Guidelines for material procurement

An inbound logistics point of view

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Summary

The goal of this thesis was to provide guidelines for material procurement from an inbound logistics and purchasing point of view. By grouping materials according to provided guidelines, the most efficient way for material procurement according to Wärtsilä DCV specific needs would always be used. The research was done by studying current material flow and warehouse system setup. During this study I realized that providing guidelines from one point of view might not be the best way to improve the supply chain. At the end of this study there is a proposal of how to handle this issue from a larger perspective, in order to truly consider all procurement related costs.

Language: English	Key words: supply chain, inbound logistics, procurement

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EXAMENSARBETE

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Abstrakt

Målet med detta arbete var att skapa riktlinjer för materialanskaffning från den inre logistikens och operativa inköpets perspektiv. Genom att gruppera material enligt riktlinjer skulle det effektivaste sättet för materialanskaffning med Wärtsilä DCV specifika krav alltid användas. Undersökningen gjordes genom med hjälp av olika metoder att studera nuvarande materialflöde och lagerkonfiguration. Under undersökningens gång kom jag fram till att detta inte var det mest effektiva sättet att förbättra distributionskedjan. I slutet av detta dokument finns förslag på hur man kunde analysera situationen från ett större perspektiv och ta i beaktande alla anskaffningsrelaterade kostnader.

Språk: Engelska Nyckelord: distributionskedja, inre logistik, anskaffning

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OPINNÄYTETYÖ

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Tiivistelmä

Työn tarkoitus oli tehdä suuntaa antavia suosituksia materiaalihankinnoista sisäisen logistiikan ja operatiivisen oston näkökulmasta. Ryhmittämällä materiaaleja suositusten ohjeistamalla tavalla, tehokkain tapa hankkia materiaaleja huomioiden Wärtsilä DCV:n asettamat erikoisvaatimukset, olisi aina toteutettavissa. Tutkimus on tehty analysoimalla nykyinen materiaalivirta sekä varastokäytäntö. Tutkimuksen aikana huomasin, että antamalla suosituksia yhden toiminnon näkökulmasta, ei välttämättä ole tehokkain tapa parantaa koko tarjontaketjua. Tutkimuksen lopussa on keskustelu aiheesta ja suosituksia miten voisi analysoida koko toimitusketjua huomioiden kaikki hankintaan liittyvät kulut.

Kieli: Englanti Avainsanat: tarjontaketju, sisäinen logistiikka, hankinta

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Preface

The journey of this thesis began in 2013. During the work there have been a lot changes at Wärtsilä Delivery Centre Vasa (DCV) that have had an impact on the outcome of the work. I have gained experience and learned a lot during this work. Many thanks to all who have helped me with this work, both to those who have helped me with the topic as well as to those who have opened my mind to different approaches during discussions.

Contents

Abbreviations

ERP- Enterprise Resource Planning

SAP- Software company providing ERP solutions

Transaction code (t-code) – Shortcut to a function in SAP ERP.

WM – SAP Warehouse Management System

WM Stock Category – Material status e.g. available, blocked or inspection stock

TO – Transfer Order

TR – Transfer Requirement

Plant – Organizational unit in SAP ERP

IM special stock – Stocks handled differently e.g. project stock

MRP – Material Requirements Planning

Work center - Organizational unit in SAP ERP defining operations

Supply area – This is the area to which materials are staged for production

BOM – Bill Of Materials

EDI - Electronic Data Interchange

1 Background of thesis

Wärtsilä delivers complete lifecycle solutions for the marine and energy market. Wärtsilä's core product is combustion engines. The company had 18,663 employees at the end of 2013 and a revenue of 4.65 billion euros during the same year. Wärtsilä is divided into three divisions: Ship Power, Power Plants and Service. Ship Power delivers products or complete lifecycle solutions for the marine and oil & gas industry.

The Vasa factory is a part of Ship Power and as of 2014 it belongs to Ship Power Product Company Finland. Power Plants deliver complete power plant solutions, including operational and maintenance agreements. Power Plants operate all over the world in both urban areas and in demanding remote environments. Both Ship Power and Power Plants have a capacity to deliver complete solutions throughout the lifecycle of the product. Service supports the customers and their installations in both the marine and energy market. Service is also able to support the customer's business operations. (About Wärtsilä)

1.1 Product Company Finland

Product Company Finland (PCFI) is the owner of the released 4-stroke portfolio. This means that the unit has profit and loss responsibility for value streams related to 4-stroke products currently in production. Delivery Centre Vasa (DCV) is a part of PCFI and DCV is responsible for the delivery of W20 and W32/34 engines and engines combined with electric generators (genset). DCV is divided into several departments. This thesis mainly discusses areas handled by the Logistics Department and the Operational Purchasing Department from DCV and the Supply Management Unit from PCFI.

I have been working in the DCV Logistics Department as a trainee for several years. I started working in the warehouse and goods receiving area and the past two years I have been working in the Logistics Planning and Operative Support Department (previously named Logistics Development Department). During my work I have gathered a lot of experience and understanding of the inbound logistics processes at

DCV. With my manager I started to discuss a thesis topic that would be both interesting and that would have a practical outcome. We decided that the topic should handle both practical material management and systems setup. In this thesis material management at DCV is analyzed from an inbound logistics and system point of view, pointing out discrepancies between system setup and logistical processes.

1.2 Thesis objectives

The aim of this thesis is to set up clear guidelines for material grouping. The guidelines should consider the needs of the Operational Purchasing Department and the Logistics Department, taking into account the full cost, number of handlings and warehousing. By following these guidelines, Wärtsilä Supply Management and Operational Purchasing should be able to put materials in the right groups before the first sourcing decision is made. When new materials are ordered an agreement between Wärtsilä and the supplier has to be made. There can be one or several suppliers to choose between and the supplier providing the most cost efficient supply chain should always be chosen. The most cost efficient supply chain refers to the lowest price of one item, throughout the complete lifecycle of the material being sourced.

By using the guidelines for materials ordered to DCV, waste in the supply chain and warehousing should be minimized, thus minimizing the true cost of the component. This approach enables one to compare the true price of material from different suppliers, not only the price that different suppliers are willing to sell the material for.

The work is done by analyzing the current situation in the material flow at DCV and, based on these observed facts the work provides a solution, alternatively a tool, to provide parameter settings for material procurement according to which group the material belongs to. A few of the parameters that can be set are lot-sizing procedures, ordering procedures and scheduling procedures. Every procedure influences the procurement in some way. There are also many other parameters that affect the way the system handles the procurement strategies. Ideally a tool would provide the parameters based on into which group the user chooses to put the material.

1.3 Research area

The current research area is limited to inbound logistics processes and operational purchasing processes at DCV. The guidelines can be integrated into the supply chain to enable transparency of procurement operations for materials ordered to DCV. With transparent operations, bottlenecks and problems in the whole supply chain are easier to recognize and eliminate.

2 Framework

This chapter describes the basic framework of the thesis. The chapter starts with an explanation of the general terminology and an introduction to different philosophies and material management concepts. In order to understand how materials flow at DCV, a basic understanding of the warehouse and inventory management strategies used at DCV is needed. These are explained in the terminology part. Different philosophies and techniques used in order to determine the most efficient way of working and analyzing material flow are described in a separate part. Different concepts of materials management and procurement methods are also introduced in this chapter.

2.1 Terminology

This chapter introduces the different philosophies and techniques that can be used to analyze the material flow. The basic SAP terminology used in this thesis is also described in this part.

2.1.1 Enterprise recourse planning

"ERP is a business model that involves all levels of the organization – hence the word 'enterprise'." (Sheldon, 2005, p. 2)

As an example, a company manufacturing and selling lemonade could be using an Enterprise Recourse Planning (ERP) solution with the following simplified setup. In the sales module, forecasting is done in order to provide the production planning with data needed to plan and schedule the production. Lemonade consists of lemon, sugar and water. When orders for lemonade are placed, dependent requirements for lemon, sugar and water are created through the material requirements planning, where "dependent" means that the requirements are dependent on the lemonade requirement. The dependent requirements are handled in the purchasing module and orders for lemon, sugar and water are placed with the supplier.

In the logistics module, transportation requests and scheduling are handled. When the products arrive at the facility, the warehouse system makes sure that the ingredients are properly stored, i.e. sugar is stored in a dry place and shelf life time is handled properly. In the production module, confirmation of the produced lemonade takes place. When the lemonade is finished, the logistics and warehousing module again handles the warehousing and transportation of the finished products.

In the financial and accounting modules, bills are handled and manufacturing costs calculated. By comparing sales and forecasts, top management decision makers are able to make decisions based on the current situation in the lemonade industry and the company situation.

Changes affecting the employees are handled in the human resource module. In this example many possible components, such as quality management module, are left out, but the reader should get a basic idea of what an ERP solution is. ERP enables a link between the customer, top management decisions through the supply chain and factory floor. (Sheldon, 2005, p. 2).

2.1.2 SAP joint-stock company

SAP is an ERP provider that was founded in 1972 and is today one of the world´s largest independent software manufacturers, with over 66,500 employees in over 130 countries. (SAP at a glance).

SAP provides the ERP solution used by Wärtsilä. As explained an ERP system consists of several modules connected together. The most important module in this thesis is the material management module and its submodules. The SAP inventory management is part of the materials management module. In the inventory management component, stocks are managed on a value and quantity basis.

The system also deals with planning, executing and documenting the movement of goods. (Inventory Management and Physical Inventory MM-IM)

The SAP Warehouse Management (WM) application provides support for the movement of goods for maintaining inventories of a warehouse complex. The WM application reflects the warehouse structure and thus enables control of the material on a lower level in complex storage facilities. In the SAP R/3 system the WM application is fully integrated. (SAP AG, 2001, p. 13.).

If the WM system is not used, the storage location from the inventory management component is the lowest level of inventory management. (SAP AG, 2001, p. 17). The following terminology is used when describing the structure and movements of material in a SAP WM storage. To further explain the SAP terminology, both the structure and movements are explained using examples.

Storage type

A storage type is a physical or logical zone in the warehouse complex. Different storage strategies can be assigned to the storage type. Storage types have one or more storage bins. (SAP AG, 2001, p. 23). The handling of stocks between the inventory management module and the WM module is done through so-called interim storage types. These storage types play an important role in the SAP warehousing solution.

Storage section

A storage section in the WM system is used to further divide the storage types into areas. The storage section can be used to group storage bins with the same characteristics. (SAP AG, 2001, p. 26). As an example, one section in the warehouse can be reserved for fast moving components and one section for slow moving components.

Storage bin

A storage bin is usually an exact position in the warehouse. The address of the storage bin usually refers to coordinates in the warehouse where the material is stored. A storage bin can also hold several quants with the same or different features. Other characteristics can also be assigned to a storage bin, such as bin type, maximum weight, total capacity and fire containment section. (SAP AG, 2001, p. 29). The coordinates consist of ten or fewer characters, e.g. storage bin A01B in a high rack system could mean shelf A, column 1 and level B. In order to benefit from the system, the naming convention should be consistent and easy to understand throughout the whole warehouse. Figure 1 shows a high rack with many storage bins. In the marking of this kind of storage bins at DCV, the first three numbers are unique for the building (120), the next letter is unique for the shelf (V), the column is described by a number (11) and the last letter is the row (C).

Figure 1. High rack with storage bins

Storage bin type (BT) and storage unit type (SUT)

A storage bin type is a description of the storage bin, e.g. the maximum height of the storage bin. The storage unit type, on the other hand, is a description of the material package, e.g. different package heights can be assigned depending on the quantity in the package. In the SAP WM, different storage unit types can be assigned to different storage bin types. (SAP AG, 2001, p. 358). Storage bin types and storage unit types are further described in chapter 3.3.4.

Quant

The quant number stores the features of the material at the storage bin level. In the quant record, the quant identification, plant, material number, batch number, stock category, special stock indicator and special stock number are stored. (SAP AG, 2001, p. 40).

The above mentioned WM terminology has to be understood in order to enable an automated system. Every exception from the normal process increases the time spent on corrections.

As an example, if the lemonade manufacturing company mentioned in the ERP explanation would be using a SAP WM module, the system could be set up with one storage type. The storage type could be divided into a dry area and a cold area using storage sections. The dry area could be used for storing sugar and the cold area for storing lemons. Further if sugar is delivered on different size pallets, the system could be set up to determine the best suitable bin size based on the bin type and storage unit type combination. For every storage bin, the system could calculate the remaining shelf life based on dates stored in the quant record.

Movement of materials in WM

Every movement of WM materials is handled with transfer orders (TO). The transfer order contains a source storage bin, a destination storage bin, material to be moved and quantity. There is also other relevant data printed on the transfer order and the layout is highly customizable.

A transfer order can be manually created or automatically produced by the system. If the transfer order is automatically generated, it is generated from a transfer requirement (TR). The transfer requirement contains the same information, but either the destination storage bin or the source storage bin is unknown.

Imagine this scenario. Lemons are needed at the squeezing point, but no lemons are available in the warehouse. Thus you place a transfer requirement stating that a specific quantity of lemons should be delivered to the squeezing point when lemons are available. Production does not care from which storage bin the lemons are taken, as long as they are delivered to the squeezing point. Thus the source storage bin is unknown. The system constantly checks transfer requirements and searches for available lemons in the background. When lemons are available in a storage bin, the system generates a transfer order from that storage bin to the squeezing point storage bin.

2.1.3 Material master database

The material master is the central repository of information, concerning all the material the enterprise uses. The material master has a hierarchical structure that is illustrated in figure 2. The illustration goes down to storage bin level in the WM in order to keep the picture simple. Missing from the illustration is the subdivision into storage sections and storage bin types.

