Lean Warehousing

Gaining from Lean thinking in Warehousing

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Preface

This master thesis has been written during the autumn of 2007 and in the month of January 2008 as the final part of our Masters of Science in Communications- & Transport systems at Linköpings Tekniska Högskola. This thesis has been collaboration between Microsoft Development Centre in Copenhagen and the division of Packaging logistics at Lund's University.

We would especially like to thank our supervisors Philippe Jacobsen and Thomas Jensen at Microsoft Development Centre in Copenhagen and Ola Johansson at the division of Packaging logistics at Lund's University, for giving us interesting inputs, valuable support and guidance all through the project.

We would like to thank the respondents at the case companies we visited for their time and willingness to provide information. Further we also like to thank Philippe's and Thomas' colleagues at Microsoft who participated at the case company interviews and gave valuable interpretations of the case companies.

Lund, February 1, 2008

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Abstract

This master thesis has been written during the autumn of 2007 and in the month of January 2008. It investigates how the Lean philosophy can be used in Warehousing businesses. Further it gives example of tools that can help Warehousing companies to become Leaner in their business.

There is a contradiction between Lean Thinking and Warehousing practice today, since Lean strive at being just in time with a pull flow with no batching production and with preferably no inventory kept between the different processes. This is an ideal scenario. In real life there exist variation in demand, uncertainty in lead time and long lead times that cannot be fully predicted. This makes a warehouse necessary to provide items to the production, assembling or customer in time.

The warehouses doesn't add any extra value to the items themselves but only to customers by giving it in the time that the customer wants it, in the right amount and in the right quality. This makes the processes in the warehouse that is necessary for maintaining that ability; necessary non-value added processes. The other processes that aren't necessary are just non-value added processes. The warehouse can also be preferred for distribution purposes. But since nothing the warehouse do with the item gives it more value in monetary terminology, little handling of the item as possible is to be preferred. But as mentioned before there are necessary non value added processes and there are those who are just non value added. The goal is to avoid the non value added activities and improve the necessary non-value added processes if they can't be avoided as well.

One way to improve the necessary value added process picking is to place the items in a matter that reduce the work for the picker when picking. It could be placing them in appropriate heights and on picking frequency to reduce travel time. This could be done by an ABC-classification on the picking frequency and dividing the picking area into zones depending on the ABC.

Another way to improve the picking process is to visualize and assign the workload as optimal as possible. This could be done with the Heijunka concept together with the shipping order logic.

Keywords

Lean Warehousing, Warehousing, ABC-analysis, Heijunka, Lean Thinking

Sammanfattning

Det här arbetet har utförts hösten 2007 och även under januari månad 2008. Arbetet undersöker hur man kan dra nytta av Lean filosofin i lagerverksamheter. Ytterligare så ger och beskriver arbetet verktyg som företag kan använda i sin strävan mot att bli mera Lean.

Det är en motsägelse mellan Lean filosofin aoch dagens lager praxis, då Lean strävar efter att vara Just-in-time med ett pull flöde och så små batcher som möjligt i produktionen för att helst inte ha några mellan lager mellan processerna. Detta är ett ideal scenario. I verkliga livet existerar variation i efterfrågan, osäkerheter i ledtid och långa ledtider från leverantörer som inte helt kan förutses. Det här gör ett lager nödvändigt för att kunna ge produkter och delar till produktion, montering och kunder i tid.

Lagren i sig tillför inget extra värde till artiklarna utan bara till kunden då de ger dem artiklarna i rätt tid, rätt antal och i rätt skick. Det här gör processerna som gör detta möjligt för lagret; nödvändiga icke-värdeadderande processer. De processer som inte behövs för denna förmåga är bara icke-värde adderande processer. Lager kan också vara att fördra för distributions syften. Men eftersom inget av det lagret gör med artiklarna ger mera värde är minimering av hanteringen av artiklarna att föredra. Men som tidigare nämnt finns det nödvändiga icke-värdeadderande processer och de som bara är icke-värdeadderande processer. Målet är att undvika icke-värdeadderande processer och förbättra nödvändiga icke-värdeadderande processer om inte de också kan undvikas.

Ett sätt att förbättra den nödvändiga icke-värdeadderande processen plockning är att placera artiklarna i plocklagren så de minimerar arbetsbördad för plockaren. Det kan vara att placera artiklarna i lämpliga höjder och att placera dem på plockfrekvens för att minimera restiden. Detta skulle kunna utföras med hjälp av ABC-klassificering på plockfrekvens och zonindelning.

Ett annat sätt att förbättra plock processen är att visualisera och fördela arbetsbördan så optimal som möjligt. Detta skulle kunna göras med Heijunka konceptet tillsammans med skeppningsorder logiken.

Keywords

Lean Warehousing, Warehousing, ABC-analysis, Heijunka, Lean Thinking

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1. Introduction

This thesis will investigate the possibilities for using Lean Thinking in warehousing and how it can be supported by using the Microsoft software Dynamics NAV. This thesis is collaboration between Microsoft, Lund's Tekniska Högskola and the two students Martin Tostar and Per Karlsson. Both from the masters program Kommunikations- & Transportsystem (Communications- & Transport systems) in Norrköping at Linköping Tekniska Högskola were the students have chosen the profile Kvantitativ Logistik (Quantitative Logistics).

1.1 Background

Lean is a concept that got its name from a research program that started in the 1980s by scientist from the Massachusetts Institute of Technology (MIT). But its idea's and principles comes from the Toyota Production System that originated in the early 1940s.

Lean in production is now a well known subject with years of practical experience. After the success with Lean manufacturing, companies are now interested to see what benefits the lean concept can do to warehousing. Microsoft wants to help companies take that step toward leanness in Warehousing with their ERP-system Microsoft Dynamics Navision.

1.2 Purpose

Today the Dynamics NAV have tools that can be used by companies to be Leaner, but not all the companies know what tools to use, when to use them, or how to use them. Therefore a project is needed to investigate how to be lean in warehousing, how this can be supported by using Dynamics NAV and if there is a need to make modifications to the software to be more able to apply the Lean Thinking.

The purpose of this thesis is to gain information on which the general internal warehousing processes are, how Lean Thinking applies to these processes, and give guidelines to which tools can be used to further leverage Lean Thinking in Warehousing.

1.3 Problem description

How can Lean thinking and warehouse practice merge and create Lean Warehousing? Which tools can be used to support Lean Warehousing?

1.4 Focus and Demarcations

This thesis will be focused on the conceptual principles of lean in warehousing and how to leverage this by using NAV. Further it will only focus on internal warehousing processes for smaller companies with businesses like distribution, manufacturing and wholesaling. The ideas for Lean Warehousing tools should be in the realms of the warehouse staffs tasks. The thesis will be limited by the short timeframe, the number of interesting companies using NAV and also of the actual available companies that will suit this thesis. This will not give as extensive data as preferred but it should give enough detail to map the interesting processes.

2. Presentation of Microsoft

Microsoft was founded by Bill Gates and Paul Allen 1975. The company develop and sells software through a network of partners to private customers, businesses and other types of organisations. The company current have over 78,000 employees worldwide. The head office is located in Redmond, Washington, USA. For the fiscal year ending in June 30, 2007, Microsoft announced net revenue of US$ 51.12 billion. [1] Their mission is "to enable people and businesses throughout the world to realize their full potential".

Microsoft is divided into three core business divisions to serve their customers:[2]

- **Microsoft Platforms & Services Division.** Includes the Windows Business Group, the Server & Tools Group, and the Online Services Group

- **Microsoft Business Division.** Includes the Information Worker Group, the Microsoft Business Solutions Group, and the Unified Communications Group

- **Microsoft Entertainment & Devices Division.** Includes the Home & Entertainment Group and the Mobile & Embedded Devices Group

MDCC was established in 2002 following the acquisition of the Danish company Navision. Today with their 900 employees they are Microsoft's largest development center in Europe.[3] The center develops a range of business management systems for customers worldwide.

The development center aim to be the world's leading software development center for business solutions. They focus on securing a continuous innovative and focused development and product management of the ERP-solutions; Microsoft Dynamics AX, Microsoft Dynamics NAV and Microsoft C5.

Microsoft Development Center Copenhagen also plays a key role in the development of a new platform that will converge Microsoft's product lines within ERP. Their name for this platform is Microsoft Dynamics.

[1] www.microsoft.com (2008-01-16)
[2] Ibid
[3] Ibid

3. Methodological Framework

This chapter will discuss the methods relevant for this thesis. A brief explanation will be given on each one. Finally a presentation will be given on which methods were used during the thesis and in which combination.

3.1 Research Methods

3.1.1 The inductive method

Induction means that general and theoretical conclusions are drawn from the collected data[4]. It is often emphasized that the data collection should occur unprejudiced.

One drawback with induction is that the theory, harshly put, doesn't contain anything more than what is already in the empirical material. Another drawback is the fact that when performing a study some selection and some theoretical standpoint have been made before the study, which indicates that being totally unprejudiced is impossible.

3.1.2 The deductive method

In the deductive method a hypothesis is made from the existing theory[5]. The hypothesis shall then be tested empirically. This way of working is often called hypothetically-deductive.

The existing theory decides what information should be collected, how it should be interpreted and finally how the result should be related to the already existing theory[6]. This give the researcher a more objective view but the existing theory could be directing the researcher in a manner that no new finding would be made.

3.2 Empirical Data

There are two types of empirical data Primary and Secondary data. These data could be quantitative or qualitative in character. The data could also have been affected by the researcher on not. It is then called stimulated data or non-stimulated data.

3.2.1 Primary and Secondary Data

Primary data is data that is collected by the researcher during the project. The secondary data is already existing data that is available and relevant to the research.

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[4] Göran Wallen, 1993, Vetenskapsteori och forskningsmetodik, Studentlitteratur AB
[5] Ibid
[6] Runa Patel, 2003, Forskningsmetodikens grunder : att planera, genomföra och rapportera en undersöknin, Studentlitteratur AB

Primary data could be eyewitness description or firsthand reporting,[7] protocol from a meeting, an interview, an observation or questionnaire.[8]

3.2.2 Quantitative and Qualitative Data

Quantitative data could be denoted as hard data, it is information that could be described as profit in dollars, unsold units or similar. Qualitative data that can be called soft data consists of information for example about comfort at work or good function.[9] It can be difficult to differ between pure qualitative or pure quantitative data, since most of the information could be best described as something in between.

3.2.3 Stimulated data and non-stimulated data

If what is investigated is intentionally exposed to a stimulus influence from the investigator in connection with the data collection. Then that data is called stimulated data. All other data are then called non-stimulated data.

3.2.4 Data collection techniques

Interviews

An interview is a method for data collection where information is gathered by an interviewer that asks questions or has a dialog with the person being interviewed. The people being interviewed are often called respondent in scientific context. The answers and statements the respondent makes are raw data.[10]

To differ between the interviews a common way is to classify after the degree of standardization. The standardization degree refers to how much the formulation of the questions and the order of the questions are predetermined before the interview. With non standardized interview one can more freely choose the questions formulation and the order of the questions. The most important is that the asked questions give answers that cover the information needed.

It could be difficult to divide interviews right in to the classifications standardized or non-standardized interviews. These interviews are referred as semi-standardized. For these interviews there are often some basic questions that are asked to all respondents and then more freely discuss them. Further the interviewer can ask specific questions to specific respondent. That could be predetermined.

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[7] Ibid

[8] Ulf Lundahl, 1999, Utredningsmetodik för samhällsvetare och ekonomer, Studentlitteratur AB

[9] Göran Wallen (1993)

[10] Ulf Lundahl (1999)

Observations

In everyday life observations are made to gather information about the surrounding world. It happens more or less arbitrary from previous experiences, needs and expectations. Observations are also a scientific tool. In this context observations must be systematically planned and the information must be registered systematic.[11]

Using the observation method, behaviors and course of events in a natural state are observed in the same time as they occur, in difference to the interviews one aren't depending on the respondent's clear memory and their ability to forward the information to us.

Case studies

Case studies often refer to an investigation that only comprise of one or a few cases, which however are studied in more detail. Case studies are often used as a purpose to:

- Formulate hypothesizes
- Develop theories
- Exemplify and illustrate

When performing a case study these following work steps are often reoccurring:[12]

- Data collection, with purpose to describe the studied phenomena. This data collection are steered by the problems nature, theoretical and practical understanding. Also which data is available.
- Description of the studied phenomena
- Interpretation of the studied phenomena with a starting point from the studying actor's subjective logic.
- Search for pattern in the studied phenomena.

Before making a case study one must ask if the knowledge developed during a possible case study equals the knowledge needed. Also one must ask what the case study will be used for hypothesis formulation, exemplification or theory development?

[11] Runa Patel (2003)
[12] Ulf Lundahl (1999)

3.2.5 Validity and Reliability

The method of collecting data has to be critically examined in order to determine if the achieved information is reliable and valid. If the study can be repeated and still provide the same result it is reliable. If the result is the same as in reality then it is valid.[13]

These six strategies can be used to ensure validity:[14]

1. Triangulation, compare different sources of information and methods to confirm the result.
2. Control by participants. The researchers' interpretations of interviews and other human sources are checked by other people to see if they are trustworthy.
3. Observation for a long period of time or repeated observations of the same phenomena.
4. "Horizontal" evaluation and criticism. Other colleagues give comments on the achieved result.
5. The studied persons participate in every part of the study.
6. Explaining the previous knowledge of the researcher that might interfere with the study.

3.3 Method used in Thesis

This thesis will identify general processes in warehousing and how the Lean Thinking concept applies to these processes. It will only consider internal processes like receiving, storing, picking, sorting, packing and loading to transports. This will be done mainly for small sized companies with businesses like distribution, manufacturing and wholesaling.

To be able to do the identification a literature study will be made. In the literature study we look at literature on warehousing processes, Lean thinking in general and the available literature on Lean in Warehousing. We have chosen not only to look at what covers Lean warehousing but to look broadly on all three areas. Because they together will most definite give a more precise picture and the fact that Lean in Warehousing is a relatively young concept, compared to Lean Manufacturing and Lean in other areas. It might not be enough with the literature available on the jointed subject Lean warehousing. This will be our secondary data.

To do the analysis on how Lean thinking applies in warehousing we will perform case studies on selected companies that use Dynamics NAV in their warehousing today.

[13] Judith Bell, 2000, Introduktion till forskningsmetodik, Studentlitteratur AB
[14] Sharan B Merriam, 1994, Fallstudien som forskningsmetod, Studentlitteratur AB

The Case study will be performed partly with observations and partly with interviews. The interviews are performed concurrent with the observations during a tour given by an employee at each company, where questions are asked during the tour to fill in information about the company as a whole and the process that are being observed. This will be our primary data. The data will be of a more qualitative nature.

The analysis will connect the existing theories with our observations at the case study and create what is unique to Lean Warehousing. Then focus will be on giving recommendations and guidelines on tools that can be used to leverage Lean thinking in Warehousing by using Dynamics NAV.

To ensure validity and reliability we use a triangulation principle to compare the different literature. When performing the case studies we were accompanied by our two supervisors from Microsoft and their colleagues to discuss our findings and interpretations after each case visit. Also during the whole thesis horizontal evaluation and criticism have been given from our supervisors.

4. Theoretical Framework

The theoretical framework is the existing theories that we have studied and used as a foundation in our analysis and conclusions.

4.1 Warehousing

In this chapter we are going to discuss the warehouse, its objectives and in general which processes can be found in a typical warehouse. There are several different equipments and design features that will not be covered in this chapter since they do not sheer any further light on how the general processes work.

4.1.1 Objectives for warehousing

The two major objectives for keeping a warehouse are to earn profit and provide customer service. To achieve these objectives several activities are established, maintained and improved. These activities aim to:[15]

- Maximize the warehouse storage utilization (either in 2-D or 3-D space).
- Maximize the utilization of the warehouse equipment
- Maximize the utilization of the warehouse staff
- Reduce Stock keeping Unit (SKU) handlings, maintain required SKU accessibility, and assure the designed SKU rotation or turns
- Minimize the company's operating expenses
- Assure the protection of the company's assets

4.1.2 General processes

Each warehouse has its own categorization of what is considered as processes in their warehouse and what these are composed by. This is a description on the general processes that can be found in warehouses and what could be included in them.

