a portal antenna. The trial proved to be successful. Marks & Spencer "...established that it takes 29 seconds to scan a dolly compared to 5 seconds via the portal. That is an 83 percent reduction in speed of read" (RFID Journal 2002). They also benefited from the ability to write to RFID tags to reflect changes in product's status. Other advantages that RFID has provided to Marks & Spencer include longer production runs, higher accuracy, reduced label costs, improved speed, and faster data movement throughout the supply chain (RFID Journal 2002).

One application of RFID that provided more valuable results than the examples above was a demonstration conducted by the Defense Advanced Research Projects Agency (DARPA), Defense Logistics Agency (DLA), Air Mobility Command (AMC) and USTRANSCOM, in 1998. The goal of this demonstration was to successfully read RFID tags on cargo boxes stacked on a pallet (Fetech 1999). Results proved that the tags could be read in all positions on the cargo boxes, including tags attached to boxes buried inside the load, tags not visible to the perimeter, and tags that were affixed to a variety of materials, including metal. Problems that occurred were issues due to shielding, speed of movement through the portal, time designated to read a pallet load, design configuration of the portal, and placement of the antenna. Reported final results included a "100 percent detection of as many as 90 tags per pallet, at walking speeds of 3 to 5 miles per hour, with an average read time of 0.47 seconds per tag" (Fetech 1999).

The type of information submitted by Fetech is valuable when considering RFID implementation into a warehouse setting. Accuracy and speed are crucial for the system to be beneficial. Again, it is unfortunate that there is very limited information of this kind in the literature because it forces the companies that are interested to conduct trials such as this before deciding if the technology will meet their needs and requirements.

The Massachusetts Institute of Technology (MIT) Auto ID Center has been a key player in researching RFID technology and its applicability into a retail environment. Some of the biggest names in retailing are joining forces with MIT to investigate the use of RFID tags to track inventory throughout the supply chain. A few of the companies involved include Gillette, Johnson & Johnson, Kraft Foods, Procter & Gamble, Unilever, and Wal-Mart (Merritt 2001). A pilot test conducted at distribution centers in Tulsa, Oklahoma, will uncover any problems in capturing the information from the RFID tags, and allow the Auto ID Center to address various issues. Kevin Ashton, Executive Director of the Auto ID Center explained, "The first thing we have to do is capture data about what's going on, to know what [products] are moving around and where they are" (Merritt 2001). The information obtained from RFID is valuable in analyzing and managing inventory, which can significantly help in keeping costs down for retailers.

Barriers to RFID Implementation

The advantages of RFID over bar codes have been evidenced in both laboratory testing as well as in experimental trials. So why aren't all companies eagerly jumping on the bandwagon to replace bar code applications with RFID? The answer hinges on the fact that there are a few obstacles for RFID to overcome before a company can justify the investment.

The first challenge facing RFID is price. Traditionally, vendors of RFID tags have made the mistake of trying to sell their tags by marketing them as a replacement for bar codes. The two technologies should not be compared apples-to-apples as vendors have started to learn. Cliff Horwitz, CEO of SAMSys Technology, explains, "Early on, it was irresponsible for some to talk about RFID as if it would replace barcoding. Paper will always be cheaper than silicone" (Loudin 1999). Since the bar code is cheap to produce and many companies already have the infrastructure set up, the higher cost of implementing RFID, even considering its many advantages, is difficult for many companies to justify.

Additionally, determining the cost in order to justify implementation can be difficult. The actual cost of RFID systems is hard to determine. Since prices are based on the volume of units sold, many vendors will submit a quote for a system based on an extremely high quantity in order to make their prices more appealing (Burnell 2001). Price also depends upon the type of tag, the amount of information it can retain, the read range, the size, as well as many other factors. However, prices have continued to decrease over the last few years, as evidenced by the literature (Burnell 2001; "Is RFID on track?" 2001; Schell 2001; McGarvey 2001). Kim Jacobs, of Menasha

Services/Orbis, claims, "the cost of using RFID has gone down 75% while the accuracy is twice as good as it was 5 years ago" ("Is RFID on track?" 2001).

Some members of industry agree with Martin Dunsby, a Deloitte Consulting manager, who claims that "price isn't an obstacle to [RFID] adoption anymore" (McGarvey 2001). One of them, Jack LeVan, former President and CEO of SCS Corp., says, "Information about unrealistic tag prices has scared off many potential users. That's unfortunate, because at today's actual cost points, many applications are economically viable" (Schell 2001). Also, Frederic Coustere, of Gemplus, states, "People say price is an issue with RFID, but the real issue is that they're not ready" (Burnell 1 1999). Others remain more skeptical. Larry Kellam, of Procter & Gamble, is interested in RFID but points out, "unless tag prices drop, 'we can't create value for the consumer'" (Forcinio 1 2001). Horwitz (Forcinio 1 2001) agrees, "technology needs to be affordable in order to deploy it on a widespread basis." In the end, a company must evaluate their current system and decide if RFID can be justified. "In many applications," states Patrick Kennedy, of The Kennedy Group, "increased productivity and reductions in lost assets or products can justify the investment into RFID systems very easily" (Forcinio 1 2001).

The second barrier to deployment of RFID is the lack of true standardization. "The importance of standards is not overrated and can't be overstated" (Burnell 2001). The acquisition of standards provides the opportunity for interchangeability of different RFID systems, thus resulting in the compatibility of equipment from different vendors. Steve Halliday, Chairman of the International Standards Organization (ISO) RFID committee states,

> "The goal is to set a standard so any manufacturer can make equipment to read any other manufacturer's tag. Right now, RFID is a fairly proprietary industry, with many companies developing their own way of creating an RFID system that typically does not port from one company to another. We hope with an ISO-compliant system any company can enter the business" (Wilson 2001).

Having ISO approval will be crucial for the utilization of RFID in a global economy. These standards will make it possible to track an item all over the world. They also offer reassurance that the purchase of a system will continue be operational in the future. "People have the security of knowing that something they bought won't be obsolete because the supplier decided to design something new or went out of business," claims Halliday (Forcinio 1 2001).

It is believed by many industry members that RFID standardization will positively impact the market for RFID products. Salkin (1999) predicts, "...the RF products market will be steadier and warehousing managers will be more likely to invest in these products." In 2000, the lack of standards caused Venture Development Corporation (2001) to report that the growth of RFID supply chain management applications will continue to be stifled by the absence of standards. When standards are finally issued, the interoperability of RFID systems "...should also eventually drive down RFID system costs" (Burnell 2001). "As equipment is built to meet standards, availability increases and costs decrease" (Forcinio 2 2001). Ultimately, lower costs are predicted to drive an increase in sales for RFID products.

Specific standards are currently in debate by RFID manufacturers, retail industry members, and industrial community members. At present time, two different standards are being promoted: one supports an industrial tag, called MH10.8.4 (commonly referred to as .4), and the other a retail-based tag, named GTAG (Cooke 2001).

The standard for MH10.8.4, originally for use of RFID on returnable containers, makes reference to a previous standard issued by the National Committee for Information Technology Standards (NCITS), dubbed NCITS256 (Cooke 2001). The details of the communication protocol in MH10.8.4 provide instructions for communication based on Intermec's Intellitag "air interface" technology (Cooke 2001). Companies supporting MH10.8.4 include Intermec, Gemplus, and Phillips (Cooke 2001). This standard is exclusive to North America and focuses on an ultrahigh frequency (UHF) band of 902-928 MHz (Forcinio 2 2001).

The retail industry promotes the second standard that is currently in debate: the GTAG. The GTAG is a joint initiative of the UCC and EAN, as well as the Automatic ID Center at Massachusetts Institute of Technology (MIT), Texas Instruments, BiStar Technology, and SCS Corporation (Forcinio 2 2001). This standard will focus on the UHF band between 860 and 928 MHz, which is somewhat broader than that of MH10.8.4 in order for it to be utilized in Europe as well as North America (Forcinio 2 2001). The GTAG is a performance standard, which does not specify the design of the transponders, but instead dictates performance requirements such as read range and anticollision algorithms (Cooke 2001).

It remains unclear if there will be one standard or two for RFID item identification (Cooke 2001). However, the acceptance of the GTAG will result in the creation of two different RFID standards that may cause problems if they remain incompatible with each other. Ron Tillinger, Program Manager for AIAG, has adopted

MH10.8.4 for now but hopes that "the tag manufacturers will allow software on the reader to capture data from both types of tags" (Cooke 2001). Craig Harmon, a chair on the industry committees that oversaw development of MH10.8.4, claims that "efforts are under way to convince the retail industry to make GTAG interoperable with MH10.8.4" (Cooke 2001).

CHAPTER THREE
METHODOLOGY

The growth and development of the RFID industry over the last few years has generated a great deal of interest from companies that are pursuing new tactics to increase supply chain efficiency. As companies strive to learn all they can about RFID technology and what it can offer to a supply chain, they will most likely discover that a significant amount of the literature available falls into one of the three following categories: a general overview of how RFID works, information about specific RFID product lines published by vendors, and opinions from RFID "experts" about the potential growth or obstacles that exist for RFID.

Although much can be learned from the preceding types of information, there is little, if any, information published that will clearly aid a company in determining whether or not an RFID system can work for their operations and also give suggestions on how to implement the technology. An RFID vendor or integrator can provide this type of assistance, however, a company could receive biased information since the vendor may try to sell his technology and products rather than suggesting other alternatives.

The proposed Model in this thesis was developed to offer companies that are interested in RFID an unbiased method that can be used as a tool to help companies decide if RFID technology is a viable solution for their operations. The model incorporates a method, in the form of decision trees, that considers current warehousing practices. From this information, suggestions for utilizing RFID in the warehouse are provided.

There are three parts to the model; each will be discussed in further detail in following sections. The first part involves the use of decision trees to explore current grocery warehousing techniques. Each path of the decision tree leads to an ending point, at which a code is given. This code corresponds to an implementation suggestion for the company to pursue. This part of the model elaborates on the appropriate code, which specifies the level of tag placement (i.e. pallet or case) and the type of reading device. The third part integrates the implementation suggestion given previously into an overall "result" that specifies how the technology can be used and also offers benefits and drawbacks to the suggestion.