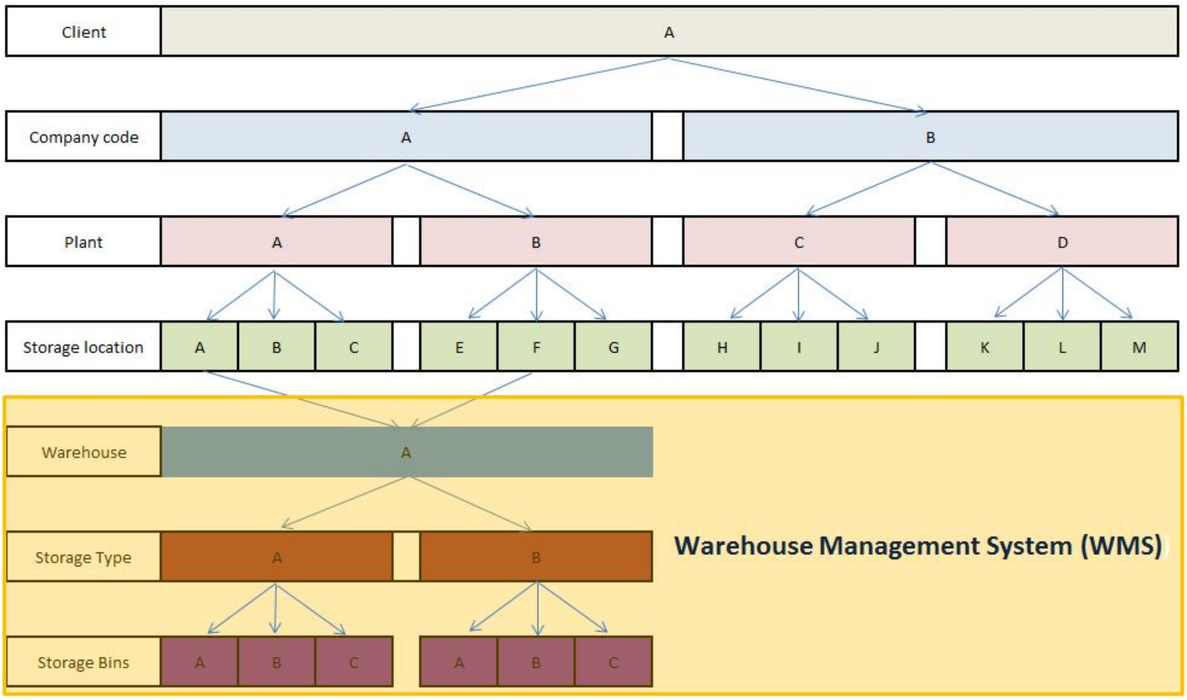

Figure 2. Hierarchical structure of the material master.

As shown in figure 2, in the material master hierarchical structure, components can be maintained at different levels. At each level different parameters, such as planning or scheduling related parameters, are maintained for the material.

As an example related to this thesis, general material data is created at the client level. These values such as weight and volume generally describe the material and do not take on different values in different places. Planning and purchasing data are maintained at the plant level, because different sites might want to order materials in different ways. Storage data is maintained at the storage location level and due to the integrated WM-module also at the WM level, which means that materials can be handled differently depending on in which storage type the material is stored.

The master data is maintained in tables, and depending on where in the hierarchy the data is stored, there are different ways to create or update the parameters. Global data is maintained by the global master data team and local data by the local master data key users.

Parameters useful in this thesis are maintained by local key users, and are mostly updated trough different views in the SAP interface. Parameters affecting plant and storage location level, are set in an view with plant and storage location data. Examples of plant and storage location specific settings, are shelf life data and storage conditions as shown in figure 3.

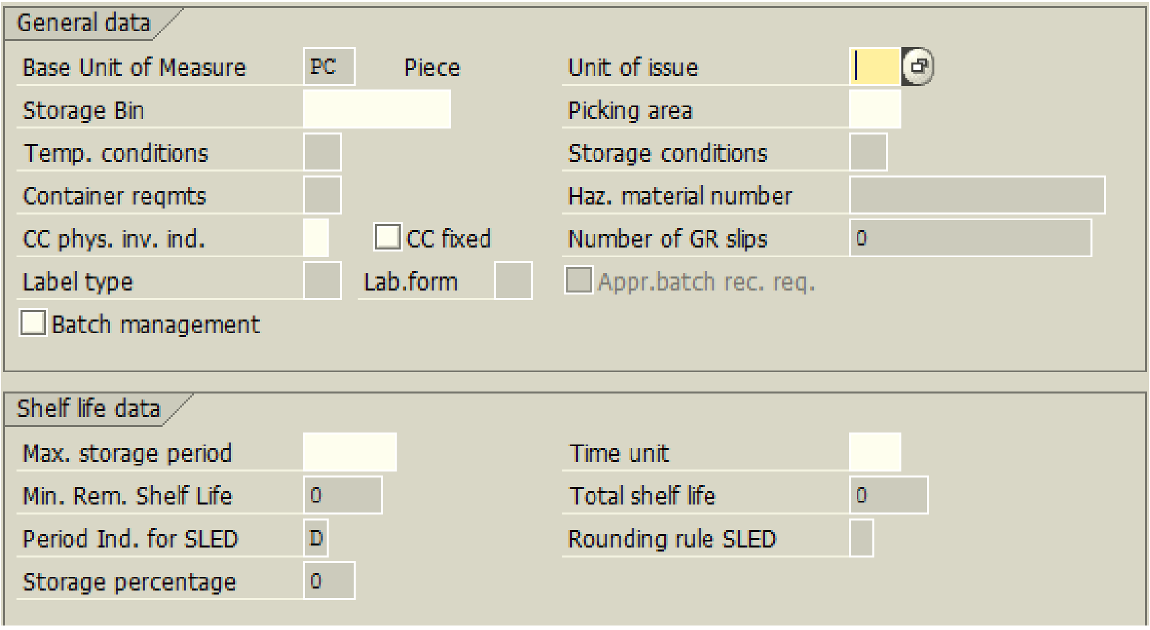

Figure 3. Plant and storage location data.(Plant/storage location view)

Parameters related to materials requirement planning (MRP) are set in the views containing MRP related parameters. In figure 4 one of several MRP views is shown. In the MRP view, among other parameters, storage location for external procurement is defined. In the same view, issue storage location is also defined. The issue storage location has two different meanings, depending on if the material is produced in-house or consumed. If the material is produced in-house, this is the receiving storage location, and if the material is consumed and backflushed, it is the storage location to which the backflush is posted. In SAP terminology backflush is the automatic withdrawal of goods from storage upon confirming a complete order.

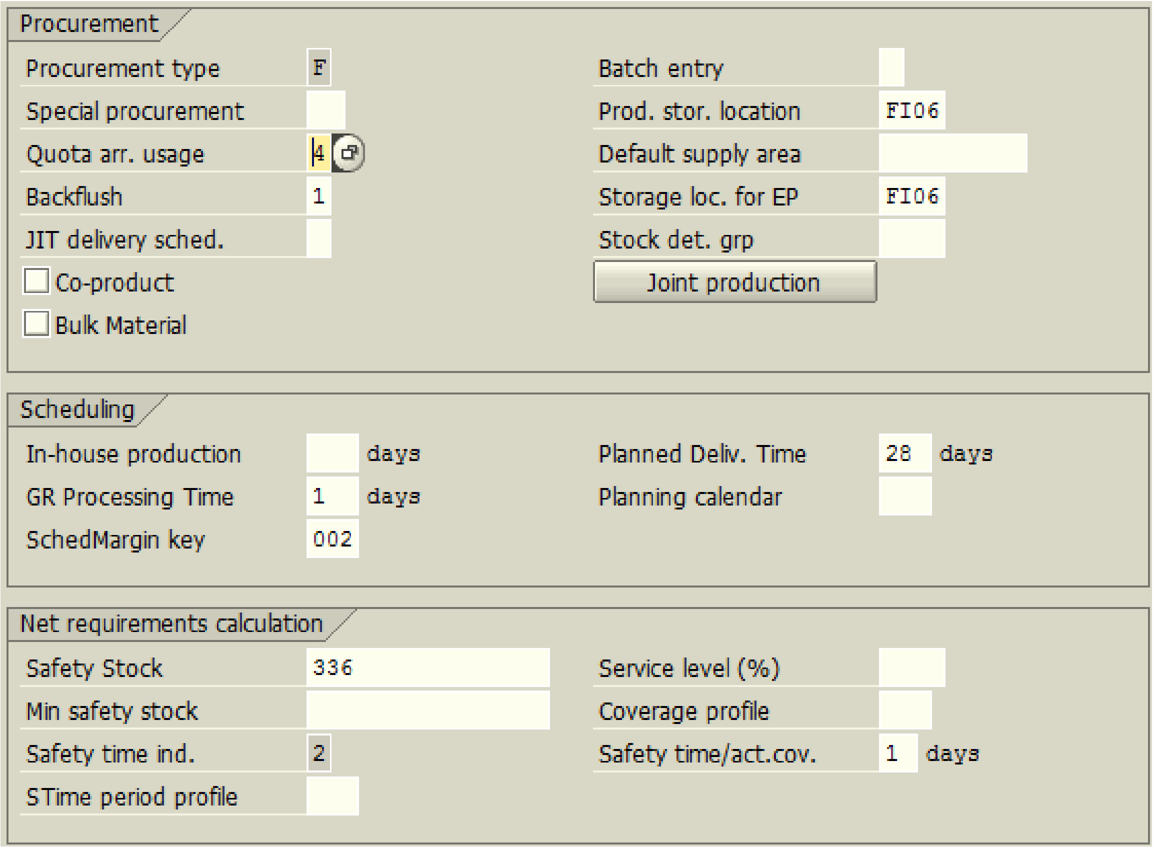

Figure 4. One of several MRP views. (MRP2 view)

These settings make up the core of the storage strategy. By changing some of the parameters, the way the system handles the material completely changes which might not support the processes. The strategy used for each material should always support the material handling processes, otherwise there will be a lot of inventory differences and lost materials.

At DCV two storage locations are currently actively WM managed. One of them is also the storage location where most of the materials are stored. When a storage location is WM managed, it is assigned to a warehouse. Under the warehouse, an assignment of storage types is possible. Under the storage types, different storage sections and bin types can be assigned. To every material that is assigned to a WM managed storage location, it is possible to define a storage type for stock placement and stock removal as shown in figure 5.

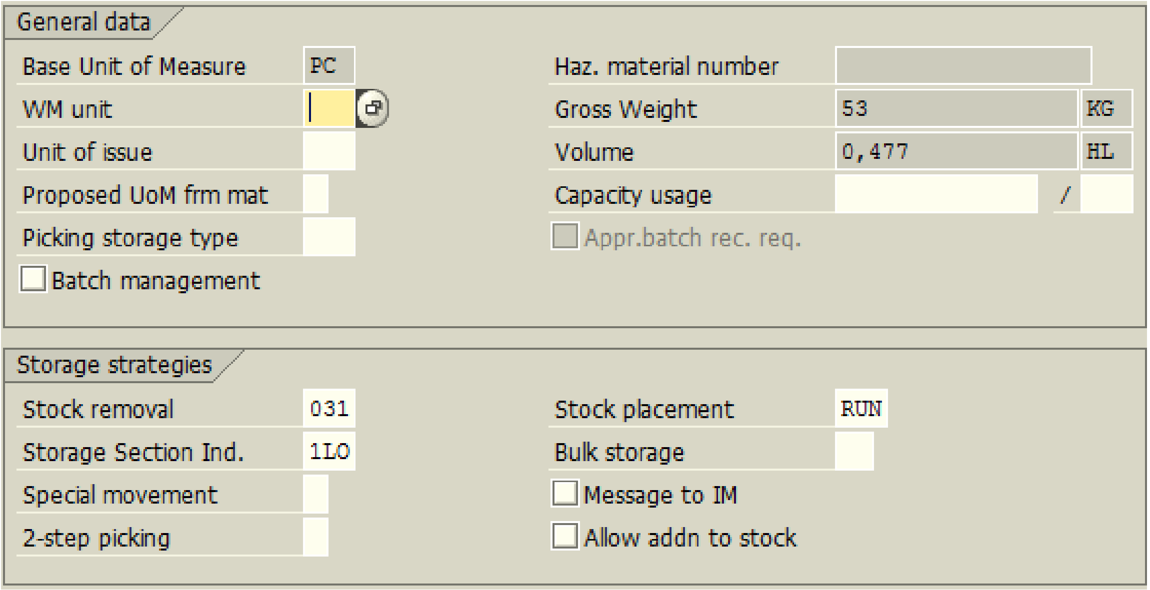

Figure 5. Warehouse Management view 1. (WM1 View).

Furthermore, section and bin type should be such that are assigned in the warehouse configuration to the storage types. Another way that is also used at DCV is assigning a material directly to a storage bin. In this approach the storage bin has to be under a storage type that has a fixed bin strategy as shown in figure 6.

The strategy of open storage types is also used at DCV. This means that the material handler can decide where to store the material in the assigned area with strategy open storage type. Storage strategies are described in chapter 3.3. It is important to remember that in DCV it is the WM level material settings that are to be considered when ordering materials, because it is at this level the parameters for the storage are maintained if the material is warehouse managed.

Most of the inventory managed materials at DCV are also warehouse managed. There are over 13 000 components that are actively warehouse managed. Without the handling at exact positions in the facilities, the search for wanted materials would take up a lot of unnecessary time. Although the exact positioning is good, it is also very strict. The strictness of the system sometimes leads to physically unutilized storage space, if from a system point of view the storage is already full (see chapter 3.3.4 The storage unit and bin types). These situations usually have their roots in unfinished or unconfirmed work, but many users have the opinion that a more visual approach would be better, i.e. if the space is physically empty it would also be available in the system.

As an example, the strategy of fuel pumps is shown in figures 5 and 6. In figure 5 we can see that the stock placement storage type indicator is RUN. This means that this is the suggested storage type where materials are stored upon arrival. The stock removal indicator is 031, which is the storage type suggested by the system when materials are consumed. With this storage strategy the movement between RUN and 031 is handled manually with a Kanban principle (see chapter 2.3.1 Kanban and chapter 3.6 Bin replenishment).