Receiving

In the receiving process the goods are received and unloaded into the warehouse. To do this several supporting processes are performed:

- *Layout and design* for the Yard and the dock facilities are made to assure smooth transfer of the goods from the delivery vehicle to the warehouse, also to minimize the in-house transports. The docks are kept at a minimum since

[15] David E. Mulcahy, 1993, Warehouse Distribution and Operations Handbook, McGraw-Hill

they are considered as an energy loss and a security risk.[16] However the internal transport is more costly for the warehouse company than the outside transport so, it can be more profitable to add one more dock if it improves the internal transports.[17]

- *Yard-control* of the area for the delivery trucks to more effective utilize the space outside the warehouse to allow quicker turnaround times for the trucks and maximize the receiving capabilities of the Yard.
- *Scheduling* of incoming transports and assigning staff and area matching the workload of the incoming transport to assure that the receiving staff and storage area is available and ready to handle the shipment.
- *Principles* and actions can be established for goods that arrive outside the determined timeframe. For example a non receiving policy outside the timeframe or a policy that says that if they do not meet the timeframe have to stand last in line until the receiving staff can receive them. Demands for the incoming goods package and labeling on them are usually made to more smoothly transfer the goods into the system both physically and in the information database. For example products can be put on the floor of the delivery vehicle without a carrier unit, on pallet, on slips and on carts.

Materials can be received in several different manners. Figure 1 is a figure for describing how the receiving process could differ for different practices.[18] For each

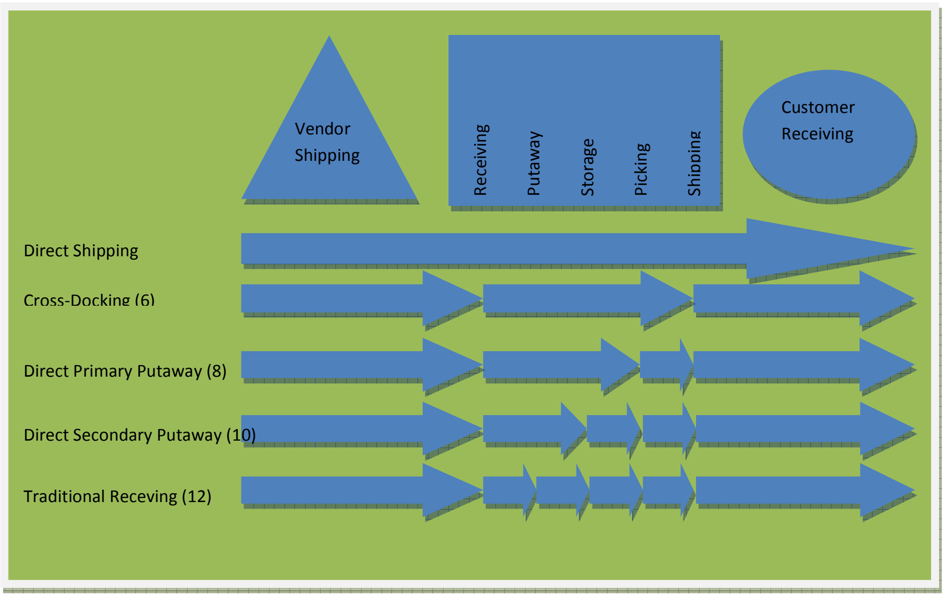

Figure 1: Touch analysis for alternative receiving practices for a typical warehouse

[17] Steven M Bragg, 2004, Inventory best practice, Wiley
[18] Edward H. Frazelle, 2001, World-Class Warehousing and Material Handling, Mc-Graw-Hill

Direct shipping is when items go directly to the customer without going to the warehouse in between.[19]

Cross-docking is when items go into the warehouse and then reloaded and shipped.[20]

Direct Primary Putaway this is when items are put into the picking area direct after receiving it.[21]

Direct Secondary Putaway this is when items are put in a secondary storage direct after receiving, before going to the picking area.[22]

Traditional Receiving in traditional receiving allocated areas are given to the receiving items and they are temporarily stored there before being put in secondary or primary storing.[23]

Unpacking/Sorting

After the products have been received they need to be Quantity and Quality checked. There are basically three methods for quality checking:[24]

- 100% Percent Accept Method. In this method no quality check is performed. This is used on vendors that have performed excellent in the past and are considered so excellent that a check is necessary.

- Random sample (7 to 10 Percent) Method. In this method a random sample of between 7 to 10 percent is checked and if they pass the entire shipment is accepted. If they don't pass a larger percentage are needed to be checked.

- 100 Percent Verification (Check) Method. In this method the entire shipment are checked. This is usually used for vendors with a history of not passing the check.

- When the delivery need to be counted for comparison with the purchase order there are three methods used:
    - Manual count method. In this method the employee physically counts each item individual item.

[19] Edward H. Frazelle (2001)
[20] Ibid
[21] Ibid
[22] Ibid
[23] Ibid
[24] David E. Mulcahy (1993)

- Mechanized method. This method is used for large scale orders the employee places the carrier unit on a scale that registers the weight. Then from expected weight of one product unit the number of units on the carrier unit is calculated.

- "Count on the fly". In this method a standard have been agreed upon to with the vendor to guarantee that each carrier unit has the same amount of product units. The carrier units are placed on a conveyor system where each carrier unit is registered and the amount of product units is calculated by the system.

The products need to be registered into the system as quickly as possible to have an accurate database. This can be done in a Delayed-entry method or an online method manner:[25]

- Delayed-entry method. In this method the products have been moved to the storage area without being registered. The registration for the inventory levels are done later. This can be a problem for products that need the products right away and if they aren't registered the pickers will not know that they have arrived and will send the orders without them. This will cause extra handling deliveries that could have been spared. It can also cause a "no-stock" problem there the products will not be including in the picking list at all since they appear not to be in stock.

- On-line entry method. Here the registration occurs when the products are moved from the receiving area to the storage area. This can cause a stock-out problem since the inventory levels are updated and the picker gets a picking list with a picking position but the products aren't there.

Storing

The storing is the activity where the goods are placed at a dedicated location until the pickers come and pick the products. The problem for the storing is to be able to have the right amount at home but not too much since that causes depreciation and unnecessary capital investment. But it is also in this placement of the products where it helps the pickers and the following processes after the storing by more custom storing to the specific products. There are several strategies that one can choose from to create a more effective storing.

For the placement a fixed, floating or mixed dedication can be used. Where the fixed says that one item always has a dedicated area. This is useful for items that have stable demand and a known frequency. Floating means that the products get a

[25] David E. Mulcahy (1993)

different location each time they are put away, depending on available slots and current strategies being used by the warehouse. The mixed location is when the warehouse uses both fixed and floating positions for the storing, where the more stable and reoccurring items get fixed while the items with more stochastic occurrence gets floating, instead of using a uniform solution for the entire warehouse.

There are three major product storage-pick position methods *the No Method, the ABC method and the Family Group Method*.[26]

- The *No Method* inventory location method randomly assigns SKUs to the storage-pick positions.

- In the *ABC Method* the SKUs positions in a warehouse are divided into three major zones: A zone, B zone and C zone. The first zone, the A zone is restricted for the fast-moving SKUs and the B zone for the medium-moving SKUs and the C zone for the slow-moving SKUs.

- The *Family Grouping* Method groups the SKUs with similar characteristics and assigns them to positions in the same aisle, zone or area. These characteristics could be the same customer, the same phase in a production process, physical characteristics and type of product.

Tracking is the most important thing to be able to control the inventory, this can be done either manually or computer-controlled:[27]

- Manually
    - Human memory. The human memory method uses the employees' memory to keep track of where the products are. This is useful for small systems and no capital investment is needed. But it is hard to work in more than one-shift and the employee productivity is low. In this method the employee places a product in a reserve position and keeps the position in his or hers memory and when it is time to replenish the pick position the employee goes to the place where he or she remembers it to be or search the aisles.

    - Manual Bin File. Here the employee lists on a form the SKUs identification number and which kind of transaction is made. Then at predetermined time or at the end of the workday the form is entered into the Bin File card to update the on-hand inventory location. This method uses no capital investment but needs one extra clerk to update

[26] Ibid
[27] David E. Mulcahy (1993)

the Bin File cards. It can handle low volume and a low number of SKUs; it can be used over more than one-shift.

- Card slot. When a product is placed in a reserve position the dedicated card for that slot is updated. These cards are kept in a card holder which is envelope slots with the sufficient amount of slots as there are positions in the reserve area. Whenever there is a transaction from or to the reserve area the correct card for the position involved is collected updated after the transfer and returned to the card holder. This method is sensitive to unclear writing, lost or damaged cards. No capital investment is needed and it easy to implement and it functions over several shifts. It handles a low volume with a medium amount of SKUs.

- Computer-controlled. In a computer controlled tracking system. The positions are stored, and the SKUs have a label on them. These are linked to each other in the system. When moving the SKUs to another position the employee documents this and then enters it into the system to update the on-hand inventory.[28]

    - Bar-code. In a barcode computer-controlled system, the employee first scans the barcode for the position before the movement, the SKU and then the position after the movement. The system then gets updates automatically.

    - RFID. In an RFID computer-controlled system the updating occurs as soon as the tags on the SKUs pass a reader.

Picking

Picking is the activity where a product is moved from storage to packing and when this occurs, the products that are being picked gets linked to an actual order. Picking is then a very important process where it is very important to pick the right products during the time that has been assigned to the picking activity.

To do an order-pick there are three basic methods where the picker either walks, rides to the product location or the products move from the storage to a picker at a workstation. All three of them require a routing pattern for the picking to direct the picker to the products or vice versa and to minimize the nonproductive time of walking, traveling between pick positions or hand movement between two pick positions within a container. The appropriate routing pattern is implemented in

[28] David E. Mulcahy (1993)

combination with some good warehouse practices like; 80/20 rule or family grouping principle, clear aisles and clear instruction.

To assure optimum results there are several elements to the order-picker routing pattern and warehouse aisle condition that should be considered:[29]

- Pick position numbers that end with even numbers on the right side as you travel down the aisle and odds on the left.
- Use arithmetic progression through the aisle (the lowest number in one end and then increased numbers as one pass through the aisle and gets to the highest number in the end of the aisle.
- Keep the picker in the aisle (work area) as long as possible.
- Improve the SKU hit concentration and hit density.
- Start the pickers in the fast-moving section.
- For single-item orders, whenever possible pick and pack at once.
- Cube out (divide) the pick activity.
- Keep the aisles clear and well illuminated.

There are several picking strategies to choose from.[30]

- Order-by-order. The picker picks and completes the orders one at a time.
- Batch picking. The picker picks several orders simultaneously.
  Batch picking could also be used in a stock-to-picker strategy. Where all the orders demand for a single item is picked at once and then sorted at a sorting are for the individual orders.
- Wave picking. The tasks for several orders are grouped together and divided optimally to the available pickers. Even a single order could, if preferred divided and allocated to more than one picker according to the wave pick principle. This intends to keep the picker in a smaller area for the duration of his picks. To minimize travel time.

[29] Ibid
[30] David E. Mulcahy (1993)

- Zone picking. Look a lot like Wave pick but differ in the aspect that a picker is assigned a zone in the warehouse first and then gets the part of the orders that have items in his zone.[31] While in Wave picking the orders items creates different routes in different zones depending on route optimization. This are then assigned to the specific pickers.

Sorting
This stations is assigned when the warehouse have a multiple order picking strategy. Then it is used to sort the items and possibly pack them at the same time.

Packing
The packing can often occur in the picking process. But it can also be a separate process dedicated for packing. In this process the packing people have a dedicated station for packing.

Shipping
Depending if the company handles the distribution their self or if a transport company does it, the handling gets different. If the distribution is contracted to another company they pick it up when ordered and plan with their other orders what is more efficient for them. If the warehouse companies themselves distribute the products they have to plan the distribution them self.

4.2 ABC-analysis

For more effective storing the ABC-analysis tool can be used in many ways to formulate each warehouse individual strategies for storing. ABC classes are based on Pareto's principle "the vital few and the trivial many". A stands for 80% of the value that's interesting (volume, frequency, cost and etc), B stands for 15 % and C for 5%. These percentages are not final but are just an initiative for a classification. The boundaries for determine ABC classes are based on how the output of percentages look and policy makings.[32]

The analysis can be used to indentify:

- products that generate the most profit
- The products that are the most fast moving through the warehouse
- The products that occur most in orders
- The products that are depreciated the most

[31] Edward H. Frazelle (2001)
[32] Jan Olhager, 2000, Produktionsekonomi, Studentlitteratur AB

- The products that have the highest demand

By using the ABC-tool to answer questions like the ones above one can get a good picture of where to, put their efforts and, which products that are stored in the wrong place and which might not need to be stored at all (phase out). It can also be of help when phasing items into the warehouse to know where to place the item.

How to perform an ABC classification on one parameter:

1. Sort the items in smallest to largest of the interesting parameter. For example volume, frequency or gross profit.
2. Calculate how much percentage each item has of the total value for the interesting parameter.
3. Calculate the accumulated percentages after each item of the total value for the interesting parameter. Starting with the items with the highest value.
4. Classify the items into classes based on the Paretos principle. Sometimes other natural groupings may come visible. Then it could be motivated to use these as criterions for the classes' boundaries.
5. Add one column for how much percentage of the total amount of items each item represent and one column for how much accumulated percentage of the total amount of articles. Starting from the item with highest value of the studied parameter.
6. To do the classification a chart could be drawn to help visualize the groupings of the items.

Example of an ABC classification: Let's consider ten items with historical data on demand. Then if we do the steps one to four we get the table below.

Table 1: Sorting and calculating on demand for each item

Prod ID	Demand	% of demand	Ack % demand	% of article	Ack % article
Socks	3000	33%	33%	10%	10%
Gloves	2000	22%	55%	10%	20%
Scarfs	1800	20%	74%	10%	30%
T-shirt	800	9%	83%	10%	40%
Boots	500	5%	89%	10%	50%
Caps	500	5%	94%	10%	60%
Jacket	200	2%	96%	10%	70%
Pants	200	2%	98%	10%	80%
Ski-dress	100	1%	99%	10%	90%
Sledge	50	1%	100%	10%	100%

When performing an ABC classification on which items that has the highest demand one can visualize it through a chart like the one below.[33] In the chart, the percentage of total demand per item is represented by the blue columns while the accumulated percentage of total demand is given by the black line, starting with the item with the highest percentages going to the one with the smallest.

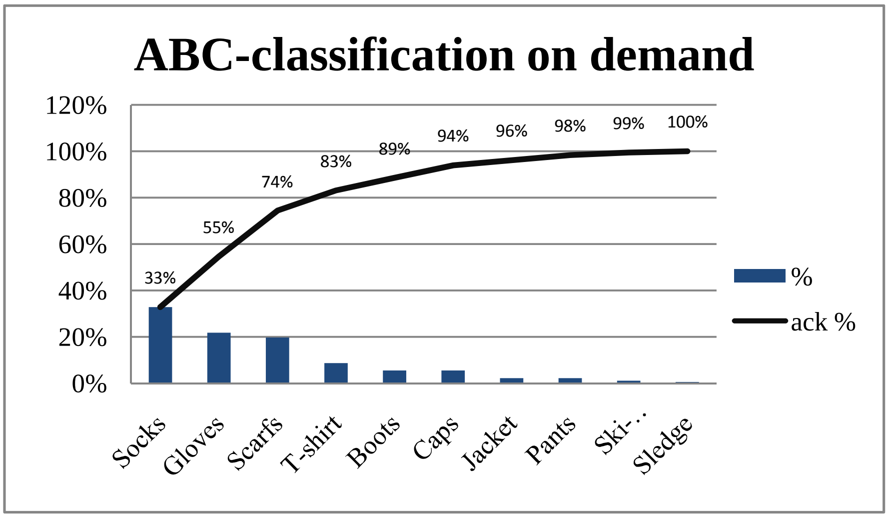

Figure 2: Chart for visualizing the percentages for each item of total demand

Looking at the table and the chart, one could draw the conclusion that the items Socks, Gloves and Scarf's would be categorized as A items, the items T-shirt, Boots and Caps as B items and the remaining items as C items. Then the classes would be:

- A class would be 30% of all items and have 74% of total demand
- B class would be 30% of all items and have 20% of total demand
- C class would be 40% of all items and have 6% of total demand

If the natural boundaries in the demand aren't visible it can create multiple interpretations of which items belongs to which class.

