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Improving the flow of materials and information from a Lean perspective

- A study performed as a part of a project improving efficiency at Faiveley Transport Nordic AB

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Acknowledgements

The research and writing of this master thesis has been conducted during the period from October 2010 to April 2011. It is the final stage of the authors' educations before graduating as Masters of Science in Mechanical Engineering under the Department of Industrial Management and Logistics division of Engineering Logistics, at Lunds Tekniska Högskola. The research has been done at Faiveley Transport Nordic AB in Landskrona. The thesis is to provide Faiveley with suggestions on how to improve the visualization, cost efficiency and availability of their supply chain. The research has been very interesting and educational, where the authors have been given lots of room, to let their interests guide them, in finding improvement suggestions that they strongly believe in. The authors have felt a great support from the people at Faiveley and have already seen signs of some of the suggestions being implemented.

The authors would first like to thank Steinar Haugen, Supply Chain Manager at Faiveley, for this opportunity and for being a most supportive, knowledgeable and overall great supervisor for this thesis. The authors would also like to thank Leif Person, for answering all continuously arising questions, along with the rest of Faiveley management and personnel, for being very nice and supportive during the research project. The authors would also like to thank our academic supervisor at LTH, Lennart Perborg. Last but not least, the authors would finally like to give a special thanks to our families and friends for their support, reading and giving their input in this thesis.

Landskrona, 2011-04-11

Christopher Carlström & Peder Emond

Abstract

Faiveley Group is an international company present in 22 countries, and with their headquarters in France. The subsidiary Faiveley Transport Nordic AB, Faiveley, is responsible for the Nordic and Baltic markets and is also the competence centre for the development of the BFC brakes. Faiveley is currently in a changing period and various projects are currently in progress, including hiring outside Lean consultants working to streamline the company. The authors delimited the thesis to purchased articles, meaning k-articles, without any need of further processing. From this starting point the authors have worked with the research questions:

- How can the material flow and material handling be improved to meet higher demands on visualizations, cost efficiency and availability?
- How can the information flow and work routines in the supply chain be improved to meet higher demands on visualizations, cost efficiency and availability?

The authors' way of conducting logistical research is based on the foundation that logistics handles real-life problems in a complex and constantly changing environment. The research is conducted as a cyclical process with both empirical and theoretical studies, giving it an abductive approach. Case studies are a strategy with similar characteristics and are intimately connected to system thinking. Data collection methods like interviews, observations, time studies and archive analysis provides researchers with both better in-depth understanding and also a possibility to triangulate the research. This makes the improvement suggestions more reliable and valid to Faiveley.

A central part of the research is the Lean philosophy and the importance to implement the whole concept of Lean and let it permeates the whole company. The authors also try to give more concrete suggestions on improvements, which together affect the whole "house of Lean". A special focus have been on Kaizen, continuous improvements, Heijunka, minimize irregularities, Kanban, pull system, and in general reducing the eight types of waste. Other theories and tools used, primarily to identify the waste, are time studies and Sequence-based Activity and Method of Analysis, SAM.

During interviews and through observations it was noted that the automatic storage units, ASUs, were bottlenecks. An analysis of the internal transactions showed that 20 percent of the k-articles accounted for 80 percent of the work. Improving the material flows for these 20 percent, by storing them in racks instead of the ASUs, much waste is saved. The solution is a so called Fast-Pick-Area, in which a warehouse worker is assigned the responsibility to replenish and maintain the area. To facilitate the work an article classification model was developed and suggested. This simple model can also be used in future Kaizen work.

Other suggestions presented, to Faiveley, are that they should start a standardization program for k-articles, along with reductions of rearranging orders in the production, to reduce waste, is part of the thesis together with an analysis of the potential introduction of a dedicated warehouse for the service department. The thesis is concluded with a list of bullet points with improvements that the authors recommend.

Key words: Material flow, Information flow, Fast-Pick-Area, Forward-Pick-Area, FPA, visualization, cost efficiency, availability, Lean, Kaizen, Heijunka, Kanban and waste reduction.

Sammanfattning

Faiveley gruppen är en internationell koncern, aktiv i 22 länder, och med sitt huvudkontoret i Frankrike. Dotterbolaget Faiveley Transport Nordic AB, Faiveley, är ansvariga för de nordiska och baltiska marknaderna och är även gruppens kompetenscenter för utveckling av BFC bromsar. Faiveley är för närvarande inne i en förändringsperiod, med fler olika effektiviserings projekt, där man bland annat har tagit hjälp av utomstående Lean-konsulter. Författarna valde att begränsa sig till materialflödet för så kallade köp-artiklar, k-artiklar, som inte är i behov av vidare förädling. Utifrån detta har författarna arbetat med forskningsfrågorna:

- Hur kan materialflödet och materialhanteringen förbättras, för att möta ökande krav på visualisering, kostnads effektivitet och tillgänglighet?
- Hur kan informationsflödet och arbetsrutinerna förbättras, för att möta ökande krav på visualisering, kostnads effektivitet och tillgänglighet?

Författarnas sätt att bedriva logistisk forskning är baserat på grunden att logistik hanterar verkliga problem i en komplex och ständigt föränderlig miljö. Forskningen bedrivs som en cyklisk process med både empiriska och teoretiska studier, vilket ger det en abduktiv ansats. Fallstudier är en strategi som har liknande egenskaper i samspelet mellan insamling av uppgifter och en abduktiv forskningsansats och är intimt kopplad till systemtänkande. Datainsamlingsmetoder som intervjuer, observationer, tidsstudier och analyser av arkiv ger forskare både bättre fördjupad förståelse och även chans att triangulera resultaten. Detta gör förbättringsförslagen mera tillförlitliga och giltiga för Faiveley.

En central del av arbetet är Lean filosofin och att det är av viktigt att hela konceptet implementeras och genomsyrar alla inom företaget. Författarna försöker ge konkreta förslag på förbättringar, som tillsammans påverkar hela ”Lean huset”. Det finns ett speciellt fokus på Kaizen, ständiga förbättringar, Heijunka, minimera oregelbundenheter, Kanban, pull-systemet, och att i allmänhet minska de åtta typerna av waste, slöseri. Andra teorier och verktyg som används, främst för att identifiera waste, är tidsstudier och Sekvensbaserade Aktivitets- och Metodanalys, SAM.

Genom intervjuer och observationer uppmärksammades att lagerautomaterna, ASUs, var flaskhalsar. En analys av plockfrekvensen visade att 20 procent av k-artiklarna stod för 80 procent av arbetet. Genom att förbättra flödet för dessa 20 procent, genom lagerhållning på vanliga hyllor istället för i lagarautomaterna, kan mycket waste reduceras. Lösningen kallas för Fast-Pick-Area, FPA, där en anställd tilldelas ansvar för att fylla på och underhålla området. För att underlätta arbetet togs även en klassificeringsmodell för k-artiklar fram. Denna enkla modell kan även användas i det framtida Kaizen arbetet.

Förslag som att Faiveley bör påbörja ett standardiseringsarbete för k-artiklar, och vikten av att minska order omflyttningar i produktionen, för att minska waste, är en del av arbetet. En annan är analysen av att eventuellt införa ett dedikerat lager för serviceavdelningen. Rapporten avslutas med en konkret punktlista över förbättringar författarna anser att Faiveley kan vara hjälpta av att genomföra.

Nyckelord: Materialflöde, Informationsflöde, Fast-Pick-Area, Forward-Pick-Area, FPA, visualisering, kostnads effektivitet, tillgänglighet, Lena, Kaizen, Heijunka, Kanban och waste reduction.

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1. Introduction

The introduction chapter will present the question formulation and background of the company. It will also clarify the focus, delimitations, purpose, target group and disposition of this master thesis.

1.1 Company presentation

The Faiveley Group is today present in 22 countries worldwide, with its head office in Saint-Denis (Paris), France. The global vision of the company is "To be the most innovative, reliable and cost effective partner for the global railway industry".[1] The aim of the company is to provide their customer with innovative products and "turnkey" solutions.[2] The Faiveley Group is present within several product categories such as:

- On-board electronic, surveilance.
- Electromechanical systems, pantographs.
- Platform screen doors.
- Passenger access systems.
- Braking systems.
- Couplers.
- Air conditioning.
- Customer service.

Theses product categories are spread over seven market segments; high speed trains, locomotives, passanger coaches, freight wagons, light rail viehicles (trams), metros and customer service.[3]

The company was founded in 1919 by Louis Faiveley in Saint-Ouen and the first product was the pantograph. A subsidiary was founded in Madrid, Spain in 1966. 1994, Faiveley SA was introduced to the Paris stock exchange for medium-sized companies. In 2004 Faiveley Transport acquires SAB Wabco, with the Landskrona site included in the deal.

1.1.1 Faiveley Transport Nordic AB

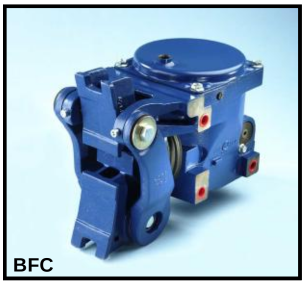
Faiveley Transport Nordic AB, called Faiveley, is situated in Landskrona and has 130 employees. Last year the site had revenue of about 275 million SEK and managed to show a 13% sales growth. Faiveley is the market and service centre for the Nordic and Baltic countries. It is also the center of competence for tread brakes and slack adjusters within the group.[4] Faiveley Transport has an order fulfillment strategy that can best be described as a Make-to-order (MTO) or Built-to-order (BTO) strategy. Products are highly customized and sold in small volumes. The individual product usually contains a wide variety of different articles, where some of the simpler, low value products are ordered with a Make-to-Stock (MTS) or Build-to-Forecast (BTF) strategy. Faiveley are certified according to ISO 9001:2008 which is an international standard for quality management systems.

[1] Faiveley internal information, (2010-11-01)
[2] http://www.faiveley.fr/uk/accueil.php, (2011-01-27)
[3] Faiveley internal information, (2010-11-01)
[4] Ibid

They also work according to the Faiveley Management System, FMS, which is a set of requirements from the Faiveley group headquarters in France.

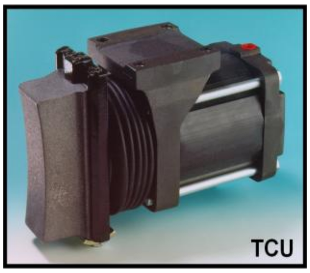
All articles, items and components have so called article numbers and will be referred to as articles until they reach the state where they are finished products. Some of the products in Faiveley's product portfolio are:

- Brake Friction Concept (BFC), their main product. Today it accounts for about 85% of the total turnover at the Landskrona site. The BFC was developed in 1974 and mass production started in 1978. The basic function of the BFC is that compressed air is pressed down on a piston, with wedge shaped edges, which in turn transfers the vertical movement into a horizontal force that presses brake blocks against for example the wheels of the rail car or a disc that slows the railway car down. The BFC can be mounted in different ways and together with link arms one BFC unit can brake several wheels. The BFC unit can also be fitted with a parking brake.[5]



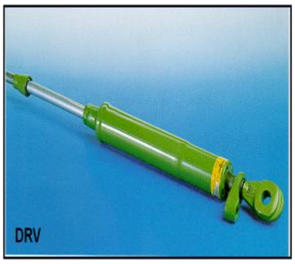
Picture 1: BFC unit

- Thread conditioning unit (TCU), is used to clear the brake surface of a railway engine or car wheel of any dirt. This will improve the achievable brake power, increase the grip between the wheel and rail as well as minimize the ware and tare of both the brake blocks and the car wheel.[6]



Picture 2: TCU unit

- DRV Slack Adjuster (DRV), automatically adjusts the slack between the brake blocks and the wheel. The DRV was invented in 1913 and the total number of delivered units has today reached more than 2 million units.[7]



Picture 3: DRV unit

[5] http://www.faiveley.com/uk/produit.php?ID=34 , (2011-01-27)
[6] Faiveley internal information, (2010-11-01)
[7] http://www.faiveley.com/uk/produit.php?ID=35 , (2011-01-27)

1.2 Faiveley's vision and current projects

Faiveley is at the moment involved in several small and medium sized projects to increase their productivity and efficiency.

New Enterprise resource planning system

Faiveley uses the Enterprise Resource Planning system, ERP system, Movex, version 12.4, and has had this system for seven years. It has been decided, by site management, to upgrade to a new modern Movex M3. The new system will have a modern interface and not be based on console commands. The system upgrade is planned to start at the beginning of 2012 and is expected to take about a year to implement.

Lean project

In January of 2011 Faiveley started a big Lean project, with the aim to increase the sites overall production output. Faiveley took help from a consultant company, called "Produktionslyftet". They have educated the staff, held seminars and workshops about the Lean concept. The project involves the whole site and is planned to continue for a total of 18 months.

Product development

The original BFC designs were first developed in 1974 and since then there has been two major upgrades. Presently generation three of the BFC is being manufactured. The Landskrona site is the world competence center for the BFC units and has been tasked with developing the fourth generation of BFC units. One of the targets is that it should be produced at a 20% lower cost than its predecessors.

Future business

Faiveley both produce new equipment and provide services on their customers old BFC units. Previously sales of new equipment was the most important goal of the company. But a new decision from management, states that Faiveley should try to grow by increasing their service department. A goal has been set for the sales department to tie more of the future service of sold BFC units directly to Faiveley, through service contracts. The long term goal for the Landskrona site is to develop their service department to be able to perform service on the whole range of the Faiveley Group's products.

Management is convinced that this will lead to higher demand and a wider assortment of different articles. The development of the new generation of BFC units is also believed to increase the assortment of articles.

Separated warehouses for production and service (L002)

Problems have been brought to the surface concerning that articles, planned to be used in assembly of new equipment, are claimed by the service department, which where the planning horizon is shorter. A suggestion on how to deal with this problem is to either purchase a new automatic storage unit, ASU, or to divide the existing warehouse into two separate sections. Any transfer between these sections has to be sanctioned by the right authority. The new section would be called L002 following the existing section L001.

1.3 Purpose

The purpose of the master thesis is to provide Faiveley with suggestions on how to improve their supply chain to the assembly stations of their BFC products. This thesis will be a part of a bigger improvement process at Faiveley. Key words in this master thesis are visualization, cost efficiency and availability.

Visualizations, cost efficiency and availability improvements of the BFC assembly need to take into consideration the effect on the whole supply chain. The supply chain includes the material and information flow from a supplier all the way to the assembly stations.

1.4 Question formulation

This master thesis will answer the following two research questions:

- How can the material flow and material handling be improved to meet higher demands on visualizations, cost efficiency and availability?
- How can the information flow and work routines in the supply chain be improved to meet higher demands on visualizations, cost efficiency and availability?

1.5 Focus and Delimitations

The focus of this master thesis will be the supply of materials to the assembly stations for the BFC, a product assembled in great volumes. This thesis will be delimited to the supply chain of the BFC. The supply chain, included in this master thesis, starts at the suppliers and ends at the BFC assembly stations. The materials in focus of this master thesis are products that need no further refinement or processing, this excludes the production process at Faiveley. The assembly and handling of finished products is not included in this project. The delimitation is chosen to ensure that measurements and suggested solutions are reasonable and possible to implement.

1.6 Target Group

The target group for this master thesis is first of all the supply chain manager and warehouse manager at Faiveley. But the master thesis is also meant to be read by engineering students, teachers, professors at Lund University, Faculty of Engineering, within the Division of Engineering Logistics along with other knowledgeable individuals, with interests, within the field of supply chain management and manufacturing logistics.

1.7 Terminology

ASU: Automatic Storage Unit is a storage machine which retrieves articles automatically with help of a computer.

BFC: Brake Friction Concept is a brake for trains and is the main product at the Faiveley Landskrona site.

Bullwhip effect: An observed phenomenon in forecast-driven distribution channels. The oscillating demand expands upstream in a supply chain and can be compared to a cracking whip.

Cripples: Are assembled units that are only 99 percent finished because of missing parts or articles.

Economy of scale: Increased scale of output due to different factors that causes the average cost per unit to fall. These cost advantages are often linked to expansions of a business.

ERP: Enterprise Resource Planning system contains and handles the internal and external information (in Faiveley's case this system is Movex).

FMS: Faiveley Management System is a set of requirements from Faiveley headquarters in France. The statements incorporate elements of ISO 9000 and Lean. Each statement can be fulfilled to 0, 30, 60 and 100 percent. Faiveley are audited according to FMS every year by Faiveley headquarters.

FPA: Fast Pick Area or a Forward Pick Area is a location in a company that is dedicated to make fast moving article easy available and make order-picking faster and more convenient

Golden zone: The recommended area of repetitive work, between the knee and the shoulder.

SAM: The Sequense-based Activity and Method analysis is a further development of the Mehtod-Time-Measurement system. SAM calculates theoretical times for a series of movements.

Takt time: Originally a German word for rhythm or measure, based on customer demand. Takt-driven production refers to the time that must elapse between two successive unit completions in order to meet the demand

WMS: Warehouse management system has the primary function to keep track of and control the flow of material. It can be a separate system or a part of the ERP system.

1.8 Thesis disposition

The thesis disposition provides the reader with a forehand insight to the structure and disposition of the master thesis.

Research methodology

The research methodology chapter discusses research methodology that is of interest to this master thesis. Here different research paradigms, approaches, strategies and data collecting methods will be presented. At the end of the chapter the authors will present which research methodology that have been used for this master thesis and also discuss the validity and reliability.

Theoretical framework

The theoretical framework consists of a wide variety of collected information that has built and supported the different analysis made in this thesis. This chapter starts with a general explanatory introduction to *why* the different theories have been chosen for this thesis. A big part of the chapter focuses on the overall concept of the Lean philosophy. Along the way there are summaries that will provide the reader with a more detailed insight to *how* each theory is applicable for Faiveley.

Empirical framework

The collected empirical information that forms the foundation of this chapter is based on semi-structured interviews with Faiveley management, middle-management and factory workers. Factory workers refer to the individuals working at the arrival station, in the warehouse and at the assembly stations. Except for the interviews, information was also collected through observations and informal talks and discussions. Some of the empirical data is based on measurements, time studies, and processed raw data from the internal Faiveley enterprise resource planning system, Movex.

Analysis

The analysis chapter contains the analytical work, based on the theories and empiric material, which was collected and included in previous chapters. The analysis will especially take a Lean perspective, both in theory and practice. The analysis is divided into five main areas of interest: Classification, Standardization, Waste reduction, L002 and Lean management.

Conclusions

In the conclusion chapter the authors makes a short discussion concerning the validity and reliability of the master thesis and also the connections to the research questions. The conclusion chapter sums up the authors' thoughts and ideas for the master thesis.

Recommendations

In the recommendation chapter all the thoughts, ideas and suggestions for improvements are summed up and presented in bullet points.

Future research

The future research chapter will handle topics that were either outside the scope of this thesis, were considered too comprehensive to include or to fit within the time constraints.

2. Research methodology

The research methodology chapter discusses research methodology that is of interest to this master thesis. Here different research paradigms, approaches, strategies and data collecting methods will be presented. At the end of the chapter the authors will present which research methodology that have been used for this master thesis and also discuss the validity and reliability.

2.1 Research paradigm

The research paradigm defines how the researcher views the world. A specific problem will be viewed differently by two researchers using different research paradigms and also, most likely, will their perception of what is important differ.

2.1.1 Positivism

Positivism is a scientific research tradition. According to positivism, for a result to be valid, it has to be able to be proven empirically. This is called the rule of verifiability. Central to positivism is that research shall be built from empirical findings and measurements and disregard the feelings and values of the researcher. The purpose of positivistic research is to present explanations in the form of cause and effect, problems are reduced to smaller constituents that affect the wholeness and all knowledge can be presented in forms of rules and laws. The researcher should be objective to the problem and not let it be affected by his or hers own values.[8]

2.1.2 Systems theory

System theory, unlike positivism, sees to the whole of the problem instead of its constituents. In system theory it is important to make sure that the studied system is well delimited and defined. System theory looks to the interaction between the different parts of the system which may result in positive synergy effects. Measurability and comparability is important in system theory. Systems can for example be found at different levels like groups, companies, and departments and so on.[9]

2.2 Research approach

A research approach is a way for the researcher to conduct his study. There are several different research approaches. Depending on which approach is chosen for the research project the view on empirical data and theory may differ.[10]

2.2.1 Inductive approach

With an inductive research approach the researcher observes the phenomenon and data is collected without any preconception. From the collected data the researcher tries to generalize the observations into theories.[11] Since the data and observations should be collected without any

[8] Wallén, (1996)
[9] Ibid
[10] Ibid
[11] Ibid

preconceptions there is no real need for a literature study.[12] It can be described as a "bottom-up" approach.[13]

2.2.2 Deductive approach

In the deductive research approach a thorough literature review is conducted. From this review along with logical reasoning new hypotheses and propositions are constructed. Then these hypotheses and propositions are tested against empirical data with the intent of either approving or discard them.[14] The deductive approach leads to theories based on previously generalized theories which in turn lead to problems when new hypotheses are to be compared to empirical data.[15] It can be seen as a "top-down" approach.[16]

2.2.3 Abductive approach

The abductive approach has a pattern that is neither strictly inductive nor deductive. It is a research methodology that has a history of great achievements, stretching all the way from today's modern logistics research, back to Aristotle.[17] When observing a research objective, abductive research makes it possible to draw conclusions about what the cause is and what the underlying reasons are.[18] By examining new perspectives, new insight about existing phenomena can be achieved by taking an abductive approach. Usually the abductive approach starts out with a real-life observation which is the same starting point as the inductive approach but this cannot be said for all abductive research since a researcher often starts out with some theoretical knowledge (see Figure 1**Error! Reference source not found.**). In abductive reasoning data collection and theory development, and furthermore the interaction between theoretical studies and empirical studies has similarities with methods like action research and case studies. [19]

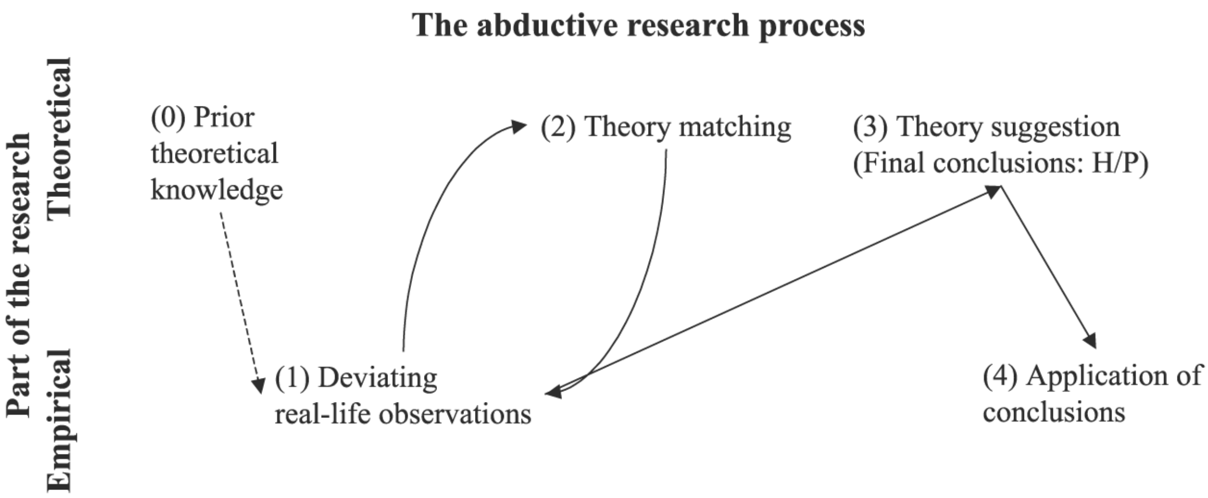


Figure 1: The abductive research approach[20]

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[12] Kovács, G. *et al*, (2005)
[13] Trochim W.M.K, (1999)
[14] Kovács, G. *et al*, (2005)
[15] Wallén, (1996)
[16] Trochim W.M.K, (1999)
[17] Kovács, G. *et al*, (2005)
[18] Wallén, (1996)
[19] Kovács, G. *et al*, (2005) and Wallén, (1996)
[20] Kovács, G. *et al*, (2005)

2.3 Research Strategies

There are several different research strategies for a researcher to choose from when conducting a research project. Listed below are three strategies that are interesting for this master thesis.

2.3.1 Qualitative and Quantitative research

The objective of qualitative research is to investigate characteristics and behaviors. Interpretations from observations in a theoretical context, piecing together fragments to get a holistic view and understanding vague and complex situations are some reasons for using qualitative research.[21] The quantitative research objective is to measure and analyze statistics. Large-scale studies with statistical reliable results, a more specific focus with a predetermined research design are some reasons for using quantitative research.[22]

A tendency of emphasizing pictures and words as the essential unit of analysis is often connected to qualitative research, while quantitative research has a tendency to emphasize numbers.[23] A simplistic view of a qualitative research is that it is more "subjective" while e.g. a quantitative research is more "objective".[24] Some questions that encounter the researcher should be handled through qualitative research and some by quantitative research and sometimes a combination of both.[25]

2.3.2 Action research

The main characteristics of action research are the effect of change at the same time as the research is conducted.[26] Action research is a cyclical process that reconnects research to practice.[27] Identified problems, improvements and results from action research go through critical reflection by the participants and lies as a foundation for further research.[28] The researcher is not collecting data and testing theory at separate occasions, the participation in the process is the actual research.[29] By spending time gathering first-hand information and understanding of the interrelationship in the organization, a researcher can gain advances in both practice and in theory. This makes action research intimately connected to system thinking.[30]

2.3.3 Case Studies

A common qualitative research strategy is case studies. Case studies are an in-depth study, ranging from a single instance to multiple instances of a phenomenon.[31] Case studies are most common in social science and usually focus on a single instance of a phenomenon, which is basically the opposite of quantitative researches like surveys.[32] The in-depth analysis of complex processes makes it possible for the researcher to understand all the different parts of the process and *how* they interact, instead of focusing on particular details and outcomes. From the analysis the researcher get

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[21] Wallén, (1996)
[22] Denscombe, M (2009)
[23] Ibid
[24] Näslund, D. (2002) and Denscombe, M. (2009)
[25] Ibid
[26] Checkland, P. (1981), Denscombe, M. (2009) and Wallén, (1996)
[27] Checkland, P. (1981)
[28] Denscombe, M. (2009)
[29] Wallén, (1996)
[30] Näslund, D. (2002)
[31] Hyde, (2000)
[32] Denscombe, M. (2009)

a fundamental understanding of the relationships and *why* results in a process are achieved, instead of *what* results are achieved, which makes it a holistic strategy. The "case" is a real-life study and encourages the researcher to use multiple methods like observations in combination of official interviews.[33] Many of these characteristic can also be found in Action research, the difference lies in that the researcher does not necessarily effect direct change at the same time as the research is conducted.[34]

2.3.4 Survey

The aim with a survey is to do research with a broad coverage. The survey is often used to take a snap shot of a situation or a problem and it is usually oriented on getting quantitative data.[35] The time and cost of performing a survey can often be calculated on beforehand and with the use of internet the time needed for distribution and collection can almost be eliminated. A big drawback with surveys is that it can be hard to get sincere and precise answers from the respondents. [36]

2.4 Data collection methods

There are several different ways for a researcher to collect data. Listed below are several ways that are of importance for this master thesis.

2.4.1 Qualitative and Quantitative data

Collected data can be categorized into being either Qualitative or Quantitative.

