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FINAL THESIS REPORT

RFID TECHNOLOGY'S POTENTIAL IN WAREHOUSE MANAGEMENT
Perspective of Victor Ek's Moving Division

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Degree Programme in International Business
March 2009
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TAMPERE 2009

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INTERNATIONAL BUSINESS

Writer(s):	Ylitalo Riikka
Study Programme(s):	International Business
Title of Thesis:	RFID-teknologian suomat mahdollisuudet varastonhallinnassa, Victor Ek:n muutto-osaston näkökulma
Title in English:	RFID Technology's Potential in Warehouse Management, Perspective of Victor Ek's Moving Division
Month and Year of Completion:	March 2009
Supervisor:	Nisula Karoliina

Number of Pages: 52

ABSTRACT

Victor Ek Incorporation is a transportation company that has a core competence in international shipping and moving services. Victor Ek's Moving Division (VEK) manages two warehouses for the storing purposes of customers' moving goods. Since the nature of VEK's warehousing differs from a common warehouse storing commercial products, another kind of approach is required also in warehouse management.

This work studies potential improvements to the current issues involved in VEK's warehousing operations, and offers knowledge for supporting suggested applications. The study was conducted based on numerous sources, both primary and secondary. The theory section covers warehousing and warehouse management, warehouse control and management systems, and radio frequency identification (RFID) technology, which is one of the automatic identification systems. Each of these parts has a complimentary section, in which the theory is applied and thus practical applications designed for the purposes and needs of VEK are formed. These include, but are not limited to, a revised order of the warehouse interior, a location numbering scheme, an Excel based WMS, and an RFID application.

The aim of the project was to offer rational solutions for the problems at hand, and to introduce tools for the possible warehouse management developments in the future. RFID technology is explained in detail, as it could offer numerous benefits for the company, such as improved productivity, constant customer satisfaction, and both accurate and up-to-date inventory records. Even though, RFID is a promising technology, one of its disadvantages is a relatively high price of the implementation. However, it is important to note that the costs depend on the planned RFID system and its infrastructure requirements.

Key words: RFID Warehouse Management WMS Auto-ID

Table of Contents

List of Abbreviations

Bill of Lading (B/L)

Chief Executive Officer (CEO)

Digital Signal Processor (DSP)

Distribution Center (DC)

Electronic Data Interchange (EDI)

Electronic Product Code (EPC)

Enterprise Resource Planning (ERP)

Frequency Modulation (FM)

Global Packet Radio Service (GPRS)

Global Positioning System (GPS)

High Frequency (HF)

Integrated Circuit (IC)

Just in Time (JIT)

Low Frequency (LF)

Optical Character Recognition (OCR)

Radio detection and ranging (radar)

Radio Frequency (RF)

Radio Frequency Identification (RFID)

Return on Investment (ROI)

Stockkeeping Unit (SKU)

Supply Chain (SC)

Supply Chain Management (SCM)

Universal Product Code (UPC)

Ultra High Frequency (UHF)

Victor Ek Incorporation’s Moving Division (VEK)

Warehouse Management System (WMS)

Wireless local area network (WLAN)

Work in Process (WIP)

1 Introduction and Research Methods

Victor Ek Incorporation is a transportation company that has a strong core competence in several areas of international shipping and moving services. This final thesis report focuses on Victor Ek's Moving Division (VEK) and further on aims to develop its warehouse management. The company is selected as the writer was previously employed by Victor Ek's Logistics Department. VEK is the only subsidiary of Victor Ek Group to own warehouses and thus manages warehousing operations instead of outsourcing them to another company.

The field of this paper is related to supply chain management (SCM), logistics, warehouse management, automatic identification (Auto-ID) systems with an emphasis to radio frequency identification (RFID), and warehouse management systems (WMS) as a whole. Main concepts will be explained and highlighted later on in this final thesis. The scope of the assignment covers the theory of warehouse management, WMSs, and RFID technology. It is based on secondary research and the utilized sources are books, the Internet material, articles, and a technical research report. Primary research for the case study is carried out via a face-to-face interview, a meeting, phone calls, e-mail correspondence, and a site assessment at the warehouse premises. According to VEK's wish, these were conducted in Finnish and then translated into English by the writer. Electronic questionnaires were not relevant for the topic and thus not executed. The research methods were mostly qualitative. The gained knowledge was applied in order to develop tangible benefits for the company and facilitate the improvement of the overall warehouse management and warehousing operations in VEK.

1.1 Victor Ek Incorporation and Its Moving Division

Victor Ek Incorporation is a Transportation Company that was established in 1885. Victor Ek's business areas include moving services, shipping, forwarding, and ship's clearance. Victor Ek forms a Group with the following companies: Fennoscandia Chartering, Transcontainer, Victor Ek Logistics and Shipek, and they operate under its ownership. Each of subsidiaries has specialized in different business operations of the core competence. Victor Ek Inc. has offices and/or other residences in Helsinki, Hanko, Tampere, and Kotka. (VictorEk's homepage, 2008) Regarding to the conglomerate, this paper focuses on Victor Ek's Moving Division (VEK) and especially on its warehouse operations in Malmi.

VEK is concentrated on international moves of client companies' employees. There are also few moves within Finland, in which the customer is a private family or a firm that is relocating its office premises. Occasionally VEK also handles household moves, such as moving process and storing of goods during a renovation of customer's apartment or other residence. On the whole there are thousands of moves annually in both Finland and abroad. VEK has employed 30 movers and two warehouse workers. In addition, there are 17 office workers, who are in charge of managing company's operations or deal with shipping and customs clearance for the clients' household goods in order to ship them to the new location. According to VEK's Resource Manager, the company has two main competitors in the moving business. (Victor Ek's homepage & Kuosmanen, 2008)

1.2 Purpose of the Study

This study is conducted with the aim of investigating and improving the overall warehouse management and warehousing operations of VEK. Several theories and methods are studied and applied in order to be able to offer a throughout solutions for VEK's current problematic issues, such as inventory management, stock location management, and a lack of a WMS. In addition, the wishes of the company have been noted, and the objectives of the final thesis report have been further developed based on these ambitions. Along with the intention of progressing the warehouse management in VEK, the purpose of the study is to activate the company into decision making process of implementing a WMS, and offer the knowledge of RFID technology and its benefits in warehousing. Among other things, the report introduces a non-commercial, custom-made WMS application, and an RFID system especially designed for the company's needs.

This final thesis report discloses a deeper insight to the potential of RFID technology in warehouse management and the gains of a proper WMS. These elements would offer a competitive advantage to the company by enabling VEK to be ahead of its time in moving business and offer more value-added services to its customers, which would in turn result in enhanced customer satisfaction. RFID applications have a major potential in SCM and are already employed globally in numerous industrial areas. VEK's warehouses have a slightly different supply chain (SC), when compared to a retailer, for instance, since the firm merely stores the moving goods of the customers with no intention of selling them. This feature has been kept in mind throughout the whole report.

2 Warehousing and Warehouse Management

According to Banks et al. (2007, p. 363) the main objectives of warehousing can be described, as stated in the next statement:

An effective and efficient warehouse operation should do the following:

- Minimize the cost of movement of goods within the warehouse.
- Maximize the effective use of space, equipment, and labor.
- Keep track of all items within the warehouse correctly.
- Respond to customer requests or enquiries in a timely manner.

In order to succeed in these demanding processes on a regular basis, skillful warehouse management is required (Tompkins & Smith, 1998). If performed properly, all of these actions improve the overall profitability of the company and should therefore be considered while defining organization's business strategy. On the contrary, they may cause additional expenditures by wasting company's resources and causing customer dissatisfaction, if problematical situations arise.

The true value of warehousing in the economy is discovered, when well performed warehouse operations supply a time-and-place utility, which facilitates companies to deliver the right product to the right place at the right time (Tompkins & Smith, 1998). Since businesses can

exist and become profitable only because of their customers, it is important to keep them pleased. There are several theories and useful tools, which are assigned to assist warehouse managers in their daily duties, while aiming to reach warehousing goals.

As the main purpose of this paper is to improve the warehousing practicalities in a non-commercial products' warehouse, which stores moving goods of customers, this study discusses methodologies that could be used while aiming to develop warehouse management in this specific case. Consequently, location numbering scheme, ABC analysis, stock location management and both inventory control and accuracy are chosen to be included in the topic.

2.1 Stock Location Management and Inventory Control

Stock location management and inventory control are vital concepts in successfully operated warehouse management. Tompkins & Smith (1998, p. 823) enlighten these topics by describing that "inventory control is the process of managing the quantity of raw material, work-in-process (WIP), or finished goods, to ensure that demand is met. Stock location management is based on the requirement that, when demanded, the product must be efficiently and accurately obtained. This implies that there must be an organized way to store and retrieve product."

Basically inventory control is aiming to satisfy customers' needs at all times, but also simultaneously manage the amount of inventory in such a manner that products stored are not adding up unnecessary costs or holding company's assets. On the other hand, stock location management's objective is to be able to constantly know exactly, where the products are within the warehouse and/or supply chain (SC) and their quantity (Tompkins & Smith, 1998). Only by fulfilling this target, it is made possible to distribute requested products to the customer. Therefore, is it understandable that Tompkins & Smith imply that the concepts of inventory control and stock location management are strongly intertwined and cannot be discussed separately (2007). However, in order to have a deeper insight of these topics, this paper divides them into two theories, while investigating tools and methods they employ.

2.2 Location Numbering Scheme

Location numbering scheme is one of the methods that is linked to the stock location management. The basic idea of its function could be compared to a postal service system, which is based on addresses of homes and businesses. Fundamentally each letter, card, magazine, or parcel sent has a specific address to where it needs to be delivered. In warehouse management the key idea of location numbering scheme is to name each position in the warehouse with a planned code and thus store each item or stockkeeping unit (SKU) in its own place, which is clearly labeled inside the warehouse and filed in the records. (Tompkins & Smith, 1998) This type of procedure is highly useful in inventory tracking, and it improves both putaway and picking activities, as a result, basic functions are more trouble-free and faster to complete.

In a figure below is one type of application of location numbering method created for a specific warehouse environment. Digits are alpha or numeric and combine a code of six characters. This code reveals the unique location of an exact SKU by informing its work area, aisle, bay and level of storage. There are also other factors each digit may disclose, but the location name codes should be formed in a clear manner and the length and format are to be compatible with computer-based information system, such as warehouse management system (WMS), the company may be using. (Tompkins & Smith, 1998)

2	**AA**	**01**	**B**
Work Area	Aisle	Bay	Level

Figure 1: Location Numbering Scheme Example (Tompkins & Smith, 1998, p. 829)

After the coding principles are agreed upon, it is necessary to define name codes for each unique location in the warehouse. Naming should be logical, kept simple, and have a sequential order. It is best to number from the staging area to the end of the building, from left to right, and from the ground level up to the top of the ceiling. For developing a location numbering scheme, it is advised to form a cross-functional team within the company, since versatile knowledge is often required before making major changes in business processes. (Tompkins & Smith, 1998) Nevertheless, in a chapter *6.3 Location Numbering Scheme Applied* a suggestion that was developed without a cross-functional team for locating each SKU in VEK's Malmi warehouse is introduced. The nature of VEK's warehousing operations and SC differs from highly complex ones, and thus the team was not required in this case.

Stock location management has six different methodologies that can be used in order to utilize the location numbering scheme properly. These means include informal, fixed location, part number, commodity, random location, and combination systems. Each of them has its advantages and disadvantages, which need to be taken under consideration along with specific operations, while choosing the most appropriate system for the company's warehousing activities. (Tompkins & Smith, 1998) Part number and random location systems are explained in more detail in a following paragraph, since they are more relevant to the topic than other methodologies.

In part number system, each SKU has a unique and specific location, which is based on the part number sequences. For instance, 1A12 is situated before 1A13 within the warehouse. This methodology suits for companies that have a constant movement volume among their products. On the other hand, random location system is used when products are stored in consistent with available storing space. SKUs are placed wherever there is room; therefore, maintaining continuous records of the SKUs' movement and quantity is required. (Tompkins & Smith, 1998)

2.3 ABC Analysis

In a process of defining the most suitable locations for each SKU, one can have a major advantage by employing an ABC analysis. It is a common and logical tool for separating the stock and less problematic warehouse management can be achieved by employing it. (Tompkins & Smith, 1998) Slack et al. states that the ABC system is based on Pareto Law, which is also known as 80/20 rule (2004). Fundamentally, stock items are differentiated according to their usage value, which is calculated by multiplying the usage rate by individual value of each stock item. The name 80/20 rule derives from the fact that normally 80 percent of all sold products consist of only 20 percent of all stock item types. Thus the more significant items on a stock can be managed efficiently and overall inventory control is improved. (Slack et al. 2004)

The traditional analysis classifies each SKU in the warehouse into three groups A, B, and C. There are 20 percent of A items, 25-30 percent of B items and 50-55 percent of C items. These SKU groups are formed based on the percentage of their movement rate, which is linked either to their demand or value. A items have a movement percentage of 80, B items 15 and C items 5. ABC model offers several adjustment possibilities depending on the operations each company and warehouse has. (Tompkins & Smith, 1998)

Since stored products are normally ranked according to their value or demand, it is important to locate items rationally within the warehouse. Tompkins and Smith (1998) suggest defining locations based on products' popularity, similarity, and/or size. They also claim that it is important to consider probable special characteristics or exceptional handling items may require, and to optimize space utilization and accessibility to each location. To be more precise, according to Tompkins and Smith, A items should be stored in an area where picking is extremely easy, similar type of items ought to be located close to each other, and heavy-bulky items should be stored close to their usage point or shipping dock. There are several factors to reflect on, but once the location order of the warehouse is designed in an orderly manner and in accordance with above mentioned principles, the overall throughput may increase significantly along with advancement in warehouse operations.

