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POTENTIAL OF RFID TECHNOLOGY IN LOGISTICS - CASE METSO PAPER -

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TIIVISTELMÄ:

Viime vuosina palveluliiketoiminnan merkitys ydinosaamista tukevana prosessina on kasvanut merkittävästi. Metso Paperin ydinosaamista on paperikoneiden valmistus mutta Service liiketoimintaan panostetaan vahvasti ja siltä odotetaan kasvua. Tällä osa-alueella logistiikalla ja etenkin materiaalin tunnistamisella on iso vaikutus prosessien tehokkuuteen. Viivakoodi on yleisesti ollut hallitseva automaattisen tunnistamisen menetelmä, mutta sillä on omat rajoituksensa. RFID:llä nämä rajoitukset voidaan voittaa. Standardisoinnin sekä teknisen kehityksen ansiosta se on nopeasti noussut vaihtoehtoiseksi menetelmäksi tehostaa logistiikkaa. Siksi Metso Paper Service on nähnyt RFID tutkimuksen tarpeelliseksi.

Tämän Pro Gradu tutkimuksen tarkoitus on selvittää, voidaanko RFID:llä tehostaa Metso Paper Servicen nimettyjä prosesseja. Tavoitteena on tunnistaa ne prosessit, joissa RFID:llä voitaisiin saavuttaa liiketoiminnallisia parannuksia ja kustannussäästöjä nykyiseen toimintamalliin verrattuna.

Tutkimus on toteutettu haastattelemalla avainhenkilöitä teemakysymyksillä kahdeksasta toimeksiantajan nimeämästä prosessista. Haastattelun ja tilastollisen aineiston perusteella, nykyiset toimintamallit ja materiaalin tunnistamiseen liittyvät oleelliset asiat on kuvattu prosessikarttoineen. Lisäksi teoriaosa esittelee RFID-tekniikan pääosin tasolla, joka käyttäjän on hyvä tietää. Tältä pohjalta on analysoitu, pystytäänkö RFID:n avulla tehostamaan prosessin toimintaa.

Tutkimuksessa havaittiin, että useampi prosessi kehittyisi jollakin tavalla RFID:stä, mutta toteutettavuus ja saavutettavan hyödyn määrä vaihtelevat. Kuitenkin yksi prosessi muodostui muita selvästi sopivammaksi. Tutkimuksen viimeisessä osassa on selvitetty RFID:n tarkemmat toiminnalliset sekä taloudelliset vaikutukset tähän prosessiin, niin tarkasti kuin se etukäteen on mahdollista. Lopputuloksena päädyttiin suosittelemaan RFID pilottiprojektia suomalaisten asiakkaiden kanssa.

AVAINSANAT: RFID, automaattinen tunnistaminen, prosessin tehostuminen, taloudellinen hyöty

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ABSTRACT:

In recent years, the importance of service business as a supporting process of core know-how has increased significantly. The core know-how of Metso Paper lies with the manufacture of paper machines, but plenty of effort has been paid on Service business and a great build-up is expected. Logistics and especially material identification affect to a large extent the overall efficiency of individual processes. In general, bar codes have been the dominant method of automatic identification, but they have their limitations. Thanks to standardisation and technical improvements, RFID has rapidly become an alternative way to improve logistics. Thus, Metso Paper Service has deemed research into RFID worthwhile.

The purpose of this Master's Thesis is to determine whether RFID could improve given operations of Metso Paper Service. The goal is to identify application areas, where significant improvements and cost savings might be gained by introducing RFID, compared to current ways of operation.

The study has been conducted by interviewing key persons of eight processes. The client has chosen the processes, and interviews were conducted with theme-questioners. Based on interviews and statistics, essential aspects of current operating and material identification methods were modelled with process descriptions. In addition, the theory section introduces RFID in the level that is beneficial to users' point of view. Based on these, it is analysed whether RFID could improve the processes.

The study found out that RFID could somewhat improve several processes but feasibility and gained improvements vary. However, one application was found out to have the greatest potential. The last part of this study clarifies detailed operational and financial issues, as far as that can be achieved in advance. As a result, the study ends up recommending a RFID pilot project among Finnish customers.

KEYWORDS: RFID, automatic identification, process improvements, financial benefits

1. INTRODUCTION

1.1 Preamble

In an industrial environment, *automatic identification* procedures have been around many years. They exist to provide information about items and related things and have become very popular. They have been used to accelerate processes and to reduce time-consuming or routine work among purchase and distribution logistics, manufacturing and material flow systems. They have resulted in more accurate inventories and more efficient material handling, because identification is not relying of human beings as much as in the past.

Some considerable time ago *bar code systems* started a revolution in logistic identification systems and nowadays they can be found in almost every product. Although they may be extremely cheap and bar code compliant devices are easy to obtain, they are proving to be inadequate in an increasing number of cases. The reason relates to their comprehensive limitations, such as the very short read distance and low storage capacity. Nevertheless, bar codes remain a very useful method of conducting identification in many applications.

Technically optimal way to carry out extensive automatic identification is based on *smart card technology*. In such a system data is stored in a silicon chip that is to be attached on a card. For instance, credit cards are based on that technology. In general, smart cards are impractical for logistic purposes, although they can store lots of data but identification is based on mechanical contact. Thus, non-contact ways for identification between object and readers were needed and developed. (Finkenzeller, 2003: 1)

In recent years the most talked-about procedure in the field of automatic identification has been *RFID*. It stands for radio frequency identification. The RFID is no longer a state-of-the-art procedure, but rapidly developing information technology has made it more attractive to an extensive amount of potential users. The development of microprocessors and silicon chips has helped RFID to overcome some technical challenges and pushes its cost downwards whenever a new generation of chips has been launched. The RFID provides capability to attach an electronic identity to a physical object, which effectively extends Internet into the physical world. For logistics this can lead to faster order automation, tighter process control, precise up-to-date inventories and real-time locations. In a wider scale, business partners are able to share information on the goods through a supply chain in a way not yet conceivable a few years ago. (Glower, 2006: 5)

1.2 Purpose, goals and definition of study

The study has been made on the assignment of Metso Paper Service. *The purpose* is to figure out whether RFID could improve given operations of Service. *The goal* is to identify application areas, where significant improvements and cost savings might be gained by employing RFID, compared to current ways of operation.

Metso Paper Service falls into many processes, where material identification is an important part of everyday operation. Depending on the character of the process, needs and ways for material identification varies but the common feature is that RFID is not yet either used or considered carefully anywhere. Thus, this study has been considered reasonable.

The definition of the study is to focus on the usability of RFID in the processes of Metso Paper Service and not on the technical details of RFID no more than to a degree necessary to understand about how RFID can actually be used. Another constraint is to focus on logistics and not maintenance operations, while identifying potential RFID application areas. In addition, possible pilot projects or implementation works are outside the scope of the study, as well.

1.3 Metso Paper Service

Metso Paper is a global provider and market leader in pulping, paper and board production, as well as power generation technologies. Its product portfolio serves customers throughout their processes, from pulp making to the wrapping of finished rolls. The company has its own operations and production in 28 countries and its products and services are sold by more than 20 sales units and 40 service centres in different parts of the world, as well as the logistics centres in Finland, the USA and China. Approximately one third of the global paper production is performed on production systems supplied by Metso Paper. The largest market areas are Europe, Asia and North America. (Metso Paper, A)

Metso Paper Service is part of Metso Paper's Paper and Board business line. It covers three sectors such as traditional *equipment service*, *maintenance* and *product support services*. The maintenance service stands for Metso Paper's partial or full responsibility of customer maintenance operations. The product support service means that Metso can support process and product development in co-operation with the customer. However, both of them are outside the scope of this study, since the study focuses on equipment service processes.

The equipment services consist of three expert sectors, which are *Field*, *Roll* and *Spare part services*. In addition, Metso Paper Service provides automation and field system services and upgrade solutions tailored to customers' needs but these are outside the scope the study. Consequently, the focus is on the processes in expert sectors, which are clarified as follows:

- The field service includes maintaining and enhancing the performance of fibre processing and paper making lines.
- The roll workshop stands for mechanical roll service, replacement of rolls and roll covers.
- The spare part service includes daily spare, spare part packages and consumables. (Metso Paper, B, 4)

1.4 Presentation of the study

The study consists of introduction, theory and empirical research sections. The first chapter is an introduction that deals with the purpose, goals and definition of the study. Chapters 2 – 6 form the theory section, giving some basic information on logistics and automatic identification methods. Chapters 4 and 5 take deeper insight into bar codes and RFID through literature review. The viewpoint is end-user oriented and deep technical details are mainly omitted. These techniques are the most famous ones to conduct automatic identification in logistics.

The purpose of the study is to determine whether RFID could improve applications in Service. However, it was also seen reasonable to introduce alternative bar codes in order to understand differences in their capabilities. Consequently, it attempts to clarify why Metso Paper Service is particularly interested in the possibilities of RFID. Finally, the theory section ends with chapter 6, which introduces two methods that can be used to determine investments advisability. These are SWOT analysis and pay-back calculation. Both of them were used during the empirical research stage.

The chapters 7 – 8 deal with empirical research. The chapter 7 takes a look into processes, in order to understand their main operational issues. The processes are studied one by one ending up to SWOT analysis, which is used to evaluate RFID suitability in that application. Finally, the chapter ends with a summary indicating the most potential processes for RFID.

The most potential one or ones will be further investigated in chapter 8, which clarifies how RFID-managed processes run operationally and what kinds of devices are needed. The chapter ends with calculations that indicate pay-back time and net savings in a given period of time. Finally, the findings are summarised in chapter 9 and suggestions made for further RFID studies.

2. THE BASIS FOR LOGISTICS AND IDENTIFICATION

2.1 Logistics

Logistics is the applied science of planning and implementing the acquisition and use of resources. However, if you ask people to define logistics each one might give a different answer. Generally, the definition depends on the concept the definer has of its application context. Thus, logistics can be defined in many ways depending on a person's business and role in life. For example, the automotive industry defines logistics as the entire process from the source of raw materials to the manufacturing process that results in cars for purchase. (Jones, 2006: 21)

Dictionary of transport and logistics vocabulary determines logistics as follows:
Logistics is time-related positioning of resources to meet user requirement. (Lowe, 2002: 147)

To clarify the concept of logistics further, it can be considered to consist of a standard set of actions. Those are definition of need, identification of limits, determination of terminal objectives, measurability and assessment. Thus, all logistics actions are based on meeting a completely predetermined need. Simultaneously each resource has limitations, ranging from minimum to maximum acceptability of the situation.

The stated set of terminal objectives guides all logistics activities in their application. By establishing measurable criteria for processes, the process holder is able to guide the progress towards terminal objectives. Measurements can be tangible or intangible. In case of a tangible characteristic, such as number of pieces, everybody can easily determine, if the criteria have been met. But intangible characteristics are usually understandable only for process holders. Continuous assessment needs to run on the background to determine the success or failure of any single activity. It is conducted by comparing the progress against the given measurable criteria. In practise, assessment before starting the activity may simply be checking that all needed things are in place. During the activity assessment controls near-term success of short-term needs that eventually lead to overall success. At the end of activity assessment it is ensured that all terminal objectives have been met. (Jones, 2006: 21-23)

2.2 Identification

Identification means classifying, counting and organising objects. These operations are the very essentials in logistics environment such as manufacturing, distribution and various stages of supply chain operating from the scale of individual consumer to global trade. In the past industrial identification was done visually just by observing the characteristics of objects. When identical objects have to be identified distinguishing markings have been added. Further accurate and efficient means are needed to recognise those markings, in order to identify the objects. Therefore, an identification system consists of identifying markings and readers of those markings. The first readers were human beings but by the time technical innovations resulted in cameras and laser devices they started to be used as readers. Simultaneously basic written markings have evolved into commonly used bar codes that can be found from almost every package and item. (Committee on Radio Frequency Identification Technologies, 2004: 3)

Typically identification in the supply chain involves tracking and controlling critical information in real-time. Consequently, it enables reacting to changing circumstances faster and gain real-time competitive advantages. For instance, effective material identification delivers transparency in supply chains and results in:

- Quicker receiving, as unnecessary manual steps are removed.

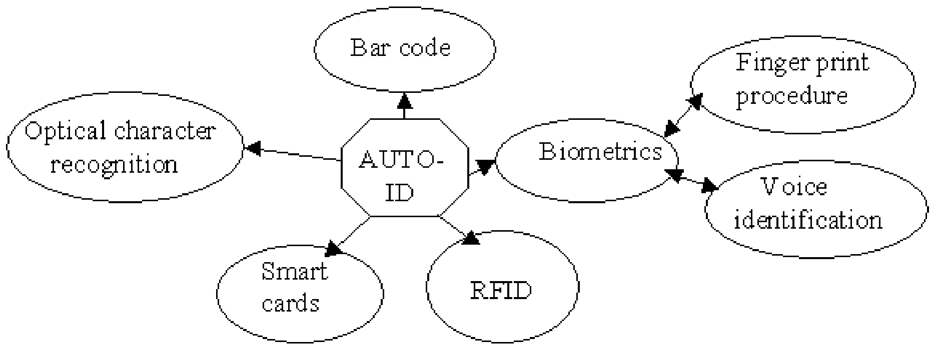
- Less time is spent in solving logistics issues.
- Early notification of subcontractor delivery issues enables corrective actions to be taken early.
- Exact status of inventory is available in real-time, resulting in fewer buffers.
- Faster and easier inventory management and efficient logistics process.
- Decreases loss of goods and assets.
- No unexpected product shortages.
- More manageable product liability.
- Increased customer satisfaction as service levels improve.

(Trackway, 2008)

3. INTRODUCTION TO AUTOMATIC IDENTIFICATION TECHNOLOGIES

When human beings are involved in the identification of objects, keeping track of changes in locations and inputting this information into a database, the process is time consuming. In addition, the process is vulnerable to human errors. (Muller, 2002: 89). Thus, automatic identification procedures (Auto-ID) exist to provide timely and accurate information on goods and products in transit. A long time ago bar code systems started a revolution in that field but nowadays there are also several another identification systems available, such as Radio Frequency Identification (RFID). Currently, bar codes and RFID are the most widely used identification procedures in logistics. Meanwhile, others not so significant procedures in terms of logistics are Biometrics, Optical Character recognition and smart card procedures. Picture 1 summarises the most important auto-ID procedures. (Finkenzeller, 2004: 1-2)

There are some features that must be taken into account when evaluating automatic identification technologies. One of them is *error rate*. It refers to the probability that a given number of scanning occasions include an error. Then the expected number of errors can be calculated by multiplying error rate by the number of characters scanned. Another one is *the first read rate*. It refers to the probability that an attempt to read a character is successful on the first attempt. The next important feature to be considered is *scanning distance* between the reader and the object and *can a moving object be scanned*. Last but not least, it must be considered whether the technology permit *modification of the recorded data* or not. That ability will offer the greatest flexibility. In addition, in a busy environment the time that a single scanning takes may play important role to an operating speed. (Palmer, 2001: 3-4)



Picture 1. Summary of the most important auto-ID procedures.

3.1 Bar code

The bar code is a binary code comprised of a bunch of bars and gaps arranged in a sequential order in some predetermined way. This design can be interpreted numerically and alphanumerically, in order to identify the object. Bar codes are read by optical laser scanning based on the different reflection of a laser beam from the black bars and white gaps. There are several different types of bar code symbols currently in use, each of them were developed for the purpose of some particular application. As a consequence, the same physical design can represent different meanings in different types of bar codes. (Finkenzeller, 2004: 2-3)

The reading distance is relatively short, ranging from the near contact only up to about a couple of meters. Reading always requires a clear line of sight to the undamaged barcode to ensure correct interpretation of it. The data security is high and normal error rate can even be less than one error in 1 million characters. Conventionally, the first read rate is better than 80 % and might even be close to 100 %. The biggest limitation of the bar code system is that codes can be written only once and any additional information cannot be added later on. Partly due that reason the price of enabling a bar code system is cheap. (Palmer, 2001: 9)

3.2 RFID

Radio Frequency Identification (RFID) is a procedure to identify objects by using radio waves. Therefore, there must be an identification element called a tag, which holds the identification data, attached to the object. The tag responds to the radio waves. Successful identification does not require a direct line of sight between the tag and the radio waves transmitter called a reader. In addition, the scanning distance can vary from near contact always up to a long way off, depending on the coupled design of the reader and the tag antenna. The error rate is very low and conventionally tags can be read on the first attempt. These characters enable quite a wide range of applications for RFID and simultaneously make it more efficient and accurate than other identification technologies.

Tags are an essential part of RFID systems. The simplest version of tags is a passive tag. It does not have its own power source and is entirely dependent on getting power from the reader. A passive tag does not provide much space for data and can not be rewritten; usually only identification date is encoded into it. Adding even a simple sensor or power source into a tag can increase its utility radically. This makes a tag active. More information can be encoded initially and even additional information can be encoded later on. The cost of RFID tags vary from a fraction of US dollars with passive tags up to several hundreds with active tags. This has been delaying RFID revolution. In recent years prices have gone down, boosting the utilisation of this technology. (Committee on Radio Frequency Identification Technologies, 2004: 3-5)

3.3 Biometrics procedures

Biometrics procedures in identification systems mean the ways that living beings are possible to identify. That is done by comparing unmistakable and individual physical characteristics. One way to conduct identification is to take a fingerprint not only from the finger itself, but also from the object that individual in question has touched. Then the system checks the database in order to find a match. This is a commonly used procedure to permit entrance and also to identify criminals. Another application is voice identification. In that case the user talks to the computer, which convert the voice into a digital signal. The software evaluates the signal against the database. If it matches, a reaction can be initiated. (Finkenzeller, 2004: 4)

3.4 Optical character recognition

Optical Character Recognition (OCR) was developed for the purpose that characters could be read both in the normal way by people and automatically by a machine. This system provides high density of information but failed to become a popular application, because of its compliance and expensive components, in comparison with other identification products. An additional negative aspect is that the reading rate is slower and error rates higher, if compared to bar code system as an example. In some scale, this procedure is used in service and administrative fields. (Finkenzeller, 2004: 3-4)

3.5 Smart cards

The smart card is an electronic data storage system. The characteristic feature of it is an integrated circuit called a chip that is incorporated in the card. The chip has components for storing, transmitting and processing data. Data is transmitted when a smart card is placed in a reader, which makes either a galvanic connection on the contact surfaces or an electromagnetic field without any contacts. The most significant advantage of the smart card is that the stored data can be protected against undesired access and manipulation. Smart card technology is also reliable and has a long lifetime. The development of chips is very fast and their capacities have been multiplied with every new generation of chips. It is possible to divide smart cards into two different categories based on their functionalities. These are memory cards and microprocessor cards. Memory cards contain EEPROM memory. The memory is for the program code needed by the application. These cards are usually specified for some particular application, which cannot be changed later on. On the other hand, memory cards are inexpensive. For that reason they are typically used in price-sensitive applications, such as prepaid mobile phone cards. (Rankl & Effing, 2004: 17-19)

Microprocessor cards contain a microprocessor, which includes ROM, RAM and EEPROM memories. Contest of ROM is defined during the manufacturing and its purpose is to incorporate the microprocessor and operating system. This memory cannot be overwritten. The RAM is temporary working memory and does not maintain the data, since the card is disconnected from the reader. The EEPROM is for application data and can be controlled by the operating system. Primarily microprocessor cards are aimed for security sensitive environments and can include a number of applications. Examples of usage are credit cards and mobile phone SIM cards. (Finkenzeller, 2004: 6)

4. BAR CODE SYSTEM

Automatic identification can be conducted by bar coding. It is an optical read-only procedure, which is based on the reflection of light off a printed pattern. The dark bars or areas of the pattern absorb light and the intervening spaces reflect the light. The contrasting absorption and reflection is observed by the reader, which decodes the information. The pattern, which is the real arrangement of parallel bars and spaces that encode the data, is usually called a bar code.

A bar code system conventionally consists of three components: the code itself officially known as the bar code symbol, the reading device and the printer. There are some international bar code standards, which determine generic rules for defining bar code symbols, as well as specific rules for some particular application. (Muller, 2002: 90)

4.1 Bar code symbol

Conventionally, a bar code symbol consists of bars and intervening spaces to encode the data. A given number of bars and spaces build up a character and a given number of characters build up a bar code symbol. It is appropriate to differentiate between the terms “code” and “symbol”. A code refers to the actual data contained in characters, whereas a symbol refers to the actual arrangement of sequential bars and spaces. In this respect, the pattern should not be called a bar code but a bar code symbol instead. Some symbols can encode only numbers, whereas other symbols encode alphanumeric characters. Bar code symbols can be divided into linear and 2D categories. (Palmer, 2001: 15-18)

4.1.1 Linear bar code symbol

A linear bar code symbol, picture 2, is a single row of bars and intervening spaces. This is the oldest form of bar codes. It has a low capacity, typically from 15 to 50 characters, depending on which type of symbol is in question. The data can be encoded either in a width-modulated or a height-modulated way. The first one means that bars and spaces vary in width and in the latter they vary in height.

Further width-modulated symbols falls into discrete and continuous types. Characters in a discrete code stand alone. There is a gap between each character. It starts with a bar and ends with a bar. This feature makes discrete code easier to read and print. Characters in a continuous code start with a bar but end with a space. There are no gaps between characters. This feature allows the insertion of more characters in a smaller space, which is a good thing with a bar code label with limited space available. The generic structure of linear bar code symbols includes three parts:

- There is *a quiet area* at both side of the symbol. Its purpose is to distinguish a symbol from its background in order for readers to identify the code accurately.
- There is a *start and stop character*. The start character indicates the starting point of the symbol and, as the name suggests, the stop character indicates the point where the symbol ends. That symbols enable scanning devices to read a bar code symbol from left to right and vice versa.
- Between start and stop characters are actual *data characters*, which compose the message. (Palmer, 2001: 16-24)

1 25002 74135 0

Picture 2. Linear bar code symbol.

4.1.2 2D bar code symbol

2D bar code symbols were developed in an attempt to reduce the room typically needed by conventional linear bar code symbols. Because the more data is encoded into a linear symbol, the taller a symbol would be. In many cases traditional symbols act as a license plate to reference information stored in a database. 2D symbols are able to do that with significant less space or even function as the database itself, because of their higher data storing capacity of up to 2000 characters. 2D bar code symbols can be divided into two categories, which are 2D stacked and 2D matrix symbols. These are illustrated in picture 3.

2D stacked symbols are basically very long linear bar code symbols cut up into shorter linear lines and stacked up in a multi-row arrangement. All the rows are the same length and either touch each other or include a single bar separating them. This is printable with similar techniques as linear symbols.

More sophisticated are 2D matrix symbols. They do not consist of rows of bars similarly as stacked symbols but rather of a grid of square cells. Thus, they are read independent of orientation. Matrix symbols have even higher data capacity than stacked symbols, but require special printing and reading equipment due to the resolution requirements. (Palmer, 2001: 17, 48, 58)

Picture 3. 2D stacked and matrix bar code symbols.