Qualitative data is consists of words and descriptions, that makes it rich in detail, but hard to analyze with statistical methods. Instead the data needs to be categorized and sorted before any real analysis can be made.[37]

Quantitative data consists of numbers and can be obtained from many different research methods. Experiments and surveys are some of the more common research methods used to obtain quantitative data but are not the crucial factor. The quantitative data does not reflect the method that is used; the important thing is what kind of data the method produce.[38] The strength of qualitative data is translating theoretical concepts into research operations[39]

2.4.2 Observations

When a researcher uses observation, as a method to gather information, he or she gets a direct view of the problem. Observing what is really happening instead of trusting the word of an interviewee can be advantageous. [40] When observing a phenomenon it is important to know, on beforehand, what to observe and why the observation will present satisfactory results.[41] In observations the researcher performs field studies, observing phenomenon's in their real natural environments. The

[33] Denscombe, M. (2009)
[34] Wallén, (1996)
[35] Denscombe, M. (2009)
[36] Ibid
[37] Höst *et al*, (2006)
[38] Denscombe, M. (2009)
[39] Glaser, B.G. *et al*, (2009)
[40] Denscombe, M. (2009)
[41] Bell, (2006)

phenomenon would occur even if the researcher were not observing it. It is therefore important that the researcher not disturbs the phenomenon.[42]

A potential problem with observations is that two researcher observing the same phenomenon might not come to the same conclusion about what happened. What one researcher perceive and what he or she remember can differ, depending on his or hers physical and emotional state. Habits and earlier experiences also affect the researcher.[43]

Participant observation is one method for the researcher to observe a phenomenon. Here the researcher takes part in the situation and asks questions trying to understand the phenomenon.[44]

Systematic observation is a way that researchers try to observe the same phenomenon by using an observation schedule. With the observation schedule the data gets registered systematic and thorough and it helps different researchers to observe the same parameters and activities of the phenomenon. [45]

2.4.3 Interviews

An interview is a systematic questioning of an individual regarding a specific topic or problem. The answers are usually written down or recorded for later analysis. Interviews can also be conducted through a telephone or e-mail conversation. [46] When conducting an interview it is important that the interviewee is aware of it and that he or she gives his or hers consent so that the interview is on record for research purpose.[47] The interviewee can request to be anonymous if the interview concern sensitive information. In an interview the researcher controls the conversation depending on what type of interview is conducted the result may differ.[48] Generally interviews take a lot of time to conduct and analyze.[49] There are three types of interviews.

In a Structured interview the researcher have a very strict set of questions with predefined answers. This gives the advantage of standardized answers, which is easier to analyze with computers. The structured interview has more in common with the survey than with the other types of interviews.[50]

During a semi structured interview, the researcher still has predefined questions, but the order of which the interviewee answers them is not rigid or predetermined. The researcher’s primary focus is to let the interviewee answer the questions on a deeper level and concentrate on the details.[51]

An unstructured interview is ever more lenient than the semi structured interview when it comes to the questions and the interviewee’s answers. The researcher tries to intervene as little as possible

[42] Denscombe, M. (2009)
[43] Ibid
[44] Bell, (2006)
[45] Denscombe, M. (2009)
[46] Höst *et al*, (2006)
[47] Bell, (2006)
[48] Denscombe, M. (2009)
[49] Bell, (2006)
[50] Denscombe, M. (2009)
[51] Ibid

during the interview, only introducing a theme or a subject in the beginning and then lets the interviewee use his or hers own words in continuing their train of thought.[52]

During interviews notes and electronic recording equipment can be used to ensure that facts and information can be traced back and recapped at the source if needed.

2.4.4 Archive analysis

In an archive analysis the researcher goes through documentation, reports and other materials collecting data that have been archived by the company. In this way, a researcher can study the development of a company for a certain time period. The data can be both electronic and conventional and of qualitative and quantitative form. [53]

2.5 Validation and Reliability

If research data and the method of obtaining research data can be defined as valid it has to be correct and accurate. Validation is about collecting research data and covering vital questions that reflects reality. If research data and the method of obtaining research data can be defined as reliable it has to consistent. Reliability is about collection research data that reflects variations of the research objective and not the variations of the method that is used to obtain it.[54]

A popular metaphor when describing the relationship between reliability and validity is the “target” (see Figure 2). Imagine a group of people is being measured and each measure of a concept represents one hit each at the target. Each hit in the center of the target represent a correct measure of the concept. If the target is hit consistently in a collected pattern but of center of the target, the measure is reliable but not valid. In other words, consistently the wrong thing is measured. If the target is hit in a random pattern over the whole target with only a few hits in the center, the average of all hits gives the correct measure of the concept. Still, each individual hit is usually wrong and inconsistent, which implies that the measures are valid but not reliable. A pattern where all hits misses the center and is still scattered over the target, the measures are neither valid nor reliable. The preferable scenario is where all hits are consequently hitting the center of the target in a collective pattern. This represents measures that are both valid and reliable.[55]

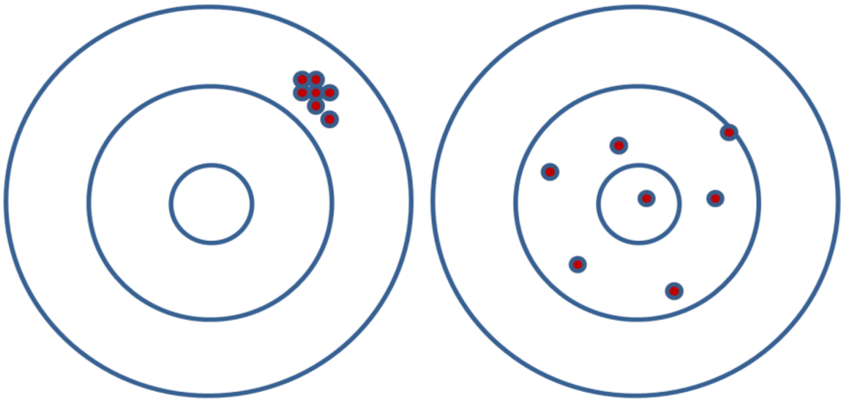

Figure 2: The Target metaphor

[52] Denscombe, M. (2009)
[53] Höst *et al*, (2006)
[54] Denscombe, M. (2009)
[55] Trochim W.M.K. (1999)

2.5.1 Triangulation

While conducting research, triangulation can be used to improve both validation and reliability. A better knowledge and understanding about the research objective can be achieved by observing it from different perspectives. The accuracy and authenticity can be improved by using different research methods that complement and validates the research findings. Triangulation can also provide complementing data and sources that provide a more comprehensive version of the research objective. [56] The use of triangulation may consist of different sources of data, different research methods and even different researchers. Methodological triangulation usually brakes down to the use of qualitative and quantitative research models. Using two distinctly different methods can provide the researcher with something new that confirms or dispute existing findings.[57] The objective is always to utilize the assets of each method opposed to aggravate the liabilities.[58]

2.6 Research Methodology used in this thesis

The authors' way of conducting logistical research, for this master thesis, is based on the foundation that logistics handles real-life problems in a complex and constantly changing environment. A key issue in logistics is to understand the synergy effects and develop improvements that take them into consideration. This thesis is not exclusively built on empirical findings and measured results, which makes the System theory paradigm more applicable than the Positivistic paradigm. The authors' ingoing knowledge and experience in logistics is a starting point that affects the course of the research, since some theories and methods for problem solving easier comes to mind than others. From this starting point the research is conducted as a cyclical process with both empirical and theoretical studies, which resembles an abductive approach. The cyclical way of working is not compatible with deductive and inductive approaches and is therefore excluded. Case studies are a strategy that has similar characteristics in the interaction between data collection and theory development as the abductive research approach and is intimately connected to system thinking.

Many problems that can be found in an organization have a mixture of attributes that are both quantitative and qualitative[59]. Qualitative and quantitative research is not mutually exclusive and case studies encourage the researcher to use multiple data collection methods. Some questions that the researcher will encounter should be handled through qualitative research, some by quantitative research and sometimes a combination of both. Case studies have more qualitative elements but it is necessary to use both quantitative and qualitative research to develop and advance the field of modern logistics. Action research has been excluded, because it requires an ongoing interaction and involvement in changes made throughout the research project. Qualitative research is an important contribution to quantitative research, which historically has dominated logistic research.[60] Methods used by the authors, like interviews, observations, time studies and data collection provides researchers with both better in-depth understanding and also triangulates the research objective. This makes the improvement suggestions more reliable and valid to Faiveley.

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[56] Denscombe, M. (2009)
[57] Ibid
[58] Jick T.D. (1979)
[59] Checkland, P. (1981)
[60] Näslund, D. (2002)

3. Theoretical framework

The theoretical framework consists of a wide variety of collected information that has built and supported the different analysis made in this thesis. This chapter starts with a general explanatory introduction to *why* the different theories have been chosen for this thesis. A big part of the chapter focuses on the overall concept of the Lean philosophy. Along the way there are summaries that will provide the reader with a more detailed insight to *how* each theory is applicable for Faiveley.

Theory introduction

Early on in the work on this thesis the authors drew flow charts, process maps and realized that a lot of the improvement suggestions were based on minimizing waste. The improvement suggestions were developed with the main goal in mind, which is increasing visualization, better cost efficiency and a higher availability of articles for the assembly stations at Faiveley. The theory most closely linked with waste minimization is Lean and the Toyota production system, so this became a key part of the work. During the abductive research, more and more problems and improvements connected to the material flows, information flows and work routines could be identified and solved by applying the wide concept of Lean. Some underlying Lean-theories and tools were identified to have more improvement possibilities than others and are now described in more detail.

For validation and reliability purposes some Lean-theories was complemented with other theories. Classification and Standardization was originally included to understand Faiveley as a company and as an explanatory section of the analysis. During the thesis work these theories became both independent improvements and parts of some of the other improvement suggestions. Lean is touching these subjects as well, but was found inadequate or not detailed enough.

Lean also emphasis the importance of cooperating with and challenging suppliers, which is the foundation for theories regarding supplier relations. On the other hand, there a no specific suggestions on how these relationships can be improved.

3.1 Purchasing portfolio analysis

Suppliers represent different interests to a company and the strategy towards the supplier markets needs to be developed accordingly. The effect on the bottom line to the company depends on the volume or amount of money that is involved.

The interest of the company can be divided in four different product groups.

- Strategic products, which usually are high-tech and high volume products that often are supplied according to customer specifications. These products often stand for a high share of the end products cost.
- Leverage products most distinctive characteristic is, that a small change in prices often results in big changes in the final products end costs.
- Bottleneck products often has few, dominating suppliers which usually results in high end product costs.
- Routine products usually have a small value per item and there are many available suppliers to choose from. The problem with this group of products is often that 80 percent of the handling and purchasing time is used for these products. That is why, it is recommended to

use a purchasing strategy that aims to reduce the logistic complexity, efficiently organize these products, and to reduce the number of suppliers to save administrative time and keep the handling costs down.[61]

3.1.1 Paretos law

Pareto's law, also known as the 20/80 rule, was discovered by Vilfredo Pareto. It was first used in a quality context by Dr. Joseph Juran, whom made the observation of the "vital few and trivial many", 20 percent of the tasks are always responsible for 80 percent of the results. Arjan Van Wheele has later expressed the 20/80 rule in a purchasing context, that 20 percent of the suppliers and products will represent 80 percent of the purchasing turnover. Also 20 percent of the small expense items, from small suppliers, stand for 80 percent of the internal handling costs.[62]

Summary

A company that does not identify the different product groups and adapt their strategy accordingly will often focus time and efforts on the strategic products, due to the fact that they stand for a high share of the end product costs. Routine products, with their low unit costs, are often neglected. Small reductions of the administrative and logistic complexity of routine products will affect large sums of the internal and external handling. Some companies have achieved this through reduction of the number of suppliers, electronic aids and standardization of product assortments.

3.2 Lean

Lean operations were developed by the Japanese automobile manufacturer Toyota and many of the common methods and terms in Lean were developed as part of the Toyota Production System (TPS).[63] Lean or Lean Productions focuses on creating value for the customer by minimizing any kind of waste in an organization.[64]

Four Rules that underlies the Toyota Production System are: [65]

- *Rule 1* - Highly specified work as to content, timing, sequence and outcome.
- *Rule 2* - All customer-supplier connection has to be direct. There has to be a distinct yes-or-no way to receive responses and send requests.
- *Rule 3* - Simple and direct pathways for all products and services.
- *Rule 4* - All improvements have to be made according to scientific methods at the lowest possible level in the organization under supervision of a sensei/leader.

When work is not specified one gets variations in the organization. The variations hide the link between the work that is conducted and its results, which hinders the organization from improving and learning. This translates to lower productivity, poorer quality and higher costs.[66]

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[61] Van Weele, A.J. (2005)
[62] Ibid
[63] Stevenson, W.J. (2007)
[64] Bergman, B. *et al*. (2007)
[65] Spear, S.J. *et al*. (1999)
[66] Ibid

Fujio Cho, the current Chairman and Representative Director at Toyota Motor Corporation[67] originally created a model to describe TPS to Toyotas supplier. This model is today known as the TPS-house or the House of Lean.[68] (see Figure 3).

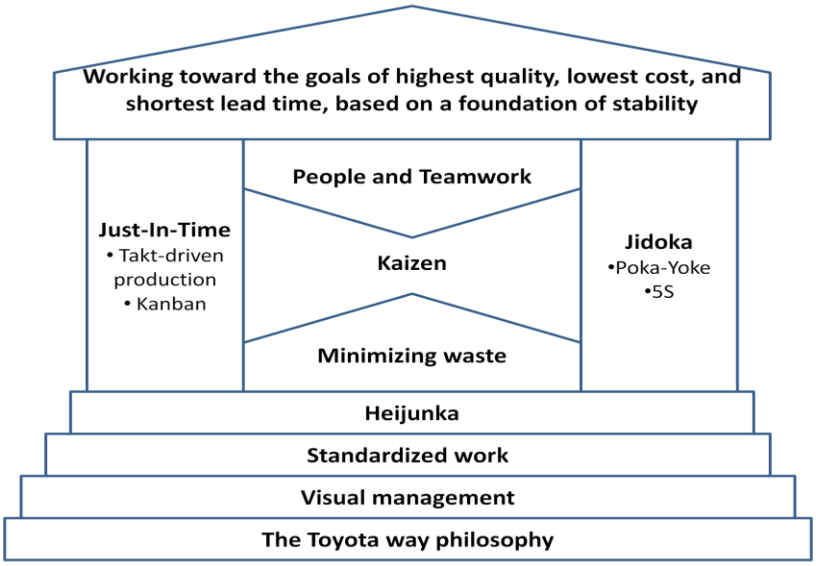

Figure 3: The House of Lean

- The foundation is about stability, customer satisfaction and The Toyota way philosophy. An important part of the foundation is Heijunka which will be described in depth later in this chapter.[69]

- One of the pillars or walls is Jidoka which is a system for continuous quality control at the source. [70] A problem needs to be visualized and solved at the source.[71] Some underlying tools are Poka-Yoke which are inbuilt safeguards in the process to remove the possibility of errors.[72] Another common Lean tool is the 5S which are seiri/sorting, seiton/structure, seiso/cleaning, seiketsu/standardizing and shitsuke/self-discipline.[73]

- The other pillar or wall is Just-in-time, JIT, is simply about getting the right amount of articles to the right place at the right time.[74] It is a system where the ideal lot size is one, the material flow is leveled and fast. Waste, inventory levels, space and transactions are kept to a minimum.[75] Takt is originally a German word for rhythm or measure, based on customer demand.[76] Takt-driven production refers to the time that must elapse between two successive unit completions in order to meet the demand.[77] Customers are usually unaware

67 http://www.toyota-global.com/company/profile/executives/, (2011-02-08)
68 Liker, J.K. (2009)
69 Ibid
70 Stevenson, W.J. (2007)
71 Liker, J.K. (2009)
72 Stevenson, W.J. (2007)
73 Liker, J.K (2009)
74 Ibid
75 Stevenson, W.J. (2007)
76 Liker, J.K (2004)
77 Baudin, M. (2002)

of their suppliers' takt time. Suppliers, on the other hand, know precisely what their customer's takt time is.[78] Producing to takt time affects the customer indirectly by reducing costs while increasing quality and delivery performance. Deviation from takt-driven production adds costs in forms of waste. It also lengthening the production lead times and by that delays the detections of defects.[79] Kanban is an underlying tool of JIT that will be described in more detail later in this chapter.

$$Takt\ time = \frac{Net\ time\ available\ to\ work}{Produced\ articles}$$

- The roof symbolizes the Lean goal, which is: Working toward the goals of highest quality, lowest costs, and shortest lead time, based on a foundation of stability.[80]

- The last part of this house is the centre of the house which consists of the people and teamwork. It is important to have the right people, who are working towards common mutual goals and has knowledge about solving problems. Constant improvement or Kaizen is one important underlying tool which will be described in more detail, later in this chapter.

The center of the house also consists of minimizing waste.[81]Waste or Muda is an activity that does not create any value for the customer and is a cornerstone in Lean operations. [82] There are original seven types of waste where Jeffrey K. Liker has added an eighth:[83] [84]

1. *Over production waste*, products that does not reach the customers, is a sign of overcapacity and failure of management creating useful tasks. The products will in the end have a lot of inbuilt waste in the form of unnecessary handling and transport.

2. *Waiting waste,* because of shortages of parts, long machine cycles or lack of tools can be a result of bottlenecks, low availability of materials but also failure of management balancing the workload.

3. *Transportation waste* or movement waste occurs every time material transports require an intervention by the materials department, like calling for a forklift (no matter if it is 50 or 500 feet).

4. *Process waste,* like unnecessary assembly steps, wrong sequence of steps or inconvenient working habits are some common examples. Waste can also accumulate, when products have a bad product design or are developed with a higher quality than what is necessary.

5. *Excess inventory waste,* are usually a result of overproduction or because of material management pushing parts on to the production organization. If there is no explanation for a parts presence on the shop floor it is most likely excess inventory. Cripples are assembled

[78] Baudin, M. (2002)
[79] Ibid
[80] Liker, J.K (2009)
[81] Ibid
[82] Stevenson, W.J. (2007)
[83] Baudin, M. (2002) and Bergman, B. (2007)
[84] Liker, J.K (2009)

units that are only 99 percent finished because of missing parts or articles (often due to unreliable supply chain). This inflates work-in-process and requires repair operations with more work and greater risk off error in a later stage.

6. *Motion waste*, is all sorts of unnecessary operations. Parts that are located at an inconvenient picking place, searching for parts and picking up the same part multiple times before usage are examples of motion waste.

7. *Production defects wastes,* like errors in picking or labeling, are the most common form of defects. Repairing mistakes, dismantlement or actual disposal of products is also waste caused by product defects.

8. *Unused creativity among employees* by not engaging and listening, a company are wasting time, competence, creativity, ideas and opportunities to improve and learn.

When asked why delays and problems occur, the most common answer given is: "If only we had all the parts we need, we could assemble all we need to do without any problems…".[85]

There is a risk of constantly striving for the optimal use of technology, but this should be done with caution. Investing in atomization to reduce cost in personnel can be a bad idea because there is no more flexible resource than a human being.[86]

A reason why Lean has had a low impact effect on some companies is because the focus has been on the tools like Just-in-time and 5S and not at the whole system of Lean. The holistic view on Lean is important and it has to permeate the whole organization to have a real effect. While implementing Lean, it is also important to remember, that 80 percent is trying and only 20 percent is education.[87]

Summary

TPS and Lean should not be seen as isolated rules, tools and approaches. It is interacting systems that requires a holistic view. The House of Lean or TPS house is more than a summary, it is a metaphor. A strong house needs a strong foundation, walls/pillars and roof. The centre of the house is the people that constantly are working with minimizing waste, through constant improvements. Although the centre of the house is as important as the rest, it is the most commonly ignored part.[88]

Faiveley's way of working and the new found desire to improve, have a lot of Lean elements. Faiveley's House of Lean, on the other hand, is defective, both the structure and the centre of the house needs to be defined and made stronger. That said, Faiveley is not a high volume car manufacturing company like Toyota and that is why they should not copy them, instead they should use the principals and create their own stable House of Lean.

3.2.1 Heijunka

The philosophy behind Heijunka is to level production. It is an important part of Lean that should be implemented in the company before popular waste minimization efforts like lowering stock levels or

[85] Baudin, M. (2002)
[86] Liker, J.K. (2009)
[87] Ibid
[88] Liker, J.K. (2004)

implementing 5S.[89] The eight types of waste (see Figure 4) or Muda are only one, out of three important parts to make the whole system of Lean work. Muri refers to work overload of people or machines.[90] Work overload can be caused by trying to compensate peaks in demand by pushing personnel and machines above an unnatural level, which often results in a decrease in quality and increase in downtime. The third part of the Lean system is irregularity or Mura, which refers to the peaks and valleys in demand. These irregularities or variations can be caused by fluctuation production volumes or customer demands, which in its turn can be created by internal problems or defects. Both irregularities and the workload need to be leveled because variations lead to waste. [91] [92]

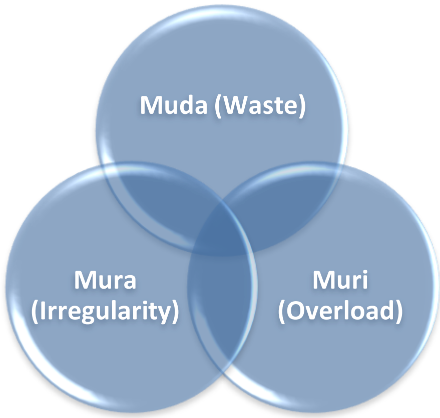

Figure 4: Three M's of Heijunka

Summary

Having a completely customer driven production, identifying and minimizing waste by reducing storage and personnel can result in a system that runs its self to the ground. A fluctuating demand can result in inefficient use of personnel and machines. The flow of articles can be irregular and create material shortages. Heijunka does not support an increase in waste, on the contrary; by leveling the demand, minimize irregularities, stability can be reach which is the foundation of Lean and waste reduction. [93] Because of Faiveley's wide variety and relatively low amount of articles, many of Toyotas methods and concepts are difficult to implement.

3.2.2 Kanban

The Kanban system is a pull system, instead of the regular push system, of products and articles. A Kanban is a signal, which is sent to a previous step or activity in the supply chain, when a demand occurs. An example of a Kanban is a card or an empty carrier with the necessary information. This pull continues cascading backwards in the supply chain. The goal is to eliminate waste that usually is related to the push system and its big batch system. This is a crucial part of the JIT pillar (see above). [94]

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[89] Liker, J.K. (2009)
[90] Ibid
[91] Ibid
[92] Stevenson, W.J. (2007)
[93] Liker, J.K. (2009)
[94] Ibid

The number of Kanban can be calculated as follows: [95]

$$y = \frac{DL(1+\alpha)}{a}$$

y= number of Kanban
D=demand/unit of time
L = Lead time, including inspection of Kanban
α= safety margin (policy variable)
a= number of units/carriers

An ideal kanban flow has a level production where the irregularities do not exceed the average demand with more than 30 percent. The products should be standardized since every article creates a new kanban flow. The delivery reliability from the suppliers is high and with short lead times. Under these conditions the kanban flow will be easy to manage, inexpensive and efficient with a high availability of the articles. A kanban flow should be avoided for articles that are bulky and/or expensive.[96]

Summary

Implementing Kanban at Faiveley needs to be done in the right way. If the carrier is the Kanban signal and the calculated number of Kanban is very low, Faiveley have a number of options to consider. Should the demand be increased, number of units/carriers reduced or should the article be excluded from the Kanban flow?

3.2.3 Kaizen

Kaizen is the process of creating value by adding improvements, no matter how small. Like any other Lean goal, Kaizen strives to eliminate activities that create costs without creating any additional values for the customers. Problems and improvements are to be discussed in the open, documented, analyzed and solved efficiently in small groups. The team needs to be independent, which means that decision making needs to be decentralized. [97] One important condition is often forgotten, for Kaizen to work it is necessary that the organization has a low turnover of staff in order to protect the knowledge base, that has been is built up in the company. There are many different models that can be used when working with problem solving and improvements, but Kaizen draws its strength from simplicity. Only 20 percent of the problem solving should be tools and 80 percent should be thoughts and analysis. Basically, you go to the source of the problem and look, analyze the situation, bring the problem to the surface and ask "why?" five times, to determine the point of cause, POC. The Kaizen work should be conducted with a sensei/leader, who can be anyone from a dedicated employee to a Lean consultant. This is the foundation for solving problems, if the improvement is efficient it becomes part of the standardized way of working.[98]

Kaizen is a big part of Lean and TPS and is much more than just an improvement tool, it is a mindset. Hansei or reflection is the monitoring stage that should be part of the Kaizen mindset and can be

[95] Olhager, J (2000)
[96] Ibid
[97] Liker, J.K. (2009)
[98] Liker, J.K. (2004)

applied at models like Plan-Do-Check-Act, PDCA. Problems and improvements should be handled with a desire to accept challenges with a creative mind and courage; that is the "The Toyota way".[99] [100]

Summary

One big reason why companies think they are Lean when they are not, is because only a few tactics and tools like Kanban and Heijunka (mentioned above) are implemented after which Lean is considered to be finished. Instead, Toyota spends a lot of time and recourses to make sure they employ the best personnel in all different areas of the company. Giving the employees the tools and incentives to constantly improve their work and finding new ways of satisfying the customers.[101] Kaizen is often translated to small, constant improvements, but this translation can be misguiding. Changes and improvement may also be big and innovative. [102] Faiveley needs to make sure that the whole organization constantly improve and learn. Decisions should be made slowly and thoroughly but implemented fast. Faiveley should emphasizes simplicity and remember that problem solving should be 20 percent tools and 80 percent thoughts. When implementing Lean as a concept it is also important to remember that 20 percent is education and 80 percent is trying. Employees, teams, management and suppliers needs to be challenged and operate according to the Lean philosophy. Faiveley have implemented tools like 5S and Kaizen groups, but needs to expand the Lean concept to get better improvement results.

3.3 PDCA

Deming's wheel or the PDCA cycle is a systematic way of conducting improvement. PDCA stands for Plan-Do-Check-Act and is considered to be a corner stone for solving problems and working with improvements.[103] The Plan step, establishes the objectives and necessary processes to deliver results to accommodate customers requirements and the organizations policies. Within the Do step, the process is implemented. In the Check step, processes and products are monitored and measured against objectives, policies, product requirements and reported back. In the final step Act, actions are taken to continually improve the processes.[104]

Figure 5: PDCA cycle

[99] Liker, J.K. (2009)
[100] Ibid
[101] Ibid
[102] Liker, J.K. (2004)
[103] Ibid
[104] Swedish Standard Institute, (2008)

3.4 Bench assembly

Bench assembly, is where the product unit does not move, all the equipment and parts are brought to it, usually in kits, and one assembler or a team of assemblers move around it. Alternative to this is line assembly and cell assembly.[105]

3.5 Line assembly

An assembly line is a system where products move sequentially through assembly stations. Each station contains the right parts, tool, machines, fixtures, instructions and operators needed to carry out one assembly step. The product is then moves one step down in the line where the next operation is conducted.[106]

Summary

A change from bench assembly to line assembly is still considered controversial in some companies. Reasons for keeping bench assembly are low production volumes, high customizations and because line assembly operations are considered unbearable for the assembly personnel.[107] Even with these reasons in mind, Lean is a strong supporter of line assembly. There is improvement potential if Faiveley change to line assembly, but it requires a lot of changes and investments.