2.4 Inventory Control and Accuracy

In today's business world, it is a well-known guideline that 'the customer is king.' This principle highlights the fact that a firm can not exists without customers, and therefore it is vital to aim at constant customer satisfaction. The above discussed instruction applies also to inventory control, which basic objective, as stated by Tompkins and Smith (1998), is to maximize profits while sustaining successful customer service. However, it is often a highly challenging task to obtain, since one needs to manage the demand of the required product's quantity, location and time exactly according to every client's expectations. Inventory control is based upon various data and calculations, which can be done to improve the warehouse operations in order to be able to continuously track and supervise the amount of inventory. (Tompkins and Smith, 1998)

Another concept that should be discussed together with inventory control is inventory accuracy. It is used as a key indicator while determining the state of a warehouse's operations.

It is significant to conclude the accurateness of a firm's inventory records, since these documentations may have a major impact on costs and the level of company's customer service. Inventory inaccuracy has a major impact on company's productivity, if the goods are not where they are supposed to be or cannot be found at all, or if there is an incorrect or unexpected amount available. (Tompkins and Smith, 1998) Obviously, this causes problems to fulfill required output and thus customer orders.

3 Warehouse Control and Management Systems

Warehouse control and management systems assist in controlling warehouse operations in such a way that the utilization of labor, space, and equipment resources is maximized and customers are kept satisfied, since their requirements are met with a high standard. As warehouse workers, also systems need to be controlled and managed in order to balance people-time with computer-time in most effective manner. Warehouse management systems (WMS) are based on warehousing strategies and different useful tools. WMSs have numerous benefits. In addition to WMSs, there are also programs like electronic data interchange (EDI) that is able to connect business partners and transfer, for example, their inventory level documentation for certain product automatically between the partners' systems. This type of system can unite suppliers, manufacturers, and retailers into a single information sharing entity. Moreover, several software applications available nowadays are even more efficient as they use automatic identification systems and databases linked to them. (Tompkins & Smith, 1998)

3.1 Automatic Identification Systems

There are several automated tools for feeding necessary data into the system as an alternative to manually typing information and identification codes. These methods are called automatic identification (Auto-ID) systems and they were developed for improving and speeding up the overall operations by eliminating unnecessary human interference. Auto-ID systems consist of the following technologies: Optical Character Recognition (OCR), magnetic stripe, voice recognition, bar coding, and RFID. (Tompkins & Smith, 1998)

Since RFID and bar coding are strongly linked to this final thesis report, they are explained in more detail than other Auto-ID technologies. RFID has own part later on in this report and it is dedicated for studying RFID technology in general and its functions and possibilities in warehousing. Bar coding is looked into as potential assisting technology for RFID, since they are a common combination in successful SCM operations.

3.1.1 Optical Character Recognition

OCR is created to read regular handwriting and printed text, but this technology does not intend to encode data. It is most popular among the post office processes. The application is used for reading zip codes from the envelopes, after which they are to be bar coded and identified according to the bar code from there on. This type of procedure diminishes human

errors and the sorting of the mail becomes a great deal faster. (Tompkins & Smith, 1998) Depending of a warehouse and its operations, similar type of OCR application, combined with bar coding, might improve data entry processes, if numerous typed or handwritten documents are still required in most activities.

3.1.2 Magnetic Stripe

Magnetic stripe (mag stripe) technology is widespread and can be found from almost every consumer's wallet in form of credit, ATM, or bonus card. The mag stripe on the back of the card has an encoded ID number, which is employed by the system to get the right account information of the client. As in ATMs or grocery store cashier devices, mag stripe requires contact and a line of sight, otherwise its reading is impossible. Since mag stripe identification is preprogrammed, it cannot be changed without reprogramming the card. Environmental factors may also create challenges to mag stripe because the encoded data may be erased by another card or strong magnetic field. However, mag stripe's strengths are discovered in dirty and greasy environments, the first-read rate is high, and it has medium data density and cost judge against the other Auto-ID technologies. In warehousing, mag stripe is mainly used for labor tracking. (Tompkins & Smith, 1998)

3.1.3 Voice Recognition

Voice recognition belongs to biometric measurement identification systems with finger- and handprinting procedures, and retina (or iris) identification. Nowadays, it is possible to utilize individuals' voice in verifying the speaker and thus trigger an action, for example, 'open door' or 'lock door.' The user needs to talk into a microphone that is connected to a computer. Spoken words are converted into digital signals and the software then completes or discards the verification by using an existing reference pattern in its evaluation process of speech characteristics. (Finkenzeller, 2004) The main advantage of voice recognition is that the operator is able to use both hands while working, since handheld readers or scanners are not obliged. (Tompkins & Smith, 1998) Nonetheless, in the operations of a regular warehouse, which does not require exceptionally high security levels, for instance, voice recognition is not a particularly effective tool.

3.1.4 Bar Coding

Bar coding functions by utilizing parallel dark bars and light spaces to represent alphabetic and numeric characters (Tompkins & Smith, 1998). There are over 200 types of bar-code symbologies in use (Sweeney II, 2005) and thus numerous methods to code and decode data. In today's warehousing and distribution, the two most accepted one-dimensional symbologies are the Code 3 of 9 (Code 39) and the Code 2 of 5 bar codes. However, encoding principles are the same with all symbologies. Light of a scanner is absorbed by dark bars and reflected by light spaces. By "seeing" the difference between these two, a photo sensor generates an electronic signal and the system decodes it. Bar codes can be read without contact, but they require line of sight. Even though, bar codes are often printed on paper and therefore sensitive to the surroundings, the technology has various benefits, such as minimal cost and very high

first-read rate. Data density is limited especially with a regular one-dimensional bar code, but two-dimensional bar code offers an improvement on this factor, since it facilitates saving a larger amount of data in a small space. In distribution operations nowadays, bar coding is the most universal Auto-ID technology used and is here to stay. (Tompkins & Smith, 1998) On a figure below, a bar code that has numeric characters combined with bars is presented.

Figure 2 Bar Code Example (Modified from Sweeney II, 2005, p. 45)

3.1.5 Radio Frequency Identification

Sweeney II states that RFID technology functions by using “a radio frequency (RF) signal to broadcast the data captured and maintained in an RFID chip” (2005, p. 37). An RFID solution makes possible to read programmed data without contact, line of sight, and influence of tag’s direction or position. One can read several tags simultaneously, and depending on the RFID system’s physical infrastructure the reading distance can be over five (5) meters. (Finkenzeller, 2004) According to Sweeney II, this communication distance may even be up to one (1) kilometer (2005). RFID has a major potential in today’s business world. Among other things, it could offer a problem-free locating of inventory in a warehouse, guarantee that shipped products are correctly verified with shipping order and received shipment includes everything ordered without unloading the goods, or avoiding stock-outs of products sold for ensuring customer satisfaction. (Banks et al. 2007) RFID is introduced in more detail in a chapter *4 RFID Technology*.

3.2 WMS Functionality

In most cases, every warehouse executes four basic functions with its products: receiving, storing, picking, and shipping. These tasks also have supporting activities, such as, order entry, order scheduling, storage functionality, and performance reporting. WMS assists these functions by operating more efficiently and more accurately than what is achievable only with labor. Owing to WMS’s order entry and order scheduling, warehouse workers can focus on completing given tasks at an appropriately prioritized order instead of wasting time on planning activities themselves. This will improve the overall performance of the business in form of increased labor productivity because employees’ time is used more competently. (Tompkins & Smith, 1998)

Storage functionality is based on several warehouse management theories. WMS will assist identifying loads that are ready for putaway after receipt records are prepared, suggests fitting

storage locations available while adjusting them according to ABC analysis, tracks each SKU's identification and their storage locations, decreases the amount of physical inventory required, and provides a real-time updates of warehouse data reports. Moreover, performance reporting is probably the most remarkable gain a WMS can offer to a warehouse or resource manager. There are several kinds of warehouse reports that aid in managing operations. A WMS can develop reports out of customer service, both inventory and order accuracy, space utilization, labor productivity, and item activity, just to name a few. (Tompkins & Smith, 1998)

3.2.1 WMS's Justifications

Tompkins and Smith have drawn attention to the fact that "An intelligent warehouse integrates computer systems, material handling equipment, storage equipment, and people into a single cohesive working unit. The quality of information is vastly improved" (1998, p.703). There are numerous benefits of a WMS, which are introduced in a figure below.

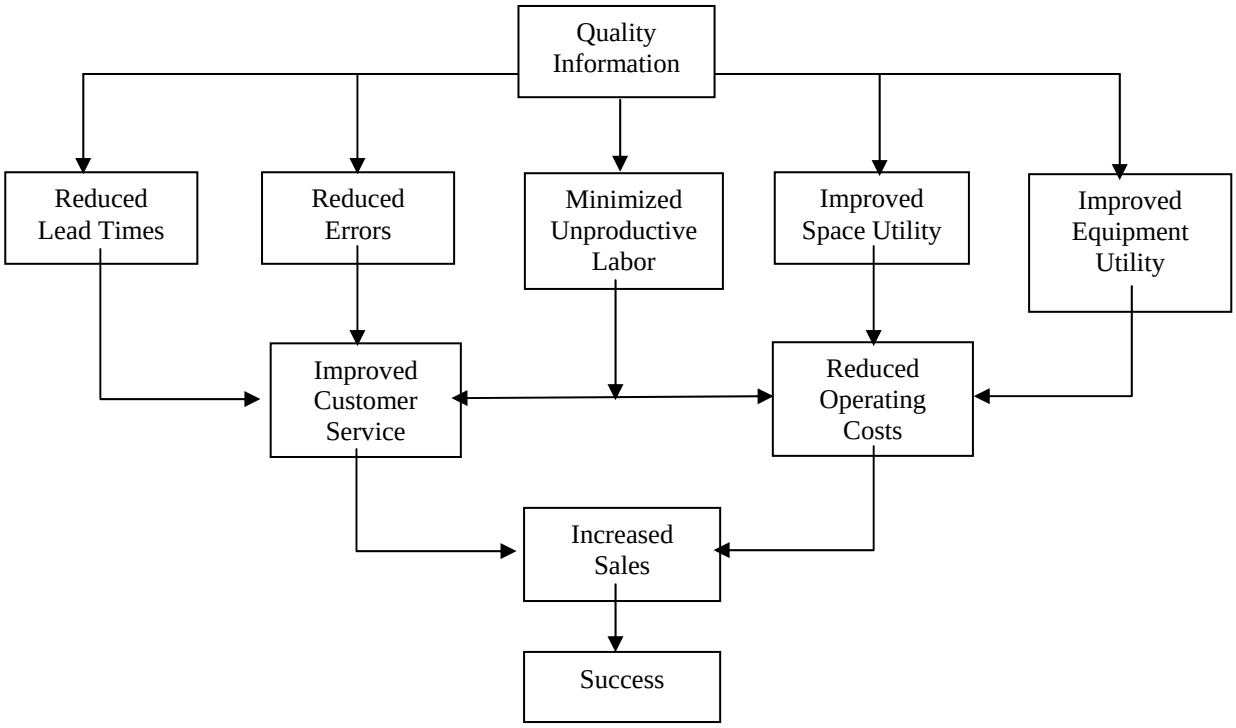

Figure 3: Benefits of a Warehouse Management System (Tompkins & Smith, 1998, p. 704)

The chain of gains begins after installing an appropriate WMS for the needs of a company, which then improves the quality of information. Accurate data results in diminished human errors, increased productive labor and shortened lead times because operations can be based on precise, real-time information. After accomplishing these, it is logical to conclude that customer service is progressing as well. If customers are pleased with the corporation and its products or services, they will naturally bring in more money for the firm in form of better

sales. (Tompkins & Smith, 1998) Often satisfied clients also attract more customers for the company, which increases sales even further.

The more accurate information achieved by implementing a WMS, the more assistance it offers for increasing space and equipment utility. These lead into decreased operating costs, which offer a possibility to better meet customers' needs or reduce prices and would therefore result in increased sales. As a conclusion the benefits of a proper WMS leads into boosted sale figures and success for the business. (Tompkins & Smith, 1998)

Because WMS provides accurate records of the current inventory, the company is able to avoid remarkable overheads caused by inaccurate inventory, such as lost sales, backorders, both excessive inventory and safety stock, missed schedules, low labor productivity, both unnecessary expediting and freight costs, and high obsolescence. Therefore, one can draw a conclusion that the outcome of precise inventory records has a major effect not only regarding to the warehouse operations, but to the total business process as well. Additionally, this kind of impact will affect to the company's customer service level along with improved customer satisfaction. Last but not least, one should not ignore the justification that implementing a WMS brings to the warehouse management. Because of increased visibility to data and operations a warehouse manager is able to control and run operations more resourcefully. Moreover, this results into more effective warehouse and thus improves the overall business. (Tompkins & Smith, 1998)

3.2.2 WMS's Challenges

Even though WMS has several benefits and advantages, its implementation is not always a problem free success story. One has to consider many aspects of the company's processes and warehouse operations before deciding a suitable software package and choosing a specific vendor. A warehouse manager has a central role in the implementation project and should have a throughout understanding regarding to warehouse software and common drawbacks related to the implementation process. (Tompkins & Smith, 1998)

A WMS is an integrated package, which objective is to manage the operations of the warehouse (Tompkins & Smith, 1998). Based on this fact, Tompkins and Smith suggest that its components "consist of RF communication devices, dedicated localized computer hardware, automatic identification equipment, and the necessary applications software" (1998, p. 708). However, there are WMSs that are simpler and do not require all of the above mentioned elements, for example, employing RFID technology is a value-added function and not mandatory for all companies. Karhunen et al. 2004 states that WMSs operate based on different databases, and programs that utilize these databases. WMSs may also be connected to the company's general enterprise resource planning (ERP) system or other firmware. (Karhunen et al. 2004)

In the beginning of an implementation process, one has to identify the needs company has and which can be fulfilled with a proper WMS. It is only after classifying all the requirements that WMS vendors should be contacted. One ought to also schedule the project with realistic expectations, make sure to test the application several times before launching, and rely on

own knowledge for the company's warehouse operations. These actions help to prevent numerous pitfalls that may be connected to the project. (Tompkins & Smith, 1998)

4 RFID Technology

"RFID is a very valuable business and technology tool" (Sweeney II, 2005, p. 9). As mentioned earlier, its objective is to detect and recognize a small reprogrammed tag by utilizing radio waves. Identification and data collection is possible from a several meters' distance. (Rinta-Runsala & Tallgren, 2004) Tags are often affixed on items, which need to be identified or located. This procedure requires four fundamental components: a transponder (tag), host computer (with reader interface layer or middleware), and a transceiver (reader), which has an antenna (Sweeney II, 2005). Certain physical infrastructures of RFID facilitate also reprogramming of the tags with a reader. RFID offers numerous application possibilities on a wide range of areas and industries, however, the utilization in the present day is concentrated on SCM, tracking of objects, and ticketing purposes. (Rinta-Runsala & Tallgren, 2004) Regardless of the challenges RFID still faces, it is extremely promising technology and in the future it might even replace other automatic identification systems, such as bar coding (Sweeney II, 2005). Below is a figure of passive RFID system's components.