[33] Jan Olhager (2000)

4.3 Lean Thinking

Lean thinking has its roots from 1940's Japan. It has been spread worldwide after the competitors seen the effect from the implementation in Toyota. The main idée is to reduce cost by eliminating waste (Muda). Lean thinking has several tools to attempt to reach the goal. Keep in mind that final goals with no wastes are not possible so lean thinking is just an aspiration for a better situation.

4.3.1 Five Lean principles

There are five Lean principles when implement lean:[34]

- Specify value
- Value stream
- Flow
- Pull
- Perfection

Specify value refers to see the value of the products from the customer's perspective. The meaning for that is the customers are just interested in the final product and the ways that the company are solving it are not interesting. It is also important to understand that customers buy results not a product, a clean shirt and not washing machine. It could also be explain with a trip, the customer wants to go from one place to another. To get there can be involved taxi check-in flying etc. Every step is reducing the value of the product.

Value stream is the sequence of processes all the way from raw material to the final customer.[35] The process can be refining, movement to the information flow. There are three types of muda that can be detected in the value stream. Type one Muda are those which creating value as perceived by customer. 2: those which creating no value but are currently required by the product development, order filling or production system and so can´t be eliminated just yet, 3: those actions which don't create value as perceived by customer.

Flow is the third lean principle and is describing the motion of the products through the company.[36] There is an aspiration to go from batch flow with queues to single product flows. This is important when trying to keep the products moving and don't make queues. To make this happen it will often require major changes in the company's structure. Such changes can be the ability to show the complete display of the current workload for everyone to see. That is an excellent example of a lean technique, transparency or visual control. Have flexible machines are also important

[34] The New Lean Toolbox
[35] Ibid
[36] Lean Thinking

to have if they are going to follow the demand and reduce the batches. When going from larger machine with a high output to a smaller it will be more often that the changeover time will be reduced and have a more stabile recourses requirements.

Pull means that no one upstream should produce a goods or a service until the customer down streams ask for it. We can think of Pull in two ways, macro- and micro-levels. In macro level the company push the products to a certain point and responding to a final customer pull signal. This is a very effective way to reduce overproduction.

Perfection is the last principle and the meaning is that nothing is ever finished. There is always something that can be improved and never to be just content. So lean thinking is nothing that can be fully implemented into a company but it is an aspiration that will lead the company into a more profitable layout.

4.3.2 Seven wastes

- Transport
- Inventory
- Motion
- Waiting
- Overproduction
- Over-processing
- Defects

Transport refers to movement of products or employees and this is processes that the customer doesn't pay for and don't add any value to the product. But it is a waste that can never be fully eliminated but it is a waste that should be continually reduced. With high level transport it will be an increased risk for damage and deterioration[37].

Inventory is also a waste that can't fully be eliminated. With an increased inventory it tends to increase lead time when there is harder to find the products while picking them and increasing the distances due to the fact that more space is needed for keeping them in the warehouse, This will also lead to higher rent for unnecessary large facilities. But there are more problems that it leads to, the more products the company purchases the more capital investment is required. That will make it harder for the company to invest in new products, in development or other areas of its business. There will also be also a risk for the products to not get sold and have to be replaced by newer products. To get rid of this problem Lean aspires towards JIT

[37] The New Lean Toolbox

(Just-in-time) to have the items available just in the right time it is needed. Since all the other time it is kept it is just allocating space and creating no value[38].

Motion refers to movement by a human or a machine. The movement could be when the employee is reaching for different articles during an assembly line or when picking. It could also be the distance robots have to move to weld circuit boards components. So it is important to have a good functional and ergonomic workplace and have an aspiration to find and continuously modify the layout to be more ergonomically[39].

Products that are stored in a warehouse or before a manufacturing process are not generating any value for the company or the customer. That is called *waiting* and is probably the second most important waste. It is directly connected to flow and is constraining it. When the products are stacking up and waiting to be processed the lead time will be suffered. There for the flexibility to change products and to have the ability to have a quick response will be suffered[40].

Overproduction is often referred to the most serious waste and is root for many problems. When the company producing more than it's needed just to be safe, it will generate more movement that is necessary. The inventory will be increased and the flexibility will be suffered. Pull is an effective way to prevent overproduction, the batches will be smaller and there will not be any processing for products that are unnecessary[41].

Over-processing refers to use to large machines or equipment. Why buy expensive machines that can be able to process a huge amount of products when you don't need it. It is better to invest in smaller and more flexible machines that are cheaper. When doing so it will lead to "pressure to run the machine as often as possible rather than only when needed, and encourages general purpose machines that may not be ideal for the needed at hand[42]."

Defects is very important to locate as soon as possible, a small part that has been notice right away can cost a few dollars but the when the final products has arrived to the customer the good will are reduces and the cost could be increased to several hundred dollars. With the Toyota philosophy a defects should be regarded as a challenge, as an opportunity to improve[43].

[38] Ibid
[39] The New Lean Toolbox
[40] Ibid
[41] Lean Thinking
[42] The New Lean Toolbox
[43] Ibid

4.3.3 Heijunka

Heijunka is the name for a box that could be found in the production line. The purpose for the Heijunka is to help the employees to level the production and make a smother flow. A example of the box are shown below.

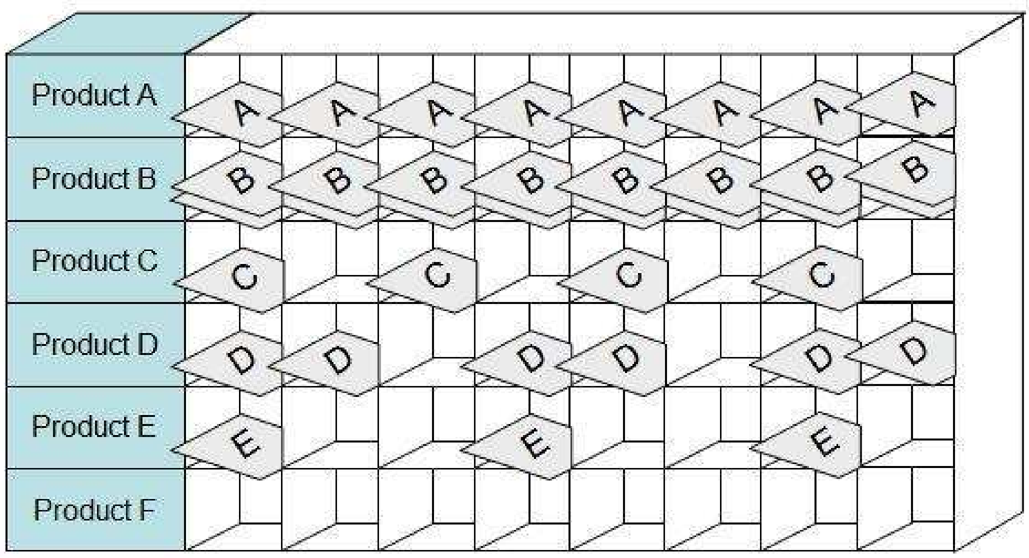

Figure 3:Heijunka[44]

The vertical columns are times intervals and the horizontal lines are for each product that will be process. The cards in the slots are cards that are telling the employee that that certain product will be process and are called kanban. The amount of that is suppose to be manufactured for each card are chosen individual. So if there is one kanban card in the time interval X for product A and two cards in the same time interval X for product B it says that it will manufacture one product A and two product B in the time interval X. With this box the employees have a good view of the workload and it will not manufacture the same product for to long time and will prevent to have too much of one product in the warehouse.

[44] http://en.wikipedia.org/wiki/Heijunka_box

4.4 Optimizing

A picking route problem can be solved by several optimizing solution. We have chosen to look at the problem with TSP (Travel salesman problem). “A salesman should visit n cities. Every city should be visit exactly one time and the salesman should decide a route that’s starts at the home-town, visit all the city’s, and return to the home-town. The goal is to minimize the total travel distance”.[45]

The algorithm can be time consuming when dealing with large numbers of products. This is because the solution space will increase with $\frac{1}{2}(n-1)!$ where n are the number of products. So if we have 100 products there are 4.6663*10^155 different solutions.

$$x_{ij} = \begin{cases} 1, if\ the\ bow\ from\ i\ to\ j\ are\ in\ the\ route \\ 0, else \end{cases}$$

$$\mathrm{c_{ij}} = \text{distance between i and j}$$

$$(1)\ \min \mathrm{z} = \sum_{\mathrm{i \in N}} \sum_{\mathrm{j \in N}} \mathrm{c_{ij} x_{ij}}$$

$$(2) \therefore \sum_{\mathrm{j \in N}} \mathrm{x_{ij}} = 1,\ \ \mathrm{i \in N}$$

$$(3) \quad \sum_{\mathrm{i \in N}} \mathrm{x_{ij}} = 1,\ \ \mathrm{j \in N}$$

$$(4) \quad \sum_{\mathrm{i \in S}} \sum_{j \in S} x_{ij} \leq |S| - 1,\ \ S \subset N, |S| \geq 2$$

$$x_{ij} \in \{0,1\},\ \ i \in N; j \in N$$

1. Minimizing the total route distance[46]
2. Make sure that that only one bow leaving node i
3. Make sure that only one bow enter node j
4. Make it not possible to sub routes

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[45] Optimeringslära

[46] Ibid

4.5 Enterprise Resource Planning systems

Microsoft Dynamics Navision is an Enterprise Resource Planning (ERP) solution. ERP is an integrated system that serves all departments within an enterprise. The ERP system can include software for manufacturing, order handling, purchasing, warehousing, human resources and other business functions.

In the 1960s software packages were of the Reorder point system type. These systems used historical data to forecast future inventory demand. When an items inventory felled bellow a predetermined inventory level more inventory were ordered. This where deigned to manage high volume production of a few items, with constant demand and focus on minimizing production cost.

Materials requirement planning (MRP) came during the 1970s these systems offered a demand based approach for planning manufacturing of products and the ordering of inventory. MRP gave greater production integration and planning.

In the 1980s MRP-II came. This stands for manufacturing resource planning. It had added capacity planning. It could schedule and monitor the execution of production plans. Where the manufacturing strategy focused on process control, reduced overhead cost and detailed cost reporting.

MRP-II where updated to MRP-II with manufacturing executions systems (MES). This provided ability to adapt production schedules to meet customer needs. It also provided additional feedback to shop floor activities. This had the focus on the ability to create and adapt new products and services on a timely basis to meet customers' specific needs.

In the late 1990s ERP came, its purpose where to integrate manufacturing with supply chain processes across the firm. It was designed to integrate the firm's business processes to create a seamless information flow from suppliers, trough manufacturing, to distribution to the customer.[47]

[47] Mary Summer, 2004, Enterprise resource planning, Pearson/Prentice Hall

5. Case studies

The focus of the case visits where to see which are the general warehouse processes and get a deeper understanding of how they look like today and have a frame of reference from real-world experience how they are performed.

For each company there will be a description on what kind of business the warehouse are in and then a more detailed description on how they run their processes.

5.1 Company A

5.1.1 Company description

Company A is a wholesaler. To provide good service to their customer and cope with the variety of products being ordered they have large inventories. They have 75000 different items on the shelves.[48] They also do a lot of “Project sale” to give the customer a more tailor made solution. Delivery time is a competing parameter and the ability to meet customer specifications.

They have know-how in various areas and utilize this to maintain a good relationship to their customers. They are not competing on price but on the added services as consultancy or solving specific issues resulting in small niche markets. The salesperson is often a technical specialist that also knows his vendors capacities and therefore he also acts as purchaser.

They currently have 100 vendors which of 20 were the engineering system integration driven. They have 3.300 “active” customers, 15% of them generated 80% of the turnover.[49]

Company A are currently improving their operations by sending sales person and other users to general financing courseware in order to get a better understanding of the cash-flow through the company and the need to lower inventory levels.

[48] Employee 1 Manager for Service & Operation

[49] Ibid

Structure

The company is divided into three divisions "Procesteknik, Maskinteknik and Entreprenør-materiel". These share resources in IT, Logistics, Warehouses, Economy and Marketing. For these three divisions the company also provides service for their products.[50]

Procesteknik division are for products like:

- Overflow handling products
- Oil lubing
- vacuum technology, pumps
- Instruments
- UV
- Filters
- Sealing

Maskinteknik division are for products like:

- Cutting
- Welding
- Robots
- Measurements technology
- Special technology
- Special made tools/ auto technology
- Material for chemical industry

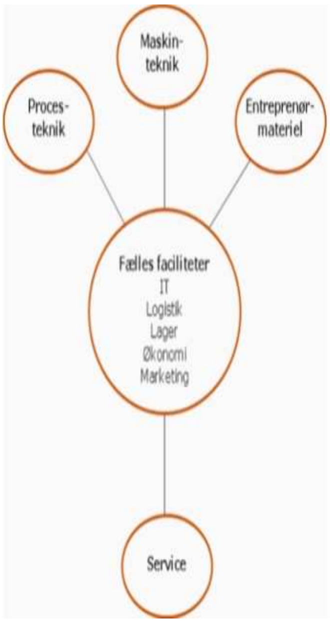

Figure 4: Structure of the company[51]

Entreprenør-materiel division are for products like:

- Generators
- Cleaning machines
- Small front loader
- Mini-excavator

Company A got service shops in Glostrup and Hadsten with 17 special assemblers and 16 service technicians. Its motto for Service is Quality, Speed and Flexibility. Company A totals about 90 employees in the company.[52]

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[50] Employee 2 Warehouse worker
[51] Employee 1 Manager for Service & Operation
[52] Employee 2 Warehouse worker

5.1.2 General information about Company A's warehousing

The warehouse runs fixed locations/bins – with the shelf information on the item card. All racks are labelled with a three digit number.

An Inventory count is performed once a year and if there is a shortage they are forced to perform another one. They use from 20 to 50 persons to do the physical inventory and it takes 2 to 3 days to perform. The obsolete items are depreciated by 30% first year and 100% the second year. Their discrepancies are quite low a pick was one year a difference of 50.000 DKK/one departments.[53]

Company A are shipping up to 130 parcel a day, in average 60 and they receive up to 5 parcel return a day – in average 2/day.[54]

- They use a shipping add-on: Win-EDI
- They used Intercompany within their subsidiary in Norway and Oslo.
- They have a turning rate of five times per year and their goal is six
- Their stock value is between 30 to 42 million.
- 6 warehouse employees – 2 in receive 4 in shipment
- All the worker seem happy and the work did not seem to be too much to handle
- They did not have any major problems other than inventory levels
- The workers were empowered to do their work correctly and to take initiatives; the material manager also said that he seldom had problems with that part of the organization.