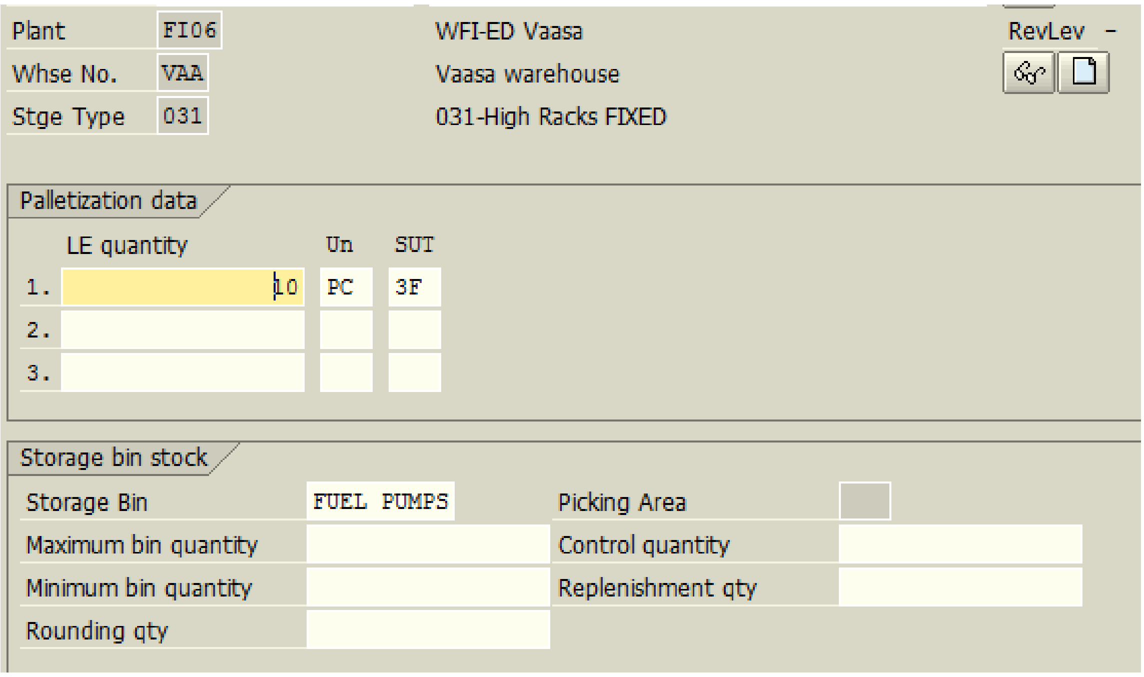

Figure 6. Warehouse Management view 2. (WM2 view)

In figure 6 we can further see that the fixed storage bin assigned to storage type 031 is “FUEL PUMPS”, which means that this material is only consumed from the storage bin “FUEL PUMPS”. The palletization data in figure 6 describes the package characteristics. In this case there are ten fuel pumps stored on one pallet which is three frames high.

For this particular material no automatic storage bin replenishment is set up. Materials utilizing this feature have quantities supporting the strategy in the storage bin stock fields. Because of the large diversity of materials used at DCV, different setups for the materials are maintained in the material master. Today most of the materials at DCV are maintained using WM and the ability to steer the material flow is greater, but at the same time this does not allow end users to make their own decisions. If some parameter is wrong or missing, the system cannot know which strategy should be used, and thus manual correction is needed.

2.2 Philosophies and techniques

There are many different production philosophies and practices used today. The following chapter introduces a few common techniques used to analyze the material flow and philosophies used to treat problems in this thesis. The philosophies described are often used to handle problems in a supply chain. As an example Lean manufacturing is a philosophy and value stream mapping a method used in Lean management.

2.2.1 Lean manufacturing

The Lean philosophy has its history in the Toyota manufacturing system (TPS). The philosophy is focused on managing resources. By eliminating waste that the customer is not willing to pay for, additional value is brought to the customer. Waste can be thought of as a non-value added cost. By identifying and eliminating waste, value is increased and the amount of work is reduced. The seven original wastes in Lean manufacturing are:

- Transport (movement of products that is not required)
- Inventory (components that are not currently being processed)
- Motion (unnecessary movement during processing)
- Waiting (unnecessary waiting and interrupts)
- Over production (producing more than needed)

- Over processing (unnecessary processing)
- Defects (inspection and correcting of defects)

The Lean philosophy includes tools and techniques to identify waste. Lean is also about continuous improvement and utilization of co-workers' creativity. (Lean manufacturing). Using Lean and its tools to analyze the material flow at DCV, waste in the supply chain can be recognized. Lean is also a way of thinking that in a successful implementation is adopted by the whole organization and thus is very effective because every co-worker's creativity is utilized.

2.2.2 Supply chain

The word "movement" gives meaning to the overall concept of a supply chain. When discussing the definition of a supply chain, the movement of resources is central. The most important resources to track are the movement of material, money and information. (Plernert, 2006. p. 6).

"A supply chain is the sequence of events that cover a product´s entire life cycle, from conception to consumption. A one-size-fits-all supply chain is doomed to failure" (Blanchard, 2010, p. 3). By thinking that you can handle every product equally you won´t be able to optimize the supply chain, and thus resources are wasted in an un-optimized supply chain.

2.2.3 Bullwhip effect

When future demands are not visible and the partners try to predict the end customer's demand, the bullwhip effect may occur. Usually the further down the chain from the end customer you go, the more the demands fluctuate. This results in a inventory that is either too large or too small. As inventories always tie money and require resources to produce, this is a waste in the supply chain. On the other hand if too little is produced, lost sales can occur, which can be considered a lost opportunity. (Ireland, 2004, pp. 5-6).

Relating again to the lemonade company, in a marketing campaign they are planning to sell lemonade for a reduced price and are expecting large sales. They place a large order for sugar in order be able to manufacture all the lemonade. The sugar retailer is not prepared for this kind of order and places a large order with the distributor. The distributor contacts the sugar manufacturer to place an order. To be able to produce the large amount of sugar, the manufacturer orders a large amount of raw sugar from the supplier.

To be able to fulfill the orders and other unexpected orders, for every step in the chain the amount ordered is increased. This scenario is shown in figure 7. Even small variations in demand amplify upstream in the supply chain, resulting in high variations in order quantity.

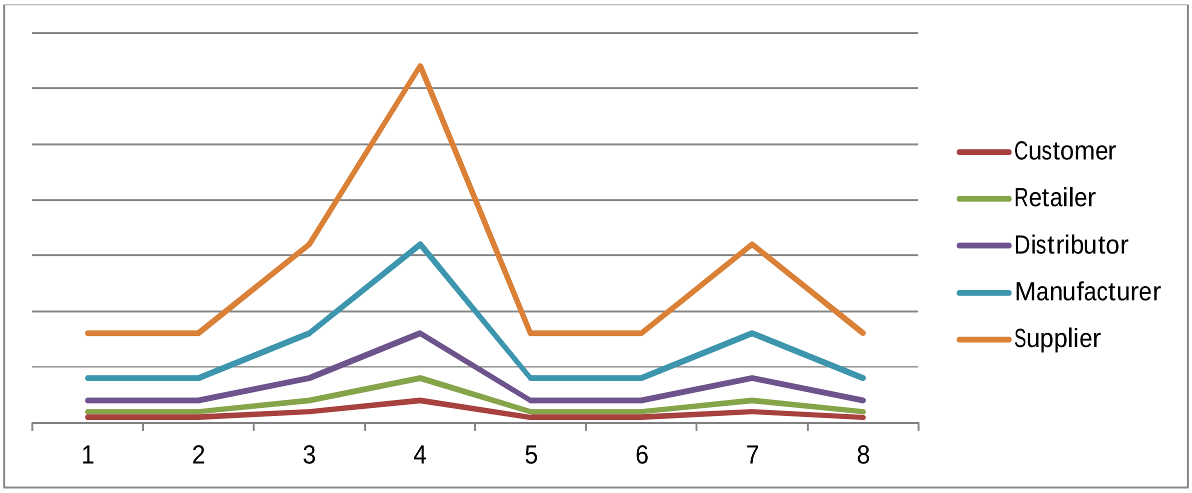

Figure 7. Small variations in points 4 and 7 result in large variations upstream in the supply chain.

2.2.4 Kaizen

In Japanese the word Kaizen means improvement or change for the better, with the goal to eliminate waste, involving all employees in the process. As with Lean, Kaizen also has its roots in Japan. (Kaizen). “Kaizen is not a one-time project; it is a process and a state of mind for continuous improvement that supports waste elimination.” (Burton & Boeder, 2003, p. 71).

In the lemonade factory it has been noticed that the kilograms of lemons used per liter of lemonade produced vary a lot. The supervisor gathers the people working with the lemons in the manufacturing process. The team notices that there is no standard process of how to squeeze lemons. Different techniques are tested and measured. The results are compared against requirements, and the most efficient way of squeezing a lemon and meeting the requirements is standardized. As new squeezing tools are introduced to the market, new techniques are tested and measured. If the new tool adds value to the squeezing operation, e.g. by reducing lead time, squeezing lemons using the new tool is standardized. This loop continues ad infinitum.

2.2.5 Value stream mapping

Value stream mapping is a method of analyzing value chains that is used in Lean. (Value stream mapping). The value stream is the activities that add value to a product. The goal of mapping is to reduce activities that do not add value to the value stream. (Weiss, 2013, p.163).

The value stream map can be thought of as an end-to-end system map, visualizing the flow of material and information through the supply chain. By doing a value stream mapping on the procurement of lemons, it is easier to identify where the problems in the supply chain are, and where to focus Kaizen events or other improvement projects.

2.2.6 Six Sigma

Six Sigma is a set of methods that aims to reduce defects and variations. As the name (sigma) implies the methods used are statistical and the goal is to have a mean no more than six standard deviations from the limit for a normally distributed process. A six sigma process has only 3.4 defects/million. (Six Sigma).

Using the statistical methods provided by Six Sigma, variations in the lemonade manufacturing process can be identified. After the variations have been identified and actions have been taken to eliminate the variations, the reliability of the new process can be measured using the same tools.

2.2.7 Lean Six Sigma logistics

Goldsby and Martichenko (2005 p. 25) define Lean Six Sigma logistics as “The elimination of wastes through disciplined efforts to understand and reduce variation, while increasing speed and flow in the supply chain.” This definition describes what should be accomplished by using the tools and techniques combined from Lean and Six Sigma.

The Lean philosophy is widely used at Wärtsilä. Kaizen events are arranged and value stream mapping is used to determine where to focus the resources. In my opinion, with the large amount of information available, the philosophy of Six Sigma could be used more often to identify variations in the supply chain, also at lower levels of the organization. Currently Six Sigma is used to measure variations in larger processes only, at least from a logistics point of view.

2.3 Concepts of material management

In this part concepts of material management and different ways to handle procurement and components are described. The difference between pull and push systems is introduced through Kanban and MRP. While reading this thesis, you will most likely at some point notice the importance of the package in an efficient supply chain. The concept of packages is introduced in this chapter. To further understand how everything is connected in the supply chain, as a last point in this chapter, the receiving window is described.

2.3.1 Kanban

Kanban is a type of material management where the procurement or production of components is based on consumption. The consumption can be monitored visually by checking the storage space reserved for a specific material, or the monitoring can be integrated in the ERP system. The aim of the Kanban method, is that the consumption triggers needed materials to be procured or produced. In a classic Kanban system there is always the same amount of components procured or produced. The parts are moved in standard packages with an attached Kanban card. The Kanban card acts as the trigger for the supplying part to produce or deliver the materials to the consumption area. (Jonsson & Mattson, 2011 pp. 310-312). Kanban acts as a typical pull-system, where the pull signal is triggered by an event further up in the chain. If lemons are stored in two boxes at the squeezing station, an empty box turned upside down acts as the trigger for the logistician to replenish the empty box. Figure 8 shows a shelf containing Kanban boxes. The two boxes turned upside down indicates that the boxes should be replenished.

Figure 8. Kanban boxes.

2.3.2 Material requirements planning

In material requirements planning (MRP) the procurement is based on the time when net requirements occur. Based on predefined parameters the system calculates when an order should be placed in order to meet the net requirement. (Jonsson & Mattson, 2011, pp. 312-315). In the above book, the following table (Table 1) and example describes how MRP works.

Table 1 Material requirements planning (Jonsson & Mattson, 2011, pp. 312-315)

Week		1	2	3	4	5	6	7
Demands		15	15	15	20	20	20	20
Inventory level	40	25	70	55	35	15	-5	-25
Incoming orders			60					
Planned orders				60				

As can be seen from the table, the inventory will become negative week six. The lead time of the material in question is three weeks and the order quantity is 60. Because of the lead time of three weeks, the order must be placed week number three.

Material requirements planning can be used both for dependent and independent demands. As insurance for changes in demands, a safety stock is often kept to cover the changes. Material requirement planning is a typical push system, where the procurement is scheduled.

2.3.3 Packages

The package has a very important role in the supply chain. A poor package can create a lot of waste, whereas a well-designed package can add value to the supply chain by reducing time needed for repacking and reducing transportation damages. This section goes through some general ideas about packages and reusability.

In a supply chain when components are transported, it is not only the component itself that is transported, but different types of cargo units are also transported between companies. The aim of a cargo unit is to enable a more secure transport, efficient handling and storing of the components. There can be several levels of cargo units that ensure efficient usage of space. The components can be loaded on a pallet, many pallets can be loaded in a container, and thus the pallet is on a lower cargo unit level than the container. To utilize as much space as possible, the maximum capacity of the pallet should be used and as many pallets as possible should be loaded in the container. To make use of the space in the container, the pallet size should be standardized. Commonly used in Europe is the EUR-pallet with a size of 1200×800×144 mm. (Jonsson & Mattson, Logistik 2011 pp. 91-93).

When developing an efficient package there are many variables to take in to consideration. Different components have different demands and the flow varies. For components with high variance in demand, a long transportation distance and lead time, it might not be economical to tie up investments in reusable packages, as a reusable package might cost several times more than a non-reusable package. On the other hand for a component with a steady demand, short transportation and lead time, it is most often not economical, nor environmentally friendly, to use non-reusable packages. It can be very difficult to determine the optimal package and most often it has to be decided from case to case. (Jonsson & Mattson, Logistik, 2011, pp. 91-93).

When choosing package type, the storing of the components should also be considered in order to minimize the need of repacking the materials. Another important aspect to keep in mind is the safety issue, both in order to protect the component and ensure the safety of the people handling the component during transportation and warehousing.

2.3.4 Receiving windows

The control of incoming materials is important in order to level out the workload for the receiving department.

*"What do we mean when we say that many facilities batch receive incoming material? We mean that in the mornings, much of the product ordered is received into the system on a first-come, first-served basis. This means that the afternoon is slower, and the off shifts (second and third) do little receiving, if any." (*Harris et al., *2011,* p. 119).

In order to have components ready for production in time, the receiving efficiency is of critical importance. With an even and steady delivery of components, it is easier to allocate resources at the right place in the right time. The workload can be distributed and the components keep a constant flow in the receiving process. The resources should be carefully considered when designing the receiving window in order to match the resources against the deliveries. The receiving window for a specific supplier can be on a given time and day of the week.