3.6 Japanese lake

The Japanese lake is a metaphor, originally connected to the JIT concept. The purpose of JIT is to minimize inventory levels in a warehouse. The metaphor is that the large submerged rocks represent problems and they are covered by a high water level that represents inventory. When the inventory level is decrease, the water is lowered; several new problems, bottlenecks and waste appear as rocks. These problems/rocks can now be dealt with and removed.[108]

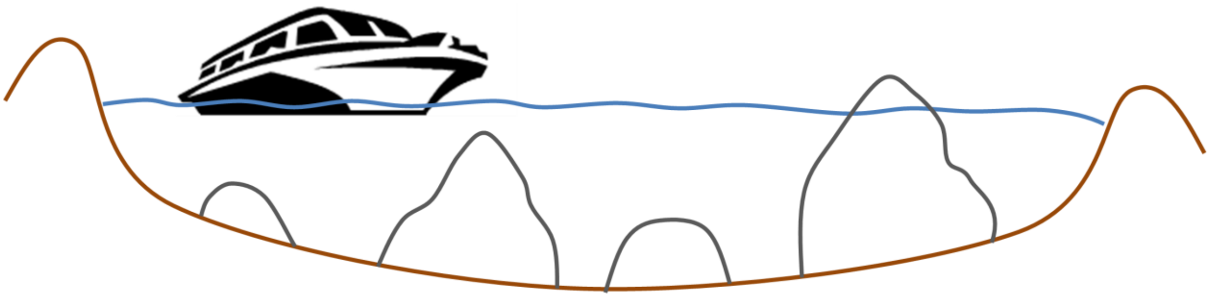

Figure 6: The Japanese lake metaphor

3.7 Measurements

Measuring the right things in the right way is important to get the desired effect. To determine *what* the company wants to achieve with the measurements, the company first needs to ask them self *why* they want to achieve it[109]. Measurements are a powerful tool, which if done correctly, can

[105] Baudin, M. (2002)
[106] Ibid
[107] Ibid
[108] Stevenson, W.J. (2007)
[109] Ljungberg, A. *et al*. (2001)

create a collective language, visualize the connections between cause and effect, motivate personnel and send clear messages to the suppliers. Measurements can also facilitate purchasing decisions, delegation of work, and be a motivational tool for change. The goal with measuring is never to create a diagram, it is to create knowledge.[110]

3.7.1 Time study

Time studies are used to determine downtimes and unit times for certain operations and products. A time study is usually used when there are demands on how a worker performs his tasks due to special method, quality or security reasons.[111]

An important tool for conducting a time study is a stop watch. There are two ways of timing the work. One is to stop and reset the watch after every observation. This technique increases the margin of error, especially if the reaction time of the time keeper is significant in relation to the observed time. The other way, is to note the accumulated time for every observation and after the study calculate the individual time for each operation. This technique gives the study greater accuracy.[112] A time study can give very accurate information on how long an operation takes and also a good insight in how the operation is performed.[113]

Summary

The goal with the time studies is not to measure how fast the workers at Faiveley are picking and storing but rather how long it takes to pick an average article from the ASUs. This time will be used as a starting point and basic level from which future improvements are to be evaluated against.

3.7.2 Sequence-based activity and method analysis

The Method-Time-Measurement, MTM, system was developed in the United States in the 1940's. The transition from a functional factory layout to line production presented the companies with the possibility to control the production in detail down to movement level. This in turn, was made possible due to the fact that each workstation only performed a specific set of work tasks. Sequence-based Activity and Method analysis, SAM, is a further development of the MTM system. SAM was developed in Sweden, in the 1980s, to help companies to meet increased customer demands and changing demands on work environment. Several criteria were set up as minimum goals for SAM to achieve. Some examples: sequence based, faster, easier, reliable and more thorough than any MTM version. It should be based on the MTM system but yet stand on its own.[114]

To simplify the SAM analysis specific symbols has been developed. As example the basic movements are Get [G], Place [P], Note [N], Step [S], Read [R], Forward and aside [FA] and so on. These in turn are specified in even greater details as example, Get specific [GS], Get handful [GH], Place precise [PP], Note text [NA], Read sequence [RA] and Read and check sequence [RB].These detailed actions are then complemented with different variables, such as specific cases and lengths of movements.[115]

[110] Ljungberg, A. *et al*. (2001)
[111] Olhager, J (2000)
[112] Ibid
[113] Ibid
[114] SRF (1990)
[115] Ibid

A very common variable is the length of movement. Movement is divided into three categories; 10 (≤10 cm), 45 (>10 cm, ≤45 cm) and 80 (>45cm). Depending on how long the movement is, it is categorized into one of these alternatives.[116]

An example of a movement can be GS45 which means, Get specific item from within >10 cm to ≤ 45 cm. This movement takes according to SAM 4 factors to perform.

In the MTM system an action or movement is measured in Time measurement unit, TMU. One TMU equals 100 000's of a second. In SAM, work is measured in factors. One factor equals five TMUs, and there are about six factors to one second.[117]

It is important to keep in mind that the time calculated in a SAM analysis, can only be regarded as a target time. In reality the task may take longer or shorter time to be completed.[118]

Summary

The SAM system was developed and implemented by famous Swedish companies like Volvo, ASEA, Saab-Scania along with workers unions, Metall and LO, and international agencies on MTM. An example of a company that gained a lot from work measurements is Volvo, who was one of the initiators to introducing MTM and later SAM.

One of the strengths with SAM is its relative simplicity. By using the special symbols rough times for activities can be calculated and altered easily. The lengths of activities, in factors, can easily be read from a data card. For example: picking up a pen within 0.45 m from you will have the code GS45. This action takes, according to the data card, 4 factors. By composing several steps one can obtain a theoretical time for an action such as picking from a shelf. This can in turn be compared to the actual measured times and analyzed to discover bottlenecks and waste.

3.7.3 Capacity and Productivity

Capacity for an activity is often referred to as the upper limit of its rate of production. Capacity can be hard to measure, which makes it even more important to ensure that a good and functional measurement is selected. [119] The general term capacity can be divided into two more useful definitions, Design capacity and Effective capacity.

- Design capacity is the designed maximum output of an activity, service, process or facility, and it is only achieved during ideal conditions.
- The Effective capacity is the Design capacity minus the allowed downtime such as maintenance, scraps and personnel time.

Other factors that may lower the effective capacity are lunch and coffee brakes, periodic maintenance, scheduling problems and changing production mix.[120] The two different definitions of capacity measurements are used to define the system effectiveness as efficiency and utilization.

[116] SRF (1990)
[117] Ibid
[118] Ibid
[119] Stevenson, W. J. (2007)
[120] Ibid

$$Efficiency = \frac{Actual\ output}{Effective\ capacity}, \qquad Utilization = \frac{Actual\ output}{Design\ capacity}$$

Both efficiency and utilization is measured in percent.[121]

Productivity is a measurement that defines the relationship between the outputs from a process compared to the input of the process. This is easily depicted as:

$$Productivity = \frac{Output}{Input}\ , \qquad Delta\ Capacity = \frac{New\ Output}{Output}$$

An example is that a decrease in resource utilization with a maintained product flow will be seen as an increase in productivity. Productivity measurements are mainly used over time to check if different changes improve or deteriorate a situation.[122]

3.8 Classification

Classification of articles and products can be done in several different ways depending on size, turnover, volume value, prize and so on. The technique presented below is chosen because of its connection with Lean assembly.

3.8.1 Product Quantity analysis

The Product Quantity analysis, P-Q analysis, is a very simple and powerful tool for grouping products or articles into categories, based on demand. Normally it is used when deciding if a certain product should be produced in a dedicated production line or in a line for a product family.

A Pareto diagram over accumulated production volume, or demand, per product is used to get an overview of the total production; this information can usually be extracted from a company's, ERP system. The products can then be classified according to the ABC principle:

- *A-products* are a few products with volumes high enough to have a dedicated line production. These products usually stand for more than 70 percent of the total demand.
- *B-products* normally account for about 25 percent of the total volume but they are usually as many as 200 different products. These products should be produced in lines dedicated to product families, which in turn are based on technical similarities.
- *C-products* are the rest of the company's products. They are mostly demanded sporadically, typically spare parts. These products should only be made-to-order with a minimum of work-in-progress.

The ABC classification can also be used for picking articles for assemblies. It is important that the selection criteria are based on objectivity, for example if the article is used in >50 percent of every product, then it is an A-item and so on.

[121] Stevenson, W. J. (2007)
[122] Olhager, J (2000)

By classifying products and articles in the material flow other businesses functions can organizes their work around this and focus on delivering the most frequently needed items to the assembly and production stations.[123]

Summary

By classifying their articles, Faiveley can manage their material flow better. It is obvious that every article is not equally important. Simple articles that can be procured from several different suppliers are of less importance to Faiveley than complex articles. Similar reasoning can be made about purchased articles that are used in great volumes at Faiveley. Classifying these articles and simplifying their handling will improve the visualization, cost efficiency and availability at Faiveley.

3.9 Single and Parallel tasks

A flow contains of several tasks and each task takes a certain time to complete. The tasks need to be completed in a specific order. The minimum cycle time is equal to the longest task time. It can be seen in the example below, where the minimum cycle time is 2 minutes.[124] In this example, the second workstation, in the single task flow, is a bottleneck (see Figure 7). In the parallel task flow (see Figure 8) the capacity of the second workstation is doubled, allowing the output in this example to double.[125]

Figure 7: Single Tasks

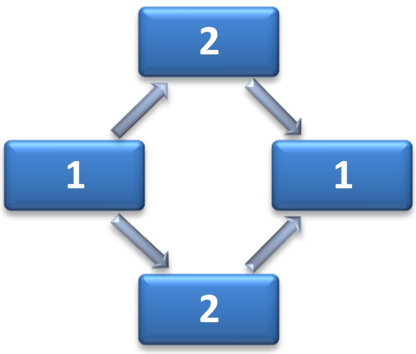

Figure 8: Parallel Tasks

Summary

One way of dealing with bottlenecks is to double the capacity for the slow section in question. This type of line balancing can be beneficial at Faiveley.

3.10 Standardization

Standardization can be viewed at several levels; branch, finished products and at article level. An example of a branch standard is the size a light bulb socket. Finished products that are made to stock are often standardized to achieve better production processes and warehouse management, even if this limits the customization.[126]

[123] Baudin, M. (2002)
[124] Stevenson, W. J. (2007)
[125] Ibid
[126] Olhager, J (2000)

The purpose of standardizing articles, in products, is to reduce the unnecessary and expensive varieties of raw materials, semi finished articles and purchased articles in the final products. The same article may be used in several different finished products. Other benefits of using standardized products are:

- Less engineering work is needed, if a suitable product already exists.
- Simplified planning and materials handling of the articles,
- Simplified purchase routines, larger purchased volumes of fewer articles, leads to better prices.
- Increased utilization of warehouse and manufacturing equipment.

A big drawback with standardization is that it can limit product development of new products and customer specific products.[127]

3.11 Modularization

The idea with modularization is that a number of predefined subsystems or "building blocks" can be assembled in a great variety of ways to meet the demand for customer-specific products. Creating a modular product takes time and it is important that the modularization concept is well established within the engineering department.[128]

There are typically three types of modules:[129]

- The base module contains articles that are in common for all the finished products.
- The version modules, together with the base module, make up the variety of finished products.
- Customer specific modules are built to ensure that special needs are met.

Reasons for modularizing a product are to lower the cost of production while keeping a wide product variation. Other reasons can be easier quality control, faster customer service/ over haul and lower capital tied in stock levels.[130]

Summary

An example of best practice in this area can be seen at Scania trucks. They started, in 1939, to engineer their most important truck components in modules. Today engines, transmission systems, axles and more are all based on modules. Today there is on average 8 000 articles in a Scania truck compared to around 12 000 in a truck from their competitors. Fewer articles decrease the capital tied up in stocks and production and makes maintenance of their products cheaper and more efficient.[131]

3.12 Fix storage and Floating storage

A storage location represents an assigned space with a unique address. Storage space is expensive in terms of costs, as rent, security, heating, air conditioning and so on. There are two main storage strategies, floating storage and fixed storage.

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[127] Olhager, J (2000)
[128] Ibid
[129] Ibid
[130] Ibid
[131] Ibid

Shared storage, or so called Floating storage, is where a product can be stored in more than one location and when empty other products may take its place. Floating storage prevents warehouse personnel from learning the location of the specific products, which is more time consuming and can cause trouble when products needs to be picked for a certain order. A floating storage requires an information system, like a warehouse management system, WMS. The main benefit is better space utilization.

Dedicated storage, or so called fixed storage, is where a storage location is reserved for a certain item. Since the location of the products do not change, more popular products can be positioned at more convenient locations or in a certain pick order, which is easy for warehouse personnel to memorize. The downside is that the average storage capacity, over time, only is utilized at a 50 percent level.[132]

3.13 Mapping

Mapping is a tool that can be used to easier understand and visualize the different parts and their connections in an organization. Maps like flow charts can be the foundation for analysis. Process maps can help visualize the interaction that creates value for the customers.

3.13.1 Flow chart

A flow chart is a tool for analyzing a specific flow. The flow chart can vary much in detail and extent, for example, it can be drawn up for anything from an entire production process to a specific step in a manufacturing process. When the flow chart is drawn up, special symbols are used for different types of activities: [133] [134]

- Operations, ○. An operation is an activity that, in one way or another, transforms the input material. It can be changes in the physical appearance or the chemical attributes of the input material. It can also be assembly or disassembly of a product as well as planning, calculating, construction and so on.
- Transports, ⇨. Transports are movements of objects between different locations without any alterations of the objects.
- Control, □. A control activity examines and verifies the result form another activity. A control activity can be to identify, measure, weight and in other ways examine an object to see if it reaches up to specific standards of quality and quantity.[135]
- Storage, ▽. A storage activity mean that objects, materials and tools, are put in storage awaiting an operation or control activity. Before and after storage activity is usually a transport activity.
- Delay, D. The delay activity is usually a queue or a wait for transport, operation or control activities.

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[132] Barthholdi, III. J.J *et al*. (2008)
[133] Olhager, J (2000)
[134] Stevenson, W. J. (2007)
[135] Olhager, J (2000)

3.13.2 Process map

The process map is part of the process approach, where the end goal is to identify and satisfy the customer´s need. A process is a repetitively used network of arranged and linked activities that uses information and resources to transform "input objects" to “output objects”.[136] Often the output object of one process directly forms the input to the next.[137] The process map describes the organization from a customer perspective. It creates a holistic understanding and identifies the most important parts of the organization. The process map clarifies how different activities are linked and interact to create a whole. [138]

This definition is confirmed by ISO 9001:2008 and states that an organization has to adopt a process approach, to efficiently manage numerous linked activities. [139]

Summary

To provide the reader with a better overview of how the work at Faiveley is conducted a flow chart and process map has been drawn up (see attachment 10.8 and 10.9). The charts are also the foundation of which the general flow of material and information is explained and analyzed. The process map is made with a specific article in mind for the purpose to display the “article process” before and after the improvements. Flow chart and process maps are emphasized tools in the process approach, ISO 9001:2008 as well as Lean and should be used at Faiveley while conducting improvement projects.

3.14 Fast Pick Area

A Fast Pick Area or a Forward Pick Area, FPA, is a location in a company that is dedicated to make fast moving articles easily available and make order-picking faster and more convenient. The Fast Pick Area is can be restocked from a nearby reserve area, with bigger bulks of the article. One reason for using a FPA is that order-picking usually results in a significant amount of material transport. The transport time can be reduced for a selected group of article by placing them in the FPA.[140] The Stock keeping units (SKU) with the most labor efficiency to be gained should be assigned to the FPA, in order to save as much as possible per pick.[141]

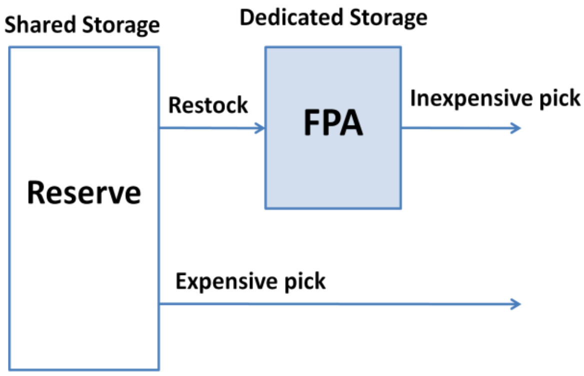


Figure 9: Fast pick area

[136] Ljungberg, A. *et al*. (2001)
[137] Ibid
[138] Ibid
[139] Swedish Standard Institute, (2008)
[140] Bartholdi, III. J.J *et al*. (2008)
[141] Ibid

Summary

The reason for a FPA at Faiveley is to reduce unnecessary transports which manly consist of moving articles in and out of the ASUs. The FPA also increases the accessibility of both fast moving and slow-moving items.

3.15 Ergonomics

Ergonomics can be defined as a cross scientific research and application field that with a holistic view treats the interaction between humans - technology - organization with the purpose of optimizing health, well being and performance when designing products and systems.[142]

During work, the body should be used in favorable work positions. Long term and repetitive work with a twisted torso, hands above shoulders or below knees, should be avoided. The recommended area of repetitive work, between the knee and the shoulder, are called the "golden zone".[143] Manual lifting of items weighing more than 25 kilograms, without appropriate equipment, should be avoided.[144]

Summary

It is important for Faiveley to protect their employees from any work hazards. By following modern ergonomic guidelines and government regulations this can be ensured.

[142] AFS 1998:1
[143] Ibid
[144] Ibid

4. Empirical framework

The collected empirical information that forms the foundation of this chapter is based on semi-structured interviews with Faiveley management, middle-management and factory workers. Factory workers refer to the individuals working at the arrival station, in the warehouse and at the assembly stations. Except for the interviews, information was also collected through observations and informal talks and discussions. Some of the empirical data is based on measurements, time studies, and processed raw data from the internal Faiveley enterprise resource planning system, Movex.

4.1 General flow of material and information

The first part of the empirical framework aims to provide the reader with knowledge of the flow of materials and information. It will also explain how the work is conducted in the areas of relevance to the master thesis. It will also show how the SAM calculations were made and how the time studies were conducted.

The enterprise resource planning system

Faiveley are using the ERP system Movex, version 12.4. The main function of Movex is to be a centre of information. It handles everything from finance to stock levels.

The system generates different orders, the three main being:

- Production orders (TO) which initiates processing, pre-assemblies and assemblies of new products or spare parts kits and retail kits.
- Customer orders (KO) which initiates customer deliveries of entire products or spare parts.
- Service orders (SO) which initiates services of products.

Every change in stock levels is registered as a transaction in the ERP system. Every time an order is created, the amount of articles needed for that order is deducted from the registered stock levels in the ERP system. These deducted transactions can roughly be seen as physical picks in the warehouse. Status updates are done manually throughout the internal supply chain.

Customer order processing

An end customer order is sent to Faiveley and received by the Supply Chain Management department, SCM department. If the customer is ordering a standard BFC the SCM department, sends the order directly to the planning office. Otherwise, the order is passed on to the engineering department. The engineering department works together with the customer, to customize a BFC to meet the customer requirements. Customization is considered by Faiveley to be one of their main and important competitive advantages. When the developed drawings are ready, they are passed on to the production department. First the production department ensures that the BFC can be produced according to the drawings, but they also check to see, if improvements or changes can be made, in order to make the BFC easier and cheaper to manufacture. After this stage, the drawings are sent back to the SCM and the Planning departments. Orders are placed for the needed materials and a production plan is created. Finally, the planning office now gives the customer a firm delivery date.

Raw materials and processing

The SCM department order castings from foundries where lead times may be as long as three months. The ordered castings are delivered to Faiveley and enter the building at the arrival station, along with all the rest of materials that is delivered to the site. The arrival station checks the castings for defects, transport damage and/or poor quality. After which they also report into the ERP system that the castings have arrived to the site. If the castings are to pass further quality controls or tests they are held at the arrival station until they are approved for usage.

When the castings have been approved, they are sent on to the warehouse and their status in the ERP system is updated. The planning office now orders the castings to be processed according to the manufacturing plan, and they are assigned to a manufacturing order (TO). Between the different manufacturing steps the castings are usually stored in the warehouse. Some castings are sent to external processing such as hardening. This usually takes about 7-14 days but some castings goes through several external processes and this can take as long as 2.5 months. When the castings have passed through all of its manufacturing steps, it has turned into an article. The article is the stored in the warehouse and its status is updated.

It happens that castings and processed materials not live up to Faiveley's quality standards. This and other delays create situations where management needs to reschedule the work plan, in order to make sure that sections of the company not go into a standstill, because of missing parts.

Ordering and storing purchased articles

In the ERP system every purchased article, k-articles, has an assigned lead time, including shipping time, arrival control and storing in the warehouse. The ERP system also allocates stored articles to end customer orders, which have their delivery dates set. This is done one week in advance. These allocations are deducted from the warehouse balance, in the ERP system. In this way, the system can compare, and calculate when the balance dips below the set ordering level, zero. When this happens, it alerts the planning office that they need to place a new order, to ensure that stock outs does not occur. Once the purchased articles arrive at Faiveley they are checked, against their delivery note, at the arrival station and then stored in the warehouse.

Pre-Part assembly

Some purchased articles are put together into pre-part assemblies. As an example, the drainage hose is assembled from a rubber hose, cut into ten centimeter long pieces, and a plastic nipple. It is then placed in a plastic zip lock bag. After this the miniature kit is sent back to the warehouse. This is usually done in large batches at the same time.

BFC assembly and shipping

When all the needed parts have been processed internally, externally and stored in the warehouse, the planning office releases an assembly order (TO), which is tied directly to an end customer order. This order acts as a signal for the warehouse to pick the needed articles, both from the high storage and the ASUs, and place the articles in a rack close to the assembly station (O-hyllan). The assembly personnel then start to assemble the order at bench assembly stations. They begin with part-assembly components, for example the brake-regulator. When all the part-assemblies are done, they continue to assemble the complete BFC unit at the end-assembly station. Every assembled BFC unit is tested to ensure sufficient brake power and functionality. Test documentation follows the units. The BFCs are then packed in creates, marked with correct labels and sent to the warehouse, which in turn ship the goods. Depending on where the BFC units are to be shipped, the transport is booked either by the warehouse personnel or the SCM department. The overall lead time for ordering, manufacturing and assembling a BFC is around 3-5 months.

Service

Faiveley have a separate service and overhaul department, called Service department, they carry out service on different Faiveley group products. It can be hydraulic door pistons, control units, BFC units and so on. The products are sent to Faiveley where they are dissembled, washed, painted and reassembled with new wear parts. For the planned services, the warehouse personnel picks the needed articles, according to a service order (SO), and delivers them to the service department. If an unforeseen demand for a specific part occurs, the service personnel seek approval for replacement of the part at the service department, and then request the part from the warehouse. After the service has been completed, the products are returned to their owners.

Spare parts kits and retail kits

The warehouse personnel are also responsible for assembling spare parts kits. These kits contains the wear parts for a common BFC unit and are stored in the same way as any other article, with a specific article number.

Retail kits are also picked by the warehouse personnel. These kits contains articles and components that sister companies in China and India have problems sourcing or manufacturing themselves. The retail kits are packed very carefully, to avoid corrosion when they are shipped by sea to their destinations. The retail kits are usually very big orders compared to any other regular order at the site and this makes them time consuming to pick and pack. Both spare parts kits and retail kits are put together according to pick orders (TO).

General warehouse organization

The warehouse is organized into two stations, the high storage and the ASUs. The high storage is made up by three aisles of racks. In these racks raw materials, semi finished articles and some k-articles are stored. A project has been initiated at Faiveley to open up the work environment around the factory. As a part of this project racks around the factory are disassembled and removed, which means that more and more of the goods have been moved to the high storage. The aisles of the high storage are serviced by a special guided very narrow aisle truck, which in turn is feed by a reach truck that collects goods from the arrival station. There are three people working the high storage during the day shift and two during the evening shift. This station is also responsible for loading and unloading delivery trucks, which is done with a counterweight truck.

The other station is the ASUs. The k-articles that are stored in the ASUs are collected by the reach truck and delivered to a small area close to the storage units. The ASU stations are responsible for ensuring that the assembly stations and service stations have all the articles needed to assemble and service the Faiveley products. The ASUs also handles the packing of goods, before shipment to the customers. They are also responsible for the picking and packing of spare parts kits and retail kits.

To lead the high storage and the ASUs there is a warehouse manager and a group leader. The warehouse managers duty is to supervise and ensure that the whole warehouse, work as one team. He also collects data concerning the stations delivery reliability and report to the supply chain manager. The warehouse manager is also the facility and production equipment maintenance manager at Faiveley.

The group leader works as a member of the warehouse team with the additional responsibilities to print the pick lists and book national transports for goods leaving the site. International transports are booked by the SCM department.

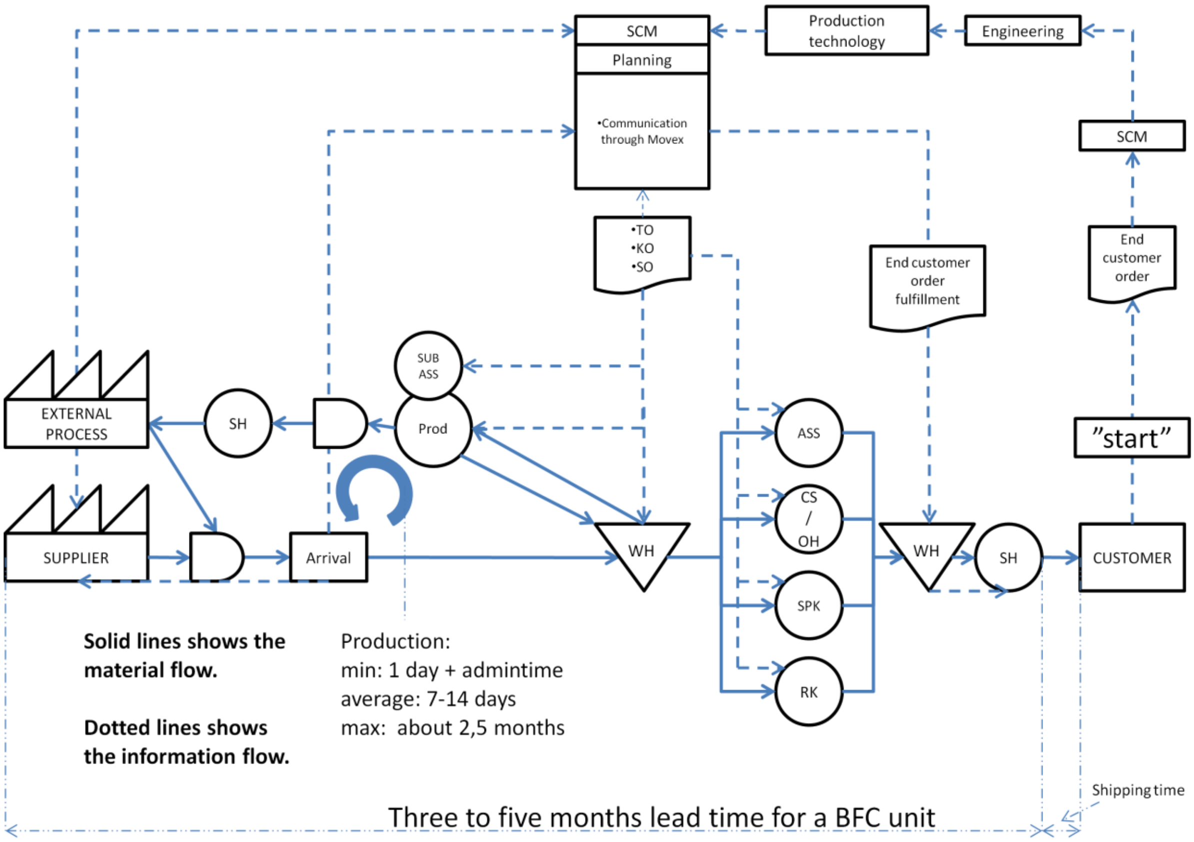


Figure 10: Flow chart over the flow of material and information at Faiveley. SH=Shipping, WH=Warehouse, Prod=Production, SUB ASS=Sub Assembly, ASS=Assembly, CS/OH=Customer Service/Overhaul, SPK= Spare Parts Kit, RK=Retail Kit, TO=Manufacturing Order, KO=Customer Order and SO=Service Order.

4.2 Classification

Faiveley classify their materials and articles into the following basic categories:

Raw materials, r-articles, are materials that need a lot of processing before they can be used. Rod material for example is a raw material. The rods are delivered in lengths of about 2.5 meters and then cut and processed in requested lengths.

Semi finished articles, h-articles, are articles that are in need of processing before they can be used. Examples of h-articles are castings. They have the rough shape of the finished article but they need processing treatments in several steps, before they possess the wanted qualities. H-articles are stored in racks on EUR pallets.