Warehousing Operations Decision Trees

The decision trees presented here encompass a broad range of the most common processes used in receiving, put-away, picking, and shipping. However, it is important to remember that there are many different methods used and it would be impossible to include all of them into one tree.

The decision trees were composed using knowledge acquired through extensive research of warehousing operations and RFID systems. This research was conducted by studying reference materials, observing processes within multiple warehouses, attending seminars and conferences focusing on RFID applications, and through conversations with multiple RFID vendors and warehouse managers. The information was compiled to develop decision trees of current warehousing systems in order to identify areas of possible RFID implementation.

Receiving Decision Tree

The Receiving Decision Tree details the process of accepting incoming goods into the warehouse, verifying the agreement to the initial order, and then adding them to inventory via a software system such as a Warehouse Management System (WMS). The decision tree provides avenues for both technologically enabled processes as well as more antiquated, paper-based processes.

One assumption is made at the start of the Receiving Decision Tree: all incoming goods arrive on a pallet. There are two reasons that govern this assumption. One, the majority of grocery warehouses receive goods from suppliers on pallet loads, and two, it simplifies the highly complex and variable system of warehousing.

The primary question in the Receiving Decision Tree, "Are pallet loads homogenous?", distinguishes between a characteristically simple receiving process and a more intricate, involved process. A homogenous pallet load refers to a pallet that contains identical product. If the incoming pallet load is not homogenous, it is called "mixed." A mixed pallet contains various quantities of different products, thus making it more difficult to identify the incoming goods.

The Receiving Decision Tree branches off into more detailed questions after the primary question in order to identify the points in need of improvement. Processes such as checking in individual cases will obviously occupy more time than accepting a pallet load "as is."

Put-Away Decision Tree

The Put-Away Decision Tree details the process of transferring goods (after they have been checked-in during the receiving operation) to their appropriate storage location within the warehouse. This process involves obtaining the storage location from the WMS, physically delivering the goods to that location, and updating the WMS with the new location of the goods in inventory.

This decision tree relies on the assumption made for the Receiving Decision Tree which is that all incoming goods arrive on a pallet. The different outcomes of this tree depend upon whether or not the warehouse currently puts-away the entire pallet load or if individual cases are removed from the pallet to be put-away to their respective locations.

Picking Decision Tree

The Picking Decision Tree involves the process of selecting goods from storage locations within the warehouse to fulfill a customer's order. The order selector, or picker, obtains a pick list that has been created by the WMS that includes items for a particular customer order. The picker must locate the item, remove it from storage, and verify the pick through the WMS. Verification of the pick notifies the WMS that the item has been removed from inventory and is on its way to the shipping area to be sent to the customer.

One assumption is made at the start of the Picking Decision Tree: all goods are shipped to the customer on pallets. As previously discussed in the Receiving Decision Tree section, this assumption was made because many grocery warehouses ship goods to their customers on pallets and, also, to simplify the complexity of warehousing.

The Picking Decision Tree branches off into detailed questions in order to identify any points that are in need of improvement. Manually recording or checking-off items that have been picked for an order and then keying the data into a computer system could potentially lead to errors as well as taking a great amount of time to complete. Also, the gap in time between the actual removal of an item from storage and the entry of the data into the computer could cause problems with inventory accuracy. When inventory levels are not accurate, mistakes can be made throughout the supply chain resulting in decreased customer satisfaction. These types of issues can affect the cost justification argument and should be carefully investigated.

Shipping Decision Tree

The Shipping Decision Tree details the process of accepting goods from the order selectors, verifying that all the goods are accounted for by comparing it to the customer's order, and updating the WMS to reflect the adjusted inventory levels. Again, the assumption regarding this decision tree is that goods are being shipped to customers on pallets.

The Shipping Decision Tree is very similar to the Receiving Decision Tree. Processes such as disassembling a pallet load and manually scanning the barcodes of each case for verification are prone to errors, not to mention the great deal of time it takes to complete.

Implementation Suggestions

The designated code obtained from the Warehousing Decision Trees is identified and explained in the second part of the model, Implementation Suggestions. This section was developed to provide companies with a specific method of utilizing tags and readers for warehousing operations.

Although there is a great deal of information about specific RFID tags and readers, it is difficult to determine which ones would be most effective for certain processes. This part of the model suggests one of two types of readers, either a handheld reader or a fixed-mount reader, and one of two ways to utilize an RFID tag, either on a case or on a pallet.

A handheld device used to read RFID tags is similar to a handheld device used to scan barcode labels. An employee points the device toward the tag and after pushing a button or a trigger, receives a response. The employee must acknowledge the response by pushing another button on the unit. Handheld devices are typically the least expensive and most versatile readers used for RFID.

In contrast, a fixed-mount unit is stationed at a specific location within the facility and cannot be moved. The tag must enter the reader's interrogation zone, so it must be transported to the reader by some means, such as a conveyor, forklift, or physically carried by an employee. Fixed-mount readers are usually more expensive but also have a longer read range and can be less labor-intensive than using handhelds.

The two levels of tag placement, case or pallet, were chosen based on current warehousing practices. Warehouses typically receive, store, and ship full pallet loads of product, but pallet loads may also be disassembled at some point within the warehouse, requiring the need for tags at case level. A case in this model refers to the packaging used to stack the product onto the pallet. The most common packaging of a case is the use of corrugated shippers, however, a case could also refer to bulk-size bags or other packages that are stacked on a pallet.

Results of Decision Trees

At this point in the model, a company has investigated its current warehousing techniques, discovered points of potential errors and wasted time, and has been advised on the method of tagging and reading the products. The third part, Results of Decision Trees, incorporates the implementation suggestion and provides additional explanation of how to actually implement the technology into an existing warehouse system, points out benefits that can be achieved, and also recommends issues to consider which can be potential drawbacks to the given system.

A thorough investigation of warehousing and RFID technology were required for the creation of the implementation suggestions. This investigation involved researching literature regarding both topics, observing warehousing practices on-site, speaking to warehouse personnel and RFID vendors, viewing demonstrations of RFID technology, and gathering information from various trade shows and seminars. Compilation of this information resulted in establishing generalized suggestions of how to effectively utilize RFID technology within the warehouse, as shown in the Model.

CHAPTER FOUR
MODEL

As mentioned in the Methodology section, this Model was developed to fill a void within the RFID industry as it relates to warehousing. There is very limited available information about how to apply RFID to warehousing operations. Companies that are interested in utilizing the technology within their warehouses may find it difficult to obtain information on their own. Speaking to vendors can help to formulate ideas; however, as salespeople, vendors tend to heavily promote their own products which has the potential of introducing bias. This Model offers companies unbiased information that can assist them in the evaluation of RFID technology.

The Warehousing Decision Trees must be consulted first in order to utilize the Model. There are four decision trees, Receiving (Figure 12), Put-Away (Figure 13), Order Selection (Figure 14), and Shipping (Figure 15). A company can determine which tree they wish to consult based upon their interest in using RFID for certain processes.

The beginning point of each decision tree starts with a primary question and is identified by a star (★). A "yes" answer to the question is symbolized with a plus sign (+) and a "no" answer is symbolized with a minus sign (-). The question leads to another question based upon a yes or no answer, until the end is reached. Each path ends with a designated code that will be required for the following section. There may be circumstance where a company answers the questions, only to find that at the end, their answer is "no" and the only option available is a "yes". In this instance, it can be assumed that the company utilizes practices that are not addressed in the decision tree. The company can choose not to pursue the Model, or continue on as if their answer had indeed been "yes". Most likely, the implementation suggestion given at the end point can benefit the company for both a yes or a no answer.

The two digit code given at the end of each path is made up of a number and a letter. The first digit of the code is numerical and refers to the implementation suggestion given in the second part of the Model. The numbers are given again below:

1. Pallet Tag with Handheld Reader
2. Pallet Tag with Fixed-Mount Reader
3. Case Tag with Handheld Reader
4. Case Tag with Fixed-Mount Reader

The second digit of the designated code is alphabetic, specifically, "A" through "D." This digit represents the process that the implementation suggestion is recommended for. The processes are defined below:

A. Receiving
B. Put-Away
C. Order Selection
D. Shipping

Once the Implementation Suggestions section has been referred to, the last part of the Model can be utilized. A company finds the code that was designated by the decision tree within the section "Results of Decision Trees." This section contains a suggested process for implementing the technology and also gives the benefits and drawbacks to that system. A company can utilize this information to determine whether or not to pursue the implementation of RFID within their facility.