According to Harris et al., (2011 p. 120), the receiving window is typically one hour. This means that the supplier should deliver his orders within the given hour. With a well-designed receiving window it is easier to plan the inventory. If you can rely on the fact that the supplier delivers the desired components on the agreed time, it is easier to trust the material to go through the receiving process and is to be stored faster with fewer errors.

3 Empirical study

The empirical study is made in order to analyze the material flow at DCV, with the incoming materials as the main point. By studying the incoming material and how different characteristics influence the flow from a system point of view, one can better understand in which way the process can be optimized. The chapter starts by going through each step, from that the material is ordered, until it is picked for assembly, analyzing the non-value adding steps in each process. After that follows a description of the system setup and problems originating from the system setup. At the end of this chapter the idea of calculating true costs is introduced using examples.

3.1 The ordering process

The ordering of materials is handled by the Operational Purchasing Department. During the ordering process, most decisions affecting the supply chain are made. In this chapter the generation of purchase requisitions and conversion from purchase requisition into purchase order are described.

3.1.1 Purchase requirement

At DCV externally procured parts are either included in or excluded from the MRP run. For parts that are included in the MRP run, an automatic purchase requisition is set to be generated based on the MRP settings in the master data. The master data settings are usually maintained using MRP profiles (see chapter 3.7 MRP Profiles). For parts excluded from the MRP run no automatic purchase requisition is generated, and thus the procurement has to be triggered manually.

As the excluded parts are managed through Kanban control cycles, a purchase requisition is created manually or by using barcode scanners. With wrong MRP parameters maintained, purchase requisitions that create a lot of workload can occur. As an example, if the system is set up to create a purchase requisition for every demand, rather than grouping demands together, there are more purchase requisitions to handle and also more orders will be placed.

3.1.2 Purchase order

Purchase orders are handled by the operative purchasing department. An MRP controller, responsible for the material, converts the purchase requisition into a purchase order and sends the purchase order to the supplier. The conversion from a purchase requisition into a purchase order can be done manually or set up automatically as a background job. Sending the purchase order to the supplier can also be done in several ways, using email, EDI system or another agreed system. The operative purchasing department is also responsible for handling delivery date confirmations and rescheduling of the purchase order. In the current setup, the solution used to determine delivery address is based on WM data. As this solution is made for Wärtsilä, all transactions used converting purchase requisitions to purchase orders do not support the setup and especially EDI systems have difficulties handling different addresses for parts ordered for the same demand. Workarounds are currently used, but by changing the system to support the processes, unnecessary work can be eliminated.

3.2 Goods receipt

When a material ordered to the plant arrives at Wärtsilä DCV, the material has to be booked in SAP before the material can be used from a system point of view. If materials are not booked, SAP does not know that the material is available and thus cannot consume the material. The receipt is made with t-code MIGO using movement type 101 (goods receipt for purchase order) or using barcode scanners.

The process starts when goods are unloaded from trucks with forklifts. If the goods are small enough and packed according to directives, they are lifted on to a roller way. At the end of the roller way the receivers of the goods are booking the goods either manually in SAP or using barcode scanners. After the goods have been booked, a receipt slip is always printed automatically and if the material is managed in a WM storage location, a transfer order is also printed automatically. The goods receiver reads the GR-slip to find our if the material is ready for storage or if an inspection lot has been generated for the material. If the material has an open inspection lot, it is stored to wait for quality inspection. If the material is ready for storage, it is transported to the storing location according to the GR-slip and, in case of a WM storage location, it is placed at the exact position in the warehouse according to the transfer order. Let us next look at the receipt process, divide it into smaller parts and identify the wastes in the process.

3.2.1 Unloading components from trucks

The trucks arrive outside the building where the goods reception area is located. There are two ways that a truck can be unloaded. Option one is to use one of the two unloading docks. Option two is that the truck is unloaded outside by a forklift. Using option one the movement of goods from the truck to the roller conveyors requires only one lift. Using option two requires at least two and often more lifts, and at least two forklifts before the goods can be placed on the roller conveyors. Comparing these two options it is easy to identify waste in option two. From the Lean original 7 wastes, three categories can be identified: transportation, motion and waiting.

Transportation

In most cases it is not actually required to unload the goods outside the building. The only exceptions are parts that due to their size are not possible or efficient to unload in any other way than outside the building.

Motion

Forklifts have to drive back and forth from the truck to the door on the outside of the building. On the inside of the building, forklifts are driving from the door to the roller conveyors. This means a lot of extra motion on both the inside and the outside of the building.

Waiting

The forklift driver on the inside has to wait for the goods at the door, the forklift driver on the outside has to wait until the area in front of the door is cleared in order to bring more goods.

Conclusion

In the current facility setup, the shortest and fastest way to unload the goods is by using the unloading docks. To make this possible, trucks should be loaded in such a way that unloading from behind is possible. The packaging of the goods also has to be such that it allows utilizing the unloading docks. If the size of the material does not allow for the unloading from the dock option to be used, option two has to be used. These cases should, however, be limited to only components that are difficult to handle.

3.2.2 Roller conveyors

The benefit of roller conveyors is that goods can be moved without forklifts. If a material cannot be placed on the roller conveyors, due to the size of the package, it is placed on the floor. Goods placed on the floor require a forklift to be moved. Figure 9 shows three roller conveyors with materials waiting for goods receipt. In the back, the lights of a forklift unloading a truck from one of the two unloading docks can be seen.

Figure 9. Roller conveyors and unloading docks

Motion

When goods are placed on the floor, the goods receipt requires additional movement of the goods receiver. It also requires the forklift driver picking up the material to drive to the floor area where the material is placed.

Waiting

Goods receipt and shelving of materials unloaded to the floor, usually take a longer time than materials unloaded to the roller conveyors. The reason for this is that materials unloaded on the floor are usually stacked or there are other materials unloaded in front of them, which makes the material difficult to reach.

Conclusion

As materials placed on roller conveyors can be easily moved, a goods receipt queue and a shelving queue can be maintained. If the materials are stored on the floor, the goods receipt and shelving will in practice be done according to a LIFO principle. This means that the material that arrived last is on top of the stack, or first in the row, and will thus be handled first. The waiting time between goods received and booked into SAP varies a lot if the materials are stacked on the floor.

3.2.3 Booking the goods

As mentioned earlier, booking of the goods can either be done using barcode scanners or transaction MIGO (SAP). By using barcode scanners, the goods receipt and the printing of marking papers are done in one step. By using MIGO, the purchase order number, the packing date and the date of arrival have to be manually entered into the system and additional marking papers have to be manually created. The waste that can be identified in this case is over-processing the purchase order.

Over-processing

When the booking is done manually, using the SAP interface, there are several steps which require a user input. Mistakes frequently occur in this process. Producing the material marking papers is also a step that requires input from the user. Although the Powerpoint template is standardized, it is a fact that users change the output, which leads to poor marking of material. As an example, if the size of the font is changed, it can be difficult to see the material number when that pallet is placed in a high rack shelf. If the receiver forgets to change some data on the output, e.g. the receiving date the information provided is not trustworthy.

Conclusion

Making a goods receipt with barcode scanners reduces errors and the booking of the material demands fewer steps. Scanning enables a faster and more accurate process, with standardized outputs.

3.2.4 Repacking

Some packages do not fit into the high rack shelves. This requires repacking in order to store the materials. Almost all components require some sort of repacking at some point, because they have to be protected during transportation. In this step it is the goods receivers’ responsibility to pack the parts so that the pickers do not have to repack the materials again further down the chain.

Over-processing

Packages that need repacking are over-processed, which means that unnecessary work is done one or several times on the same package.

Waiting

The next step in the goods receiving process cannot be taken before the material is repacked. The material should be available right upon arrival and in case of packages that take a lot of time to repack, this is not the case.

Conclusion

A standardized package minimizes repacking. This leads to a faster receipt process and the time from that the material arrives until it is available at the assembly point is decreased.

3.2.5 Shelving

Depending on the size and storage strategy of the material, the system decides where it is to be stored. If the material is small, it is usually placed on a pallet containing other small materials that are stored in the same area. The small materials on the pallets are later on distributed to the correct storage area. If the material is large, forklift drivers pick up the material from the roller conveyors and transport the material to its final storage area.

Of course this process could also be optimized, but the aim of this thesis is to provide the guidelines for material grouping and in this process there is no waste related to the material grouping. In the next chapter however, wastes and problems related to finding an empty storage bin are described. The waste analysis above, shows that the root causes for a slow receiving process and long lead times can often be directly related to failures in the supply chain, i.e. insufficient packages, poor marking (missing barcode) etc. Due to the large variation in size of materials ordered to DCV, every waste is difficult to eliminate. As an example, roller conveyors cannot be used for large parts.

3.3 Warehouse management storage strategies

The stock placement and stock removal strategies depend on each other, as some strategies need to be set up in pairs in order to work as expected. In the following chapter the DCV WM setup is described, for both stock placement strategies, referred to as putaway strategies, and stock removal strategies, referred to as picking strategies. These strategies determine how the system handles stock placements for arriving parts and stock removal for parts that are picked. The chapter starts with an explanation of how the system handles putaway requests and what options the system provides. After that follows a similar explanation of picking requests and strategies. This chapter also provides a basic understanding of the vertical lifting system setup and the relationship between bin types and storage unit types.

3.3.1 Putaway strategies and WM setup

To understand how the materials are stored, it is good to know what kind of putaway strategies are used at DCV. The following section will describe the different strategies and how the Warehouse Management system handles the goods receipt. The integration of the SAP Warehouse Management System (WMS) with the Inventory Management (IM) at DCV is set up in such a way that when posting an IM movement, the system posts a negative or positive quantity into the sufficient interim storage type in the WMS. In the WMS the postings can be automatically or manually handled in order to update the WMS stock overview.

Most of the postings are set up to be handled automatically, but if errors in the postings occur, a manual correction has to be made. The following steps describe how the DCV setup handles goods receipt for warehouse managed materials. When the goods receipt is posted with movement type 101, a material document is created. This document can be viewed as a line in t-code MB51 with a positive quantity added to the stock. The system also creates a quant and posts a positive quantity into the interim storage type 902 in the WMS. When a positive quantity is posted into the interim storage type 902, a transfer requirement is automatically generated.

For the WM movement type, the automatic creation of a transfer order is set up. Thus the WMS tries to create a transfer order for a storage bin in the storage type assigned as the materials stock placement storage type. If no empty storage bins are available, the transfer requirement is left unprocessed and the system periodically checks whether storage bins are available and creates a transfer order if there is space available. This whole process is set up as a background job and the parameters are controlled through control tables. Figure 10 shows a transfer order for a material PAAE082934. This particular transfer order tells the user to move the material from the interim storage type 902 to the storage type 040 and the storage bin “121B36H”. The storage bin “121B36H” is located at an exact coordinate in the warehouse.

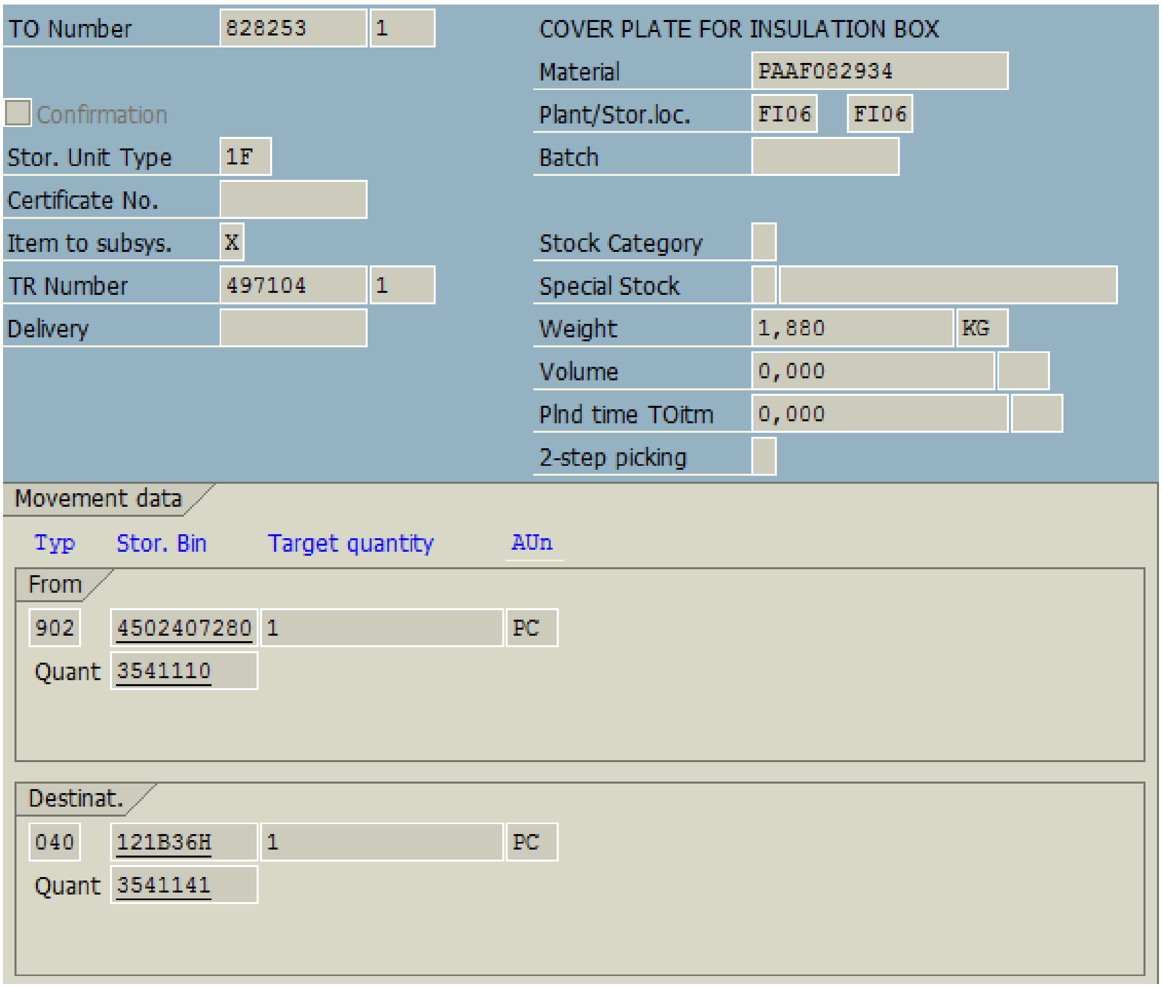

Figure 10. Transfer order overview putaway. (LT21 TO: 828253).