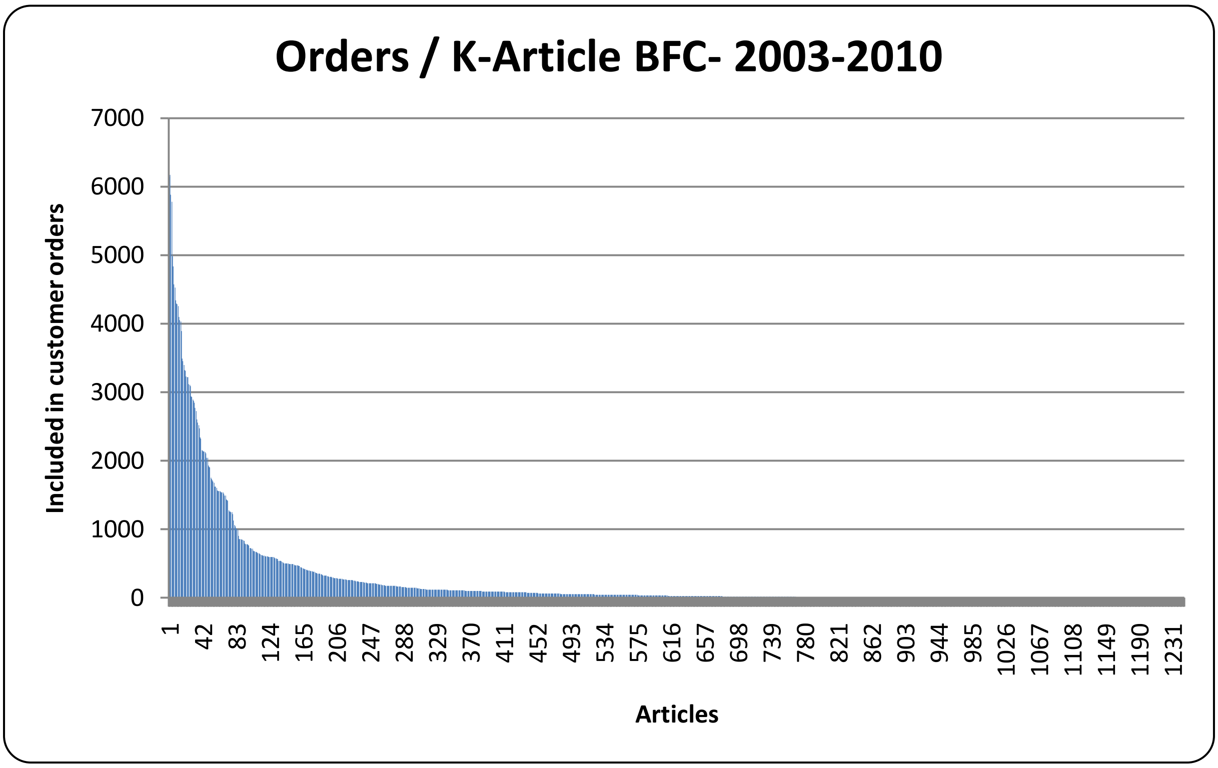
Purchased articles, k-articles, are articles that are ready to be used in a Faiveley product. Typical k-articles are nuts and bolts, sprints, springs, o-rings, plain bearings, bearings and similar articles. These types of articles are usually stored in the ASUs.

All of the different articles that are delivered to Faiveley are, if possible, delivered on standardized EUR pallets, with a maximum height of two EUR pallet collars, 390 millimeters. Some articles are delivered in original cartons placed on EUR pallets other articles are placed loose directly in the EUR pallet, boxed in by one or two collars. The reason for this is to simplify the handling of the material at the site and at the arrival station. Some raw materials are too big to be on a pallet and they are therefore handled with specialized carts.

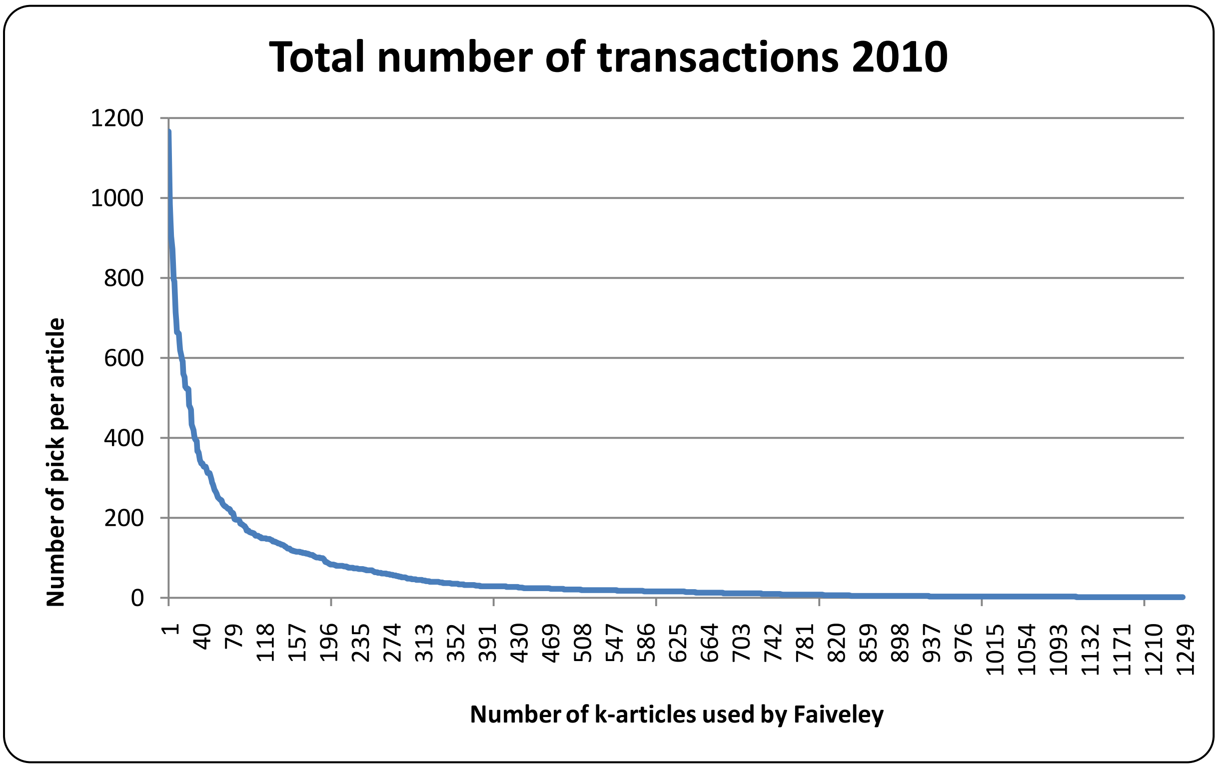
Some of the articles have further classification as Batch-articles. This means, that Faiveley needs to be able to trace these products backwards, through the supply chain in case of a product failure, since the breaks are classified as safety equipment. Each article or batch of articles has a specific number. In this case it is vitally important that the correct article is picked in accordance with the pick list. Some batch articles have been moved out of the ASUs, along with some ordinary k-articles, to simplify their picking and storing process. A reason for this may for example be the piece volume of the articles or bulkiness of the article, like 1741074003 (Manschett). Another reason why articles are not stored in the ASUs is the way the articles were originally packed by the supplier and delivered to Faiveley, for example a EUR pallet with springs 1741011001 (Reglerfjäder), without original cartons, (see Picture 4).

Picture 4: EUR pallet without original cartons

A BFC unit is made up of several different types of articles. Purchased articles, k-articles, generally represent around 2/3 of the articles in a BFC. Collected data from the ERP system showed that since 2003 up until 2010, 1245 different k-articles have been used in the different BFC units. Graph 1 below, shows the distribution of how common an article is in a customer order, compared to how many articles there are in total. Graph 2 below, shows how many transactions of articles there has been during 2010. The 1249 different types of k-articles in Graph 2 include a wider assortment of articles than just the BFC in Graph 1. According to the warehouse personnel and the IT-manager the “number of transactions” can roughly be translated to “number of picks” of articles. The analysis of the k-articles will be based on data from Graph 2.



Graph 1: Number of BFC articles used in different customer orders 2003-2010



Graph 2: Number of k-articles used in different transactions 2010

4.3 Standardization

The engineering department is not working, actively, to reduce the assortment of k-articles used in the BFC units. On the other hand, Faiveley are working on finding a standardized carrier and rack system for their factory. This process is still under development and there are for example at least five different sized plastic containers in different colors.

4.3.1 Articles

K-articles are low priority, when it comes to the design and development of a BFC unit. The engineering department designs to meet customer demands, focusing on the desired functionality of the product. According to the engineering department, this results in innovative solutions but increases the number of k-articles, since they usually are "put in" last in the design process. An example of how many varieties of k-articles there are in the assortment was revealed during an interview with a supplier. They said that they sometimes have to remind the engineering department, that Faiveley already purchase a similar article, which would meet their desired standards and requirements.

4.3.2 Carriers

Faiveley uses several different carriers for different articles in the material flow. In common for almost all articles is that they enter the building on a EUR pallet. Some articles lack primary packaging and are just shipped on standardized EUR pallets. The articles that arrive in their original corrugated cardboard cartons, on a EUR pallet, are opened and put in a plastic container. This procedure is done when they are stored in the ASUs or when the article is piece picked for a TO order.

Faiveley have explored the idea to use customized cartons in their material flow. This requires that the suppliers start to deliver their products in cartons with specific dimensions. There should only be a few different customized cartons sizes, for the suppliers to choose from, which are designed to function in thought-out rack system.

Faiveley have several standard plastic containers of different sizes. One of the most common is the "12 x 12" plastic container, with the measurements 200 x 330 x 150 millimeters (Width x Depth x Height). Another plastic containers, worth mentioning, is the "small plastic container" with the measurements 150 x 250 x 130 millimeters (W x D x H).

Zip lock bags are frequently used when picking a customer order or a service order. Articles that are to be sent by sea are picked and packed in blue zip lock bags. These bags protect the articles better from moisture which prevents corrosion. During interviews both the warehouse and assembly personnel pointed out that opening and closing the zip lock bags are a source of irritation.

An A4 sheet paper is attached to every EUR pallet. All smaller carriers like plastic containers or zip lock bags are marked with a label, to ensure that the articles always are accounted for. There is no standardized way of selecting which carrier to use for a specific type of article, this standardization process is still under development.

4.3.3 Racks

Racks are used as middle storage for articles picked and awaiting assembly. The smaller type 1 rolling rack have five shelves with the measurements 0.97 x 0.43 x 1.75 meters (W x D x H) and can carry 35 small plastic containers. Theses racks are used for transporting articles between the storage area and the assembly area. Type 2 rolling racks are bigger and heavier, with the measurements of 1.37 x 0.96 x 1.68 meters (W x D x H). They also have five shelves and each shelf can contain 120 small plastic containers. The shelves are slanted and evenly distributed in the “golden zone”. There are no wheels or other similar features, on the shelves, to help the carrier to move, which was pointed out as a disadvantage during the interviews. These racks are used as an extra storing space close to the assembly area. The type 2 racks also stand on wheels, which can be locked for more stability, but they are rarely moved (see Picture 5).

Picture 5: Type 1 rolling rack and Type 2 rolling rack with small plastic containers

4.4 Waste reduction

Faiveley constantly works to utilize their factory space in the most efficient way. Examples of this is lowering of stock levels, removing racks to create visibility and free a clearly marked area for future improvement projects, which is in accordance with FMS.

Routines for picking and storing

When articles are picked from the ASUs, a pick list is sent to a computer, controlling all three ASU’s. The optimal sequence for picking all the articles is computed and a pick order is determined. Only one pick list can be processed at the time, but the option of making changes in the list is available, if necessary. The ASUs then initiate this pick sequence by presenting the appropriate levels/shelves in the three machines. When the warehouse worker has picked an article he confirms the pick on the computer, which tells the machine to present the next level/shelf in the sequence. In total, one ASU can contain 44 levels/shelves each containing 24, 12 x 12 containers, resulting in a total of 1056 containers in one unit. The articles that are taken out of the storage units are then placed in a carrier which is tagged with a printed label. This label contains information about the article such as order number, article number, number of articles, date, name of the article, ID-number and its original storage place. There is also a barcode, on the label, but this is not used by Faiveley today. The labeled carrier is then placed on a pallet or in a box and the worker starts to pick the next article.

When articles are delivered to the warehouse, for storage in the ASUs, there is always documentation following them. The information in these documents is sent to the computer, which computes a storage sequence. Much like picking this sequence is initiated and the correct shelves are presented along with information of which place of the shelf that should be used, and how many articles that every place are calculated to contain. Articles are checked, counted and divided into the appropriate amount for storage in the predetermined boxes. In some cases new places has to be assigned due to extra large orders or that new articles is introduced into the system. In both cases the computer decides were the articles are to be stored.

Picture 6: The ASU area

To ease the storage and pick processes, when dealing with articles in large quantities, scales are available. The worker places five pieces in a standard box on the scale and the scale calculates an average weight of one piece. When this is done the worker can just shovel pieces into the box and read from the display on the scale the amount of pieces picked. When the appropriate amount is reached the worker can either store the articles or place them in a plastic bag depending on the activity performed. This technique is considered to be very important, for the work in the warehouse, by the personnel at Faiveley.

Sometimes it happens that articles not are picked and delivered to the assembly and service stations in the right quantity. When this occurs, the assembly and service personnel walk over to the warehouse and ask for the missing article. The warehouse personnel then either abort their current job in order to pick the missing article or the assembly and service personnel have to wait, depending on how much there is to do in the warehouse at that specific time. This wait can be everything from five minutes to several hours. Both cases result in a waste of time.

Articles that are stored in the ASUs are put in blue plastic containers. The shelves in the ASUs are dedicated to a specific type of plastic container. The different types of plastic containers vary in the aspects of physical measurements and ways that they can be divided into several smaller compartments. The standard carrier is the type 12 x 12 container. All articles stored in the warehouse, high storage and ASUs, are all picked according to the First-In-First-Out, FIFO, principle.

Two of the storage units, called ASU 1 and ASU 2, were purchased at the same time and the third, called ASU 3 was purchased three years later. ASU 3 is mainly used to store oddly shaped and unusual articles and is only filled to around 60 percent.

From observations and interviews, it was seen that fluctuating takt time and uneven demand for picked articles, resulted in that pick orders was queued and being completed later than expected. It also became clear that the ASUs sometimes stood still for long periods of time. These types of phenomenon are part of what will later be referred to as peaks and valleys in demand.

4.4.1 Time study

To validate the perception, by the workers at Faiveley, that the ASUs are bottlenecks a time study was conducted.

The aim of the time study was to measure how long it takes for a warehouse worker to store or pick an article in the ASUs. It was explained to the workers that is was not them that were being timed, but the machines. The workers were also asked to work as normal and that any interruptions or disturbances would be treated as any other day.

From the recorded total time, the time for interruptions and disruptions were deducted to ensure that it was the average time of an actual storing or pick of one article that was recorded. The total time was then divided with the number of storing or picks made. Depending on how much of each article that was stored in the storage units and how many positions that the article occupied, the total amount of picks of one article could require picks from different positions in the ASUs. If the same article needed to be picked from two different positions in the storage unit, this counted as two picks.

The measurements were made at different times of the day, with different amounts of articles to be picked and by different, experienced, workers operating the ASUs. This in an attempt to get a representative average time for each picked article. The average time for picking one article from the ASUs was measured to be 60 seconds. The time for storing an article in the storage units was measured in roughly the same way. The measured average time for storing one article in the storage units was 71 seconds (see Attachment 10.2). During the time studies it was noted that the ASU 3 stood still during long periods of time. During a pick order it was for example observed that ASU 3 stood still around 40 percent of the time.

SAM analysis

To get an appreciation of how long it takes to store and pick articles from a rack, a SAM analysis were performed. The SAM analysis can only be seen as a target time and have therefore been rounded upwards, to ensure reliability in the results, meaning that any possible changes/improvements, based on the analysis, will be reachable goals.

Following conditions and assumptions were taken into account for the SAM analysis (see Attachment 10.3).

- All articles that are to be stored in the FPA arrive on the same EUR pallet.
- All different articles, that is to be stored, arrive separated into groups on the EUR pallet.
- Empty plastic containers are picked from "behind" in the racks.
- There is room on the EUR pallets for the articles, plastic containers and other equipment that is needed during the storing process.
- All original cartons and full plastic containers weight more than 5 kilograms.
- All hand, arm or body movements are longer than 45 centimeters.
- All movements, with a load, are longer than 45 centimeters.
- The picker always needs to check five shelves when looking for a specific article number.

- Searching is represented by the read movement.
- Opening zip lock bags are incorporated in the take and move movements.
- There are six factors to one second.

The following five different work activities have been identified and SAM analyzed:

1) *Storing one original carton into one plastic container in the FPA*, this activity took 28.8 seconds, equal to 173 factors.
2) *Storing one original carton in several plastic containers in the FPA*, this activity took 36.2 seconds, equal to 217 factors.
3) *Piece picking a small number of articles in the FPA*, this activity took 22.5 seconds, equal to 135 factors.
4) *Piece picking a large number of articles in the FPA*, this activity took 44.9 seconds, equal to 270 factors.
5) *Picking a full plastic container from a rack in the FPA*, this activity took 12.8 seconds, equal to 77 factors.

4.4.2 Fixed or floating storage

The articles in the automatic storage have floating storage spaces, since it is more space efficient. The software automatically assigns and keeps track of the articles storage spaces. The high storage has floating storage spaces as well, but here the location of the articles has to be assigned into the system by the warehouse personnel. The storage space at the assembly stations are fixed for some of the k-articles. The decision of which k-articles that should be placed at the assembly stations are were based on experience and old data. There are no complete data on which these articles are or how many of each.

4.5 L002

There have been conflicts between the service department and planning office at Faiveley concerning allocation of material.

The planning office is responsible for ordering material and standard k-articles to Faiveley. Special k-articles, ordered for example for a special service, are ordered by the service department themselves. When the material has arrived at Faiveley, the planning office allocates the materials to the different TO-orders. These allocations are done one week in advance and their demand is often clear and easy to calculate due to long production lead times.

The service department on the other hand has two demands of which one is known to them for example a BFC unit is sent to Faiveley to have all its wear parts changed. Service then plan and order for these wear parts, which are picked and delivered to the service station by the warehouse. But there may be unforeseen changes in their demand, since it happens that hidden/internal parts may need replacement. Service then contacts the customer to get a confirmation for the extra repair and if it is sanctioned, they order the needed parts from the warehouse. The needed parts are then allocated to the service order and picked from the warehouse.

The problem is, that the planning office, might have ordered these articles for another TO-order that the system have not allocate articles for yet. The reason for this is that Faiveley often struggles to reach the minimum order quantity of their supplier before a new order is placed. When it is time to allocate articles for this TO, the articles have already been taken by the service department. A new order is placed, but the lead time for the missing article, may sometimes be long, and the planned, but not allocated, TO-order has to be delayed.

According to Faiveley a solution to this problem would be to establish a second warehouse, both virtually in Movex and physically in the facility. The new warehouse would be called L002, the present is called L001, and every k-article would, in the future, be stored in two physically different places. To ensure that there would be enough warehouse capacity the investment in a new paternoster machine is being considered.

4.6 Lean management

Faiveley have started to implement the Lean concept as part of FMS, they have for example implemented a 5S program throughout the whole site. Faiveley have been ordered, by Faiveley headquarters, to adjust and work in accordance with the FMS. The FMS statements incorporate elements of ISO 9000 and Lean. Each statement can be fulfilled to 0, 30, 60 and 100 percent. Faiveley are audited according to FMS every year by Faiveley headquarters.

Management and middle management have in general, wide areas of responsibility at Faiveley, for example the Supply chain and production manager. Work routines and job descriptions are however poorly documented and updated at Faiveley. The reason for this is that management lacks the time and manpower to correct them. Several instructions are directly false and a lot of the everyday routines are spread orally.

4.6.1 Flexibility

The request for materials and information from previous activities in the supply chain can be seen as internal demand. The work connected to this internal demand is transferred through the different activities and areas at Faiveley. Observations showed that the amount of work that is conducted in the different areas of Faiveley varies a lot. Some times the amount of work is so high, during so called peaks in demand, that external help is required from consulting firms. During some time periods it can also be observed that the amount of work that is conducted is low, with some filler activities, during so called valleys in demand.

The minimum order size of k-articles orders are generally considered big. The main reasons for the big minimum orders are to lower the price through economy of scale. Some pre-part assemblies are made in big batches to stock. All units are finished in every assembly step before moving on to the next, compared to, for example, splitting a customer order up in smaller batches and letting them pass through the assembly step sequentially.

If articles are delayed from a supplier or are not approved at the arrival station because of quality defects, it can delay an entire assembly order. When this happens, Faiveley management reprioritizes the orders, to make sure that parts of the factory do not go to a complete standstill. Usually this is done at a weekly meeting, but in some unforeseen cases, it is done the same day when the problem occurs. The general term for this is flexibility, which is considered necessary by Faiveley management. Through observations and interviews with factory personnel these reprioritizing are handled in different ways, there is no standardization or written guidelines.

Without going into details, the work that is conducted is put aside and the new prioritized order started the same day.

4.6.2 Kaizen

Many of the changes and improvements decisions made at Faiveley derive from the FMS. This system is basically a list of tools and suggestions to quickly get Faiveley working with changes. Some of the tools can also be found in Lean like 5S and a Kaizen white board. The more of these tools each Faiveley facility implements, the more points they are awarded. FMS includes no guidelines or explanations to why these tools should be implemented. A model that is used, by Faiveley, is the PDCA, which also is a requirement by the ISO 9001 standard, and it is used at some improvement meetings.

Kaizen is a word that has only been used at Faiveley in later years. It is a tool that has been around longer than the concept of Lean. There are selected members of staff, working in a Kaizen group where problems and improvement suggestions are discussed and decided upon. The Kaizen groups consist of top and middle management. At Faiveley the connection between Lean and Kaizen are not fully understood by all members of the Kaizen groups.

A lot of smaller and medium sized improvements are discussed under more informal circumstances between single members of top and middle management. This kind of informal improvement decisions are also common between middle managers and factory workers. Smaller improvements are often decided upon directly and implemented the same day. Some problems and improvements suggestions are discussed at regular monthly or weekly meetings, but there are no structured ways on how this is handled and no documentation.

Faiveley has a suggestion box, where workers may leave their improvement suggestions. This is however no longer a major contributor to the improvement work, today. The suggestions are handled by an improvement committee. Depending on how much savings the suggestion is evaluated to generate to the company, the committee decides on a financial reward for the worker.

Faiveley work with different improvement models like PDCA, which are used at some improvement meetings. Most improvements that are made are done as a reactive response on problems that occurs and needs to be dealt with immediately. These problems are discussed in groups, like the Kaizen group. Different solutions or projects are worked out to handle the acute problems, but usually not through a specific model.

5. Analysis

The analysis chapter contains the analytical work, based on the theories and empiric material, which was collected and included in previous chapters. The analysis will especially take a Lean perspective, both in theory and practice. The analysis is divided into five main areas of interest: Classification, Standardization, Waste reduction, L002 and Lean management.

Analysis introduction

One might argue that it is not important to put a lot of work in improving the material flow of the k-articles. They are relatively low cost and there are a lot of different suppliers to choose from. This is however only half true. Yes, the k-articles are low cost and one might feel tempted to take advantage of economies of scale and purchase big batches at low prices from the cheapest supplier and just overstock these articles to ensure availability. But this would tie a lot of capital and material in the warehouse and the already stringed amount of space would overflow of articles.

5.1 Classification

Faiveley's way of classifying articles is very rough and simple. It is developed strictly from a manufacturing point of view. Due to the way that the classification is made up, it is pretty easy and clear just from looking at an article or a material to see what class it belongs to and in general how it should be handled in the flow through the factory.

However, when looking more closely at the k-articles, there are some different flows that cannot be distinguished just by looking at them. Some very similar articles may have different flows, which often have been decided by middle management, based on knowledge and experience. These flows can be difficult to understand and improve, since they are not clearly defined and documented. For example there is no information of were an articles should be stored. Article 1741074003 (Manschett) and article 1741260000 (Plugg) are both k-articles, but the Manschett is stored in the high storage and the Plugg is stored in the ASUs. It is the built up knowledge of the warehouse personnel that ensures that the articles are stored at the right location.

There is a risk of creating waste when classifying articles. A to detailed classification can create confusion and result in "special" flows through the site. So there is strength in a simple classification model.

5.1.1 Portfolio analysis

K-articles are typical routine products, since they are standardized items, which are easy to manufacture and with many available suppliers, of course with some exceptions. A majority of the handling time in the warehouse is spent on k-articles. Every time an article is handled, it increases in value because of the time spent to perform the activity in question. Every time an article is stored it also increases the capital bound in stock, which results in increased costs and a higher value. For these low cost articles, the increase in value can be several hundred percent at the end. It is therefore desirable that the handling and storing of k-articles is kept to a minimum.

5.1.2 P-Q analysis

To determine which k-articles that should be classified as f-articles respectively s-articles a P-Q analysis is suitable. But instead of focusing on the volume value for each article, the classification should be based on the number of transactions, which each article is involved in over a time period of for example a year. In this way, the analysis will be based on factual and repeatable measurements of the articles "popularity" rather than its annual volume value. This data is easily extracted from the ERP system. Focusing solely on the volume value might give a distorted classification since the connection between the amounts of work needed to satisfy the demand, for the specific article, does not have to be tied to the volume value. Since this way of classifying articles are connected to the process flow, it could help standardizing the flow, so that the special treatment of articles is kept to a minimum. Less confusion, less uncertainties, less special handling and easy workable data, results in less waste.

The classification of k-articles could be done into two categories f-articles and s-articles and it is a continuous process. The first time the new classification is made it could be based on the ERP data, article classification model (see Attachment 10.1) and experience. After this, there should be a periodic update of the classifications, where data regarding k-articles are extracted from the ERP-system and evaluated periodically. The extracted data should contain article number, number of transactions, quantity and class.

As a part of the Kaizen work at Faiveley, this could be done by the warehouse personnel together with a leader/sensei. Classification is also an ongoing process, since every time an article changes flow, it needs to change class or vice versa. With this ongoing routine there should never be any uncertainties regarding the correct flow of an article.

After the initial classification is completed, the future changes of classifications should be carried out fast and efficient. The extracted data will now contain the articles with their present classification. Irregularities, like an article, where the number of picks differs from the present class, can now easily be discovered and dealt with in accordance with the articles classification model. In a perfect world, where all f-articles are identified in advance, due to the Kaizen work, an annual update would simply be a verification process.

It is important to bear in mind, that there is no difference in importance between f-articles and s-articles and that orders are likely to contain both types of articles.

5.1.3 F-article

To draw the line for which articles that should be classified as f-articles, the authors' starting point was Pareto's law. As suspected, the authors found that 20 percent of the articles actually stood for 79 percent of the picks. The 250 articles, making up these 20 percent, ranges from 1166 to 68 picks during 2010 (see Attachment 10.7). Since Lean emphasizes on listening, engaging and taking employees input into consideration, the line of what constitutes high amounts of picks, were discussed with the warehouse personnel. During the interviews, several warehouse workers stated that 100 transactions a year, should be considered as a high amount of transaction, but not less than that. The authors used data from 2010 and had the transactions divided into TO, SO and KO orders, to get a better understanding of where the demands occurred (see Attachment 10.6). If the sum of TO, SO and KO reached above 100 transactions a year, the article were considered to be suitable for the f-article classification.

These articles, 186 in total, where then examined closer. During this examination it was found that around 30 of these articles where not stored in the automatic storage units, ASUs, but on EUR pallets. The main reason for this special treatment of articles where due to the high demand, which can be seen as a step in the right direction. Unfortunately, the articles where spread out all over the factory and warehouse.

The final classification of f-articles should be done by the warehouse personnel themselves, to ensure that their knowledge of the articles and products are taken into account. This is especially important for articles with close to a 100 transactions per year. They might deserve to be an f-article, but for example due to irregular data for the last year they have ended up below the limit.

5.1.4 S-article

The rest of the k-articles, that are not f-articles, could be classified as s-articles. Common for all s-articles are that they have a low annual picking rate. The article can still be of vital importance, to meet a specific BFC customer's specification. Some s-articles may also have been specially ordered or have long lead times. The same situation goes for the service department and the fact that they have an even greater number of s-articles, with low picking frequencies and unpredictable demands. In these cases the long lead times for some s-articles is an even bigger problem, since the lead time to a service customer, is expected to be shorter.