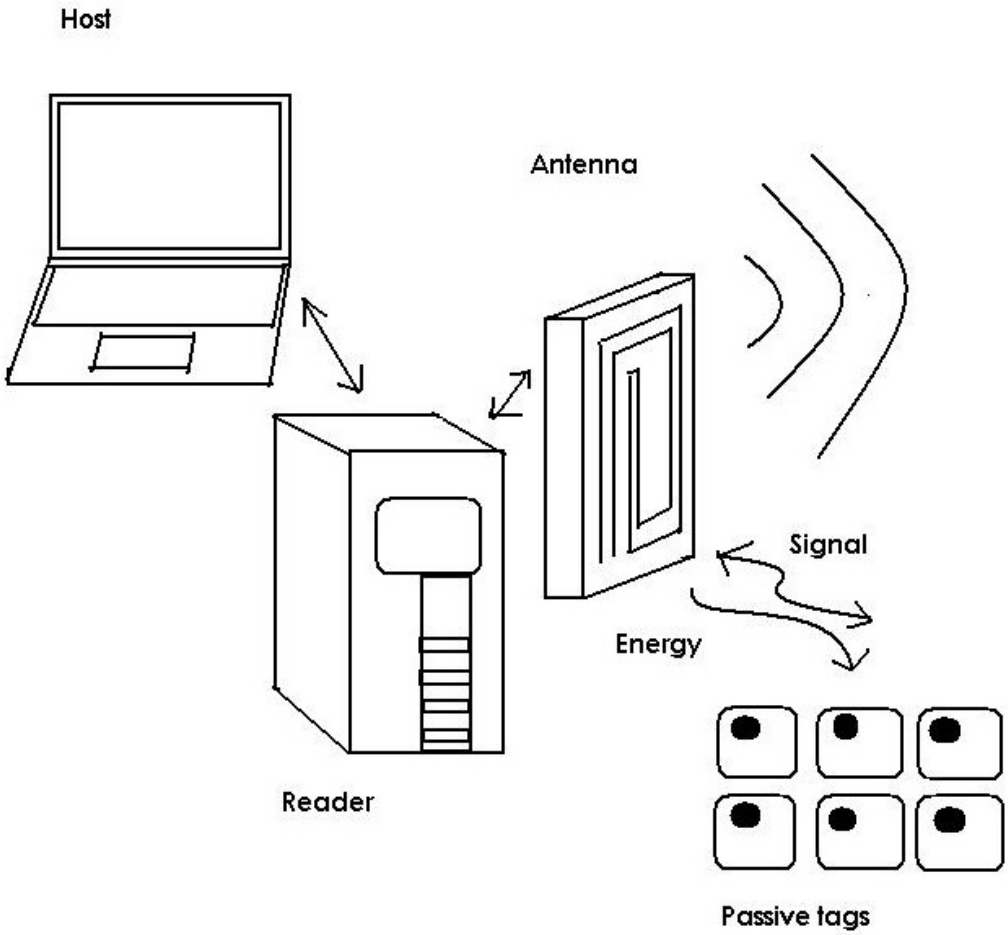

Figure 4 Components of a Basic RFID system (Modified from Sweeney II, 2005, p. 38)

4.1 Infrastructure and RFID Network

There are three different main categories of tags: active, passive, and semi-passive. These transponders operate in different radio frequencies, depending on the country of origin and their structure. The physics of RFID are simplest in a passive RFID system. The system's operating procedure may be described according to the following explanation. Firstly, an antenna and transceiver generate a radio frequency field. The tag is activated as it reaches the RF field. (Either the object that has the tag affixed is moved, or the reader is moved to the proximity of the tag.) Secondly, as a result it processes the signal received and transmits an RF wave, which is programmed in its computer chip (or memory area) and uniquely identifies the tag. Thirdly, the antenna detects the response. Fourthly, the reader sends this data to the middleware system in a host computer. Lastly, after processing, middleware forwards the data to other systems that are meant to have the information. (Sweeney II, 2005)

4.1.1 Tags' Characteristics and Types

As mentioned earlier, the main types of RFID tags are active, passive, and semi-passive. In addition, there are multiple classes and generations of tags, such as Class 0, Class 1, and Gen 1, Gen 2, which are classified according to their capability of data modification. Transceivers and transponders have antennas, since they are both radio devices in their own way. As the size of the tags is considerably small, their antennas are only a few centimeters long or even less. The antenna is connected to tag's integrated circuit (IC), also known as chip or microchip. Tag's main function is to absorb a signal it receives from the reader and send out a slightly modified signal, which can then be read by a transceiver. (Sweeney II, 2005)

The most simplified tags have only a unique identification code, such as manufacturer's reprogrammed serial number or an electronic product code (EPC) (Rinta-Runsala & Tallgren, 2005). The EPC is a comparable standardization for RFID than a universal product code (UPC) is for bar codes. They are both type of standards that are used to identify products by utilizing the Auto ID systems. The structure of an EPC code is more sophisticated than UPC's, but they both have their advantages and disadvantages. (Sweeney II, 2005) A common character between the previously mentioned standards is the fact that, while verifying the labeled products, one has to have an access to a certain database, which connects the identifiers with data related to it. Otherwise, they are only meaningless codes. (Ahson & Ilayas, 2008). However, all of the tags do not carry an EPC, instead they may have memory capacity for several hundreds of characters and it is also possible to rewrite or insert data. One can reprogram and add diverse information about the tagged product, such as handling instructions, or a link to an Internet page or other external database. (Rinta-Runsala & Tallgren, 2005)

4.1.1.1 Active

Active tags have their own power supply and are able to broadcast a RF signal constantly, but some of them are manufactured in a way that a reader is required to activate them. Because of the battery power, an active tag is able to run the microchip's circuitry and thus broadcast the signal. The most advanced active tags can communicate as far as one (1) kilometer's distance. As these transponders are larger than passive or semi-passive tags, their memory capacity is greater as well. For instance, as opposed to only carrying a programmed serial number in them, active tags may have a vast amount of information, such as the full contents of a specific container, its destination, and origin. This type of data storing method enables instantaneous information retrieval, since data is available even without an Internet connection. Because of their outstanding benefits, active tags are also the most expensive ones to purchase, if compared to other RFID transponders. Nonetheless, for several applications, they have demonstrated a considerable return on investment (ROI). (Sweeney II, 2005)

In a SCM and logistics context, Sweeney II has drawn attention to the fact that "... active tags used in the railroad and shipping industries can integrate with an onboard Global Positioning System (GPS), cellular communication network, or satellite system to give exact whereabouts and provide constant communication back to a tracking program" (2005, p. 38). These types of highly sophisticated technologies can be used to track any object transported, for example case, pallet, or container, but also living beings, such as humans and animals. Privacy concerns, as a result of utilizing RFID in a retail industry, have raised some resistance among consumers (Rinta-Runsala & Tallgren, 2004).

4.1.1.2 Passive

Passive tags do not have their own battery; instead they transmit energy from the electromagnetic field created by the signal from the reader. The tag responds to the transceiver's RF wave with its own information. This is called backscattering, since the tag 'scatters' back the signal. Passive tags are the most inexpensive transponders, since they only have a small amount of data programmed into their memory, in many cases it is only their unique serial number. (Sweeney II, 2005)

4.1.1.3 Semi-Passive

Semi-passive tags have a power source, which communicate the chip's circuitry as active tags function. On the other hand, as semi-passive tags' name implies, they also derive the energy of a transceiver, as passive transponders operate, in order to beacon their signal. Because of the battery they are larger and less cost efficient than passive tags, however, their communication ranges are greater. (Sweeney II, 2005)

4.1.2 Frequencies: LF, HF, UHF, Microwave

Generally the most common frequencies of RFID systems are unlicensed low-frequency (LF), high-frequency (HF), and ultrahigh-frequency (UHF), but in some applications also microwave is used. In Europe, operation frequencies are 125-134 kHz (LF), 13.56 MHz (HF), and 865.6-867.6 MHz (UHF). UHF differs depending on the geographical location and is slightly diverse in the USA, Australia, Japan, and Europe. Furthermore, the power levels vary as well. Radio waves do not perform similarly at different frequencies. The wavelength shortens as the frequency enhances. Based on this fact, the smaller the tag's antenna, the higher the used frequency band should be, with the intention that the tag could be read from a greater distance. (Sweeney II, 2005) In a figure below, two HF passive tags are illustrated.

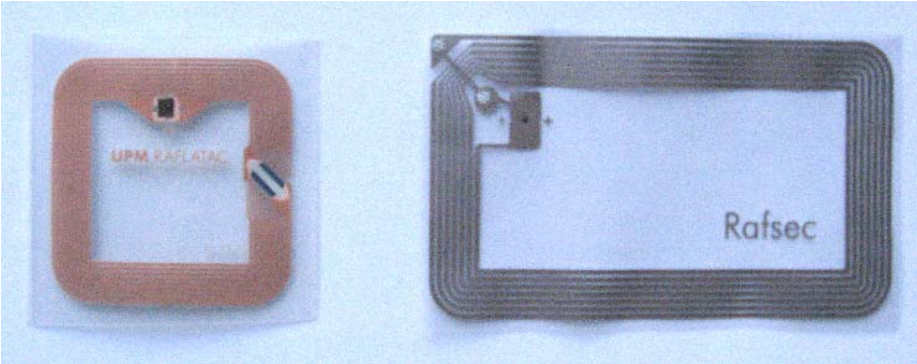

Figure 5 Examples of UPM Raflatac's Passive HF Tags

Since the aim of this paper is to study and discuss the possibilities of RFID in warehousing, one should point out that a passive UHF tag can be read several or even a dozen meters (40 feet) and more apart. The most typical applications of passive UHF tags are SC, asset management, and access control for vehicles. In contrast, direct contact on liquids and metal causes problems to this RF as its signal is somewhat easily absorbed by liquid and reflected by metal. (Sweeney II, 2005)

4.1.3 Reader's Operation Process

Typically a transceiver has one to four antennas connected to it. Reader's function is to make an antenna to create a suitable RF field and thus send out reader's signals. An RF field may envelop an area from approximately 2.5 centimeters (1 inch) to circa 30 meters (100 feet) or more. With its antenna(s) the reader receives tag's signal, decodes it, and then transmits the data to a host computer system. There are readers that are able to synchronize tag with a transceiver, activate the tag, interrogate its contents, or even rewrite and modify tag's information. (Sweeney II, 2005)

In more detail, the operation process of a reader can be described as follows. Firstly, a reader uses an external power supply to transmit the radio wave. Possible power sources are a battery or a wall outlet, for example. Secondly, the flow of electricity is controlled in the interior of reader distinctively by a digital signal processor (DSP) chip and a regular processor, while aiming to modulate the frequency and the amplitude of the wave the transceiver produces. (In

this context, amplitude is a distance of an electromagnetic wave's middle part to the top or bottom.) Thirdly, a complex circuitry anchored by the DSP is controlling the flow of electricity, which is forwarded via coax cable to an antenna(s). Fourthly, the antenna(s) transmits an RF wave, which has reader's data in the signal. The process is called modulation and basically it implies a process of transmitting information by means of slightly varying the electronic signal to facilitate encoding and processing of a vast amount of data. Fifthly, the reader transfers the information received from a tag via the antenna(s) back to its inner components. These electronics then decode the data into usable information. (Sweeney II, 2005)

4.1.4 Readers

There are three (3) different reader options: portal, truck-mounted, and handheld. However, whether fixed or mobile, all of the readers require a fixed reference point, which is used to associate an activity to a certain location, where it takes place. This is possible by scanning both the tag in an object (case, pallet, or item) that is moved, and the tag in a reference point. (Ahson & Ilyas, 2008)

4.1.4.1 Portal

An RFID portal is a type of fixed reader that can be installed, for instance, at the dock doors or around a conveyor belt. If the RFID portal is utilized in a dock door area, the reader's antennas are positioned on each side of the door and the height is decided according to the products' movement elevation. Antennas need to be protected from the goods transported and other external factors by placing them behind bollards. The fixed reader allows received goods' tags to be automatically scanned. However, it might miss some case level tags and necessitates a bigger investment than other two transceiver alternatives. (Ahson & Ilyas, 2008)

4.1.4.2 Truck-Mounted

A truck-mounted reader is a mobile reader, which is mounted on the forklift or pallet truck. Truck-mounted readers offer a drastically greater visibility of stored products than a portal reader, since the equipment they are mounted on handles the moving of goods. At the same time, it scans the SKUs it carries and this data is saved in the RFID system and can be looked into, while tracking products' and their whereabouts. Because a mobile reader is more inexpensive than an RFID portal, expenditures of purchasing and installing the reader could be reduced. This would affect also to the total cost of implementing an RFID system. (Ahson & Ilyas, 2008)

4.1.4.3 Handheld

The third type of reader is a handheld reader. Although, this is also a mobile reader, it needs to be operated manually and carried by a warehouse worker. In a way this is a "semiautomated" solution, and therefore may not be as efficient in most applications as two other reader types. The handheld transceiver consists of a strong exterior and has a keyboard and a monitor. These readers face some challenges also because of the limited battery power supply. As it may not be recommended as its own, to be used in assisting and improving warehousing operations, a handheld transceiver might be an excellent way to complement the other readers because of its small size and dexterity. (Ahson & Ilyas, 2008)

4.1.5 Antennas

Directivity, gain, and polarization are the most important electrical characteristics of an RFID reader's antenna and need to be taken under consideration, while choosing an ideal antenna type for one's RFID application. (Sweeney II, 2005) (Lehto, 2006) Few other antenna parameters are radiation efficiency, and driving point impedance, but these properties are taken care of by the manufacturer. Naturally, manufacturers' goal is to provide antennas, which have correctly designed transmitters, and therefore also these factors are carefully based to the radio industry standards. When it comes to readers' antennas, the company implementing an RFID system needs to focus on making proper decisions regarding to directivity, gain, and polarization. (Sweeney II, 2005) One is able to conclude that there are numerous models of basic antenna, with several features, which can all be employed in RFID readers depending on the application.