[53] Employee 3, Warehouse manager
[54] Ibid

5.1.3 Process description and information flow

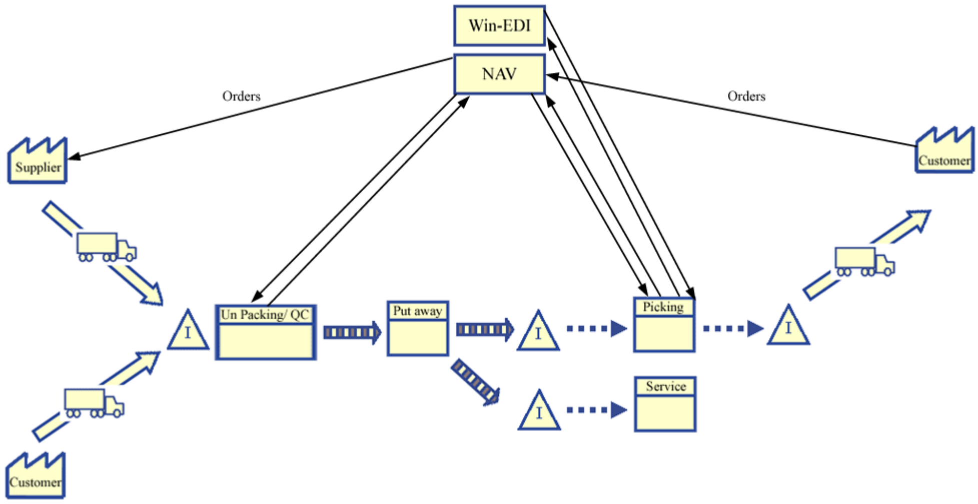

Figure 5: Process map for Company A

Receiving

Figure 6: Receiving dock

Company A are having about 60 inbound deliveries each day including approx. two for return handling, up to 10 deliveries a day.[55] When the products are delivered, they put them on the floor inside of the docking port, where it is moved to available room in close proximity to the unpacking and sorting area. If there isn't room available it is moved to an empty spot deeper in the warehouse for temporary storage until the receiving staff can process them. The available space in the receiving area did not seem to be an issue.

[55] Employee 4 Warehouse worker

Unpacking/Quality Control

Just beside the receiving area is the unpacking and sorting area. Here all the products have to go through before they can be put away for storage. In this station the products are randomly counted and visually checked. A more technical test is performed for larger and more complex products. If they need expertise they call in technicians to come and test products for them. After the products have gone through the counting and testing process they are entered into the Inventory levels. In the database the warehouse staff can see at which location the products will be placed.

Figure 7: Receiving/sorting area

Storing

The products are moved from the unpacking and sorting area either by a cart or a truck. The products are stored in a strategy that the handpicked items are in a reachable level and the larger ones are put higher up. The products have fixed position which is defined with a three digit label.

Figure 8: Products stored on pallets

Figure 9: Items stored in cabinets

The products are moved from the unpacking and sorting area either by a cart or a truck.
The products are stored in a strategy that the fast moving products are in a reachable level and the more slowly moving are put higher up. (no assistance from the system for this task – based on the experience person knowledge) The products have fixed position which is defined with a three digit label. The warehouse is not only for regular storing on pallets but there are storage rows for smaller products. These are open cabinets filled with smaller plastic boxes for the smaller products to be stored in. These cabinet rows submit to the three digit system which is used in the entire warehouse. But they also have a code for the plastic boxes which one can use to locate them when one has arrived at the location that the three digit system pointed out.

Picking

The picking lists are made in the NAV system and are printed. In the picking lists one can see the products number and its picking location. Also in the picking list every part of a product has its own number and every final product has it owns. They have added the total available products for each pick to indicate to the picker that goods should be available even if they aren't found at the exact location that has been given.

They pick order-by-order: the orders are handled by one picker for each order, even if the destination is the same for several orders only one is handled at a time. When the order is picked they enter it into NAV and the inventory level is updated. When that is done the delivery note is printed. They pack in a box and write the order number on the tape that is sealing the box. Then the delivery note is printed and put a plastic pocket and is attached over the previous written number with a printed label that says destination, company name and box ID.

Shipping

The finished orders are stored close to the shipping dock until it is collected by the shipping company. Company A tries to find the best shipping option between sending single orders and several together for each shipment. This by looking at the transport times, costs and capacity to store orders at the shipping area until the shipping company arrives.

Figure 10: Printed label for shipping

Return handling

Company A receives up to 5 parcels in return per day, in average 2 per day. These shipments can be with products that have been sent in to large quantity, are defective or old products that need service. To determine what to do with the receiving products a note for each product is sent to the sales people. They determines if the customer should receive a new product or if it should be repaired and if the customer should be charged for the service or if Company A stands for the costs.

When the products are received they are not put in the NAV system again but they are entered in to a journal were each entry is given a three digit number. Then a yellow note with the corresponding number to the on in the journal is put on the box and another on a piece of paper were the problem of the product is written and information about who is the sender. That note is the note that the sales department receives.

Information handling

1. The sales department receives the order by fax or Phone and these orders are input to the Navision system.
2. The picking lists for the Warehouse staff are created with NAV.
3. After completion of the picking task the order is entered and the inventory level is updated in NAV, labels and delivery note for the shipment are created and printed.
4. The company uses Win-EDI for their invoices.

5.1.4 Problems for the warehouse

- One major pain point was that they made too many and to large purchases which resulted in unnecessary high inventory levels and that some products could get stuck there for several years.

- One problem for the inventory was that sometimes the sales department could come down and take some products from the storage without notifying the warehouse staff and without updating the inventory levels. Which lead to inaccurate inventory data in the system?
- One problem that they didn't mention but as we notified could be one was that a lot of products were stored in the aisles which probably made it difficult to reach some products and could cause unnecessary movement.
- A problem that they didn't considered as one is the returning. If they are planning to be a service company they need to have taken into account the flow of returning goods in their business. Now they take up room in the original flow but they are not put in the NAV system. Even if they are not a problem today it might be one tomorrow if the service business of the company grows and the return flow grows and start to affect the flow for normal products.

5.2 COMPANY B

When we visited COMPANY B's warehouse in Herlev the mayor focus was on Subsidiary one and Subsidiary two. From the first of August 2007 Subsidiary one have been running with Microsoft Dynamics NAV 3.7 for their material handling. However Subsidiary two which are a larger company has not yet fully implemented Dynamics NAV but is expecting to be fully operational at the first of November.

5.2.1 Company description

COMPANY B is a Holding company in the fashion industry. They design products themselves and then contract producers from Europe and Asia e.g. China, India Italy and France. They have two trade fairs each year where they promote their products in their new collections.[56]

Because of the long lead time from their contractors, they are forced to purchase the products before the trade fair, and buffer up before the expected sales wave after the trade fairs. They have to have good market sense when forecasting the demand since ordering in new product can take as long as a month, which is the expected lead time for the contractors in China.[57]

After the trade fairs they have to temporary hire three to four extra warehouse workers to handle the temporary increment of the order quantity. These people don't have much knowledge and experience with the work so there is a great need of simple

[56] Employee 5, Responsible for implementation and maintenance of NAV at Company B
[57] Ibid

material handling routines with as many pokayokes as possible to reduce the error rate.[58]

Structure

Company B consists of three subsidiaries.[59]

- Subsidiary one is their own company which is selling accessories such as earrings necklaces, belts and shoes. Their customers are stores in the Nordic countries.

- Subsidiary two sells clothes that are mainly purchased from China apart from the scarfs that are coming mainly from Italy and France.

- Subsidiary three sells clothes and accessories to companies but them only handle larger orders.

5.2.2 General information about COMPANY B's warehousing

- Company B have floating positions for the storing locations for the picking area and the reserve in the reserve storage the items are placed wherever possible.

- Subsidiaries one and two have one designer and one purchaser each; also there are a total of 60 to 70 salespeople.

5.2.3 Process description and information flow

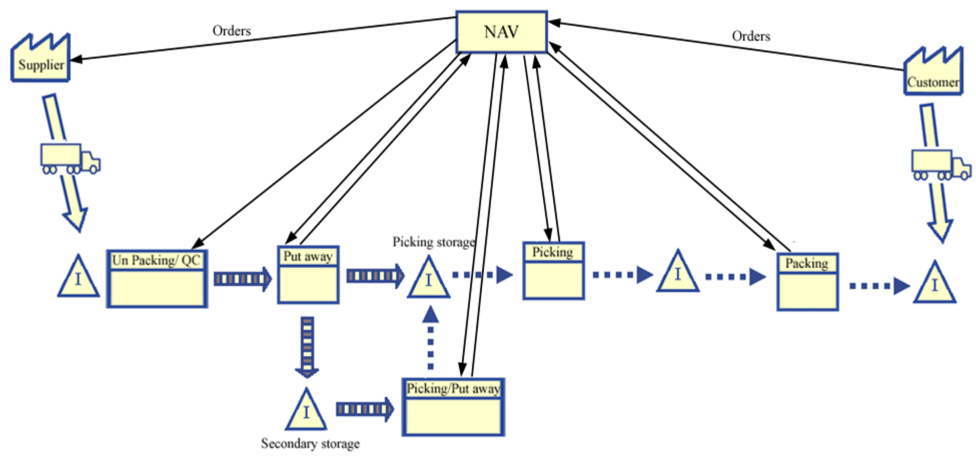

Figure 11: Process map for Company B

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[58] Ibid
[59] Ibid

Receiving

The receiving frequency varies under the year, before the trade fair there is a period of time for about three month where the incoming goods are up to five to sex times a week. After that the frequency reduces more and more the longer after the trade fairs and are at minimum about one time a week.[60]

When the goods arrive, the people who will receive the shipment don't know what's in the boxes so they have to go to the sales department for the paper that will connect the order number against the products that's ordered. Visual quality controls are made for the cardboards to notice if some products are damaged during the transportation. Every order is also check to ensure that the products are marked correctly; this is the most ordinary error.

Storing

After the control, products can be stored in three different locations, the picking storage and two secondary storage locations. These locations and the exact location are written down on the piece of paper along with the individual product id.

Figure 12: Picking storage

Figure 13: Storage area

They are using most of their warehouse so they are placing the products where ever there is some place left, but trying to gather the same types of products at the same place.

The information is written in to the NAV system when there is some time left. That results in that it could be done on the contiguous night or maybe the day after.

Picking for Subsidiary one

Because Subsidiary one are using NAV and Subsidiary B are using a paper based system there are rather large difference regarding the material handling so we will describe them separately.

They are using a picking cart that is installed with a stationary computer operated on a battery. To see the current inventory level they are using a touch screen where they

[60] Employee 6 Warehouse worker

can see and change the amount in stock. Other of information they can see on the screen are:[61]

- Active carrier unit
- Order number
- Products
- Number off each product type in the order
- Product placement
- Numbers in stock
- Numbers of products or incoming products
- Date of the incoming products
- Sorting method
- Special information for the packing station

Figure 14: Cart for picking

Figure 15: Screen for picker

When they have selected an order and start the picking they shoot in the product with a hand scanner one time for each product that will go into the carrier unit If there is a large numbers of a certain product type they can use the touch screen and the keyboard to enter the amount.

[61] Employee 7 Warehouse worker

Figure 16: Tote for picking

Figure 17: Scanning when picking

When the picked amount is equal as the ordered amount the product line will go from a red to a green colour. After the carrier unit are filled the picker place it on the conveyor where they will be stored until the order are finished and all the carrier units are on the conveyor.

If they are missing some products in stock they will mark that the product is not available at the moment and also mark the order as an incomplete order and send the incomplete to the customer. The missing product will be send to the customer when it arrives. When the products are marked as incomplete it will turn green so that the picker has the ability to finish the order and send it further. The missing product will then be stored in the system as a "rest order" and will be handled when the products become available.

When all the line has been picked the order is also going from red to a green colour and the order information send to the packing station.

Picking for Subsidiary two

The picker gets a pick list of what products that is in the order. He will then take a picking cart and carrier unit.

The pick list is showing the information:

- Customer number
- Delivery address
- Products
- Number off each product type in the order
- Product placement
- Number in stock
- When the order suppose to be at the customer

When the carrier unit is full they put it on the conveyer and when the order is completed all the carrier units will be pushed together to the packing area. The picking list will then be handed over to the personal that write the changes in the NAV system.

Packing Subsidiary one

After all the products has been picked into a carrier unit and been placed on the conveyor it will be send to the packing area.

Here they scan one of the carrier units barcode, the NAV system recognize the number and the order that has been connected with that specific number will be displayed on a screen. This screen will show information about the order such as:

- Numbers of carrier units
- The specific carrier units ID
- Special information about the order, such as if the customer has to pay in advance or if the products will be sent free of charge
- Package tracing number

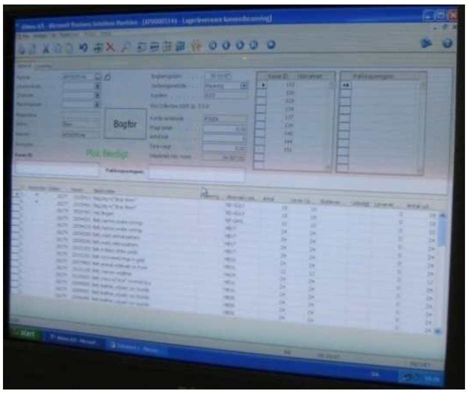

Figure 18: Screen at packing station

Figure 19: Conveyor to the packing station from the picking area

The packing personal then put the products in appropriate sized cardboard boxes and scan a DPD label for each of the boxes, this label will be placed on the boxes and are used for the distribution company. That number is very helpful if the companies want to track the consignment, and are often used when the customer hasn't received all boxes at the delivery.

When all the products are packaged they print a delivery note and an invoice that will be put in a plastic slot and be placed on the box.

Packing Subsidiary two

At the packing area they will package all the products that are in the carrier units and control that with the picking list. They also print out a delivery note and an invoice also a DPD label is placed on the box for the delivery company.

5.2.4 Problems for the warehouse

There are a lot of materials in the warehouse that are never used. If some products hasn't been used for a long time it will be transported to another warehouse. There it will be stored for up to 7 years when the company is trying to sell it to other countries and companies for a cheaper price.

When they are having their trade fairs there are lack of communication between the sales personal and the NAV system. This will result in over booked products, when they don't know how many products that are reserved, incoming and the level in the warehouse. It will therefore result in loss of sales and put additional stress on the sales personal.

The receiving procedure can be improved. Now there are a period of time when the products are physical in the warehouse but not in the NAV system just on some paper. This period of time can vary from several hours to over a day. This lead to, that when the staff is trying to pack the products they see that there are no products left in stock and the order will not be send completed. When they are just using a paper when they receive the goods it takes a longer time for the receiving personal to accept the order. That depends on that they have to go and fetch the order list so they know what products are expected in that specific order.

The order in the warehouse is fairly messy. There are way too much products in the warehouse and it leads to many products that can't be moved because the lack of space.

The large amount of products in the warehouse is also leading to an increment of time when they are filling up their picking storage.

Because of the products locations are randomly it can take more time to find and replenish it.