To ensure the availability of these s-articles, it is necessary to store them at Faiveley for longer periods of time. One of the most efficient ways to store these articles, would be in the ASU. The benefits with storing s-articles in the ASU are the high space utilization and the possibility of parallel flow with the f-articles. How the work at the ASUs could be conducted will be analyzed further in the chapter about L002.

5.1.5 Batch articles

Some k-articles, both f-articles and s-articles, have special product safety requirements, demanding traceability. To obtain traceability, the articles are given documented batch numbers, tied to a specific order.

This connection between batch numbers and orders are made in advance, which means that all articles that are batch articles, needs to be picked piece by piece. The present batch system with piece picking makes it problematic to put these articles into a Kanban flow. If for example order #1, with batch article #1, is moved to make room for order #2 in the assembly, the batch article #1 also needs to be exchanged with batch article #2, otherwise the traceability will be lost. This is in conflict with how the Kanban flow should work. A Kanban flow, at Faiveley, will be analyzed in the waste reduction chapter.

5.2 Standardization

The importance of standardized components and modules in any production cannot be emphasized enough from a supply chain perspective. Faiveley are presently planning to develop a new version of their BFC system. This is of course a good opportunity to start the work with standardization. Standardization affects not only articles but also carriers and racks. Having a wide variety of carriers and racks can result in poor space utilization. Trying to adapt racks to carriers and carriers to the size of articles are time consuming and restricts the possibility of change, problem solving and improvements.

In the past the focus of the engineering department has been on customization and functionality of the products. This is considered to be one of the main competitive advantages at Faiveley. It is of course extremely important that Faiveley continues to meet these customers' demands, but there is also a lot to gain by using a standardized k-articles assortment in their production. A reduced variation of articles should result in a simpler and easier flow to manage, with less handling, throughout the whole supply chain. Standardization of k-articles will also result in increased order sizes and lower unit prices. A more standardized variety of k-articles will not reduce Faiveley's competitive advantage since these articles are routine products.

5.2.1 Carriers

The three types of carriers that have been discussed previously and found to be suitable at Faiveley are original cartons, plastic containers and customized cartons.

Original cartons

In most cases the primary packages of the k-articles are cartons of corrugated cardboard. A big advantage with using the original cartons, as standard carrier, is that there will be less motion waste, due to less repacking of articles. The sizes of these cartons vary a lot, which makes them difficult to adapt to standardized racks. With some arranging of the different carton sizes, the width and dept of the racks can be used in an efficient way, but the height is more difficult manage. The interval in height of a frequently used suppliers most used articles cartons is 130 millimeters. In an attempt to find at least three categories of different sized original cartons, the authors found that there still is an interval of 43 millimeter. Note that the difference in sizes of the articles from this supplier is low and the data material only is comprised for 12 different articles (see Attachment 10.4). When comparing one of the biggest k-articles cartons with one of the smallest, the difference in height is 350 millimeters (see Picture 7). Even with flexible racks and different categorizations, because of different heights, there would still be a lot of waste in space utilization. Changes in suppliers packaging may result in a reconfiguration of the storage racks. For example, a small change in a single carton dimensions, may result in that the article in question must be moved from one rack size to another, also requiring a change in the ERP system.

Picture 7: Different sizes of original cartons in which k-articles are delivered to Faiveley.

Making sure to minimize the work at the assembly stations, the original packages always have to be pre-opened, no matter what carrier solution is used. This means that the reduction in motion waste, when storing articles in their original cartons, compared to putting them into an alternative carrier is close to zero. Using original cartons as the carriers also requires a more elaborate opening procedure, to ensure easy access and visibility of the articles. This may also lead to an increased risk of paper scraps and dust, contaminating the articles, which in turn can lead to future quality problems.

Plastic container

Presuming that the plastic container can be standardized to only a few different sizes, there are several advantages to be gained. The use of standard plastic containers facilitates the construction and maintenance of any storage solution. Changes in suppliers packaging will not result in a reconfiguration of the storage racks.

Storing articles in plastic containers provide both the warehouse workers and assembly workers with easy access to the articles when they are to be picked. The lowered front edge of the container is a more visual way of displaying and presenting the articles to the workers which increases the articles availability.

The plastic containers are very robust and stable in its design. The containers can be places on any surface, without being disfigured and it can also be hung on its edges, without any risk of its bottom collapsing. It is design to be griped and handled in a working environment and it can be efficiently stacked with or without content.

To protect its personnel, Faiveley have a policy of not handling material that weight more than 15 kilograms manually by hand. This is a lower limit than what the Swedish Arbetsmiljöverket recommends, which is a maximum of 25 kilograms. By using standardized plastic containers, for all k-articles, the maximum volume limits the maximum weight of the container automatically. By choosing a smaller plastic container, than the earlier mentioned 12 x 12 plastic container as a standard carrier, waste like unnecessary high "middle storage" and high amount of tied capital at the consumption stations, will be limited. For example an assembly station will not contain an annual supply of any article. Using smaller plastic containers, as a standard, will both result in more efficient space utilization in the containers (see Picture 8) and also more efficient space utilization overall.

Picture 8: Same amount of articles fit in the smaller plastic container

The plastic containers, in combination with labels can be used as an efficient visual signal. An empty container signals refilling and the label signals of what and where. Also different colors of the plastic containers can be used to emphasize the flow of the articles inside. For example, blue containers can exclusively be used in a Kanban flow, while grey containers are for piece picking. This minimizes the risk of putting piece picking containers into the Kanban flow, by mistake.

Compared with using original cartons, there is an initial investment cost. Although plastic containers can be reused many times, there will also be some costs for cleaning and replacing old and damaged containers.

Customized cartons
Minimizing the variety of different original cartons in order to utilize space better and easier adapt racks can be done by customizing the cartons from the suppliers. This could increase the cost of each package and must be compared to the cost reduction gained by better space utilization. Generally all desirable characteristic of the plastic container can be obtained by customizing the cartons, but each customization will increase the cost. Since the k-articles are generally low cost items or routine products, the cost and the handling should always be kept at a minimum.

Zip lock bags
Today zip lock bags, in different sizes and colors, are used for piece picking. They are disposable carriers at a low cost. Articles that arrive at a consumption station in zip lock bags with a label are easily identified, but are not as accessible as when the articles are placed in plastic containers. Zip lock bags are a source of irritation because they require opening and closing at the warehouse and then reopening at the consumption station. The lack in sturdiness of the zip lock bags limits the use of available surfaces compared to the plastic container. It can for example not be placed in certain rack systems. The bags can easily be damaged and when opened the articles can easily be lost.

5.2.2 Racks
Faiveley have several types of racks, which are used for different purposes. For a picking purpose the rack should be constructed so that the majority of the picks are conducted in the "golden zone" to minimize work tension and maximize work efficiency. Flexibility like wheels, adjustable shelves and light weight are desirable features. Flow racks with slanted shelves facilitate the accessibility of the articles on the shelves, since an empty space are "automatically" refilled by a waiting carrier. The flow racks could be fed from the back without disrupting the work conducted in front of the rack. A flow rack, if fed correctly, also facilitates a FIFO flow of articles.

Faiveley's type 2 rolling racks are not flow racks, but they still have slanted shelves, which enables FIFO to some extent. The shelve surface are not restricted in separate lanes or aisles, with edges, but they are relatively difficult to adjust in height. This makes them ideal for carriers with different width and depth, but the difficulty to adapt in height restricts their flexibility. The racks stability and the fact that they are on wheels increases their overall flexibility however.

An alternative rack solution could be modular racks. These racks are made up by a framework of metal rods and connector joints which can be built and adjusted to fit Faiveley's specific needs. Even though these modular racks may take some time to assemble, the wide variety of different logistical solutions supports change. This lack of restrictions makes them very flexible, which is preferable according to Kaizen. There are several modular racks that can be equipped with rolls and/or wheels to create flow racks.

5.2.3 Label

No matter which rack solution or carrier that is chosen every position in the rack is to be marked with an exclusive number. For example 5-1-1, showing for example, fifth rack – first shelf –position one. If the carriers are marked with a corresponding label, visualization could be increased and everyone would know exactly where the articles are supposed to be stored. A fixed numbering of storage positions will increase visualization even further, and result in quicker stock refills (see Picture 9).

Picture 9: Modified label

5.3 Waste reduction

Warehouse storage space is a cost that must be paid for every month. When trying to minimize waste, in order to reach the goal of highest quality, lowest costs, and shorter lead times, based on a foundation of stability, it is easy to forget the space costs. Waste, because of poor utilization of space, may not be a distinguishing part of the eight types of waste, but it is easy to understand, that if extra space is acquired, when the existing warehouse still is not completely full, it is a waste. At Faiveley there are a lot of changes going on and many of them are targeted at removing racks and machines to make space for more important activities and equipment. This chapter will basically focus on what activities an opening up of space may be used for. Since there are no established, available area measurements to originate from, the analysis is based on utilization of an undefined space as efficiently as possible.

The space limitations of the ASU today will become a key issue when the k-article assortment will increase, due to expansion in the service business area. The time it takes for the ASU to change shelf, in relation to the time it takes for a warehouse worker to complete a pick, limits the minimum pick time. An average pick, in the ASU's, takes 60 seconds per article, much due the working speed of the machines. The weighing of articles, in and often also out of the ASU's, in combination with the restricted speed, reduces the availability further, create double handling and altogether decrease the cost efficiency of the warehouse. When the warehouse needs to increase the pick capacity, they usually use two warehouse workers instead of one. The times study showed that the picking capacity only increases with about 25 percent. The way that the ASU works today, prevents parallel work flows of storing and picking. Since two different orders cannot be picked at the same time from the ASU, this not only prevents parallel work flow, but also creates situations where queues occur. If there is a high internal demand on k-articles, the restriction of parallel work in combination with the limitation of increasing capacity, creates a bottle neck in the material flow (as illustrated in Graph 3). Due to the uneven distribution of articles, and the fact that the ASUs cannot provide different flow per article, based on the turnover, machine 3 stands still about 40 percent of each pick session. This kind of bottle neck can in worst cases create downtime in other parts of the company due to lack of materials.

Graph 3: Intuitive capacity increase with number of warehouse workers

If articles are picked in advance, to increase the availability, and to prevent limitations during peaks in demand, the capital tied in work in progress will increase. Added effects are typical overproduction waste, like for example the increase in incomplete pick orders.

To analyze improvements in the warehouse layout, three different possibilities are presented and evaluated. Two of these possibilities can be viewed as opposite extremes are exclusively racks or only ASUs.

5.3.1 Automatic storage unit solution

One way that Faiveley can increase their storage capacity is to invest in a new ASU. A new ASU would increase the warehouse capacity for storing small articles and decrease picking time, due to faster work speed of the new machine. This solution is a very space efficient but also expensive.

The ASU computer optimizes the work sequence and automatically takes FIFO into account. Unfortunately the current software cannot handle picking multiple orders simultaneously and this prevents parallel work flows. Another drawback with the ASU is that it requires a computer system to run at all. Manually controlling and keeping track of articles in the ASU would be an enormous task.

Like any other machinery, the ASU continuously needs maintenance and eventually they need to be replaced, at a great cost to Faiveley. There will also be foreseen and unforeseen downtime during the ASUs lifetime, due to maintenance and breakdowns.

From a Lean perspective, the authors have identified three main areas of waste connected to the ASUs:

- Many articles are transported unnecessarily much. An example, of this motion waste, is that the needed article will be presented, to the picker, on a shelf together with many unwanted articles. Presenting unwanted articles, along with wanted articles, might create confusion and increase the risk of mistakes along with unnecessary strain one the machinery.
- Waiting for the ASU to present the wanted article is a classic sign of waste. This can be seen, especially, when only one article is picked. But also when machine number three is “empty”, not containing any of the wanted articles in the pick order, when only 60 percent of the order is picked. This happens due to an uneven distribution of different articles in the ASUs and it also becomes an unwanted constraint for the computer optimizing the pick sequence.
- A significant process waste is the fact that every article stored in the storage units, has to be manually counted, both when storing and picking, to ensure that the balance in the pick computer is correct. This is very time consuming without adding any value to the products or end customers. A balance error creates extra work for the picker and sometimes if articles are missing a whole new shelf needs to be presented which is time consuming.

To sum up, if every k-article is stored in the ASU, there will be no special treatment based on the turnover per article. This will increase the risk of sub optimizing the entire material flow. The described scenario is not realistic since some articles already have been placed outside of the ASUs mainly due to their size, but this does not eliminate the risk of sub optimization, since these decisions have not been based on facts but rather on feelings. Investing in a new ASU risks being a short term solution, since it is not determined how much the article assortment will increase due to the increase in business at the service department.

5.3.2 Rack solution

The opposite solution to the same problem, of increasing the storage capacity at Faiveley, is to empty all the ASUs and store everything on racks. This solution is not space efficient and it would require a lot of free floor area to set up. The racks are on the other hand cheap to invest in and can easily be altered to fit with changing material flows. Time studies together with SAM analysis will give an accurate average time needed, to pick an order from the racks. This can in turn be used to balance and optimizing the workforce in the warehouse.

Storing all k-articles in racks will increase the search time, per article. In the SAM analysis the search time is represented by the "read movement" (see Attachment 10.3). In order to find the right article the picker reads a three digit number on five different shelves at an average. With an increased number of articles, this search time will increase.

An advantage with a shelf solution is that parallel workflows can be achieved and several pickers can work with different orders at the same time, increasing the availability of all stored articles. A drawback with the shelf solution is that a new WMS is needed to keep track of every articles location. The system could either be electronic or manual in its design.

A manual system may for example be to arrange the articles in article number order. When new articles are introduced, they are placed "last" in order to avoid rearranging the warehouse for every new article. With a manual system it is likely that the time spent searching for the needed articles would increases because there is no electronic support system guiding the worker. An electronic system, on the other hand, would ease the management of the warehouse and increase availability. An electronic WMS should include a route optimizing function, similar to the ASU computer system, to ensure minimal backtracking and crossing flows during the pick process.

In this solution the s-articles will also be stored on racks. These articles tend to be stored in smaller quantities, usually they would fit in a single standard plastic container. If the racks were flow racks this would present a problem because the one article, fitting in one plastic container, would require as much space as another article, fitting in three plastic containers, this because different article numbers cannot be stored behind the first plastic container on the shelf.

Two specific kinds of wastes that the shelf solution may create are:

- Searching for a specific article among all of the 1249 k-articles, will be time consuming. The time spent searching is typical waste and should be minimized.
- When all articles are stored in racks the fist article picked will have travelled quite some extra distance since it will follow the picker. This transportation increases the strain on the worker especially if big orders are picked and the total weight of the articles is significant.

With the shelf solution the material flow will be the same for all k-articles, no matter if they are f-articles or s-articles. This is not desirable from a supply chain point of view. For example an f-article is more likely to be needed than an s-article and therefore the handling and flow of this f-article should be prioritized.

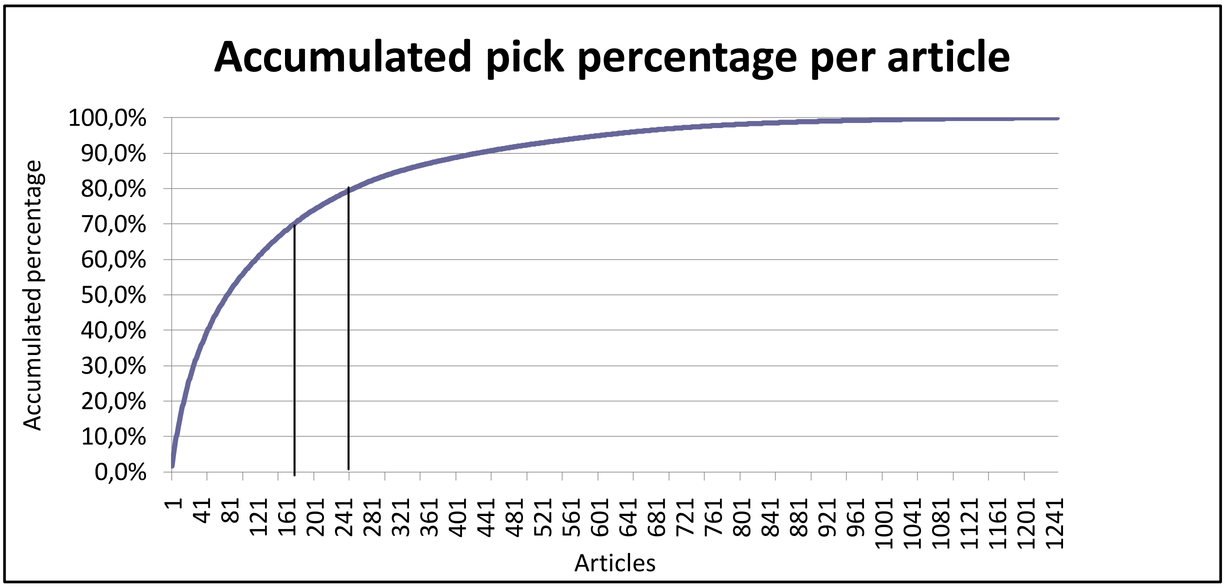
5.3.3 Fast pick area solution

A hybrid alternative, with a mix of ASUs and racks, from here on called Fast Pick Area, FPA, is a third solution. The main idea behind a FPA is to increase the availability of articles with a high turnover, f-articles, and in the process minimizing their handling time. Articles with a low turnover, s-articles, are kept in the ASUs or in the high storage depending on their sizes. This means that space utilization still will be kept at a high level. Minimizing the handling time of f-articles will make the process more cost effective and time can instead be spent on continuously improving the work routines and flows. The FPA will also improve the f-article visualization, compared to the ASUs and rack solution. It also creates a good overview, which could help an FPA-General who would be responsible for storing, picking and improving the FPA.

Creating a FPA have a low investment cost, since it requires no new system or machinery apart from racks. With an implemented FPA solution, there is a potential to keep initial investment cost low since Faiveley are already have some potential racks for the solution.

A FPA allows for parallel work flows. The picking of the same or two different orders can be executed at the same time, one in the FPA and the other one at the ASUs. The parallel workflows capacity can be increased to meet peaks in demand. There can even be several warehouse workers picking several different orders in the FPA at the same time, which also increases the capacity of the solution. It is important to take into consideration that there are some limitations. Too many warehouse workers in the FPA, at the same time, can cause queues and with an increase in size of the FPA, comes increases picking times, due to transportation time and search times for specific articles. Generally the possibility of parallel flows would be an improvement, with a decreased probability of queuing, compared with an entire shelf solution or an increase in the automatic storage solution. Since the most popular articles are placed in the FPA, it increases their availability towards the internal customer. It is important that routines and article classification, concerning picking at the FPA are established to minimize waste, caused by confusion and ineffective handling.

The FPA concept is flexible, since it can be adapted to fit with area limitations compared with the previous mentioned racks solution. Even a small introduction of f-articles into a FPA solution, will have significant reduction in pick times. The graph below shows how many articles that stand for a certain percentage of the total number of picks, made by the warehouse. For example 250 articles, around 20 percent, stands for about 80 percent of all the picks in accordance with the Pareto principle (see Graph 4). The tangent of the curve can be seen as a measurement of how much that can be gained, by storing the article outside of the storage unit. The steeper the tangent, the more savings there are to be made. These claims can be a bit misleading however since Faiveley already have places some f-articles outside of the storage units and this is not taken into account in the graph. It can also be more easily adapted with other improvement suggestions, for example using original or customized cartons.



Graph 4: Accumulated pick percentage per article

To keep track of where articles are placed, minimize search time and facilitate introduction of new articles in the FPA, some sort of organizing system is needed. This system can either be manual or electronic it its design.

With an FPA solution, with fixed storage, the warehouse workers would not have to weight/count when storing, as long as the articles are distributed evenly in the carriers to facilitate the material flow. In this way the size of the plastic containers will automatically regulate the approximate amount of articles per container. The point of counting the articles when storing in the ASU is to tell the computer how much and where the articles are stored, this step is no longer necessary. The number of times an article is stored during a year is far less than the number of times it is picked. Still it is important not to sub-optimize the storing activity. The time measured for storing an article in the ASU, according to the time study, was 71 seconds. The SAM analysis showed that a theoretical time for storing one article in a FPA is 29 seconds, which is a 59 percent faster than storing in the ASUs.

Some of the k-articles that are delivered to Faiveley, in great quantities, are shipped in bulk on EUR pallets with one or two collars (see Picture 10). The time study shows that storing two carriers in the ASU could take 142 seconds (71*2). The SAM analysis shows that storing two carriers in the FPA, of the same article, would only take 36 second, which would be a decrease of about 75 percent (see Attachment 10.3).The articles in the picture, would roughly require 10 carriers and take about 618 seconds longer to store in the ASU, compared with the FPA.

Picture 10: K-article shipped in bulk

Piece picking an article from the ASUs takes on average 60 seconds. The SAM analysis for the same action in the FPA would be 45 seconds (see Attachment 10.3). This means that if 186 f-articles were to be piece picked from the ASUs, the total picking time, for 2010, could be 816 hours. These 186 f-articles stand for 72 percent of the total amount of picks. Piece picking these 186 articles from the FPA would take about 615 hours, which is a 25 percent decrease in time. The FPA is also a good foundation for a Kanban system, which would help to increase time savings even more. These theoretical time savings, in storing and picking, could both help to reduce the effects of the ASU as a bottle neck but also improve the total cost efficiency at Faiveley.

One possible layout of a FPA

Using the limit of 100 transactions per year, the FPA would include 186 articles. The authors estimate that every article, in the FPA on average, needs three positions that are three plastic containers deep. With nine small plastic containers per article, 186 articles will need a total of 1674 small plastic containers. If the type 2 rolling rack is used, they can fit 120 small plastic containers, each, which mean that 186 articles require about 14 racks. Due to the fact that there is a need for piece picking articles, and sometimes in large quantities, a scale should be placed in connection to the racks. The scale could be placed in the center of the FPA resulting in a longest transport distance of 4.6 meters. According to SAM analysis this transport should take a maximum of 4.6 seconds.

One possible layout of a FPA consisting of 14 rolling racks with a maximum distance of 4.6 meters to the scale could be two parallel lines, with the scale in the middle (see Figure 11). Refilling the racks can then be done from behind and the picks are done in the center. Granted that the racks are placed along walkways, so that no extra space is needed for replenish aisles, the needed area would be about 62 square meters.

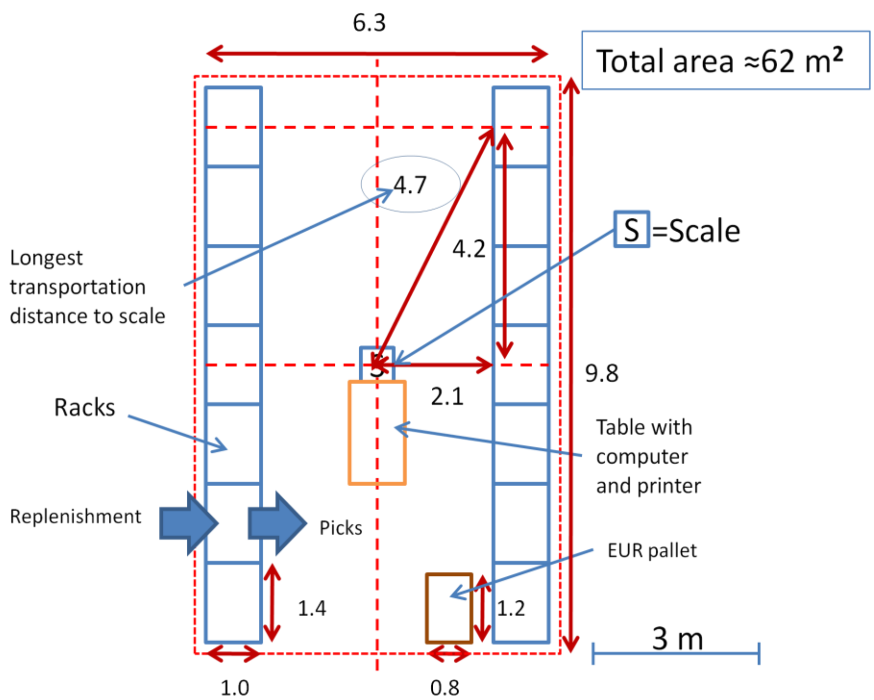


Figure 11: One possible layout of a FPA

5.3.4 Fix and floating storage

The main benefit with the ASU is the high space utilization. Since the articles have floating storage positions the space utilization is almost optimal. For a FPA to have floating storage space the picking area requires a WMS to keep track of the articles. With fixed storage spaces in combination with a clear labeling system of racks and carriers, the picking procedure can be conducted faster than the ASU, even without a WMS. With fixed storage spaces the replenishment and picking of articles in the FPA should be simple and fast with minimum of transportation waste.

5.3.5 Kanban flow

The most frequently used articles, are the most suitable to have in a Kanban flow. In general, the frequently used articles have a more regular demand and higher potential for improvements to reduce waste. The Kanban flow can be designed to cover the demand for a certain period of time, for example two weeks at an assembly station.

If Kanban signals are collected, accumulated and then dealt with, when "there is time", it creates waste and actually turn the pull system into a push system. Theoretically there should not be any need for more than one carrier at the assembly station. Ones a carrier is empty, it should be replaced by a new one, in other words, the right article at the right place at the right time. The authors have already shown that that there is a potential to save time by not weighting the articles when storing, similar time savings can be done when articles are picked in a Kanban flow.

To simplify a Kanban flow to the assembly stations, there could be a few central points, where all empty Kanbans are placed. In doing so, the warehouse personnel maintaining the Kanban flow, only needs to visit a few places in order to collect all the empty Kanbans. This could in turn be organized into a daily routine, which could take place when demand for picks is low, thus leveling the flow. In some cases, where the articles are very bulky, and not suitable for storing in plastic containers, the original cartons could be used as a Kanban. This solution requires, that the material flow is modified, for example with modular racks in both the assembly and storing areas. This could be a part of the Kaizen work.

A vision could be, that all articles stored in an FPA, should be Kanban articles. If the 186 most frequently picked articles would be Kanban picked, instead of piece picked, this could reduce the picking time from 816 hours to 175 hours annually (see Attachment 10.3), a reduction of 79 percent. One possible issue might be that the correlation between the amount of articles in Movex and the sizes of the plastic Kanban containers are off. If for example Movex says that there should be available Kanban articles in the FPA, but in reality all the available articles have been sent to fill up for example the assembly stations. Reasons for this might be that the article actually is not suitable to be a Kanban article, or it might have been an s-article, close to the line and the flow for this article should be changed. The plastic container working as a Kanban might be too big, containing enough articles to supply the assembly station for several months.

Since the Kanban is a self replenished system, with clear signals, the administrative work would be reduced. A Kanban pick will not require any pick list or Movex updates. This time and focus can instead be shifted to the piece picked articles. Since a functional Kanban flow should provide the assembly stations with at least one weeks of supply before replenishment is required, the Kanban work can be conducted during a time when demand for picks are low.

Example

In this example the article 1410283, (see Attachment 10.5), is used to provide the reader with a deeper insight into how a Kanban flow could be functioning at Faiveley. The total pick frequency is 340 picks per year, with 136 picks per year to assembly, which makes it suitable to locate in a FPA. The article is not very bulky, but a little bigger than average. Today, 300 pieces are put in a 12 x 12 plastic container, weighing about 13 kilograms. With a total average of 605 pieces picked per months, equal to about two weeks supply. The weight and supply per container is within the set boundaries for a good Kanban size, but will be even better if switched to the small plastic containers. If so, the weight would be 6.5 kilograms and the supply, per plastic container, would be equal to about one week. Using the small plastic container the total number of Kanbans in a FPA would be about 14 containers, where two should be placed at the assembly stations. Note that the maximum amount of this article being stored at Faiveley during 2010 was 3365, which would require at least 23 small plastic containers, which is one reason why the article flow needs to be leveled. This will be further analyzed in Lean Management.