Putaway strategies

Every storage type has its own putaway strategy. The putaway strategy determines how the system searches for a storage bin. The putaway strategies are described in (SAP AG, 2001, pp. 354-359).

Strategy blank

This strategy means that the warehouse worker decides in which bin in the storage type the material is to be stored. This strategy is not currently used at DCV. This strategy does not allow any automation nor any strategy of how the warehouse is filled, because everything is up to the user to decide.

Strategy F: Fixed storage bins

Materials that are stored in a storage type with a fixed storage bin strategy are always stored in the same place. This means that if the capacity check allows additional quantity in the storage bin, the system automatically creates a transfer order to the fixed bin for the material. Capacity check can be configured in many different ways. As an example, it can be based on the LE quantity (see figure 6, p. 22) or on the weight of the material. This strategy demands that the storage type allows addition to existing stock.

This strategy is used at DCV in several constellations. One way this is used is to direct material straight from the goods receipt to the consumption area. In this configuration both stock placement and stock removal have the same storage type. There are also materials that are only consumed from fixed bins. These materials are stored in another storage type because there is not enough space to store all in one place. The warehouse worker responsible for the area visually monitors the consumption bins in order to manually create transfer orders in order to always keep the right material available in the storage bin. This strategy can also be set up with automatic replenishment, but is currently only used manually. The same strategy for fixed bins is also used for materials with several different consumption areas (see 3.6.1 The L3X stock removal p. 57). In this setup the consumption bin is assigned through the storage type search sequence and the responsible warehouse worker checks that material is moved from the main storage to the consumption area. This means that the material has two storage types assigned, one for the main storage, i.e. putaway, and one for the consumption bin, i.e. stock removal.

Strategy C: Open storage

This strategy allows mixed storage and is generally used for materials that are stored in one section of the warehouse. The strategy is used at DCV generally for parts that differ much in size. In the setup, transfer orders are always created for the same storage bin. When the warehouse worker shelves the material, he/she enters the exact coordinates into the system. As every transfer order always has the same destination storage bin as default in this setup, it is difficult to find the material if the warehouse worker forgets to enter the exact coordinates into the system upon confirmation of the transfer order.

Strategy I: Addition to existing stock

In this strategy the system checks whether stock exists in the storage type. If stock exists, the system does a capacity check based on the capacity check method assigned to the storage type. If the capacity check allows, the material is added to the existing stock. This strategy violates the First In First Out (FIFO) principle, but at DCV it is mostly used for small materials with a fast turnover. This is the main storage type used in vertical lift systems at DCV.

Strategy L: Next empty bin

This strategy is best supported for high racks where the materials can be randomly organized. When a material is assigned with a stock placement storage type with the next empty bin strategy, the system finds the next empty storage bin according to a defined sort order. At DCV this strategy is mainly used for parts that are picked by the logistics department and for main storage materials. Note that these can be stored within the same storage type.

Strategy K: Putaway near picking bin

This strategy attempts to store the materials as close to the fixed picking bin as possible. The system checks if storage bins close to the picking bin are empty and creates a transfer order for the closest empty bin. The system always searches from bottom to top. This strategy is currently not used at DCV.

Strategy P: Storage unit type

This storage strategy takes storage unit types into consideration while creating a transfer order. This is typically used to assign storage sections with storage unit types. Thus the system is able to check if space is available in the storage bin. This strategy is not used at DCV but the principle of storage unit type check is used in almost every strategy.

Strategy B: Bulk storage

This strategy allows materials that demand large space to be stored in a block-row structure. When a transfer order is created, the system checks in which row space is available. This strategy is not used at DCV, but the same setup is used with other strategies. This strategy could be implemented in push-through racking systems at DCV, but to support the setup a capacity check supporting the configuration also has to be set up.

Strategy Q: Dynamic quant number

In this strategy the system creates a dynamic storage bin based on the quant of the material. This can be used as a temporary storage bin for the material. At DCV this is used for materials in quality inspection. When the material has stock category Q, which is quality inspection, the system automatically creates the storage bin in which it is stored until a usage decision is made. Note that strategy Q and stock category Q have two totally different meanings.

Conclusion

While analyzing the putaway strategies it can be noticed that some kind of capacity check is often used. This prevents the system from overfilling a storage bin. How is this related to the supply chain? My answer is standardized packages. If a supplier always delivers different packages, it is not possible to automate the putaway process. It does not matter whether the capacity check is executed using weight or quantity if the packages always differ in size.

A few alternatives can be set up, but a standardized package is from my point of view the best alternative. Another thing to notice, is that the next empty bin strategy always searches for an empty bin to support the FIFO principle. If the same material arrives at the same time but as different purchase order lines, the material is stored in different storage bins because two different quants are posted to the interim storage type 902. Appendix 1 describes a typical bin search for a storage type with active storage unit type check and a next empty bin strategy. Which strategy is to be used has to be decided based on the material’s characteristics, such as consumption area, delivery frequency, size and price.

3.3.2 Picking strategies and WM setup

The picking strategies are assigned to the storage type in order to determine which strategy the system uses when materials are consumed. There are several strategies that can be used to fulfill business requirements. At DCV consumption is most often generated from demands in production order. There are also other types of consumption but these are statistically a very small amount and from a WM point of view the process is similar.

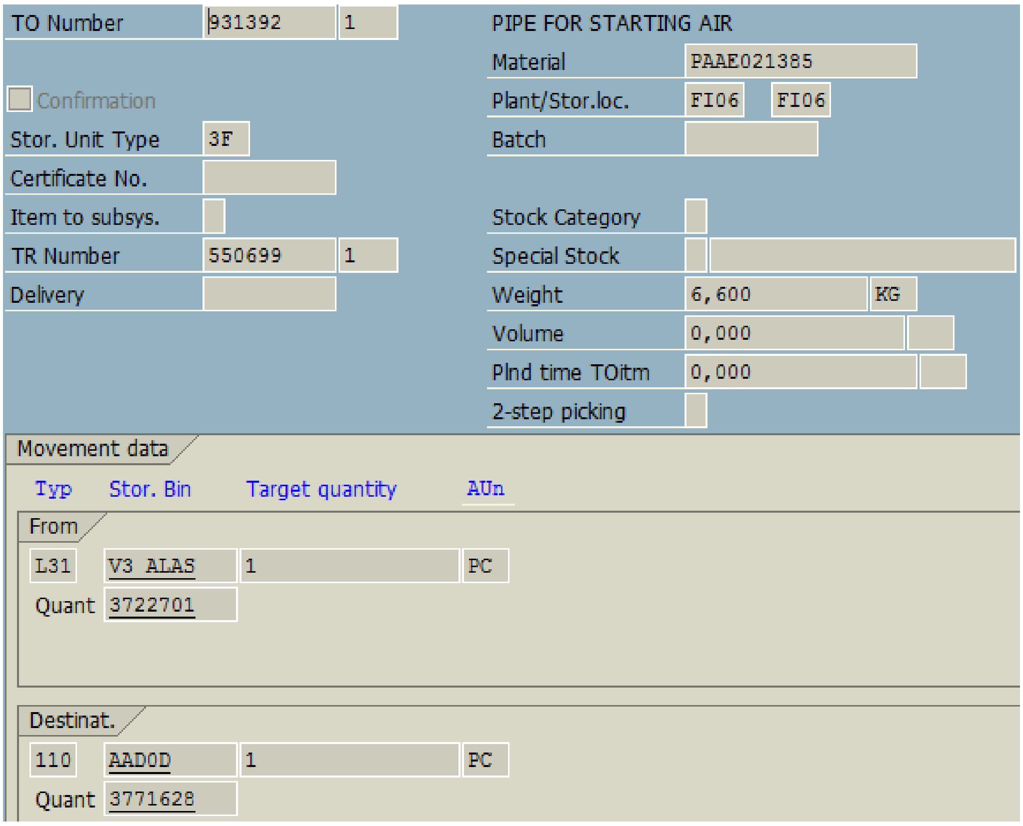

Figure 11. Transfer order overview picking.(LT21 TO: 931392)

The WMS is connected to the production planning module through the Warehouse Management-Production Planning (WM-PP) interface. This setup enables staging of materials assigned to production orders. Through material staging, a transfer requirement is created for the demanded quantity to the interim storage type assigned to the supply area for the specific operation. For the interim storage types, automatic transfer order creation is set up and bin determination is done based on the strategy assigned to the material's stock removal storage type. Figure 11 shows an overview of picking a transfer order. This is a transfer order to move one pipe for starting air from the fixed storage bin "V3 Alas" to the interim storage type 110. This material has an unloading point, "AAD0D". This is the exact position near the assembly point and also the storage bin from which this particular material is consumed, when the production order is confirmed and the backflush takes place.

Picking strategies

Each picking strategy has its own characteristics and the strategy best supporting the picking process should be used. It should, however, also be remembered that the strategies can behave differently if assigned to a storage type with a putaway stategy that does not support the logic of the picking strategy. As an example, putaway strategy A (addition to existing stock) cannot be used with a FIFO picking strategy, because the dates used by the FIFO logic change when components are added to already existing stock. Below is a description of the picking strategies available in the system.

Strategy F: Oldest quant FIFO

In this picking strategy the system searches for the oldest quant, based on the good receipt (GR) posting date stored in the quant. The GR date is assigned to the quant based on the IM posting that created the quant or manual entry. This strategy or the stringent FIFO strategy is used for almost every storage type at DCV.

Strategy blank: Stringent FIFO

By leaving the picking strategy blank, the system searches through all storage types that are not excluded from the stringent FIFO for the oldest quant. Storage types typically excluded from stringent FIFO are the interim storage types, because materials stored here are already staged for production. This strategy is also defined through the storage type search sequence by assigning *** to the storage type. This means that the system overrides all other strategies in order to find the oldest quant. As mentioned in strategy F, the FIFO principle is the main strategy at DCV.

Strategy L: Most recent quant LIFO

As the strategy indicates this finds the newest quant within the storage type. This strategy is not used at DCV. The logic behind is the same as for the FIFO principle, i.e. based on the goods receipt posting date.

Strategy A: Partial quantity management

The aim for this strategy is to have as few partial quantities as possible in storage. The prerequisite for this strategy is that the material is stored in standard quantities. When the system creates a transfer order, it tries not to pick partial quantities from a storage bin. At DCV this approach is used for large components that are either picked in odd or even quantities, thus preventing unnecessary handling of large materials. As an example, picking of cylinder heads is done using partial quantity management. This is because cylinder heads are stored on pairs on one pallet, but every cylinder only requires one cylinder head. For an engine with nine cylinders a package has to be broken, but the cylinder head left in the shelf will be excluded from picking until the next engine with an odd number of cylinders is in production and requires cylinder heads.

Strategy M: According to quantity

This strategy allows the system to determine the source storage bin according to if the quantity is small or large. In this way the picking of materials stored in fixed bins and in the main storage can be efficiently carried out without unnecessary handlings. The system determines if the quantity is small or large according to the control quantity defined in the material master. At DCV this strategy is assigned to the materials in quality inspection, but as the transfer order is always created manually, with the dynamical storage bin as reference, this strategy is practically never used.

Strategy H: According to shelf life time

“With this picking strategy, the system ensures that materials with the oldest expiration date will be removed from stock first.” (Warehouse Management guide, 2001, p. 399). At DCV there are no products handled in WM that have an expiration date and therefore this strategy is not used at DCV. If products with an expiration date are needed, they are ordered when needed and not kept in storage.

Strategy P: Fixed storage bin

This strategy determines the bin from which the material is to be picked according to the fixed bin assigned in the material master. This strategy is used for fixed bins at DCV.

Conclusion

In the picking strategies, the same conclusion can be made as for the putaway strategies, i.e in order for partial quantity management to work, the package quantity should always be the same. A standardized package also supports an internal Kanban system where the system can be set up to pull materials from the main storage area to the consumption point when the consumption point inventory reaches a control limit. If the package differs in size or the quantity in a package varies, it is more difficult to set up a working system.

3.3.3 Vertical lifting system

The vertical lifting devices mainly consist of bins with the dimensions 0.2 m*0.8 m*0.1 m and on each level there are 12 bins. There are also bins that are 0.4 m*0.8 m*0.1 m meant for larger parts but these are few. The levels 2.4 m*0.8 m can of course be divided into other sizes also, but it haven been proved that these two sizes are most efficient. The reason for this is that, with larger bins, the size is coming closer to that of a pallet and thus the materials can be stored on pallets. Small materials, on the other hand, are often cheap and not inventory managed at DCV. In vertical lifting devices, the SAP putaway strategy is A. As mentioned earlier, A means add to existing stock. That means that SAP automatically generates a transfer order with a destination storage bin that already contains the material. If, however, the quantity exceeds the control limit set as maximum capacity, the system searches for the next empty bin. Small parts that are not stored near the assembly area are generally stored in vertical lifting systems, that is parts with low or medium consumption (see chapter 3.4 Material types).

3.3.4 The storage unit and bin types

As mentioned earlier storage types consist of bins. The bins are assigned a bin type (BT) that describes the characteristics of the bin. To combine a material with a storage bin, the system checks the storage unit type (SUT) assigned to the material in the material master. At DCV the SUT and the BT have the same naming convention in order to fast determine which kind of SUT is required for the bin type.

When creating a transfer order the system checks the material's storage unit type indicator against the bin type table. There are several different storage unit types describing the package. Mostly used for euro pallets are 1F, 2F, 3F, 4F and 5F. The number tells how many frames the pallet consists of. Thus the appropriate bin type can be determined from F1, F2, F3, F4 and F5. A typical row from the storage unit type check table may look like this:

Storage unit type	Bin type 1	Bin type 2	Bin Type 3	Bin type 4
1F	F1	F2	F3	F4

With this bin type search setup, for a material that demands a one-frame storage bin, the system first checks for an empty one-frame (F1) storage bin. If no empty bin is found, the system checks for two-frame bins, continuing until an empty bin is found at the end of the table.

There are downsides to this setup. In one scenario pallets with a one-frame (1F) are stored in bins designed for four frames (F4). This occurs when no smaller storage bins are available. When smaller bin types become available, the one-frame pallets have to be moved to smaller bins to make larger bins available for materials requiring F4 bin types. On the other hand, if the system is set up to stop the search for an empty bin earlier in the table, the system cannot find any empty storage bins if all F1 bins are occupied.