4.1.5.1 Linear and Circular Polarization

Most likely, the biggest functional difference between different models is whether an antenna is linear or circular polarized. Polarization can be described as the orientation of the electromagnetic wave's radiation generated by an antenna. Linear polarized antenna is called dipole (or "stick") and it transmits the wave in a line. (Dipole name implies to the fact that the antenna has two poles on top of each other.) On the other hand, circular polarized helix (or helical) antenna generates an RF signal that spins. (Lehto, 2006) (Sweeney II, 2005) Roughly put, a helix antenna is best suited for applications where the tags may be in different positions and in many places, whereas, dipole antennas are most suitable ones for tags that are scanned in a certain orientation known beforehand, for instance on shelves. The former has the ability to read tags further and the latter can scan them in a wider circle. (Ahson & Ilyas, 2008)

4.1.5.2 Directivity and Gain

In the case of RFID, one needs to aim at the highest directivity, and best gain. Directivity measures the point-to-point communication ability of an antenna. Since RFID reader's interrogation zone, the area it affects and activates the tags within, is preferably reduced to scan only the tags within its own zone; one has to try to target the RF signal to this zone and

not to broadcast it allover the facility, as a typical FM (frequency modulation) radio would do with sound waves. Otherwise, the result is receiving also unwanted phantom reads or ghost reads which might interrupt the middleware's successful operation or result in incorrect scans. Gain is a slightly similar kind of parameter as directivity. If one succeeds in targeting the signal effectively and thus the highest directivity is reached, gain measures the strength of this signal. Best gain is accomplished, when a reader antenna can communicate with a strong signal, a tag is promptly able to backscatter an almost equally strong signal, and/or the reader antenna is able to detect also the weak signals of tags. (Sweeney II, 2005)

4.1.6 Host Computer

In order to be able to use middleware or other software systems, one needs a computer. This hardware unit acts as a platform for running the required applications, such as middleware, WMS, and ERP. The efficiency requirements of the middleware and the database server(s) depend on the infrastructure of the RFID system, the amount of readers in use, and the type and quantity of tags involved. In addition, the storing capacity and turnover of the warehouse have an effect as well. (Sweeney II, 2005). For example, Wal-Mart as a major American retailer has significantly higher requirements for the RFID system's software and hardware than a small store would have. It is also important to decide beforehand, if an Internet access or systems, such as EDI, are mandatory parts of the RFID application for the firm's SCM (Sweeney II, 2005). One should consider all the specifications of the required hardware on a case-by-case basis, and consult also the chosen RFID vendor(s) in order to achieve an optimal solution for the company's specific needs.

4.1.7 Middleware: Software and WMS

Middleware software has many names, for example, reader interface layer, EPC information server (electronic product code) and Savant (Sweeney II, 2005). Middleware is probably the most descriptive name, since it serves its purpose to imply that the middleware is developed to connect the RFID architecture with organization's other fundamental software systems, such as warehouse management system (WMS), enterprise resource planning (ERP) suite, or inventory management packages. (Ahson & Ilyas, 2008) Basically, middleware is a data-collection component, which links together company's RFID readers, antennas, tags, and the information they gather or share. Because of this software it is possible to unite the basic elements of an RFID system among one firm into a local network which interacts within itself to exchange data by utilizing RFID technology. These can be further connected into a global network with some other local networks. It is possible to link RFID systems into applications that provide vast amount of information about the products and can be accessed globally. (Sweeney II, 2005)

Reader and device management, data management, application integration, and partner integration are elements of an RFID middleware. These facilitate users to perform configuring, monitoring, deploying, and command issuing to transceivers, as well as, filtering and routing of gathered data to the client's host software systems. Furthermore, it is possible to integrate all of the data into company's other systems, which then are able to further utilize

it in organization's different divisions. If the company has vital business partners, the middleware may even offer collaborative solutions, which can make basic business operations more efficient. (Sweeney II, 2005)

On one hand, the middleware is the brain of an RFID system, since it manages and coordinates its operation. In a way, this reader interface layer does the thinking for the whole application. Readers, tags, and antennas are mainly used for collecting, carrying, and signaling the data. Middleware is the component that cleans and filters the information, and also decodes it if necessary, in order to make it usable for the other systems, such as the Receiving System, WMS, or ERP system. (Ahson & Ilyas, 2008)

4.1.8 Feedback Mechanisms

Even though feedback mechanisms are rarely mentioned, while discussing the basic RFID elements, they make a notable difference in some applications (Ahson & Ilyas, 2008). Ahson and Ilyas claim that "... they are required in order to provide a signal capable of being interpreted by a human that will indicate an error in the information process" (2008, p. 304). The most common feedback mechanisms are light stacks, audible devices, and monitors. After reading a tag, a horn in a handheld reader can 'honk,' for instance, and present tag's information on a handheld monitor screen. Thus warehouse worker may proceed accordingly. (Ahson & Ilyas, 2008)

4.2 RFID's Challenges

The first RFID application took place in the World War II in a form of a type of radar (radio detection and ranging) system, which was used to recognize the invading army's aircrafts or naval ships apart from the own army's returning ones. (Shepard, 2005) Although RFID technology and its applications have greatly improved since then, it is difficult to meet all of the requirements expected and hoped for in today's complex applications. The most significant challenges are to create harmonized global standards, and further develop the performance of an RFID system. Issues include, but are not limited to, frequency variations especially with UHF in different geographical areas, and required improvements in scanning distance and time. In addition, there are consumers, who find it disturbing that because of the RFID technology, they could be tracked based on the purchased groceries or other products. (Rinta-Runsala & Tallgren, 2004)

In some countries, UHF band is already partly in use, for example, by mobile phones. Naturally it has delayed the development of a single unified international standard frequency range, and hence postponed RFID technology's spreading globally. There have also been differences in allowed power levels based on geographical location, which has affected in read distances. Problems, such as tag collision or reader collision, have already been looked into in a manner that the read rates have been improved. (Rinta-Runsala & Tallgren, 2004) RFID vendors have also designed several tags for special conditions and the material of a tagged item is getting to be less important. The RFID Research Center at the University of Arkansas has developed some methods to improve the read rates of hard-to-read products as

well. Earlier it was not possible to reliably scan products that had metal parts or included liquid. Nowadays, these problems can be overcome. (Adams & Turri, 2008)

5 RFID's Potential in Warehousing (and Logistics)

RFID technology can be used to assist and improve processes involved in numerous industries, such as automotive, cattle ranching, health care, manufacturing, marine terminal operation, the military, warehousing and distribution systems, retailing, and transportation (Banks et al., 2007). This paper discusses RFID's potential especially in warehousing, but to some extent also in logistics, since these concepts are more or less linked together.

RFID technology has lately become a popular tool in developing operations of SCM, which covers warehousing operations as well. There are several benefits, which adopting RFID with a suitable WMS can offer for this specific field. Banks et al. (2007, p. 323) states that "In addition to more effective warehouse management and product tracking; the deployment of an RFID-enabled WMS can eliminate inaccurate order sequencing and incorrect shipment and can increase the overall operation efficiency and service level" (p. 323). It is quite obvious that these kinds of improvements play an important role on today's market and might help companies to create a competitive advantage. In order to stay on top of business, firms should look into the possibility of implementing RFID and the chances it may present.

5.1 RFID's Advantages in Warehousing

RFID technology's benefits, as well as constraints, depend on the level of RFID employment. Roughly the level can be categorized according to the chosen tagging method: item, case, or pallet. (Banks et al. 2007) Each RFID implementation should be considered carefully beforehand, while deciding the correct approach regarding to the tags to be used, objects in which they are to be attached and so on. However, one needs to keep in mind the operations of the specific warehouse, distribution center (DC) and/or SC in order to achieve the most advantageous gains and be able to avoid most of the disadvantages.

While exploring the benefits of RFID employment in warehousing, Banks et al. (2007) suggests that "... RFID technology can facilitate the automation of all manual processes" (p. 364). This type of statement should draw at least Human Resources manager's attention, since it is quite clear that the more automation is involved in company's processes, the less labor is required. Naturally, nothing is as black and white, but the idea of completely automated warehouse or DC owing to RFID is fascinating. Reference to Banks et al. (2007) also reveals the facts that executing RFID technology into one's warehouse operations will, among other things, lead into reduced labor costs, and improvements in both data accuracy and in overall throughput.

Tompkins & Smith (1998) have expressed a similar type of view and argue that real-time RF communications offer noteworthy gains, such as information availability, labor pacing, and material tracking. Information availability is based on the real-time status updates of receipts, manufacturing requests, and customer orders. Management is able to maximize performance by utilizing warehouse's resources according to these system records. Labor pacing is

obtained as the system communicates with operators in real-time and optimizes each command by considering different warehouse workers. Thus operator does not have to return to central location after completing each task to receive new instructions. Material tracking is possible by verifying each transaction concerning material locations. Since status updates are immediate and available in the system, one is able to detect and solve location errors. In addition, RF communications assists in informing empty locations within the warehouse. (Tompkins & Smith, 1998) It could be concluded that "... RFID technology is gradually becoming a strategic tool in warehousing to defeat competitors by improving the customer service level while keeping the cost of operation to a minimum" (Banks et al. 2007, p. 363).

5.2 Warehouse Activities and RFID Applications

Warehouse operations are related to the movement of goods, handling paperwork, and other supportive activities. As a WMS also an RFID system is meant to assist and speed up these operations, and reduce the costs involved. RFID is highly beneficial application in inventory control and stock location management as well. When integrated with the WMS, it helps to avoid labor-intensive work, such as performing physical inventory or recording manually SKU locations. It is also possible to monitor the movement and real-time locations of the trucks and forklifts in the warehouse, which together with a WMS assists in managing equipments and SKUs. In addition, RFID has potential in warehouse environments that have security control or theft problems. The aim of applying RFID technology is to achieve an efficiently operating warehouse with a constant visibility to products stored. (Banks et al. 2007)

5.2.1 Receiving

Firstly, the goods are transported to the warehouse from external sources. Thus they are received and checked against the Bill of Lading (B/L), packing list, or waybill, which are all types of shipping documents revealing the contents of the received goods and other necessary information. Depending on the typical warehouse practices of the specific company, the goods may be reloaded, divided up, or assigned into SKUs for identification purposes within the warehouse. Manual receiving process is time-consuming and has a high potential for human errors. Bar coding is a good tool for verifying the products, but it does not change the fact that the goods are to be scanned individually by the operators and they have to be rotated or moved in the right angle as well, since bar code reader requires line-of-sight in order to function correctly. Even with bar coding, receiving process requires a lot of work and if there happens to be several products in multiple quantities, the work load is increased. (Banks et al. 2007)

On the other hand, if the goods received are in advance affixed with RFID tags, they can be scanned and identified nearly instantaneously. Operators do not have to unload pallets or cases, data of the goods will be transferred into the information system for confirmation, and warehouse workers receive proceeding instructions from the system, which also informs if there are damaged goods or special handling requirements. An RFID system can also handle various loads at the same time and the orientation of the goods is irrelevant, since RFID does not require line-of-sight and is able to scan tags even through a wall. There is no need to retag

the goods with SKU number, since it can be programmed into the tags. RFID offers several benefits even during the receiving process alone. (Banks et al. 2007)

5.2.2 Cross-Docking

Cross-docking is not one of the main warehousing activities; nevertheless, it is a distribution strategy that coordinates and forwards received goods instead of storing them. It is based on a rapid turnover and continuous distribution between suppliers, a company, and end users. Since products are not to be stored, inventory costs, and customer lead times are minimized. By employing RFID, one is able to make the function of cross-docking faster and more accurate; as the system scans the goods received and informs the operators of the goods that need to be cross-docked and not stored. (Banks et al. 2007)

5.2.3 Putaway

As previously mentioned in a chapter *4.1.4 Readers*; one of the RFID reader types can be attached onto a truck lift or forklift. Thus the transceiver scans the tags of the SKUs as moving them within the warehouse. Furthermore, putaway activity is tremendously improved by integrating the data obtained from the tags with the WMS in use. This procedure makes it possible for the system to provide forklift operator instructions of the most suitable storage location for the goods. Information is received to the monitor (or terminal) installed on the forklift, which eliminates useless roundtrips with the equipment and increases labor productivity. As a result, RFID is a valuable tool in putaway activity. (Banks et al. 2007)

5.2.4 Picking and Shipping

Picking process is triggered by a new customer order. This activity requires an operator to select right quantity of correct items according to the order, which can thus be forwarded to the shipping dock. Deliveries aim to be 100 percent accurate in order to guarantee customer satisfaction. (Banks et al. 2007) However, human errors are common especially because of the today's trend of demanding nature of complex customer orders with several products in numerous quantities, which are often required to be delivered JIT (just-in-time). JIT is one of operations management's methods and as its term suggests, its basic goal is to produce and deliver products or services precisely when demanded with a tight time frame. This approach minimizes inventory and eliminates waste especially from manufacturer's or retailer's point of view. (Slack et al. 2004)