4.2 Industrial bar code symbols

All different bar code symbols have their own fixed alphabets made up of bars and spaces coupled with the rules for how they are presented. Some of them employ only numbers, whereas others also employ alphabets and even special characters. Some widely used industrial symbols are presented below. (Muller, 2002: 95)

Code 39

Code 39 is popular in industrial bar code applications, such as warehousing, tracking shipments and manufacturing. It is illustrated in picture 4. It contains 43 data characters; numbers, all uppercase letters and seven special characters. The code can be printed easily by most software available and can vary in length. It is also self-checking and discrete. Self-checking means that a single printing error cannot cause a character to be mixed with another valid character in the same symbol. All of its characters consist of 9 elements, five bars and four spaces. Three of these elements are wide and six are narrow, making up its name code 39. (Palmer, 2001: 27-30)

CODE39

Picture 4. Code 39.

Code 128

Code 128 is a linear symbol, which is increasingly used, for instance, in retail distribution applications for serialised carton tracking. It is illustrated in picture 5. It is continuous and can vary in length. This code type supports all the ASCII characters, so all alphabets can be used in upper and lower case letters, as well as numbers and all special characters. The code 128 has three alternate character sets.

Each of them includes shift and start codes to control which set is used. This feature permits changing a character set inside a symbol, in order to express the encoded message as shortly as possible. Each character of the code consists of 11 elements with equal width, which further build up totally three bars and spaces. For example, a single bar could be from 1 up to 3 elements wide. (Palmer, 2001: 34-37)

Picture 5. Code 128.

Code 49

Code 49 is a 2D stacked symbol. It contains two to eight adjacent rows separated by a single-module separator bar. Each row has eight characters consisting of 70 elements, which equal 17 bars and 17 spaces eventually making up four words. Rows can be in any order, because each row contains a row number and the bottom row encodes the total number of rows in the symbol and check characters. The number of rows depends on the number of the characters being encoded. For example, eight rows provide enough room either for 49 alphanumeric or 81 numeric characters. The code 49 supports ASCII characters. (Palmer, 2001: 48-50)

4.3 Bar code reader

A device that reads bar code symbols is called a bar code reader or a bar code scanner. The purpose of these devices is to determine the exact width of bars and spaces and decode that information into digital forms that a computer can understand. This is accomplished by projecting a tiny laser beam that crosses the bar code symbol and then measuring the amount of reflection off bars and intervening spaces. A reading device is able to transmit decoded data instantly to the attached computer or can interact with an application program that is resident in the reading device itself.

To avoid misreads and compatibility problems with given bar code symbology the beam of light of scanning devices must not be larger than the X dimension of a bar code symbol. That dimension is the width of the narrowest bar, as well as space in a given type of symbol, such as code 39. In addition, readers for 2D codes are able to read linear codes, as well but that does not work the other way around.

Bar code readers fall in the following subcategories. These are contact, non-contact and conveyor readers. (Muller, 2002: 101-103)

4.3.1 Contact readers

As the name suggests, contact readers physically touch the symbol that is being scanned. Typically those kinds of devices come in the form of a light pen or wand and are used in an office environment to scan bar code symbols on the papers substituting a manual key entry. The beam of the device is fixed and the scanning motion comes from the user, who manually passes the device across the bar code symbol. Despite contact with the symbol it still has some depth of field, meaning that a thin laminate can be employed to protect a bar code symbol being scanned. (Palmer, 2001: 126-127)

4.3.2 Non-contact readers

Non-contact readers can either be handheld or stationary. Handheld means that users need not write but must place the reader near the bar code symbol. Stationary is for automatic reading, then the object must be placed under a scanner in some predetermined position within a given distance that a direct line of sight exists between the object and the reader. In addition, non-contact readers are able to read codes on soft or irregular surfaces even through thick laminates or windows. Typically non-contact readers come in the shape of a pistol. These readers employ fixed beam, moving beam, and charged couple device CCD and rastering laser technologies:

- Fixed beam scanners use a stationary beam to scan a bar code symbol. The operator provides the scanning motion.
- Moving beam scanners use a moving beam to scan a bar code symbol and no additional moving motion is required.
- CCD scanners scan the light path as a whole with electronic detectors.
- Rastering scanners have higher horizontal and vertical scanning amplitude in order to capture a rectangular area, which matches to 2D symbols.

(Palmer, 2001: 128-132)

4.3.3 Conveyor bar code readers

Bar code readers alongside a conveyor face some special challenges. Basically, the location and orientation of symbols on the object are fixed but the position and orientation of the object on the conveyor are unknown. In addition, the speed of the conveyor must be taken into account as well. Existing device alternatives are orientation-dependent and omnidirectional laser scanning.

Orientation-dependent laser scanning utilises a fixed-mount moving beam technology. If the object and symbol orientation are fixed, then those types of devices can be used. Also the scanning line length, scanning rate, bar height and conveyor speed should be such that a scanner has the minimum of four opportunities to scan the object as it moves by. If a rastering scanner is utilised, a successful scan is more likely, because it moves the scan line direction perpendicular to the scanning motion. Then poor symbol placement is better compensated.

The probability of a successful scan is far better if omnidirectional laser scanning is utilised. It is a sophisticated version of fixed-mount moving beam technology. The primary idea is to project a series of straight or curved scanning lines of varying directions in a star-shaped form over the object. Then at least one of the scanning lines will be able to cross the symbol, no matter what symbol orientation or location. It must be mentioned that 2D symbols cannot be read by omnidirectional laser scanning. (Palmer, 2001: 147-150)

4.3.4 Vision-based reading

As the name suggests, vision-based reading devices take electronic pictures including a symbol of the object. No laser is used. Then special software detects and decodes the symbol from the electronic picture. This procedure is independent of careful position and orientation of either the object or the symbol. It has the ability to interpret basically all conventional linear symbols as well as 2D stacked and matrix symbols. Three basic types of devices are available:

- Handheld vision scanners take a picture when the operator discharges a trigger.
- Fixed-mount vision scanner using 2D imager can be used to take a snapshot of the screen or a continuously strobed 1D imager can be used to snap continuous images of passing objects. Both can be done unsupervised.
- Fixed-mount vision scanners using linear imagers are typically custom built. They can be used to scan symbols in a 2D format on rapidly moving conveyor lines. This happens automatically and does not require an operator.

(Palmer, 2001: 153-155)

4.4 Printing of bar code symbol

In a bar code system everything starts with a symbol. That symbol must be generated in some practical form available. Usually this is done by printing a symbol on the label or various kinds of similar substrates, which are attached to the object. Bar code printing can be divided into offsite and onsite printing.

Offsite printing

Offsite printing conventionally takes place at a location different from the one the bar code symbols will be actually used. These techniques are designed for mass production of identical or sequenced symbols. Often this kind of printing service is purchased from specialised service providers, such as print shops and bar code symbols are included in the actual carton or packaging material permanently.

Onsite printing

It conventionally takes place at the time and place symbols are to be used. This enables the encoding of unique data into each symbol on demand. On the other hand, it is not a competitive solution in terms of speed for large-scale printing of identical symbols. The absence of this feature is not a problem in its typical application in warehouse and retail industry. (Palmer, 2001: 159-165)

Some basic onsite printer techniques are described below:

Direct Thermal

- Printer forms symbols on a paper by selectively heating localised areas of paper. This is done by the elements in the printhead, which is in contact to the paper.

Thermal transfer

- Printer forms a symbol on a paper from a ribbon that is heated by the elements in the printhead.

Ink jet

- Printer has a fixed printhead, which sprays tiny droplets of ink on paper.

Laser / xerographic

- Printer has a controlled laser beam, which creates a symbol on paper. (Aim, 2008)

4.5 Standards

Standards are very important for the acceptance and adoption of new technologies. Consequently, there are three main standards to ensure successful operation with bar codes. These are symbol, print quality and application standards. In addition, there is also an organisation called Association for Automatic Identification and Mobility (AIM) to control and develop this area.

Standards for bar code symbols define the appearance of the certain bar code symbol. In other words, it determines the exact width of bars and spaces and how the data is encoded. Standards also carefully determine all other features of bar code symbols such as spots, voids, reflectivity, contrast and edge roughness. For example, there are standards for all commonly known linear and 2D symbols, such as code 39, code 128, code 49 and data matrix. (Aim, 2008)

Print quality standards define bar code symbol measurement methods. Consequently, the standards are used to check whether some particular bar code symbol fulfil the requirements of its standard or not. There is one standard recognised worldwide and it is referenced in all symbol and application standards. It is called ANSI X3.182 bar code print quality guideline published by American National Standard Institute (ANSI). (Aim, 2008)

Application standards are specific to certain industries. They define how technology is used to boost productivity by achieving desired scan rates. Conventionally application standards consist of a symbol based on AIM standard and print quality level based on ANSI X3.182 standards. Often application standards relate to the distribution of an item in an open system. Open systems have several parties which all are able to operate under a given standard. There is one ultimate “shipping label” standard recognised worldwide called ANSI MH10.8M for unit loads and transport packages. (Palmer, 2001: 105)

5. RFID

RFID stands for Radio Frequency Identification and it is an automatic identification procedure. The basic idea of this system is to identify objects at a distance without requiring a direct line of sight by using radio waves. The two most talked-about components are a tag and a reader. The tag is an identification device containing the data and it is attached to the item. The reader can recognise the presence of nearby tags and read the data stored into them. The reader communicates with software called middleware, which connects the RFID system to an application, such as an enterprise resource planning (ERP) program. These main parts are described in more detail in coming sub-chapters. (Glover & Bhatt, 2006: 1)

5.1 Tag

The purpose of an RFID tag is to attach encoded data to the object, since then the object is recognisable whenever necessary. Tags are available in a wide variety of shapes and sizes as well as for different usage environments. However, a connective feature for all tags is that they have some internal system for storing data and are attachable to the object in some way. Each tag must also be able to communicate with the reader on some radio frequency. This is why tags always include some kind of antenna or coil. In addition, many tags may have one or more of the following features:

Kill / disable

- Some tags can cease to function permanently by a command of the reader. After this the tag will never respond again.

Write once

- The data is permanently encoded into the tag during the factory manufacturing process and cannot be changed. If the data for some reason needs to be changed, the only way to do it is to replace the tag.

Write many

- Some tags allow users to rewrite new data into the tag over and over again.

Anti-collision

- Sometimes readers may find it difficult to separate tag responds from each other if many tags are in very close proximity to each other. Thus, tags with an anti-collision ability are able to queue and respond in turn.

Security and encryption

- Some tags will only respond to readers that can identify themselves by giving a password. Other tags, on the other hand, are able to communicate under some encryption.

Standard compliance

- A tag may have been manufactured according to a standard so it is able to talk with readers within the same standard.

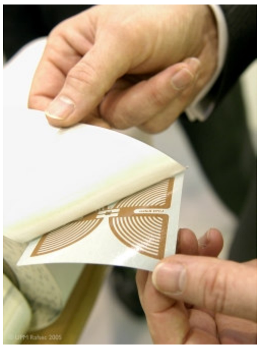
(Glover, 2006: 55-57)

5.1.1 Tag categories

Conventionally, tags are categorised into 3 types depending on their power source. A new arrival is the so-called *two-way tag*. In addition, the power source has major influence on the price and lifetime of a tag and partly with operational frequency impact on the read range.

Passive tag obtains all of the required energy by a method of transmission from the reader and because of this it has a virtually unlimited lifetime. It does not require maintenance and is the cheapest (20 – 40 cents) but read range is also shortest, varying from a very short distance to a maximum of 10 meters, depending on the operating frequency. A passive tag requires a more efficient reader, since they have no battery.

Passive tags can operate at a low frequency LF (124 kHz, 125 kHz and 135 kHz), a high frequency HF (13,56 MHz) and at an ultra-high frequency UHF (860 – 960 MHz). Different frequencies have different properties, in terms of read range, permeability of material and speed of data transfer. For example, LF and HF tags form a magnetic field with the reader for communication purposes. This method of communication is called inductive coupling. In such a system the tag must be fairly close to the reader, which limits the read range of the system. Simultaneously, tags with LF are well suited for applications, where an item needs to be identified through some material but not work accurately through metal or water. LF tags can be read within 0,33 meters. Tags with HF have a read range of maximum 1 meter and tags with UHF have a read range of up to 3,3 meters, because they use radio waves instead of magnetic fields in communicating with a reader. This is called propagation coupling. HF and UHF have greater data transfer capability than LF but cannot penetrate materials as well and especially UHF tends to bounce off many objects. However, LF / HF tags are good for the identification of individual items, whereas UHF is good for pallets and shipping units. UHF is the frequency area in which the most modern systems operate. Picture 6 illustrates a passive UHF RFID tag. (RFID Journal: 2 A)



Picture 6. Passive label shaped RFID tag. (Vilant)

Active tag includes its own battery to power communications, processor memory and possible sensors. This is the most expensive type of tag, the price of which ranges from a couple of euros to up to dozens of euros. Conventionally, active tags operate at 455 MHz, 2,45 GHz or 5,8 GHz frequencies and have extremely long read range, varying from 20 to 100 meters. Despite of the long read range, they can be read reliably, because they broadcast a signal to the reader differently from passive tags. Active tags can even perform some activities without the presence of a reader, such as environmental measuring by an included sensor. Additional features requiring power highly affect the operational time of tags, which may due to this reason be only around 10 years. (RFID Journal, 2008: 1). ***Two-way tag*** includes a battery and is capable to initiate communication with other tags of its kind without the support of a reader. (Glover, 2006: 58)

A Semi-passive *tag* is a recent term for a tag that includes its own battery to power some functions but powers communication with the energy of the readers. The read range and price are somewhere between passive and active tags. (Glover, 2006: 58)

5.1.2 Smart labels

Smart labels combine a RFID tag and bar code, as well as human-readable text into the paper label. In other words, it allows a user to encode a RFID tag with the identity and also print a bar code and / or human readable text on to the paper label. Therefore, the basic anatomy of a smart label is that the surface of the label is for a bar code and label text. The backside of the label has an adhesive coating, so that the label is attachable to the object. Thus, the RFID tag is extremely thin and sandwiched in the middle.

Smart labels are currently one of the most commonly used tags in RFID applications. It is probably the easiest way to get into the world of RFID, because it can be encoded and printed on-site, based on the users´ needs. It is also reliable, because printing devices verify that all of smart labels function correctly before being attached to the item. (Kleist, Chapman, Sakai, Jarvis, 2004: 66-68)

5.1.3 Standards

Some tags operate internally in some applications of a single company. Thus it is not so important which standard the company has decided to use. Some other tags must share information with partners in open logistic supply chains and in a situation like this it is extremely important to use standardised tags validated by the field of business. Generally, the purpose of standards is that different parties use certain kinds of tags and related devices that partners are able to understand. In addition, many manufactures could manufacture tags according to a standard, so users are not dependent on a certain manufacturer. In the long run, standards will also drive the cost of tags down and boost their utilisation. (Glower, 2006: 71)

Until recent years, the RFID industry has been driven by two different proposed standards. The first one is based on the Electronic Product Code (EPC) system that has digits to identify the manufacturer, product category and the individual item and a storing capacity ranging from 64 to 256 bits. The EPC is being developed by EPCglobal, a non-profit organisation founded by EAN International and the Uniform Code Council (UCC). The second standard is being developed by the International Organisation for standardisation (ISO). The two competing standards were limiting the worldwide adoption of RFID, as end users were reluctant to invest on either one of them, because it was unclear, which would become the leading standard in the end. No matter, that plenty of effort has been put into finding a way to blend these two standards into one. (RFID journal, B) Basically, standards in the RFID environment are actually seeding a new industry, rather than describing existing practices and technologies. (Glower, 2006: 215)

One major challenge slowing down the development of new standards is the different radio spectrum regulations from country to country. EPCglobal is maintaining a list about UHF regulations worldwide. The goal is to harmonize those regulations into a range of 860 to 960MHz. For example, most of the European countries conform to the frequency range 865.6 – 867.6 MHz but China has decided to use 840.5 – 844.5 MHz, as well as 920.5 – 924.5 MHz. The USA has a frequency range of 902 – 928 MHz. (EPCglobal, 2008, A)

EPCglobal defines a combined method of classifying tags that specifies frequencies, coupling methods, types of keying and modulation, information storage capability and modes of interoperability. All of its tags are intended to carry the Electronic Product Code (EPC). The different classifications of tags recognised by EPCglobal are as follows:

- Class 0, passive read-only
- Class 0+, passive write-once but using class 0 protocols
- Class 1, passive write-once
- Class 2, passive write-once with extras, such as encryption
- Class 3, rewritable, semi-passive with integrated sensors
- Class 4, rewritable active, two-way, powering their own communication
- Class 5, can power and read class 1, 2 and 3 tags and read class 4 and 5 and acting as class 4 themselves (Glower, 2006: 72)

ISO has developed standards for the RFID automatic identification; item management and air interface protocol how tags and readers communicate. The standards for tracking goods in open supply chains are known as the ISO 18000 series and are aimed to cover major frequencies used in RFID systems around the world. They are as follows:

- 18000-1: generic parameters for air interfaces for globally accepted frequencies
- 18000-2: air interface for 135KHz
- 18000-3: air interface for 13.56 MHz
- 18000-4: air interface for 2.45 GHz
- 18000-5: air interface for 5.8 GHz
- 18000-6: air interface for 860 to 930 MHz
- 18000-7: air interface for 433.92 MHz

EPCglobal class 0 and 1 tended to be used in similar supply chain applications although they are interoperable, i.e. the user must have two types of devices to operate. Thus, in early 2004 there was a need to develop a new class to replace classes 0 and 1. This means that one reader could read all EPC tags. At the same time ISO was developing its 18000-6 series. Some major vendors also worked with these two coming standards and put huge pressure on the two standard organisations to merge them. It was a great opportunity to create one standard, because the new EPC class seems to be quite close to ISO’s 18000-6 series. (RFID journal, B)

As a result, in summer 2004 EPCglobal has announced class 1 Generation 2 (Gen2) standard and in summer 2006 ISO has amended its ISO/IEC 18000-6 type C, formally known as 18000-6C, to include Gen2 standard. In practise, this means that RFID systems using Gen2 standard are also compatible with systems made up according to ISO 18000-6C standard. End users finally have a clear vision about which type of RFID devices to invest, in order be able to operate successfully in global open supply chains. (RFIDUpdate, 2006)

As a summary, Gen2 is a standard which combines EPC classes 0 and 1 and ISO 18000-6C standards. It defines the physical and logical requirements for a passive, reader (interrogator) talks first (ITF), RFID systems operating in the UHF (860 – 960 MHz) frequency range. RFID systems in this context mean transactions between tags and readers allow the maximum read range of up to 10 meters. (EPCglobal, 2007, B)

It must be highlighted that there are no standards for active and HF tags. Each supplier of active tags has their own standard and related devices, which are not compatible with systems of other suppliers. In addition, EPCglobal is working on an HF standard but it is still in process.

5.1.4 Information storage capacity

RFID comes in a wide range of storing capacity. The simplest tags store only 1 bit. These tags can only recognise the absence or presence of the tag and can not identify individual items. These are conventionally used in libraries and clothing stores to prevent theft. Some tags may store kilobytes of data but typically a tag carries no more than 2 kilobytes of data. That is enough to store some basic information about the item the tag is attached to. Larger data storage capacities require active tags. The higher the data storage capacity, the more the tag costs. In order to reduce cost it is recommended to store only an identifier on the tag and look up rest of information on a database. (Glower, 2006: 67-68)

As mentioned earlier, the EPC tags have a user memory ranging from 64 to 256 bits, which allows user-specific data storage. For example, commonly used EPC standard tags have 96 bits of user memory, which can store 24 HEX-digits. HEX digits consist of numbers 0-9 and letters A-F. Generally, 1 digit equals 4 bits, so a tag with 256 bits can store 64 digits. (Lahtinen, 2008)

5.1.5 Tag protocol

A tag protocol is a set of formal rules describing how to transmit data between readers and tags. Some important terms related to tag protocol are s*inqulation* and *anti-collision. Singulation* refers to a procedure that reduces a group of things to a stream of things that can be handled individually. *Anti-collision* is a term that describes a set of procedures to prevent tags from interrupting each other and talking out of turn. (Glower, 2006: 77-78)

The ways in which readers and tags communicate can roughly be categorised as *tag-talk-first* (TTF) high-end active tags or *reader-talk-firs*t (RTF) smart labels and other passive tags. However, it would be simplest if tags arrived on the scene to announce their presence to all involved. In practise, this will cause reading problems, unless tags are able to speak taking turns, instead of all speaking at the same time. This is why RTF protocols are preferred. The most common of these protocols are:

Slotted aloha

With this anti-collision protocol tags begin to broadcast their ID´s as soon as they have arrived at the read range of the reader, then they are able to obtain energy from the reader signal to energise them. The reader only receives the signal and does not reply in any way. This is simple and fast but unworkable with more than 12 tags. Thus, adding even some concept of sinqulation and requiring tags to broadcast only at particular time slot remarkable cuts the chances of a collision. Variations of slotted aloha is used for ISO 18000-6 type B and Gen2 RFID types of tags.

Adaptive binary tree

EPC class 0 and 1 UHF tags use this sinqulation and anti-collision protocol. In this protocol a binary search is used to find one tag among a bunch of tags. At first the reader sends a query asking, “Does any tag have an ID beginning with a bit 1?” Tags that answer “No” then step out of conversation, whereas tags that answered “Yes” are asked similar question about the next bit. The tags are narrowed down until only one tag is left.

Slotted terminal adaptive collection

Part of the EPC specification for HF tags is described with the abbreviation STAC. This protocol is especially suitable for the sinqulation of a large tag population, because it provides up to 512 slots. A group of tags or a single tag is selected based on matching lengths of tags with an EPC code beginning with the most significant bit (MSB) and ending in the least significant bit (LSB). Since an EPC code is organised by header, domain manager number, object class and serial number from MSB to LSB, this protocol can easily select tags belonging to some particular group, such as a certain object class.

EPC Gen2

The protocol has three alternative ways for communication between readers and tags. A reader may *select* tags by asking them to compare themselves to each other. A reader may *inventory* tags by sinqulating them, until it has recognised each tag within range. A third way to communicate is to *access* tags. That includes reading stored data, writing new data and killing or locking some memory sections of the tag. This protocol also allows devices to operate both under European and USA radio frequency regulations, which is impossible for EPC class1 gen1 devices. (Glower, 2006: 87-96)

5.2 Reader

The purpose of RFID readers is to recognise the presence of nearby RFID tags. Typically, the reader transmits signals and tags inside the operating range pick up the signal. The signal is sufficient to power the semiconductor chip inside a tag, which stores the identity of the tag. After this, the tag returns the identity to the reader. This is only one way, in which readers and tags interact and some others may work in slightly different ways. Readers are available in various kinds of shapes and sizes and can be found in stationary as well as portable handheld selections. In addition, readers are devices that connect tags to a network. (Glower, 2006: 36-37)

Readers for passive tags cannot recognise active tags and vice versa, because in passive systems readers talk first, whereas in active systems tags talk first. Thus, transmitted and received signals do not come across in an appropriate way. Therefore, if passive and active tag systems are needed to run simultaneously, a double number of devices must be purchased.