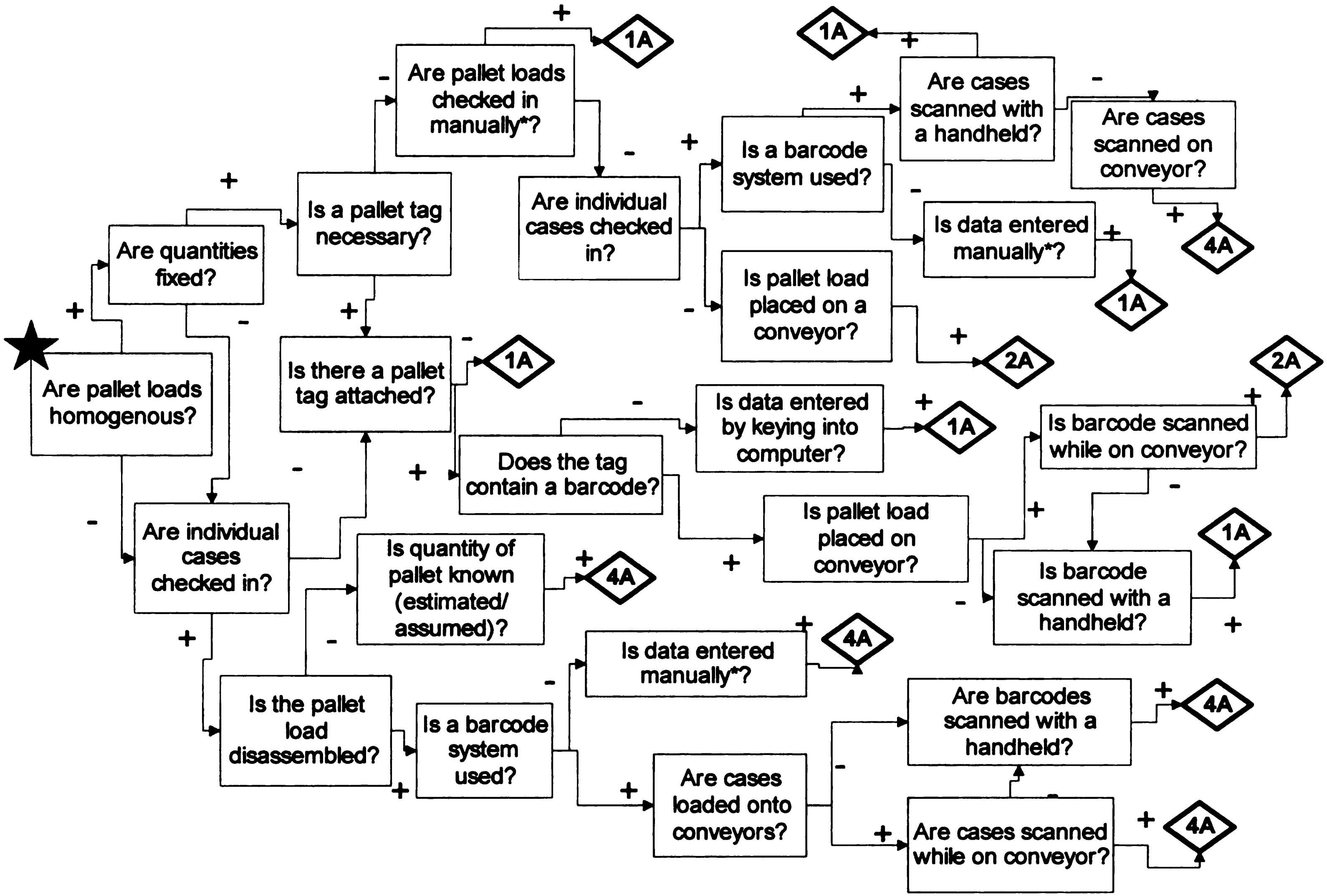

Figure 11: Receiving Decision Tree

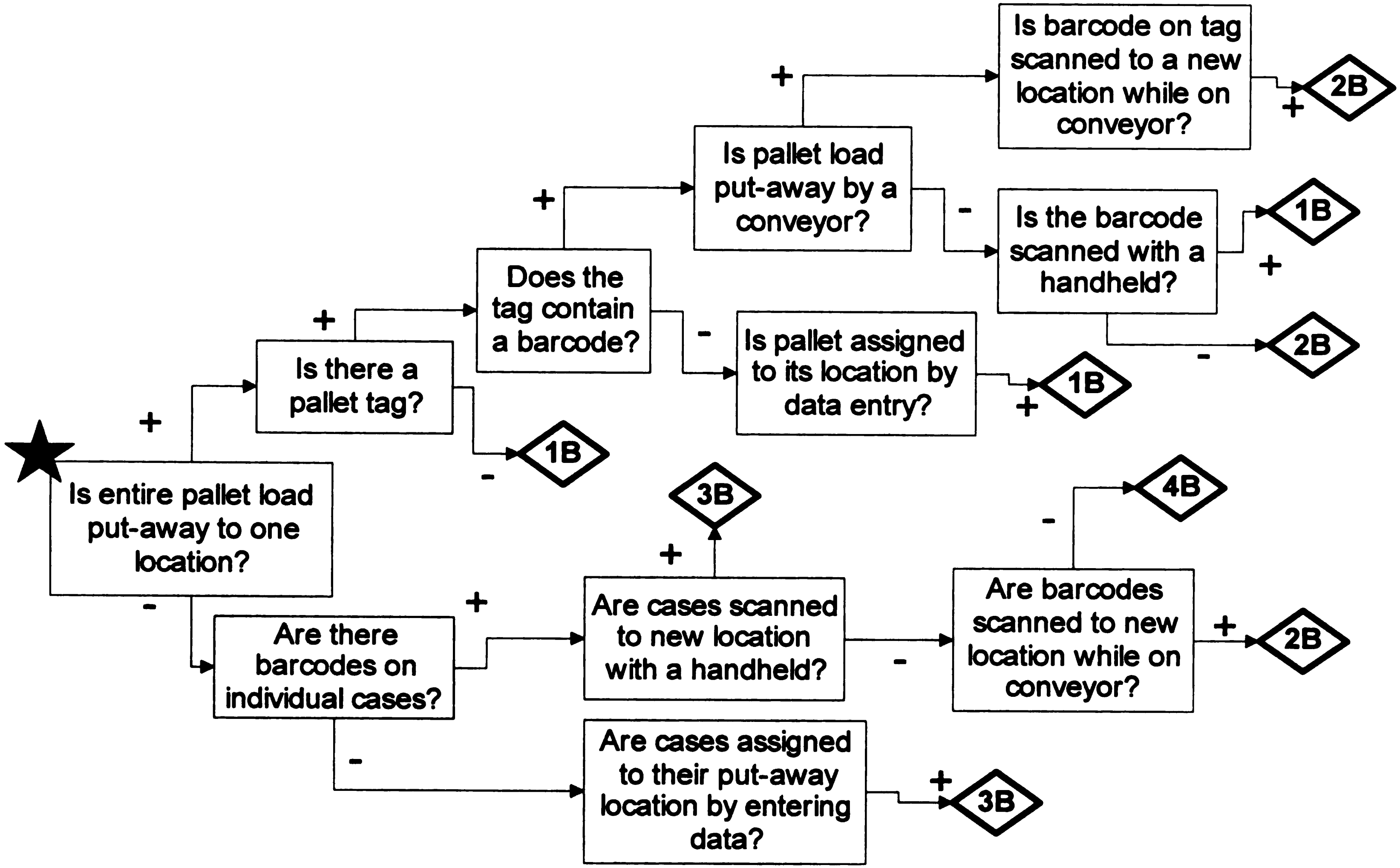

Figure 12: Put-Away Decision Tree

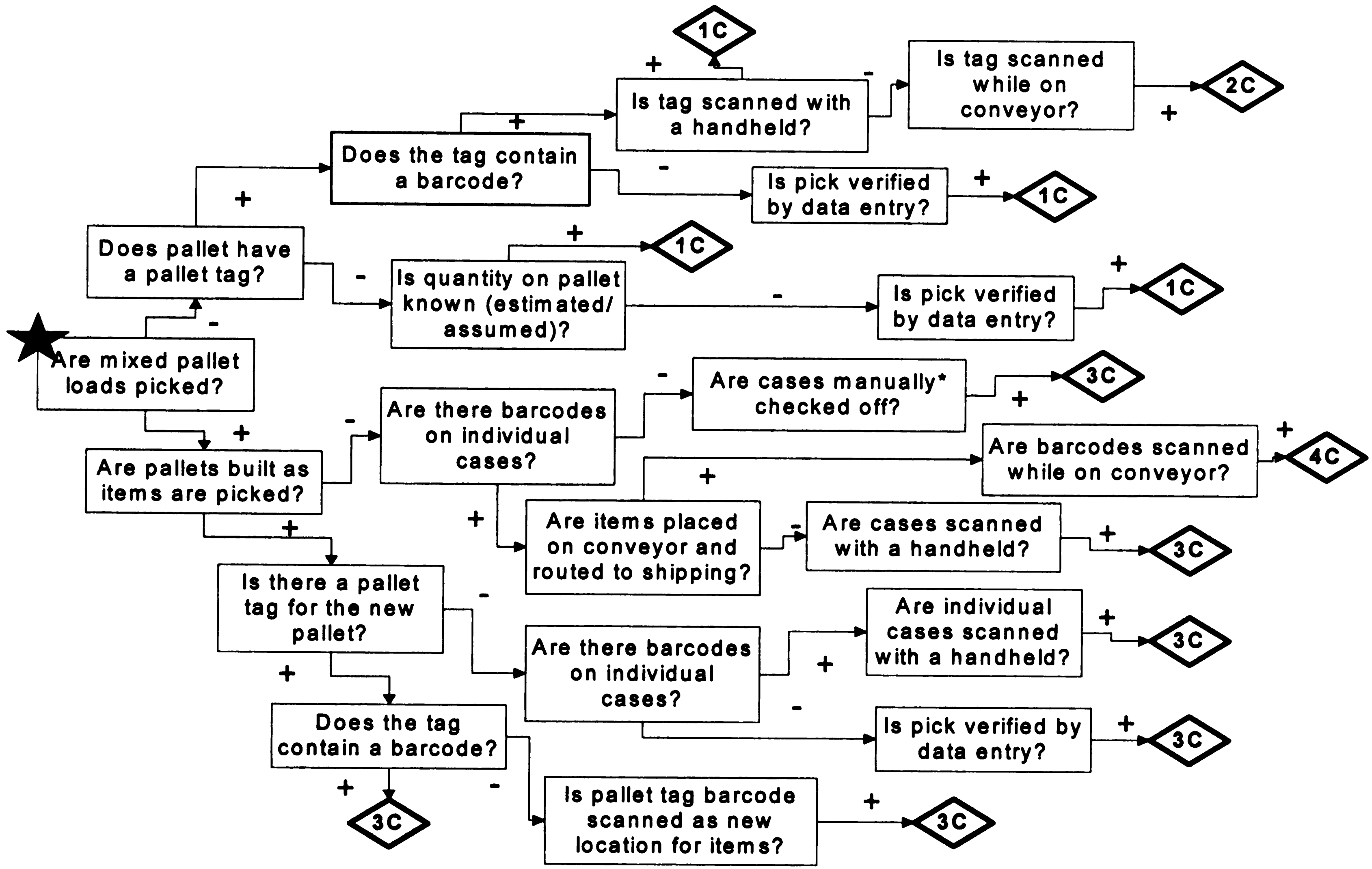

Figure 13: Order Selection Decision Tree

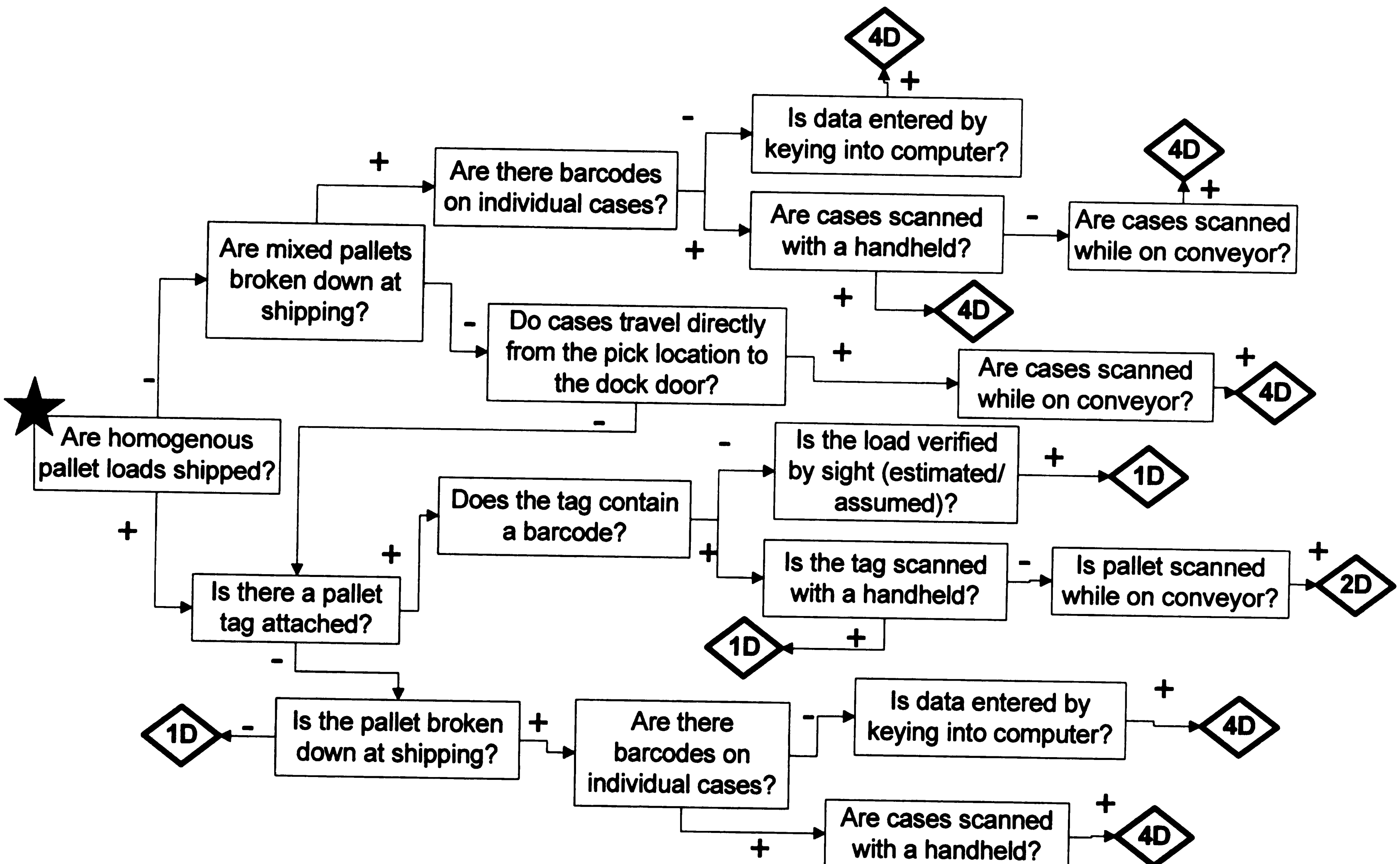

Figure 14: Shipping Decision Tree

RESULTS OF DECISION TREE

I. RECEIVING DECISION TREE

1A: Pallet Tag with Handheld Reader

Process: As the pallet is removed from the vendor's trailer and brought into the warehouse, an employee would use a handheld reader to read the contents of the pallet tag. Basically, an employee would approach the pallet and read the tag with the reader within the specified read range of the tag. The reader then sends the data to the computer system which updates the WMS with the receipt of goods. The WMS assigns the goods to a particular storage location within the warehouse.

Benefits: Using a pallet tag instead of individual case tags can drastically reduce the time required for the receiving process since only one tag has to be read. Using an RFID pallet tag instead of a barcode pallet tag offers many benefits. One benefit is that an RFID pallet tag can withstand harsh environments that may render a barcode useless. Water damage, ice, dirt, grease, oil, and breakage can all interfere with the ability of a barcode to be scanned but will not render an RFID tag unusable.

Another benefit is the read/write capability of RFID tags, where applicable. By using a read/write tag, information can be added, deleted, or changed upon the pallet tag by using the handheld unit. For example, the time the pallet was received can be written to the tag during the receiving process. Also, the tag can be reused if desired, which can cut the cost of new tag purchases.

The use of a handheld reader voids the issue of read range, which offers another benefit to this process. The employee will be able to get close enough to the tag in order to read it, which means that the complex process of assuring that the tag enters the reader's interrogation field can be dismissed.

Two other benefits are the minimal space requirements with using a handheld reader and the low cost compared to other RFID systems.

Issues to Consider: Using a handheld reader may require extra time for an employee to locate and read the tag, therefore the tag location should be standardized. Extra time spent by employees may result in extra costs to the company in hourly wages and also in decreased efficiency.

The process is also dependent upon the employee so human error can be an issue. The employee may forget, or choose not to read the tag and, hence, the pallet may not be received properly, if received at all. The employee could also read the pallet more than once during the receiving process, which, depending on the equipment and software used, may result in data confusion for the WMS.

2A: Pallet Tag with Fixed-Mount Reader

Process: As pallets are removed from the vendor's trailer and brought into the warehouse, they must pass through a "choke point" either by forklift or conveyor. The choke point is an area within the warehouse through which all pallets must pass; fixed-mount readers are positioned at this choke point in order to identify the incoming goods. For the receiving process, the choke point might be the receiving bay doors. Using a portal antenna to surround the entryway would be one option for receiving pallet loads of goods. If pallets are placed on a conveyor upon arrival, a fixed-mount reader positioned on the side of the conveyor can read the pallet tag as a pallet approaches. For either example, the information acquired from the tag is transmitted to the computer system, which updates the WMS with the receipt of goods. A storage location is assigned by the WMS and the conveyor routes the pallet to the appropriate location.

Benefits: Using a pallet tag instead of individual case tags can drastically reduce the time required for the receiving process since only one tag has to be read. Using an RFID pallet tag instead of a barcode pallet tag offers many benefits. One benefit is that an RFID pallet tag can withstand harsh environments that may render a barcode useless. Water damage, ice, dirt, grease, oil, and breakage can all interfere with the ability of a barcode to be scanned but will not render an RFID tag unusable.