The key objective of a shipper can be described according to the following statement: "... to deliver the right product to the customers in correct quantities, free of damage, on time, with accurate shipping documentation" (Banks et al. 2007, p. 367). If any part of this goal is not successfully met, consequences may include claims, returns, and/or inaccurate inventory. Furthermore, client companies or their customers are rarely pleased, if their consignment is delayed, has wrong contents, or arrives with damaged goods. (Banks et al. 2007)

Since case-level or even item-level picking has formed to be a rule rather than an exception, it is obvious that time spent and amount of errors occurred has increased in picking activity. Inaccurate shipments or deliveries are undesired and careful verification of each order to be shipped enhances time and labor costs involved. By applying RFID technology, one is able to improve picking and shipping by quickening the procedures, eliminating human errors, and confirming the correct products ready-to-be shipped. This reduces manual work involved, frees up staging space, and improves the throughput of the warehouse (Banks et al. 2007)

5.3 RFID's Challenges in Warehousing

Even though RFID technology has overwhelming benefits in warehouse operations and is easily seen as a major opportunity for the company, there are still potential downsides involved. One of them is the cost of implementing an RFID system. Because the technology is continuously improving, tag prices are decreasing, however, there are other expenditures entailed, such as purchasing readers. In order to receive ROI soon after implementation, careful planning regarding the hardware components and process consideration is strongly recommended. Often the tangible benefits of an RFID system do not appear immediately, but will emerge overtime. (Banks et al. 2007) In some cases it is required to buy at least one new host computer, upgrade software systems and/or acquire an Internet connection, which obviously result in additional costs. These kinds of procedures may be required, since the amount of information that needs to be processed by software systems on a daily basis is drastically increased after adopting RFID in comparison to bar coding technology for instance (Banks et al. 2007). Jones and Chung have expressed a similar type of view and drawn attention to the fact that an RFID system may overpower even an extremely capable information system by its major bandwidth requirements that may occur (2008).

Other drawbacks include potential difficulties with the facility and its layout from the perspective of RFID, additional devices in the warehouse functioning along with readers and tags and their electromagnetic interference to RF signals, potential insufficiency of only one reader resulting to multiple transceivers and thus numerous simultaneous scans, which need to be filtered. As in most of the SCs it is too risky to rely on a single supplier, similarly it could be too precarious to rely on only one RFID vendor. (Banks et al. 2007) This is the case especially, if the RFID implementer company cannot complete its business processes without certain type of tags, or supplier companies business partners mandates them to use tags in every pallet, case and/or item that is to be sold for them. Some of the companies in this category, which actually have this type of power over their suppliers; are Wal-Mart, U.S. Department of Defense (DoD), Target, Albertsons, and Best Buy in the USA, as well as Metro AG and Tesco in Europe. (Sweeney II, 2005)

6 Warehouse Management in VEK

VEK has warehouses in two separate locations. Mainly the warehouse in Hyrylä, Tuusula is meant for storing moving goods of people who have a longer employment abroad. On the other hand, warehouse in Malmi, Helsinki is focused on storing goods for example a year per move. However, it is impossible to know how long certain wooden boxes have remained in

Malmi, if it is not checked from the warehouse records. The Resource Manager of VEK, Mr. Sami Kuosmanen supervises the warehouse operations in both locations, and gave an estimation of one to two years storage time per customer. In addition to the storing space indoors, there are also few containers on the warehouse yard in Malmi for seasonal storing only during the summer time. This practice frees up the space inside the warehouse during the busiest season of business and lessens the amount of handling required. Unnecessary moving of objects always adds risks of causing damage to them, for that reason, it is beneficial to eliminate pointless unloading and loading whenever it is possible.

This final thesis concentrates primarily on improving warehouse management in Malmi warehouse with an emphasis in RFID technology. Currently there are a number of issues regarding VEK's warehouse management, which also require attention and are linked to a successful implementation of RFID. These matters have to be considered because they would affect the functionality of RFID and are a huge bottleneck at the moment. These predicaments include, among other things, a lack of WMS, not having up-to-date data of stored wooden boxes and their whereabouts, along with difficulty to discover is the capacity of warehouse fully utilized.

6.1 VEK's Business Process in International Moves

Normally the moving process abroad begins with a site assessment. VEK is contacted by a customer and an appointment for consulting is agreed on. An employee from VEK will meet the customer in their residence, estimate the amount of household goods and movers needed after which prepares an offer. If the client company has an annual contract, there is no need to make a separate offer.

After the evaluation a freight forwarder will plan work instructions for packing and marking the goods according to the country of destination. Required documentation is prepared as well and sea and/or air transportation is scheduled and booked. However, moving goods which will remain in Finland do not need any kind of customs clearance and a packing list and a warehouse sheet is made of them for transporting and storing purposes.

Moves last from two to three days. If an apartment is 80 square meters or larger, it often takes three days. During the first day movers arrive with a van and begin packing property. On second or third day of the move, movers come with pick-up truck(s) and load crates and furniture for transportation. Goods are then transported to the warehouses for storing and/or waiting to be shipped to the destination country.

6.1.1 A Need for Efficient Computer System

Currently, warehouse management in VEK is supervised via computer with two folders of Microsoft Excel sheets named after each customer. These warehouse sheets are saved and divided according to their status into goods, which are stored in warehouse (file named Warehouse X) and household goods, which will be shipped to the temporary apartment in the country of destination and stored only for a week or so before transportation (file named Import Export).

Invoicing of client companies is conducted with eTrans system, which is used also for freight forwarding operations. Before preparing sales invoice, one needs to feed into the system all the required information of the move and create a project reference in order to be able to manage the data efficiently. The reference number is also important prior to filing documentation for each move. One can search data of a particular move with the letter-number code of the wooden box(es), date, customer number, or a project reference. Resource Manager Mr. Kuosmanen is hoping to lessen the amount of manual work involved, while handling invoicing and also to be able to have a warehouse management system, which would be more reliable with invoicing. eTrans does not keep track of moving projects or their invoicing status and this has caused some nuisance and puzzlement previously.

eTrans is in use within the whole company, but has caused dissatisfaction also in other branch offices. Victor Ek Group is presently in quest of more suitable software and has done some research and organized meetings for choosing a proper system. One can say, it is timely to define, if the implementation of RFID would be a possibility for VEK's warehouses, since RFID requires an up-to-date software, which needs to be considered while choosing an appropriate WMS.

6.1.2 Handling Moving Goods

During the move personal effects are packed into cardboard and/or plastic boxes. If object is strangely shaped and/or excessively large, for example furniture of some sort, it may be packed into metal roller cage, pallet, wooden box, or on shelf. If storing time is short, roller cages are preferred, since goods packed inside them are vulnerable for dust and other harmful external factors. Crates are named according to the room they were in and are numbered after their packing order, for instance, box 1, kitchen; box 2, living room; box 3, bedroom and so on. Also their content is marked roughly on top of them. In the pictures below, one can see VEK's cardboard moving boxes and wooden storage boxes.

Photo 1: Cardboard Moving Boxes
(Victor Ek's homepage, 2008)

Photo 2: Wooden Storage Boxes
(Victor Ek's homepage, 2008)

Packing list is made for every move performed. It is a manually written list and consists mainly of the information of what kind of household goods belong to the each client. However, it does not offer highly specific descriptions and it would be difficult to find a particular object from crates if needed. Often the estimated value of household goods is also mentioned, since it may be needed for insurance purposes.

After transporting crates from customer's residence to warehouse area, they are loaded into wooden boxes with furniture that fits inside. The volume of a wooden box is approximately seven square meters; the width is 1.4 meters, the length 2.25 meters, and the height 2.25 meters. The mover who brings the household goods discusses with a warehouse worker, who then prepares a warehouse sheet of the contents with Excel and adds it in a file named Warehouse X, which is sorted in alphabetical order after the customer's name. The sheet contains only rather general information, such as the name of the client company and the customer, the address of the residence, the place of delivery (warehouse in Malmi or Hyrylä), a project reference, the number of the wooden box(es), a customer number, a moving date, the code of the truck that was used for the delivery, the type of goods, the volume of goods, their insurance value, and the amount of items and the title letter(s), which approximately informs the storing row of the box(es) inside the warehouse.

Inside the Malmi warehouse the wooden boxes are organized into seven or eight lines depending of the amount of household goods to be stored at that time. One line consists of ten boxes. These lines are piled on top of each other and they form three levels. There are 210-240 boxes in the middle part of warehouse. Next to this middle section are two aisles for forklifts. On the right side wall close to the entrance are shelves for storing pallets and behind them are additional wooden boxes stacked on top of each other. On the left side next to the other aisle are roller cages, more shelves and storing space for packing materials. Behind this 'wall' is an area for manufacturing wooden boxes and packing household goods in a proper way for shipping them in air cargo. Malmi warehouse has three dock doors for loading and unloading goods, but one of them is used only rarely. The storage area, including receiving but not manufacturing area, is 30.38 meters in width and 32.90 meters in length. This equals to circa 1000 square meters. The width of the receiving area is approximately 30.37 meters and the length is circa 6 meters. Thus its surface area is roughly 182.22 square meters. On the next page are four photos for illustrating the interior of Malmi warehouse.

Photo 3: Aisle on the Right

Photo 5: Middle Part from Left

Photo 4: Middle Part from Right

Photo 6: Aisle on the Left

Wooden boxes are organized into rows according to their title letter. They are marked with a type of serial number and with a project reference code, which has letters HEI, HEE, HEX, HIM or HLO and is combined with a HPV number that is created by eTrans system and is used as a moving project reference for invoicing purposes. The title letter stands for the row and a number on the side of the box is a running number that approximately defines its location within the row, but the figure does not continually appear in a sequential order. For example, A102 and D423 are mentioned while describing the location method, but there are not enough positions to have a location with the number 423. Moreover, if space behind a box becomes available it is filled with a box front of it. Naturally this procedure mixes up the tracking completely and often a huge effort of loading and unloading boxes with a lifting truck is required from warehouse workers to be able to find exact wooden boxes. The fact that it is nearly impossible to know which wooden box has which moving goods inside is problematic. It is also difficult to uncomplicatedly locate particular furniture or winter tyres of a car, for example, if a customer wants them with him/ her at some point before moving back to Finland.

Resource manager Mr. Kuosmanen finds it frustrating that it is difficult to discover is the capacity of warehouse fully utilized because one can not see behind the boxes that take up the main space in the middle of the floor. Therefore, he is simply forced to take warehouse workers' word for it, even though, they may not be sure of the situation either. This issue is something Mr. Kuosmanen wishes to be looked into and solved somehow. He told that the capacity of Malmi warehouse should be 400 wooden boxes, if there would not be any roller cages, pallets, shelves, or aisles. Therefore, it is quite obvious that improvements are welcome.

6.2 Stock Location Management and Inventory Control Applied

Based on the previously presented knowledge of the topics, it is rather easy to discover that there are several points linked to inventory control and especially to stock location management to improve in VEK's warehouses. Although the warehouses concerned in this report are not meant to have a rapid turnover and are not used for storing commercial products for sale, it is still important to know the exact location of customers' moving goods at all times. Every once in awhile a customer visits Finland for a short period of time and requests certain household goods from his/ her stored belongings or would like to add something to the boxes assigned to his/ her property. These kinds of customers' needs often cause challenging situations for the warehouse workers. After finding the right files, they are able to check the amount of boxes the customer has and have a list of all items stored, but fail to know exactly where the boxes are in a warehouse and which one of them has the goods requested or some empty space left in them.

Once the letter codes and numbers of the customer's boxes are known, the warehouse workers start looking for the right boxes by moving other boxes one by one with lifting trucks. First the area where the boxes are supposed to be, according to the paper work, is checked, but often boxes have been moved to the places of other boxes over time, since somewhere close by has been space available and new boxes have needed storing space. Similar type of searching procedure takes place also when customer returns to Finland after working abroad and wants to move back home. It is obvious that there is a huge amount of wasted time of

employees, which naturally leads to extra costs. If these requests are numerous, for instance, during the busy summer season, it is possible that the workers do not have enough time available to look for the specific boxes. Moreover, this leads into customer's dissatisfaction, which is not desirable for any company.

6.3 Location Numbering Scheme Applied

As previously mentioned, each box has its own letter and number code combined with a title letter and a running number that imply its project reference and should also roughly define its location. However, part of the problems involved in VEK's stock location management could be fixed by improving the current tracking method. Instead of using only a title letter and number as a locator of the row and possibly line, it would be recommended to prepare the whole code or 'name of the place' in order to define its unique position in the warehouse, which inform row, level and line of each SKU.

In VEK's Malmi warehouse location numbering scheme could improve the overall warehouse management tremendously. Moreover, it could be used as a basis of developing a similar type of format also for Hyrylä warehouse. In the following paragraphs the gained knowledge of warehouse management is applied and a possible solution for tracking boxes and defining each position in Malmi warehouse with only three characters is introduced. This procedure could function only with Excel sheets, but computerized WMS is recommended in order to make operations more efficient. There will be a deeper insight into a possible WMS later on in this report in a chapter *7.3 A WMS Designed for VEK*. An Excel based WMS is presented as a simple tool for controlling warehouse operations by using location numbering scheme model, which will be introduced in this chapter.

First of all, everything that does not belong to Malmi warehouse ought to be moved in Hyrylä or in containers on the yard outside Malmi warehouse. For instance, old files or property of the company, such as used refrigerators or dishwashers, should not be stored in the warehouse that was originally meant to have better turnover than Hyrylä. One ought to make a throughout inventory of everything that is inside the warehouse and make a decision if it is supposed to be there. It is highly possible that there are a lot of items that could be discarded or recycled, since they have only been forgotten inside the warehouse.