Physical parts of the reader are antenna subsystem, controller and network interface. *An antenna subsystem* enables interaction between reader and tag. Some readers may have only one or two antennas, one to transmit and one to receive signals, whereas other readers may use many antennas at remote locations. *A controller* implements communication protocols and controls the transmitter and also determines when information read is worth sending to the downstream of network via middleware. *A network interface* enables readers to communicate with middleware or other devices. Furthermore, readers have four internal functions to perform within a controller, which is capable to operate with tags and middleware. These are application programming interface, communications, event management and antenna subsystem.

Application programming interface (API)

- Creates messages and parses received messages from middleware. For instance, parsed messages might be a request for tag inventories, monitoring the health of the reader or control configuration settings, such as power level.

Communication

- Handles details of communication, made up by the API, over any transport protocol the reader may use to communicate with middleware.

Event management

- Most of the time many tags are visible to a reader. This is called observation and observation, which differs from previous observations, is called an event. Event management is a tool, which defines events and further determines which of the events are valuable to send forward to the middleware.

Antenna subsystem

- This component must implement tag protocols and it consists of the interface and logic that enables the RFID reader to interrogate the RFID tags and controls the physical antennas.

(Glower, 2006: 108-110)

5.2.1 Layout for readers and antennas

Since the purpose of RFID systems is to sense the presence or absence of items, the environment dictates the details of any installation. Possible variations are infinite but the most typical layout for readers and antennas is portal. Thus, an RFID portal is an arrangement of antennas and readers designed to recognise items with attached tags entering or leaving through a doorway. This is widely used in warehouses and factories, where items move between different sections of the factory. A new much talked-about application is called smart shelves. These are shelves with antennas and readers can recognise the arrival and departure of items from the shelves. These kinds of shelves are capable to do inventories on demand and also match item IDs against a database to find oncoming expiring dates, for example. (Glower, 2006: 113-116)

5.2.2 Reader protocol

A reader protocol is a set of formal rules defining how one or more readers and hosts communicate within a network. The host can be either application or middleware. Communication includes alerts and observations from a reader to a host and commands from a host to a reader. An alert is a message with information on the condition of a reader. An observation is a record about a movement of tag at some point of time and place. A command is a message that causes a reader to perform some actions, such as read or write tag information. These methods of communication are the basis for all reader protocols. In addition, communication can be either *asynchronous,* meaning that a reader can contact a host any time or possibly at scheduled times or *synchronous,* meaning that a reader waits until a host sends a command requesting pending, as well as immediate information. (Glower, 2006: 119-122)

In the past standardisation has mostly focused on tags and tag protocols and not much attention has been paid to reader protocols, this was the result in many proprietary protocols developed by vendors. Recent years have witnessed plenty of ongoing work to set up global standards for reader protocols. For instance, EPCglobal and Internet Engineering Task Force (IETF) were developing separate standards. (Glower, 2006: 122-125) However, IETF gave up the developing of a standard called The Simple Lightweight RFID Reader Protocol (SLRRP), whereas EPCglobal ratified a standard in spring 2007. This standard will most likely become a global one.

EPCglobal reader protocol

In April 2007 EPCglobal announced a standard called the Low-Level Reader Protocol (LLRP). It is called low-level, because it provides control of RFID air protocol operation timing and accesses to air protocol command parameters. LLRP specifies an interface between reader and host. In practise, this ensures some basic cross-compatibility among readers and host devices provided by different vendors. In addition, they are able to extend the protocol to vendor-specific features, in order to tailor devices to match various requirements of RFID end users. LLRP also provides maximum support to the earlier published tag-to-reader Gen2 protocol. (EPCglobal, 2007, C)

LLRP consists of three layers. These are reader layer, messaging layer and transport layer. Below is a structure and short explanation about its functionality.

1. **Reader layer**: defines the allowable content and format of messages sent between the reader and host. This layer is divided into four subsystems.
    1. *Read subsystem*: responsible for reading tags and supplying tag information to the event subsystem. It also determines the timing of reads and filters valuable read, which differentiates a given pattern set by a host, from non-valuable reads to be submitted to event subsystem. Read subsystem cannot tell the difference between newly arrived and already detected tags.
    2. *Event subsystem*: responsible for turning reads into meaningful events, such as arrival of a new tag or the absence of a tag that was read previously.
    3. *Output subsystem*: decides what data the reader will report by comparing data against the filters set by the host. Then it buffers the data until the host has requested it or send it at scheduled times (trigger).
    4. *Communication subsystem*: responsible for implementing reader layer to a combination of messaging and transport layers. It also packages and translates the data to comply particular transport layer requirements.
2. **Messaging layer**
    1. The layer provides three messages channels, a basis for all reader protocols, such as *commands* from host to readers and *alerts* and *observations* from reader to host.
3. **Transport layer**
    1. The layer controls transports between a reader and a host.

(Glower, 2006:125 – 133)

5.3 RFID Printer for smart labels

RFID printers include a RFID reader function, as well. The reader can both read tags and write tags that allow writes. Consequently, RFID printers are devices that make smart labels by encoding tags and printing bar codes, as well as human-readable texts to paper labels that house the tags.

RFID printing devices can also include an apply device. In a low volume application an operator is capable to manually attach smart labels to the item but in high volume applications this must be done automatically. Thus, the printer can be considered to consist of four separate functions. There is the reader that is already familiar to us and the printer, which is no different than any other bar code printer. In addition, there is a verifier and an applicator. The purpose of a verifier is to check that both RFID and bar code are functioning properly. The same reader, who wrote the tag performs the RFID verification. Bar code verification is performed by an optical scanner located just after the printer. If the tag fails it will be discarded, before it is attached to the object.

An applicator is a function that attaches the smart label to the passing object. This can be done either with the a wipe-style, in which tags peel off a roll directly on the items or pad-style, in which has a pneumatic arm to press tags to the items. In bar code systems, typical applicator solution blows the tag onto the object with compressed air but it is not convenient with RFID, because it may damage the electronic components inside an RFID tag. However, it is used in the small scale. (Glower, 2006: 111-112)

5.4 Middleware

Middleware refers to a server with software that is located between readers and enterprise applications. The purpose of middleware is to filter data from readers and pass on only the useful data to enterprise applications. In addition, middleware can also be used to manage readers and query RFID observations within a network. Thus, RFID middleware consists of application-level interface, event manager and reader adapter.

In practise, companies utilising RFID have readers from one or more vendors. Each vendor has specified a reader interface that should be adjusted to the enterprise application separately. This awkward feature creates the need for a *reader adapter*, which provides means to eliminate differences of reader interfaces and expose a single interface to enterprise applications.

Readers make a huge amount of observations every second. Because of sheer volume of the data, it must be further processed to be meaningful to enterprise applications. For example, owing to the physics of radio frequency communications current readers operates at a 80 to 99 % of read rate. If there is more than 100 object to be identified, at least one of them will be missed in every read cycle. Passing that information directly upstream will cause continuous fluctuation to the inventory level, which further loads down the enterprise application and may even bog it down. Therefore, there is the *event manager* to control raw observations coming from the readers and lets only the application-relevant ones pass.

Middleware also has an *application-level* interface that allows the enterprise application to manage readers, such as set up event processing methods to filter data and make queries about filtered RFID observations. EPCglobal has developed a standard called Application Level Events Specification (ALE) for that purpose. In practise, the ALE standard allows an application to describe what information they are interested in and how they wish to receive it, without worrying about the physical RFID infrastructure. In addition, one of the most significant benefits of ALE-compliant middleware is expandability to interface with devices other than RFID readers. The ALE standard also separates the interface from implementation, which means implementation details are left to the vendors. For example, this approach allows the vendor to decide on technology platforms, deployment options and add-on features. (Glower, 2006: 137-140)

6. HOW TO DETERMINE INVESTMENT ADVISABILITY

This chapter introduces two methods that can be used to evaluate how well or how poorly a planned investment will turn out. Since the current process exists for a reason it is absolutely important to figure out whether the investment actually improves the process and is reasonable in financial terms, instead of just installing it without adequate insight on the results.

6.1 SWOT analysis

SWOT analysis is a simple framework used to evaluate the internal aspects of the company as *Strengths* or *Weaknesses* and external situational factors as *Opportunities* or *Threats* involved in a project or in a business venture. SWOT is applicable in both corporate level and business unit level and especially popular for marketing plans. The first part of any SWOT is to collect a set of key facts about the company and business environment with regard to the overall objective. The second part of the analysis is to determine whether they constitute one of the following:

- **Strength** is a resource or capacity that the company can take advantage of to achieve its objectives.
- **Weakness** is a limitation, fault or defect that prevents the company to achieve its goals.
- **Opportunity** is any favourable situation in the business environment, which may assist to obtain goals. Usually, it is new technology that can be taken into use or a trend or change in customer behaviour, which increase demand.
- **Threat** is any unfavourable situation in the business environment, which has the potential to harm, constrain or cause problems to achieving the goals.

Since the classification has been completed and items prioritised within classes, it is possible to consider interactions of items with regard to the objective and decide whether it is attainable or not. In case the objective seems attainable, the outcome of the analysis can be used in forming possible strategies. In general, an effective strategy is one that takes advantage of the opportunities of the company by emphasising its strengths. In addition, an effective strategy avoids threads and corrects or compensates for weaknesses. The picture 7 illustrates SWOT analysis. (Kotler, 2006: 52-56; NetMBA)

Picture 7. Illustrative diagram of SWOT analysis. (Wikipedia)

6.2 Pay-back time calculation

Pay-back time is the period of time it takes until positive cash flow generated by the investment covers the negative cash flow. This is a very simple method and particularly suited to the initiate stage of the project when cost and savings are only outlined. In addition, it is good guide at any given stage of the project when modification is suggested. Appropriate pay-back time is naturally specific to context and is calculated as follows:

$$\frac{Cost\ of\ Investment}{Annual\ savings} = \text{Pay-back time}$$

This method is very simple and widely used. However, it has one basic deficiency, because it does not automatically pay attention on interest rate. Naturally this is easy to fix, because annual net savings can be discounted to the present value of investment moment by applying the market interest rate. Then it is possible to observe, how many years of discounted savings are needed to cover the cost of the investment. According to the pay-back method, the investment becomes even more advisable the faster it is able to cover the investment cost. (Aitken, 2000: 105; Neilimo, 2005: 223)

7. PROCESS DESCRIPTIONS

As mentioned in the introduction, the purpose of this study is to figure out whether RFID could improve given processes of Metso Paper Service. The Service falls into many sub-processes but only some of them come in question when searching for ones which will benefit the most from RFID. Therefore, the processes eligible for process description phase must conform to some of the following criteria, in order to be potential applications for RFID. The criteria are *great volume*, *critical process for customer*, *feasibility*, *cost savings* and *increase of sales.*

- Great volume criterion stands for high item turnovers with remarkable financial value.
- Critical process for customer means that output of the process is extremely important for customers and failures may cause unplanned shutdowns.
- Feasibility criterion means that, in theory, RFID is possible to set up for the process or it could simplify things.
- Cost saving criterion means that RFID would make the process more effective, faster or reduce routine work or risk for identification errors.
- Increase of sales criterion refers to a hypothesis that RFID would provide new data about product life cycle, which could be used to support sales.

Based on the above criteria, the following processes are eligible for the process description phase. These are: *warehouse operations, direct delivery process for Sizer consumables and Doctor Blades*, *consignment stocks for Doctor Blades, spare part packages, return and repair orders, roll coatings and roll workshop.*

Data was collected by interviewing key persons of the processes and other people involved, in order to understand how each process works and to discover problems and reasons behind these problems. The interviews were conducted by using *semi-structured theme questionnaires* tailored to suit a particular process. It was not possible to make only one set of questions relating to every process, because they are so different. Basically, the following questions were asked concerning all the processes:

- At what stages of the process and how identification is conducted at the moment and what information is collected?
- What additional information would be useful to collect?
- What kinds of problems are faced with the current practice?
- What stages (routines) of the process would be good to automate?
- Does automatic identification provide any development of the process?

However, this method allowed detailed answers and it was possible to get some examples about the problems and further needs for development. In addition, process descriptions were drafted to make them more understandable.

At the beginning, every eligible process is broadly presented and its potential for RFID stated. Then process characteristics and data transfer actions are described, ending up with stating possible problems and needs for additional data collection. Finally SWOT-analysis has been carried out to evaluate how RFID could influence the processes in operational, economical, technical and organisational ways.

Siegel sign-test is used to indicate the magnitude of items in SWOT. Two plus signs (++) mean great positive magnitude, whereas two minus signs (--) mean great negative magnitude and single signs are mean values of those limiting ends. Based on the SWOT, the number of processes is narrowed down at the end of this chapter by discarding processes, which do not seem to have potential for RFID at this point of time.

7.1 Warehouse operations

Metso Paper has four logistic centres for spare part deliveries. They are located in Kerava, Sundsvall, Beloit and Shanghai. Until spring 2008, one centre in Finland was located in Jyväskylä but that has been out-sourced and moved to Kerava. It handles spare part deliveries to customers in Finland and Europe but supports other market areas, as well. Beloit and Shanghai mainly focus only on their own continents.

The logistic centre in Finland is described first. Its average volumes in 2007 were about 2850 received and 3900 shipped lines per month. The higher rate of shipped lines is explained by the fact that a received line may include many units, which spread out to several sales orders. The logistic centre always keeps 3000 of its highest circulating or critical items in stock, whereas rest of the items will be purchased-to-order and may have very short turn-around times. Since the volumes are great, there is a need for efficient material handling. Thus, it is topical to go through how different operations are currently managed and consider whether they might perform even better with the help of RFID. Appendix 1 displays warehouse operations.

7.1.1 Characteristic

Receiving

The purpose of receiving is to receive incoming goods, check their quantities and general quality and attach Metso item labels, measure weight and place them on storing locations, as well. Suppliers tend to mark shipments in their own style and the corresponding Metso purchase order can sometimes be very challenging to interpret. In the perfect world supplier packing lists indicate the Metso PO number and item codes and items themselves have the codes as well. In case the items are marked appropriately, the identification process takes an average of 3 minutes.

Bar coding is not used but it is notable that there are devices for bar code utilisation. This would require a paper called “a receiving note” to be printed out for every single PO in advance to indicate bar codes, because suppliers are not capable to mark them. No wonder employees find it inconvenient to use and carry out receiving in the traditional way. Receiving is manually entered into Baan, which is simple, as well, but makes employees go in and out the office during the operation. The receiving note is in Appendix 2. In this stage Metso item labels is attached to items, which makes them recognisable. The label is in picture 6. It indicates the item code, date, and possible SO number and storing location. Most of all, the item code is expressed in the form of a bar code (code39) as well, which will boost forthcoming warehouse operations.

Figure 6. Item label.

Shelving and stocktaking

Shelving is very simple and fast thanks to bar codes. If a recently received item has no existing storing location, the employee can store it wherever s/he considers best. In that case, s/he reads bar codes from the location and item with a handheld mini-computer, which includes bar code reading / writing applications and types the quantity. The logistics centre has on-going stocktaking, the purpose of which is to go over some predetermined locations every week. Inventory records, printed on paper from Baan, are compared against actual items at the location and differences can be fixed right away with the mini-computer. Bar codes have improved these two operations the most. Short reading distance is not a slowing factor, because stocktaking is based on visual count.

Picking and packing

The Baan automatic application prints the picking list a couple of days before the planned delivery date, but only if items are on hand. This is the input for delivery actions. The picking list is in Appendix 3. It indicates the SO number, items and storing locations, quantities, delivery date and the customer. Packers print sales order labels for items, which also include customer item codes if sales have inserted those into Baan while entering the order into the system. After items have been collected and packed, the SO must be updated in Baan. This is done manually, the function erases allocated inventories per items associated to that particular SO and prints the address label. The packer attaches it onto the package and delivers it to the dispatching area. The address label is in picture 8.

Picture 8. Address label.

Picking lists and item labels have bar codes and updating the SO is also possible with a mini-computer, but practise has revealed this impractical. The process works manually, as well. In addition, usually only few items need to be picked up for the SO and physical packing itself definitely takes most of the time, so employees have not considered bar coding attractive at this stage.

Shipping and Forwarding

The input for forwarding actions is the packing list, which is to be printed out whether domestic or export forwarding at the time the packer has updated the SO in Baan. The packing list is in Appendix 4. Forwarding in Kerava handles domestic shipments and export forwarding in Jyväskylä takes care of international shipments. After delivery has been booked, a waybill number is entered into the packing list, which will be printed out again. Forwarding at Kerava attaches the list on the package and it is ready for courier. At this stage operations are carried out in the Baan system.

7.1.2 Problems

Bar code devices exist for warehouse operations but are not widely utilised. Devices have mainly been set up for the existing way of operating and do not provide actual benefits over traditional ways of operating. Especially in receiving operations bar codes have a lot of potential to speed things up. But receiving cannot be completely carried out with handheld mini-computers in the receiving area. In any case, employees have to print item labels and “the receiving note”, go to the office and pick them up. Printing the receiving note is an additional task compared to traditional receiving. Basically, it may help if the printer is re-located close to the receiving area and the mini-computer would have a wider screen for added ease of use. It would significantly help, if suppliers could set up bar codes for Metso item codes. However, the target is that new receiving employees in Kerava begin to use mini-computers, but time will show if that proves successful.

Sometimes items cannot be received based on packing documents, because items are marked insufficiently. Then the supplier must be contacted. Unfortunately, this tends to take a long time, because difficult cases are usually postponed until other shipments have been received. Occasionally, receiving employees ask the associated purchaser to figure things out, but it may not be any faster. Basically, warehouse operations run fine.

7.1.3 SWOT

The purpose of this SWOT is to assess how RFID would change warehouse operations. The premise is that bar code devices are replaced with RFID devices and every item has an RFID tag. After this all operations are performed with the help of RFID.

Strengths

++ Passive RFID system is convenient, because there are no needs for tags to continuously send signals to readers as active ones do.

++ The reading from a distance feature would be speed stocktaking up to a degree. But it cannot totally take the place of visual observation, because every unit cannot have an RFID tag.

Weaknesses

-- In practice it is impossible to attach a RFID tag to every item, such as small ones like screws, springs and nuts, which can be sold individually.

-- Generating and printing of bar code symbols is basically free of charge but convenient passive RFID tags costs 10 – 20 cents.

-- Impossible to use in receiving until suppliers could fit items with RFID tags. At the moment they cannot do that even with bar codes.

-- Very low benefits in terms of time savings for picking and packing, due to the fact that the SO typically consists of few items and the packing itself takes most of the time.

-- The re-write feature is wasted, if tags are not erased during the shipping phase and then re-used.

- Generally warehouse operations work fine the way they are and there is no need to change them.

Opportunities

++ Automatic receiving, since suppliers could fit items with RFIDs.

++ If it would be possible to attach a tag to every unit, stocktaking would happen automatically within seconds and inventories would be accurate all any time.

+ Possible to use RFID only in some areas of warehouse operations.

Threads

-- Bar code devices are not widely taken advantage of, this could happen to RFID, as well if employees do not see any significant operational benefits.

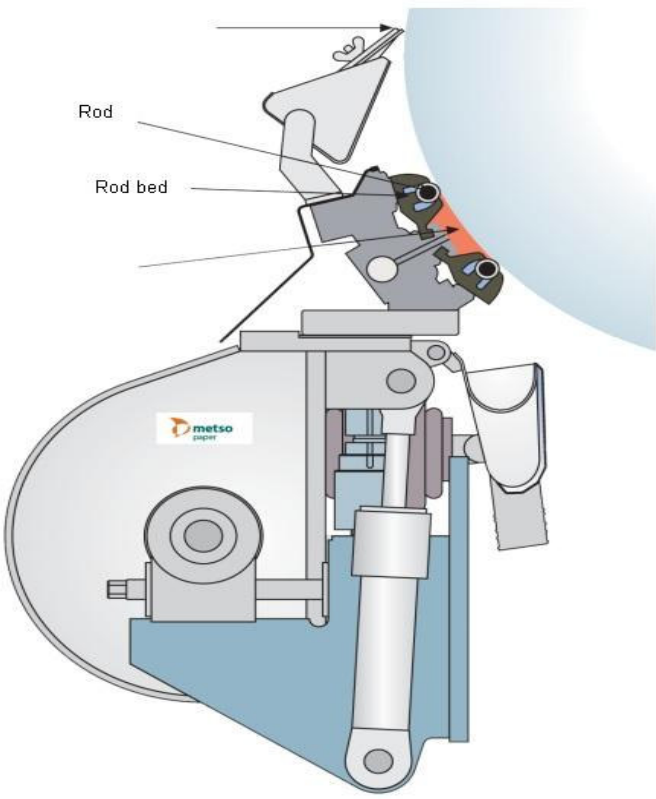
It seems RFID is not attractive for warehouse operations, because it has some remarkable weaknesses, which decrease its feasibility. Currently bar codes are used to a degree, but they have faced some reluctance hampering the ultimate breakthrough, because they have not benefited operational work much. Besides, it is quite obvious that RFID would be extremely difficult and expensive to set up successfully and would not offer additional improvements over bar codes in that kind of a warehouse environment. Since the suppliers could fit items with tags, RFID becomes extremely useful, but this does not seem to be the case in the short term. Because of this it is my opinion to keep focusing on bar codes at this point.

7.2 Direct delivery processes

Metso has considered it reasonable to always ship some parts directly from the supplier site or production unit to customers instead of taking them to a logistic centre first and then shipping them forward to the final destination. This is called direct delivery process. Sizer consumables and Doctor Blades are delivered that way but practices are not identical. The purpose for checking direct deliveries is to figure out whether it occasionally happens that parts are shipped but not invoiced, because the SO is not updated in Baan. Additionally, volumes for both products are great and parts critical for customers, so it is worth considering whether RFID could benefit the deliveries.

7.2.1 Sizer consumables

Sizer is a coating unit at the end part of paper machine. It plays an important role relating to the coating and surface sizing of paper to produce excellent quality. Sizer has wearing parts, which are generally categorized as Sizer consumables. These consist of *rods* manufactured by Komas in Jyväskylä, and *rod beds* manufactured by Finn-Valve in Joutseno. These are always made to order. Parts are critical for customers, because the paper manufacturing process must be shut down, if parts run out. Rod and rod bed are illustrated in picture 9.



Picture 9. Rod and Rod bed locations in coating unit.