Today it takes about 5.7 hours per year, piece picking article 1410283. If introduced in a Kanban flow it would take about 11.3 minutes per year, which gives a 97 percent increase in productivity. If the Kanban flow of this article is restricted to assembly, the productivity would still increase with about 37 percent. This does not include the reduction in the administrative work connected with piece picking. With a standardization of articles, the irregularities in demand should decrease. Some s-articles could be replaced by f-articles and the Kanban should result in even higher productivity overall.

Piece picking flow

The possibility of piece picking articles from the ASUs, racks or FPA solution is an important point which must not be overlooked. The KO and retail kits will require this function. Since the articles in the Kanban flow and the FPA are not tied to a specific order until they are used, this will not be a problem. Every article in the FPA will be available as long as Movex says they are.

5.4 L002

The three ASUs have some advantages, which were analyzed in the Waste reduction chapter. Even with a FPA implementation the advantages of high space utilization could be exploited for the s-articles. There is a potential to improve the pick frequency of the ASU, without investing in a new machine. Slow moving s-articles may be placed on shelves, as far up as possible, in the ASUs, in order to allow the more ”popular” s-articles to be stored closer to the pick area. All the s-articles should also be stored evenly in all three ASUs to get the most even utilization of the machines. All three ASUs should work together with one order to ensure highest possible capacity. In this way, the machines internal lead times could be decreased, which in turn decrease the total pick times from the ASUs. These time savings will show when two pickers use the ASUs to pick the same order.

The ASU creates a conflict of interest between the service department and the planning department. The planning department constantly tries to minimize the capital tied in stock by using JIT in the production. On the other hand, the service department depends on having articles in stock to be able to fulfill unexpected demands, arising during service projects. This has lead to misunderstandings when service have used articles in a SO, that were planned to be used in a TO, by the planning office, but had not yet been allocated to the order in question. The solution that

Faiveley have come up with is to buy a new ASU in order to physically separate the stock and create a new separate warehouse for the service department called L002.

Creating a whole new warehouse for the service department would have its advantages. It would certainly decrease the risk for double allocations or “stealing” articles between the two departments. The downside is that it would require additional personnel to maintain, store and pick from the new L002, together with increased administrative work in the form of separate orders being place from service department. Dividing the ASU’s means that their full capacity cannot be utilized, this would make them an even bigger bottle neck. More capital will be tied in equipment and stock as well. Another drawback is that the FIFO principle cannot be ensured with two physically divided warehouses.

A risk with a separated L002 could be that the stock levels might rise due to the high minimum order quantities for certain articles and two separate safety stock levels. On the other hand, this could be avoided, if L002 always order their articles from L001 and Faiveley places their orders from one central function in the company. The separation and physical transactions between L001 and L002 will probably cause an increase in motion waste. This motion waste will become even greater if a FPA became part of the L002. Theoretically this would create a divided FPA with one L001 part and one L002 part, in other words four separate storing locations.

An alternative to physical dividing the L001 and L002 is to create the separated L002 in the computer system, Movex only. The system would keep track of the SO and place orders for the foreseen demand as usual. The unforeseen demand would be fulfilled from the virtual L002. When the ordering point for an article in L002 is reached, an internal electronic Distribution Order, DO, is sent to the planning department, who is in charge of L001. The DO requests the amount of articles that is required to electronically “fill up” the L002 supply of a specific article. At this point of time the service department should have about one lead time worth of supply, to cover any unforeseen demands, for the specific article in L002, until the DO has been approved by the planning department and the electronic transaction has been made. This would decrease the risk of, for example service “stealing” articles that are planned to be used in the assembly.

When the DO is electronically confirmed, the articles will be, immediately available to the service department. Since all TOs have a long lead time, the demand for k-articles in L001 is very predictable. With the short lead times that most k-articles have, there is now no longer any need for a large safety stock in L001. If the situation should occur, where L001 would have a shortage as example due to a delay from a supplier, then L002 could cover this shortage.

The service department should be responsible for optimizing the size of L002 and setting its order points. This would be a part of the Kaizen work, to continuously try to optimize the L002 balance, with a long term goal of minimizing capital tied in stock. Overall, the total amount of articles should not need to be increased with these electronically divided warehouses. With a better insight, Kaizen work and better cooperation between the planning and service departments, the total amount of stock should decrease over time.

Connecting the service department to the Kanban flow might first seem like an obvious improvement. According to the classification chapter, an article which has more than 100 transactions should be in the FPA and be evaluated, to see if the article is suitable for the Kanban flow. The same applies for any article, with more than 100 transactions for service orders alone. But when it comes to service, the number of transactions might be a bit deceiving, since SO orders often contain fewer BFC units than TO orders. This could mean that a TO Kanban might contain an annual supply of an article for the service department, even if there are more than 100 SO transactions per year, containing that specific article. This information is hard to see in the collected data, especially since spare part kits are put together as TOs and then used to fulfill SOs at the service department. A Kanban flow for the service department would also enable "stealing", if a Kanban container includes articles which are not part of L002. The authors recommend that further research is conducted in this area to see if there are any suitable articles to have in a service Kanban.

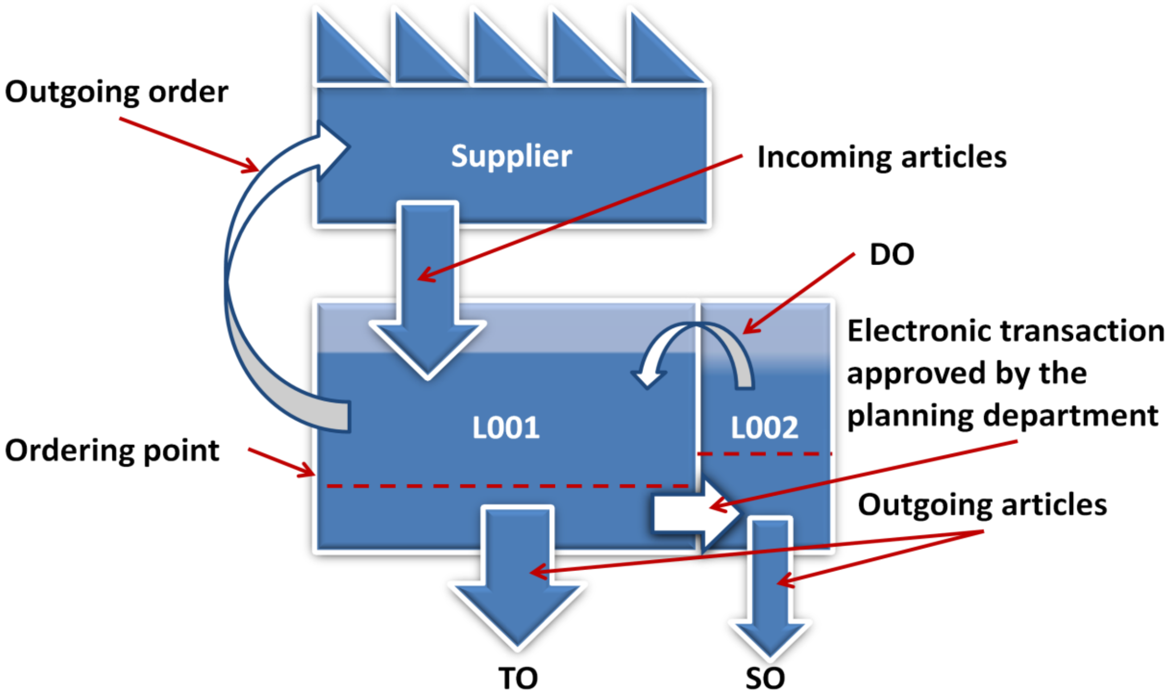


Figure 12: Theoretical picture over the electronic L002 in Movex.

5.5 Lean management

When minimizing waste, it is important to keep a holistic view and look at the whole supply chain. If an activity, defined as waste, is made more efficient or removed but at the same time creates more or even a new wasteful activity, somewhere else in the supply chain, the change is pointless. These types of waste tradeoffs can often be seen between Faiveley factory workers and management. This chapter will bring forth some of these tradeoffs and at the same time analyze some alternatives on how work can be conducted and divided, to create a more Lean way of working.

According to Toyota, specifying work is when every bolt is tightened in the same way every time, there is no unnecessary work being conducted and no room for errors. The authors would like to point out that they do not recommend, unlike Toyota, Faiveley to specify every work sequence, because the factory workers at Faiveley have a broad area of responsibility so it cannot be specified in great detail. By assigning more clearly defined but broader responsibilities for different areas, problems will be attended to and dealt with, before it becomes a high management issue.

5.5.1 Heijunka

The takt time at Faiveley has been proven to fluctuate relatively often and there are different reasons for this, but also different options to handle this problem. The reason why this is a problem is confirmed by the theories in Lean. Since variation, Mura, leads to waste in time and resources, it is desirable to level the work load to create stability. When the workload is frequently peaking different days of the week and different weeks in the months, the actual workforce needed is hard to determine. These peaks in work load can be seen as a high internal demand for picked articles. This internal demand can originate from many different sources, like for example, quality issues or supplier delivery reliability. The bullwhip effect, which often is used in a context of demand between suppliers in a supply chain, can sometimes be seen in Faiveley's internal flow as well. When there are peaks in workload in different areas at Faiveley, it is often transferred and increased in effect, to the next step in the internal supply chain.

When asking the question of "why did we not make our deadline?" one of the most common answers given are "If only we had all the parts we need, we could assemble all we need, without any problems." Focusing and blaming this issue on one problem alone can cause for example management to increase stock levels, increase the workforce and spend a lot of resources on improvement projects with the one purpose to fix this problem alone. The factory workers might lose their trust in the management, since the problem is difficult to solve quickly. The improvement work, conducted by the factory workers may go to a standstill, because all resources are dedicated to reducing the effect of missing parts. All of this creates irregularities with peaks and valleys in demand.

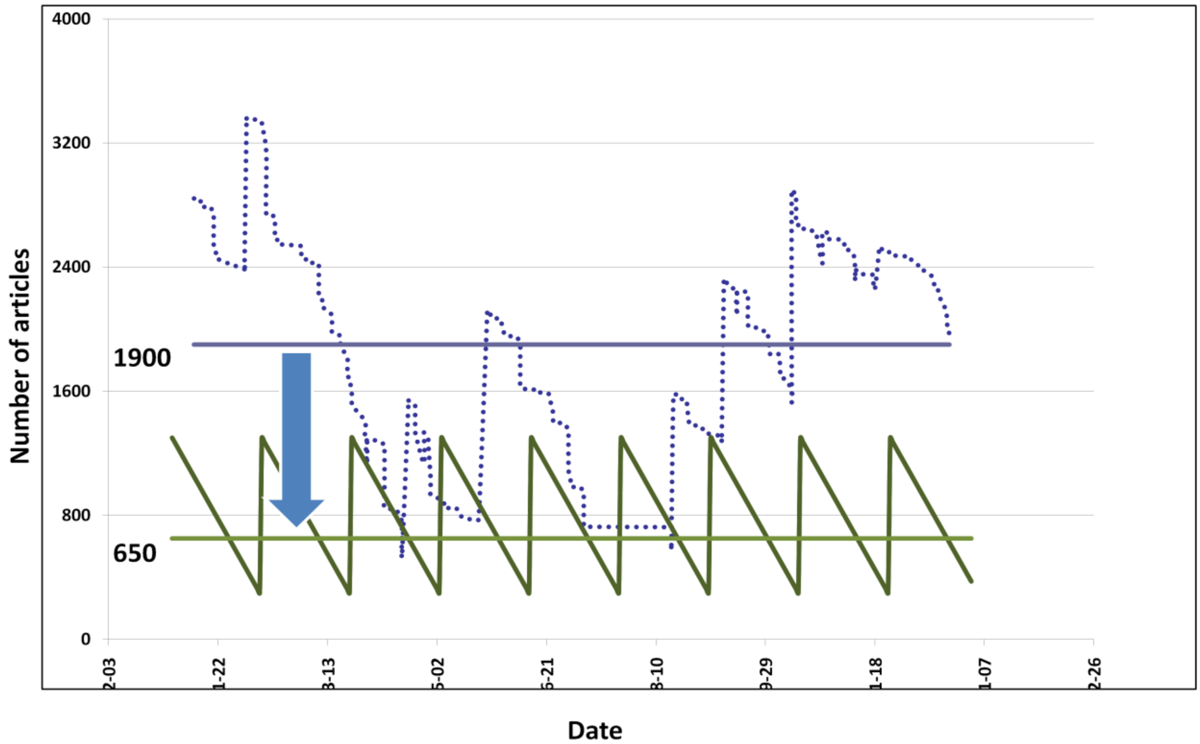
The authors have divided the way of handling these peaks of internal demand, into two main options. The first one is to minimize the effect caused by bottlenecks. Using the Japanese lake metaphor, this symbolizes removing the visual rocks from the lake. One bottleneck was observed at the ASUs when the demand of k-articles was high. One reason why it is a bottle neck, is that the maximum capacity for two warehouse workers are limited to about 125 percent. Capacity constraints like this means that some extra resources are needed at one place, while at the same time some other activities may stand still, which in turn can create new problems with longer lead times, availability and costs. Minimizing the effects of these types of bottlenecks will both reduce waste but also, more importantly, reduce the effect of irregularities. Some suggestions on how this can be made have already been analyzed in the Waste Reduction chapter.

The other way to handle peaks is to try to level the variation in internal demand, which is more of a continuous management issue. Using the Japanese metaphor again, lowering the water level and making rocks visual. Faiveley management is actively working on being flexible by moving orders, activities and workforce, and in some cases, temporary expanding the workforce. Observations of overproduction, excess inventory, assembling cripples and pick-orders that are only 99 percent done are waste and can be seen as a side effect of the flexibility. This indicates that it is not only hard and important to handle peaks in demand, but also to handle the valleys in demand. Moving activities, resources and workforce around can also create shortages in capacity elsewhere. It also hides problems and makes it difficult to find the reasons why shortages occur in the first place. In other words, the desire to level variations in demand should not be reached at the expense of increased waste.

Ordering and assembling big batches of articles is a source of peaks in demand. Bigger batches lead to more irregular takt time, which in its turn lead to less flexibility and more waste in form of waiting. In the warehouse the high minimum order quantity, of k-articles, contributes to less handling of incoming goods, which can be portrait as a low amount of motion waste and transportation waste. But seen from a leveling perspective, the total amount of waste actually increases with the increase of irregularities. Instead, by increasing the frequency of orders, by lowering the minimum order quantity, will result in a more leveled flow of articles, which in its turn will result in a more leveled workload. Leveled work is more value adding, with less overproduction waste, higher utilization of personnel and space. An added result of this is also the decreasing batch sizes and amount of stored articles in the warehouse, which will in its turn reduce the weight of each batch and the amount of tied capital in storage.

Example

One way of detecting irregularities are by studying the data. In this example transactions for article 1410283, (see Attachment 10.5), is extracted from Movex and analyzed. The average consumption of this article is 605 pieces per month with an average stock level of 1903, which is more than three times the consumption. The maximum amount of articles, during 2010, were 3365 pieces while the minimum were 548 pieces between the time period 4/2 to 19/4 2010. There were time to receive a new order, before reaching the set safety stock level of 800 pieces, but more than one months of supply were used during one week alone, just before the delivery arrived. This shows that the planning, picking and storing is irregular, and it also shows signs of overproduction waste and excess inventory waste. The articles only cost about 7.2 SEK per piece so the average capital tied in stock is only about 13 700 SEK per month. By increasing and leveling the order frequency from 6 to 8 orders per year, the average stock level would be 1300 pieces per month. By lowering the safety stock level from 800 to 300 pieces, the average would be 650 pieces per month. That represents a decrease by 65 percent, which would reduce the tide capital in stock with 9 000 SEK per month. This is of course interesting, but will only make a significant difference, in tied up capital, if the same is possible for all k-articles. However, the amount of tied capital does not increase the cost of the k-articles significant and it must therefore never be used as an excuse to lower the availability of the articles. The point that is made here is that it is mainly the amount of work that increases the costs of the k-articles. Multiple transports, counting/weighing, storing, picking, status updates before final assembly are all activities that multiply the costs for the articles multiple times. The more unnecessary handling of articles, the more waste they cause. This is why handling and waste, associated with k-articles needs to be reduced and leveled, according to Heijunka.



Graph 5: Example of irregularities for article 1410283

5.5.2 Kaizen

The eighth types of waste are "Unused creativity among employees" which is one of the most important reasons for implementing Kaizen.

Decentralizing the responsibility is an important part of Kaizen but it requires trust. One example of this is the materiel flow of batch articles. Delegating the responsibility to the assembly workers of making sure that batch articles are clearly registered and connected to the assembly orders, when used. This can result in mistakes that are difficult to correct, but it also has some benefits. If and assembly order is delayed and another one is prioritized instead, the assembly workers still can use the available batch articles, since the connection between order and batch articles is not made in advance. A new set of batch articles does not need to be retrieved, which saves both time and space for the assembly personnel. For this to work, the responsibility for upholding the traceability must lie on the assembly workers, which requires well established routines and trust from Faiveley management. Another problem, which makes this difficult for Faiveley to implement, is that their ERP system, at the moment, does not support this type of linkage between batch articles and orders. A recommendation could be to see if this functionality could be implemented when the next generation of ERP system is launched at Faiveley.

When interviewing personnel from different parts of Faiveley, it is clear, that the majority have many years of experience and knowledge. A lot of the problems, which are mentioned in interviews, are handled through self-evolved ideas. For example reprioritizes of orders, made by the Faiveley management, have fast transitions with little time and information. These fast transitions are made possible by the built up experience of the factory personnel. There is no documentation or defined ways of working to handle these fast transitions or the problems that creates them. This makes it difficult for both personnel and outsiders to understand how the work in these transitions is conducted. Short term, this way of working is a very efficient way of handling problems since it requires minimum input of work from management. Long term, however, some problems are never visualized and can therefore never be corrected at the source. In short, one can say that the factory workers are constantly learning, but not the company. From a Lean perspective, by not engaging and listening to the workers, the company is wasting time, competence, creativity, ideas and opportunities to improve and learn as a whole.

There are different models that may be used to evaluate problems and create improvement suggestions. One of the most common models is PDCA, which is included as a part of the ISO 9001 certificate, which Faiveley possess. Because of its simplicity, it is a good base to use when working with improvement suggestions, making sure that even small improvements have effect. Bigger improvement suggestions are more demanding to implement and needs to have a well thought out plan that are understood by all affected personnel.

Once a plan has been made up for how to proceed with an improvement suggestion, Lean encourages fast implementation, with an 80 percent focus on trying and only 20 percent personnel education. It is more important to try and maybe fail, than to never try at all. That is why both management and factory workers needs to stand behind the suggested improvement, from the start, and have perseverance, since results might not be seen on a short term basis. The incentive for future improvements comes when the effect can be measured and is found to be beneficial in the long run.

Documentation enables measuring the success and follow up the effect of the Kaizen work that is conducted. The documentation could also serve as a foundation for future Kaizen work and as an incentive, visualizing the constant improvements and development of the company.

Example

One example of how to use the concept of Kaizen is to describe how the decisions and work with a potential improvement like, a FPA can be conducted. Kaizen stresses the importance of having the best person making the improvement decisions. A bigger decision like improving the material flow by implementing the concept of FPA should be made by someone who has good knowledge of the articles, but also know how to extract the needed information from the ERP system. This person should also know how to use the information and what available area and financial means that may be used. But Kaizen also means constantly improving, so decisions must be followed up, reevaluated, further improved and documented. The same person, who made the decision, can be part of a Kaizen group consisting of people with different knowledge and experiences to get a broad range of experience, suggestions and feedback.

When initially deciding which articles that are suitable for the FPA, there is always room for mistakes due to the fact that analyzing each article separately, would be too difficult and time consuming. The wide variety of articles differs a lot in number of picks, quantity per pick, size and weight which makes the decision even harder. The FPA-General, who is responsible for, and working in the FPA, should have a deep knowledge about the articles. He is a part of the warehouse team and its daily/weekly Kaizen work. The team as a whole, should job rotate, to make sure that knowledge is spread and to ensure that as many ideas, as possible, are taken into account. If an article is identified by a person as not suitable for FPA, the decision to act and to move it to the ASUs should be made easy and fast. This constantly improves the FPA without adding to the pile of management decisions.

This example of Kaizen work includes managing the Kanban flow and the classification of Kanban articles in the FPA. For this to work efficiently the decision making process needs to be documented, defined and decentralized. Kaizen suggests that improvement ideas, decision and implementation should be made by the person closest to the problem, in collaboration with the Kaizen team and a sensei/leader.

6. Conclusions

In the conclusion chapter the authors makes a short discussion concerning the validity and reliability of the master thesis and also the connections to the research questions. The conclusion chapter sums up the authors' thoughts and ideas for the master thesis.

Conclusion introduction

Ensuring the validity and reliability in this thesis has been an important part of the work. The authors have constantly tried to triangulate the data from several different types of collection models like interviews, observations, archive analysis and established theories. Different sources have been used for example individuals working at different parts and levels of the company. There have been several informal observations and talks during the time of the project, which has added much information that might have been harder to collect through formal, recorded interviews. During the informal talks, several of the authors' proposals for improvements have been discussed, confirmed/rejected and developed further. Since the authors have spent so much time at the company, taking a lot of individual thoughts into consideration, have made the thesis applicable but also to some extent affected the work. The improvement suggestions might have been affected negatively, from an objectivity perspective, but it has also made the suggestions more relevant for Faiveley.

The research questions in this thesis have been answered by developing several suggestions that improves the flow of material and information at Faiveley. The reduction in capacity constraint, picking time and improved routines and measurements, with help of the different Lean philosophies, will make it possible to handle peaks in demand as well as an increase in the k-article assortment, without hiring additional workforce. The FPA is an example of an improvement, where several of the Lean philosophy models can be implemented to increase visibility, cost efficiency and availability of the flow of materials and information. A visual example can be seen when comparing the two process maps (see Attachments 10.8 and 10.9).

6.1 Classification

Classification of articles is an improvement on its own, but also the foundation for future improvements in the flow of information.

Classifying k-articles into clearly defined classes, with clearly defined flows of information and materials, will improve the overall material handling of k-articles by reducing waste like confusion, uncertainty and special treatments of certain articles. Classification will also increase visualization and help to produce easy workable data for future classifications and improvements.

Classify k-articles as fast movers, slow movers and Kanban articles. It is important to base the classification on a combination of measurements, experience and a classification model. This should be an annual routine, in combination with the Kaizen work in the FPA. A strong focus on only one of the factors will sub optimize the classification. The classification of fast moving articles should be based on articles with a total of 100 transactions per year or more, not the volume value of the articles. Slow moving articles are articles with less than 100 transactions a year and should be stored in the ASUs. As many of the fast movers as possible should be converted into Kanban articles, with the exceptions of articles that are too bulky.

A clear classification will contribute to increased visibility which in turn is a foundation for the following improvements suggestions in the thesis.

6.2 Standardization

Standardization of articles, carriers and racks is an improvement on its own but also the foundation for future improvements of the materials flow.

Standardizing the k-article assortments for present and future BFC models, starting in the engineering department, will present economies of scale on a long term basis. Standardization will reduce the effects of an increase in the k-article assortment, due to an increase in business, while facilitating efficient space utilization in the warehouse and the assembly stations. A more standardized k-article assortment will reduce: process waste, excess inventory waste and overproduction waste.

A problem at Faiveley is that carriers are usually too big and contain several weeks and sometimes even several months' worth of supply for a single article. By choosing the so called small plastic containers, with its robust design, as a new standard carrier, will reduce the number of pieces, weight and also increase the visualization and easy access. The choice of plastic container facilitates the use of different colored plastic containers as signals in the materials flow.

The choice between the type two rolling racks and new modular racks is a question about how much Faiveley is interested in investing in flexibility. Both solutions support FIFO and can be adjusted to "golden zone" picks. The biggest reason for choosing the modular racks is the flexibility in height and the overall ability to experiment with, and modify these racks as a part of the Kaizen work. Modular racks in combination with the small plastic containers, plus a maximum of two other sizes, will be a very visual, flexible and space efficient way of creating an efficient FPA.

Introducing a new, short positioning number for storing articles, in the FPA and assembly stations, in the form of "Rack-Shelf-Position" number, has the advantage of decreasing search time and gives all the information about the articles and their flow.

6.3 Waste reduction

A hybrid solution with a mix of ASUs and racks solution would be to create a Fast Pick Area. Articles are transported directly from the arrival station to the FPA, where the racks are replenished from behind, according to FIFO. The FPA solution has a low investment cost compared to an investment in new ASUs.

Due to the simple concept of the FPA, the visibility and availability of k-articles will be high, decreasing the waiting waste and therefore satisfying the internal demand more efficiently. The design and amount of articles that are stored in the FPA is very adaptable and expandable and are only limited by the amount of space that Faiveley are willing to use. One of the benefits with the FPA is the flexibility, both in its layout and also in the number people working there. People who are working, thinking and learning are the most flexible resource there is, compared to atomization. It is for example easy to expand the workforce in the FPA without creating queues, if the internal demand for picked articles is remarkably high.

The FPA solution allows for different flows, for different types of articles, based on their annual turnover and size. The f-articles, articles with more than 100 transactions per year, are in total 186. These should roughly fit in the 62 square meters that the authors propose as a starting point for the FPA. The f-articles in the FPA and the s-articles in the ASUs make parallel workflows possible. The parallel workflows reduces the capacity constraints, while taking advantage of the high space utilization of the ASUs, in combination with a reduction in the overall picking time by about 25 percent, if all articles were piece picked. The FPA solution does not require the warehouse workers to weight the articles when replenishing the racks, reducing the storing time by 59 - 75 percent, depending on the minimum order quantity. This way of storing and picking will reduce both motion waste and waiting waste.

Kanban flow

Since an article has to be placed in a plastic container, before it arrives at the assembly station, this should be done immediately, when the article arrives at the FPA. A FPA-general, responsible for the Kanban system, makes a daily round to collect empty Kanbans, which serves as signals for refill, at central collection points in the assembly area. The empty containers are placed in the racks from behind and full Kanbans are picked from the front and delivered to the assembly station, all within the hour. When a new f-article arrives at Faiveley it is transported to the FPA and the FPA-general stores the articles in the empty Kanban containers.

Since the Kanban system is self replenished, at the assembly stations, there will never be a shortage of articles, given that the daily round is conducted. There will not be a need for any pick lists since the point of Kanban is that every empty container with a label is a clear signal to be refilled immediately. The label also shows were the Kanban should go when filled. Given that all 186 f-articles were introduced into a Kanban flow there would be a reduction in total pick time of roughly 79 percent, compared to piece picking in the ASUs.

Piece picking

Piece picking should be done in plastic containers instead of a zip lock bags for the internal flow. This is to increase the efficiency and minimize the irritation of handling the bags at the assembly stations and warehouse. To minimizing the effect of confusion created by having more plastic containers in circulation, the piece picking plastic containers should be in a separate color, so that they never get mixed up with Kanban containers.

6.4 L002

Create an electronic warehouse for the service department, to avoid “theft” of articles. A transfer between the warehouses needs to be approved by the corresponding system owners.

This should be done without increasing the total stock level. A physical separation, of the warehouse, is unnecessary and will only create waste due to article transports between L001 and L002, capacity constraints in the ASUs, a loss of FIFO and extra handling by separating arriving articles.

6.5 Lean management

Work routines and areas of responsibility needs to be established to create a sense of commitment, locate problems and handle them quickly. The workforce still needs to work as a team and should rotate between the different areas of responsibility, to reduce the risk of isolating knowledge. A holistic view needs to be established so that focus and problem solving is not isolated to one thing, like for example shortage of articles.

6.5.1 Heijunka

High internal demand, connected to the article flows and the work that is involved in handling the products are usually transferred through the supply chain. These irregularities create peaks and valleys in internal demand and needs to be leveled. By working towards the goal of reducing reprioritizing of orders, better planning, smaller batches, smaller minimum orders, higher frequency of orders, shorter lead times from suppliers, shorter internal takt time and better distribution of the workforce, a more leveled and stable organization can be obtained. With a stable and leveled internal demand, the actual internal demand will be easier to evaluate, problems will surface and a better foundation for improvements will be established.