Secondly, each wooden box needs to be arranged in a more logical manner inside the warehouse. The suggestion of this final thesis is to have three aisles instead of two. This would mean one line of boxes next to both the wall and the work area, and two groups of four lines in the middle of warehouse floor. Each line has ten boxes on one level, but since boxes are stacked on top of each other and form three levels, a rational conclusion is that if fully utilized one line has 30 boxes in total. If there were only boxes in the warehouse, this would mean 300 positions for them.

The above mentioned, reorganization recommendation is based on calculations conducted by using the layout of the Malmi warehouse (appendix 2) as a source. The width of the storing area in the warehouse is 30.38 meters (33.53m + 3.16m - 6.31m= 30.38m). Wooden box's width is 1.4 meters. The width of a current aisle with eight boxes' line formation in the middle of the warehouse is circa 8.19 meters and with seven boxes' line formation about 8.89

meters (1.4 * 9 + 2x= 30.38; 2x= 30.38 -12.6; 2x= 17.78; x= 8.89 and 1.4 * 10 + 2y= 30.38; 2y= 30.38 – 14; 2y= 16.38; y= 8.19). If two aisles were to be replaced by three, the width would be 5.46 and 5.93 meters (3x= 17.78; x=~ 5.93 and 3y= 16.38; y= 5.46). The resource manager of VEK has confirmed that 5-5.5 meters should be enough for a proper operation of lifting trucks.

One is able to define each of the planned 300 unique positions in the Malmi warehouse by only three characters according to following implication. Plainly put, each row is numbered 0-9 from dock doors to the back wall. Each line is lettered A-J in alphabetical order from left to right and each level of boxes is numbered 1-3 from the floor level towards the roof. For example, a box on the right side of the second aisle lying on the floor at the end of its line has a position code 9F1 in which 9 is row, F is line, and 1 is level. This code reveals the exact location of personnel effects to warehouse workers and the box can be easily retrieved with a lifting truck should customer need it. Nevertheless, it is vital to keep up-to-date records of each box's whereabouts also during the busy seasons and make sure that the paperwork and records match with the actual location of each box. The reorganization recommendation, along with defined position codes are illustrated in a figure below.

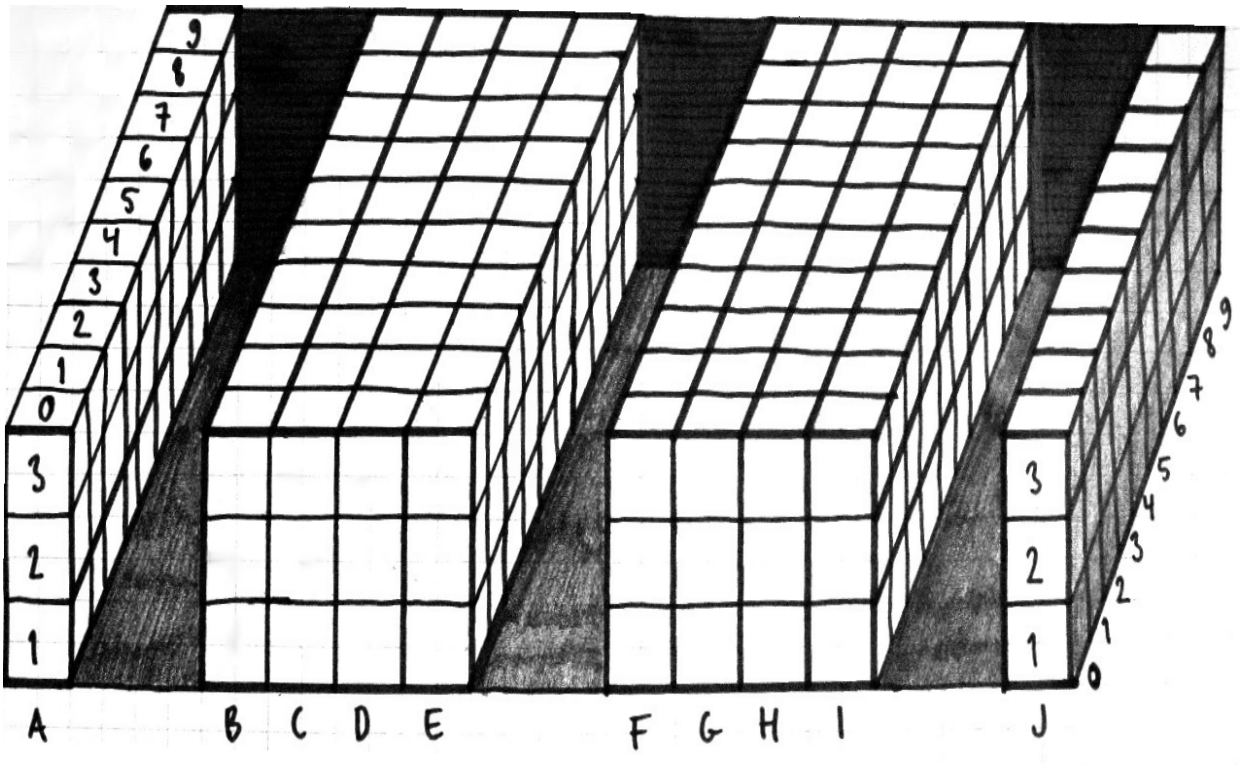

Figure 6 Order Suggestion for Malmi Warehouse with Position Codes

6.4 ABC Analysis Applied

The only tangible product group comparable to commercial products in VEK's Malmi warehouse is packing material, since they are sold or rent along with the moving service. These encompass cardboard and plastic moving boxes, air bubble film, kraft paper, packing

tape, cardboard for framed art/ paintings and carpenter manufactured customized plywood boxes for fragile and valuable items (Victor Ek's Homepage, 2008). In addition to previously mentioned ones, also wooden storing boxes belong to this product group. Packing materials are the most important products in VEK's warehouse because they are needed in every move and thus have a fast turnover. They should be stored within the easiest access inside the warehouse.

In VEK's case ABC model should be considered according to the demand of each SKU, since most of the products stored are customers' property and not for sale. Few modifications need to be made into the traditional ABC model. A items could be divided into two groups A_1 and A_2. A_1 items are 8 percent of previous A items and will represent 50 percent of their demand. A_2 items are 12 percent of A items and amount to 30 percent of the SKUs' movement. A_1 products could consist of empty cartons and plastic boxes, since they are all required in every move before the operations can begin. A_2 articles could include wooden boxes and wood for carpentering special boxes because they are entailed in all the moves before storing. B and C groups remain more or less as in traditional model. B items could be SKUs that are stored less than a year and C group could be formed out of boxes that are stored over one year.

Classification	**Percent of SKUs**	**Percent of Movement**
A_1	8%	50%
A_2	12%	30%
B	25%	15%
C	55%	5%

Figure 7 Modified ABC Analysis (James A. Tompkins & Jerry D. Smith, p. 835)

While performing the physical inventory in VEK's warehouses, it would be highly recommended to investigate, which moving goods will be stored the longest. Based on this information positions of the boxes should be considered according to estimated or known storage time required of each customer. It would be rational to store boxes that will remain the longest time in the warehouse, in the middle or behind other boxes or transport them to Hyrylä warehouse. Conversely, boxes that require a shorter storing time should be placed in easier picking locations, since it will lead into lessen labor time of the warehouse workers while retrieving them for returning customers.

6.5 Inventory Control and Accuracy Applied

Based on the warehouse management theory, this paper offers applied tools for improving both inventory control and inventory accuracy. These suggestions include location numbering scheme and ABC analysis, which were presented earlier and modified for VEK's needs. By applying these, VEK is able to maintain up-to-date information of the inventory and hence progress the overall inventory control and customer service. From VEK's standpoint the most significant knowledge to acquire is to concentrate the efforts on controlling inventory and keeping track of each SKU. This will lead into improved profitability in form of more efficient labor time and enhanced customer service.

7 Warehouse Control and Management Systems in VEK

As formerly discussed in a chapter *6.1.1 A Need for Efficient Computer System*, VEK is presently managing its warehouses with a database of numerous Excel sheets. Mr. Sami Kuosmanen has mentioned the fact that they are thinking over a prospect for installing a proper WMS in addition to or for completely replacing the eTrans system. One also needs to keep in mind that the Victor Ek Group is currently on the lookout for a software system that could replace eTrans from the whole organization. However, this type of action would affect to several functions of all divisions and therefore has to be thoroughly considered.

Before making any final decisions in VEK of the WMS implementation, all the possible systems need to be looked into in order to define, which WMS on the market would have the best functionalities for improving VEK's warehouse management with the cheapest acquiring price. Since comparing different systems is often a rather long process, this final thesis introduces a template for Excel based WMS designed for VEK's moving division in a chapter *7.3 A Temporary WMS Designed for VEK*. Thus the company can have a head start to begin computerized controlling of warehouse operations, before the actual system is launched.

7.1 Possible Auto-ID Systems

VEK does not currently use any kind of Auto-ID system in tracking its inventory. Based on the automatic identification system's theory part in this paper, it is rather easy to disclose optical character recognition (OCR), magnetic stripe, and voice recognition technologies in this case because they are not relevant to the topic and do not offer any rational advantages for improving VEK's warehouse management. VEK's resource manager informed that the possibility of implementing bar codes has previously been considered. Thus it is beneficial to define, if it would be a rational alternative for the company.

Barcoding has a number of advantages, such as inexpensiveness and reliability. It is also widely used and standardized. However, there are also drawbacks, for example, barcoding requires a line-of-sight, is orientation sensitive, can be scanned only one-by-one, hence it is somewhat slow and labor-intensive. Compared to RFID tags, the amount of data stored in bar codes is rather small and cannot be rewritten. (Banks et al. 2007)

Both of the technologies have become important tools in SCM and are often utilized in same applications, nevertheless, barcoding would not be a value-added system for VEK. This is mainly because of its limitations. On one hand, if bar codes were attached on cardboard boxes during the move, it would only make possible to identify each box without knowing the exact contents. Even this requires multiple scans, which would be time-consuming. On the other hand, if bar codes were to be affixed on wooden boxes, one should move boxes with lifting truck in order to be able to scan the bar codes. As the products stored are not commercial and VEK is not a retailer, for instance, one would not benefit only from the basic information that could be encoded into the bar codes. RFID application could offer numerous benefits for the company; therefore, a customized RFID solution is introduced later on in this paper.

7.2 WMS Functionality Applied

Acquiring a WMS instead of using a number of Excel workbooks and manual records of the moving projects is highly recommended. Even though VEK does not store any commercial products in its warehouses, the firm still needs more accurate and trustworthy method of keeping track of its inventory. The amount of labor time wasted by employees, while seeking specific information among each datasheet and/or filed documents, may be considerable (Tompkins & Smith, 1998). It is much faster to search the information from a computerized system and thus the paperwork can be diminished. Systems offer increased accuracy and minimized uncertainty, which can often be considered as better than human labor (Tompkins & Smith, 1998).

By implementing a WMS, customer satisfaction is increased because clients get to know where their moving goods are almost instantly after inquiring about them and reaching an employee. Therefore, one can say that a proper WMS results to a considerable reduction in the information lead time, since it is possible to check all the vital data regarding to customer's belongings from the system. Furthermore, if connected to a suitable Auto-ID technology, the information retrieval could be almost instantaneous. (Tompkins & Smith, 1998)

Moreover, it is sufficient to execute all the required financial duties with an appropriate WMS, thus eTrans would not be needed anymore. WMS would not assist only warehouse workers, but also any group within the company that deals with inventory, purchasing, and customer orders (Tompkins & Smith, 1998). Entering data only one time into the system would be enough also for invoicing activities. Along with other important aspects, a proper WMS is an important factor in improving customer service because of increased amount of current information about shipments and products' whereabouts. Therefore, one can say that, among other things, the WMS offers organizations a competitive advantage (Tompkins & Smith, 1998).

While improving warehouse management in VEK, space utilization and item activity reports would be the most important ones of WMS's performance reporting for VEK's warehouse operations. These reports, for instance, reveal the information of the free space in the warehouse and its different storage locations, along with each SKU's movement and usage records (Tompkins & Smith, 1998). With location numbering scheme a suitable WMS could fulfill VEK's demand for the knowledge, is the capacity of warehouse fully utilized. If the movement of the boxes and other SKUs would be kept up-to-date, the space utilization could be checked from the WMS, whenever the information was needed.

7.3 A WMS Designed for VEK

As mentioned earlier, VEK is filing its moving projects by using numerous Excel workbooks with supplementary handwritten records and paperwork. Based on these Excel warehouse sheets and the information required on them, a template for a WMS was designed. It is basically a database of VEK's warehousing operations in Excel format. The figure below illustrates the information that needs to be feed into the system after a physical inventory is performed in Malmi warehouse. It is possible to form a similar type of Excel database for

Hyrylä warehouse and likewise as in the figure it could be on a second sheet of a same workbook. Thus the whole inventory management could be supervised with a single Excel file and the currently utilized warehouse sheets could be replaced with a more efficient system.