Another benefit is the read/write capability of RFID tags, where applicable. By using a read/write tag, information can be added, deleted, or changed upon the pallet tag by using the fixed-mount reader. For example, the time the pallet was received can be written to the tag during the receiving process. Also, the tag can be reused if desired, which can cut the cost of new tag purchases.

If the pallets pass by the reader while on a conveyor, the use of a fixed-mount reader can eliminate the need for employee involvement. Therefore, the time and cost of an employee to use a handheld device to read the tags can be utilized elsewhere in the warehouse. If the pallet is handled by a forklift, a terminal and screen contained upon the forklift would display information and directions to the driver, which would enable the driver to read the pallet tag during the normal process of moving the pallet. Thus, no additional time would be required for this process.

Issues to Consider: This process may require that the reader be positioned on or near a conveyor, so there must be a location on the conveyor to do this. Also, all pallets must pass by this same point, or in other words, all pallets must be placed upon the same conveyor to ensure that every pallet that enters the warehouse is officially received.

Similarly, if forklifts are used, the forklift must be equipped with a terminal and screen and the employees must be trained to operate it correctly. The fixed-mount antennas must be positioned so it is accessible to the drivers but does not interfere with the normal activities of the warehouse. A portal antenna may require a significant amount of space and also may require additional fixtures such as concrete posts for protection from forklift damage.

Another issue to consider when using fixed-mount readers, especially a portal antenna, is that once they are positioned, they can be very difficult, even impossible, to move. It is important to make sure that the location for these antennas/readers will be permanent.

A pallet tag must enter the interrogation zone of the reader, so read and write range can be an issue with this process. Since the tag must pass by the reader within its read range, the pallet should be positioned accordingly. This may require that the pallet be placed upon the conveyor in a specific orientation (tag facing reader).

4A: Case Tag with Fixed Reader

Process: As pallets are removed from the vendor's trailer and brought into the warehouse, they may be disassembled, or "broken down" in order to check in each individual case. These cases may be placed upon a conveyor for routing to their storage locations. A fixed-mount reader positioned on the side of the conveyor can read the case tag as the case approaches.

If a conveyor system is not used, the use of RFID can eliminate the need for employees to disassemble pallets for check-in. As the pallet is moved by forklift, it can pass through a choke point, or an area within the warehouse through which all pallets must pass. Fixed-mount readers are positioned at this choke point in order to identify incoming goods. For the receiving process, the choke point might be the receiving bay doors. Using a portal antenna to surround the entryway would be one option for receiving pallet loads of goods.

For both examples, the information acquired from the tag is transmitted to the computer system, which updates the WMS with the receipt of goods. A storage location is assigned by the WMS and the conveyor routes the case to the appropriate location.

Benefits: Using an RFID case tag instead of a barcode case tag offers many benefits. One benefit is that an RFID case tag can withstand harsh environments that may render a barcode useless. Water damage, ice, dirt, grease, oil, and breakage can all interfere with the ability of a barcode to be scanned but will not render an RFID tag unusable.

Another benefit is the read/write capability of RFID tags, where applicable. By using a read/write tag, information can be added, deleted, or changed upon the case tag by using the fixed-mount reader. For example, the time the case was received can be written to the tag during the receiving process.