5.3 COMPANY C

5.3.1 Company description

COMPANY C is the world's biggest producer of cloves and grass seeds. They have subsidiaries in Denmark, UK, Germany, Holland, France, USA, New Zealand and representative offices in Russia and China.[62]

Numbers[63]

- They have 50% of the European market and 20% of the world market.
- They have revenue of 270 million Euros - 2 billion Danish crowns
- They have 810 fulltime employed staff. 225-250 are NAV users (200 regularly using NAV)
- They have about 800 species of seed of which about 400 is used regularly.
- Their world export is around 600 000 ton Clover and grass of which
    - 240 000 tons are in EU
    - 270 000 tons are in North America
    - 18 000 tons are in New Zealand but they have only been on their market for 2 years
    - 72 000 tons are in other parts of the world

They work with both large and small scale orders and always try to keep the customers demand in mind. They do this by trying to give their customers as many varieties as possible, because customers have many different preferences and they want to match each preference individually. Since their ability to meet the customers demand is what makes the customers choose them.[64]

The Growers (COMPANY B, 5400 growers) own 95% of the company and 5% are owned by others. This means that the owners buy their own products. This put them in the dilemma of wanting to earn money and wanting to buy cheap products. [65]

"Will stand to be the leading global player by offering our customer high-yield seed products and solution for all usage of cool season cloves and grasses"[66]

Their agenda to keep on expanding and continue to be one of the leading companies in their field are they going to achieve by:[67]

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[62] Homepage for Company C (2007-10-15)

[63] Ibid

[64] Employee 8 - Navision coordinator

[65] Ibid

[66] Ibid

[67] Ibid

- Focus on customer demand
- Focus on seed processing and packaging technologies
- Focus on effective logistics and planning management
- Benefit from large scale economies
- Automate to be more efficient

They have used NAV 3.01 B for 5 years. They haven't switched to a newer version yet because they have added a lot of functionality so much that they have used 25000h for the modifications. Some modules they have changed are: contractors and vendors module.[68]

Structure
COMPANY C clover and grass breeding is carried out by the Group's plant breeding departments in Denmark, Holland, the Czech Republic, France, New Zealand and the USA. The product life cycle for the seeds is research-production-sales-research.[69]

To get the products to the market takes a lot of time for development and testing. For example the products we see today in the markets started to be developed for about 5 - 10 years ago (including the final growing). When they develop the products they are testing the products for different areas in the world. Because the customer need different products in different areas of the world, for example in Denmark they usually prefer light green grass while in the US they usually prefer a darker green. The conditions for growing are quite different around the world so they must be suitable for the intended market. Also the customs demand is one thing they have to keep in mind. For example in the US 99% purity is a limit for acceptance.[70]

A problem is the unpredictable nature. They never know how good the harvest will be. For example this year they had a bad season and only got 80% of the expected amount, this has already been sold. This will force the company to either buy from competitors that might push the price up if they also had a bad season, or to give the customers a product that might not be as good as they could have got. If they produce to much they would have to lower the price because they can’t keep the seeds in stock for longer than one to two years. This is because the seeds lose germination over time and won’t be as productive for the consumer.[71]

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[68] Employee 8 - Navision coordinator
[69] Ibid
[70] Ibid
[71] Ibid

They usually contract growers for three years. The growers need 8 kilos for one hectare. This lasts for three years. Depending on which of the three year the seeds come from they are named first, second and third generation seeds.[72]

5.3.2 General observation about COMPANY C's warehousing[73]

- They keep a 3 kilo bag for every incoming field for security reasons to easily go back and check the sample if complaints are made.
- They have three machines for cleaning and they use 75% machine time (06:00 to 23:00). They use on machine for one seed and they have to clean before using another type of seed. The warehouse keeps three different types of seed when operating normally.
- They have 9000 boxes for the seed of which all have unique ID and there is no shortage of boxes.
- The station handles 19000 hectares of which 30% is in the facility and the rest is kept at the growers' farm at a cost.
- They Lorries come each day which can contain up to 100 cubic meters of raw material and they ship 500 tons of seed every Tuesday and Friday.
- Five boxes of seed are depreciated each year

5.3.3 Process description and information flow

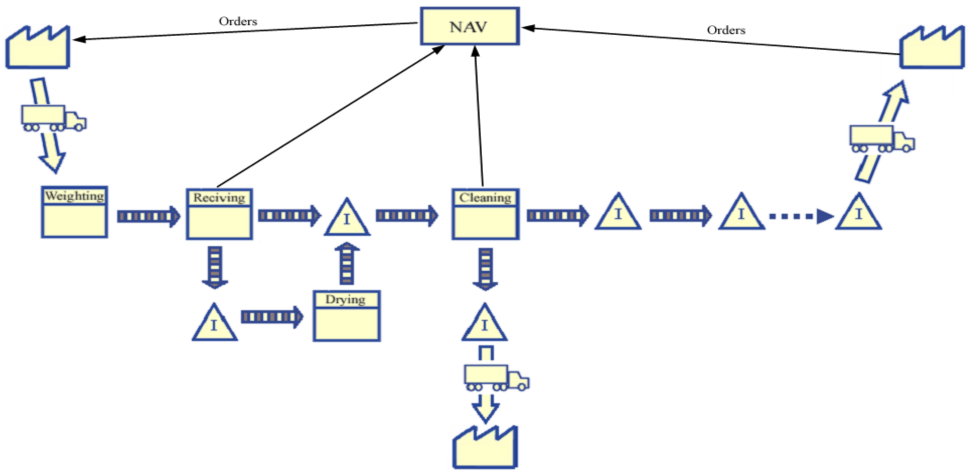

Figure 20: Process map for Company C

Receiving

[72] Ibid
[73] Employee 8 Navision coordinator

When a shipment arrives they weigh up the whole truck and does humidity control of the seeds. If the humidity is more than twelve percent the seeds will need to dry before being treated as the rest of the seeds.[74] To keep track of which field the seeds come from the driver brings a delivery note with the field number. The number is written on the delivery note like: year/field number/status/delivery number. For example for field 23089, this year, raw material and delivery number 3 the number would be 0723089R003. When the truck is cleared the truck goes to the unloading station.

Unloading

The truck unloads its cargo into a pit where the seeds are divided into wooded boxes with individual ID number. To keep track of the seeds a yellow A4 paper is used where each box's ID number is noted and to what field number they belong. For each shipment a three kilo bag is kept to be able to backtrack the sold items to a specific field. In case there would be a problem with the seeds, they have a sample to study. Also on this station a quality check is performed. They take a small sample and if the seed is approved they get a blue label that is put on the box.

Drier

Here the seeds that had humidity percentage above twelve percent dry until their humidity goes below twelve percent. The boxes are put here without a lit on large fans that dries the seeds with one percent per hour.

Cleaning

This station has three different cleaning machines that the seeds can pass through. These are divided to process one type of seed each. These machines are currently operating in 75% of the time. In the remaining time it is not in use.

Figure 21: Certification note

From the amount of material that goes in to one of the cleaning machines one third is what's comes out as "pure" seeds. The rest goes out as waste that is transported way from the warehouse in separate boxes. Because of the waste the seeds need to be redistributed in the boxes to fully fill each box. When that is done the new Box numbers are given a LOT number instead of a field number. This LOT number is linked to the field number for backtracking purposes. It's also here the price that the company will pay to the growers are decided.

[74] Employee 9 Warehouse Worker

After the cleaning process a sample is collected and is sent to an external organization for certificated to be sold to customer in Denmark or other countries in the world. This process is very time consuming and if the products are not approved they would have to clean it again. To speed this up the company have a machine (picture) that makes their own test. If it doesn't pass this one, they can clean it again before they send it to the external organization.

Packing

The boxes go to the packing station only when they have an actual order. Depending on the order the seeds will be filled in either 25kilo bags or in one and a half tonnage bags. The smaller bags are put on a pallet and stored in a separate area, the bigger ones are stored in large rackets. Also the smaller bags can wait in the finished goods storage on a pallet waiting for the pallet to be completed.

Storing

Since the warehouse house is built around the production processes the boxes with seeds are given place depending on what stage of processing the seeds are on. The boxes are stored before the drier, cleaning and packing. The storage before the packing is divided in a quarantine so that non approved seed do not go on until given a certificate. They are not physically divided but just that the boxes don't proceed until given clearance. There are also several storage areas for finished goods.

In each zone the boxes are stored inside yellow lines that are drawn on the floor with a three digit number to identify them. Each zone can have several boxes in row, one in width and up to five boxes high. When they put boxes in the zone they are listed with that zone number. But in which row and on which height is not noted. When they come to pick one of the boxes they have to look manually and move boxes out of the way to find where the box is stored.

Figure 22: Storage with yellow zone and three digit markings on the floor

Figure 23: Another storage area

Shipping

The warehouse receives Lorries that come to pick the bags up at Tuesdays and Friday. The larger bags are put on the lorry by truck that picks them up from the rack and moves them to the lorry, while the smaller bags are put on a conveyor which loads the lorry automatically.

Information handling

- They use NAV to keep track on which field number belong to which box ID and then after the cleaning the give the final price through NAV to the suppliers.
- In between the processes they use a paper system with different colours that say in which step of the production they are in. they only enter into NAV which zone they are in.

Examples of the colour codes used for the tracking

Figure 24: Pink code

Figure 25: Green code

Figure 26: Yellow code

5.3.4 Problems for the warehouse

- The major pain point is the ability to keep track of where the products are stored and in which order they should be picked. Every second month they misplace a box and are forced to search for it. They usually find it but in general five boxes per year are depreciated.
- One problem is communication of the work that needs to be done. For example one truck driver can move a box from side A to side B and then go back to A empty handed to see what else needs to be done. While another truck driver can move from side B to A with its own box and then go back to B to see what the next task. This could have been done with one truck.
- Facility layout can be optimized more. Now they have to move one box to another side just for storing and then back for next process step. Also they have several docks and storage areas for outgoing goods. If these were to be located together they could minimize unnecessary movement.
- Maybe the need for rework after the cleaning is taking up to much time of the machine time.

6. Analysis

6.1 Lean Warehousing

In this chapter we go through our ideas on how Lean Thinking could look like in general Warehousing businesses.

There is a contradiction between Lean Thinking and Warehousing practice today, since lean strive at being just in time with a pull flow with no batching production and with preferably no inventory kept between the different processes. This is an ideal scenario. In real life there exist variation in demand, uncertainty in lead time and long lead times that cannot be fully predicted. This makes a warehouse necessary to provide items to the production, assembling or customer in time.

6.1.1 The Five Lean Principles

Specify Value from the point of view of the customer

When looking at how the warehouse provides the customer with value it is by giving the customer the right products in the right time. The warehouse doesn't add any extra value to the item itself but only to customer by giving it in the time that the customer wants it and in the right amount. This makes the processes in the warehouse that is necessary for maintaining that ability; necessary non-value added processes. The warehouse can also make it possibly to postpone production further along the chain by holding modules of the components of the items and when it is ordered it sends it to production or assembling. This saves money because the companies don't need to have as much finished goods, since the item increases in value more as it nears completion. It also requires more capital investment which makes it more desirable to postpone the production or assembling until it is needed. The warehouse can also save money in transport because by acting as a distribution center it can exchange many long transports with shorter ones. This means like if ordering items from Russia to Sweden and there is one hundred places that the item needs to delivered to then instead of ordering one hundred trucks to transport the items from Russia to each location in Sweden, we instead consolidate the items into fewer truck to transport it to an warehouse closer to the destinations and then distribute the items from that center.

Value stream

To do a value stream in warehousing one thing to keep in mind is that it is not value adding to have a warehouse. Since nothing the warehouse do to the item gives it more value in monetary terminology. So, little handling of the item as possible is to be preferred. But as mentioned before there are necessary non value added processes and there are those who are just non value added. The goal is to avoid the non value added activities and improve the necessary non-value added processes if they can't be avoided as well.

Flow

In the Warehouse theory we described earlier in the report under the receiving section we talked about direct shipping, cross-docking and etc. If we consider the picture with the touch analysis, it is most lean to be direct shipping and then comes cross docking. To be leaner then means in one way to minimize handling and also to minimize the lead times to be more just in time and thereby reduce inventory levels.

To improve the flow into the warehouse one could keep in mind the touch analysis of the different receiving concepts. With this in mind try to minimize number of times the item is touched. Which means there is less handling and there by unnecessary over-processing waste is saved. Another thing to reduce waste is to minimize the lead time from vendor because of the connection between inventory levels and the time to get item into inventory after ordering them.

For the flow going out of the warehouse one needs to consider the processes after storing like Picking and packing. To improve these processes the workload of picking, replenishment, packing, sorting have to be optimally visualized and distributed. To distribute the workload it is important to be able to visualize how much is the workload and how to manage it. For orders that need to be picked it needs to be visualized how much work each order is and available resources, resources such that the item is available in stock and available resources for picking it. When having multiple orders it might be more appropriate to split the orders into smaller pieces and then batch the pieces together to create a new picking route which will give less travel (wave pick). This is motivated when the cost of having a sorting station for the batch pick is less than the profit made from changing from order by order to wave pick. A type of Heijunka tool could be used to visualize the different strategies and assign the workload in the picking process.

To improve the picking process one could try to minimize the unnecessary traveling for the picker, by placing the items that are more occurring than others together and closer to the shipping area. This can be made by ABC analysis on frequency. Other strategies like the one Company A had to place the picking items in picking height and the rest higher up is also a strategy to improve the picking process.

Pull

To reduce lead time we can look at two flows, the flow of items coming in and items going out of the warehouse. The point we divide these two flows is the storing since the "pull" flow from orders to the warehouse ends at the storing. One can consider the storing as "supermarkets" to be able to prolong the pull flow to vendors and further.

This would then be replenished by replenishment Kanbans. But as this still is delivered on the basis of forecasting, reorder-point or some shortage emergency the items isn’t linked to the single order that came into the warehouse. Unless it is the shortage scenario in which one firstly order items to the warehouse to cope with that specific order or orders.

Perfection

The perfect state would be direct shipping, which mean total elimination of the warehouse. This however isn’t always achievable or desirable, depending on the company’s businesses. Instead one could have as a goal to have as little touches as possible and concentrate on continuously improving the flow and reduce the different wastes.

6.1.2 The 7 Wastes

Previously in the Lean thinking chapter we have discussed the 7 wastes. This section gives examples of how these wastes could look like in a warehouse and give examples of how the different wastes occurred in the Case companies.

Transport

In the warehouse transport waste would be unnecessary travel like for example in the picking process. If several order comes in that are almost identical and they do the orders order by order. Then a lot of transport waste would have been saved by batching several orders together or split and wave pick them.

- In the picking area this waste occurred in Company A due to the large inventory kept and that the items were not organized in a matter to minimize the travel distances but only to minimize the motion waste.

- Company B had its items in a type of item placement. Placing similar items together. This creates transport waste since the items aren’t placed to reduce travel distances. But only to have the picker to know where to look for the items.

- Company C had this waste in the common scenario described earlier when two workers going in the opposite direction and back, which could have been done by one worker.

Inventory

Inventory waste is in the warehouse not to have enough inventories available and to have too much available. Not having enough is waste since then the customer receives no value at all. Having too much gives unnecessary capital investment. It is also a waste to store the wrong items. Since this does not provide the customer with items it wants and that it gives capital investment that is lost, because no one or not enough want to purchase it.

- Company A did had to large inventory waste because they made too many and to large purchases.

- Company B had large inventory waste because the uncertainty of the market and the long lead times from the vendors. The company experienced the inventory waste of not having items and having too much items.

- Company C had this waste because of the internal flow of the material in the warehouse and the lacking ability of tracking their items. This created inventory waste because having the seed when not being able to keep an steady processing flow created inventory between the processes and demanding space in the warehouse which could have been used for other purposes or one could have used a smaller warehouse.

Motion

Motion waste in the warehouse is like for example when not having picking items in picking height causing motion waste when the picker stretches to reach it or bends to pick it up.

- Company A reduced this waste by placing hand pick able items in picking height and larger items further up.

- Company B had much motion waste in the bulk area. Because when fetching items to the picking area the worker might have to move items to find it or stretching and bending when searching for it.

- Company C experience this waste when fetching a box for a process and not knowing were in a zone it where, then the worker has to move boxes around to find it causing motion waste.

Waiting

Waiting waste could be not to have the items required in an order at the picking area. So, the picker has to wait until the picking area has been replenished from the bulk area. It could also be that not enough equipment for a task is available and then the task gets delayed until the resources become available.

- Company A had waiting waste for the items being received were they were waiting for the unpacking/sorting station to be able to process them.

- Company B had waiting waste at the packing station when placing item on the conveyor and waiting for the packing staff to be able to start on the next order.

- Company C had this waste for the boxes before each process where they were waiting to be processed. There was also waiting waste when waiting for humidity test and the certificate by the external organization.

Overproduction
Warehouses do not generally have production processes so this cannot be defined for them. But for Warehouses with production processes like Company C this is waste of doing more than the market demands and being forced to store the items until they are demanded which creates unnecessary capital investment.

Over-processing
Over production can be when re-entering information into a system more than necessary. It can also be when using equipment with unnecessary high capacity for a task that need less capacity.

- Company A had in the returning flow a manual system which required the workers to enter the information into a logbook. This were then given to the sales department, which then used the information in the logbook and the information in the system to decide what to do with the items. If the return flow were somehow input to the system so that the logbook function were given to the sales department through the system it would save over-processing waste for both the sales department and the receiving staff.

- Company B had to when receiving the deliveries go to the purchaser to get the order to check that the items had arrived then manually enter the information into the NAV system. They already use barcodes in the warehouse which indicates they also could implement a scanner in the receiving process and thereby reduce over-processing waste.