Figure 8 Presentation of the Excel Based WMS

Location	Reference	HPV	CompanyNr	Company	ClientNr	Customer	Residence	Date	Mover/Truck	Cbm	Items	Contents	Special objects	Insurance €	Occupied	Empty	Usage
0A1																1	78,79 %
1A1	HEX3796	804	32511	Supplier Inc.	39222	Heinämies Esko	Sipoo	30.4.2008	TAHVO	4	10	HHG		6000,00	1		
2A1	HLO23929			Retailer Corp.		Huittinen Kalevi	Vaasa	29.5.2008	SK	7		MG	H11/Piano 17 Cbm		1		
3A1	HLO23929			Retailer Corp.		Huittinen Kalevi	Vaasa	29.5.2008	SK	7					1		
4A1																1	
5A1	HLO3032	865		SCM Oy	53644	Sipilä Juha	Espoo	18.12.2008	VE	7	100	MG			1		
6A1																1	
7A1	HLO23929			Retailer Corp.		Huittinen Kalevi	Vaasa	29.5.2008	SK	7					1		
8A1	HEX2702	692	41043	WholeSale Ltd.	49755	Sandvik Robert	Kaarina	31.8.2006	VE6	7	26	HHG			1		
9A1	HEX2702	692	41043	WholeSale Ltd.	49755	Sandvik Robert	Kaarina	31.8.2006	VE6	3	25	HHG			1		
0A2	HEX3567	777	45378	WMS Oy	44553	Ainasjoki Ritva	Espoo	21.12.2007	VE18	7	30	HHG		10000,00	1		
1A2	HEX3567	777	45378	WMS Oy	44553	Ainasjoki Ritva	Espoo	21.12.2007	VE19	7	30	HHG		8000,00	1		
2A2	HLO3032	865		SCM Oy	53644	Sipilä Juha	Espoo	18.12.2008	VE	6	72	MG			1		
3A2																1	
4A2	HEX3567	777	45378	WMS Oy	44553	Ainasjoki Ritva	Espoo	21.12.2007	VE22	6	30	HHG		8000,00	1		
5A2	HEX3567	777	45378	WMS Oy	44553	Ainasjoki Ritva	Espoo	21.12.2007	VE23	6	30	HHG		8000,00	1		
6A2	HIM2279	511	12775	Auto-ID Inc.	46495	Hietanen Aune		10.10.2005	JP	7		MG			1		
7A2	HIM2279	511	12775	Auto-ID Inc.	46495	Hietanen Aune		10.10.2005	JP	7		MG			1		
8A2	HLO2964	860	52610	RFID Oy	53414	Eskola Markku	Vaasa	23.10.2008	VE	7	32	MG			1		
9A2	HLO2964	860	52610	RFID Oy	53414	Eskola Markku	Vaasa	23.10.2008	VE	1	32	MG			1		
0A3	HEI 456			Company Inc.		Haapaniemi Jani	Kotka	27.4.2004	CS	7	19	MG			1		
1A3	HEI 456			Company Inc.		Haapaniemi Jani	Kotka	27.4.2004	CS	7	10	MG			1		
2A3																1	
3A3	HIM2279	511	12775	Auto-ID Inc.	46495	Hietanen Aune		10.10.2005	JP	6		MG			1		
4A3	HEX3567	777	45378	WMS Oy	44553	Ainasjoki Ritva	Espoo	21.12.2007	VE20	7	30	HHG		8000,00	1		
5A3	HEX3567	777	45378	WMS Oy	44553	Ainasjoki Ritva	Espoo	21.12.2007	VE21	6	30	HHG		8000,00	1		
6A3																1	
7A3	HLO23929			Retailer Corp.		Huittinen Kalevi	Vaasa	29.5.2008	SK	7					1		
8A3	HLO23929			Retailer Corp.		Huittinen Kalevi	Vaasa	29.5.2008	SK	7					1		
9A4	HLO23929			Retailer Corp.		Huittinen Kalevi	Vaasa	29.5.2008	SK	7					1		
0B1	HLO2964	860	52610	RFID Oy	53414	Eskola Markku	Vaasa	23.10.2008	VE	7	32	MG			1		
1B1	HLO2964	860	52610	RFID Oy	53414	Eskola Markku	Vaasa	23.10.2008	VE	7	32	MG			1		
1B2																1	

According to the wish of VEK's resource manager, the system is able to calculate the usage percentage of the warehouse's storing capacity. It is based on the data of occupied and empty positions, and thus is up-to-date as the records are kept in order. The formula of the usage percentage is formed by using the sum of all the occupied positions and dividing it with the amount of the whole storing capacity, which is multiplied with 100 in order to get a percentage value. One can see the result on the WMS on a right-hand-side on the second row. In an example template the result is 78.79 percentages. As a side note, the HPV number shown in the figure is a project reference number created by eTrans system employed by Victor Ek Group at the moment, and it is mainly used for the invoicing purposes.

Excel's data filtering tools, such as AutoFilter, facilitate trouble-free retrieval and searching of specific information from the designed WMS. Thus one is able to search all the warehouse occupied positions of a certain company, customer, moving date, or residence, for instance. As the Malmi warehouse alone has approximately 300 positions, typing manually all the information in the database and conducting a physical inventory are time-consuming activities. However, the time spent on the implementation process, will most likely to be rewarded after obtaining numerous benefits of a WMS. By utilizing the introduced system, one is able to save a significant amount of labor time in the future and improve inventory management and stock location management processes. Nonetheless, it is still recommended to look into WMSs available on the market and evaluate the benefits compared to the price and implementation costs. Suggested Excel based WMS could be a temporary solution as well.

8 Customized RFID Solution for VEK

The customized RFID solution for VEK, presented in this chapter, is mainly planned to be implemented in Malmi warehouse. Naturally, it is possible to design an RFID system also for Hyrylä warehouse based on Malmi's plan, but it should be noted that certain differences may appear, for instance, regarding to the storage area and operations. The best RFID solution for VEK's warehousing would most likely be to employ two mobile truck-mounted RFID readers with one or two handheld ones that could be utilized by the movers and the operators. Tags could be affixed to both cardboard and/or plastic boxes as well as to the separate furniture and wooden boxes. One should preferably be able to program data into cartons' tags (c-tag) memory, but a smaller memory capacity would be sufficient to tags attached to the wooden boxes (w-tag) as they are connected to the database. One possibility is to use tags only with wooden boxes, but this type of SKU-level tagging would not offer enough advantages for VEK. The usage and selection of tags depends on the benefits one is aiming to achieve and also the budget that is reserved for the RFID implementation.

UPM Raflatac is a major Finnish manufacturer and vendor of RFID tags. Mr. Jari Ovaskainen is employed by the company and works as a Business Development Director regarding to RFID in Industrial Segment. His opinions are highly appreciated and referred to in this RFID solution section as he is an expert of RFID technology, different types of tags, and their implementation procedures and requirements. Consulting Mr. Ovaskainen facilitates a deeper insight to the final thesis project.

8.1 Infrastructure and Required Updates

In VEK's case, a (one or several) new computer(s) is required, since RFID system needs a vast memory capacity in order to be able to process all the data gathered by the readers. The middleware retrieves the data stored in a WMS's database and links the tags' information to it. Moreover, a temporary WMS designed for VEK introduced in a chapter *7.3* could fulfill, after minor modifications, VEK's demand for a WMS that should otherwise be obtained from a software vendor. Implementing a software system is always a costly commerce and demands staff training and other additional resources in form of spent time or capital. This is especially the case with complex ERP systems, such as SAP and Oracle. However, obtaining only a WMS adequate for a smaller company is naturally less expensive than implementing a system for the whole firm and all of its divisions, branch offices, and subsidiaries.

Another issue that should be discussed is a need for WLAN (wireless local area network) within the VEK's warehouse. It ought not to be a problem or cause significant expenses to install additional router(s) and extend WLAN coverage, which is already in use in the office of VEK's moving division as the office premises are in the same building with the warehouse. WLAN is not a mandatory part of the planned RFID system, instead it is recommended as one is able to keep the warehouse records up-to-date and prevent simultaneous data modifications by several operators, which improves other processes as well, such as sales invoicing and customer service. According to Mr. Ovaskainen the WLAN installation would almost certainly be a cost-efficient solution for this specific company and could properly complement the planned RFID system. He also claims that another possibility with RFID systems is to use GPRS (general packet radio service), which is connected to a database and/or server (Ovaskainen, 2009).

8.1.1 Tags

The usage and selection of RFID tags depends on several factors and should be conducted based on knowledge of each individual case and the company's operations. While comparing to passive tags, active and semi-passive tags would be unnecessarily powerful for VEK's warehousing purposes. Best tags for VEK's wooden and cardboard boxes are passive UHF tags. Since the cases and furniture needs to be tagged during the move at the customer's premises, the most efficient tags are so called smart labels. These are RFID tags that are glued to an adhesive label, therefore, smart labels are easy and fast to attach on an item, case, or pallet (Ahson & Ilyas, 2008). On the other hand, wooden surface of plywood boxes is not ideal for smart labels, especially when the storing time is counted in years and not in days or months. Thus it is suggested to use different type of tags and attach them by other means than adhesive label.

As a side note, the utilization of EPC codes is not suggested in this case. This is mainly because VEK's moving division does not have suppliers, retailers and/or commercial products in the basic sense of these terms. If the EPC codes are not compulsory for the overall business process, for example mandated by a major partner retailer, it is cleverer to avoid the additional costs of using the EPC network (Ahson & Ilyas, 2008). Furthermore, it is rather obvious that by applying EPC identification to each item would be more of a source of confusion, additional costs, and wasted labor than an advantage, since VEK does not store commercial

products, which need to be uniquely identified or have numerous items within similar product groups and in several locations. As a consequence, there is no need for acquiring an access to an EPC database and cartons, plastic boxes, furniture, and wooden boxes can be tagged with tags that do not have EPC code programmed into their memory.

During moves handled by VEK, cardboard boxes are normally used for customers' goods in international moves and plastic boxes are rented for clients that wish only to relocate within Finland. To simplify the presentation of suggested solution, all tags affixed to the cartons, plastic boxes or furniture during the moves are referred to as c-tags. Tags that are attached onto the wooden boxes at the warehouse are named w-tags. C-tags do not require an excessive memory capacity, but it would be useful to be able to program some information in them and/or link their unique identification codes to the customer within the database, while packing boxes before transportation to the warehouse. Thus one could avoid or at least lessen the amount of paperwork by utilizing a handheld reader and tagging boxes already at the customer's residence. If the memory capacity of c-tags would be adequate, one could replace handwritten packing lists by feeding necessary data into tags' memory. This would allow obtaining the knowledge of each box's interior without opening them later on, while searching specific objects, for example. One could also reveal the exact quantity of cartons or furniture packed in each wooden box by scanning the c-tags of the box. An alternative for programming the data into the tags memory is to manually feed the information straight to the (Excel based) database as described previously, but this procedure would require a mobile internet connection and a laptop to be carried with to every move. W-tags are attached onto the wooden boxes and it would be suggested to program a position code for each w-tag according to location numbering method designed for Malmi warehouse and introduced in a chapter *6.3 Location Numbering Scheme Applied*.

8.1.2 Readers and Antennas

Two truck-mounted readers for putaway and picking activities are required for the planned RFID system. In addition, one or two handheld reader(s) is urged to be acquired for programming the necessary data into tags during the move and for assisting the receiving process. There are only two operators working in the warehouse and the receiving activity could be highly improved, because of the data concerning the goods has already been programmed into the tags memory and the mover who transports the goods, would only assist with the data management, packing customer's belongings in wooden boxes, or moving confirmed goods in the storage area in proper locations.

Instead of handwritten warehouse documents, one still needs to feed the same information in the WMS by manually typing on the keyboard and scanning the tags of received goods before loading them in the wooden boxes. However, the packing list is no longer required and it is possible to keep the warehouse records up-to-date, as the data is saved in electronic form into the WMS. This is also a more convenient way than current method that relies on manually filled paper forms and one Excel file per customer. By implementing an RFID system and even the suggested Excel based WMS it is possible to save employees' time and improve the efficient use of warehouse's equipment and space. One can check proper, vacant position codes from the system and figure out the best storing locations for each new load of customer's goods based on their estimated storing duration and optimized putaway activity.

However, if a proper WMS was employed, the system could automatically inform the operators of the best locations or other activities that need to be completed with the goods handled.

The truck-mounted readers are to be equipped with two circular polarized antennas, since the transceivers need to be able to read the w-tag and c-tags in each wooden box they move within the warehouse. The most up-to-date trend is to equip the forklifts with laser and acoustic sensors, which are activated as an object is picked up with a forklift; this in turn triggers the reader to scan the tags that are attached to the load lifted (RFID Journal, 2009). For handheld readers linear polarized antennas are better as they are mainly used in scanning c-tags. Moreover, if one needs to locate a wooden box from the storing area, a linear polarized antenna has a longer reading ability as its RF field is more concentrated and radio waves proceed in a form of a line. However, it might be hard to find a reader that could read w-tags through three or more wooden boxes as the power of handheld transceivers is limited. Thus the deployment of planned location numbering scheme is recommended also with the suggested RFID system, since the scanning of the entire formation of 120 wooden boxes in the middle of the warehouse is challenging. It might be possible to read the tags in half of them and therefore three aisles instead of current two are urged, while reorganizing the boxes during inventory.

8.1.3 Software, Host and Feedback Mechanisms

VEK's operations form a rather simple supply chain, which does not have highly important business partners or other alliances that they should be able to share information in real-time via EDI (electronic data exchange) or other type of information platform. In addition to being able to operate without these kinds of programs, VEK can also save the expenditures of using the EPC network or other similar database, since the products stored are not commercial of their nature.

As previously mentioned, an RFID system could be linked even to an Excel based WMS and host computer would only need a purchased middleware's installation. However, a host would have to be a proficient computer with a remarkable memory capacity. Thus VEK's computer used in the warehouse should be replaced with a newer model that has all the required elements and possibly an external hard disk. If implementing an RFID system becomes timely for VEK at the same time with acquiring an ERP system for Victor Ek Group, it would be intelligent to consider the possibility of installing a software system that has a middleware and a WMS, which would all suit well for the needs of VEK's warehouse management.

Feedback mechanisms are optional part of an RFID system, but could be beneficial. Often the readers have some type of means to inform the operator, whether the data was gathered successfully or not. In VEK's warehousing, one could suggest a pop-up window that appears to the reader's terminal, lamb that goes on in the forklift, or an audible sound in the transceiver that 'beeps.' These actions are triggered by the scanning of tags.