These two parts have high rates of item turnovers. For example, volumes at 2007 were 3683 units of rods and 2685 units of rod beds. These built up 625 shipments, 313 for rods and 312 for rod beds. The length of Sizer consumables vary between 3,5 – 11,5 meters, depending on the width of the paper machine. The parts are used together, but it is not necessary that parts are combined to each other, until they reach the customer's site. Since the length of parts is great, and suppliers have good quality control, it is reasonable to deliver them directly from production sites to the customer's site, in order to reduce costs and speed up the delivery.

7.2.1.1 Characteristics

The direct delivery of Sizer consumables includes many steps and seven participants. The process is pretty much identical with both suppliers and is presented in Appendix 5. The sales receive the customer purchase order and create an SO in Baan, then items show up on the purchase queue. Purchasing creates a PO into Baan and sends it to the supplier by email or EDI. At this stage, only typical sales information, such as customer PO, SO and item identifiers and quantities are transferred between participants. Basically, Baan controls the whole process according to delivery date set by sales.

The next impulse, which moves things forward, is notice of readiness of the PO. The supplier emails it to forwarding, after he has finished the parts and the delivery process begins. The notice contains appropriate order and packing information, such as the PO number, weight and size. If forwarding does not receive the notice, the parts will never be shipped and invoiced and the process stops. Besides, suppliers do not get paid, until Metso has updated the PO in Baan. Thus, it also in the supplier's interest to ensure the process continues. Based on this notice, forwarding receives the PO into Baan and updates the SO that launches invoicing, arrange transport and sends packing documents to supplier by email. Parts themselves stay at the supplier site all the time.

The packing documents are important for transport, but also for identification. Packing list and item labels also indicate items with bar codes (Code 39).

Unfortunately packing documents include bar codes only for the Metso SO number and part numbers, not for customer ones. However, bar codes exist but there is no need to use them in direct delivery processes, but theoretically customers can use Metso bar codes in receiving.

After the courier has picked up the delivery, its journey can be monitored on the courier's web page, where the actual shipping status is updated in real time, thanks to the courier's internal bar code system. Normally, Metso checks the shipping status only, if the customer has complained about a late deliver,, although the goods left on time, or if the shipment is very critical for some reason. Parts are very sensitive and require careful packaging to avoid damages during transportation. This is why sturdily built plywood boxes are used. The boxes are relatively expensive and Finnish customers are requested to return them. The return address is painted on boxes permanently and the supplier pays the shipping fees.

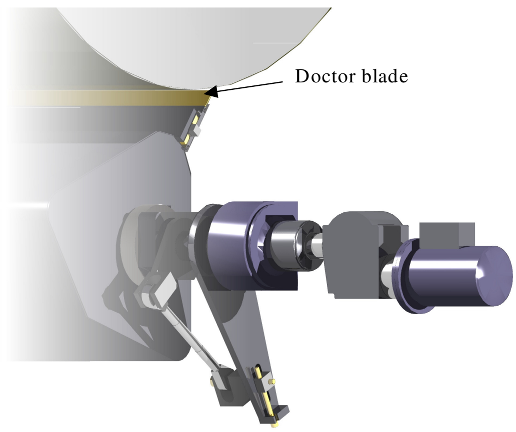
7.2.1.2 Problems

Possible problems mainly relate to customer orders, which are requested with too tight a schedule compared to parts lead times, because the customer is running out of parts. Currently, there is no way to follow up customer consumption or inventory levels. For this reason it has been suggested that it would be useful to be aware of it in some way and be able to make refill reminders. Sometimes product updates cause problems, if they are not updated into Baan correctly or the customer has not informed, when he has started to use a revised version of the part. However, the direct delivery processes themselves work fine and without any problems.

7.2.2 Doctor Blades

Doctoring in paper manufacturing process means removing all kind of contamination such as fibres, water and fillers from the surface of rolls and prevents a sheet from wrapping around a roll causing serious damage. For this reason, there has to be a doctoring device for each roll in the machine. In general, optimised doctoring will result in better runnability and easier maintenance of the machine and ensures even paper surface and further improves paper quality. Doctoring devices consist of many parts, but one of the most critical parts is a *Doctor Blade.* It is a wearing part, because it touches the roll and therefore needs to be replaced regularly.

At 2007 Metso delivered around 36,000 units of Doctor Blades. The delivery unit is 10 pieces, which equals 3,600 transport cases. An average length of Doctor Blades is about 7.5 meters, but blades can be rolled up in order to fit a transport case in size 90 x 90 x 10 cm, which enables economical delivery. Doctor Blades are always made to order, because they must be specific for certain rolls and usually rolls tend to differ from each other. For example, distinctive factors are the width of the roll, location of the roll, method of fastening, running speed and the product being manufactured. Thus, Metso has approximately 11,300 different Doctor Blades in its records but not all of them are active. Doctor Blades are directly delivered from production unit Metso Paper Varkaus to the customer’s site. Doctor Blade is illustrated in picture 10.



Picture 10. Doctor Blade.

7.2.2.1 Characteristic

The direct delivery process for Doctor Blades is described in Appendix 6. The input comes from the customer to Metso Service sales, usually by email. It includes information such as the PO number, customer or Metso item code, item description and quantity and requested delivery date. The sales and production unit operate within the same ERP system. After sales create the SO in Baan, it generates a production order directly to the manufacturer's production system, and therefore a traditional purchase phase is not needed. All functions are carried out within the Baan system.

When parts are finished, Metso Paper Varkaus maintains the production order and SO in Baan, which always launches the invoicing process. Manufacturer prepares packing documents and books transport for domestic shipments, but export forwarding in Jyväskylä takes care of international shipments. An input for export forwarding is a packing plan, which is printed out automatically at the time the SO is maintained. Thus, notice of readiness is not used. If the packing plan does not reach export forwarding, the part will never be shipped and the process stops. Export forwarding arranges the transport and prints finalized packing documents to the manufacturer. However, if Metso Paper Varkaus does not receive those documents within a couple of days, they know that something is wrong and contact export forwarding. The packing documents are homogeneous in all Metso Service shipments. In addition, Doctor Blade item labels contain a four-digit raw material number (R-number). If the delivery status needs to be followed up, it can be done on the courier's web page, similarly as Sizer consumable deliveries. Generally, the entire process including document transfer between export forwarding and manufacturer works fine.

7.2.2.2 Problems

Problems typically relate to cases, where a customer is running out of Doctor Blades and is requesting urgent delivery, instead of normal lead times. The only way to prepare for this, is to keep up adequate inventory levels for raw materials and semi-finished products. These inventory levels are based on sales history, but accurate information about Doctor Blade lifecycles is not available. Metso would like to know exactly, when the Doctor Blade is installed and when it is replaced. This information would also assist salespeople's work and product development.

Sometimes customers try to place an order based on a rival's product specification. In these cases, delivery is not possible, because Metso cannot be sure whether the product works properly, so on-site engineering is needed.

7.2.3 SWOT for direct deliveries

This SWOT aims to assess, whether RFID could benefit direct deliveries. There are some modest differences between practises with Sizer consumables and Doctor Blades, but it is appropriate to evaluate them together in one SWOT to avoid unnecessary repeating. The premise is that every item has a RFID tag and customers have readers to deliver a message of arrival to Metso.

Strength

++ Suppliers can easily attach tags on Doctor Blade transport cases in the packing stage.

++ Passive RFID system is convenient and tags cost only 10 – 20 cents.

Weaknesses

-- Non-existing feasibility to track deliveries with RFID, because there should be a tag on every product and every customer should have a reader, which is impossible to realise. Moreover, the courier´s tracking service already enables real-time follow-up of delivery status.

-- RFID cannot be used to make critical document transfer between export forwarding and supplier more efficient, because it is accomplished by email, or documents are printed directly to the receiver's office.

-- RFID benefits, such as re-write and mass-receiving, are useless with direct deliveries, because in this case tags are disposable and the number of shipments at the time is low or only one.

- Tags are difficult to attach on rods and the tag must be erased, when the rod is taken into use.

Opportunities

++ Items with RFID tags and customers with readers enable lifecycle data collection, which could be used to optimise raw material and semi-finished product stocks at production stage. This would result in some cost savings.

Threads

-- RFID readers must be invested on for every customer, and if the customer starts to use rival products, the investment will not pay off.

It is obvious that RFID cannot improve direct delivery processes. First of all, real-time status of delivery is already possible with the courier's tracking service. The feasibility to track deliveries with RFID is very low, because every customer would need a reader. In practice this is impossible to carry out and becomes expensive. In addition, currently critical document transfer between supplier and export forwarding is working well. This means that all parts that have been shipped will be invoiced as well, because it is impossible to carry out deliveries without Baan. All in all, it is my opinion that direct delivery processes are not eligible to be conducted with the help of RFID.

7.3 Consignment stock process for Doctor Blades

One of the products best suited to run under consignment stocks are Doctor Blades. They have high item turnovers and are always packed in an equally sized of a transport case, picture 11, so the physical consignment stock is easy to set up. It is a closet and has room for 20 boxes. Doctor Blades inside consignment stocks are Metso´s property and will be charged and filled based on actual use of a customer. Controlling and re-ordering of consignment stocks are made either by a customer or a Metso sales agent. Inventory levels are the most important things to follow up. Unfortunately, this is problematic and requires much of a sales agent's time. So, it is worth it to check, if RFID could correct this problem.

In 2008, Metso has 28 consignment stocks. 23 of those are located in Finland and 5 elsewhere in Europe. However, most of the customers who are using Metso´s Doctor Blades are not operating under a consignment stock process. In 2007, there were only 8 consignment stocks, the accumulated volume of which was about 250 boxes. The process description is in Appendix 7.

Picture 11. Transport cases for Doctor Blades.

7.3.1 Characteristics

Doctor Blades in consignment stocks are categorised either as SIC (Standard Industrial Classification) or MRP (Material Requirement Planning). SIC stands for items, which have given order quantities and re-order points, so that new supply can always be made easily. A tiny minority are MRP items, which do not have those definitions, so a new supply can vary in size and time depending on customers´ needs.

The inventory levels are the most important things to follow up, so that determined service level can be guaranteed and re-orders and invoicing run correctly. At present, either a customer or a Metso sales agent takes care of this. The sales agent visits approximately once in a month to check actual inventory levels and considers further actions, such as need for re-orders and also keeps in touch with the customer. Consequently, the sales-agent advises sales to create an SO, the used items are removed from Baan inventory and can be invoiced. Typically, re-order-points were set up per use of boxes, not individual items. Re-orders happen according to a normal direct delivery process, and the customer will put items into consignment stock after receiving.

Doctor Blade manufacturer, Metso Paper Varkaus, maintains production orders in Baan, after the orders have been finished. This automatically adds items to consignment stock inventory, although items have not yet been shipped. Sometimes this gap causes errors, if stocktaking takes place in-between times. Baan provides data about sales history but cannot provide data about the actual consumption of items. Consequently, this is something Metso would like to know in more detail.

Thirteen consignment stocks are called intelligent stock, picture 12, because they utilize semi-automatic identification. The remaining twelve consignment stocks look similar as intelligent ones, but do not utilize automatic identification in any form. Intelligent stocks have a mechanical trigger to sense the presence or absence of a box in a particular place on a shelf. A particular place stands for a particular item that inventories can be monitored. A trigger has been connected to a mobile phone permanently located in the closet. The phone calls to the sales agent´s mobile phone after a short secure time to give information on the absence of some box. This is input for invoicing and replacement process. In the past, using bar codes has been tried, in order to keep up with inventories, but it did not work properly. Problems occurred when employees ignored bar code readers and simply took boxes out of the closet. This resulted in inventory errors. The cost of founding new intelligent stock is 5600 €.

Picture 12. Intelligent consignment stock.

7.3.2 Problems

The biggest problem in managing consignment stocks is that the actual and Baan inventory levels are not in balance. Sometimes this causes out-of-stock incidents but normally rush orders, huge delays in invoicing and the feeling of unreliable customer service. The ultimate reason behind the problem is that there is no efficient way to deliver real-time consumption information automatically to Metso. Thus, sales agent's monthly-based stocktaking is fundamental and this is very expensive to Metso.

Controlling the actual use of items in consignment stock is also very difficult with an intelligent system, because the correct placement of boxes in the closet is extremely critical here. It cannot recognize misplacement and will trigger incorrect invoicing and replacement. However, intelligent stocks work relatively fine, as long as the mobile network works fine. Even a short disruption can mess up the system and requires a sales agent to come and fix it. This sets up operational and reliability limitations for wider utilisation of such a system.

In addition, there is great need to set up more consignment stocks for new customers around the world. However, current systems in use are not that accurate and reliable to make it happen. In general, managing consignment stocks should not be based on sales agents´ stocktaking in monthly intervals.

7.3.3 SWOT

This SWOT aims to highlight, how RFID could affect the management of Doctor Blade consignment stocks. The premise is that the supplier attaches tags on transport cases and every stock has an RFID reader, which automatically delivers real-time consumption information to Metso sales.

Strengths

++ RFID enables real-time and accurate controlling of consignment stock inventories without human interventions. This has been a notable problem so far.

++ Savings in operating costs, because monthly based stocktaking is not needed anymore.

++ Can be implemented globally.

++ Passive tags are convenient and cheap, only 10 – 20 cents. Many providers are available.

++ Increasing volume, about 250 boxes, achieved already with only 8 stocks in 2007 and number of stocks has been tripled in early 2008.

++ Better customer service, due to reliable inventory monitoring, which diminishes risk for out-of-stock cases

++ Possible to keep lower inventory levels, because re-orders happen instantly and automatically, this results in cost savings.

++ Good feasibility and usability, passive tags on transport cases and stationary reader in every stock takes care of the rest. People just use the products.

\+ RFID can replace intelligent stock and product placement is not critical anymore.

\+ Costs of founding RFID managed stock (4860 €) is cheaper than intelligent stock (5600 €).

\+ It is possible to collect actual data about consumption, such as delivery date, receiving date and implementation date.

Weaknesses

- All items must be categorised to be SIC, so that manual observation will not be needed.
- Re-write function is not needed.

Opportunities

++ Increase of volume, because RFID enables the setting up of consignment stocks in distant areas, such as Asia, which are not easy for the sales agent to reach every month.

++ SIC items would run fully automatically.

++ Reliable inventory monitoring enables speeding up item turnover rates, which decreases invested capital and results in cost savings.

++ Actual consumption data may assist product development.

Threats

-- If non-functioning RFID tags end up on transport cases, the readers on consignment stocks cannot recognise arriving items. But the risk is very low, because RFID printers verify every single tag after it is printed.

Consignment stock process for Doctor Blades seems highly potential for RFID and feasible, as well. RFID could solve a basic problem relating to the management of consignment stocks. Sales agents would not have do stocktaking every month and this would generate operational savings. Basically, the benefits significantly exceed the weaknesses and threats. In addition, it becomes attractive to set up more consignment stocks in areas, which have been unattainable earlier with the current way to manage stocks. My opinion is to take this process to further modelling with RFID.

7.4 Receiving process of spare part package

Spare part packages are big entities, which are sold for new paper machines to support successful start-up, as well as the early stages of a machine. It contains items that have been considered necessary to stock by the customer, in order to avoid shutdowns. Sometimes spare part packages have also been sold for existing machines to support maintenance operations.

Spare part packages may consist up to several thousands items, depending on the extent of machine sales or customer budget. In practise, gathering every single item to a logistics centre takes months and packing also takes several weeks. All items are striven to be shipped together as a one shipment, but depending on the project there might be many shipments. The value of one spare part package varies a lot and can sometimes even be 10 millions of euros. Typically, greater packages are letter of credit type of sales. An average number of packages are 5 – 7 every year. These features separate them from ordinary daily spares. Because of the great value and number of items, receiving at customer's site needs special attention. Usually, the project manager and possibly more people from Metso go there and carry out receiving in co-operation with the customer. However, this is time-consuming and expensive, so it is worth to check whether RFID could ease the process. The process description is in Appendix 8.

7.4.1 Characteristic

Most items must be labelled properly, so that they are identifiable. The item label contains Metso item codes and SO numbers with bar codes. If the customer has item codes, they are also printed on the label, but without bar codes. A large number of items are challenging to handle at the shipping stage, and therefore small items are packed together into bigger transport cases and eventually these are loaded into a container. The container always makes its way to the destination, but some of the individual transport cases may disappear. This is why big shipping units are preferred, for freight costs reasons alone. Transport cases and the container always include packing lists to indicate their content.

After the spare part package has arrived in the destination, depending on the number of items, Metso usually sends 1 – 2 employees to control and assist receiving operations. Normally, this person is the project manager of the sale, because s/he is extremely familiar with the case. Sometimes persons might be from the nearest sales location, as well. The purpose of this practice is to ensure that receiving happens correctly and items are in a good condition, so incorrect claims will not be placed about missing or damaged items. The exact number of items that require someone on-site has not been determined; this will be considered case by case. Typically, Metso representatives stay there for 4 – 10 days. Transport cases are opened and the content compared against the packing list and the quality of every item is checked. Metso representatives bring copies of packing documents in paper form and after the item is identified, it is marked on the packing list. At the end missing or damaged items can be stated and replacing process started. For re-shipments Metso does not send its representatives to the site anymore.

7.4.2 Problems

The biggest problem is that it is expensive to send and accommodate people at the customer's site for many days to assist with receiving operations. This has been considered necessary in order to fasten things up, avoid receiving problems and from the point of view of good customer service, as well. In addition, spare part shipments generally consist of parts, which are sold from different sales locations and each location tends to send their own representative to handle only their own parts. So, eventually several people from Metso go to the site and some of them only need to do very little work. Unloading and unpacking at the destination is time-consuming, because appropriate forklifts or even drills to extract screws are not always available on behalf of the customer.

It is not a problem for Metso to identify items that are actually found on transport cases, thanks to good packing and Metso item codes. The factor slowing things down is the lack of customer item codes on item labels, because the customer also needs to identify the parts and enter them into the operating system. Unfortunately, customers do not always have codes in advance and they set them up alongside receiving. In practice, if Metso sales have the customer codes and enter them in Baan while entering the SO, codes will always end up on the label. This would significantly speed things up at the receiving stage.

7.4.3 SWOT

This SWOT aims to highlight the estimated benefits and disadvantages, if RFID is used in spare part package receiving. The premise is that every item has been labelled with a RFID tag in the packing stage, and Metso representatives bring and set up moveable readers for receiving at the customer's site.

Strengths

++ One moveable reader with antennas is enough, because Metso representatives can take it to the destination, set it up and take it down.

++ Passive tags are convenient and cost 10 – 20 cents.

++ No need to invest in middleware, because it is not necessary to connect Baan and RFID. Since the SO is already maintained, the purpose is just to ensure that all parts are shipped correctly.

++ Feasibility, tags attached in the packing stage and moveable readers in the receiving stage

++ Would speed up receiving, because no direct line of sight is needed.

Weaknesses

-- Every item must be quality-checked, so they have to be handled individually and benefits of RFID will be wasted.

-- Remote reading feature is wasted, because of the checking.

-- Mass-receiving feature is wasted, because of the checking.

-- RFID cannot help with the underlying customer code problem, the codes must be entered manually into Baan at the SO stage to speed up receiving.

-- Items have bar codes, which could be taken into use to speed up receiving.

-- Low usability, because RFID does not make receiving any faster, because of the checking.

- Re-write feature is not needed.

Opportunities

++ Customer could utilise existing RFID tags in his warehouse operations.

++ If quality-checking becomes useless in future, or items need not be handled individually, then RFID could speed up receiving and the number of Metso representatives can be reduced in order to generate savings.

Threads

-- If tags are placed incorrectly and many items packed into same transport cases, some metallic items could make tags unreadable.

Theoretically RFID is highly potential for spare part package receiving operations. Feasibility is good with movable readers, which can be set up at the customer's site, all unopened transport cases gone through and items read in few seconds. However, this is not possible as the quality-check of items has been considered an important part of the receiving process. However, this is hard to advocate, because parts are packed by the supplier and again checked, packed and shipped by logistics. Eventually Metso sends persons to verify that previous steps in the process have be handled properly. This duty eliminates major improvements that RFID would have offered, such as the remote reading and mass-receiving features, because all items must be handled individually in any case. So a band of Metso representatives is still needed to control receiving.

Besides, RFID is not a solution for customer item codes, which can be solved at sales stage. Items have bar codes but they are not utilised at receiving. My recommendation is to ensure there are customer codes on item labels, try to use bar codes, as well and later on, if item inspection becomes unnecessary, to consider RFID again.

7.5 Return and repair processes

Occasionally customers send items back to the logistics centre. Reasons vary from incorrect delivery, customer's incorrect order and quality claims to the need for repair. Naturally, return volumes are only a tiny fraction compared to outgoing volumes but large enough to occur everyday as an average. The logistics centre records all returns on an internal Excel form and informs the sales about arrival. After this sales starts to manage it. In 2007, there were 416 returns recorded on the Excel form and the absolute majority of returns were repair orders.

It has been very difficult to create a careful return or repair process, because customers make first actions in a way they consider the best. The processes are kind of push guided, which means that after downstream is ready; things are pushed upstream, which reacts only after that. Generally, data transfer between participants has been problematic and time-consuming. After logistics was outsourced in spring 2008, it is very topical to check whether RFID could ease operations.

7.5.1 Characteristics of returns

Customers either inform sales about a return or simply send them back without announcement. If customer contacts sales s/he gets instructions about marking the shipment. Consequently, a supervisor in logistics knows who to contact in sales, in order to get instructions about what to do with the return as it shows up. The process works relatively well, if the item will be taken back to Baan inventory and can be resold. Thus far, all returns have been recorded on an internal Excel list, so that they can be controlled and participants reminded, if actions seem to take too long. The purpose is that sales inform logistics about what to do with the return, so that it will not be left in a temporary location for a long time.

A return should include the following identifiers: customer contact person and Metso contact, item code, original SO number and reason for return. Currently, identifiers are always in text form and methods of automatic identification are not used. Sometimes it is impossible to identify a return shipment, until the customer makes contact and asks when s/he can expect to get it back. It is notable that a supervisor handles returns, not receiving employees. He is very experienced and familiar with the parts and sales; therefore he is able to deal with many complicated cases. A new warehouse operator in Kerava contacts him in Jyväskylä, whenever returns show up and it is all handled remotely. The return order process is in Appendix 9.

7.5.2 Characteristics of repairs

The Baan system provides data that the most generic items to be repaired are different kind of oscillators, in 2007 there were about 40 units. After that came dilution valves with about 20 units and the rest falls into several categories but the numbers of individual items was not so great. The repair order process is in Appendix 10. Repair orders need manual observation to ensure that the process does not get cut off. Differing from other returns, customers usually send a PO for repair orders or ask, whether Metso is able to re-condition it in advance. Sales should not create an SO yet, but send the customer a cover letter to be filled and attached on the shipment that receiving can handle it quickly. The purpose of a cover letter is to indicate identifiers, such as Metso contact person, item codes and the original SO number. This would speed things up at the receiving stage, but unfortunately cover letters are rarely found from shipments. However, no kind of automatic identification is used.