Through the control table the logistics department is able to control how the storage bin search is executed. To be able to optimize the space utilization, statistical methods should be used. But to be able to trust the statistics, the material data has to be correct, i.e. the storage unit type value stored in the master data has to match the package size. The package also has to be standardized otherwise it is difficult to optimize the usage of space. It should also be mentioned here that modifications of the high racks are not something you do very often because it require a lot of work.

3.4 Material types

As the different storage strategies have now been explained, the following chapter will further underline the need for different storage strategies depending on the type of material that is to be stored. At DCV the components vary a lot in size, consumption and lead times. By dividing the materials into groups, an understanding of what is small and what is large can be formed. The concept of small, long, large and so on is very abstract but after this chapter the reader should have a basic understanding of what is meant by these abstract expressions. This chapter also describes the storage strategies currently used for different material types.

3.4.1 Dimensions

By the dimensions of parts I mean the size and weight of the materials. The storing of 100 washers differs a lot from the storing of two crankshafts. By using three different abstract expressions, small, medium and special, materials can be grouped. Every group is also given a few examples in order for readers familiar with components used in large combustion engines to get a picture of the size.

Small parts

Small parts can be handled in batches. A warehouse worker can easily move a box containing a batch of a material in the small parts group without using a forklift. Examples of small parts are, small pipes with the approximate size of a drinking straw, bolts, nuts, small sheet metal covers, pipe clamps, small brackets, flanges, connection pieces, unions etc. Small parts are either inventory managed or cost center managed. If the material is cost center managed, it is usually stored in boxes and the logistics department is responsible for checking the availability.

In most cases there are two boxes of each material needed at the consumption area. An empty box turned upside down acts as a trigger point for the area responsible to set the status of the box to empty, upon which the system automatically generates a purchase order. The empty status is set either by scanning a barcode or manually setting the status to empty in SAP. The purchase order created is connected to the box and when the goods receipt is posted, the status of the box is set to full. Since the Kanban materials are excluded from MRP, no automatic requirements are generated. If a small material is inventory managed, it is usually stored in a vertical listing device or in fixed bins. In both cases, as the material is inventory managed, it also needs to be consumed from the inventory.

Medium parts

Medium parts cannot be moved longer distances without a forklift or another lifting device nor is it possible to move the whole batch without a forklift. Medium parts are usually stored in high rack shelves. Examples of this type of parts can be pumps, filters, bearings, valves, covers etc. Medium parts are always inventory managed. Sometimes medium parts are reserved for a specific engine, this is usually for classification or configuration purposes. Medium parts are always included in the MRP run. Thus procurement proposals are generated automatically.

Special parts

I choose to refer to big parts as special parts because these always demand some special warehousing due to their dimensions. Examples of special parts are crankshafts, engine blocks, assembled modules etc. These parts are often home call materials because of their size (see 3.7 MRP Profiles p. 61). Special parts are not easy to move and always require some kind of lifting device or forklift to be moved.

3.4.2 Consumption

It is very difficult to determine the consumption of a component because the engine series are usually short and many components are different in different series. One way to approach the problem is to group the parts into consumption groups. But this approach does not make it much easier to determine the consumption if you only have values, especially not for new parts. The following groups are based on engine types and by following this approach the consumption can be estimated on a large scale.

Low consumption

Parts with low consumption are usually components required for one specific engine or engine series. These materials can be referred to as components that should be ordered for only the quantity needed. These components should always belong to a logistics picking set (see 3.5 Picking parts p. 55).

Medium consumption

Components with medium consumption are usually used in one or a few engine types. From an inbound logistics point of view, the medium consumption parts should be monitored in order to determine if a change from a medium to high or a medium to low status should be considered.

High consumption

High-consumption parts are frequently used and sometimes in several different places in different engine types, or in several places in one engine. These parts have a high demand and a safety stock can be maintained if needed. These parts should be close to the assembly area when possible.

3.5 Picking parts

The picking of parts for assembly can be divided into two different operations: parts picked by the logistics department and parts picked by the assembler. It plays a large role in the supply chain to which group the material belongs. The logistics department always has picking lists with the location where the material is found. The assemblers, on the other hand should not be wasting time on searching for parts to assemble, they should spend their time assembling the module. This chapter provides a basic understanding of the difference between logistics pick parts and assembly pick parts.

3.5.1 Logistics pick parts

Logistics pick parts are picked by the logistics department and brought to the assembly area. An overall goal is to have the parts belonging to the same picking set as close to each other as possible, with the exception of small parts that are stored in vertical lift systems. The picking process starts by converting the planned order to a production order. Here the system alerts if there are missing parts in the converted production order. After the production order has been converted, it is either manually released or automatically released depending on the material profile in the master data at plant level.

All production orders containing materials that are picked should be manually released. Thus the system alerts if there are missing parts. By releasing the production order the system triggers printouts and automatic material staging depending on the profile mentioned earlier. A picking list (transfer order) can contain many materials at various locations in the warehouse. According to the storage type of the parts to be picked, the transfer order can be split into many papers, thus enabling distribution of the workload.

The picking of the components is done using picker forklifts where the material handler is on the same level as the forks. This enables the picker to pick parts from every level in the high racks. To be able to efficiently pick components from pallets, the components should not be attached to the package, neither should there be unnecessary packing material in the package. Waste such as motion and transportation occurs also here if the component is not properly packed. Even though the goods receivers should repack the product in such a way that enables picking, it is not always possible. If the component is too heavy to pick by hand some kind of lifting tool is needed to move the component. This also creates waste in the supply chain, as the assembler also later lifts the component when assembling it. This kind of heavy parts should be close to the assembly area so that the part can be lifted and assembled at the same time.

3.5.2 Assembly pick parts

Assembly pick parts are located close to the assembly area where the assemblers can easily reach the material when needed. Assembly pick parts consist mostly of materials handled as bulk materials, but also inventory managed parts. The material handlers responsible for the area check that the right materials are at the right place at the right time. In practice this means that the material handler is responsible for ordering Kanban materials. If needed the material handler is also responsible for creating transfer orders from the main storage to the consumption bin for inventory managed materials handled in WM.

3.6 Bin replenishment

When the assembly area runs out of components, replenishment has to take place. There are several different ways that the replenishment can be conducted. Replenishment of some components is outsourced to companies that are responsible for the availability of the components. Other parts are ordered as Kanban and delivered straight to the consumption area after the goods receipt. A third category of parts are replenished from the main storage. This can be handled by visually monitoring the storage bins or by setting up the system to automatically replenish the bins. When the replenishment is automatically set up, the system calculates the replenishment quantity. To avoid unnecessary handling and irregular replenishment, the packages should consist of standard quantities. With a standard package quantity, the trigger point can be set at an appropriate level in order to have time to replenish the bin.

3.6.1 The L3X stock removal

For components used at several different assembly areas, the stock removal cannot be the same for inventory managed materials. If the stock removal was the same, there would be no visibility on the stock situation as all the components would be in the same storage bin in the system, but physically in different places. This is because every storage type assigned to the material can only have one fixed storage bin.

As an example, a material should be picked from *V1 Alas* (Phase 1 down) at the W32 line assembly. For that storage type only one storage bin can be assigned as the fixed bin for that storage type and material.

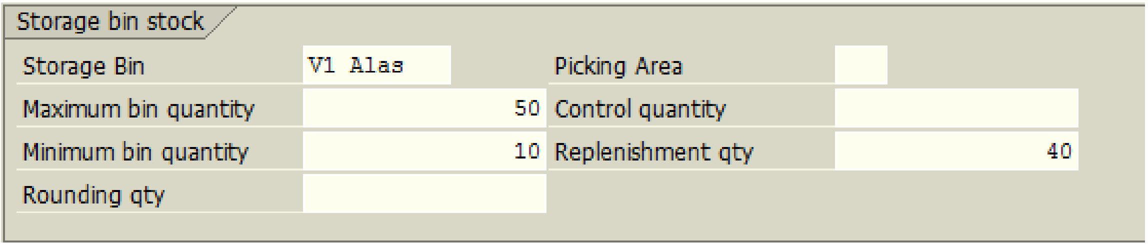

Figure 12. Storage bin V1 Alas assigned to a storage type material combination. (WM2 View)

What often occurs is that the same material is also needed at other assembly points, such as at the W20 line assembly, the turbocharger line assembly etc. In those cases it is not possible to have only one stock removal storage type because, as mentioned, only one storage bin can be assigned for each storage type. The solution used at DCV is a strategy internally called L3X.

L3X Settings

For the material in question the storage type indicator for stock removal is set to L3X.

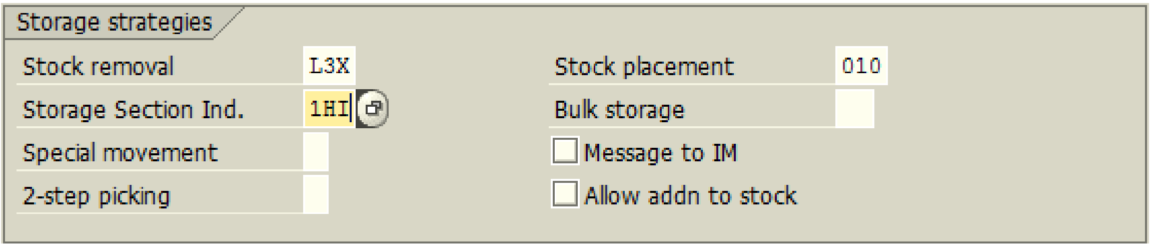

Figure 13. Example of storage strategy for L3X material. (WM1 View)

The material WM data is created for each L3* storage type. Examples of the storage types are L31 (W32 line), L35 (W20 line), L39 (Automatic cylinder head assembly). When the data is created the stock removal and the stock placement should be kept as they are, the only thing that needs to be changed is the storage bin.

L3X Logic

In order for the system to determine the right storage bin for stock removal the following data is maintained: work center, production supply area, WM movement type, and WM control cycle. Each one of these is connected and plays different roles in the stock removal bin determination. For each production supply area a destination storage type is defined for pick parts, this is the storage type from which the actual backflush takes place when the IM level goods issue is posted.

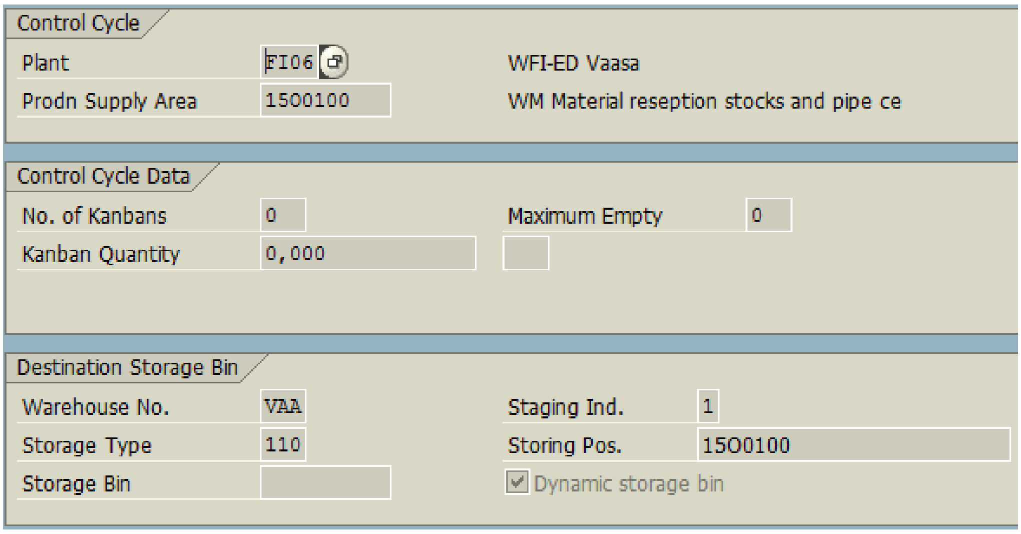

Figure 14. Destination storage type 110 in warehouse VAA assigned to production supply area 15O0100 in plant FI06.(WM Control Cycle).

The system determines the supply area for each component in the production order based on entries in the work center master data. The production supply area can also be assigned in the Bill Of Material (BOM), but in most cases the production supply is assigned to the picking operation of the production order. The work center master data has higher priority than the BOM.

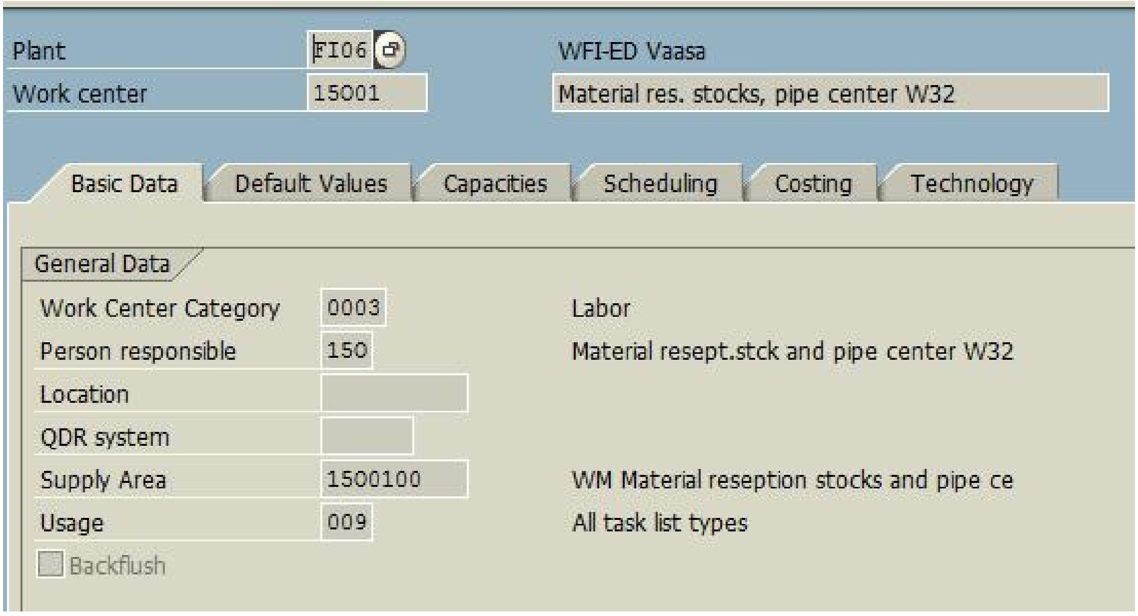

Figure 15. Supply area 150O100 assigned to work center 15O01. (Work center, basic view)

Now the system is able to determine the production supply area and the destination storage type. In the storage type control table, a WM movement type can be assigned for the storage type replenishment.