Another benefit to this process is that placing tags on individual cases identifies, or helps to identify the case during its journey through the put-away process. Therefore, if the case becomes misrouted, the tag could be read and the case sent to its proper location. Tags on individual cases can also serve as a record of where a case has been.

If the cases pass by the reader while on a conveyor, the use of a fixed-mount reader can eliminate the need for employee involvement. Therefore, the time and cost of an employee to use a handheld device to read the tags can be utilized elsewhere in the warehouse. If the pallet containing the cases is handled by a forklift, a terminal and screen incorporated upon the forklift would display information and directions to the driver, which would enable the driver to read the case tags during the normal process of moving the pallet. Thus, no additional time would be required for this process.

One benefit for using a portal antenna around a dock door is that all pallets must enter through the dock door, so every pallet that is received has to pass through the portal. Therefore, no tagged goods can enter the warehouse without being acknowledged and accepted by the WMS. Occurrences of misplaced or lost goods would be virtually eliminated.

Issues to Consider: Placing tags on individual cases can drastically increase costs associated with implementing the system. Costs can be minimized if care is taken to select tags with minimal functionality, such as those containing read only capability, small memory capacity, short read range, or small size. Also, ordering a large volume of tags may decrease the price since most vendors have price breaks at certain volumes (although most are very high volumes).

Another issue to consider that relates to the cost of the tags is that the tags would most likely be placed on expendable cases, which means that the tags would be disposed of along with the packaging. Tags placed directly on cases can rarely be reused, except where the expendable case is reused.

Since a tag must enter the interrogation zone of the reader, the read range is an important issue with this process. The tags on the cases within the pallet load must each be located at a distance within the read range to the reader. The most critical cases are the ones buried in the middle of the pallet, which would be the farthest away from the reader (assuming antennae on each side of the pallet). The signal from the portal reader can (usually) penetrate to the center of a pallet load if all conditions are optimal. This may require that the tags on the cases be placed in a specific orientation to the reader. This would require that the vendor stack its pallet accordingly, which may have an affect on pallet stacking patterns or space utilization.

The frequency of the tags is an issue if the product they are attached to contains components that interfere with radio waves. For instance, a 915 MHz tag on a case filled with liquid might have problems being read, especially on those cases that are buried in the middle of the pallet load. The frequency also affects the read range, and a 915 MHz tag boasts a longer read range than a 13.56 MHz tag. In some instances, the 13.56 MHz frequency might not allow a long enough read range to read all the tags on the pallet.

Since many tags might need to be read at one time, anticollision is also an issue. Most tags have an anticollision mechanism that allows them to be "turned off" once they are read in order for the other tags to be read. Anticollision is a characteristic of the tag, so this issue should be acknowledged when choosing a type of tag. Similarly, some portal readers can only read a maximum number of tags at one time. This also needs to be accounted for.

This process may require that the antennae be positioned on or near a conveyor, so there must be a location on the conveyor to do this. Also, all cases must pass by this same point, or in other words, all cases must be placed upon the same conveyor to ensure that every case that enters the warehouse is officially received.

Similarly, if forklifts are used, the forklift must be equipped with a terminal and screen and the employees must be trained to operate it correctly. The fixed-mount antennas must be positioned so it is accessible to the drivers but does not interfere with the normal activities of the warehouse. A portal antenna may require a significant amount of space and also may require additional fixtures such as concrete posts for protection from forklift damage.

Another issue to consider when using fixed-mount readers, especially a portal antenna, is that once they are positioned, they can be very difficult, even impossible, to move. It is important to make sure that the location for these antennas/readers will be permanent.

II. PUT-AWAY DECISION TREE

1B: Pallet Tag with Handheld Reader

Process: As the pallet is transported from the receiving area to its storage location, an employee would use a handheld reader to read the contents of the pallet tag. When the pallet arrives to the storage location, the employee would approach the pallet and read the tag with the reader within the specified read range of the tag. The reader then sends the data to the computer system which updates the WMS with the new location of goods.

Benefits: Using a pallet tag instead of individual case tags can drastically reduce the time required for the put-away process since only one tag has to be read. Using an RFID pallet tag instead of a barcode pallet tag offers many benefits. One benefit is that an RFID pallet tag can withstand harsh environments that may render a barcode useless. Water damage, ice, dirt, grease, oil, and breakage can all interfere with the ability of a barcode to be scanned but will not render an RFID tag unusable.

Another benefit is the read/write capability of RFID tags, where applicable. By using a read/write tag, information can be added, deleted, or changed upon the pallet tag by using the handheld unit. For example, the time the pallet was put-away can be written to the tag during the put-away process. Also, the tag can be reused if desired, which can cut the cost of new tag purchases.

The use of a handheld reader voids the issue of read range, which offers another benefit to this process. The employee will be able to get close enough to the tag in order to read it, which means that the complex process of assuring that the tag enters the reader's interrogation field can be dismissed.

Two other benefits are the minimal space requirements with using a handheld reader and the low cost compared to other RFID systems.

Issues to Consider: Using a handheld reader may require extra time for an employee to locate and read the tag, therefore the tag location should be standardized. Extra time spent by employees may result in extra costs to the company in hourly wages and also in decreased efficiency.

The process is also dependent upon the employee so human error can be an issue. The employee may forget, or choose not to read the tag and, hence, the pallet may not be put-away properly, if put-away at all. The employee could also read the pallet more than once during the put-away process, which, depending on the equipment and software used, may result in data confusion for the WMS.

2B: Pallet Tag with Fixed-Mount Reader

Process: As the pallet is transported from the receiving area to its storage location, it would pass through a choke point, or area within the warehouse through which all pallets must pass, by a forklift or conveyor. This choke point would contain fixed-mount readers that can read the contents of the pallet tag. For the put-away process, a choke point might be the entrance of a freezer. Using a portal antenna to surround the entrance would be one option for the put-away of frozen goods.

If pallets are transported to the put-away location by conveyor, a fixed-mount reader positioned on the side of the conveyor can read the pallet tag as the pallet approaches. For both processes, the reader sends the data to the computer system which updates the WMS with the storage location of goods.

Benefits: Using an RFID pallet tag instead of a barcode pallet tag offers many benefits. One benefit is that an RFID pallet tag can withstand harsh environments that may render a barcode useless. Water damage, ice, dirt, grease, oil, and breakage can all interfere with the ability of a barcode to be scanned but will not render an RFID tag unusable.

Another benefit is the read/write capability of RFID tags, where applicable. By using a read/write tag, information can be added, deleted, or changed upon the pallet tag by using the handheld unit. For example, the time the pallet was put-away can be written to the tag during the put-away process. Also, the tag can be reused if desired, which can cut the cost of new tag purchases.

If the pallets pass by the reader while on a conveyor, the use of a fixed-mount reader can eliminate the need for employee involvement. Therefore, the time and cost of an employee to use a handheld device to read the tags can be utilized elsewhere in the warehouse. If the pallet is handled by a forklift, a terminal and screen contained upon the forklift would display information and directions to the driver, which would enable the driver to read the pallet tag during the normal process of moving the pallet. Thus, no additional time would be required for this process.

Issues to Consider: This process may require that the reader be positioned on or near a conveyor, so there must be a location on the conveyor to do this. Also, all pallets must pass by this same point, or in other words, all pallets must be placed upon the same conveyor to ensure that every pallet is officially put-away.

Similarly, if forklifts are used, the forklift must be equipped with a terminal and screen and the employees must be trained to operate it correctly. The fixed-mount antennas must be positioned so it is accessible to the drivers but does not interfere with the normal activities of the warehouse. A portal antenna may require a significant amount of space and also may require additional fixtures such as concrete posts for protection from forklift damage.

Another issue to consider when using fixed-mount readers, especially a portal antenna, is that once they are positioned, they can be very difficult, even impossible, to move. It is important to make sure that the location for these antennas/readers will be permanent.

A pallet tag must enter the interrogation zone of the reader, so read and write range can be an issue with this process. Since the tag must pass by the reader within its read range, the pallet should be positioned accordingly. This requires that the pallet be placed upon the conveyor in a specific orientation (tag facing reader).

One other issue to consider is that it may be difficult to specify choke points for the put-away process. Certain storage locations that have definite entryways, such as freezers or coolers, offer an advantage for implementing fixed-mount readers.

3B: Case Tag with Handheld Reader

Process: As a mixed pallet is transported from the receiving area to storage locations, an employee would use a handheld reader to read the contents of the case tag. When cases arrive to their storage location, the employee would remove the cases and read the individual tags with the reader within the specified read range of the tag. The reader then sends the data to the computer system which updates the WMS with the storage location of goods.

Benefits: Using an RFID case tag instead of a barcode case tag offers many benefits. One benefit is that an RFID case tag can withstand harsh environments that may render a barcode useless. Water damage, ice, dirt, grease, oil, and breakage can all interfere with the ability of a barcode to be scanned but will not render an RFID tag unusable.

Another benefit is the read/write capability of RFID tags, where applicable. By using a read/write tag, information can be added, deleted, or changed upon the case tag by using the fixed-mount reader. For example, the time the case was put-away can be written to the tag during the put-away process.

Another benefit to this process is that placing tags on individual cases identifies, or helps to identify the case during its journey through the put-away process. Therefore, if it became misrouted, the tag could be read and sent to its proper location. Tags on individual cases can also serve as a record of where that case has been and, additionally, continue to keep track of every place that it goes.

The use of a handheld reader voids the issue of read range, which offers another benefit to this process. The employee will be able to get close enough to the tag in order to read it, which means that the complex process of assuring that the tag enters the reader's interrogation field can be dismissed.

Two other benefits are the minimal space requirements with using a handheld reader and the low cost compared to other RFID systems.

Issues to Consider: Placing tags on individual cases can drastically increase costs associated with implementing the system. Costs can be minimized if care is taken to select tags with minimal functionality, such as those containing read only capability, small memory capacity, short read range, or small size. Also, ordering a large volume of tags may decrease the price since most vendors have price breaks at certain volumes (although most are very high volumes).

Another issue to consider that relates to the cost of the tags is that the tags would most likely be placed on expendable cases, which means that the tags would be disposed of along with the packaging. Tags placed directly on cases can rarely be reused, except where the expendable case is reused.