After the shipment has arrived at receiving of the logistics centre, it is passed on to a supervisor, similarly as basic returns, which identify and record it on an internal Excel spreadsheet and contact sales. Typically, this is the point, when data transfer is critical and is done mostly manually. Sales must have a customer PO to repair the preliminary SO with an open price, and delivery can be created and further purchasing buy re-conditioning. Altogether it may take a lot of time, until a supervisor gets the purchase order, which indicates that the item can be shipped to a supplier for repair. This step must be handled manually, because Baan automatic applications can not print a picking list for purchase orders, otherwise the process will stop. A PO will always be attached to the shipment, so that the supplier should not have any trouble identifying it. Later on, the supplier will advise cost and delivery, then Metso PO and SO can be finalized into Baan. From now on, everything runs as ordinary warehouse operations.

Since the oscillators are the most generic items to be repaired, Metso has a couple of re-conditioned oscillators in stock and when customer sends one for repair s/he will get one instantly from the stock. The one s/he sent ends up on stock after re-conditioning. This practice will speed things up significantly, but customers tend to complain, because they do not get back the one they shipped, although this is always explained to them.

7.5.3 Problems

Both returns and repairs face similar problems. The largest one is insufficient information on packages. Usually customers can provide only an internal item code. Many times identification at receiving stage is merely based on the experience of a supervisor, who can trace the intended sales representative and things begin to roll. The second problem is the time it takes, until the contact upstream informs what to do next. It is time-consuming, because it is not always known why the part has been returned or there is no customer PO for repair. However, many times the slowest responder is the customer itself, when additional information such as PO is requested. As a result, the item will be forgotten in a temporary stock.

Sometimes returns also generate warehouse management problems. This occurs if a credit order is done and maintained by sales, before the item is actually received by logistics. In this case, the customer gets credit and Baan believes that the item is in stock, which is not true. Consequently, somebody could sell the item to another customer ignoring the default lead-time, but at the time of delivery there is nothing to deliver.

Normally, Metso does not know in advance about how much a repair will cost and how long it will take. Thus, semi-finished orders are used, until the supplier has seen the parts and confirmed price and delivery time. The negative aspect is that customers would like to know these things, while deciding whether the part should be reconditioned or replaced. For this reason fixed re-conditioning prices for some products has been suggested and used, regardless of actual cost. More conflicts occur, if parts cannot be repaired, but the supplier charges an inspection fee. The customer is typically very reluctant to pay it.

7.5.4 SWOT for repairs and returns

This SWOT aims to assess, whether RFID could benefit these processes. There are some modest differences, but it is appropriate to evaluate them together in one SWOT to avoid unnecessary repeating. The premise is that Metso sales encode tags, send them to customers who attach tags on items and eventually a RFID reader in receiving at a logistics centre identifies items automatically.

Strengths

++ Only one handheld reader with writing capability is needed for the logistics centre. It costs about 2500 €.

++ Passive tags are convenient and cost only 10 - 20 cents.

++ RFID will ease identification in receiving.

Weaknesses

-- RFID will only support identification in receiving, but not necessary communication between participants, which is time-consuming, as well.

-- Low feasibility, because preceding customer contact is required. The items should have tags when they arrive in receiving so it would benefit the process. In practice, this means that sales should send programmed tags to customers to attach on items. Besides, customer purchasing and warehouse might be located far apart, and therefore it is very challenging for tags and parts to come across.

-- Current cover letter method hardly works, so it does not promising for RFID, which should be programmed and posted to customer, whereas letters can be sent by e-mail. So the required amount of work will not decrease.

-- Annual return volume is low. In 2007 it was 416 items.

- Remote reading feature is wasted.

- Cannot prevent early credits made by sales. The solution for this is training.

- Cannot help in obtaining price and delivery data for repairs in advance.

Opportunities

++ Re-write tags can be re-used many times.

++ RFID can be used to identify parts, when they come back from re-conditioning.

Threads

-- Tags may disappear during re-conditioning work.

It seems that in practice repairs and returns are not feasible with RFID. Main problems are insufficient identification data in receiving and long-lasting data transfer between participants. It requires lot of of effort both from sales to encode and send tags and customers to attach them to items. This is the major obstacle, but if this could be overcome, RFID would ease receiving, but not so much data transferring inside Metso, because the slowest responder is the customer itself. Currently, there is a handy but unpopular cover letter method that already provides exactly the same benefits than RFID would without any costs, so RFID does not provide any actual improvements. My opinion is to remind sales to emphasise the meaning of cover letters to customers even with basic returns and not to consider RFID at this point of time.

7.6 Roll coatings

The purpose of roll coating is to ensure an even surface and straight profile of paper with special emphasis on the durability of covers and easy maintenance in the long run. In addition, coatings have great impact on the overall runnability of machines. Roll coatings fall into two main categories of hard and polymeric coating. Hard coating includes ceramic, carbide, and G-strip covers, whereas polymeric one includes rubber, composite, and polyurethane covers. In total there are about 90 different coating types tailored to match the special needs of some particular stage of the paper manufacturing process, such as centre, former, press, calendering and suction rolls. Metso Paper service has three coating units in Finland. Jyväskylä takes care of hard coating, ceramics, carbides and polyurethane. Oulu has rubber coatings

and Järvenpää has composites. In addition, there are 14 units around the globe. In 2007, 227 rolls were coated in Jyväskylä.
Metso is the leading manufacturer of ceramic coatings and third with rubber covers. On top of end customers, Metso Paper Service also makes all coatings for new paper machine deliveries. Since coatings plays an important role in machine performance, it is worth it to check, if RFID has something to offer here.

7.6.1 Characteristics

Roll coating wears out in time. Typically, hard coatings last several years until they need re-coating but polymeric ones wear out faster. To ensure the best performance for coatings, **they should get ground** approximately once a year. Paper mills are able to do that but re-coating rolls must be delivered to the Metso paper roll workshop. The process description is in Appendix 11. Gathering up information on the use of rolls is important relating to coatings, although roughness of coating is measured using topography. However, very little information is available after the roll has been delivered to customer. Metso has records, where manufacturing and maintenance data of every roll is stored in detail. Any kind of lifespan information must be requested from the customer, but generally they are somewhat reluctant to share databases with Metso. Every single roll has a unique ID stamped on it, so it is always identifiable.

The most important information for Metso is the actual running time of a roll. This data will be used for coating reference and development purposes. References can be used to support coating sales, as they indicate customer experiences about the product during its lifespan. In addition, it would be easier to examine the roll when it arrives for re-coating, if actual running data is available. Also possible claim situations would be easier to figure out. Besides, Metso would like to know how many times the customer has ground the roll and grinding measures, as well. Running speed and Nip pressure, which is the pressure between two rolls touching each other, would also be valuable information to collect.

Usual wear and tear can be predicted by using references, if running speed and nip pressure are known. It is extremely rare that coating wears off, the recommendation is that 60 % of it should still be left when it is time for re-coating. Customers seem to follow that rule, and often before the limit is reached rolls typically face some incidents, which damage the coating. Coating thickness is about 20 mm for polymeric and 1 mm for hard coating. Lead-time is normally one month. Process description is in Appendix 8. Without exceptions, rolls can always be restored to the same condition as brand new ones.

7.6.2 Problems

It is generally problematic to collect life-cycle information, after the roll has been delivered to customer. It typically takes a long time to get any reply from the customer and details are more or less inaccurate, so there is a great need to find an efficient and reliable way to collect life-cycle data. Probably the most benefits will be gained if life-cycle data about polymeric coated rolls in press and calender sections can be obtained in some way.

7.6.3 SWOT

This SWOT aims to assess, if RFID could improve data collection relating to roll coatings. The premise is that the roll workshop attaches tags with integrated sensor capabilities on rolls for data collection at the time the roll is being coated. Later on, when the roll comes back for re-coating the tag can be read.

Strengths

++ Feasibility in theory and only few readers are needed.

++ Number of rolls is huge and RFID could enable large-scale data collection.

++ Detailed data could be read instantly in the roll workshop, and there is no need to wait weeks until the customer provides running data estimations.

++ Easy to arrange pilot runs in the Jyväskylä product development centre, where paper machines run for test purposes.

Weaknesses

-- Present semi-active and active tags can measure only temperatures and humidity within the integrated sensor capability.

-- Sensors are not yet capable to measure running speed and times.

-- In practice, rolls can be identified easily and RFID does not provide any extra functions.

-- Dependency on a certain tag / reader supplier, because there is no standardisation for active tags and readers. Devices between suppliers might be incompatible.

- Tag readability from a distance does not offer any extra functions or opportunities, unless it can be done from the roll workshop to customer site, while the roll is in use.

Opportunities

++ In future sensors might be capable to measure running speed and times.

+ Measured data about usage is useful, if coating damage occur.

+ Real-time remote reading would be possible to set up, but then every roll must be equipped with a reader and this becomes very expensive.

Threads

-- The durability of semi-active and active tags in harsh environments

-- Generally, the data storing capacity of tags, because rolls may have been used for years until they come back to the Metso roll workshop.

- The roll may never come back to Metso.

There is a need to collect running speeds and times for reference purposes, but it looks that the present FRID technology is not yet capable to measure them. In addition, the memory capacities of tags are too small for long-term data collection and will run out in a very short period of time. These limitations prevent taking this RFID vision for further detailed modelling at this point in time.

7.7 Roll workshop operations

The Metso roll workshop does coatings and mechanical maintenance operations for rolls for both end customers and the Metso manufacturing department. As already mentioned in the roll coating section, there are 14 units overseas and 3 units in Finland. The one in Jyväskylä focuses on sizer, press, calender, centre, suction and deflection compensated rolls. For example, in 2007 volumes in Jyväskylä were 227 coated rolls, of which 73 were ceramics, 59 were polyurethane and about 40 of them were carbides. In addition, there were about 100 rolls in mechanical maintenance. The roll workshop and roll coatings are closely related to each other, so the coating process description in Appendix 11 can also be used for the roll workshop. Although RFID could not improve roll coatings, it would still be worth it to check, if it could somehow improve the functions of the roll workshop.

7.7.1 Characteristics

After the roll has arrived in the roll workshop, it can be recognised based on the unique roll ID, which links it to a particular SO. This happens manually. The SO has generated a production order, which indicates all details, such as a drawing number (DWG), bill of material (BOM) and the task that needs to be completed, such as coating or mechanical service. This has been the input for production planning. The roll workshop in Jyväskylä has resources to have 10 rolls in simultaneous process with an average lead-time of one month.

Basically no information about the usage rolls is available, when they return to the roll workshop, but actually the data is not needed for roll workshop purposes themselves, if a customer has not claimed anything. The roll workshop report database includes manufacturing and maintenance history with delivery dates for every roll ID. The Baan production order includes exhaustive work details for the roll. For mechanical maintenance of Metso rolls, BOM assigns some common spare part, which can be purchased in advance. Generally, only few parts are purchased until the roll has been investigated, because it is not known what parts should be replaced.

Accurate running time, speed, nip pressure and temperatures will be highly appreciated in roll workshop's point of view, in case coating or the roll itself have not worked as planned and the customer has complained. Reference records are mainly for sales purposes. In case of claim, the data would indicate whether the customer has not followed Metso´s instructions and the product has damaged. These cases are typically very expensive and, for example, in 2007 claim costs were about 150 000 €.

The delivery temperature between the roll workshop and customer is not allowed to go below zero degrees, because it will harm the coating. During winter this is occasionally measured by a sensor attached on the roll surface during transport. Customer is asked to send it back and the warranty will not be valid, until this has been carried out. This method is also used to control temperatures with critical material deliveries from a supplier to the roll workshop.

Bar codes are used in production orders, to which employees mark working hours. Material requirements can be counted based on DWG, but it was proposed that the actual consumption of coating materials would be useful to measure by bar codes, as well.

One possible application area for RFID in the roll workshop is tool management. As an example, there are hundreds of instruments categorised as lifting tools. They include lifting ropes and sling chains. These items must be quality-checked once a year by law. For this reason, all of them have been recorded on *Metso Paper lifting tools database* with details, such as item code, serial number and description. The database indicates forthcoming inspection dates for every item and also assists by indicating what kinds of assets workshops actually have. The individual lifting instrument has an attached item code for identification, but codes are unnecessary for the actual operational work. Tools which do not have that kind of legal specification are not marked with item codes.

7.7.2 Problems

It is not always that simple to identify a roll. Although there is the Metso ID, there might also be a customer ID and Metso´s competitor's ID making things confusing. Sometimes IDs might have worn so much they are unreadable.

Sometimes an SO includes faulty details and Baan automatically transforms it into a production order. For example, dimension such as crauning, which indicates flexure of surface, has been changed from the original and it is not fixed to the DWG. These kinds of mistakes are time-consuming and expensive to fix afterwards. Many times the error is not caught, until the customer has installed the roll.

7.7.3 SWOT

The SWOT is basically pretty much equal with roll coatings and there is no need to repeat those similarities. Only some characteristic aspects are highlighted. The premise is the same; therefore the roll workshop attaches tags with integrated sensor capabilities on rolls for data collection at the time the roll is being coated. Later on, when the roll comes back for re-coating the tag can be read.

Strengths

++ RFID tags can ease roll identification. Passive tags are convenient to store an identifier and the rest is stored to the roll workshop report database.

Weaknesses

-- RFID cannot help with the matter of DWGs that are not up-to-date. The only way to avoid this is active conversation with the customer while planning the service.

- Internal production logistics work fine with job tickets, and as rolls stay for days in some operation stage, real-time RFID-controlled manufacturing does not offer any real benefits for production.

Opportunities

++ One day when semi-active, as well as active tag sensor capabilities have evolved to enable running speed and time collection, both the roll workshop and roll coatings gain remarkable benefits.

+ In future with evolved RFID technology, claims would be easier to manage and this means possible savings, if damage can be proved to have happened because of product misuse.
+ Tools with legal specification could be managed with RFID.
+ Semi-active as well as active tags could measure delivery temperatures, but on the other hand there already is method to collect this kind of data.

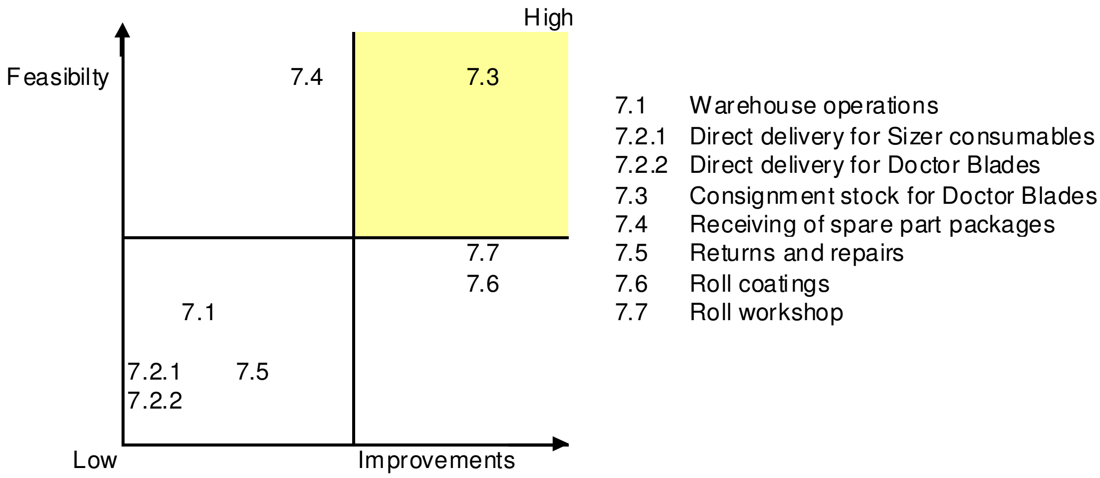
Threads

-- Metso competitors may erase tags if the roll goes there for maintenance.
-- Competitors may read tags and get valuable data relating to Metso roll coatings.

Roll coatings and workshop could both benefit, if RFID enables data collection relating to the usage of a roll, although their intentions are somewhat different. From the point of view of the roll workshop, the benefits of RFID mainly concern occasional claim situations, but savings might be several thousands of Euros. Nevertheless, required data collection is not yet feasible with present RFID technology. In addition, RFID can neither help with the matter of obsolete DWGs, nor improve workshop-internal production logistics. In addition, passive tags would ease roll identification in receiving, if the physical roll ID has almost worn invisible. RFID also provides an alternative way to collect delivery temperatures, but the same can be done with present sensors. As a result, there are some attractive possibilities but at this point they do not seem to be the most potential for further modelling in this study.

7.8 Summary

As a summary, picture 13 clarifies processes in terms of feasibility relating to the set-up of RFID and the improvements that RFID entails. These were earlier evaluated in the SWOT analysis. The vertical axis indicates feasibility and horizontal axis indicates improvements. The higher the process is positioned on the axis, the more potential it has for RFID and vice versa. The most potential process is located in the shaded upper right-hand corner.



Picture 13. Processes potential for RFID.

Picture 13 illustrates my opinion that only consignment stock processes for Doctor Blades are adopted for further modelling with RFID. In this case, RFID enables accurate on-time inventory controlling, which has been difficult so far. Thus, it is highly useful and reduces work bound to the controlling of consignment stocks, and therefore significant operational savings are expected. The study with this process continues in the next section.

Roll coatings and workshop seem to have plenty of potential for RFID usage, as well. Actually, both of them could gain benefits from the same RFID investment, where active or semi-active tags collects running data during the roll lifespan. Unfortunately, it turned out that this is not a feasible vision, because the sensor and memory capabilities of tags are not yet capable for this kind of data collection. In addition, gathering lifecycle information of rolls comes very close to responsibilities of maintenance service and may therefore be out of the scope of this study focusing on logistics. However, the roll workshop also has some other RFID possibilities, such as RFID-managed lifting tools, but those are not potential enough to generate financial savings. Thus, they are not so interesting at the moment.

It is notable that spare part receiving may benefit significantly from the adoption of RFID, as well. More often than not spare parts packages are delivered by ocean freight to distant countries, so item quality checking is considered important at the receiving stage. This requirement makes RFID features, such as mass-receiving without opening transport cases and remote reading useless. In consequence, the process is not eligible for further modelling until quality checking of every single item is not requested anymore. Remaining processes in the lower left-hand corner have some severe limiting factors, which is why they do not seem to have enough potential at this point.

8. EVALUATING SELECTED PROCESS IN MORE DETAIL

Based on the results of the process descriptions in the previous section, the consignment stocks for Doctor Blades turned out to be the most potential for RFID, as highlighted in picture 13. However, the purpose of this section is to describe how RFID-managed consignment stock processes work operationally and technically. There is also a broad pay-back and net saving calculation to indicate expected pay-back time and total net savings in RFID’s accounting lifetime. As a result, it remains to be seen, if investing is advisable or not.

8.1 Modelling operational RFID-managed consignment stock

In 1990, Michael Hammer, a former professor of computer science at the Massachusetts Institute of Technology (MIT), claimed that the major challenge for managers is to obliterate non-value adding work, rather than use technology to automate it. Especially information technology has been used primarily to automate existing work, rather than use it as an enabler for making non-value adding work obsolete. Most of the work done does not add any value for customers and this work should be removed and not accelerated through automation. Instead, companies should reconsider their processes in order to maximise customer value, while minimising the consumption of resources required for delivering their product or service. (Hammer: 1990, 104-112)

RFID will partially automate the consignment stock process in Metso Paper by providing a non-laborious and reliable way to manage them. However, before employing RFID with the present way of operating, it is beneficial to find and eliminate any non-value adding work done today. Thus, a re-engineered process description, Appendix 12, has been designed, as well as closer-operating details described in Appendix 13. For comparison, the original process description is in Appendix 7.

Stocktaking

The most significant benefit gained from the new RFID process, is the diminished need for stocktaking by sales agents. As explained earlier, managing these stocks today lay absolutely too much on the sales agents´s monthly visits, the purpose of which is mainly to check inventory levels. This is time-consuming, laborious and becomes expensive. In other words, it ties down a lot of resources. The Doctor Blade sales manager told that all-including expenses for one visit could be as high as € 1,000. Basically, this visit is good customer service, but is also fundamental for the controlling of inventories. As this happens in high intervals, it is pretty much non-value adding work.

Appendix 12 illustrates and Appendix 13 explains how stocktaking is automated in the new process by using RFID. In practice, these enables actual inventories to be viewed in maintain *items by warehouse* session in Baan. It is also possible to command readers to perform stocktaking via Baan. As a result, on-time inventories are finally obtainable any time. In addition, different stocks must be set to report on different days to middleware, so that Metso Paper Varkaus production management is loaded regularly. This enables even production planning and balancing of peak periods. Moreover, automated RFID stocktaking releases sales agents to concentrate on value-adding work, such as negotiating with potential new customers. This will increase overall sales of Doctor Blades.

Automating sales

Entering sales orders manually into Baan is kind of non-value adding work as well, because it could be done automatically over Electronic Data Interchange (EDI). It is defined as *the transfer of structured data, by agreed message standards, from one computer system to another without human intervention.* (www.edigenie.com). Today the process is prolonged, until the sales agent has passed the information on to sales and the SO has been entered into Baan, and finally an MRP re-order e-mailed to Metso Paper Varkaus. Generally, the involvement of many participants means higher possibility for typing errors as well.

The new RFID process makes these human interventions needless. The reader delivers intake events to middleware, who automatically generates an EDI sales order into Baan and further production order to MP Varkaus. This would speed things up and there is no room for typing mistakes. Moreover, sales have more time to focus on customer inquiries, as an example. Baan already has an EDI feature, which is used, for instance, in purchasing and internal sales. From this point onwards, the process goes to Baan as an ordinary sales order, which means that Baan does not need any tailoring for RFID.

Item classification

Currently most of the items running under consignment stocks are categorised as SIC items, but MRPs are definitely a minority. In the new RFID-managed system, all items must be SIC, so that EDI can handle re-orders automatically. Then Baan compares SO outcomes against SIC set-ups and generates re-orders, whenever the inventory goes under a re-order point.

Packing and generating tags

In the new RFID-managed process, Metso Paper Varkaus generates and attaches tags on transport cases similarly as conventionally item labels today. Item controlling at transport case level is considered adequate, because of customers typically take the entire transport case in one go to the target of use. It would be possible to tag every single item and move on to item level controlling, in order to lower invested capital or increase the rate of item turnover in stock. However, it is not topical, due to current customer behaviour.

In the new process Baan delivers a message to an RFID printer to write and print a “smartlabel”, which includes an item code, production date and R-number. The data is in the RFID tag’s memory, but it additionally exists in a human-readable text and bar code form, as well to ensure higher usability. In practice, “smartlabels” are generated exactly the same way as present labels. Feasibility will be higher, if “smartlabels” are printed automatically for every production order, no matter if the delivery goes to consignment stock or not. So, there is only one practice to label transport cases. Otherwise packing happens similarly as before.

An RFID tag supplier advised that the delivery unit of tags that can be used to generate “smartlabels” is 5000 or 10000 units. As there were 3600 shipments in year 2007, it means that the smaller delivery unit will easily last over a year.