- Company C transferred information in paper form on the boxes this information were manually written. If there were a way to not having to do this manually the over-processing waste could be reduced.

Defects
Defects in warehousing are when damage comes to the item within the warehouse, when the wrong items are picked and when not the right amount of item is picked.

- Company A had a return flow caused by defect waste. That could be erroneous picks or damage on the items. Items could also be return for not reaching the quality test at the customers this would not be defect caused by the warehouse, since it is not responsible for manufacturing the items. However if there is a testing station in the warehouse then it could be considered defects caused by the warehouse, because the warehouse let the item reach the customer.

- Company B hired temporary workers during high season to cope with the high demand. These could sometimes due to their inexperience pick the wrong items causing return flow and another shipment to the affecting customer.

- Company C would have defect waste if the items don’t pass the certification test and thereby forcing the seeds to be re-processed.

6.2 Lean warehousing at the case companies

In this chapter there will be an analysis of how the different warehouses where acting Lean. By this we mean what aspects of their businesses could be considered Lean. It could be for example if the workers are empowered, if the warehouses have good visibility or just-in-time deliveries. Also some thoughts will be given about how they could become Leaner, depending on their prerequisites today.

6.2.1 Lean Warehousing at Company A

How are they acting Lean?

- They are Lean in the Customer relationship were they have very close relationship. Which have given the insights on what the customer want and so on what the customer defines as value. Which are availability, that the products meet their specific needs also that they can get products that are
- The workers were empowered to do their work correctly and to take initiatives – they were acting “Lean”, the material manager also said that he seldom had problems with that part of the organization.
- They are given more participation and visibility for the cash-flow through the education program they have begun to give the workers to get a wider understanding of the cash throughout the company.
- They add the total available at the location on the pick order - as a low key indication to the picker that the goods should be available (Lean handling of moved items)
- Company A are improving their operations by sending sales person and other users to general financing courseware in order to get a better understanding of cash-flow and the need to optimize procurement.

How can they be Leaner?

- Increase visibility of
  - Inventory kept and incoming
  - Tracking the items

    - Cash-flow to see the consequences of their purchasing decisions
- Increase the accuracy of the inventory levels by improving the update procedures
- Increase communication between warehouse staff and sales department
- Take in the returning products into the system and design a flow for them separately
- ABC-classification. It was proven that there is a potential with a different categorization when a former employee responsible for a department did a lot with categorization of items and had much more profitable inventory than the other departments. It required some set-up and some maintenance but it was as mention much more profitable.

6.2.2 Lean Warehousing at COMPANY B

How are they acting Lean?

- Every product are scanned before they been put it in the carrier unit, that works like a *Pokayoke* and will drastically reduce the risk of picking the wrong item. If the picker scans another item the system will notify the user of the mistake.
- The visibility is good for the picker and he can easy see the current workload. It is also very easy to see how much of the order there are left because of the coloured lines.
- After the picker have completed the order it will be send to the packing station, this will reduce the risk that they start to handle the order before it is completed. It will also result in a more efficient packing process when all the products are there and the packer can make a more compact and in one flow.
- Total Coli number prevent customer to call back if a box is missing

How they can be Leaner?

- Their major problem is the increment of products in stock and one improvement is to increase the flow through the warehouse. It can be done by more accurate ordered predictions or to have more control over the products and visualize the time they have been in stock. When a product has been in stock for over X days it should be sent away to the other warehouse and sell further. Right now they are bounding up materials that are never going to be used for approximate 12 million Danish crowns.
- To handle the order problem they can update the NAV system to a newer version or to make sure that they have more accurate information when they are at the trade fairs.
- To improve the receiving procedure they could use their current system in a larger scale. They could set up a computer at the receiving station or maybe a mobile unit to the receiving personal. This will shorten the receiving time and make the system more up to date.

- ABC – classification on time of item in inventory to more easily phase the items out
- Increase visibility of the workload

6.2.3 Lean Warehousing at Company C

How are they acting Lean?

- They are lean in their customer relationship. They have made it their business to give the customer a large variety to make it possible for the individual customers to find a product that gives them a higher value.
- They only have 30% of all the seeds in their warehouse and the rest are at their suppliers. They have to pay for the storages but they don't have to invest in a larger warehouse and unnecessary material handling. They are using pull technique when they order the products from the suppliers when they know there is room left or there are demands of it.
- They never package a product before they got an actually order. This will reduce the risk of products that will not be sold and lover the handling cost.
- They don't have to throw away so much material because the seed rarely stay in the warehouse for so long time it will lose so much germination. Seed that had been in the warehouse for a longer time sells to vendors for cheaper price and are not labelled with the company name.
- Numbers of time the Certification test are rejecting the samples are reduced when they are using a testing machine at their facility. This leads to a shorter lead time for some products.
- When they wait to pay the suppliers after goods have been cleaned it will save time so they don't have to do some unnecessary transactions. It will also increase the income when the money stays in the company for a longer time.

How can they be Leaner?

- Warehouse layout could be designed for a door-to-door flow instead of the flow that is going back and forth. For example if they receive goods at one end they and then have the warehouse divided so that products are stored in front of the different process takes the need to go through they could try to make as many processes follow each other in one straight line from one end of the warehouse to the other. This will help visualize the inventory levels before each process.
- The deliveries into the warehouse could be designed to just not be pull but also more JIT. This could be done by increasing the communications with the farmers. Making the delivery time shorter and improve ability to make delivery request on short time. This will help the flow flowing in and out of the facility.
- Implement the storing position into NAV. To be able to update the storing position they could have a touch screen that they entered the position of each box

and update it as soon as a position is changed. To Pokayoke the updating process one could use a system that is based on either Barcode or RFID technology

- Increase visibility of the workload to not use two trucks for a job that can done with one truck.
- Enhance the pull flow from the Warehouse to the farmers to provide more just in time deliveries into the Warehouse.

6.3 Cross-case analysis

In this chapter an analysis between the case companies on comparable processes will be given. From the Case study we found that receiving, storing, picking and packing were the most comparable of their processes, although that their warehousing and businesses were different. These four is interesting because they are basic and most necessary to get their businesses running smoothly. Why processes for shipping and distribution aren't considered is that for all three companies they had an external company that did this for them.

6.3.1 Receiving

Table 2: Cross-case table for the receiving processes

	Company A	Company B	Company C
Labelling	Delivery note	Barcode each product	Delivery note
Package	Carton box	Carton box	Bulk
Carrier unit	Pallet or by hand	Container or pallet	Lorry
Identification	Manual	Manual	Manual
Information flow	Inventory update at unpacking station	First paper then inventory update later	First paper then inventory update later
Equipment	Manual Pallet truck	Manual Pallet truck	Filling machine

All three of the companies receive the items first and then do the update at a later time. This can cause a stock-out problem. COMPANY B has the advantage that with equipment they already have in their possession could automate the identification, and minimize the stock-out problem and reduce errors in entering the information. Through automation unnecessary steps for information handling is eliminated and the information flow improved.

Company C had the advantage that they had short delivery lead times which enable the possibility of more just in time transport. This however demands better tracking of the inventory kept in the warehouse to know more precisely when to schedule the next delivery.

6.3.2 Storing

Table 3: Cross-case table for the storing processes

	Company A	Company B	Company C
Strategy	Frequent/slower in picking height/higher up, fixed position	Random location, try to cluster similar products	Zone placement, FIFO
Information flow	Inventory update	Inventory update	Only on paper
Carrier unit	Carton box or pallet	Carton box or pallet	Wooden box
Equipment	Cart or manual pallet truck	Cart or manual pallet truck	Fork lift
Visibility	Slot placement from system	No information about placement	Fixed zones

For Company A the placement were fixed and the strategy where somewhat adjusted to help the picking process, with picking item in picking height and so on. But it did not take into consideration items that were occurring often. By placing items that are occurring often together and with shorter distance to the shipping area unnecessary travel would have been minimized.

COMPANY B has floating item placement with the strategy that as much as possible place similar items together, like belts together, hats together and etc. COMPANY Bs picking area had thin aisles which if the items were placed in specific zones like more occurring items in one area, and less in another one could keep the picker in that aisle for a longer time and make room in the other aisles for other pickers. However this could be difficult since they have to change items very often to not be out of fashion and because of this not having enough historical data to do such a classification on which items will be picked more often.

They have at most three different kinds of seed in the whole warehouse. So, the same strategic placement as suggested for the other two companies would not be appropriate. This because the warehouse is partly a production facility and the placement of items needs to be adjusted to the following production step instead of shipping area.

Both Company A and COMPANY B could benefit from ABC classification on picking frequency for more intelligent placement of items in their picking area. An ABC would reduce travel for picking since the more frequent picks is closer to the shipping area the picker doesn't have to go so far to pick them. DLF would mainly need more tracking possibilities.

6.3.3 Picking

Table 4: Cross-case table for the picking processes

	Company A	Company B	Company C
Strategy	Order by order	Order by order	FIFO to cleaning then Order by order
Information flow	N/A	Inventory update, workload	New label, new position written on paper
Personal	4	3-4?	20-30 at this location
Carrier unit	Carton box	Plastic container	Wooden box
Equipment	Cart or manual pallet truck	Cart	Fork lift
Visibility	Current inventory level	Current inventory and expected arrivals	N/A

All three companies would benefit from better visualization and assignment of the workload. This could release resources for inventory counting or other tasks for maintaining the warehouse. It could also be useful to compare picking strategies like order by order with batch pick or some other picking strategy. This however might not always be desirable since some companies only do order by order and it might only be confusing and add unnecessary complexity for them. It would only be a problem if the benefits don't outweigh the downside with adding complexity. Even if a company uses only order by order it could be useful to see how it would have look liked with other picking strategies, to verify that the company uses the right strategy. All three companies use order by order and do not have other strategies available to them at the moment.

6.3.4 Packing

Table 5: Cross-case table for the packing processes

	Company A	**Company B**	**Company C**
Strategy	While picking	Order by order	Order by order
Information flow	Inventory update, print invoice	Print invoice and unique box ID	Inventory update, print invoice
Personal	2	2-3	Included in above
Carrier unit	Carton box or pallet	Carton box or pallet	Sacks or "big bags"
Equipment	Pallet or by hand	Pallet or by hand	Fork lift or conveyor

For the packing station consideration should be taken for the customers receiving process and following processes. By making their processes go more smoothly the packing station provides more value to the customer through saving them work. One way to make their work go more smoothly is provide with information on the labels that otherwise usually would lead to extra work. Like how many packages totally there is and which package each labels is on. Like COMPANY B did. Also what is not included that have been ordered and why they aren't shipped. To save the customer time to not go search and call and ask where these items are.

6.4 Possible lean warehousing tools

In this chapter, suggestions on tools that can help companies improve their businesses and become Leaner in the terms of Lean Warehousing, is described. When deciding what tools can be used to be Leaner, we focused on how to improve the flow through the warehouse and increase visibility of the workload. We decided to keep the focus on tools that can be used by people working in the warehouse. To get tools that improves the daily operations and that runs with the Gemba principle of being at the location of the affected area for decision making.

If we only look at the processes that people working in the warehouse plan, control and perform, then of the compared processes in the Cross-case analysis, the one that is really a necessary-non-value adding process is the picking process. Because if we look back at the touch analysis, we saw that direct shipping was the perfect state of lean in warehousing. But in direct shipping, there is no process there is no handling within the Warehouse. The next best state was cross docking. There, the items were unloaded from vendor deliveries and bulked picked right into the distribution transports. In this state, picking is the only internal warehousing process and necessary to make it work. For the Direct primary put away state, storing in the picking zone is added, and in the Direct secondary put away state, bulk storing is added, and then in Traditional receiving, a temporary storage in the receiving area were added. Important to remember that warehouses do not fall directly under the categorization of the touch analysis been given because they have they might have an extra testing station or some additional handling somewhere between their processes.

The necessary non-value added processes are then in an order of which they can be avoided first. For example traditional receiving can be changed by placing the items direct into bulk area. The order of how much the internal processes are necessary non-value added processes given in the touch analysis is:

1. Picking
2. Storing in the picking area
3. Storing in the bulk area
4. Receiving into a temporary storage

Since this touch analysis is supposed to represent a typical warehouse we concentrated on trying to improve the picking process and the storage of items in the picking area. To do this we focused on using ABC on picking frequency for item placemen and Heijunka for visualization and assignment of the workload in the picking process.

6.4.1 How are ABC and Heijunka Lean?

Lean tries to avoid all kinds of waste. To not use ones resources optimally is also a kind of waste or it will lead to waste. ABC classification used in the right way is an effective means of reducing that waste.[75] ABC helps to separate the important from the less important.

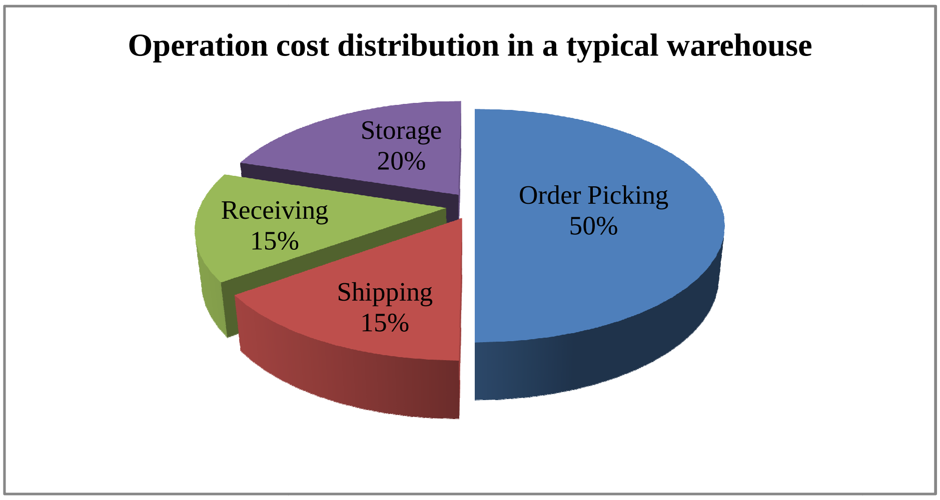

Figure 27: Operation cost distribution in a typical warehouse[76]

If we look at the operation costs for the processes in a typical warehouse they are distributed as above (Frazelle, 2001). We can see that the picking process is the process with the largest operation cost. Improving the picking process is then a must for the general warehouse if they aren't aspiring to become leaner. ABC can be used to create storing strategies for the picking area to improve the picking process. The main goals for such usage of the ABC are then to minimize transport and motion waste.

The Heijunka concept is a tool used in Lean in production to level the production as mentioned in the chapter about Lean thinking. In the picking process the shipping order can level the picking routes and the Heijunka can visualize how the workload is divided. The leveling would be on how for example how long a route it, how much the items in a route weight or on volume. This could help companies become leaner because it would clearly visualize the workload and reduce transport waste.

[75] Stig-Arne Mattsson Artikel i Bättre Produktivitet , Nr 8, 2003
[76] Edward H. Frazelle (2001)

6.4.2 ABC-tool

To use the strategy to place the items more appropriate for picking one can look at the picking frequency to minimize transport waste. This because only the distances from picking zone to the packing station should be considered. Since the movement of going between picking zone to the packing station is much more often than replenishment movements. Because replenishment moves are moving larger quantities of the item.

Data

To be able to place an item depending on an ABC classification on its picking frequency, data is necessary. The data could be obtained by creating historic data from orders. The needed data is the number of times the item is occurring in orders for a period which is called the picking frequency.