Using a handheld reader may require extra time for an employee to locate and read the tag, therefore tag location should be standardized. Extra time spent by employees may result in extra costs to the company in hourly wages and also in decreased efficiency.

The process is also dependent upon the employee so human error can be an issue. The employee may forget, or choose not to read the tag and, hence, the pallet may not be put-away properly, if put-away at all. The employee could also read the pallet more than once during the put-away process, which, depending on the equipment and software used, may result in data confusion for the WMS.

4B: Case Tag with Fixed-Mount Reader

Process: As the cases are transported from the receiving area to their storage locations, they would pass through a choke point, or area within the warehouse through which all the cases must pass, by a forklift or conveyor. This choke point would contain fixed-mount readers that can read the tags. For the put-away process, a choke point might be the entrance of a freezer. Using a portal antenna to surround the entrance would be one option for the put-away of frozen goods.

If cases are transported to the put-away location by conveyor, a fixed-mount reader positioned on the side of the conveyor can read the case tag as the case approaches. For both processes, the reader sends the data to the computer system which updates the WMS with the storage location of goods.

Benefits: Using an RFID case tag instead of a barcode case tag offers many benefits. One benefit is that an RFID case tag can withstand harsh environments that may render a barcode useless. Water damage, ice, dirt, grease, oil, and breakage can all interfere with the ability of a barcode to be scanned but will not render an RFID tag unusable.

Another benefit is the read/write capability of RFID tags, where applicable. By using a read/write tag, information can be added, deleted, or changed upon the case tag by using the fixed-mount reader. For example, the time the case was put-away can be written to the tag during the put-away process.

Another benefit to this process is that placing tags on individual cases identifies, or helps to identify the case during its journey through the put-away process. Therefore, if it became misrouted, the tag could be read and sent to its proper location. Tags on individual cases can also serve as a record of where that case has been and, additionally, continue to keep track of every place that it goes.

If the cases pass by the reader while on a conveyor, the use of a fixed-mount reader can eliminate the need for employee involvement. Therefore, the time and cost of an employee to use a handheld device to read the tags can be utilized elsewhere in the warehouse. If the pallet containing the cases is handled by a forklift, a terminal and screen incorporated upon the forklift would display information and directions to the driver, which would enable the driver to read the case tags during the normal process of moving the pallet. Thus, no additional time would be required for this process.

Issues to Consider: Placing tags on individual cases can drastically increase costs associated with implementing the system. Costs can be minimized if care is taken to select tags with minimal functionality, such as those containing read only capability, small memory capacity, short read range, or small size. Also, ordering a large volume of tags may decrease the price since most vendors have price breaks at certain volumes (although most are very high volumes).

Another issue to consider that relates to the cost of the tags is that the tags would most likely be placed on expendable cases, which means that the tags would be disposed of along with the packaging. Tags placed directly on cases can rarely be reused, except where the expendable case is reused.

Since a tag must enter the interrogation zone of the reader, the read range is an important issue with this process. The tags on the cases within a pallet load must each be located at a distance within the read range to the reader. The most critical cases are the ones buried in the middle of the pallet, which would be the farthest away from the reader (assuming antennae on each side of the pallet). The signal from the portal reader can (usually) penetrate to the center of a pallet load if all conditions are optimal. This may require that the tags on the cases be placed in a specific orientation to the reader.

The frequency of the tags is an issue if the product they are attached to contains components that interfere with radio waves. For instance, a 915 MHz tag on a case filled with liquid might have problems being read, especially on those cases that are buried in the middle of the pallet load. The frequency also affects the read range, and a 915 MHz tag boasts a longer read range than a 13.56 MHz tag. In some instances, the 13.56 MHz frequency might not allow a long enough read range to read all the tags on the pallet.

Since many tags might need to be read at one time, anticollision is also an issue. Most tags have an anticollision mechanism that allows them to be "turned off" once they are read in order for the other tags to be read. Anticollision is a characteristic of the tag, so this issue should be acknowledged when choosing a type of tag. Similarly, some portal readers can only read a maximum number of tags at one time. This also needs to be accounted for.

This process may require that the antennae be positioned on or near a conveyor, so there must be a location on the conveyor to do this. Also, all cases must pass by this same point, or in other words, all cases must be placed upon the same conveyor to ensure that every case that enters the warehouse is officially put-away.

Similarly, if forklifts are used, the forklift must be equipped with a terminal and screen and the employees must be trained to operate it correctly. The fixed-mount antennas must be positioned so it is accessible to the drivers but does not interfere with the normal activities of the warehouse. A portal antenna may require a significant amount of space and also may require additional fixtures such as concrete posts for protection from forklift damage.

Another issue to consider when using fixed-mount readers, especially a portal antenna, is that once they are positioned, they can be very difficult, even impossible, to move. It is important to make sure that the location for these antennas/readers will be permanent.

III. ORDER SELECTION DECISION TREE

1C: Pallet Tag with Handheld Reader

Process: After a pick list is generated for an order, an employee travels to the appropriate storage location to retrieve the pallet. The employee would use a handheld reader to read the contents of the pallet tag. The employee would approach the pallet and read the tag with the reader within the specified read range of the tag. The reader then sends the data to the computer system which updates the WMS with the selection of goods.

Benefits: Using a pallet tag instead of individual case tags can drastically reduce the time required for the order selection process since only one tag has to be read. Using an RFID pallet tag instead of a barcode pallet tag offers many benefits. One benefit is that an RFID pallet tag can withstand harsh environments that may render a barcode useless. Water damage, ice, dirt, grease, oil, and breakage can all interfere with the ability of a barcode to be scanned but will not render an RFID tag unusable.

Another benefit is the read/write capability of RFID tags, where applicable. By using a read/write tag, information can be added, deleted, or changed upon the pallet tag by using the handheld unit. For example, the time the pallet was selected can be written to the tag during the selection process. Also, the tag can be reused if desired, which can cut the cost of new tag purchases.

The use of a handheld reader voids the issue of read range, which offers another benefit to this process. The employee will be able to get close enough to the tag in order to read it, which means that the complex process of assuring that the tag enters the reader's interrogation field can be dismissed.

Two other benefits are the minimal space requirements with using a handheld reader and the low cost compared to other RFID systems.

Issues to Consider: Using a handheld reader may require extra time for an employee to locate and read the tag, therefore the location of the tag should be standardized. Extra time spent by employees may result in extra costs to the company in hourly wages and also in decreased efficiency.

The process is also dependent upon the employee so human error can be an issue. The employee may forget, or choose not to read the tag and, hence, the pallet may not be selected properly. The employee could also read the pallet more than once during the picking process, which, depending on the equipment and software used, may result in data confusion for the WMS.

2C: Pallet Tag with Fixed-Mount Reader

Process: After a pick list is generated for an order, an employee travels to the appropriate storage location to retrieve the pallet. As it is selected, the pallet must pass through a choke point, or area within the warehouse through which all pallets must pass, by a forklift or conveyor. This choke point would contain fixed-mount readers that can read the contents of the pallet tag and verify that the pallet was selected. For the order selection process, a choke point might be the exit of a freezer. Using a portal antenna to surround the exit would be one option for the order selection of a pallet of frozen goods.

If pallets are transported to a conveyor as they are selected, a fixed-mount reader positioned on the side of the conveyor can read the pallet tag as the pallet approaches. For both processes, the reader sends the data to the computer system which updates the WMS with the selection of goods.

Benefits: Using an RFID pallet tag instead of a barcode pallet tag offers many benefits. One benefit is that an RFID pallet tag can withstand harsh environments that may render a barcode useless. Water damage, ice, dirt, grease, oil, and breakage can all interfere with the ability of a barcode to be scanned but will not render an RFID tag unusable.

Another benefit is the read/write capability of RFID tags, where applicable. By using a read/write tag, information can be added, deleted, or changed upon the pallet tag by using the handheld unit. For example, the time the pallet was selected can be written to the tag during the order selection process. Also, the tag can be reused if desired, which can cut the cost of new tag purchases.

If the pallets pass by the reader while on a conveyor, the use of a fixed-mount reader can eliminate the need for employee involvement. Therefore, the time and cost of an employee to use a handheld device to read the tags can be utilized elsewhere in the warehouse. If the pallet is handled by a forklift, a terminal and screen contained upon the forklift would display information and directions to the driver, which would enable the driver to read the pallet tag during the normal process of moving the pallet. Thus, no additional time would be required for this process.

Issues to Consider: This process may require that the reader be positioned on or near a conveyor, so there must be a location on the conveyor to do this. Also, all pallets must pass by this same point, or in other words, all pallets must be placed upon the same conveyor to ensure that every pallet is officially selected.

Similarly, if forklifts are used, the forklift must be equipped with a terminal and screen and the employees must be trained to operate it correctly. The fixed-mount antennas must be positioned so it is accessible to the drivers but does not interfere with the normal activities of the warehouse. A portal antenna may require a significant amount of space and also may require additional fixtures such as concrete posts for protection from forklift damage.

Another issue to consider when using fixed-mount readers, especially a portal antenna, is that once they are positioned, they can be very difficult, even impossible, to move. It is important to make sure that the location for these antennas/readers will be permanent.

A pallet tag must enter the interrogation zone of the reader, so read range can be an issue with this process. Since the tag must pass by the reader within its read range, the pallet should be positioned accordingly. This requires that the pallet be placed upon the conveyor in a specific orientation (tag facing reader).

One other issue to consider is that it may be difficult to specify choke points for the order selection process. Certain storage locations that have definite entryways, such as freezers or coolers, offer an advantage for implementing fixed-mount readers.

3C: Case Tag with Handheld Reader

Process: After a pick list is generated for an order, an employee travels to the appropriate storage location to retrieve the cases. The employee would use a handheld reader to read the case tags. The employee would select the case and read the tag with the reader within the specified read range of the tag. The reader then sends the data to the computer system which updates the WMS with the selection of goods. At this point, the employee can add the case to a pallet that he/she is building for the order, or send it to the shipping area by conveyor or some other method.