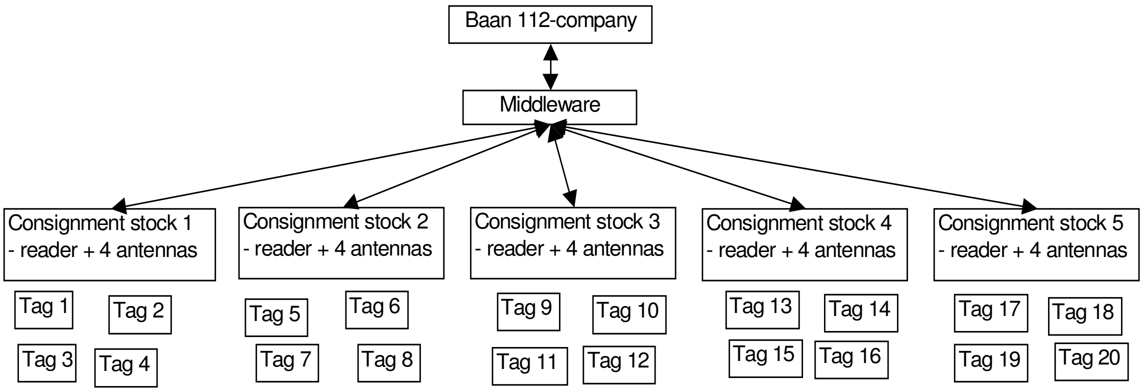
Actual dates of events

At the moment, after a production order has been maintained, the item inventory for consignment stock increases instantly, although the item has not been shipped yet. Sometimes this receiving gap causes mistakes, if a sales agent carries out stocktaking, when the item is on the way. There is also a delay between usage of products and the place of SO, which reduces inventory levels and is input for invoicing.

The new process with RFID could fix these gaps in a way explained in Appendix 13. As a result, actual dates of events can be seen from the *display inventory transactions by item and warehouse* session in Baan. Again, the new procedure diminishes the chances for mistakes, but is fundamental to carry out, because RFID will recognise a receiving gap as an intake event, which is input for a new SO. Based on individual RFID tag ID, it becomes possible to check in detail how long some particular transport case has been in stock, because RFID has registered the production, delivery, and receiving dates.

8.2 Modelling technical architecture for RFID-managed consignment stocks.

Picture 14 displays overall architecture of the new RFID-managed consignment stocks. On top of the hierarchy is Baan112 company. The company stands for Metso Paper Service and individualises service operations from other Metso Paper Baan operations. Second highest is middleware, which is an exclusive interface between Baan and stocks. This simplifies things, because readers are easy to connect on middleware but not individually to Baan. Consignment stocks are on the third level of the hierarchy. Readers inside stocks record events, such as intakes and shelves and deliver them to middleware according to settings. In practice, data transfers run from consignment stocks to Baan via middleware, but opposite traffic are also possible. For example, readers can be asked to perform stocktaking any time. Basically a non-limited number of consignment stocks can be added to the architecture.



Picture 14. RFID architecture.

Baan - middleware

The purpose is that a Baan session, such as *maintain items by warehouse,* which indicates item inventories, can be used as they are and tailoring is not needed. RFID just enables reliable on-time managing of consignment stocks in Baan. This has been very challenging so far. Technically, middleware and Baan communicate over TCP/IP protocol. The Metso Enterprise Application Integration (EAI) handles message transfer between those systems. For example, Electrobit has a suitable middleware device RNC1000, which supports ALE 1.0, 1.1 and EPCIS interfaces.

Middleware – reader in consignment stock

An appropriate communication interval for a particular reader to deliver registered events to middleware is 14 days. Even this rate is twice as often as today. At other times there is no traffic loading the network with unnecessary data transfers. Data transfer can be conducted in three ways. These are GPRS, 3G and LAN. The latter refers to Internet. The reader has an IP address inside the customer's Local Area Network. In practice, this method is abrasive and it is laborious to go through firewalls. Moreover, customers will not be willing to let Metso to enter their network. GPRS and 3G are mobile networks and data transfer happens just like in ordinary mobile phone calls, and any permission relating to the customer LAN is not necessary. GPRS and 3G are better for Metso purposes, but the system additionally needs a GPRS or 3G router for every stock. The router is equipped with a SIM card that enables data transfer via a mobile phone network. For example, Viola Systems offers an appropriate device called Arctic GPRS (EDGE) Router.

Reader in consignment stock - tags

Technically RFID readers are possible to adjust to read the content of consignment stock even continuously, but in these cases it is not intentional. The sales manager told that reading once a day would be adequate. The reader stores events on its memory and delivers those upstream, according to settings via a GPRS or 3G router. Each consignment stock has one reader with four antennas. An example of an appropriate reader is Eletrobit URP1000-ETSI, which is compliant with EPCglobal Class-1 Generation-2 and ISO 18000-6C UHF RFID Standards.

Writing and printing tags

Based on details in production orders, Baan automatically generates a "smartlabel" for every transport case. For example, a convenient device to both write and print RFID tags is Intermec PM4I RFID printer and appropriate tags are passive Short Dipole or Dogbone manufactured by UPM Raflatac. The tags and printer are compliant with EPCglobal Class-1 Generation-2 UHF standard.

Conventional RFID tags can store only 24 units of HEX digits in the EPC memory. HEX digits cover up numbers from 0 to 9 and six first letters of the alphabet. Metso item codes for Doctor Blades are in the form ILE0000123. So they do not fit directly in HEX, but it is not a problem according to RFID system providers, because they can be altered to decimal form. Besides, RFID tags have 512 bits (62 ASCHII digits) user memory, where the item code, delivery date and R-number can be easily entered. However, ASCHII digits must be converted into bits when writing and vice versa when reading.

8.3 Pay-back time and net savings

The purpose of pay-back calculation is to indicate how long it takes, until savings have covered all costs. If that happens no later than the desired period of time or before the RFID device´s expected lifetime runs out, the investment is profitable. Generally, the desired deadline for pay-back time is considered to be 3 years and the expected lifetime for RFID devices about 10 years. Net savings stand for actual savings, which can be counted for a given period of time.

The calculation starts from the premise that at the beginning of the first year, all necessary costs are paid, such as the cost for middleware and RFID printer, as well as establishing costs of three RFID-managed consignment stocks. During the next 5 years, five new stocks will be established annually. Eventually on a six-year time scale, all 28 currently existing consignment stocks have been altered to be RFID-manageable. Net savings are counted from that period of time, as well. At first, all costs and savings need to be defined. At this point installation costs between Baan and RFID are estimated according to the worst case scenario, because the final cost is impossible to obtain in advance.

8.3.1 Costs

Investment costs

RFID system provider Electrobit gave a ballpoint figure for the cost of RFID devices that they expect to be close to actual ones. Readers have volume discounts, depending on the number of units that are bought, but this calculation does not take it into account. In addition, installation costs for stock and installation costs for middleware are estimated. The following picture 15 illustrates investment cost factors for every single consignment stock and one the costs for an entire RFID-managed consignment stock system.

One of costs	Price €	Cost per stock	Price €
Middleware includes 4 licenses	5000	Reader	2500
Installation of middleware to Baan	30000	4 Antennas / reader	560
RFID printer + installation	4000	Lisence / reader	300
		GPRS or 3G router	500
		Installation work	1000
TOTAL	39000		4860

Picture 15. Investment cost factors.

One of costs for RFID-managed consignment stock system is 39000 € and consists of three factors, which are described in picture 15. This amount is constant and does not depend on the number of consignment stocks established. However, the greater the number of stocks, the smaller the fraction is that falls on an individual stock. It must be kept in mind that the highest separate cost factor of 30000 € is the middleware connection to Baan, which is estimated to be laborious. The actual cost is impossible to obtain in advance and may also be much lower.

Establishing *costs per stock* are 4860 € and consists of five factors, which are individualised in picture 15. Installation work was estimated, as well and includes materials such as a blank closet, which is a body for the consignment stock. RFID System providers charge license fees for any additional readers connected to middleware. The middleware itself includes a license for 4 readers, therefore 28 stocks require only 24 licenses. This explains minor deviations between annual investments costs. Within the first year no licenses need to be purchased and also the first consignment stock during the second year needs no license, but after this a new license must be purchased for new stock. Picture 16 illustrates investment cost accumulation on a six-year time scale.

Annual investment cost	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
Number of new stocks	3	5	5	5	5	5
One of costs Costs of new stocks	39000 13680	24000	24300	24300	24300	24300
TOTAL €	52680	24000	24300	24300	24300	24300

Picture 16. Annual investment costs.

Operating costs

In practice, operating costs are insignificant. Basically, they consist of data transfer via a mobile network between consignment stock and middleware, as well as RFID tags. Mobile phone service providers charge based on the amount of actual kilobytes transferred. In this case, the number of calls and amounts of data transfer are very low, so the accumulated operating costs amount only to a couple of Euros a year. In addition, every stock must be invented once in a year by law. Thus, annual operating costs per stock are budgeted at 1000 €. Delivery unit of tags is 5000 and it costs 1000 €. Although a delivery unit will last way over a year with the current production level, it is appropriate to budget 1000 € for tags every year. Picture 17 illustrates the annual accumulation of non-discounted operating costs, which increase as number of stocks increase.

Annual operating costs	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
Number of stocks	3	8	13	18	23	28
Tags Operating costs for stocks	1000 3000	1000 8000	1000 13000	1000 18000	1000 23000	1000 28000
TOTAL €	4000	9000	14000	19000	24000	29000

Picture 17. Annual operating costs.

Depreciation

Expected lifetime for RFID devices is at least 10 years, but Metso's policy is to amortise it over 5 years by using a straight-line depreciation. Residual value is expected to be zero. Since RFID investment is carried out by and by on a six-year time scale, the annual depreciation increases every year, until the first year investment cost is amortised at the end of year five. Picture 18 illustrates annual depreciation.

Annual depreciation	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
TOTAL €	10536	15336	20196	25056	29916	24240

Picture 18. Annual depreciation.

8.3.2 Benefits

Benefits consist of savings that RFID could offer. Today the managing of consignment stocks accumulates stocktaking costs every month for every stock. This cost turns out to be savings, if RFID is taken into use, because stocktaking becomes unnecessary in such short interval. The Doctor Blade sales manager advised that all-including stocktaking costs are as high as 1000 € per stock per month. Naturally some near-by customers are not that expensive, but customers in distant locations may cost even more, therefore this cost supposes to be a convenient average for calculation. In practice, this means that stocktaking expenses are 12000 € for a single consignment stock in a year. However, only 11 stocktaking events can be cut off per stock, because legal-based stocktaking must be done once a year. In practice, expenses of 11 stocktaking events turn out to be savings, which means 11000 € per consignment stock a year. Picture 19 illustrates the annual non-discounted savings, which increase as number of RFID-managed consignment stocks increase.

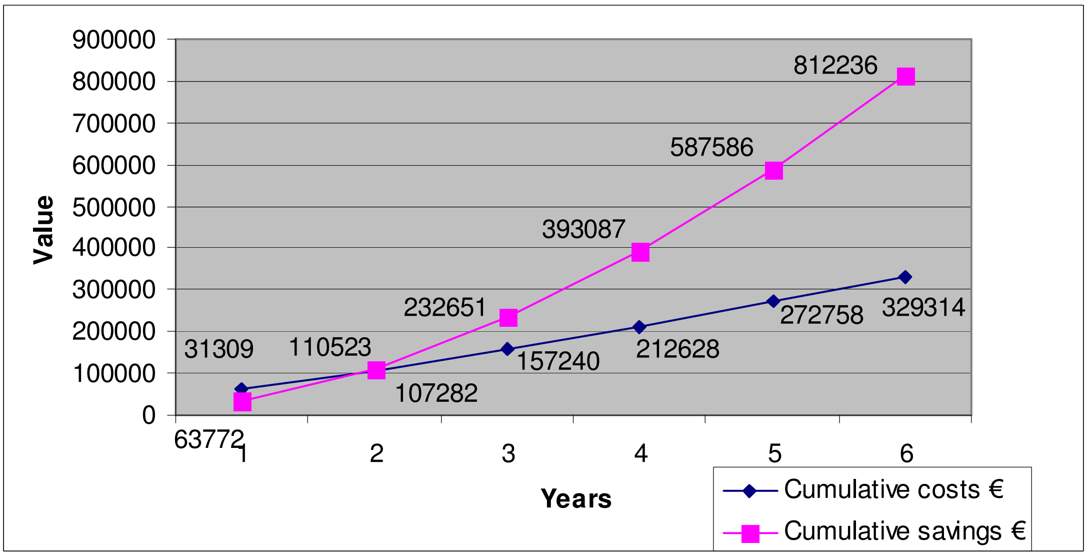
Annual savings	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
Number of stocks	3	8	13	18	23	28
TOTAL €	33000	88000	143000	198000	253000	308000

Picture 19. Annual savings.

Basically, stocktaking is the only cost factor that can be easily calculated in monetary terms. On top of that come some additional benefits, such as improved customer service, because managing of consignment stock becomes more reliable and out-of-stock incidents are avoided. These are impossible to convert to monetary terms, but are surely remarkable benefits, as well. Besides, if the legal-based stocktaking reveals mistakes between actual and Baan accounting, the difference cannot be charged from the customer, but instead must to be cut down from the Metso Paper Service revenue. Every year this causes some losses, and in some cases very remarkable ones. Monthly stocktaking has been one method to keep the accounting difference in control that it will not end up decreasing revenue.

8.3.3 Pay-back time and total net savings

The pay-back time indicates how long it takes, until benefits have covered investments. In this case the desired deadline is 3 years. All needed figures for the calculation are defined in detail in the previous cost and benefit sections. At first, the annual costs and savings are added up and then discounted from net present values by using a market interest rate of 5,4 %. Then, the annual accumulation of cumulative costs and savings are counted and a line chart, picture 20, created to indicate pay-back time, which is the crossing point of the lines. The above figures indicate cumulative savings and the figures below the cumulative costs.



Picture 20. Cumulative figures and pay-back time.

The pay-back time is about two years and goes way under the desired 3-year deadline. This means that RFID investment becomes profitable after two years with eight RFID-managed consignment stocks. After this it begins to generate net savings, which is a margin between cumulative savings and costs. At the end of year six with 28 consignment stocks, RFID has generated the net savings of about 483000 €. Financial findings are very promising and leave room for some inaccuracies in cost and benefit factors. As a result, investment in RFID is definitely advisable for consignment stocks.

9. CONCLUSION

9.1 Summary of findings

The purpose of the study was to find out, if RFID could improve any of the defined processes of Metso Paper Service, and further consider how it would impact the most potential one(s). At this point, only the consignment stock process for Doctor Blades appears to have large potential for the adoption of RFID, whereas other defined application areas do not seem to benefit from RFID for various reasons.

RFID provides significant improvements to manage Doctor Blade consignment stocks. First of all, it can solve basic problems, such as the dependency on monthly stocktaking, which ties down a lot of resources and accumulates expenses. Stocktaking performed this often is actually the consequence of the root cause of the problem, which is inadequate ways to monitor item consumption real-time. Existing ways are customers´ occasional notifications of consumption and sales agents´ monthly visits. RFID will help overcome these problems and also enables reliable remote warehouse management. Consequently, sales agents can focus on finding new customers and further increase the sales of Metso Doctor Blades.

In chapter 8 the consignment stock process for Doctor Blades is discussed in detail. At first, it is re-engineered in an operational way, since RFID partially automates the process and enables to bypass some traditional steps, such as stocktaking, e-mail data transfer between people and manual typing of sales orders. As a result, the re-engineered process will simplify and speed things up by taking advantage of the EDI feature in Baan. Secondly, the consignment stock process is modelled technically to indicate convenient RFID devices and functional settings, such as data transfer methods and intervals between readers and Baan. Finally, the most important aspect of any investment is to figure out the financial benefits, in order to see if it is advisable or not. This was calculated in sub-chapter 8.3 and is based on the premise that investment will be conducted gradually on a six-year time scale.

The costs were divided into *investment*, *operational* and *deprecation costs*. Besides, the first mentioned falls into one-of-cost of fundamental devices that must be purchased in any case for RFID, as well as stock specific costs. *One-of-cost* for RFID managed consignment stocks is 39000 € and is not dependent on the number of stocks established. At first, the *cost of* founding *a single consignment stock* is 4560 € but when starting the fifth stock it increases up to 4860 €, because licenses need to be purchased for middleware. The annual *operating costs* increase as the number of stocks increases, but it is 1000 € per stock and also 1000 € for tags in a year. Annual *depreciation* increase step by step and achieve its turning point during year five, when the first-year investment costs have been amortised. Some cost factors are estimated, because they remain more or less unknown, before the actual installation. Just in case these are considered to be almost as expensive, as in the worst case scenario.

Benefits consist of stocktaking events, which become needless, after RFID is in use. Consequently, 11 events will be saved per consignment stock a year, because one legal-based event will stay in any case. The cost of a single stocktaking event is 1000 €, which translates to savings of 11000 € per stock a year. Consequently, the annual savings increase, as the number of RFID-managed consignment stocks increases. On top of that, there are some benefits impossible to convert to monetary terms. These are explained at the end of section 8.3.2.

It is notable that the higher the number for annually founded RFID-managed consignment stocks, the shorter the pay-back time and the greater the net savings will be. This happens, because annual stock-specific savings are much greater than annual operating costs. Even first-year stock-specific savings exceed the investment cost. With the planned investment pace, three stocks during the first year and five stocks annually during next five years, it takes six years to alter all 28 consignment stocks into RFID-managed ones. Despite of the relatively slow pace of the investments, RFID gains a very promising 2-year *pay-back time* and within a six-year time scale generates *net savings* worth 483000 €. Since the financial findings are so promising, it leaves room for some inaccuracies in the cost and benefit factors, especially with the estimated ones. Nevertheless, an RFID-managed consignment stock for Doctor Blades definitely appears a profitable investment.

All in all, the study has achieved its objective. A potential application area was found and evaluated to a depth possible to achieve in advance. In my opinion, Metso Paper Service should carry out a RFID pilot project with several Finnish customers, and later on when RFID-managed consignment stocks are running well in Finland, move on to foreign customers, as well as new customers.

9.2 Suggestions for further studies

At this point of time one application area seemed to be more potential for the utilisation of RFID, than other defined applications. Since the RFID project for consignment stocks is making good time, I recommend considering the receiving process of spare part packages again. It will require minor re-engineering that item quality-checking becomes unnecessary. After this, receiving with RFID is feasible and possible savings can be estimated. In addition, some other applications include tasks that could be carried out with RFID, as well. These are, for example, the monitoring of roll delivery temperatures from the roll workshop to customer site and the managing of lifting tools in the roll workshop, but expected benefits may not be remarkable.

In future, it might be feasible to collect actual running data during the lifetime of roll with active or semi-active RFID tags. This would be extremely beneficial for reference and product development purposes in roll coatings and workshop applications. In any case, RFID is rapidly developing technology, and Metso should continuously keep an eye the latest improvements in this field.

10. SOURCES

Aitken, William. (2000). Planning and Controlling Projects. Broadstraits, Kent, UK: Scitech Educational. 128 p. ISBN0948672676.

Committee on Radio Frequency Identification Technologies (CB). (2004). Radio Frequency Identification Technologies: A Workshop Summary. Washington, DC; USA: National Academies Press 51 p.

Finkenzeller, Klaus. (2004). RFID Handbook, Fundamentals and Applications in Contactless Smart Cards and Identification. Ed.2. West Sussex, GBR: John Wiley & Sons ltd. 425 p. ISBN 0-470-84402-7.

Glower, Bill. & Bhatt, Himanshu. (2006). RFID Essentials. 1. Edition. Sebastobol CA: O´Reilly Media Inc. 260 p. ISBN 0-596-00944-5.

Hammer, Michael. (1990). Reengineering Work: Don't automate, obliterate, Harvard Business Review, Jul/Aug

Jones, James V. (2006). Integrated Logistics Support Handbook. Blacklick, OH, USA: McGraw-Hill Professional Publishing. ISBN 97-0-07-147168-8.

Kleist, Robert A. Chapman, Theodore A. Sakai, David A. & Jarvis, Brad S. (2004). RFID labeling, smart labeling concepts & applications for the consumer packaged goods supply chain. Irvine, CA, USA: Printronix inc. 211 p. ISBN 0-9760086-0-2.

Kotler, Philip. & Keller, Kevin L. (2006). Marketing Management. 12. Edition. Prentice Hall, Upper Saddle River, New Jersey. 729 p. ISBN 0-13-145757-8.

Lowe, David. (2002). Dictionary of Transport and Logistics. London, GBR: Kogan Page, Limited 561 p.

Metso Paper general material (2008), B**.** Power to Serve - Supporting your best performance 12 p.

Muller, Max. (2002). Essentials of Inventory Management. Saranac Lake, NY, USA: AMACOM

Neilimo, Kari. & Uusi-Rauva, Erkki, (2005). Johdon laskentatoimi. 6 edition. Helsinki: Edita Prima OY. 366 p. ISBN951-37-4109-5.

Palmer, Roger C. (2001). THE BAR CODE BOOK, a Comprehensive Guide to Reading, Printing, Specifying and Applying Bar Code and Other Machine-Readable Symbols. 4. Edition. Peterborough, New Hampshire, USA: Helmers Publishing, Inc. 452 p. ISBN 0-911261-13-3.

Rankl, Wolfgang. & Effing, Wolfgang. (2004). Smart Card Handbook. West Sussex, GBR: John Wiley & Sons ltd. 1120 p. ISBN 0-470-85668-8.

Trackway. Real time transparency into your supply chain. (2008).

Electronic sources:

Association for Automatic Identification and Mobility (AIM) 2008. Bar code Standards [cited 25.03.2008]. Available from Internet: www.aimglobal.org/ standards/aimpubs.asp.

Association for Automatic Identification and Mobility (AIM) 2008. Bar code print quality verification [cited 25.03.2008]. Available from Internet: www.aimglobal. org/technologies/barcode/barcode /verification.asp.

Association for Automatic Identification and Mobility (AIM) 2008. Bar code printing. [cited 25.03.2008]. Available from internet: www.aimglobal.org/ technologies/barcode/barcode_printing.asp.

EDIgenie. EDI: what is it? [cited 30.06.2008]. Available from internet: www.edigenie. com/content/view/29/58/

EPCglobal, Frequency Regulations UHF, A. [cited 07.04.2008]. Available from Internet: www.epcglobalinc.org/tech/freq_reg/RFID_at_UHF_Regulations_ 20080120.pdf.

EPCglobal, RFID Class 1 Generation 2 UHF, B. [cited 07.04.2008]. Available from Internet: www.epcglobalinc.org/standards/uhfc1g2/uhfc1g2_1_1_0-standard-20071017.pdf.