I addition, the movement type can have different settings but relevant for the L3X solution is the reference movement type for the storage type search sequence. The storage type search table contains an entry combining the storage type indicator L3X with a movement type and the correct storage type for stock removal.

Table 2 illustrates a simplified view of the storage type search sequence table. For the storage type indicator L3X, the reference movement type decides from which storage type the parts are picked.

Table 2 Storage type search sequence

Storage type indicator	Reference movement type	Storage type
L3X	1	L31
L3X	2	L35
L3X	3	L39

This setup is used for many components at DCV and is fully automated. Problems which lead to inventory differences occur when the wrong data is entered in some of the material master records.

3.7 MRP profiles

The aim of MRP profiles is to make it easier to maintain the MRP master data for a material. The information to be stored for different materials with a similar constellation is set in the MRP profile. The MRP profile provides availability to define which fields to be filled in, default values for the fields and whether the values can be changed or have write protection.

At DCV there are four different MRP profiles used for components with external procurement that are included in MRP. For components that are procured externally, but are excluded from MRP, there are five different MRP profiles used, depending on if the components are manually ordered by the Kanban principle or if the procurement is outsourced. In addition to these, there are several others created for both external procurement, internal procurement and mixed procurement. The following section contains an elementary explanation of some of the parameters, followed by a description of the characteristics of the MRP profiles currently used at DCV.

3.7.1 Description of parameters

The focus of this thesis is not on the material requirement planning logic and procedures but, by starting with a short description of the MRP parameters affecting the warehousing and ordering, it is easier to understand what kind of impact different parameters have.

Lot size

The lot size parameter defines which procedure the system uses to determine the quantity that is to be procured or produced. Several different procedures can be used e.g. exact lot size, fixed lot size and period lot size. In the current setup two keys are used for materials procured externally: the fixed lot size which determines the quantity based on the fixed lot size value and the lot for lot order quantity, which creates a static lot quantity for every demand.

MRP type

This key determines if the material should be planned using MRP and, if it is to be planned, the key also determines how. Also here, there are several different keys available: reorder planning, automatic or manual, forecast based planning etc. In the current setup there are two keys used, planned with MRP and no planning.

Other parameters

In each MRP profile there are also several other parameters used to manipulate procurement and availability check for each material with the profile assigned. The keys determine among other things, MRP procedure, lot sizing procedure, scheduling, net requirements calculation, procurement types and quota arrangements. By changing one of the parameters several others might also need to be changed in order to support the setup. As an example, if the lot size procedure is lot for lot, a fixed lot quantity cannot be maintained.

3.7.2 CO01: Purchased to engine

Parts with the MRP profile CO01 are procured to a specific engine. There can be several reasons for this, but one of the most important is if the material requires classification. If classification is required, there is currently no other way to assign correctly classified material to the right engine. If classification is not required and there is no other valid reason why a material should be procured to a specific engine, this profile should be avoided, because it creates more waste from a logistics point of view.

3.7.3 CO05: Pre-order purchased components

This profile is used for so-called home-call components. These are components that are stored at the supplier and ordered with a just-in-time approach for production. Home-call components are usually large and difficult to store and this is the main profile for such components.

The downside of this profile is that it creates more monitoring and work for the operative purchasing department and the logistics department, because in order to trigger the pull request to the supplier, manual monitoring of the production has to be done. In order to automate this process, the phase of the production line should be the trigger from a system point of view, not manual monitoring. In this way automatic scheduling would be more reliable because the time interval would be smaller and an automatic pull request could be sent to the supplier.

3.7.4 CO06: Purchased component with safety stock

CO06 is the profile of a component ordered with a fixed lot size and safety stock. This profile is used for components with high or medium consumption. Based on the net requirement calculation, a purchase requisition is generated (see 2.3.2 Material requirements planning MRP p. 29) with a quantity according to the fixed lot size.

This profile is highly usable until the component reaches a point when consumption drops and the component finally becomes obsolete. In these cases the safety stock might never be consumed and thus left in storage. Before the component reaches this stage, the MRP profile should be changed to a lot for lot procedure in order to ensure that no dead stock is left in storage and availability is still ensured.

3.7.5 CO08: Purchase to stock, lot for lot

In order to fully utilize storage space it is not optional to keep safety stocks and a stock of material that is not needed in the storage. For inventory managed components with low consumption, the MRP profile CO08 is used. This profile is set up to generate a purchase requisition for every demand. The profile increases the number of rows to order and the number of pallets to store if the material has the putaway strategy next empty bin.

3.7.6 KA01: Visually controlled bulk material

This MRP profile is excluded from the MRP run and thus no purchase requisition is automatically generated although the material is externally procured. For materials with this profile the purchase requisition is generated manually or by using barcode scanners. The materials having KA01 as MRP profile are also excluded from the availability check. This profile is used for cost center managed materials with high consumption and in exceptional cases even for inventory managed materials.

3.7.7 Outsourced procurement

In addition to the above mentioned profiles, the BM0* profiles currently used are assigned to materials the availability of which a third party is responsible for. The settings are similar to the KA01 profile, but the material is never inventory managed and no purchase requisitions are generated. Due to this, these parts are not handled by the Logistics or Operative Purchasing Department in normal cases, only if problems with the availability occur.

3.7.8 Problems and challenges

Many new materials with low or medium consumption are ordered with the MRP profile CO08. The MRP profile is CO08 configured to create a purchase requisition for every dependent and independent demand with an exact lot size. This leads to many purchase requisitions with different availability dates. In practice this means that the supplier delivers the components on different dates.

This might sound good in a lean way, with just-in-time delivery. In practice, because of a continuously changing production schedule, components are often stored over a period where the first demand overlaps the last availability date and the bullwhip effect occurs when production schedules change. If the component is stored in high racks, this means that every procured component is stored in its own storage bin over the period. By looking at the situation from the Operative Purchase Department point of view, this increases the purchase requisitions and purchase orders that have to be handled. From a warehouse point of view, this increases material handlings and space required to store a component. As the components are ordered separately for every demand, this also means that the package is usually not standardized because the quantity needed may vary depending on the demand.

Sometimes manual orders are done in order to fulfill business requirements. As an example, if a part does not require classification, but one engine does, the part is assigned to the WBS of the engine. The problem here is that the production planning module tries to find a part not assigned to a WBS, because this is the way the system is set up in order to support normal cases. Manual changes to the production order have to be made in order for the system to consume the material. In order to automate this, SAP batch management could be a solution. In batch management the system stores properties of the materials' technical and physical characteristics.

Batch management provides creation of rules and methods to determine the right component for production. This would also support the tracking of revision changes for materials. Batch management requires changes to the warehouse setup to avoid batch mixing but also changes in the ERP system at higher levels in order to track components that are transported between plants. Material determination logic for production orders also has to be changed to support batch determination. Batch management would require many changes in both system and processes, but would also add a lot of value to the supply chain, with a better traceability of components.

A typical scenario

A series of eight engines requires a new type of pipe. Every engine requires only one pipe and the dimension of the pipe is such that ten pipes can be placed on a standard euro pallet with one frame. After the BOM explosion of upper level material, a dependent demand is created for each pipe. The dependent demand for each pipe is generated with different availability dates. Thus, due to the exact lot size procedure, purchase requisitions are generated for every dependent demand.

The person responsible for the material converts every purchase requisition to a purchase order with different delivery dates. If automatic creation of purchase orders is maintained for the material, this happens automatically. The supplier of the component makes the deliveries on agreed dates. The difference between the last and the first availability date may vary a lot but in this scenario an availability date of one month is used. This leads to eight incoming pallets, eight different purchase orders that need to be processed and eight pallets that need to be stored. As can be understood from this scenario, the workload is eight times larger than if all pipes were ordered at the same time. If all pipes were ordered as one purchase order line, inventory value would increase but the workload would be reduced a lot.

Harris et al. (2011, p. 112) state that *“You´ll also need to deal differently with components that have a low a low usage quantity. Low-usage parts are often best ordered on an as-needed basis.”*

But, in my opinion, the system should be set up to group demand within a timeframe together as a compromise between CO06 and CO08 MRP profiles. This would reduce work when dealing with components that are used in only a few engine series.

Currently workarounds are in use. The MRP controller manually groups requirements together if the automatic purchase order creation is inactive. The Logistics Department stores all the pipes in the same storage bin in the vertical lifting devices which use the add-to-stock functionality, but this can only be used for small components. In these workarounds human errors often occur as it is up to the human to remember the manual corrections.

3.8 Safety stock

Safety stock is the buffer in the warehouse. At DCV safety stock for purchased parts is only used for components with the MRP profile CO06. Harris et al. (2011, p. 48) states that, the buffer acts as an insurance that you are willing to pay for in the warehouse. The buffer is held in cases of poor quality, insecure inventory levels and other factors that have an impact on the availability of the material. How much are we willing to pay for this waste and is the price equally high for every component? The answer, as you may expect, varies from case to case. Due to different lead times, price and size of components, the price that is paid to store the buffer also varies.

Another way to look at the problem is to look at the fluctuation in the production. A supply chain with a just-in-time delivery is difficult to reach especially for parts with long lead times if there is a large variation in the planned availability date and the actual requirement date when the part is needed. When a safety stock is kept in storage, there should always be a plan for how to remove the safety stock. In a worst case scenario, old safety stocks gather dust in the storage until they are considered obsolete and finally scrapped. This is not a cost efficient way to handle safety stocks. Inventory value is increased and storage costs are increased which all adds up to the price of one item. Finally with all that value added to the item price, the components are in a worst case scenario scrapped.

3.9 Supplier kitting

If a supplier delivers multiple parts that are assembled at the same stage, kitting by the supplier should be considered an option. Kitting at the supplier used for the right components is a great way to eliminate waste for both the operative purchasing department and the logistics department. In SAP the kit is handled as one material, thus the MRP controller gets fewer materials to control. This means that the purchase requisition lines generated are reduced. The possibility of materials getting lost is also decreased because all items in the kit are delivered in the same package. For the logistics department, material handlings are reduced for the same reason.

When components are delivered as a kit there is one purchase order item to book instead of several, repacking is reduced and the inventory levels are reduced. In the picking process there are also fewer lines to pick. Thus motion and transportation are reduced. Counting all these together, the true cost of the kit can be estimated. When this is compared to the true cost of each component in the kit if they were ordered separately, there will be a noticeable difference.

Kitting at the supplier can be used for both large and small pieces. All the covers that are assembled at stage one may be delivered as a kit, pipes can be delivered as kits, bearings and extension pieces can be delivered as kits. To fully benefit from kitting at the supplier, the packing of kits for V engines should be taken into consideration. If the parts are assembled on different sides of the engine, the kit should be packed on separated pallets or in such a way that it is easy to split the kit and deliver to both sides of the engine. The splitting can be done in many ways but to simplify the picking and to maintain a standard process, the setup of the kit should always be supported by SAP. Thus the impulse that the set has to be split can be forced from the system.

Kits with a high consumption that always contain the same materials can be ordered as CO06, i.e. with a fixed lot size based on net requirements. Kits with a low consumption always containing the same materials should be ordered as CO08 to avoid redundant inventory. If the kit is ordered as separate materials but kitted at the supplier, all the included materials have to be assigned to a WBS element to ensure that the right kit is picked for the engine. Problems with the WBS assigned materials occur if the components have poor quality. If the poor quality is noticed at the assembly line, a similar component is usually taken from a kit assigned to an engine scheduled to be assembled later. This creates a lot of SAP work for the logistics department and the operational purchase department. A new component has to be ordered and the inventory has to be updated through several steps. When rescheduling is done, kits are left in the storage waiting for the assigned engine or, if possible, the assignment is manually changed to another engine.

When kitting at the supplier is used, a safety stock of the components in the kit might be necessary in case of poor quality or in case the components in the kit get damaged during transportation. As this safety stock is dead stock without any dependent or independent requirements, it should be thoroughly considered if safety stock can be avoided without interfering with the availability of the components in the kit.

3.10 Raw material to supplier

At DCV there are a lot of materials that are processed both externally and internally. As an example, supplier A delivers raw material to Wärtsilä and the materials are stored at DCV. The machining of the raw material is done both at DCV and at supplier B. When the raw material is stored at DCV it goes through the same processes as other materials, i.e. goods receipt, shelving etc. In addition to the processes that are performed when goods arrive, the goods also go through the picking process and transportation has to be scheduled. These steps can be avoided if supplier A delivers the raw material directly to supplier B.

3.11 True costs through process

To be able to calculate the costs of one item, one has to know how the costs are gathered through the process. When the cost for each step is known, a model can be used to calculate the true cost. The model can be built into a spreadsheet or as a standalone application. It does not really matter into what kind of application it is built as long as standard inputs are used and clear outputs are generated.

In the Lean supplier development book, section 3 (Harris et al., pp. 59-106), the true cost model is discussed. By going through all the ongoing costs and identifying those in the process for material procurement at DCV, a model for calculating the true cost of parts delivered to DCV can be created. Ongoing costs are calculated for as long as the component is supplied. In this chapter I will go through some of the costs mentioned in the above book with examples.

3.11.1 Visiting the supplier

In every supplier relationship it is likely that you will visit the supplier at some point. The visits can be customary to sustain good communication and ensure that both parties can fulfill the expectations. The visits can also be made to discuss changes or issues. May the reason for the visits be whatever, they should still be considered when counting the true cost for materials, because three trips per year to Denmark are more expensive than three trips to a local supplier located in the same region. The cost for each trip can be calculated from travel costs and lost time. Travel costs are gathered from tickets, hotels, food and so on. The lost time is time you could be doing something else, other than visiting the supplier. It may seem that this is a part of the job but when you really think about it, the cost actually belongs to the component. At DCV the logistics department does not visit the supplier, but purchasers and engineers responsible for the quality of the component make visits to the suppliers and this should be considered in the true cost. The increase in price per piece can be counted using the following formula.

$$\frac{Trip\ price\ * Trips\ per\ year}{Annual\ usage} = Price\ increase\ per\ pc$$

Equation 1. Travel costs.