If the employee is building a new pallet for the order with the goods he/she selects, the new pallet could contain an RFID pallet tag. As the employee reads the case tag that he/she selected, he/she could also write the information on the case tag to the new pallet tag, if it allows this operation. After all the cases are selected, the pallet will contain one pallet tag with information about each case that rests upon it. This method would make the shipping process quicker since only one tag (pallet) would need to be read instead of each individual case tag.

Benefits: Using an RFID case tag instead of a barcode case tag offers many benefits. One benefit is that an RFID case tag can withstand harsh environments that may render a barcode useless. Water damage, ice, dirt, grease, oil, and breakage can all interfere with the ability of a barcode to be scanned but will not render an RFID tag unusable.

Another benefit is the read/write capability of RFID tags, where applicable. By using a read/write tag, information can be added, deleted, or changed upon the case tag by using the fixed-mount reader. For example, the time the case was selected can be written to the tag during the order selection process.

Another benefit to this process is that placing tags on individual cases identifies, or helps to identify the case during its journey through the picking process. Therefore, if it became misrouted, the tag could be read and sent to its proper location. Tags on individual cases can also serve as a record of where that case has been and, additionally, continue to keep track of every place that it goes.

The use of a handheld reader voids the issue of read range, which offers another benefit to this process. The employee will be able to get close enough to the tag in order to read it, which means that the complex process of assuring that the tag enters the reader's interrogation field can be dismissed.

Two other benefits are the minimal space requirements with using a handheld reader and the low cost compared to other RFID systems.

Issues to Consider: Using a handheld reader may require extra time for an employee to locate and read the tag, therefore tag location should be standardized. Extra time spent by employees may result in extra costs to the company in hourly wages and also in decreased efficiency.

The process is also dependent upon the employee so human error can be an issue. The employee may forget, or choose not to read the tag and, hence, the pallet may not be selected properly. The employee could also read the pallet more than once during the picking process, which, depending on the equipment and software used, may result in data confusion for the WMS.

Placing tags on individual cases can drastically increase costs associated with implementing the system. Costs can be minimized if care is taken to select tags with minimal functionality, such as those containing read only capability, small memory capacity, short read range, or small size. Also, ordering a large volume of tags may decrease the price since most vendors have price breaks at certain volumes (although most are very high volumes).

Another issue to consider that relates to the cost of the tags is that the tags would most likely be placed on expendable cases, which means that the tags would be disposed of along with the packaging. Tags placed directly on cases can rarely be reused, except where the expendable case is reused.

4C: Case Tag with Fixed-Mount Reader

Process: After a pick list is generated for an order, an employee travels to the appropriate storage location to retrieve the cases. As it is selected, the case must pass through a choke point, or area within the warehouse through which all cases must pass, by a forklift or conveyor. This choke point would contain fixed-mount readers that can read the contents of the case tag and verify that the case was selected. For the order selection process, a choke point might be the exit of a freezer. Using a portal antenna to surround the exit would be one option for the order selection of a case of frozen goods.

At this point, the employee can add the case to a pallet that he/she is building for the order, or send it to the shipping area by conveyor or some other method.

If cases are transported to a conveyor as they are selected, a fixed-mount reader positioned on the side of the conveyor can read the case tag as the case approaches. For both processes, the reader sends the data to the computer system which updates the WMS with the selection of goods.

If the employee is building a new pallet for the order with the goods he/she selects, the new pallet could contain an RFID pallet tag. As the employee reads the case tag that he/she selected, he/she can also write the information on the case tag to the new pallet tag. After all the cases are selected, the pallet will contain one pallet tag with information about each case that rests upon it. This method would make the shipping process quicker since only one tag would need to be read instead of each individual case tag.

Benefits: Using an RFID case tag instead of a barcode case tag offers many benefits. One benefit is that an RFID case tag can withstand harsh environments that may render a barcode useless. Water damage, ice, dirt, grease, oil, and breakage can all interfere with the ability of a barcode to be scanned but will not render an RFID tag unusable.

Another benefit is the read/write capability of RFID tags, where applicable. By using a read/write tag, information can be added, deleted, or changed upon the case tag by using the fixed-mount reader. For example, the time the case was selected can be written to the tag during the order selection process.

Another benefit to this process is that placing tags on individual cases identifies, or helps to identify the case during its journey through the picking process. Therefore, if it became misrouted, the tag could be read and sent to its proper location. Tags on individual cases can also serve as a record of where that case has been and, additionally, continue to keep track of every place that it goes.

If the cases pass by the reader while on a conveyor, the use of a fixed-mount reader can eliminate the need for employee involvement. Therefore, the time and cost of an employee to use a handheld device to read the tags can be utilized elsewhere in the warehouse. If the pallet containing the cases is handled by a forklift, a terminal and screen contained upon the forklift would display information and directions to the driver, which would enable the driver to read the case tag during the normal process of moving the pallet. Thus, no additional time would be required for this process.

Issues to Consider: Placing tags on individual cases can drastically increase costs associated with implementing the system. Costs can be minimized if care is taken to select tags with minimal functionality, such as those containing read only capability, small memory capacity, short read range, or small size. Also, ordering a large volume of tags may decrease the price since most vendors have price breaks at certain volumes (although most are very high volumes).

Another issue to consider that relates to the cost of the tags is that the tags would most likely be placed on expendable cases, which means that the tags would be disposed of along with the packaging. Tags placed directly on cases can rarely be reused, except where the expendable case is reused.

Since a tag must enter the interrogation zone of the reader, the read and write range is an important issue with this process. The tags on the cases within the pallet load must each be located at a distance within the read range to the reader. The most critical cases are the ones buried in the middle of the pallet, which would be the farthest away from the reader (assuming antennae on each side of the pallet). The signal from the portal reader can (usually) penetrate to the center of a pallet load if all conditions are optimal. This may require that the tags on the cases be placed in a specific orientation to the reader.

The frequency of the tags is an issue if the product they are attached to contains components that interfere with radio waves. For instance, a 915 MHz tag on a case filled with liquid might have problems being read, especially on those cases that are buried in the middle of the pallet load. The frequency also affects the read range, and a 915 MHz tag boasts a longer read range than a 13.56 MHz tag. In some instances, the 13.56 MHz frequency might not allow a long enough read range to read all the tags on the pallet.

Since many tags might need to be read at one time, anticollision is also an issue. Most tags have an anticollision mechanism that allows them to be "turned off" once they are read in order for the other tags to be read. Anticollision is a characteristic of the tag, so this issue should be acknowledged when choosing a type of tag. Similarly, some portal readers can only read a maximum number of tags at one time. This also needs to be accounted for.

This process may require that the antenna be positioned on or near a conveyor, so there must be a location on the conveyor to do this. Also, all cases must pass by this same point, or in other words, all cases must be placed upon the same conveyor to ensure that every case that enters the warehouse is officially selected.

Similarly, if forklifts are used, the forklift must be equipped with a terminal and screen and the employees must be trained to operate it correctly. The fixed-mount antennas must be positioned so it is accessible to the drivers but does not interfere with the normal activities of the warehouse. A portal antenna may require a significant amount of space and also may require additional fixtures such as concrete posts for protection from forklift damage.

Another issue to consider when using fixed-mount readers, especially a portal antenna, is that once they are positioned, they can be very difficult, even impossible, to move. It is important to make sure that the location for these antennas/readers will be permanent.

IV: SHIPPING DECISION TREE

1D: Pallet Tag with Handheld Reader

Process: Pallets designated for specific orders may arrive to the shipping area unitized and ready to load onto the trailers. An employee would use a handheld reader to read the contents of the pallet tag. Basically, an employee would approach the pallet and read the tag with the reader within the specified read range of the tag. The reader then sends the data to the computer system which updates the WMS that the goods are ready to ship. Once the pallet tag has been read, the pallet is loaded onto the trailer for shipment.

Benefits: Using a pallet tag instead of individual case tags can drastically reduce the time required for the shipping process since only one tag has to be read. Using an RFID pallet tag instead of a barcode pallet tag offers many benefits. One benefit is that an RFID pallet tag can withstand harsh environments that may render a barcode useless. Water damage, ice, dirt, grease, oil, and breakage can all interfere with the ability of a barcode to be scanned but will not render an RFID tag unusable.

Another benefit is the read/write capability of RFID tags, where applicable. By using a read/write tag, information can be added, deleted, or changed upon the pallet tag by using the handheld unit. For example, the time the pallet was shipped can be written to the tag during the shipping process. Also, the tag can be reused if desired, which can cut the cost of new tag purchases.

The use of a handheld reader voids the issue of read range, which offers another benefit to this process. The employee will be able to get close enough to the tag in order to read it, which means that the complex process of assuring that the tag enters the reader's interrogation field can be dismissed.

Two other benefits are the minimal space requirements with using a handheld reader and the low cost compared to other RFID systems.

Issues to Consider: Using a handheld reader may require extra time for an employee to locate and read the tag, therefore tag location should be standardized. Extra time spent by employees may result in extra costs to the company in hourly wages and also in decreased efficiency.

The process is also dependent upon the employee so human error can be an issue. The employee may forget, or choose not to read the tag and, hence, the pallet may not be shipped properly, if received at all. The employee could also read the pallet more than once during the shipping process, which, depending on the equipment and software used, may result in data confusion for the WMS.

2D: Pallet Tag with Fixed-Mount Reader

Process: Pallets designated for specific orders may arrive to the shipping area unitized and ready to load onto the trailers. As the pallet enters the shipping area, it must pass through a choke point, or area within the warehouse through which all pallets must pass, by a forklift or conveyor. This choke point would contain fixed-mount readers that can read the contents of the pallet tag and verify that the pallet is matches the order to be shipped. For the shipping process, a choke point might be the shipping bay doors. Using a portal antenna to surround the door would be one option for the shipping process.

If pallets are transported to the shipping area via a conveyor, a fixed-mount reader positioned on the side of the conveyor can read the pallet tag as the pallet approaches. For both processes, the reader sends the data to the computer system which updates the WMS to acknowledge that the goods are ready to ship.

Benefits: Using an RFID pallet tag instead of a barcode pallet tag offers many benefits. One benefit is that an RFID pallet tag can withstand harsh environments that may render a barcode useless. Water damage, ice, dirt, grease, oil, and breakage can all interfere with the ability of a barcode to be scanned but will not render an RFID tag unusable.