For example if one day's incoming orders looks like in the tables below:

Table 6: Order from customer X

Customer X		**Order ID 2303**
Item ID	**Description**	**Amount**
P001	Nails	500
P022	Bolts	1000
P039	Screwdriver	100
P050	Saw	20

Table 7: Order from customer Z

Customer Z		**Order ID: 2349**	
Item ID	**Description**	**Amount**	**Other**
P001	Nails	700	
P050	Saw	10	
P032	Hammer	50	

Table 8: Order from customer Y

Customer Y		**Order ID 4503**
Item ID	**Description**	**Amount**
P001	Nails	1000
P032	Hammer	30

Then the picking frequency for the items that day would be like in the below:

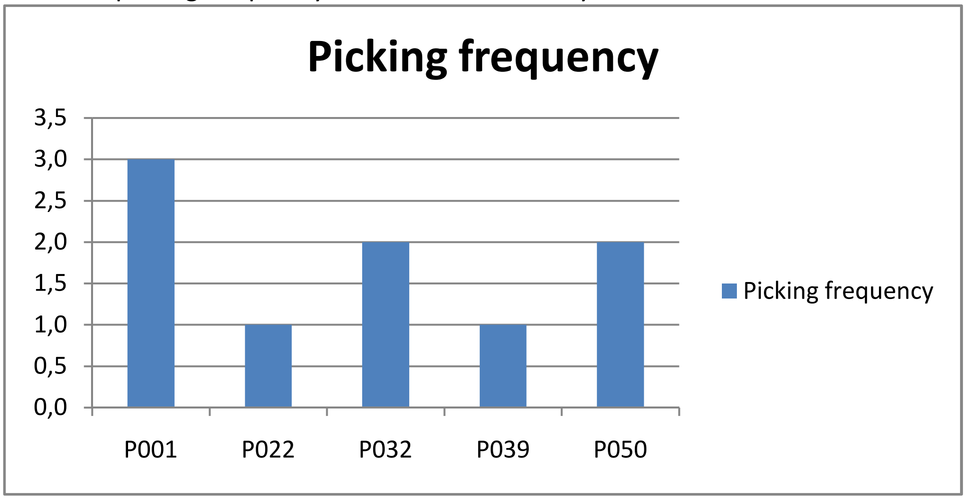

Figure 28: Picking frequency for the items from the example orders

Item placement

To do an ABC classification on picking frequency for the items, one use the ABC classification method described in chapter 4.2, using the data on picking frequency and items ID. The classes are then determined as described depending on the output data of the chart.

To use the ABC classes to store items we can first look at the simplest example. Lest consider one rack with bins only at picking level (all in the same height) and only in one side of the aisle. Then to minimize the travel time for the picker the items needs to be at the bin location with the shortest distance to the packing station or another converging point for the items. Let's say it is the packing station for all the following examples. Then it is pretty simple to place the items. It is so simple it could be done without the ABC classification but only with sorting the items with the highest frequency in one direction and have the bins distances to the packing station in the direction so that the bin with the shortest distance to the packing station is in the same level in a table then it is very clear in which bin each item should be stored. The ABC is mainly for grouping the items and allocate resources accordingly to their needs.

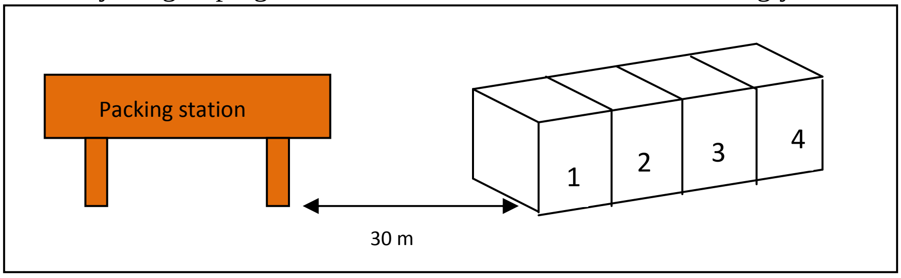

Figure 29: Distance between bins and packing station

From the picture above it becomes visible that the bin closest to the packing station is the bin labeled one then they follow as; two, three and four. The logic is the same for every layout of a warehouse where there is only one height level of storing bins and there is a mutual converging point for the items being picked. Or the converging points are located closely to each other.

Table 9: Distance to packing vs. Picking Frequency

Item ID	Picking frequency	Distance to packing	Bin
Glove	3	36m	4
Socks	7	34m	3
Scarfs	16	32m	2
Pants	30	30m	1

The table above shows how to sort the bin with the shortest distance to the packing station to match the bin with the highest frequency.

In real life there is the fact that there are several height levels with storing bins and that the bins needs to able hold the necessary amount of items. This means that consideration must be taken to the space available at the bin and the necessary space requirements for the items. The bins size must be changed to match the required volume as much as possible. It is very common that more than one bin store an item to meet the customer demand. The bins are then located next to each other to minimize travel and confusion for the workers.

Through discussions with Microsoft it became reasonable to expect that all the items that are stored for picking is in picking height for the picker. This limits the option for storing bins for picking, but there could still be more than one height level for bins that are in picking height. Consider the racks that have the physical construction that they are made up by pillars and shelves like in the picture below. There are off course other possible constructions for racks in a warehouse but this is the type we saw at Company A and in Company B Warehouses.

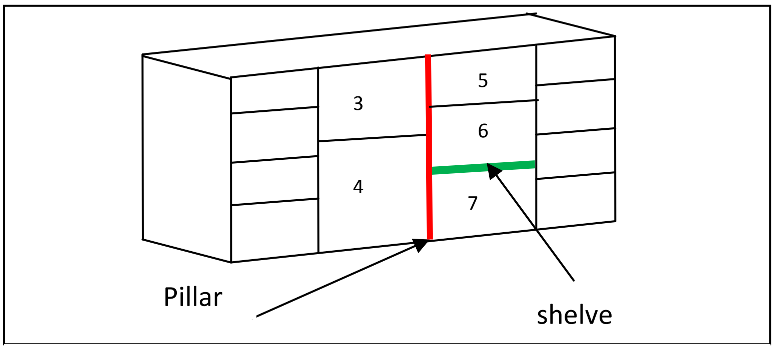

Figure 30: Example of constructions of bins in a warehouse

If having a construction like this, one have to keep in mind that moving a pillar to change bin sizes affects the width of all the bins it is in direct contact with. In the picture above moving the red pillar would affect the width of bins 3,4,5,6 and 7. While moving, adding or removing shelves only affect the height of the bins it comes in direct contact with. In the picture moving the green shelve would change the height of the bins 6 and 7. To be able to take into account the possibility to change the bins one must know the construction of the racks to know how the bin sizes will change.dd

Example of changing bin sizes

Let's consider the items in the table 9 and the same storing bins in figure 28, with added volume properties for the bins and space requirements for the items as the table below.

Table 10: Item requirements for storing

Item ID	Picking frequency	Amount needed at picking bin	Measurements (m^3) per item	Space requirement (m^3) in picking bin
Glove	3	250	0,002	0,5
Socks	7	800	0,001	0,8
Scarfs	16	250	0,002	0,5
Pants	30	660	0,003	1,98

Table 11: Bin specifications

Distance to packing	Capacity (m^3)	Bin
36m	2	4
34m	2	3
32m	2	2
30m	2	1

Table 12: Difference between bin capacity and item requirements

Capacity (m^3)	Space requirement (m^3)	Difference
2	0,5	1,5
2	0,8	1,2
2	0,5	1,5
2	1,98	0,02

If we compare the capacity at the bin with the capacity required for each item we can clearly see that it is not optimal to have these sizes on the bins. But if we consider the top of the bins as the maximum height for picking height then we could split the bins into smaller ones where it is preferable. If a shelve for splitting up the bin let's say requires $0,01m^3$ in space then one way could be to split up the second bin into three smaller bins to store the items Scarf's, Socks and Glove. In the picture x.x one can see how this splitting could look like and that we have now release the capacity of bin three and four for other items.

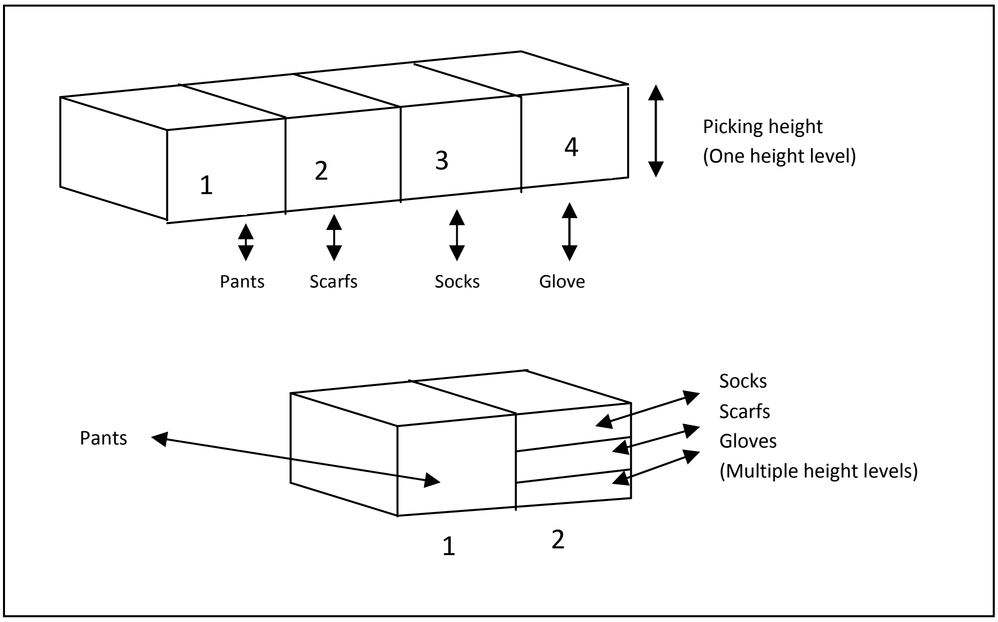

Figure 31: Comparison between before splitting the bins and after

When talking about changing bin sizes the idea of moving items to more optimally place the items to minimize the required space comes to mind. This however requires a way to know:

- The required space for the items in the picking bins, how much should be stored. One or more bins to be assigned to the items?
    - How much is stored in the carrier units used in the bulk bins and how much items is the smallest carrier unit for moving the current item carrying?
    - How much is the demand and how many replenishments are reasonable for a specific period for the picking area?
- Is it possible to change the bin sizes?
    - Max and min size for the bin?
    - How much space is used for a shell, to keep item on?
    - How much is gained by changing items location or to changing bin size?

The changing of places for better usage of the space capacity should only be done as a secondary criterion after frequency; otherwise one would lose the benefits from the placement of items according to their picking frequency. But using space as secondary criterion could create the problem of first assigning all the A items, then B and when C is to be assigned bins there aren't enough left. This makes it necessary to know the total capacity limit for the picking area before starting to assign items to bins. One way to avoid the problem to not have enough room is to first decide how much space each ABC zone should have. When deciding this, one can keep in mind that the space necessary for an item probably depends on the characteristics of the item, the amount of the item to be stored and how many times it is replenished.

$$\frac{Demand * the\ items\ space\ volume}{Replenishment} = amount\ of\ items\ in\ picking\ bin$$

If one replenish more often less is necessary to be stored at the picking bin and if less is stored at the bin more items could be stored closer to the shipping area minimizing the travel distances for picking. This however increases the travels for the replenishments. It is for this very important to motivate that increasing replenishment moves is justified for reducing picking moves. This is not a tested formula but only an example on how the relation could look. Further observation and testing are needed to get a valid formula.

Lean talks about reducing the changeover time to have smaller batches to be able to more swiftly change the item being produced. This reduces the inventory between machines and other parts of the production. This could be compared with minimizing the items kept at the picking bins to be able to more swiftly be able to pick the next item like in a producing company more swiftly change the item being produced. But still, having too much replenishment will create more waste than it reduces.

Replenishment also has to be done in an amount that doesn't create too much extra handling. For example if pants are packed in cartons of 20 in each and on each pallet in the bulk area 6 cartons are stored. Then if the average replenishment is a number of 50 then the replenishment has to be 60 or 40. Since it would cause extra work to split a package and only replenish ten and the picking bin needs to be able to meet the demand. This however might not be a problem if the items have been opened when being received or another station before being put away to enable replenishment with amount not only dividable by the number kept in the smallest carrier unit. In this case twenty.

Items that are small like nails might not be appropriate to make replenishment moves often although the demand indicates that. Because it doesn't allocated so much space, for example if one box of nails meets customer demand but it only uses 20% of the space in a bin and the height of the bin cannot be adjusted. Then it could be more appropriate to keep that bin more filled and make less replenishment moves. That is something that will have to be decided for each item when it is assigned a bin.

6.4.3 Intelligent movements for maintaining ABC zones

Movement will be needed to maintain the ABC zones. These are not value added but can be considered as necessary non value added processes since they improve the items flow from the storing to the shipping area.

Phase out for items that aren't being picked and Phase in for new items that are needed to get a class assigned to them, can benefit from the ABC analysis. Since it can tell where to place the new items in the picking area and point out those items that aren't being picked as much, as necessary to be kept in the warehouse.

Moves are also required when an item changes ABC class. To know when an item has changed class there can be an indication when the item has reached another frequency than in the present class. Then to know that the item probably will stay in the new class one can look at the history of picking frequency to see if there is a history of shifting in picking frequency. Then it might not be suitable to change into the new zone.

Also one can look at the forecasted demand to see if there has been an increase or decrease in demand and if the new levels are stable or not. But it is not appropriate just not to look at the forecasted demand since that doesn't say how many times the items probably would be picked but only how much that would be picked totally during a period.

When a zone change for an item has been motivated, then the same questions to optimal placement according to space in the new zone are asked; if one should resize bins, assign multiple bins to one item and move items around to make place?

Possible to implement an ABC-tool in an ERP system?
To be able to implement a tool that show in which order the items should be placed in the picking area with shortest distance to the packing station is probably not so difficult since the small examples can be easily done in excel.

To get consideration on how much space each item needs is probably neither so hard to achieve since it is as in the examples showed a matter of checking the capacity vs. the needed space.

To get the possibility to change the bins and have a system to automatically calculate which amount is optimal to be kept at each bin. To not get to much replenishment moves and not to exceed the capacity of the picking area further investigation is needed on optimization algorithms for such problems. This is however what is most desirable because handling some items manually like in the examples showed previously is okay. But when handling thousands of items and thousands of storing bins it is not practical to decide for each item continuously how much space and replenishment is appropriate. Since it requires continuously checking the items if their picking frequency changes so much that they need to be moved they also might need to have other parameters in replenishment and space allocation.

6.4.4 Picking optimization

To reduce the picking time it is crucial to reduce the movement between the products that's been picked. To be able to optimize the picking route we have to know the distance between all products. To do so we are using a grid that all the products are placed in. We can´t use the shortest distance because of the warehouse layout. It could be shelf or other structures in the way. To go around this problem we insert end points in both sides at the shelf. From that point the user have to measure the distance to all the other end points. By doing so the user doesn't need to measure the distance from each product because that would make that process very time consuming. Each end point is entered into the grid and makes it possible to calculate the distance from the products placement and the end point. That is possible because the distance from a product that´s in the section of the shelf and the end point are a straight line so the formula below can be used.

$$D = \sqrt{\Delta x^2 + \Delta y^2}$$

With this method we get four different distances and we choose the shortest one.