To sum up, the flexibility at Faiveley today creates waste. By leveling the work flow in the supply chain according to Heijunka, waste can be reduced and create a stable foundation for further improvements.

6.5.2 Kaizen

Kaizen draws its strengths from its simple concept of decentralizing responsibility and harness the creativity of the workers. Problems and improvements suggestions should be brought to the surface and dealt with in an organized way. When a problem occurs, the routine should be to go to the source of the problem and look, analyze the situation, bring problem to surface and ask why five times to determine the point of cause. Kaizen is not only used to solving problems, but also to develop and implement improvement suggestions, to prevent problems to occur in the first place. The whole of Faiveley should take active part in the Kaizen work. Small teams, on every level of the company, should be established. A sensei/leader should be appointed to lead and guide the Kaizen workshops and the implementation of the improvements that comes as a result. The work should be done according to a simple model, for example PDCA, and be clearly documented. The main purpose with a model like the PDCA is to get an easy, organized and structured way of working with improvements. The documentation serves three main purposes. It is as a way to measure the success of a project, a foundation for appreciation and act as an incentive for future projects.

6.5.3 Measurements and routines

Measuring is sometimes hard, it is easy to get it wrong and measure too much, but measuring is important because it creates knowledge. SAM and time studies have helped to create knowledge about some of the suggestions in this thesis. When using SAM and time studies the authors asked them self “why do we need to measure”, and the answer was to improve the materials flow. These measurements are in them self an improvement suggestion. It is important to keep in mind that it is not people that should be measured but the activities and processes that they are a part of.

Faiveley need more defined and updated work routines, with established measurements, to provide knowledge about the activities and create a foundation for further improvements. Lean promotes standardized work but it needs to be applicable for Faiveley. Establishing work routines like the “FPA-General” will ensure more standardized work with fewer irregularities. The FPA-General is not a specific person but an area of responsibility. Whoever is working as the FPA-General has a broad area of responsibility and is constantly evaluation and improving the FPA in collaboration with the rest of the warehouse team. The built up knowledge about the work that is conducted at the FPA needs to be distributed to the team, but more important, to Faiveley as a company.

This master thesis contains some specific improvement suggestions, but the authors are convinced that the thoughts and ideas presented can be implemented in a larger context throughout Faiveley Transport Nordic AB.

7. Recommendations

In the recommendation chapter all the thoughts, ideas and suggestions for improvements are summed up and presented in bullet points. A general recommendation is that Faiveley continues implementing the whole concept of Lean without focusing too much on individual tools.

Classification

- Classify k-articles in fast movers, slow movers and Kanban articles based on factual measurements, data and experience with the help of a classification model.
- Classify after transactions and not volume value of the articles.
- Make an annual review of the classification in combination with Kaizen work in the FPA.

Standardization

- Start standardizing the k-article assortment for future BFC models. If possible incorporate the present BFC models in the standardization program.
- Invest in modular racks and small plastic container and use them as the new standard carriers and use different colors on the plastic containers in the piece picking flows and the Kanban flows.
- Implement an easy to understand and standardized way of labeling the plastic containers and racks in the FPA, as well as the racks at the assembly station and introduce a new, short positioning number for articles in the form of “Rack-Shelf-Position” number.

Waste reduction

- Create a Fast Pick Area for f-articles with more than 100 transactions per year.
- Implement Kanban flow, for as many f-articles as possible, with daily replenishing rounds.

L002

- Create a virtual warehouse for the service department, to avoid “theft” of articles. This should be done without increasing the total stock.

Lean management

- Keep a holistic view and continue working towards improvements on a broad spectrum.
- Update and clarify defined routines and areas of responsibility and use job rotation.

Heijunka

- Work toward the goal of minimizing the reprioritizing of orders in the assembly.
- Level the flow of articles and work to create a stable foundation for future improvements.

Kaizen

- Decentralize responsibility for improvements
- Create Kaizen teams, headed by a sensei/leader, working according to PDCA.
- Use an easy, simple way to document the Kaizen process.

Measurements and routines

- Define and update work routines
- Create appropriate measurements to follow up on Kaizen work.

8. Future research

The future research chapter will handle topics that were either outside the scope of this thesis, were considered too comprehensive to include or to fit within the time constraints.

8.1 Line assembly

The Lean theory propagates line assembly in contrast to bench assembly. Michel Baudin goes so far as to say that, if the P-Q classification is done correctly, the only manufacturer that would not benefit from Line assembly are companies with extreme sized products like aircrafts. Since the scope of this thesis end at the assembly station a recommendation is to conduct further research into this area to continue to improve the efficiency at Faiveley.

8.2 Supplier relations

Some benefits could be obtained and problems like quality issues could be solved through better supplier relations. The supplier base for k-articles is relatively big and economy of scale could be obtained by reducing the number of suppliers. Introducing tighter relationships with the remaining suppliers to improve quality, improve the delivery accuracy and other possible joint venture improvements. This could be done through VMI and EDI. The main improvements in form of cost efficiency should be obtained for strategic products and are therefore recommended for further research.

8.2.1 VMI

During an interview with the Supply chain manager at Faiveley information about a possible implementation of Vendor Managed Inventory, VMI, was brought up. The base of the VMI concept is that the suppliers are responsible for the customer's inventory. This means that the customer, in this case Faiveley, can save a lot of money by reducing the amount of tied capital, since the articles does not change owner until the article is used. This also means that the supplier is obligated to make sure all articles are available at all time. The reason why the supplier does not overflow the customers' warehouse with articles, is the same reason why the customer does not do it, and that is because the amount of tied capital and unnecessary handling is not beneficial for either part. The risk of betrayed trust is usually regulated by contracts. In the past there has been research and discussions with suppliers about VMI, but none of the ideas where ever implemented. While discussing VMI with people at Faiveley and one of their suppliers, there was a lot of focus on the physical transportation of articles. One suggestion involved a plastic container flow all the way from the supplier to the assembly stations. This type of idea is the same as the customized cartons idea. If Faiveley are willing to increase the cost per article, this could reduce the handling significantly. One of the biggest benefits with VMI is also one of the biggest down sides. Due to the reliance on a supplier that is tied by VMI makes it much harder to negotiate prices and conditions. But this and the ability to better plan the deliveries, are the main reasons for the supplier to be interested in VMI.

8.2.2 EDI

A good foundation for VMI is Electronic Data Interchange, EDI. This basically means connecting the supplier to the customers ERP system. This enables better communication and visibility. If combining VMI with EDI the supplier can get a direct insight in the customer's stock levels and can thereby plan production, transportation and still keep a optimum stock level at the customer without almost any safety stock in the own storage.

8.3 Barcode system

To further reduce waste, connected to the handling of k-articles, could be done by introducing a barcode system. A barcode system could reduce the administrative work performed by the warehouse workers. System updates in Movex could be minimized to simple scanning operations. If the FPA would expand to the point where the search time and article balance mistakes are starting to become an issue, a barcode system can be a good complementing improvement. If a change would be made so that the batch articles were not connected to a specific order, a barcode system could also be used to ensure traceability at the assembly stations.

With a barcode system, reductions in Movex article balance can be seen in real time, thus reducing the chance of double allocations of the same articles. This type of improvements of visibility would improve a solution like EDI even further, since orders to suppliers would be based on more correct and updated data of work in progress and order stocks. It would be an even more important improvement if a VMI solution would be implemented. Suppliers in charge of articles in Faiveley's warehouse would need daily updates of the order stock, to base replenishment decisions on, to ensure availability.

Some possible risks connected to introducing a barcode system could be the risk of downtime due to computer system failure and communication problems. There would be a learning curve for using the scanners and the system. Further research is needed to calculate the actual decrease in administrative time and the return on investment for the system. Note that the investment calculation needs to include the programming cost to connect and adapt the barcode system to Movex. If Faiveley decide to implement a barcode system it would be important to ensure that the new system do not increase the complexity of the materials flows, keeping in mind the difference between increased complexity and new work routines.

Note that an investment like RFID might seem like the obvious choice to get the latest technology and stay ahead of competitors, but for a relative small company like Faiveley, this would just be falling for the classic "Silver bullet" phenomenon. To get a good return on investment on a RFID system would require a joint venture in the whole supply chain, including a majority of the suppliers and customers.

9. References

The reference chapter contains all literature, articles and internet sources that were used during thesis. It also includes the names, job title and years of work experience at Faiveley, of the people that were interviewed for this thesis.

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9.4 Interviews

Steinar Haugen, Supply chain Manager/Production Manager, 2 years at Faiveley

Karl-Erik Pärsson, Supply chain/Manufacturing planer, 32 years at Faiveley

Gerry Göransson, IT-Manager, 10 years at Faiveley

Leif Person, Warehouse/Maintenance manager, 20 years at Faiveley

Göran Andersson, Assembly manager, 28 years at Faiveley

Stefan Engström, Arrival station worker, 35 years at Faiveley

Maria Hangan, Warehouse group leader, 21 years at Faiveley

Ingela Åkersson, Warehouse worker, 22 years at Faiveley

Thomas Fagerström, Warehouse worker, 19 years at Faiveley

Jimmy Andersson, Warehouse worker, 12 years at Faiveley

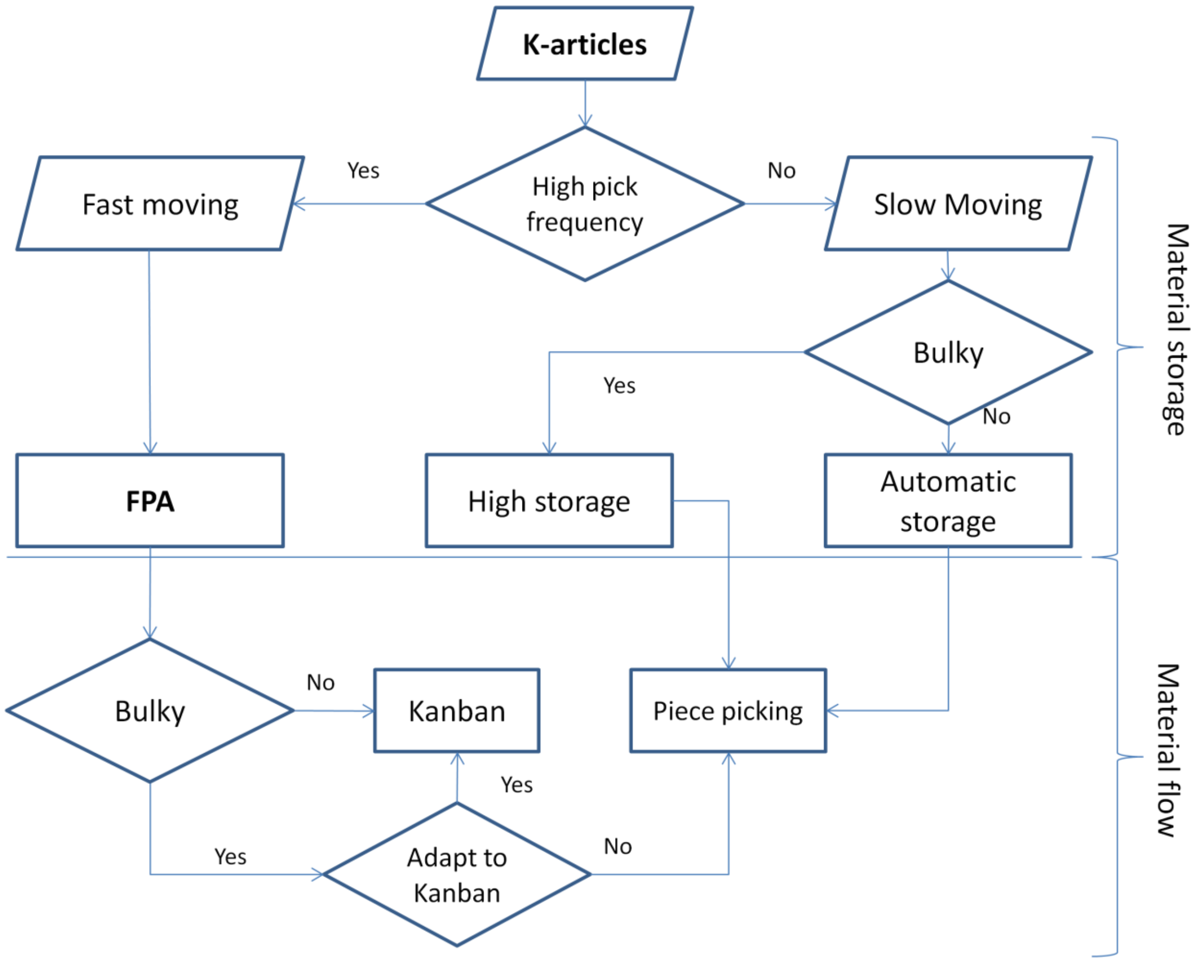
Mario Jukic, Warehouse worker, 10 years at Faiveley

Per Gabrielsson, Techno Skruv AB, 17 years working with Faiveley

10. Attachments

This chapter contains raw data, calculations and models that have been used in this thesis.

10.1 Attachment: Classification model



10.2 Attachment: Time study

Time study - Picking

Date	2010-12-15	2011-01-18	2011-01-19	2011-01-19	2011-02-09	2011-02-16	
Number of warehouse workers	1	1	2	1	2	1	pickers
Number of picking sequences	15	32	25	10	45	23	sequences
Measured time	19:08,0	24:11,0	21:51,1	10:46,9	39:44,0	27:20,0	minutes:seconds
Interruption time	02:45,0	00:26,0	04:14,0	01:09,0	02:07,0	00:00,0	minutes:seconds
Efficient picking time	16:23,0	23:45,0	17:37,1	09:37,9	37:37,0	27:20,0	minutes:seconds
Picking time per pick sequence	01:05,5	00:44,5	00:42,3	00:57,8	00:50,2	01:11,3	minutes:seconds

Mean pick time per pick sequence:	**00:59,8**	(1 warehouse worker)
Mean pick time per pick sequence:	**00:46,2**	(2 warehouse workers)
Increase in capacity	**0,23**	

Time study - Storing

Date	2011-01-18	2011-01-18	2011-01-20	2011-01-28	2011-02-15	2011-02-24	
Number of warehouse workers	2	1	1	2	1	1	pickers
Number of storing sequences	20	4	16	8	19	12	sequences
Measured time	20:31,0	05:25,0	18:28,0	07:27,0	23:37,0	13:52,0	minutes:seconds
Interruption time	02:03,0	00:17,0	00:11,0	00:58,0	01:32,0	00:00,0	minutes:seconds
Efficient storing time	18:28,0	05:08,0	18:17,0	06:29,0	22:05,0	13:52,0	minutes:seconds
Storing time per storing sequence	00:55,4	01:17,0	01:08,6	00:48,6	01:09,7	01:09,3	minutes:seconds

Mean storing time per storing sequence:	**01:11,2**	(1 warehouse worker)
Mean pick time per pick sequence:	**00:52,0**	(2 warehouse workers)
Increase in capacity	**0,27**	

10.3 Attachment: SAM analysis

General assumptions:

- All articles that are to be stored in the FPA arrive on the same EUR pallet.
- All different articles, that is to be stored, arrive separated into groups on the EUR pallet.
- Empty plastic containers are picked from "behind" in the racks.
- There is room on the EUR pallet for the articles, plastic containers and other equipment that is needed during the storing process.
- All original cartons and full plastic containers weight more than 5 kilograms.
- All hand, arm or body movements are longer than 0.45 meters.
- All movements, with a load, are longer than 0.45 meters.
- The picker always needs to check five shelves when looking for an article number.
- Searching is represented by the read movement.
- Opening zip lock bags are incorporated in the take and move movements.
- There are six factors to one second.

Assumptions for special movement patterns:

Walk over to the next rack, pushing a EUR pallet, with a step length of 50 centimeters.

	Factors	**No. steps**	**Time needed**	
STEP 3m	18	6	3	seconds
STEP 4.7m	28,2	9,4	4,7	seconds

Read and check which shelf the article are to be picked from

RB	35	5	Shelves checked

Moving an article weighting more than 5 kilograms adds two factors

Heavy/Extras	2

Summary

	Factors	**Time**	
Storing one original carton into one plastic container in the FPA.	173	28,8	seconds
Storing one original carton in several plastic containers in the FPA.	217	36,2	seconds
Piece picking a small number of articles in the FPA.	134	22,3	seconds
Piece picking a large number of articles in the FPA.	271	45,2	seconds
Picking a full plastic container from a rack in the FPA.	77	12,8	seconds

Total time savings for picking the >100 transactions articles

	Time per pick	Transactions	Seconds	Hours	Saved time	Saved work weeks
ASUs (Time study)	60	48989	2939340	816	0	
FPA, only large picks	45,2	48989	2212874	615	202	5,0
FPA, Only Kanbans	12,8	48989	628692	175	642	16,0

Storing one original carton into one plastic container in the FPA.

Description of movement	Code	Factors	Heavy/Extras
Read and check which shelf the article are to be picked from	RB	35	
Take empty plastic container from rack	GS80	5	
Take empty plastic container and place on EUR pallet	PP80	8	
Read four original carton in EUR pallet	RB	28	
Take original carton	GS80	5	2
Place original carton next to plastic container on EUR pallet	PP45	7	2
Take knife	GS45	4	
Move knife to original carton	PP45	7	
Open original carton with the knife	FA45	5	2
Move knife to EUR pallet	PP45	7	
Take original carton	GS45	4	2
Fill up plastic container	PP45	7	2
Take full plastic container	GS45	4	2
Move full plastic container to rack	PP80	8	2
Check article from list	NA	5	
Read next article	RA	2	
Walk over to next rack, pushing EUR pallet, step length 0.5 m	STEP 3m	18	
Total		159	14
Total number of factors	**173**		
Total time in seconds	**28,8**		

Storing one original carton in several plastic containers in the FPA.

Description of movement	Code	Factors	Heavy/Extras
Read and check which shelf the article are to be picked from	RB	35	
Take empty plastic container from rack	GS80	5	
Place empty plastic container on the EUR pallet	PP80	8	
Read four original carton in EUR pallet	RB	28	
Take original carton	GS80	5	2
Place original carton next to plastic container on EUR pallet	PP45	7	2
Take knife	GS45	4	
Move knife to original carton	PP45	7	
Open original carton with the knife	FA45	5	2
Move knife to EUR pallet	PP45	7	
Take original carton	GS45	4	2
Fill up plastic container	PP45	7	2
Take full plastic container	GS45	4	2
Move full plastic container to rack	PP80	8	2
Take empty plastic container from rack	GS80	5	
Place empty plastic container on EUR pallet	PP80	8	
Take original carton	GS45	4	2
Fill up plastic container	PP45	7	2
Take full plastic container	GS45	4	2
Move full plastic container to rack	PP80	8	2
Check article from list	NA	5	
Read next article	RA	2	
Walk over to next rack, pushing EUR pallet, step length 0.5 m	STEP 3m	18	
Total		195	22
Total number of factors	**217**		
Total time in seconds	**36,2**		

Piece picking a small number of articles in the FPA.

Description of movement	Code	Factors	Heavy/Extras
Read and check which shelf the article are to be picked from	RB	35	
Take zip lock bag	GS45	4	
Place zip lock bag by body	PP45	7	
Take handful articles	GH80	11	
Place articles in zip lock bag	PP80	8	
Count the right amount of articles	RB	7	
Put back excess articles in plastic container	PP80	8	
Place zip lock bag on EUR pallet	PP45	7	
Take label	GS45	4	
Place label on zip lock bag	PP45	7	
Take zip lock bag	GS45	4	
Place zip lock bag on its right place on the EUR pallet	PP45	7	
Check article from list	NA	5	
Read next article	RA	2	
Walk over to next rack, pushing EUR pallet, step length 0.5 m	STEP 3m	18	
Total		134	0
Total number of factors	**134**		
Total time in seconds	**22,3**		

Piece picking a large number of articles in the FPA.

Description of movement	Code	Factors	Heavy/Extras
Read and check which shelf the article are to be picked from	RB	35	
Take plastic container	GS80	5	
Place plastic container next to body	PP45	7	2
Walk to scale, step length 0.5 m, 4.7 meter away	STEP 4.7m	28,2	
Take five articles	GS45	4	
Place articles on scale	PD45	4	
Press buttons on scale	NA	10	
Get articles, handful, 1	GH45	10	
Place articles on scale	PD45	4	
Get articles, handful, 2	GH45	10	
Place articles on scale	PD45	4	
Take the last few articles	GS45	4	
Place articles on scale	PD45	4	
Walk back to rack, step length 0.5 m, 4.7 meter away	STEP 4.7m	28,2	
Put back plastic container	PP45	7	
Walk to scale, step length 0.8 m, 4.7 meter away	STEP	17,6	
Take articles on scale	GS45	4	2
Take zip lock bag	GS45	4	
Place zip lock bag by articles	PP45	7	
Place articles in zip lock bag	PP45	7	2
Put back plastic container on scale	PP45	7	
Place zip lock bag on EUR pallet	PP45	7	
Take label	GS45	4	
Place label on zip lock bag	PP45	7	
Take zip lock bag	GS45	4	
Place zip lock bag on its right place on the EUR pallet	PP45	7	
Check article from list	NA	5	
Read next article	RA	2	
Walk over to next rack, pushing EUR pallet, step length 0.5 m	STEP 3m	18	
Total		265,0	6
Total number of factors	**271,0**		
Total time in seconds	**45,2**		

Picking a full plastic container from a rack in the FPA.

Description of movement	Code	Factors	Heavy/Extras
Read and check which shelf the article are to be picked from	RB	35	
Take plastic container	GS80	5	2
Place plastic container on EUR pallet	PP80	8	2
Check article from list	NA	5	
Read the next article	RA	2	
Walk over to the next rack, pushing EUR pallet, step length 0.5 m	STEP 3m	18	
Total		73	4
Total number of factors	**77**		
Total time in seconds	**12,8**		

10.4 Attachment: Statistical calculations of original carton sizes

Art.no. Techno Skruv	Art.no. Faiveley	Description			Weight(kg)	Width	Height	Depth	Volume dm3	Class
M6SFTT080161	1400080	SKRUV DIN 7500D 8X16 FZB TAPT		1	1,30	280	160	260	11,65	L
70421001601	1400259	MUTTER LÅS M16-10 NF FZ		2	3,55	140	120	185	3,11	M
991179002	1400023145	SKRUV ISO 8100 12X25 10.9 FZ T		3	3,60	180	140	140	3,53	L
991179059	1741070000	GÄNGINSATS 20X2.5X25 MIDGRIP		4	1,55	245	165	230	9,30	L
93110161001	1400260	SKRUV ISO 4014 M16X100 10.9 FZ		5	18,6	120	115	190	2,62	M
991179127	1410353	PLUGG för M8-hål Ack IKPT107S		6	0,02	140	160	140	3,14	L
991179049	1400081	GÄNGINSATS M16X16 FILTEC Plock		7	0,65	235	80	230	4,32	S
BRB0321	1400200108	BRICKA BRB 3,2X6 FZB HB 200		8	0,01	75	70	55	0,29	S
991179015	1400002	SKRUV ISO 8100 12X80 8.8 FZB		9	9,05	145	95	270	3,72	S
991179024	1165101000	BRICKA		10	0,08	75	90	50	0,34	S
991179096	1400573	SKRUV MFTS TORX 10.9 M16x45 FZ		11	7,12	250	110	280	7,70	M
KDS60064	1400040117	SKRUV KDS 6X6 FZB SMS 1549		12	0,09	75	90	50	0,34	S
			Total	Average	3,80	163,33	116,25	173,33	4,17	Interval
				Sigma	5,52	73,80	33,17	86,19	3,62	
				Sigma/Average	1,45	0,45	0,29	0,50	0,87	
				95% conf. interval +	14,62	307,99	181,27	342,27	11,27	130,05
				95% conf. interval -	-7,02	18,68	51,23	4,40	-2,93	
			S	Average	0,06	121,00	85,00	131,00	0,32	
				Sigma	0,04	70,57	10,00	109,57	0,03	
				Sigma/Average	0,73	0,58	0,12	0,84	0,09	
				95% conf. interval +	0,15	259,32	104,60	345,75	0,38	39,20
				95% conf. interval -	-0,03	-17,32	65,40	-83,75	0,27	
			M	Average	9,76	170,00	115,00	218,33	4,48	
				Sigma	7,86	70,00	5,00	53,46	2,80	
				Sigma/Average	0,81	0,41	0,04	0,24	0,63	
				95% conf. interval +	25,17	307,20	124,80	323,12	9,97	19,60
				95% conf. interval -	-5,66	32,80	105,20	113,55	-1,02	
			L	Average	2,66	211,25	156,25	192,50	6,90	
				Sigma	3,00	63,03	11,09	61,85	4,24	
				Sigma/Average	1,13	0,30	0,07	0,32	0,61	
				95% conf. interval +	8,54	334,79	177,98	313,72	15,20	43,46
				95% conf. interval -	-3,23	87,71	134,52	71,28	-1,40	