Another benefit is the read/write capability of RFID tags, where applicable. By using a read/write tag, information can be added, deleted, or changed upon the pallet tag by using the fixed-mount unit. For example, the time the pallet was shipped can be written to the tag during the shipping process. Also, the tag can be reused if desired, which can cut the cost of new tag purchases.

If the pallets pass by the reader while on a conveyor, the use of a fixed-mount reader can eliminate the need for employee involvement. Therefore, the time and cost of an employee to use a handheld device to read the tags can be utilized elsewhere in the warehouse. If the pallet is handled by a forklift, a terminal and screen contained upon the forklift would display information and directions to the driver, which would enable the driver to read the pallet tag during the normal process of moving the pallet. Thus, no additional time would be required for this process.

Another benefit to using a fixed-mount reader for the shipping process is that the dock doors serve as an excellent choke point for pallets to pass through. Every pallet or case that is loaded onto the trailer must go through the door, so it gives an excellent opportunity to gather information on the goods being shipped and compare it to the customer's order before the trailer leaves the site.

Issues to Consider: This process may require that the reader be positioned on or near a conveyor, so there must be a location on the conveyor to do this. Also, all pallets must pass by this same point, or in other words, all pallets must be placed upon the same conveyor to ensure that every pallet is officially selected.

Similarly, if forklifts are used, the forklift must be equipped with a terminal and screen and the employees must be trained to operate it correctly. The fixed-mount antennas must be positioned so it is accessible to the drivers but does not interfere with the normal activities of the warehouse. A portal antenna may require a significant amount of space and also may require additional fixtures such as concrete posts for protection from forklift damage.

Another issue to consider when using fixed-mount readers, especially a portal antenna, is that once they are positioned, they can be very difficult, even impossible, to move. It is important to make sure that the location for these antennas/readers will be permanent.

A pallet tag must enter the interrogation zone of the reader, so read and write range can be an issue with this process. Since the tag must pass by the reader within its read range, the pallet should be positioned accordingly. This may require that the pallet be placed upon the conveyor in a specific orientation (tag facing reader).

4D: Case Tag with Fixed-Mount Reader

Process: Cases designated for specific orders may arrive to the shipping area on unitized pallets, ready to load onto the trailers. Since each individual case contains an RFID tag, a fixed-mount unit should be able to read each tag on a pallet load. As the mixed pallet enters the shipping area, it must pass through a choke point, or area within the warehouse through which all pallets must pass, by a forklift or conveyor. This choke point would contain fixed-mount readers that can read the individual tags and verify that the cases match the order to be shipped. For the shipping process, a choke point might be the shipping bay doors. Using a portal antenna to surround the door would be one option for the shipping process.

If pallets are transported to the shipping area via a conveyor, a fixed-mount reader positioned on the side of the conveyor may be able to read the case tags as the pallet approaches. For both processes, the reader sends the data to the computer system which updates the WMS to acknowledge that the goods are ready to ship.

Benefits: Using an RFID case tag instead of a barcode case tag offers many benefits. One benefit is that an RFID case tag can withstand harsh environments that may render a barcode useless. Water damage, ice, dirt, grease, oil, and breakage can all interfere with the ability of a barcode to be scanned but will not render an RFID tag unusable.

Another benefit is the read/write capability of RFID tags, where applicable. By using a read/write tag, information can be added, deleted, or changed upon the case tag by using the fixed-mount reader. For example, the time the case was shipped can be written to the tag during the shipping process.

Another benefit to this process is that placing tags on individual cases identifies, or helps to identify the case during its journey through the shipping process. Therefore, if it became misrouted, the tag could be read and sent to its proper location. Tags on individual cases can also serve as a record of where that case has been and, additionally, continue to keep track of every place that it goes.

If the cases pass by the reader while on a conveyor, the use of a fixed-mount reader can eliminate the need for employee involvement. Therefore, the time and cost of an employee to use a handheld device to read the tags can be utilized elsewhere in the warehouse. If the pallet containing the cases is handled by a forklift, a terminal and screen contained upon the forklift would display information and directions to the driver, which would enable the driver to read the case tag during the normal process of moving the pallet. Thus, no additional time would be required for this process.

Another benefit to using a fixed-mount reader, especially a portal antenna, for the shipping process is that a mixed pallet load does not have to be disassembled prior to shipping. Breaking down a pallet in order to verify individual cases can take a significant amount of time and manpower. This method eliminates the need for disassembly, which also eliminates the chance for human error.

Issues to Consider: Placing tags on individual cases can drastically increase costs associated with implementing the system. Costs can be minimized if care is taken to select tags with minimal functionality, such as those containing read only capability, small memory capacity, short read range, or small size. Also, ordering a large volume of tags may decrease the price since most vendors have price breaks at certain volumes (although most are very high volumes).

Another issue to consider that relates to the cost of the tags is that the tags would most likely be placed on expendable cases, which means that the tags would be disposed of along with the packaging. Tags placed directly on cases can rarely be reused, except where the expendable case is reused.

Since a tag must enter the interrogation zone of the reader, the read range is an important issue with this process. The tags on the cases within the pallet load must each be located at a distance within the read range to the reader. The most critical cases are the ones buried in the middle of the pallet, which would be the farthest away from the reader (assuming antennae on each side of the pallet). The signal from the portal reader can (usually) penetrate to the center of a pallet load if all conditions are optimal. This may require that the tags on the cases be placed in a specific orientation to the reader.

The frequency of the tags is an issue if the product they are attached to contains components that interfere with radio waves. For instance, a 915 MHz tag on a case filled with liquid might have problems being read, especially on those cases that are buried in the middle of the pallet load. The frequency also affects the read range, and a 915 MHz tag boasts a longer read range than a 13.56 MHz tag. In some instances, the 13.56 MHz frequency might not allow a long enough read range to read all the tags on the pallet.

Since many tags might need to be read at one time, anticollision is also an issue. Most tags have an anticollision mechanism that allows them to be "turned off" once they are read in order for the other tags to be read. Anticollision is a characteristic of the tag, so this issue should be acknowledged when choosing a type of tag. Similarly, some portal readers can only read a maximum number of tags at one time. This also needs to be accounted for.

If forklifts are used, the forklift must be equipped with a terminal and screen and the employees must be trained to operate it correctly. The fixed-mount antennas must be positioned so it is accessible to the drivers but does not interfere with the normal activities of the warehouse. A portal antenna may require a significant amount of space and also may require additional fixtures such as concrete posts for protection from forklift damage.

Another issue to consider when using fixed-mount readers, especially a portal antenna, is that once they are positioned, they can be very difficult, even impossible, to move. It is important to make sure that the location for these antennas/readers will be permanent.

CHAPTER FIVE
DISCUSSION/CONCLUSION

As competition in business continues to grow, companies need to seek out improvements within their supply chains in order to remain competitive. Achieving total customer satisfaction while simultaneously operating at ideal efficiency is a goal that many companies aspire to, and thus, are increasing their efforts in the strategic planning of their supply chains to meet this goal.

There has been increased interest in expanding information technology within businesses as a way to streamline the supply chain. Enhanced information technology can help to alleviate communication problems between supply chain partners. The faster and more accurate the communication can flow through the supply chain, the more functional the supply chain can be.

The role of warehousing within the supply chain has been receiving more attention due to many commonly identified areas that are in need of improvement. As discussed in the Background Chapter, the efficiency and accuracy of warehouse processes greatly contribute to the overall success of the supply chain as a whole. Investing in information technology is one avenue that companies are exploring to improve warehouse processes.

Automatic identification is an information technology that has great potential to increase the accuracy of warehouse processes. It is a fast, reliable method of data collection that can replace manual tasks and eliminate human error. The Literature Review section provided examples of the many ways that automatic identification has contributed to the success of various business processes.

The focus of this thesis was on Radio Frequency Identification (RFID) as an automatic identification method that can provide many benefits to the supply chain, or more specifically, warehousing. RFID is gaining recognition as an exciting emerging technology that can potentially provide a competitive advantage to a company.

As RFID continues to gain popularity, more information becomes available to the general public. However, concrete evidence and specific data of how RFID has benefited companies is still closely guarded. As long as RFID remains elusive, the companies that are first to use it will achieve a competitive advantage, and are therefore unwilling to divulge any specific information.

The reluctance of companies to publish data on RFID implementation was a major hurdle in the development of this thesis. The majority of information given regarding RFID systems is very general (i.e. components, benefits). Although this information is made available to companies, there is very little information relating to how to actually implement the technology to achieve the greatest benefits. A goal of this thesis is to assist companies in bridging the gap between general information about RFID and implementing RFID into current warehousing processes.

The Model was developed for companies to relate their own warehousing processes to a method of implementing RFID that would potentially result in the greatest benefits. The Model acknowledges current processes and aims to provide a non-disruptive suggestion on how and where to use RFID. It offers benefits of implementation as well as issues to consider that may lead a company to decide that RFID is not the best option at the present time.

The Model is directed toward each warehousing process individually, in order for a company to isolate one process at a time to determine weaknesses and areas of improvement. A company may determine that RFID may not be needed for each activity, or that different methods of operation may be required. It is impractical to suggest one method of RFID for each process since they are all unique.

This Model is intended to provide a basis for future research. There are many important issues presented by the Model that deserve to be explored further. As technology advances, some of the assumptions given may be obsolete (e.g. read/write ranges, anticollision, cost) and will need to be updated to include new information. Individual warehousing processes can be investigated more thoroughly to provide more customized decision trees for specific industries or businesses. More diverse methods of reading and writing to the tags can be examined, as this Model only gives general information. Field trials could be conducted using RFID to track an item throughout warehouse processes and analyzing the benefits compared to barcodes. A survey could be created for various companies and industries to reveal actual data about the opinion of RFID systems.

There is an unlimited amount of options for future research on RFID. Many areas of the technology have yet to be explored. There will remain a remarkable interest in research that can offer companies further insight into the possible competitive advantages that can result from RFID. The Model presented in this thesis is just the beginning.

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