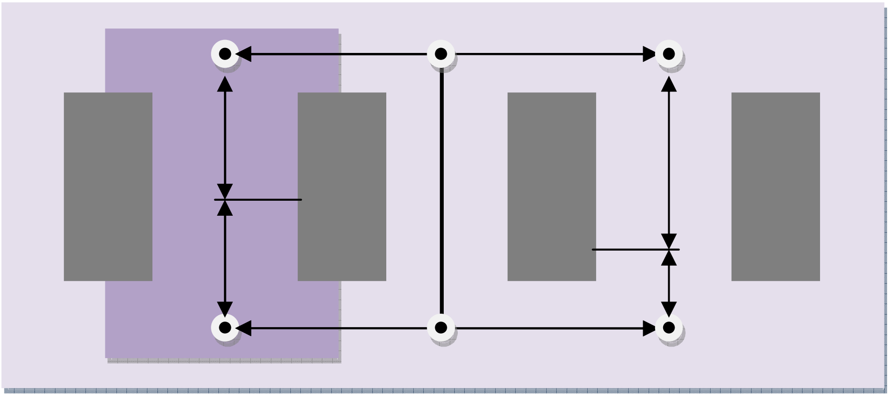

Figure 32:Shortest path

After we have the distance matrix we can use a modify TSP (Travelling salesman problem) method to calculate the most optimized routs.

$$K = numbers\ of\ personnel$$
$$b = capacity$$
$$d_i = demand\ for\ product\ i$$
$$c_{ij} = travel\ time\ from\ product\ i\ to\ j$$
$$i = product\ (i = 0\ are\ the\ start\ point)$$
$$p = number\ of\ products$$
$$a_i = \begin{cases} 1, if\ product\ i\ are\ in\ route\ j \\ 0, else \end{cases}$$
$$y_{ik} = \begin{cases} 1, if\ product\ i\ have\ been\ collected\ by\ personnel\ k \\ 0, else \end{cases}$$
$$x_{ijk} = \begin{cases} 1, if\ personnel\ k\ are\ comming\ directly\ from\ i\ to\ j \\ 0, else \end{cases}$$
$$(1)\ \min z = \sum_{k=1}^{K}\sum_{i=1}^{m}\sum_{j=1}^{m} c_{ij}x_{ijk}$$
$$(2) \therefore \sum_{i=1}^{m} a_i y_{ik} \leq b, k = 1, \dots, K$$
$$(3) \sum_{k=1}^{K} y_{ik} = K, i = 0$$

$$(4) \sum_{k=1}^{K} y_{ik} = 1, i = 1, \dots, m$$
$$(5) \sum_{i=1}^{m} x_{ijk} = y_{jk}, j = 1, \dots, m; k = 1, \dots, K$$
$$(6) \sum_{j=1}^{m} x_{ijk} = y_{jk}, i = 1, \dots, m; k = 1, \dots, K$$
$$(7) \sum_{i \epsilon S} \sum_{j \epsilon S} x_{ijk} \leq |S| - 1, 2 \leq |S| \leq m, k = 1, \dots, K$$
$$(8) \sum_{j=1}^{m} y_{ik} \leq p$$
$$x_{ij} \in \{0,1\}, i = 1, \dots, m; j = 1, \dots, m; k = 1, \dots, K$$
$$y_{ik} \in \{0,1\}, i = 1, \dots, m; k = 1, \dots, K$$

1. The main function, minimizing the total transport time all the personnel.
2. Subsidiary condition to control the capacity
3. Set the numbers of personnel to K
4. Make sure that every product are visit one time by exactly one employee
5. Make sure that only one employee pick the product j and comes from i
6. Make sure that only one employee are leaving product i
7. Make it not possible for sub routes for each employee

The main idea with this LP-solving method is to use the shipping order that has been generated to allocate optimized picking routes to the employees. To assign a certain numbers of lines per route a constant b are used. If the maximum numbers of products are six we assign the number six to b. It could also be used as a constant to limit the volume or the weight an employee can pick. So by enter the product number and the amount it is possible to calculate the total volume or weight that the employee supposes to pick.

To control how many routs that would be generated we take the total numbers of lines in the shipping order and divide it with b. The result is rounded up to next integer. This will ensure that every picking route will be as close to six lines per route as. The routes can then be distributed to the employees. When the numbers of products in the shipping order grows larger the complexity to solve the LP-problem will also increase rapidly. There are several of different methods to make it simpler to solve such as Lagrange relaxation but we will not go deeper such methods.

6.4.5 Order handling tools

To handle an order can be much more complex than first sight. Each order can be handling separately or can be merge together to a shipping order. To handle an order separately is especially useful when the warehouse is small or there is a large variety of products. This is because the travel times between the products are small and merging of several orders will not compensate the time it take to sort and repack the orders. If there is a large variety of a product there is a low probability to have same products in several orders. And therefore it will not be much to gain and it will just make it more complex and time consuming.

The example below is showing three orders that are quite similar regarding the different products in each order. Therefore when merging together this orders the amount of total picking locations will be reduced from twelve to seven. That will result to a reduction of the total travel time dependent on the position of the products.

Order 1

Product	Numbers
4	12
12	3
32	37
43	4

Order 2

Product	Numbers
2	3
12	43
43	21
53	7

Order 3

Product	Numbers
1	6
2	32
12	4
32	11

Shipping order

Product	Numbers
1	6
2	35
4	12
12	50
32	48
43	25
53	7

Pick order 1

Product	Numbers
1	6
2	35
4	12
43	25

Pick order 2

Product	Numbers
12	50
32	48
53	7

Figure 33: Shipping order

When we have a shipping order for all the orders it is easier to distribute it to more compact picking routs. And as in this case it will reduce the routs from three routes to two. As we see in the picture below the routs will be less complex and the risk that a picker will have to wait for another employee will be reduced drastically.

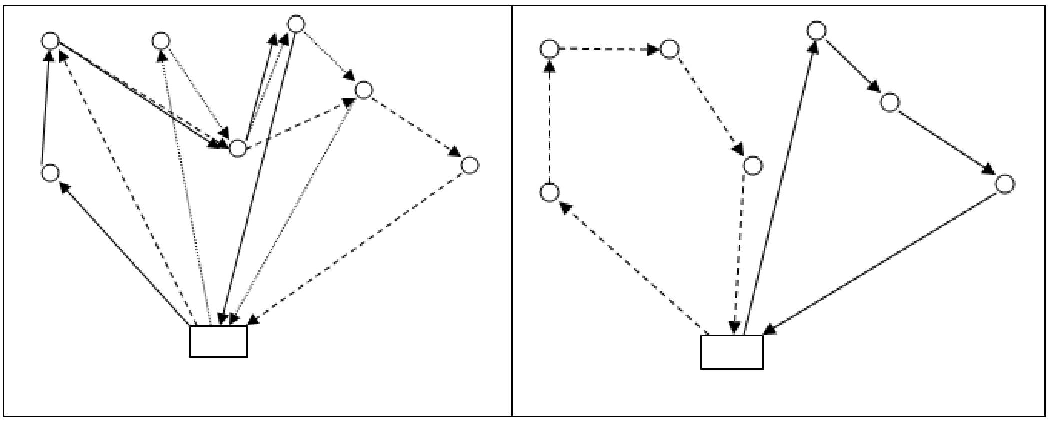

Figure 34: Picking routs

To decide how many orders that will be in a shipping order can be decided in many different ways. It can be chosen so that one shipping order never goes pass a fixed number of lines or maybe a maximum volume. The most common way should properly be a limit in shipping time. So every order that should be done before a certain time would be merged together. That would be very useful when a common company would have regularly pickup time each day.

It would be more effective regarding travel time the more orders that would be handle at the same time. But the user should remark that for every order that will be added making it more time consuming to sort the products after the pick. Because the sorting time and picking time are different for each company it will result in different levels for each company.

A big profit while doing it this way is that it can free up personal that can be used for other purpose, like sorting, packing and replenishment of products.

Which order handling way to choose are depending on the structure of the company and are unique for each company. There should be some ways to assist the user on the selection of method. An example of that is shown in *figure 35*.

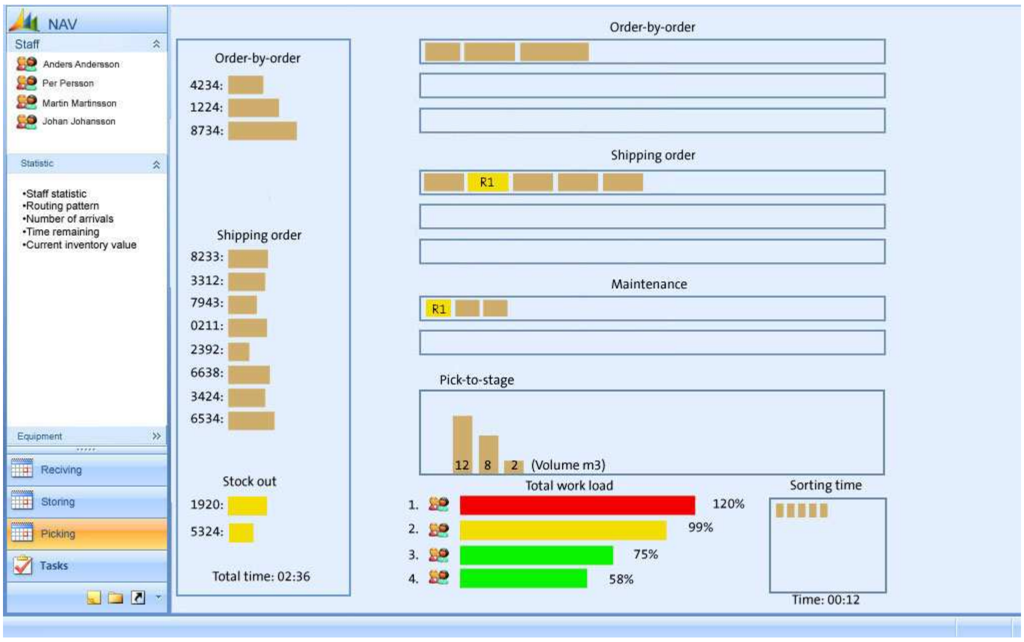

Figure 35: Planning tool

The main ideas is when the user have chosen some of the orders he/she want to process they come to this window. Here the orders are placed under shipping order (combination of several orders). It could be easy to move the orders from a shipping order to an order by order by moving the order in the order list (left side). Here it is possible to see if a certain product volume will be larger than an employee can handle in one pick. The volume for these orders are visualizing in Pick-to-stage. The user can then choose to get a larger volume of that product and place it near the sorting area. Those movements are then handle as a pick to stage route and will be placed under maintenance. The sorting time square are showing the time it will take to sort the routs that has been laid as shipping orders. "Total work load" are showing the workload for the employees under a certain time frame when using 1-4 workers in this example.

6.4.6 Heijunka

Heijunka are made to be useful when levelling production, but it is also useful in a warehouse environment. It will make some improvement in several areas such as visualization and order handling.

Heijunka box are often referred to as a physic box where the production cards are placed in different time slots as been told in previous chapter. But when using the computer based with NAV the customer have the advantage to use computers and screens to visualise the layout as a digital Heijunka box. The positive when using a Heijunka box in digital form is that it can be shown in many different layouts and it can also be at several places at the same time. It will make it easier for the production planer to delegate the orders and make it more transparent.

Figure 36: Exampel of a Heijunka

After the production planer has used the planning tool above to confirm how the order should be handling he can use the Heijunka box as shown above. The lengths of the rectangles are the same as in the planning tool, the processing time.

Each employee that is assign for a picking process will be shown here and the production planer can delegate routs to them. They do that by drag a rout from today’s window to the specific employee, by doing so the user can easy see each of the employee’s and their workload, therefore make a more fare allocation of picking routes.

When a route is a part of a shipping order it will not be completed when that route are completed, so the program are showing all the unfinished orders at the “Sorting” box. In this example one of the half finished orders are selected and are showing that it consists of three different picking routs. The colours are presenting the current status of the picking rout. A green rectangle is a finished picking route; yellow started picking route and the last one haven’t started yet. The box named “Ready for shipment” is the position that finished orders that haven’t been shipped are visualized.

7. Conclusions

This chapter will be a summary of the findings in the analysis and about what to go further with in developing the suggested tools.

7.1 General internal warehousing processes

From the case companies we visited four processes appeared to be general; Receiving, Storing, Picking and Packing, this because we observed them in all three companies and they are all internal processes. Further shipping was done by an external company in all three cases and testing processes did not seem to be general because testing can be inside these four processes, between the processes or some just don't have it. These four processes also became reasonable to be considered general when looking at the touch analysis in *Figure 1* for companies using the traditional way of receiving and storing items.

7.2 Lean warehousing

Warehousing is often necessary to provide items in time, in the right amount and in the right conditions to the customer it is also a strategic business for cost reduction in distribution. To be Lean in warehousing is to improve the processes that are necessary for maintaining the warehouse's purposes and to avoid processes that can be avoided without reducing the warehouse's ability to perform its function. Possible tools for further leverage Lean in warehousing should then be tools that primarily improve the flow and increase the visibility; this together with efforts for avoiding processes and wastes. The tools suggested in chapter 6.4 is intended for improving the flow and increase the visibility if the workload in the picking process.

"Lean is not an eclectic selection of tools, but a system. This is true. But hopefully it is useful to collect up the tools and concepts that Lean draws upon." (Bicheno, 2004) Developing tools such as the ones suggested and described one gives companies the possibility to strive forward to and maintaining a Leaner philosophy in their warehouses.

Implementation of the planning tool and Heijunka will make it easier for a production planer to plan for daily orders. He can see the current workload very simple and have the possibility change the position of the workers. A reduction of picking time would be gained but specific how much depends on the company's structure, products and layout.

The possibility of using an ABC tool is to get information to enable more effective picking. ABC is in its present form used by many companies to just improve their storing. But ABC is often routinely misused on demand only. To use an ABC on frequency data is necessary to be collected as described earlier. The information given by an ABC on frequency can be enough to point out for the warehouse manager where to put the items. But when having many items a more automatically tool is needed. It can off course also be preferred for the small companies as well. To get a tool that uses ABC and automatically place out items in the picking bind several problems are needed to be tested before formulating a general formula or algorithm. These are the ones that we think should be necessary for such a tool:

How much space is needed at the picking bin for an item, One or more bins?

- The items physical characteristics (size of item)
- Number of replenishment:
  - Amount to be replenished each time
    - Possible carrier unit quantities
    - Picking frequency. High frequency more often?
    - Distance from bulk or if not having a bulk area lead time from vendor
    - Size of item. Larger more often?
  - Demand
- Total space in picking area
- Bin size capacity. Max and min?
  - Possibility to change bin size
    - Different kinds of constructions

When having all these parameters and relations an optimization problem or algorithm needs to be developed to give the optimal location for all the items without exceeding the capacity of the picking area.

In addition to being able to place out all the items optimally a maintenance function is needed to avoid having to do the optimization to many times. This maintenance functions needs to be able to sense changes in picking frequency to see if an item changes ABC class and then see if it is likely to stay in the new class. Then it needs to find a new optimal placement and volume for the item, also if it is motivated to move it to the new location. To do this these problems should be addressed:

- Detecting class changes: does the frequency lies outside the assigned class.
- Validate class change: has it stable frequency history, trend or seasonal effect.
- Motivate location change: assign new bin or bins
  - Search for empty bin or move other items to make room?
    - Replenishment
      - Increase or decrease in number of trips of affected items

    - Changes in volume kept at the bin/bins
        - Optimal volume for this item when changing to new position with consideration of the total flow of all items within the picking area? (or affected items)
- Increase or decrease in distances of trips of affected items
    - New positions
- Benefits of keeping item at its current place vs. benefits from moving the item. If moving items around to make way for current item then the benefits for all items affected need to be better. Also they need to be weighted according to their importance, for example picking frequency, cost or other.

When looking deeper to a problem like this surely more problem areas will be found and some that are mentioned here might not be problem areas. But it would need a deeper study with modeling and testing to become valid and reliable.

There are as mentioned many problems to look into but it would help the majority of warehouses with their storing and picking process. If one were to design a tool like this with the possibility for the manager to choose storing strategy and the rest would be up to the system, which could generate output in form of simple moving instructions for the warehouse worker. Then it would be a really attractive tool for anyone trying to become leaner in Warehousing.

8. References

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8.2 Articles

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8.3 Internet sources

www.microsoft.com (2008-01-16)

Homepage for Company C (2007-10-15)

8.4 Respondents

8.4.1 Company A

Employee 1: Manager for Service & Operation

Employee 2: Warehouse worker

Employee 3: Warehouse manager

Employee 4: Warehouse worker

8.4.2 Company B

Employee 5: Responsible for implementation and maintenance of NAV at Company B

Employee 6: Warehouse worker

Employee 7: Warehouse worker

8.4.3 Company C

Employee 8: Navision coordinator

Employee 9: Warehouse Worker