As an example, shown below are two different increases of the item price for a component with an annual usage of 1248 pc. The increase is based on travel costs of 3000 € per visit for the long distance supplier and 300 € per visit for the local supplier. For each supplier visits are made two times per year..

$$\frac{300 * 2}{1248} = 0.48€\ per\ pc$$

$$\frac{3000 * 2}{1248} = 4.81€\ per\ pc$$

If the supplier manufactures many different components, the traveling costs should be distributed over several components, but even so the cost for traveling belongs to the components. In the above scenario there is a large difference in the item price between the local supplier and the long distance supplier.

3.11.2 Repacking

As mentioned in the goods receipt process, repacking of components has to be done if the package cannot be stored properly or components cannot be picked from the package. It is to be remembered that repacking is almost impossible to eliminate because the components have to be protected during transportation. Considering that, the longer the transportation distance is, the more likely it is that the repacking takes longer. This is because if the transportation is longer, the components are often cross docked by the transportation company. Thus the parts have to be better protected.

As an example, we have a local supplier delivering goods on standard euro pallets. The pallet is covered with plastic film and the frame is secured with one steel belt. The repacking of this package does not take long. When the steel belt and the plastic film have been removed the package is ready for storage. Compare this to a long distance supplier delivering the components in non-standard sealed boxes. The boxes have to be opened and the parts have to be lifted to standard euro pallets. If the box consists of several components, it is likely that the material handler needs to look at drawings in order to distribute the right material to the right pallet. It is also likely that a component from a long distance supplier has heavy rust protection which has to be removed in order to be able to handle the component.

This whole process is time and space consuming. Damage to the components also occur due to the unnecessary movement of the components. The cost of the repacking should be considered in the true cost analysis in order to make the right sourcing decision. The cost of repacking can be calculated from following formula.

$$\frac{Labor\ cost * repack\ time/day * workdays/year}{Annual\ usage} = price\ increase\ per\ pc$$

Equation 2. Repacking costs.

To determine the repacking time per day for components delivered on a monthly basis, the average repacking time can be multiplied by packages delivered per year and then divided by working days per year.

The following example is a calculation of the difference in the item price between a local supplier and a long distance supplier delivering the same amount of components each year. The reason why repacking time per day should be calculated is that this time can also be used in calculations for resource management. If we know the time it takes to repack and the days when the packages will arrive, resources can be allocated according to the need. When considering outsourcing of repacking operations, a repacking time per day time can be used to calculate if it is lucrative or not.

Annual usage: 1248

Working days / year: 251 (2014)

Labor cost: 60 € /h

	Local supplier	Long distance supplier
Repacking time / delivery	1 (min)	120 (min)
Components / delivery	24	104
Deliveries / year	52	12
Repacking time / day	$\frac{1 * 52}{251} = 0.21\ min$	$\frac{120 * 12}{251} = 5.74\ min$

$$\frac{60\ € * \frac{0.21}{60}\ h * 251\ days}{1248\ pc} = 0.042€\ per\ pc$$

$$\frac{60\ € * \frac{5.74}{60}\ h * 251\ days}{1248\ pc} = 1.15€\ per\ pc$$

In this repacking scenario there is also a big difference between the local supplier and the long distance supplier.

3.11.3 Storage cost

When calculating the storage cost, there are several parameters that need to be considered. Size of component, quantity in package, package size and environmental impact are the main categories that need to be taken into account. For materials that can be stored in high racks, the annual price per pallet can be used. At DCV the annual price per pallet has been calculated based on annual warehouse cost and maximum pallet capacity. The maximum pallet capacity is based on a four frame pallet with a maximum load of 1000 kg as module size and a 3 m space between racks. This has been done for each storage building.

When calculating the cost for storage of components that are too large to store high in racks but, to sustain the quality of the component, have to be stored inside, the annual price per square meter is used. In addition, there are components such as castings that do not require storage inside. In these cases cost per square meter outside can be used. As the prices from building to building vary a lot, the stock removal and stock placement strategies should be considered while calculating the cost for storage. When a suitable storage is found for the material, the storage cost can be calculated based on the price of the storage and the time the material is to be stored.

In cases with dead stock, large safety stocks and obsolete materials, the cost added to the piece price can be large especially for materials with a small piece price. For components with a high piece price, the added storage cost might not be so large for storage over long time but, in these cases, the total inventory value should be considered.

3.11.4 Conclusion

According to Harris et al. (2011, p. 16) success in the future global market is going to be based on the functionality of the whole supply chain. Rather than trying to compete in areas such as raw materials, labor costs, etc., you should focus on establishing a competitive supply chain in order to be successful. “The best supply chain wins!” (Harris et al., 2011, p. 16).

As seen from the above examples, the piece price can vary a lot depending on different sourcing decisions. In the above examples only a part of the cost adding elements are mentioned. To calculate the true cost the whole supply chain should be considered, not only parts of it. To provide guidelines from only one perspective can be misleading and in a worst case scenario add cost to other parts of the supply chain. With optimized lot sizes from an inbound logistics point of view, the storage cost and the repacking cost might decrease, but transportation costs, document handling and accounting cost may increase more. Thus the item price will also increase.

3.12 Guidelines for WM parameters

As mentioned earlier, at DCV there are several options for material consumption. WM parameters are set depending on which group the component belongs to. In this section, assembly picking sets are referred to as A and logistics picking sets as S. This naming is used because different departments use different naming conventions for the picking sets but A is always for assembly (APH, ATCL, APCL etc.) and S is always for logistics picking sets (SPH, STCL, SPCL etc.). This naming convention is not standard, but can be used as an example for the current engine portfolio at DCV. It should also be noticed that all subassemblies are not divided into A sets and S sets, one example the cylinder head subassembly.

3.12.1 Rules

In the current way of working the rules can be divided into two different sections: one for new parts that are delivered for the first time and one for materials that are frequently delivered. The overall goal would be to have components delivered right already from the first time. It is time consuming to constantly monitor and change the settings of the parts.

3.12.2 New parts

As a rule, new parts should not belong to an assembly pick set (A).If the material belongs to an A set, the component has to have a specific place at the assembly point. If the place at the assembly area is undefined, the logistics department does not know where to deliver the part and the assemblers do not know where to find the part. Thus the components should be in an S set and picked by the logistics department with other components belonging to the same S set. Parts with the MRP profile CO08 should not belong to an A set either because they are ordered separately for every demand and should also be picked for that specific demand. As the new parts are always picked, stock removal and stock placement are always the same. The storage type depends on which set and which engine/module type the component belongs to.

3.12.3 Frequent delivery

When components are delivered on a more frequent basis and the consumption is high enough, the components' MRP profile can be changed to CO06 and the components can be moved to an A set if needed. If the component is cheap at this point, the components can also be changed to a Kanban controlled part.

3.12.4 Getting the rules right

The main goal should always be to get the rules right already before the first delivery is made. In this way the settings would not need to be changed if the parts' consumption does not change. If the new material number has its roots in a design change the new material should adopt the settings from the previous used material. It should further be noticed that a balance should be maintained between A set materials and S set materials. It is not possible to store as many components as needed close to the assembly point because there is simply not enough space.

4 Discussion and suggestions

The expected outcome of this thesis was guidelines for material procurement considering the full cost for the DCV Logistics Department and the Operational Purchasing Department. While writing this thesis I realized that the topic is much larger than this. It is possible to define guidelines from the inbound logistics and operative purchasing point of view, but the guidelines might conflict with the way of working of other departments.

While introducing new products and new processes, the effect on the supply chain and material flow should also be carefully considered. While striving for standardized and optimized processes, all exceptions create a lot of waste. In order to automate standard processes, exceptions should not exist. However with a realistic view of the business, I believe that there will always be some exceptions and a way to handle them as smoothly as possible would be through clear guidelines. A suggestion would be to gather a workgroup with members from all the departments through the supply chain.

People with expertise in their own field are able to rapidly determine the impact of changes to their departments' processes. As a supply chain is not only about the flow of materials, but also about money and communication flow, these fields should also be represented in the workgroup. With this workgroup gathered on a regular basis, guidelines on a much larger scale can be set up and continuously improved. This workgroup should also be responsible for defining rules and tools in order to identify waste in the supply chain. Note that they should not be responsible for using the tools.

With the tools and rules, wastes such as dead stock, patterns of missing parts, problems with vendors, unutilized space, unnecessary transportation costs etc. could be found and eliminated. SAP provides a lot of standard analyses and also supports users in defining their own parameters for analyzing. Wärsilä also supports several other analyzing tools with a data warehousing concept. By combining these, a large amount of data to measure and work with is available.

When new techniques such as RFID, barcodes and wearable computing are implemented at some stage in the supply chain, this workgroup should be responsible for analyzing the impact on the supply chain, in order to prepare and inform departments affected or departments that can also use the information generated. The main focus of the workgroup should be explicitly on improving the supply chain from a DCV point of view, considering the total cost rather than focusing on the cost in the own department. To further improve the Wärtsilä supply chain, the workgroup should have an open global communication.

4.1 Other findings

Points in this thesis bring up the issue of insufficient MRP profiles and unnecessary safety stocks. The existing MRP profiles do not really fulfill the requirements in my opinion. The step from C008 to C006 is too large if a safety stock is maintained. As a suggestion, a new profile grouping requirements together but without a fixed lot size should be investigated.

Furthermore with high consumption parts, a replenishment strategy based on the actual consumption of parts with short lead times should be investigated. The actual consumption based planning can be set up using a reorder point strategy, where the reorder point would trigger a request to pull the material from the supplier, based on a minimum stock quantity. In addition, the process of home-calling should be automated. When an engine reaches a specific phase, a pull request is automatically sent to the supplier. These changes have an impact on several different processes and need to be fully investigated, perhaps by the supply chain workgroup.

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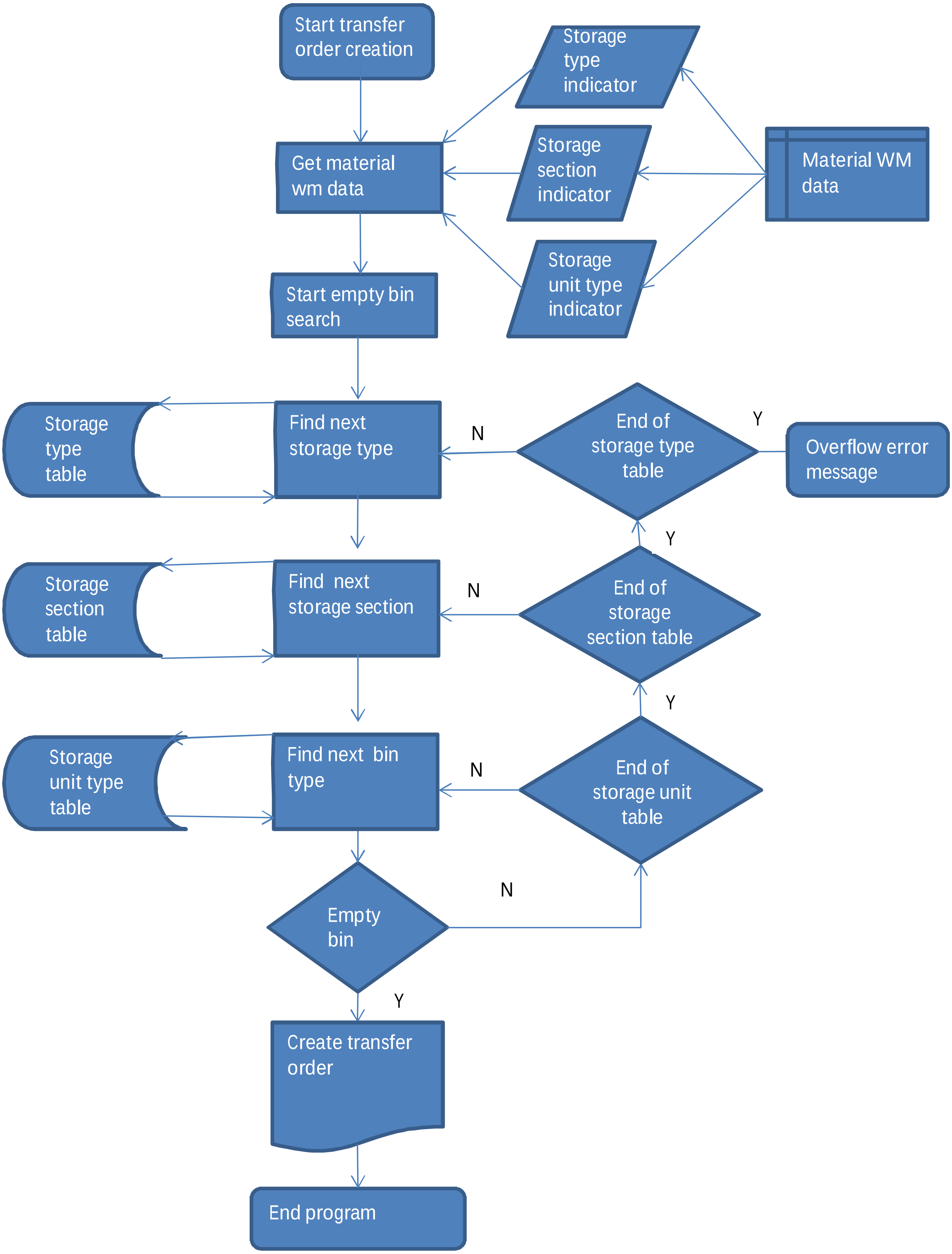
Appendix 1

Next empty bin logic



The system start the transfer order creation function. For the material in question, if nothing else is specified, the system gets the parameters from the WM parameters in the material master. The search for the right storage type starts by comparing the storage type indicator against the storage type search sequence table. When the first storage type defined is found, the system compares the storage section indicator against the storage section search sequence table for that specific storage type. When the storage type and the storage section are found the system compares bin types against the storage unit type indicator defined for the storage type. When storage type, section and bin type are determined, the system searches for an empty bin according to the sequence defined in the storage bin master record, i.e. row by row or isle by isle. If no empty bin is found, the system checks for the next entry in the storage unit search table. When the storage unit table contains no more entries, the system starts the same search in the next section defined. When the section table comes to an end, the system checks the next storage type. The loop continues until the system finds an empty storage bin. If no empty storage bin is found when all the entries are checked, the system generates an error message.