8.2 UPM Raflatac's Product Suggestions

After consulting UPM Raflatac's Business Development Director, Mr. Jari Ovaskainen, of the suggested RFID system for VEK, he agreed that passive UHF tags would be the best solution in this warehousing application. He drew attention to the fact that UHF tags provide longer read range than HF technology. In addition, he states that HF technology is based on magnetic coupling and the scanning distances vary only from couple of centimeters to few dozens of centimeters. Mr. Ovaskainen mainly recommends two passive UHF tags from their product selection, ShortDipole and DogBone. They can easily obtain a required reading distance for this application. He also claims that packing material makes a difference and in this case plywood absorbs an RF signal more than cardboard, for instance. Therefore, it is good that the reading distance exceeds the minimum requirements, since the circumstances rarely are ideal for an RFID system in a warehouse environment.

One should also note that UHF tags require a small distance from objects that have metal parts or contain liquid because metal reflects RF waves and liquid absorb them. It is possible that metal or liquid between the transceiver and reader may even result in completely failed scanning procedure. (Ovaskainen, 2009). However, according to VEK's resource manager Mr. Kuosmanen, the goods stored rarely have any metal parts and he is almost positive that there have never been any liquids (Kuosmanen, 2008). Sometimes the reading ability is affected by the placement of a tag. For example, the w-tags could be attached close to the bottom of the box and preferably in the middle as a forklift reader scans the tags while operating. C-tags can be affixed on top of the closed cartons or on one side of the box, since they are read mostly one by one and are handled manually especially during the receiving process.

Product examples of ShortDipole and DogBone tags are shown in a figure on the next page. They have metallic quality and the upper picture illustrates ShortDipole tags and the lower picture has DogBone tags. Both of them are in a form of smart labels and are produced onto adhesive plastic labels, which are rolled into rolls.

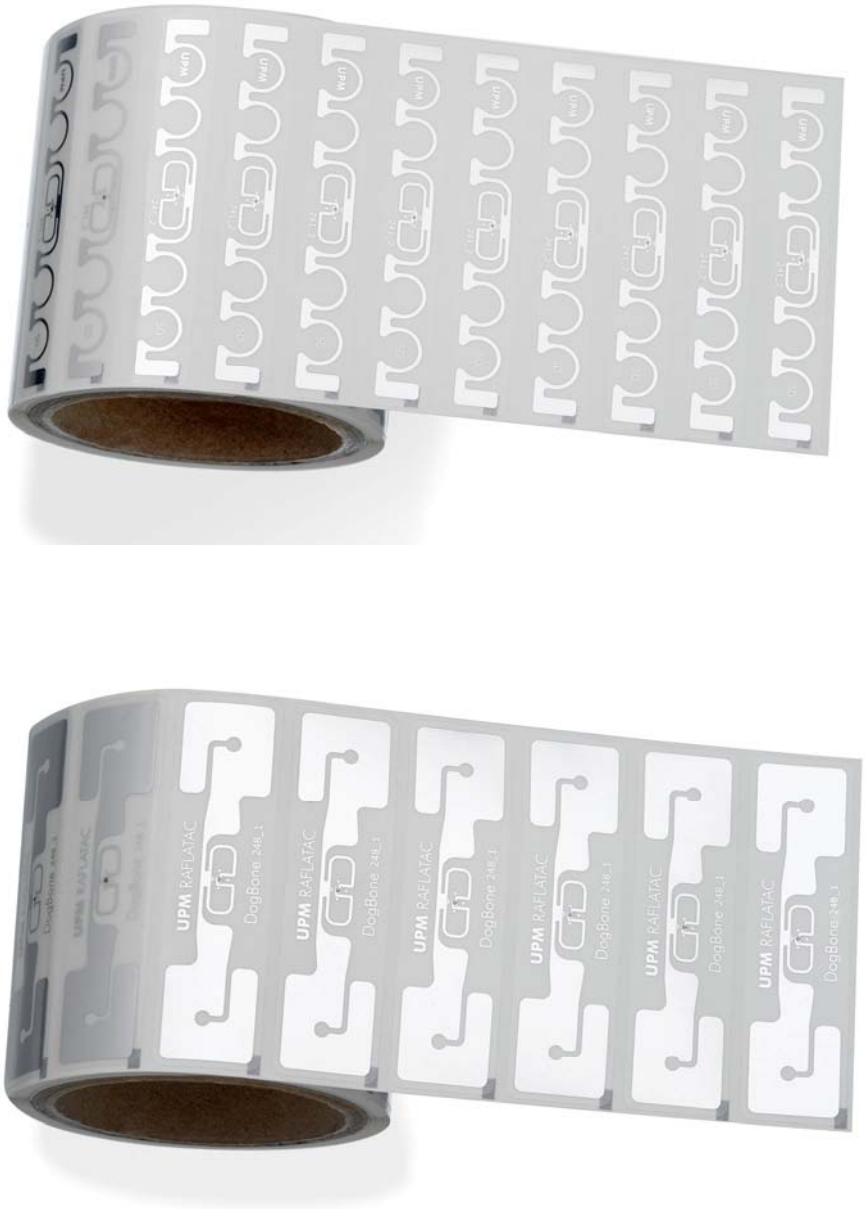

Figure 9 Examples of UPM Raflatac's Passive UHF tags

Both types of tags have a EPC Class 1 Gen2 protocols and can thus operate globally. Memory capacity is 96 or 240 bit with optional user memory of 512 bit. ShortDipole's measurements are 92 * 11 millimeters and DogBone's are 93 * 23 millimeters. They are popular in SCM applications. (UPM Raflatac's Information Leaflet, 2008).

As UHF Gen2 protocol functions globally regardless of the RF range, it could be used to identification and verification of a received container that is transporting VEK's moving goods. This is a value added factor, in particular, if a customer has exceptionally expensive property, such as paintings or jewelry. With semi-passive or active tags the location of a shipment can be determined with a GPS (global positioning system).

8.3 Achievable Pros and Probable Cons

If a right kind of middleware system is acquired, one is able to integrate even the introduced Excel based WMS with RFID system. However, the ideal solution for VEK would be to implement a proper WMS together with the suggested RFID application, which could be integrated. One alternative is also to choose the Victor Ek Group's ERP system, which will replace eTrans system, based on the WMS and middleware requirements of VEK. Two latter options could facilitate even completely automated customer invoicing, which would be a major improvement for the company's current invoicing processes. Other advantages include, but are not limited to, optimization of storing capacity, assets management, and inventory control. In addition, customer service level would increase drastically.

The most significant limitation for implementing RFID is its price. It is difficult to convince the financial department or CEO (chief executive officer) in advance that the investment will definitely pay off in the future. VEK would also have to train its staff in order to be able to familiarize with the new technology, and especially movers and operators should learn how to utilize readers and host computer with middleware and a WMS. However, warehouse operations would be improved tremendously.

9 Conclusions

The purpose of the final thesis was to study and improve the warehouse management and warehousing operations of the chosen company. The structure of the paper is formed to consist of three main sections: warehousing and warehouse management, warehouse control and management systems, and RFID technology. Each of these individual parts supports the thesis objectives and facilitates a deeper insight and various points of views in order to thoroughly consider beneficial and rational application suggestions for VEK.

Firstly, warehouse management section covers the concepts of stock location management, inventory control, location numbering scheme, ABC analysis, inventory control, and inventory accuracy. Based on the gained knowledge each of the subjects was applied and useful tools for improving the warehouse management of VEK were presented. The most concrete outcomes were probably the custom-made location system and new order suggestion for VEK's Malmi warehouse. Even by applying only these, VEK would be able to save resources, and progress both stock location management and inventory control.

Secondly, warehouse control and management systems part highlighted different automatic identification systems, with an emphasis on barcoding and RFID, and advantages of implementing a WMS and the challenges, which might be faced in the process. As VEK does not currently have a separate WMS, it is an essential addition that an Excel based WMS is introduced and could be utilized by the company after a physical inventory. The database template is formed based on the required information of warehouse sheets and applied location numbering scheme.

The third part's topic is RFID technology, which could offer numerous benefits and even a competitive advantage to the firm. This is the main subject of the thesis and thus it is covered in more detail than other two. This is also partly because the matter is rather complex and in this case requires more explanation. RFID technology introduces the operation process, basic components, RFID's possible advantages and challenges, and its potential in warehousing and logistics. Based on the theory a customized RFID application for VEK is developed and presented. This application is consulted with an RFID vendor, and a couple of product suggestions are presented as well. RFID technology is recommended to be looked into in warehouse management, since it could offer several benefits to the company. However, it is still a rather demanding implementation process to complete with a high cost-efficiency.

The study is composed of three main parts: warehouse management, WMSs, and RFID technology. The current problematic issues of the company related to warehouse management include slightly inaccurate inventory control, inefficient stock location management, and a lack of a WMS. The main purpose of the report was to provide the tools for improving the warehouse management of VEK. However, it was also important to offer the knowledge and solutions for overcoming some of the current challenges, such as problematic inventory control or not having a WMS. One of the goals was to supply information about Auto-ID systems and especially of RFID technology, its potential and possible applications in warehouse management. If the suggestions of this final thesis report are employed by VEK, it is probable to achieve tangible benefits and more successful business operations.

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Appendices

Appendix 1: Interview of VEK's Resource Manager

Mr. Sami Kuosmanen, October 15, 2008

What type of WMS is currently in use in VEK?

Warehouse management is conducted with Microsoft Excel. Each moving project has an own warehouse sheet, which informs the name of the customer, the residence of the origin, moving date, the mover etc. Later on the letter and number code of the wooden box is added to the information. These are in a form of HIM, HEX or HMO and are combined with a number. The name of the customer is used for the identification of each project; there are numerous Excel workbooks in two files named 'Warehouse X' and 'Import Export.' The latter is for international moves and goods that will be transported to the customer's new location abroad. These household goods are stored only about a week and thus cross-docking is performed.

Only the invoicing is done with eTrans system according to a project reference created by the system. It is very troublesome to manually feed the information into the system only for invoicing purposes. With two different systems, one also has two references for the same project, which is inconvenient. Victor Ek is planning to implement an unified ERP system for the whole group.

When is the planned implementation of a new system and which software system it is?

Victor Ek has not yet made any final decision about either of them.

Does VEK utilize any kind of automatic identification system?

There are not any bar codes or other means in use at the moment. The title letter of each box implies the row of storing location. The exact location of wooden boxes is not know, as it changes depending on if the space behind them frees up.

What type of boxes or other SKUs are used for storing?

Cardboard boxes are packed inside the wooden ones. Roller cages are utilized only if the amount is small and storing time short, as the contents may be damaged by external factors, such as dust. During the summer season also the containers on the yard may be used for storing. This is beneficial, since the goods are less subject to damage, if the amount of loading and unloading procedures is minimized.

Is the order of the warehouse organized based on some factor (such as storing duration) or area?

No, but the goods that are known to be stored longer are transported to Hyrylä instead of Malmi. If they do not fit in wooden boxes, the shelves or roller cages are used. Sometimes it is not clear in which wooden box some specific furniture, such as a couch that customer wants before returning to Finland is. Then it needs to be searched with a lifting truck and by opening the boxes manually one-by-one.

How are the goods packed in the wooden boxes?

They are filled with cartons and/or furniture. Every now and then, large objects have to be loaded into the containers.

What type of goods the stored items normally are?

Mostly VEK handles regular household moves, but the customer's employer company pays the move as they are relocating because of the work.

Are there often items that have metal or liquid?

Those kinds of items are not numerous, there are some kitchen utensils and furniture with metal parts, but there are no liquids.

How long the goods are stored per a move?

It is hard to tell, probably a couple of years. Some of the goods stay in Finland as the customer travels to work abroad.

Are the goods packed during the move at the customer's premises or at the warehouse?

They are packed into cartons during the move, the wooden boxes are packed at the warehouse. Sometimes after the customer has returned Finland the wooden boxes might be transported as such to the customer's residence without unloading at the warehouse.

At which point the identification information is attached/ marked?

They are already in wooden boxes. Cartons are prepared during the move, the room is marked with a tick, the content is written on the box, and the number of the packing list is added. Packing lists are ready formes, but they are filled manually.

How is the transportation handled?

VEK has 16 trucks and semi-trailers altogether. The main movement is done with trucks. The bigger trucks are used only, when the goods are ready for the transportation.

What kind of automation is utilized in VEK's warehouses?

Mainly the trucks and a computer are in use. There are no conveyors or bar code scanners or the type. Warehouse sheet is made as soon as the goods are received.

How many employees are in the warehouse?

Two in a full time job, but movers assist if it is a busy season. There 30 movers.

What is their job description?

Movers are handling the moves, packing cartons, carrying furniture etc. Warehouse operators are packing the wooden boxes and prepare air cargo for transportation, for instance.

What is a typical international move like?

The customer contacts, one of the VEK' employees will perform a site assessment. The offer is prepared based on the estimated need of the movers etc. VEK's forwarder prepares instructions for the handling and shipping of goods. If the apartment is 80 square meters or larger, it is often a three days move. There is only a small part of the moves that a customer takes only the necessities along to the air plane and nothing needs to be shipped.

Does VEK have partner companies abroad?

VEK has a good network of partner companies abroad. For example, in Europe local firms are cooperating nearly always. If problems arise, one is able to get help from the main cities or other bigger towns. The shipping documentation varies from waybill and packing list to work permit etc. In some countries each carton is weighted. Also electronic devices may cause troubles and need to be marked very clearly.

What type of identification systems they use?

Basically the similar activities are performed than in VEK. Customs clearance is sometimes difficult to obtain depending of the country.

What are the main problems in VEK's warehouse management currently?

The usage percentage of storing capacity would be good to know. Right no it is impossible to find out is there available space and how much.

Are there any wishes how the movement of the goods, their storing or managing could be improved?

It would be beneficial to be able to tell the date of the move. Some of the customers need part of the stored goods before returning to Finland.

Does VEK have competitors?

Yes, there are two Niemi and Grundell. They have pretty much similar type of procedures.

Appendix 2: Modified Layout of Malmi Warehouse