EPCglobal, Low-Level Reader Protocol (LLRP), C. [cited 11.04.2008]. Available from Internet: www.epcglobalinc.org/standards/llrp/llrp_1_0-standard-20070412.pdf.

Metso Paper homepage, A. About us. [cited 18.04.2008]. Available from Internet: www.metsopaper.com

NetMBA, Strategic management => SWOT Analysis. [cited 11.07.2008]. Available from Internet: www.netmba.com/strategy/swot/

RFID Journal, A. The basics of RFID technology. [cited 31.03.2008]. Available from Internet: www.rfidjournal.com/article/articleview/1337/1/129/

RFID journal, B. The standard problem. [cited 04.04.2008]. Available from Internet: www.rfidjournal.com/article/articleprint /757/-1/1

RFIDUpdate. ISO incorporates Gen2 into RFID standard. Wednesday July 12th 2006. [cited 07.04.2008]. Available from internet: www.rfidupdate.com/ articles/ index.php?id=1156.

Vilant Systems. What is RFID. [cited 11.07.2008]. Available from internet: www. vilant.com/272.

Wikipedia, SWOT Analysis. [cited 11.07.2008]. Available from internet: www.wikipedia.org/wiki/Image:SWOT_en.svg

11. INTERVIEWEES

Interviews were conducted at 06.05 – 09.06.2008

Hiljanen Esko, Customer Service Engineer, Metso Paper Service Jyväskylä

Huittinen Mikko, Customer Service Engineer, Metso Paper Service Jyväskylä

Huuska Petri, Roll Workshop Manages, Metso Paper Service Jyväskylä

Hyvärinen Joose, Forwarding Coordinator, Metso Paper Service Jyväskylä

Juntonen Sanna, Product Manager of Roll Coatings, Metso Paper Service Jyväskylä

Kautto Ari-Pekka, Product Manager of Sizer consumables, Metso Paper Service Jyväskylä

Karhu Saara, Customer Service Engineer, Metso Paper Service Jyväskylä

Lahtinen Jukka, Account manager, Elektrobit.

Lilja Sanna, Customer Service Engineer, Metso Paper Service Jyväskylä

Luhanko Tuomo, Forwarding Coordinator, Metso Paper Service Jyväskylä

Luomalahti Mikko, Logistics Coordinator, Metso Paper Service Jyväskylä

Majanen Ari, Receiver, Metso Paper Service Jyväskylä

Peltoniemi Teemu, Logistic Engineer, Metso Paper Service Jyväskylä

Sironen Timo, Senior Product Sales Manager of Doctor Blades, Metso Paper Service Jyväskylä

Syrjä Tero, Manager, Item and Inventory Management, Metso Paper Service Jyväskylä

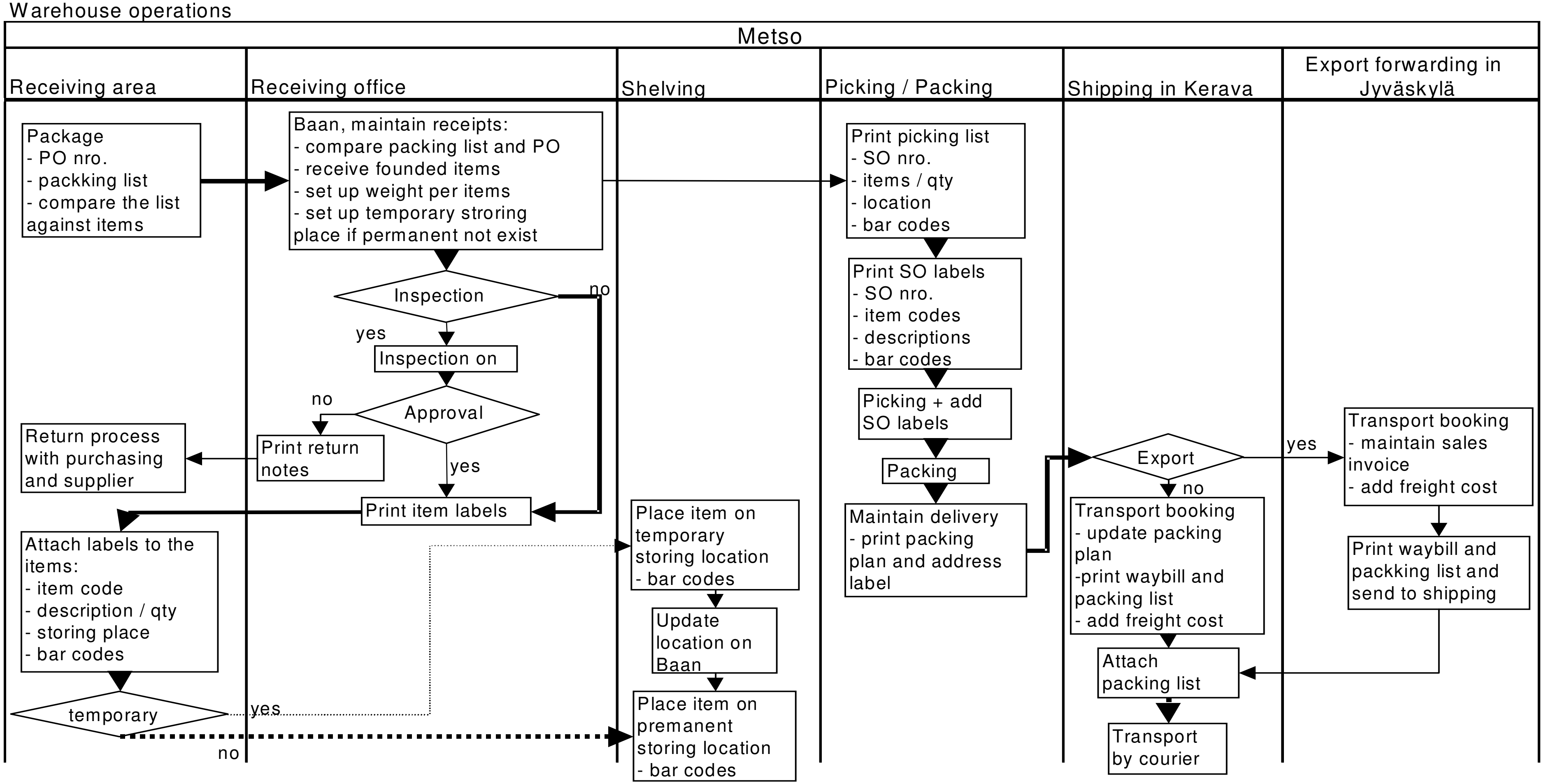
Vasara Heikki, Product Manager, Metso Paper Service Jyväskylä

Viitasalo Pasi, Global Product Manager of Doctoring products, Metso Paper Service Jyväskylä

Väisänen Kare, Global Technology Manager, Metso Paper Service Jyväskylä

12. APPENDICES

Appendix 1



Appendix 2

metso paper

Service

GOODS RECEIVED NOTE

Page 1 / 1

Order: 704346

Supplier

FP Finnprofiles Oy
Vammalan tehdas - Pääkonttori
Paljekatu 1
VAMMALA

Supplier:	500296	Forwarder:	Kiitolinja Oy PMM As.No.946524	Date:	11-06-2008
Order:	704346	Reference:	Raimo Kimpimaki	Buyer:	Hämäläinen Hannu

Item	Weight	Critical	Ord.qty	Del.qty	Unit	Received	Del Date	Wk/Yr	Inspect
Puchase Order 704346 totally 1 positions									
Delivery Dates: 18-06-2008 - Pos 1									
Warehouse: S01 LC NOC Inventory									
RAUA213764	5.5 kg		**2**	**2**	PCE	______	**18-06-08**	**25/08**	**NO**
LOADING HOSE									1
DWG RAU1201846									

Sales Order:	393020 541/503461;
Position:	1
Del Date	23-06-2008

Appendix 3

metso paper

Service

PICKING LIST 123792

Page 1 / 1

Order: 394023

Customer

Fortek Oy
Oulun liiketoimintayksikkö
PL 95
90101 OULU

Delivery address

Fortek Oy
Keskusvarasto
Ovi 810
Nuottasaarentie
90120 OULU

Customer: 152380 **Forwarder:** **Date:** 23-06-2008

Reference: 4500838474;Pirjo Vuorenmaa

Ship Mark: 4500838474/Joni Matala

Terms of Delivery: DDU OULU

Sales Location: JYVÄSKYLÄ

Sales Rep: Friman Auli

Telephone: 20 482 5261

Pono	Location	Item	Weight(kg)	Ord.qty
		Sales Order 394023 totally 2 positions Delivery Dates: 26-06-2008 - Pos 1, 2 Warehouse: S01 LC NOC Inventory		
1	H1522	VAL0071491 EYE BOLT B M36x360-SS2324	3.95	2 PCE

Appendix 4

metso paper

PACKING LIST **Page:** 1 / 1

Packing Plan: 394138 **Package Number:** 1	**LBU Project:** EUSL	**Packer:** Hyytiäinen Jani **Packing Date:** Jun 11, 2008 **Company:** 112
Dimensions (cm): 35 x 30 x 6 **Volume (m3):** 0,006 **Container:**	**Net Weight (kg):** 0.2 **Gross Weight (kg):** 0.3 **Type of Package:** CARTON **Storage Type:** IU: Inside unheated	**Sales Order No:** 394138 **Customer PO No:** ANL149036 **Shipping Area:** JAR/KER

CUSTOMER/delivery address: Aylesford Newsprint Ltd Maintenance Storage Bellingham Way ME20 7DL AYLESFORD KENT UNITED KINGDOM	**Marks and Numbers:** 014 ANL149036 Diane Barker Sandra Bennett

Name of the Package:

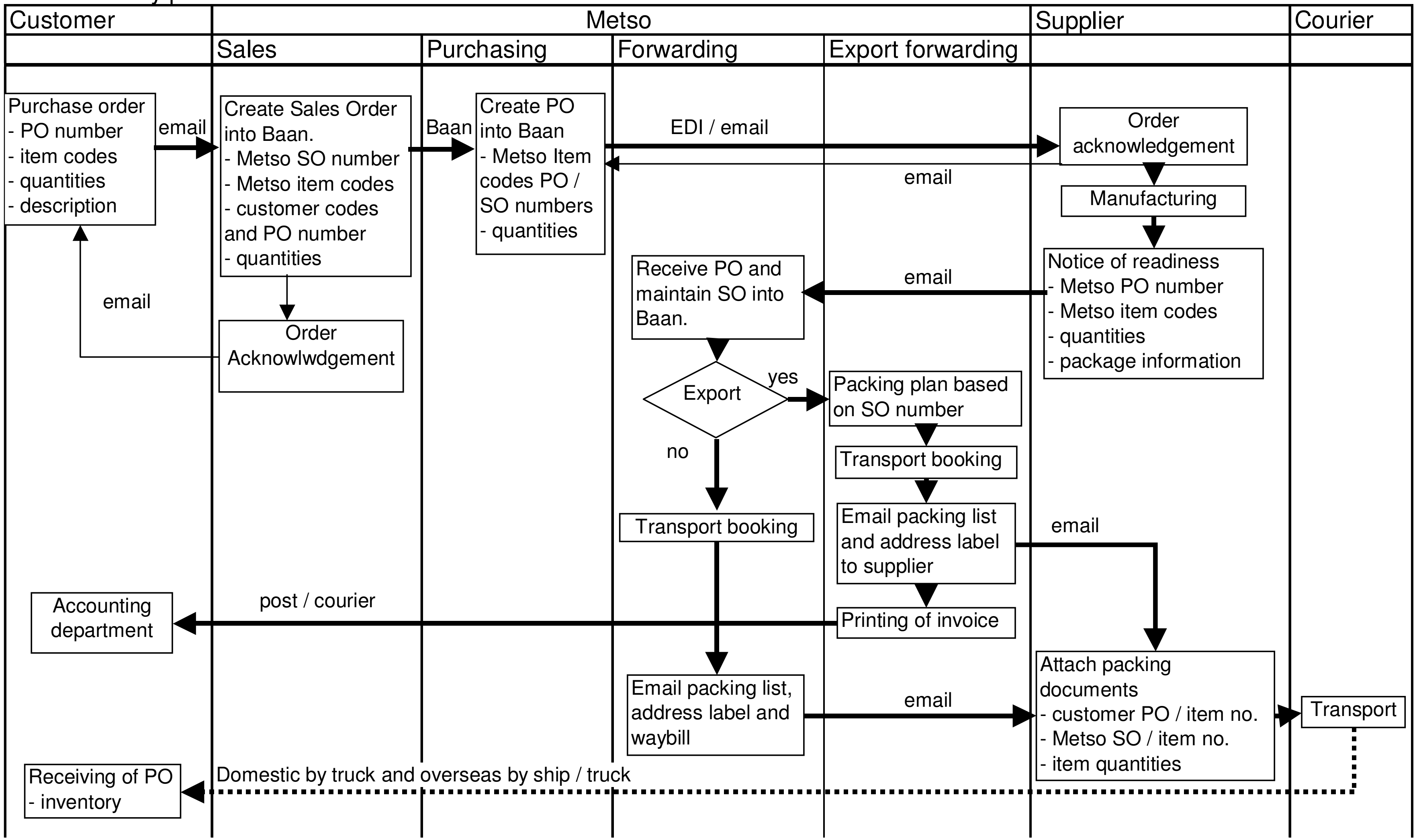
Notes: DHL 6296039691

Terms of Delivery: DDU Aylesford Incoterms 2000

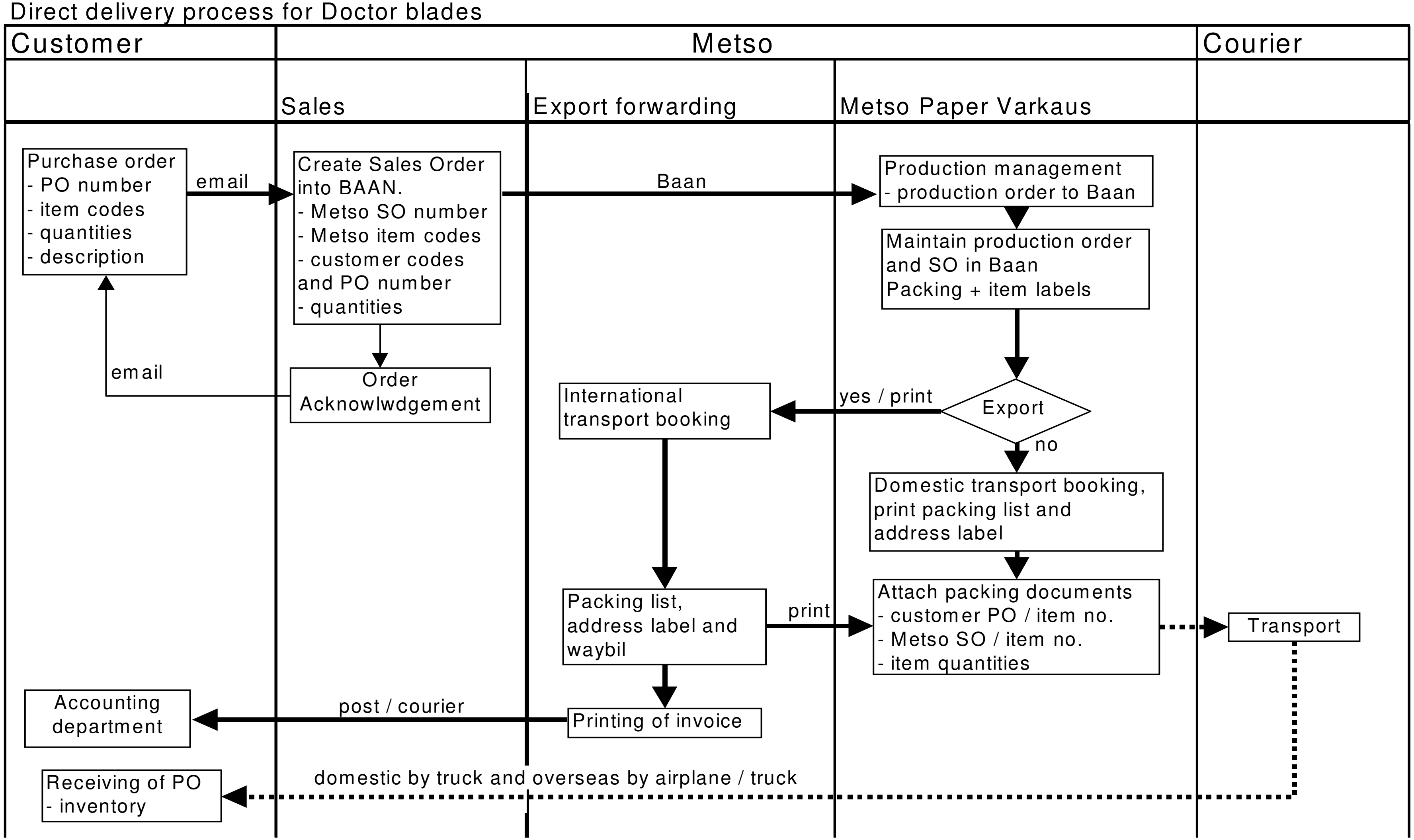
Parent Item Item	/ Pos	Parent Item Description Item Description	Drawing	Parent Drawing Quantity	Unit	PCS-Projec
VAL0011180	/ 1	OIL LEVEL GLASS A61539		4	PCE	

Appendix 5

Direct delivery process for Sizer consumables

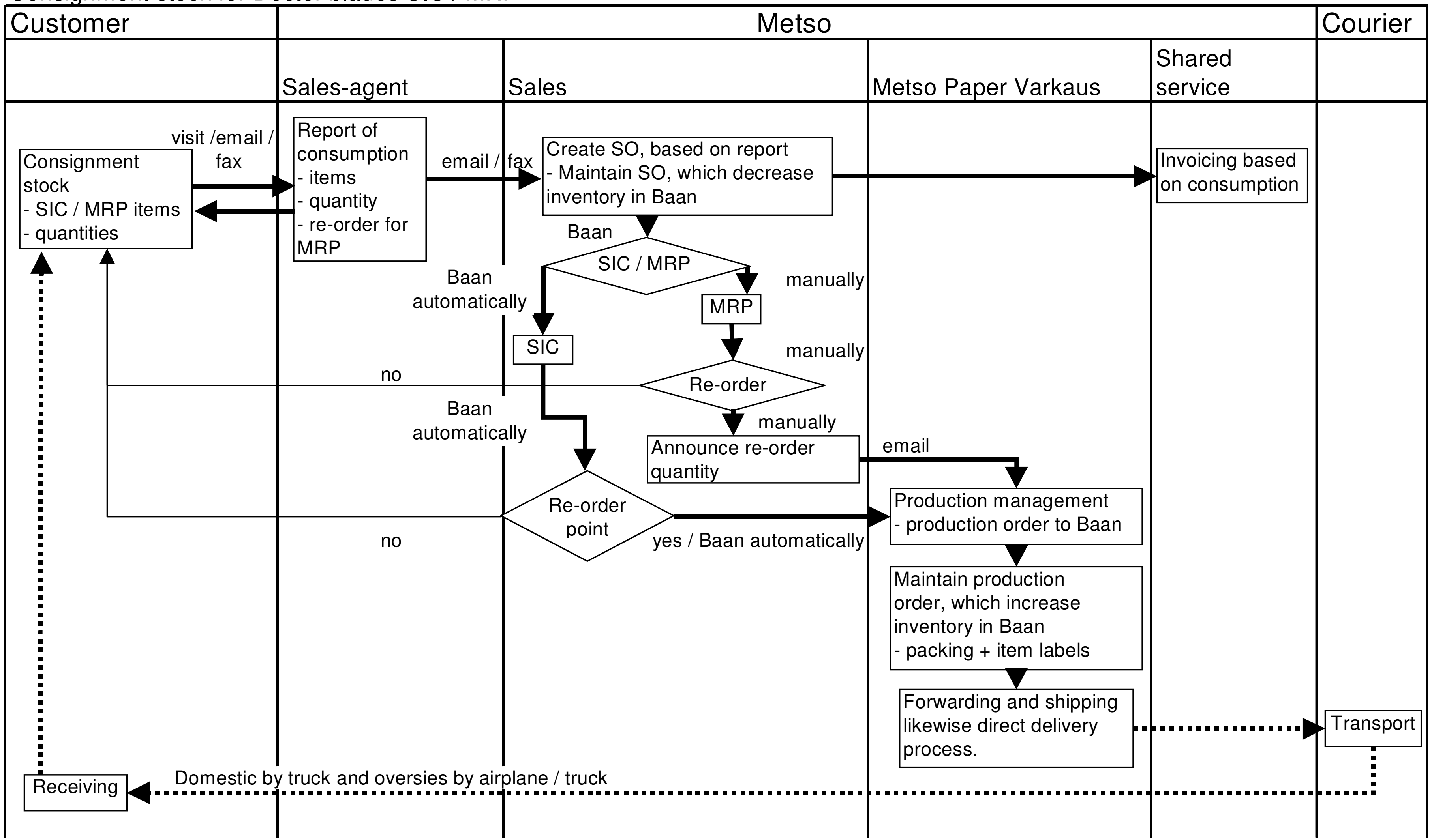


Appendix 6


Direct delivery process for Doctor blades
Customer
Metso
Courier
Sales
Export forwarding
Metso Paper Varkaus
Purchase order
- PO number
- item codes
- quantities
- description
email
Create Sales Order into BAAN.
- Metso SO number
- Metso item codes
- customer codes and PO number
- quantities
Baan
Production management
- production order to Baan
Maintain production order and SO in Baan
Packing + item labels
email
Order Acknowlwdgement
International transport booking
yes / print
Export
no
Domestic transport booking, print packing list and address label
Packing list, address label and waybil
print
Attach packing documents
- customer PO / item no.
- Metso SO / item no.
- item quantities
Transport
Accounting department
post / courier
Printing of invoice
Receiving of PO
- inventory
domestic by truck and overseas by airplane / truck