Confidence interval

$$I = \bar{x} \pm \lambda_{\alpha/2} * \left(\frac{\sigma}{\sqrt{n}}\right)$$

$$\lambda_{\alpha/2} = 1,96$$

10.5 Attachment: Kanban example

Example: 1410280 - Kulhållare med Kulor 50					
TO (picks/year)	**KO (picks/year)**	**SO (picks/year)**	**Total no of transaction (picks/year)**		
136	6	198	340		
TO (pcs/year)	**KO (pcs/year)**	**SO (pcs/year)**	**Total no of transaction (pcs/year)**		
-5784	-250	-1225	-7259		
12x12 plastic container			**Storage**		
Pieces per contaier	300	pcs	Safety stock	800	pcs
Weight per container	13	kg	Safety margin (alfa)	1,3	
Supply per contaier	0,5	month (Tot)	Average stock level	1903,0	pcs
Supply per contaier	0,6	month (TO)	Maximum storage 2010	3365	pcs (2010-02-04)
Number of Kanban (y)	6,7	containers	Maximum plastic buckets 2010	22,4	small plastic contaiers
Small plastic container			Minimum storage	548,0	pcs (2010-04-16)
Pieces per contaier (a)	150	pcs	Article cost	7,2	SEK
Weight per container	6,5	kg	Tied capital 2010	13701,6	SEK/month
Supply per contaier	0,2	month (Tot)	Tied capital (theoretical)	4680,0	SEK/month
Supply per contaier	0,3	month (TO)	Difference in tied capital	9021,6	SEK/month
Number of Kanban (y)	13,4	containers	**Time**		
Average pick (Tot)			Lead time (L)	1,4	moths
Total picks per monts	28,3	picks/month	Piece picking time (Tot)	5,7	hours
Total pieces per monts (D)	604,9	pcs/month	Kanban picking time (Tot)	11,3	minutes
Average pick TO			Difference in pick time (Tot)	0,97	
Picks per month	11,3	picks/month	Piece picking time (TO)	2,3	hours
Pieces per month	482	pcs/month	Kanban picking time (TO)	9,0	minutes
			Remaining piece pick (KO & SO)	3,4	hours
Number of Kanbans (y):			Difference in pick time (TO)	0,37	

$$y = \frac{DL(1+\alpha)}{a}$$

10.6 Attachment: Raw ERP data

Art.no.	Desciption	TO	KO	SO	Total	TO pcs.	KO pcs.	SO pcs.	Total pcs.
1741074003	MANSCHETT DIAM 178	925	112	129	1166	-19539	-5914	-633	-26086
1741260000	PLUGG MED GŽNGA	864	25	94	983	-37558	-10049	-1271	-48878
1400030479	O-RING 174,3x5,7 TR10<-45grC	820	34	88	942	-21535	-3278	-477	-25290
1741037000	GLIDRING	683	77	143	903	-9626	-5941	-704	-16271
1741065001	LAGER 30x50x22	615	62	195	872	-23978	-7982	-1761	-33721
1741066001	LAGER F™R BAKTAPP	588	54	193	835	-22190	-1612	-1768	-25570
1400030266	O-RING 17,17X 1,78	650	20	125	795	-55338	-5507	-1024	-61869
1400080	SKRUV DIN 7500D 8X16 FZB TAPT	615	9	167	791	-24709	-1501	-4797	-31007
VI-7507	SKYLT 40 x 25 x 0,5 MM	11	0	702	713	-185	0	-3417	-3602
1400030285	O-RING 29,82x2,62BS1806SMS1587	613	17	62	692	-28796	-6547	-502	-35845
1741061000	O-RING 74,5 X 3	582	19	63	664	-13374	-2517	-255	-16146
1400030223	O-RING 36,2 X 3	582	19	62	663	-26748	-7167	-502	-34417
1400030269	O-RING 28,3x1,78BS1806 SMS1587	582	17	62	661	-26748	-6117	-501	-33366
1741044004	CYLINDERFODER BFC STANDARD	492	114	32	638	-6401	-3138	-57	-9596
1741049000	REGULATORBUSSNING BAKRE	466	43	110	619	-6899	-3273	-451	-10623
1741029000	GLIDBUSSNING	458	36	110	604	-6900	-2326	-451	-9677
1400040114	SKRUV KDS 4X5 FZ SS 1549	468	6	120	594	-13833	-2584	-1194	-17611
1741007001	MATARMUTTER BFC	539	46	6	591	-10896	-1897	-6	-12799
1741008000	MATARHYLSA	527	26	7	560	-10869	-713	-8	-11590
1400050630	SKYDDSPLUGG CAPCO KONISK	408	3	140	551	-58606	-1660	-4858	-65124
1410353	PLUGG f'r M8-h†l Ack IKPT107S	374	4	150	528	-18666	-1002	-1438	-21106
1400500152	L• SRING SGA67 DIN471 D1400	453	10	63	526	-7128	-1053	-251	-8432
1741038000	L□ SRING F™R LOSSLŽGE	496	25	2	523	-10328	-1554	-2	-11884
1400500335	L• SRING SGH75 DIN472 D1300	454	5	63	522	-7129	-453	-251	-7833
1410327	PLUGG med rillor	517	3	1	521	-36729	-44	-21	-36794
1410245	SLANGKLŽMMA 88-99 5mm rf	413	16	52	481	-6258	-834	-213	-7305
1400050635	SKYDDSPLUGG DBI-DUT 41 0035	454	2	19	475	-9896	-21	-152	-10069
1741045014	BŽLG	395	40	35	470	-8129	-1453	-172	-9754
1741048001	REGULATORBUSSNING FRŽMRE	296	36	101	433	-4751	-2648	-430	-7829
1400259	MUTTER L• S M16-10 NF FZ	284	10	135	429	-17013	-898	-714	-18625
1400500149	L• SRING SGA29 DIN471 D1400	361	4	53	418	-9834	-570	-482	-10886
1741067003	L• SBAND TY-RAP TY 28 MX	199	11	196	406	-3494	-932	-670	-5096
1741047001	KOLVFJŽDER	372	19	7	398	-4310	-625	-7	-4942
1741415000	BAKTAPP SMST	362	24	9	395	-7766	-395	-12	-8173
1741015000	BAJONETTRING	383	6	3	392	-4718	-446	-3	-5167
1034002301	KULLAGERBRICKA DIA.55	136	33	197	366	-11568	-7056	-2484	-21108
1741046001	REGULATORFJŽDER	341	19	6	366	-4067	-755	-6	-4828
1741013001	MATARFJŽDER	352	9	2	363	-4150	-386	-2	-4538

Art.no.	Desciption	TO	KO	SO	Total	TO pcs	KO pcs	SO pcs	Total pcs
1741014001	BROMSBRICKA	333	11	0	344	-4487	-404	0	-4891
1410283	PL• TKULH• LLARE MED KULOR 55	136	6	198	340	-5784	-250	-1225	-7259
1400500128	L• SRING SGA45 (DIN471) D1400	113	19	204	336	-4013	-3860	-645	-8518
1741012001	KOPPLINGSFJŽDER	316	17	2	335	-4099	-1026	-2	-5127
1741006100	TRYCKBRICKA	316	13	1	330	-3739	-366	-1	-4106
1741114000	TŽTNINGSRING	320	8	0	328	-4067	-1203	0	-5270
1400050615	SKYDDSPLUGG,ANVŽND 1400083	261	0	66	327	-5549	0	-1396	-6945
1741143004	GLIDLAGER NEDRE	289	14	24	327	-7944	-372	-138	-8454
1400245	O-RING 53 X 3 SMS 1586,1587	289	8	25	322	-15888	-2710	-288	-18886
1400800143	STIFT FRP 4X 8	138	4	174	316	-6017	-504	-590	-7111
1741088000	SKYLT BFC	298	5	9	312	-3520	-701	-62	-4283
1400023145	SKRUV ISO 8100 12X25 10.9 FZ T	229	8	75	312	-11794	-778	-1858	-14430
1036184000	BUSSNING F™R STOPPSKRUV-DRV	110	6	195	311	-4009	-396	-631	-5036
1410328	SLANGKLŽMMA 108-119 5MM W4 SG	242	21	43	306	-3860	-803	-194	-4857
1741153002	TŽTNINGSRING ™VRE 50x32x4,5	223	38	34	295	-14484	-7329	-708	-22521
1036123101	STOPPSKRUV	105	6	177	288	-3514	-400	-570	-4484
1400260	SKRUV ISO 4014 M16X100 10.9 FZ	158	7	120	285	-1819	-213	-608	-2640
1036023002	MATARMUTTER PLAST	102	78	100	280	-2859	-5359	-330	-8548
1741169000	GLIDLAGER ™VRE	222	12	35	269	-7242	-1324	-356	-8922
1410280	PL• TKULH• LLARE MED KULOR 50	93	10	164	267	-2909	-560	-567	-4036
1400447	L• SRING SGH63 DIN472 D1300	243	1	20	264	-2942	-200	-45	-3187
1400500329	L• SRING SGH60 DIN472 D1300	212	3	45	260	-4197	-203	-224	-4624
1400030411	O-RING 13,1x1,6 TR10<-45grC	163	16	71	250	-3123	-1760	-271	-5154
1165114000	DŽMPNINGSRING BFCF	165	19	65	249	-2274	-741	-258	-3273
171373	SKYDD VID ŽNDTAPP	227	8	12	247	-4229	-416	-25	-4670
1165061000	GLIDRING 70/66X3,6	183	33	29	245	-2601	-1320	-121	-4042
1400083	SKYDDSPLUGG DBI-DUT 41 0016	95	2	147	244	-2849	-101	-2012	-4962
1410273	SLANGKLŽMMA 58-69 5mm rf	228	4	11	243	-4265	-434	-22	-4721
1741154004	TŽTNINGSRING NEDRE 81x66,5x4,5	189	21	26	236	-6230	-2620	-294	-9144
1400002	SKRUV ISO 8100 12X80 8.8 FZ	151	8	73	232	-6436	-457	-1220	-8113
1036177000	STYRRING	117	13	100	230	-3969	-542	-272	-4783
171371	REGLERFJŽDER BFC-VA	225	2	1	228	-2083	-7	-1	-2091
1165060000	KOLVRING FK6 ASD DIA 70	194	25	9	228	-4433	-1121	-21	-5575
1036002301	ROSTFRI KULLAGERBRICKA	94	7	124	225	-3074	-1000	-852	-4926
1036004000	STYRPINNE	18	8	198	224	-780	-390	-603	-1773
1400500367	L• SRING SGH57 DIN472 D1300	183	8	31	222	-2601	-115	-127	-2843
1741070000	GŽNGINSATS 20X 2.5X25 MIDGRIP	212	4	6	222	-12878	-678	-30	-13586
1500070000	FILTER 1/4"	72	12	137	221	-3209	-2537	-1898	-7644

Art.no.	Desciption	TO	KO	SO	Total	TO pcs	KO pcs	SO pcs	Total pcs
1036176000	SP• RRING	112	9	95	216	-3969	-425	-272	-4666
1165045001	MANSCHETT GLY-60 TR10<-45grC	154	38	21	213	-2381	-2159	-101	-4641
1036102001	ST™DBRICKA M KULBANA	85	6	121	212	-2694	-305	-458	-3457
1741150001	LAGERRING	182	23	5	210	-4338	-526	-11	-4875
1400573	SKRUV MFTS TORX 10.9 M16x45 FZ	193	10	1	204	-6784	-6494	-2	-13280
1036178000	L• SRING	102	10	85	197	-3474	-915	-240	-4629
1741004001	KOPPLINGSBRICKA	176	16	3	195	-2712	-919	-4	-3635
1036459000	TŽTNINGSRING M FJŽDER	17	23	155	195	-1560	-4259	-990	-6809
1165101000	BRICKA	178	14	3	195	-5856	-320	-40	-6216
1161130001	MANSCHETT V NYK ERS AV 1400521	135	38	21	194	-3665	-2573	-200	-6438
1036456000	TŽTNINGSRING MED FJŽDER	17	28	148	193	-1560	-9545	-904	-12009
1741146000	FRIKTIONSFJŽDER	171	15	6	192	-4370	-869	-12	-5251
1741045100	FRŽMRE BŽLG	159	23	3	185	-2837	-791	-3	-3631
1400066	L• SRING RW6 DIN7993A	176	4	4	184	-7952	-602	-81	-8635
1400105	L• SRING RB55 DIN 7993B	102	4	77	183	-3474	-225	-203	-3902
1400800169	STIFT FRP 6X10	17	0	165	182	-780	0	-511	-1291
1400067	L• SRING RB12 DIN7993B	176	2	3	181	-2928	-109	-20	-3057
1400104	O-RING 35,5 X11,5	74	8	96	178	-4652	-384	-358	-5394
1036175000	STYRBUSSNING	74	5	97	176	-4652	-430	-368	-5450
1741147001	GLIDPLATTA	166	3	5	174	-1665	-21	-7	-1693
141035803	KIT EMBALLAGE STOR	168	0	0	168	-3712	0	0	-3712
172211	REGULATORBUSSNING DY92	162	0	5	167	-1628	0	-6	-1634
1741544200	K• PA KOMPAKT, KOMPLETT	156	9	2	167	-1665	-83	-2	-1750
1741156000	SKRUV M16X 43	41	6	118	165	-1120	-352	-1212	-2684
1164466000	TŽTNINGSKŽGLA BFC	118	26	18	162	-1745	-750	-80	-2575
171522	SPŽRRTAPPSST™D	136	3	23	162	-4164	-1	-133	-4298
1165026000	LOCKST™D	96	2	64	162	-3560	-6	-1072	-4638
1165047002	MANSCHETT MY10A TR10<-45grC	122	18	21	161	-2389	-1825	-103	-4317
1410006	KULA RB 6.35/ III	153	8	0	161	-3298	-1691	0	-4989
1088199000	BUSSNING 31,3/33,3 L23,9 SLITS	120	4	35	159	-4119	-240	-137	-4496
1501011000	MEMBRAN	70	23	63	156	-1534	-1887	-232	-3653
1400375	SKRUV ISO 4762 8X 16 8.8 FZB	33	4	118	155	-666	-433	-1210	-2309
1400081	GŽNGINSATS M16X16 FILTEC Plock	148	6	1	155	-3166	-254	-1	-3421
1036103000	KOPPLINGSSKIVA	7	11	136	154	-165	-1069	-452	-1686
1741138000	HYLSA	149	5	0	154	-3103	-100	0	-3203
1165049000	AVSTRYKARRING 10X14X3	104	28	20	152	-1547	-1337	-99	-2983
1741077000	HYLSA	149	2	0	151	-3103	-18	0	-3121
1096027000	AXIALKULLAGER 51107	128	17	6	151	-1308	-232	-13	-1553

Art.no.	Desciption	TO	KO	SO	Total	TO pcs	KO pcs	SO pcs	Total pcs
1741143003	GLIDLAGER	131	17	1	149	-2837	-1276	-1	-4114
1741292000	FRIKTIONSBYGEL	138	11	0	149	-2813	-133	0	-2946
1741306000	PLASTPLUGG	132	16	1	149	-5674	-1441	-2	-7117
1400216	MUTTER L• S 20-8 NF FZB DIN 980	146	3	0	149	-2022	-1150	0	-3172
1400199	O-RING 79,5 X 3 SMS1586 VITON	131	16	1	148	-5674	-1590	-2	-7266
1400198	O-RING 38 X 3 SMS 1587	131	16	1	148	-5674	-2463	-2	-8139
1741011001	REGLERFJŽDER	131	16	0	147	-2237	-1097	0	-3334
1400119	O-RING 64,5 X 3 SMS 15	131	15	1	147	-5674	-2070	-2	-7746
1400508	O-RING 25x2,5 TR10<-45grC	134	1	11	146	-5016	-2	-40	-5058
1400521	MANSCHETT CR SIL 16x22x6	116	7	23	146	-3947	-25	-285	-4257
1400197	O-RING 49 X 7 EPDM	131	14	1	146	-5674	-1423	-2	-7099
1400195	O-RING 50 X 5 EPDM	131	13	1	145	-5674	-1609	-2	-7285
1164030001	SKYLT BFCF	141	3	0	144	-2201	-1	0	-2202
1501005000	TRYCKMEDIUM	67	12	64	143	-1840	-637	-232	-2709
17153702	STYRHYLSA KOMPLETT	137	4	0	141	-3411	-7	0	-3418
1741289001	LAGERBRICKA	135	6	0	141	-5626	-141	0	-5767
1741067002	L• SBAND TY-RAP TY 244MX	113	22	6	141	-1325	-4163	-21	-5509
1400196	L• SRING 47X2,5 STECE 70640	131	7	1	139	-7676	-1199	-3	-8878
1088197000	LABYRINTTŽTNINGSHALVA	99	2	37	138	-6378	-700	-276	-7354
241000	BROMSBLOCK	93	43	1	137	-698	-3479	-2	-4179
1501020000	SKYDDSHUV DET. 20	69	2	65	136	-1525	-220	-233	-1978
1501084000	PACKNING DET 84	68	4	64	136	-1842	-210	-232	-2284
171211	FJŽDER	126	9	0	135	-5626	-475	0	-6101
1400030211	O-RING 13,3 X 2,4	68	2	64	134	-1842	-200	-232	-2274
1400030202	O-RING 4,3 X 2,4 SMS1586-87	68	2	63	133	-1842	-200	-232	-2274
1400200108	BRICKA BRB 3,2X6 FZB HB 200	128	4	0	132	-9714	-88	0	-9802
1501017000	FILTER	58	10	64	132	-2750	-1512	-464	-4726
1161102000	GŽNGINSATS M10X 1.5 MIDGRIP	128	2	0	130	-4216	-508	0	-4724
1088198000	SPOLSKYDD	92	2	35	129	-3189	-340	-137	-3666
1400331	SKRUV ISO 4029 8X12 Fz	125	2	0	127	-2972	-502	0	-3474
1400312	O-RING 32,2 X 3 NBR 70	91	1	35	127	-3089	-40	-137	-3266
171068	BRICKA	118	6	0	124	-2550	-102	0	-2652
241016	BŽLG	116	7	0	123	-1084	-120	0	-1204
1400561	BRICKA A2 10,5x22x2	116	3	3	122	-3864	-13	-20	-3897
1036032000	L• SSKRUV	0	2	120	122	0	-290	-380	-670
1165027001	ANSLUTNINGSNIPPEL	105	12	4	121	-1189	-115	-4	-1308
1400500438	L• SRING J85X3V M1308	0	1	119	120	0	-20	-376	-396
1410373	MANSCHETT SNI30-10 10x16x4,5	103	4	11	118	-3401	-21	-40	-3462

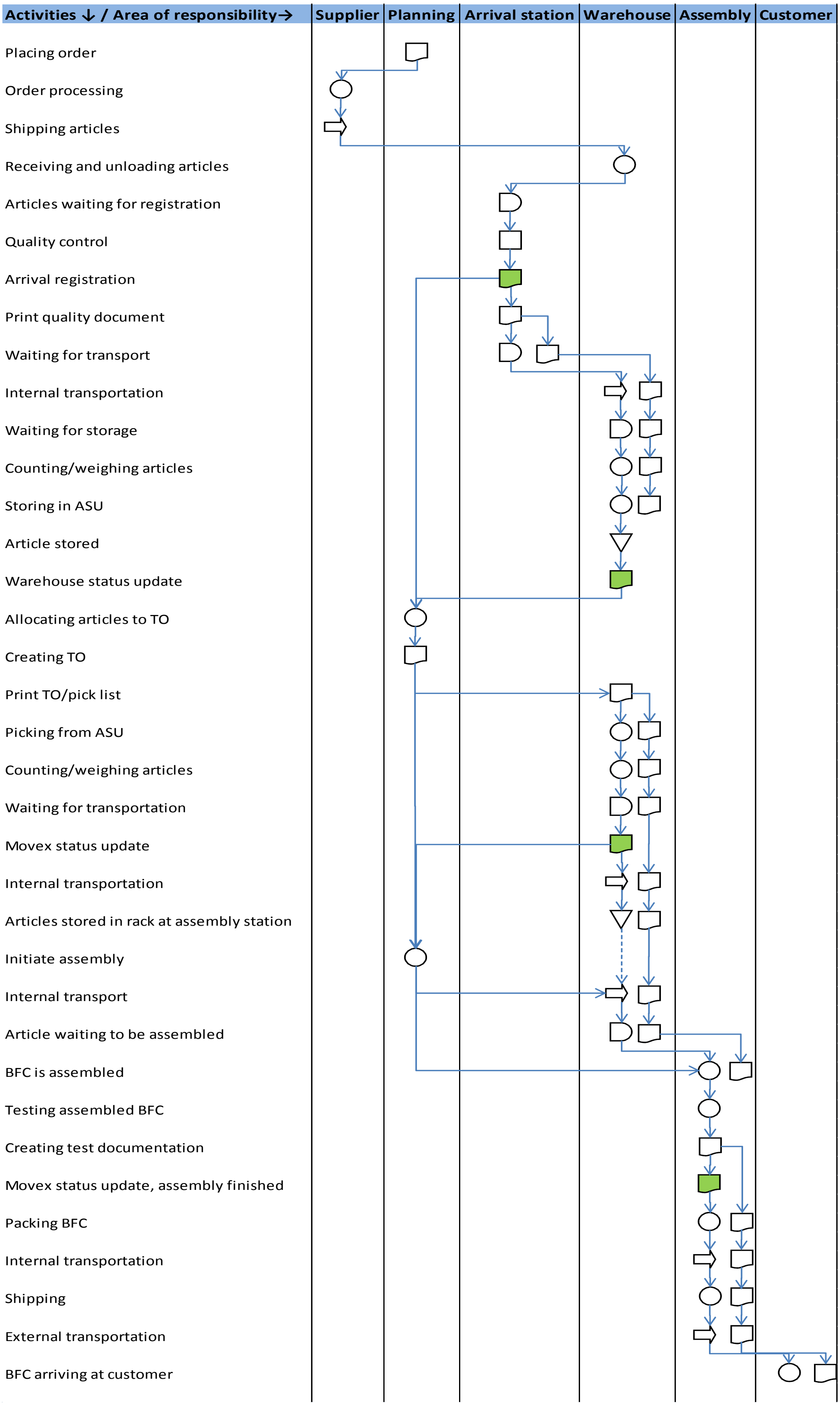
Art.no.	Desciption	TO	KO	SO	Total	TO pcs	KO pcs	SO pcs	Total pcs
1036094000	GUMMITŽTNING	3	8	107	118	-106	-861	-365	-1332
1410174	MANSCHETT GLY85X100X9 TR10<-45	108	9	0	117	-1084	-209	0	-1293
1825600700	GUMMISLANG 8X10 EPDM 70 SH A	103	0	13	116	-2391	0	-29	-2420
1400479	SKRUV ISO 4762 10X 50 FZB	108	2	6	116	-1676	-270	-22	-1968
1400040117	SKRUV KDS 6X6 FZB SMS 1549	105	1	9	115	-2488	-13	-66	-2567
1501014001	SPINDEL	44	7	64	115	-933	-354	-232	-1519
1410176	KOLVST• NGSSTYRRING 50/56x13	108	7	0	115	-1084	-189	0	-1273
1410175	KOLVSTYRRING 100/94x13	108	7	0	115	-1084	-195	0	-1279
1400030214	O-ring 16,3X2,4 Siliconoljebeh	96	2	16	114	-2786	-496	-186	-3468
241008	STYRPINNE	108	6	0	114	-1084	-64	0	-1148
1400347	O-RING 108 X 3	108	5	0	113	-1084	-175	0	-1259
241009	HYLSA	108	5	0	113	-1084	-29	0	-1113
241010	L• SPINNE	108	5	0	113	-1084	-29	0	-1113
1410329	FJŽDER STECE 21750	109	0	3	112	-2096	0	-10	-2106
1410330	FJŽDER STECE 22760	108	0	3	111	-2096	0	-10	-2106
1410243	SLANGKLŽMMA 98-109 5mm rf	103	7	1	111	-1421	-472	-1	-1894
241011	DAMASK TCU	107	4	0	111	-1036	-244	0	-1280
171491	FRIKTIONSSEGMENT	105	4	1	110	-2610	-77	-1	-2688
171492	FRIKTIONSSEGMENT	105	4	1	110	-2610	-73	-1	-2684
1164035000	N• LLAGERBRICKA CP3553 NADELLA	98	9	3	110	-1230	-299	-3	-1532
1164034000	AXIALN• LLAGER AX3553 NADELLA	98	9	2	109	-1230	-309	-2	-1541
241045	DŽMPNINGSBRICKA	107	2	0	109	-1082	-120	0	-1202
1400374	L• SRING 2,5 Dy=60	85	5	17	107	-2694	-265	-57	-3016
1741045010	FRŽMRE BŽLG	63	28	16	107	-813	-1310	-36	-2159
1410372	MANSCHETT MA28-70L 70X60X6	95	4	8	107	-3345	-3	-20	-3368
1400627	SKRUV ISO 4762 12X45 10.9	96	4	6	106	-900	-9	-11	-920
241006	KOLVFJŽDER	102	2	0	104	-900	-45	0	-945
241022	SKYLT 45X25 TCU ADHESIV	96	7	0	103	-900	-750	0	-1650
1410215	SLANGKLŽMMA 1-™RIG 11,3-13,8	102	0	0	102	-26288	0	0	-26288
241003	CYLINDER	94	6	1	101	-852	-75	-1	-928
1741141003	L• SBAND TY-RAP TY232 MX	74	11	16	101	-1267	-2930	-36	-4233
1036012000	KOPPLINGSFJŽDER	85	15	0	100	-2694	-710	0	-3404
1400222	SKRUV ISO 4762 8X 40 12.9	98	2	0	100	-1397	-21	0	-1418
1236699300	VENTILKROPP	13	3	84	100	-270	-85	-727	-1082

10.7 Attachment: Pareto calculations

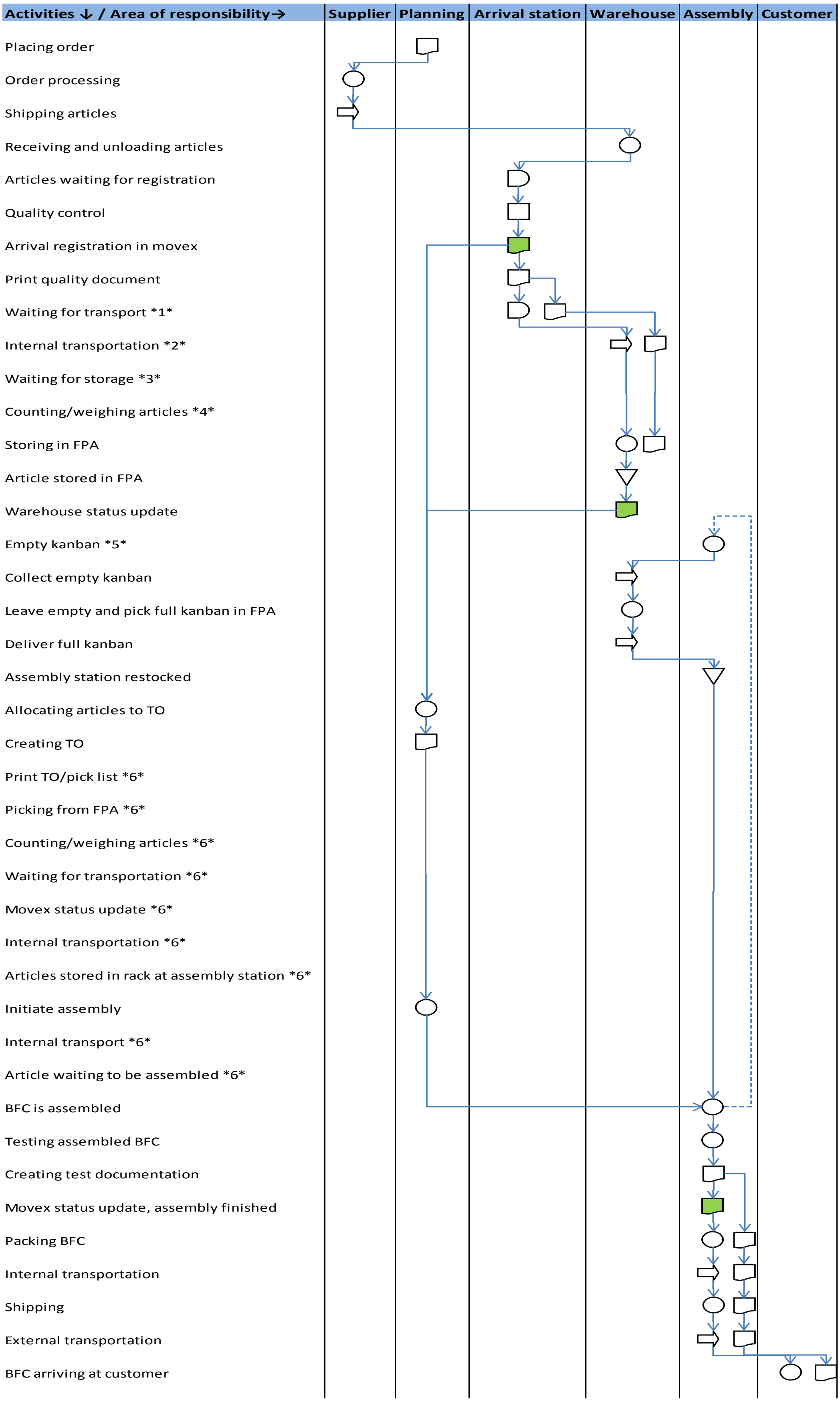
Pareto calculations	
Total number of k-articles	1249
Total number of transactions	68045
20 percent of the k-articles	250
Transactions for the top 250 articles	54018
20 percent of the k-articles stands for:	0,79
Articles with >100 transactions per year	186
Transactions for the top 186 articles	48989
20 percent of the k-articles stands for:	0,72

* Transactions ≈ Picks

10.8 Attachment: Process map for K-article flow (before)



10.9 Attachment: Process map for F-article flow (after)



10.10 Attachment: Process map symbols and comments

Description

Operations: An operation is an activity that, in one way or another, transforms the input material.
It can also be assembly or disassembly of a product as well as planning, calculating, construction and so on.

Transports: Transports are movement of objects between different locations without any alterations on the objects.

Control: A control activity examines and verifies the result form another activity.
A control activity can be to identify, measure, weight and in other ways examine an object to see if it reaches up to specific standards of quality and quantity.

Storage: Storage activities means that object, materials and tools, are put in storage awaiting an operation or control activity.
Before and after storage activity is usually a transport activity.

Delay: The delay activity is usually a queue or a wait for transport, operation or control activity.

Document: The document activity means that information in the form of electronic or physical documents are transferred to the next activity

Electronic Document: Transaction, updates and sent information through the ERP system, for example a Movex update

Comments for F-article process

1 Change routine and measurements
2 To FPA
3 Routines and no waiting for ASU
4 no Counting and weighting
5 empty plastic container due to previously assembled BFC
6 no need due to Kanban