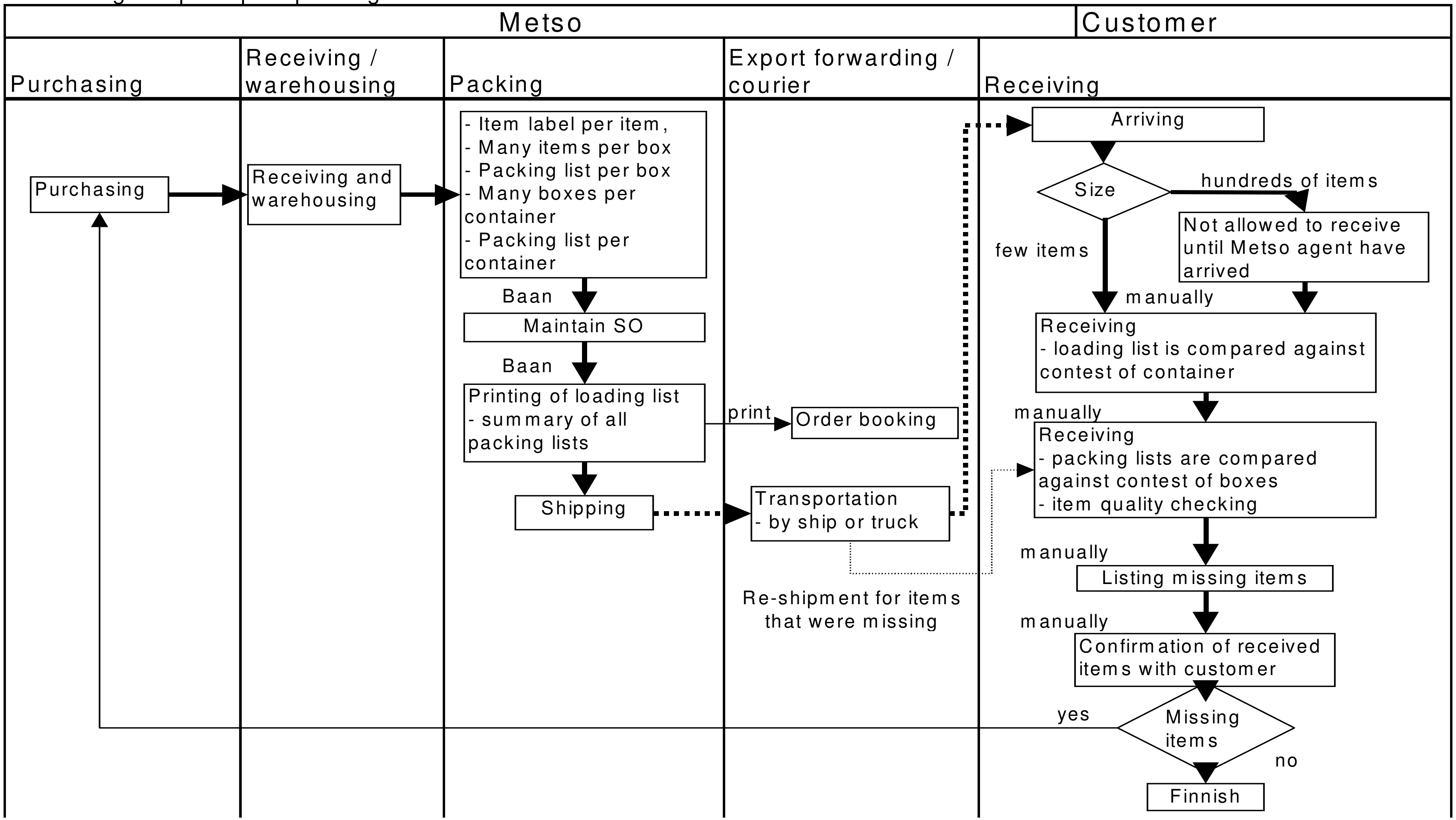
Appendix 7

Consignment stock for Doctor blades SIC / MRP

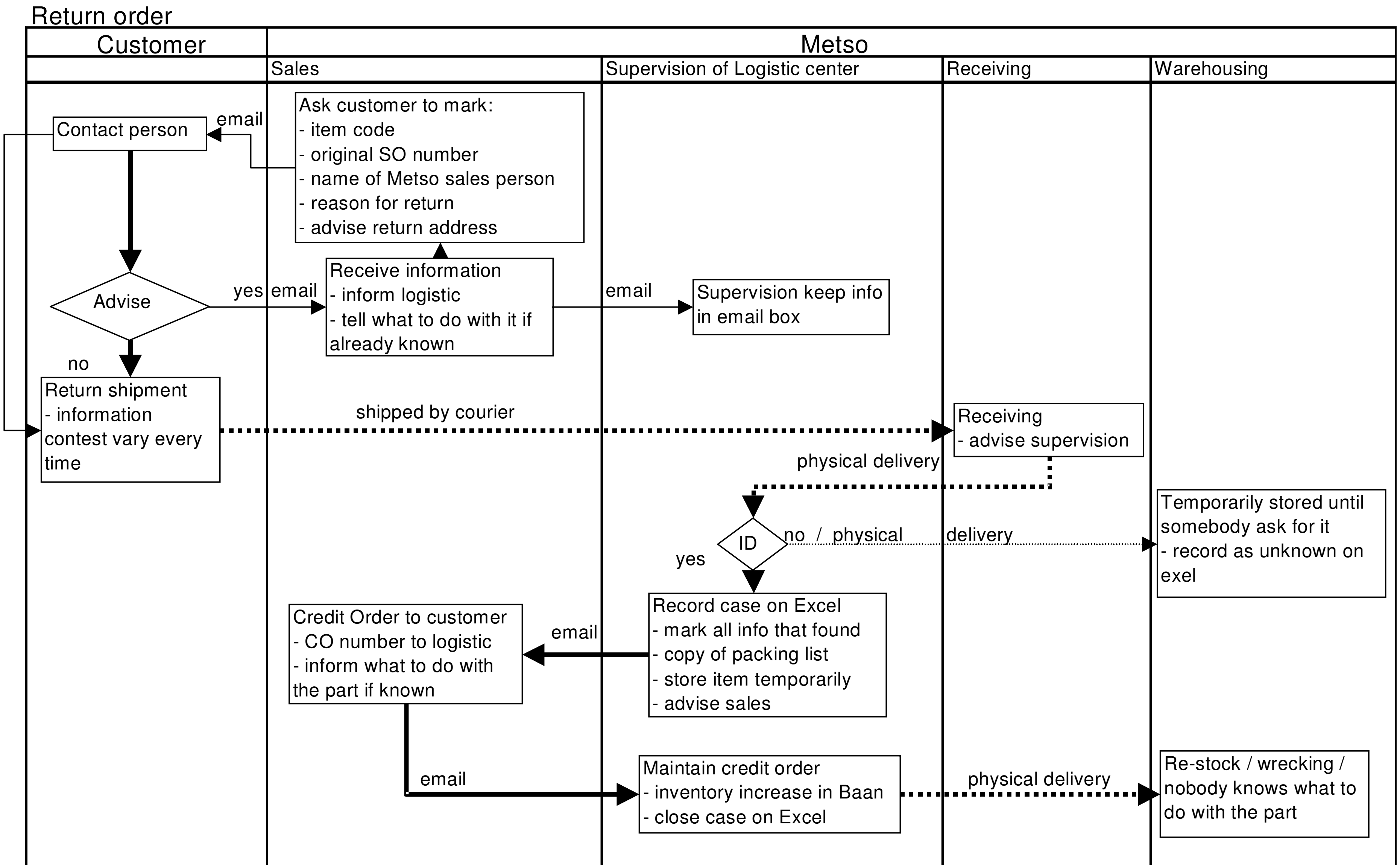


Appendix 8

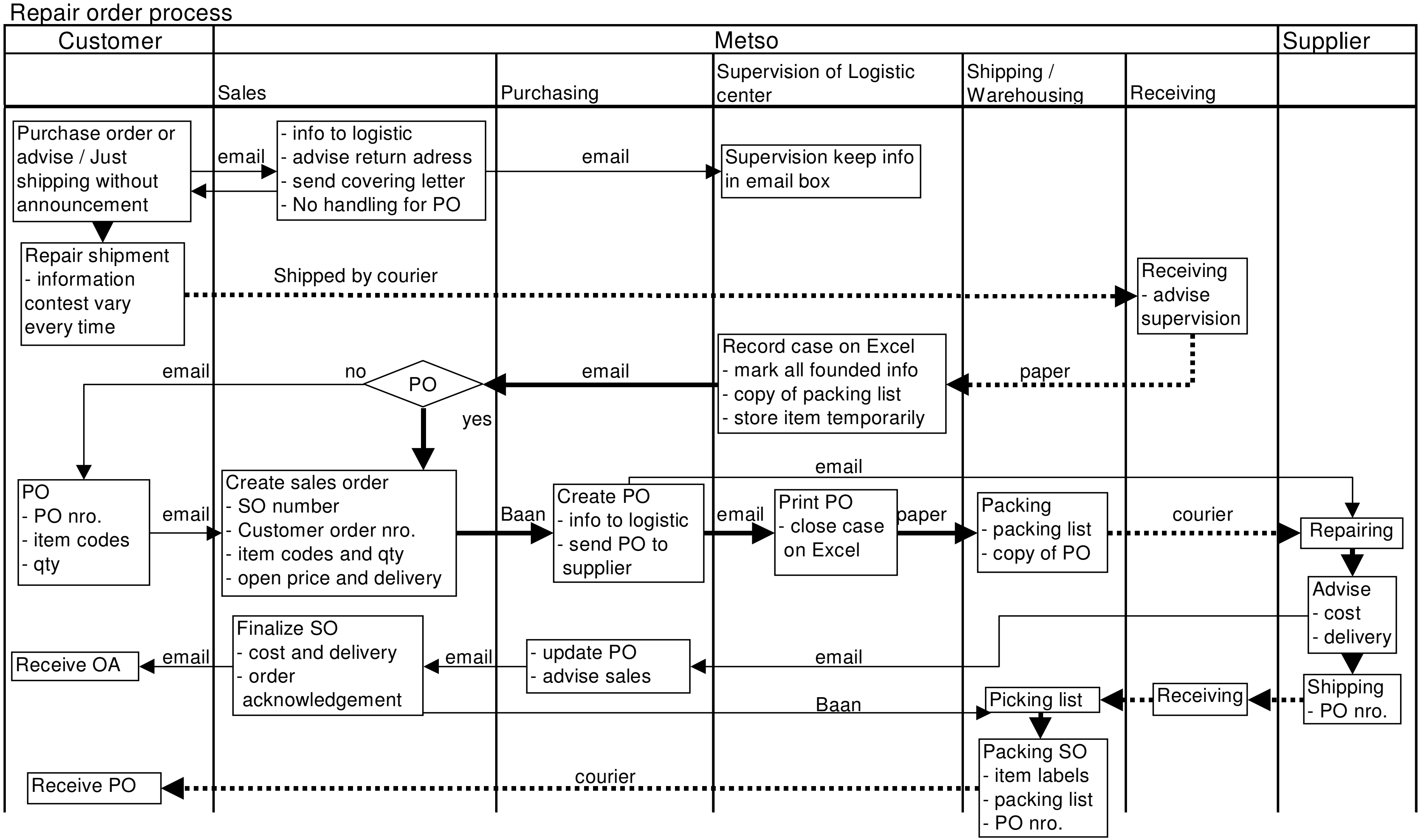
Receiving of spare part packages



Appendix 9

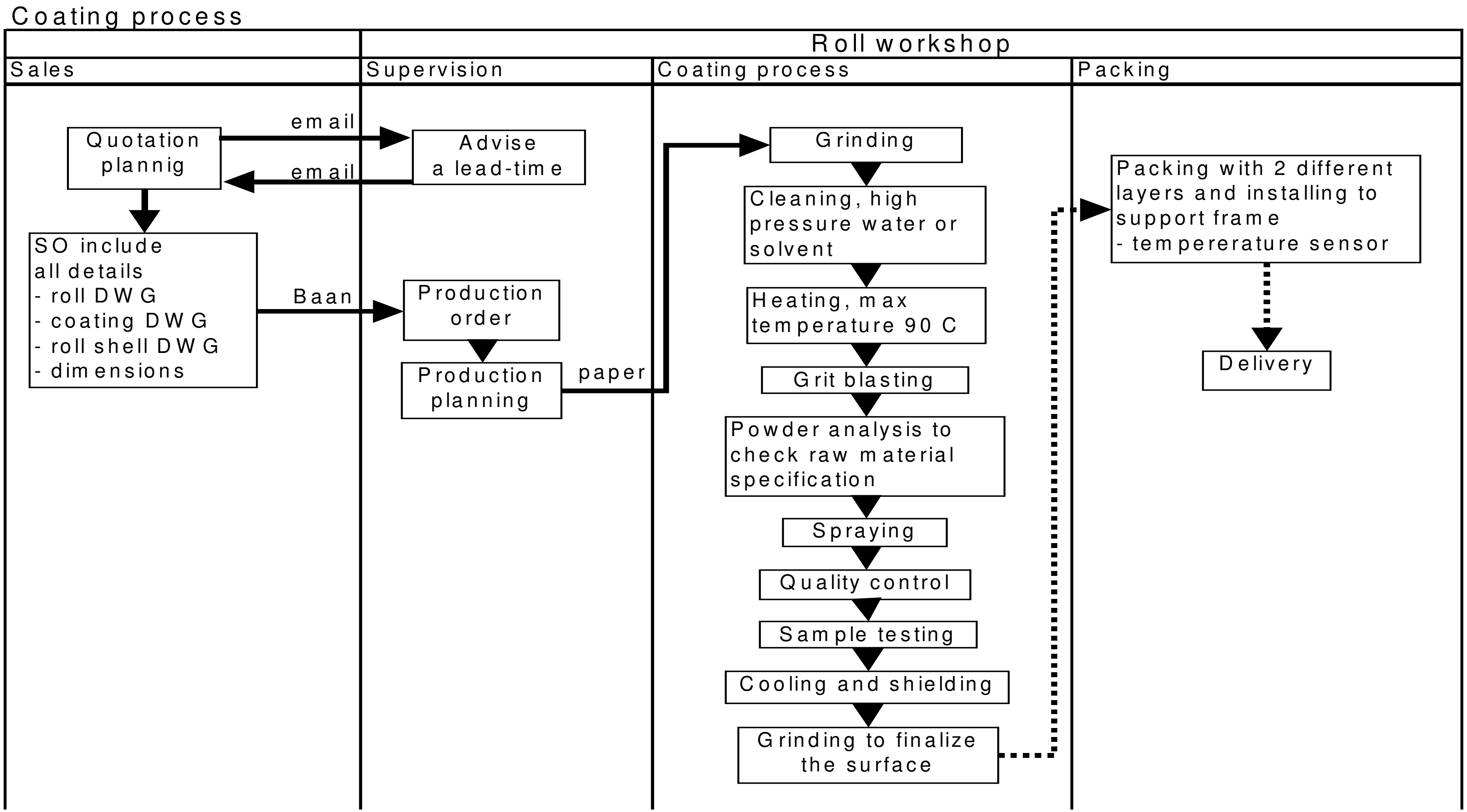

Return order
Customer
Metso
Sales
Supervision of Logistic center
Receiving
Warehousing
Contact person
email
Ask customer to mark:
- item code
- original SO number
- name of Metso sales person
- reason for return
- advise return address
Advise
yes
email
Receive information
- inform logistic
- tell what to do with it if already known
email
Supervision keep info in email box
no
Return shipment
- information contest vary every time
shipped by courier
Receiving
- advise supervision
physical delivery
ID
no / physical delivery
Temporarily stored until somebody ask for it
- record as unknown on exel
yes
Record case on Excel
- mark all info that found
- copy of packing list
- store item temporarily
- advise sales
email
Credit Order to customer
- CO number to logistic
- inform what to do with the part if known
email
Maintain credit order
- inventory increase in Baan
- close case on Excel
physical delivery
Re-stock / wrecking / nobody knows what to do with the part

Appendix 10



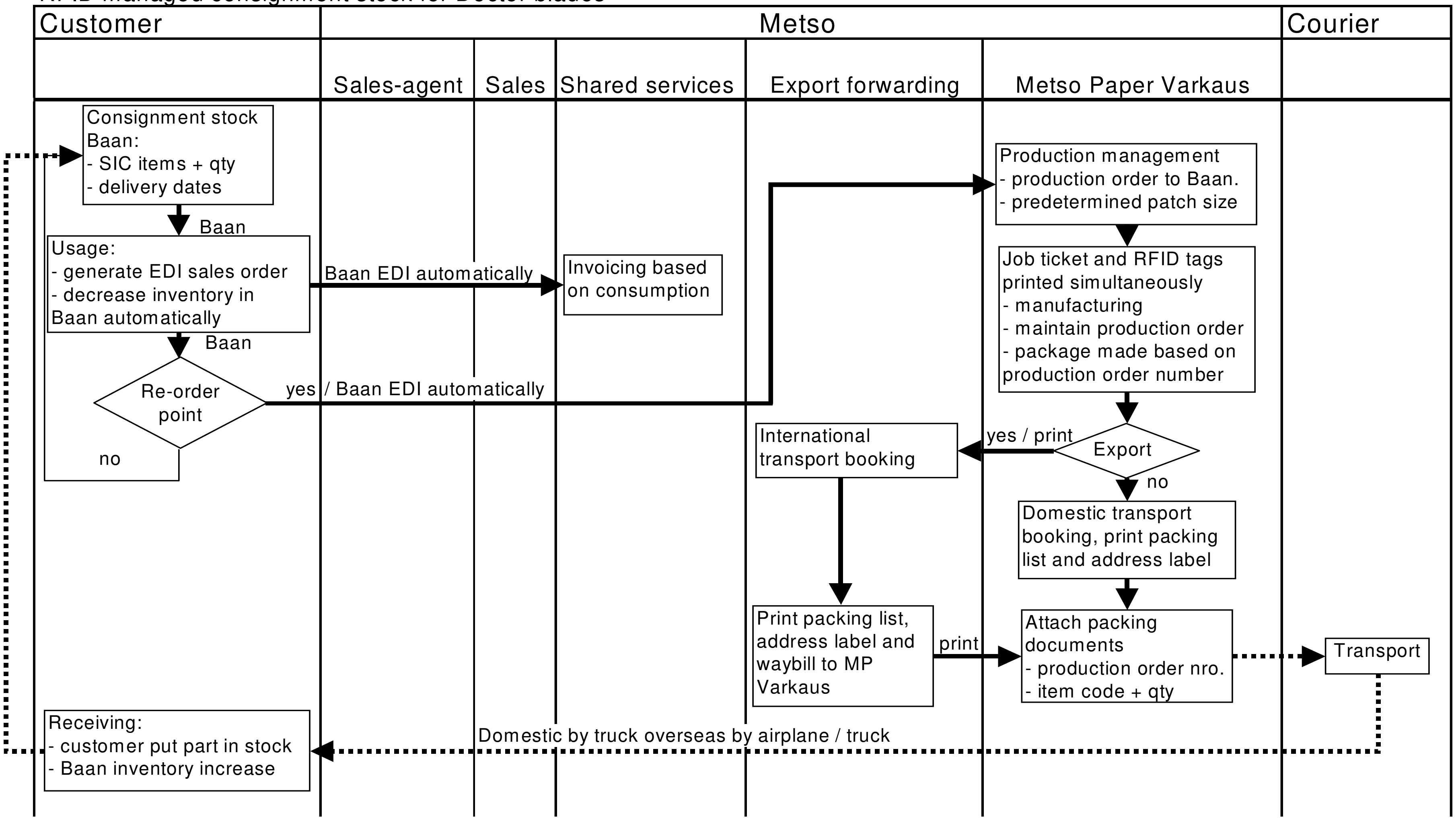
Repair order process
Customer
Metso
Supplier
Sales
Purchasing
Supervision of Logistic center
Shipping / Warehousing
Receiving
Purchase order or advise / Just shipping without announcement
email
- info to logistic
- advise return adress
- send covering letter
- No handling for PO
email
Supervision keep info in email box
Repair shipment
- information contest vary every time
Shipped by courier
Receiving
- advise supervision
Record case on Excel
- mark all founded info
- copy of packing list
- store item temporarily
email
no
PO
email
paper
yes
email
PO
- PO nro.
- item codes
- qty
email
Create sales order
- SO number
- Customer order nro.
- item codes and qty
- open price and delivery
Baan
Create PO
- info to logistic
- send PO to supplier
email
Print PO
- close case on Excel
paper
Packing
- packing list
- copy of PO
courier
Repairing
Advise
- cost
- delivery
Receive OA
email
Finalize SO
- cost and delivery
- order acknowledgement
email
- update PO
- advise sales
email
Baan
Picking list
Receiving
Shipping
- PO nro.
Packing SO
- item labels
- packing list
- PO nro.
Receive PO
courier

Appendix 11


Coating process
Roll workshop
Sales
Supervision
Coating process
Packing
Quotation plannig
email
email
Advise a lead-time
SO include all details
- roll DWG
- coating DWG
- roll shell DWG
- dimensions
Baan
Production order
Production planning
paper
Grinding
Cleaning, high pressure water or solvent
Heating, max temperature 90 C
Grit blasting
Powder analysis to check raw material specification
Spraying
Quality control
Sample testing
Cooling and shielding
Grinding to finalize the surface
Packing with 2 different layers and installing to support frame
- tempererature sensor
Delivery

Appendix 12

RFID managed consignment stock for Doctor blades



Appendix 13

This is how a RFID-managed consignment stock for Doctor Blade runs.

1. Consignment stocks at customer site include RFID readers.
- Inventories and delivery dates per items are in Baan.
- Readers read tags once a day and register events, such as intakes and shelves with dates in their memory.
- Readers report these events to middleware at a 14-day interval, but only if there have been events.

2. Reader at stock communicates to middleware via a GPRS or 3G connection.

3. Middleware generate changes in inventories to Baan over TCP / IP protocol
- Shelving event of a particular item increases its stock inventory in Baan and registers actual receiving date.
- Intake events generate an EDI sales order to Baan.

4. EDI sales order.
- Decreases inventory for sold items.
- Generates invoicing impulse to a Metso shared service.

5. Baan compares changed inventory levels against SIC specifications.
- If inventory level does not reach the re-order point, nothing happens.
- If inventory levels go below the re-order point, Baan generates a production order into Metso Paper Varkaus production management, according to a predetermined patch size.

6. Manufacturing at MP Varkaus.
- Baan prints a job ticket and delivers a message to a RFID printer to write and print RFID tag´s "smartlabel" that includes an item code, production date and R-number.
- Otherwise production runs as always.
- Maintaining production orders does not increase the consignment stock inventory, but instead the item goes to a special on-transit stock in Baan, until the customer has received the items.

7. Packing at MP Varkaus.
- Attach RFID tags on transport cases, not on every single item.
- Packing list based on production order number and address label

8. Shipping and forwarding.

- Similarly than before. MP Varkaus handles domestic ones and export forwarding in Jyväskylä international shipments.

9. Receiving at customer site.

- Transport case shelving into consignment stock does not require any registration actions by the customer.
- Reader registers the shelving event and date during the next reading cycle and stores it in its memory.
- Reader reports that event to middleware during the next reporting cycle. Then Baan transfer items from the on-transit inventory to a consignment stock.

10. Occasionally transport case does not end up in a consignment stock.

- Since 14 days has gone from maintaining the production order, which puts inventory in an on-transit stock, Baan automatically transfers the inventory into a consignment stock.
- The next reading cycle recognises the absence as an intake event and processes runs as already explained.

11. Baan session *maintain items by warehouse* display only inventories.

- By running a Baan event report for a certain consignment stock, all items with inventories, as well as production dates, delivery dates and actual receiving dates come visible.

12. Stocktaking

- Product managers can command readers to perform stocktaking any time via Baan.