CHALMERS

Towards flow efficiency at company expansion:

Material flow investigation and redirection through concept model development at ABB Ludvika

Master of Science Thesis in the Master Degree Program Supply Chain Management

Authors: Petter Kostmann & Christoffer Ljungbäck
Supervisor: Per Medbo

Department of Technology Management and Economics
Division of Logistics and Transportation

CHALMERS UNIVERSITY OF TECHNOLOGY
Göteborg, Sweden, 2013

Report no. E2013:118

REPORT NO. E2013:118

Towards flow efficiency at company expansion: Material flow investigation and redirection through concept model development at ABB Ludvika

PETTER KOSTMANN
CHRISTOFFER LJUNGBÄCK

Department of Technology Management and Economics
Division of Logistics and Transportation
CHALMERS UNIVERSITY OF TECHNOLOGY
Göteborg, Sweden 2013

Towards flow efficiency at company expansion: Material flow investigation and redirection through concept model development at ABB Ludvika

PETTER KOSTMANN
CHRISTOFFER LJUNGBÄCK

Technical report no. E2013:118
Department of Technology Management and Economics
Division of Logistics and Transportation
Chalmers University of Technology
SE-412 96 Göteborg Sweden
Telephone + 46 (0)31-772 1000

Printed by Chalmers Reproservice
Göteborg, Sweden 2013

Towards flow efficiency at company expansion: Material flow investigation and redirection through concept model development at ABB Ludvika

PETTER KOSTMANN
CHRISTOFFER LJUNGBÄCK
Department of Technology Management and Economics
Division of Logistics and Transportation
Chalmers University of Technology

ABSTRACT

A large number of manufacturing companies are struggling with inefficient material flows to and from production. As a result, the flows get very long lead-times with many logistics processes. One way to improve the material flows efficiency to and from production is by letting all flows go through the same resource, as a warehouse or a LC. ABB Ludvika has decided to build a new Logistic Centre (LC) at an external area outside the production facilities. The company is actually forced to move the material handling from the production facility due to space issues, i.e. there are no more room for logistics processes outside of production. This thesis investigates how the new LC could be developed in order to improve the material flows to and from production. The research found out that there are many factors affecting the development of a LC, but also how to improve the material flows. These factors are summarized in a LC Concept Model, which states four main constraints; (1) Context, (2) Production, (3) External material flow and (4) Internal material flow, which all provides there specific emphasises on a complex problem. By investigating ABB Ludvika with the four constraints, several logistical problems were identified. The theoretical framework together with a benchmark of Volvo Car's LC in Torslanda, the DHL Terminal, set the foundation for the analysis of the four constraints of ABB Ludvika. The analysis resulted in large improvement recommendations for ABB Ludvika. Firstly, the context constraint suggests a better cooperation and communication between the five different production divisions if the new LC should be able to work as a centralised logistics hub. Secondly, the production constraint recommends that logistic activities as well as production preparation, with similarities, currently made decentralised should be monitored and possibly moved to the new LC. Thirdly, the external material flow constraint proposes to change the relationships atmosphere with the 3PL from confrontation, where only money and power matters, to a closer cooperation, where the parties develop together with trust in the long-term. If ABB Ludvika would achieve this, more responsibility could be placed on the 3PL, which can improve the external material flow. Fourthly, the internal material flow constraint suggests a future state map with a large lead-time improvement, containing less buffers and less logistics processes. As a result, all of the four constraints give their specific input of how to develop the new LC.

Keywords: Logistic Centre, Warehouse development, Material flow, ABB Ludvika.

ACKNOWLEDGEMENT

Numerous persons have been involved in our thesis and together they have contributed through valuable input into our result. The authors of this thesis would like to express their gratitude to a few persons who deserve special thanks:

To begin with, Lecturer and thesis supervisor Per Medbo of the Technology Management and Economics, Chalmers University of Technology, who has given invaluable supervision during the work of this thesis. Not only has he provided support but also a nice working environment and good atmosphere aside from an excellent source of information. His colleague and brother, Lars Medbo of the same department, who has assisted material flow mapping activities, should also be mentioned.

We would also like to thank Kurt Nordahl, who has been our supervisor at ABB Ludvika, for his engagement in our thesis solution and commitment for the new Logistic Centre. Kurt has frequently guided us through our work, given constructive feedback and motivated us during the study. Filip Bengtsson, project manager at the facilities departement, also deserve our thanks here.

Further thanks to our opponents, Patricia Andreina, Vanja Carlén and Antonis Pekopaoulos who have given excellent feedback and advise while sharing their reflections on our work.

Finally we would like to thank all employees at ABB Ludvika, who have crossed our path, for their support, helpfulness and understanding during our field study interviews and observations.

Göteborg, 17th of December 2013

Petter Kostmann
Christoffer Ljungbäck

Table of Contents

1 INTRODUCTION

The chapter will introduce the main problems regarding material flows and explain the role of a LC in order to mitigate these problems. Next follows a company description of ABB with their five different divisions. Thereafter, the situation of ABB Ludvika will be described and the background to the new LC. Additionally, the chapter will present the purpose, the problem analysis and the demarcations of this thesis.

1.1 Background

In today's global world, an enormous amount of products are made available everyday for hundreds of millions of people and thousands of companies (Rosenblom, 1995). Not many are aware of the large amount of tasks involved in providing the customers the right products in the right time with the right quality. The increasing needs and demands from the customers have made firms more and more specialised over the years. As a result, the traditional supply channel has developed into a network of actors (Ford, Gadde, Håkansson & Snehota, 2003). To cope with the increasing demand of customers and the new network structure, all companies need to reduce their costs and at the same time provide even bigger customer service (Oswald & Boulton, 1995). But, reducing cost and increasing service at the same time is a problematic equation.

Supply chain management (SCM) is an area that increases the coordination across firm boundaries and challenges the view of cost and service trade-off, due to that reorganisation of activity structures can reduce cost and improve services. According to Christopher (2005), the purpose of SCM is to create as much value as possible in the whole supply network, in both products and services. In a supply chain, a network of suppliers delivers goods to the manufacturing unit, where the products are produced. Thereafter, the products are going out to a distribution network and finally to the end customers. What happens in both the supply network and the distribution network affects the manufacturing unit (Baudin, 2004). Hence, the plant needs to control the material flow both from its suppliers and to its customers. Companies want to be sure that the parts are available in the right time, right quantity and right quality when needed. But, many manufacturing companies are struggling with ineffective material flows to and from production. As a result, the material flow gets very long lead-times with many logistics processes to and from production. Also, many companies are forgetting that they are actually part of one or several supply chains in order to deliver what the customers demands. This means that the external material flows can have an even longer lead-time than the internal.

The importance of an efficient material flow within a supply chain has been stated by many authors (Chopra & Meindl, 2012; Lumsden, 2012; Stadtler, 2005; Christopher, 2005). In order to increase the material flows efficiency to and from production is by letting all flows go through the same resource, as a warehouse or a LC (de Koster, Le-Duc & Roodbergen, 2007; Baudin, 2004). Furthermore, a centralised resource with the purpose to perform logistical processes can have many different functions and can be designed in a numerous different ways. It all depends on the requirements or factors, influencing the material flows and thus the development of the logistic hub. One of many areas setting requirements on the material flows is the production. Depending on when the production needs the material, the LC could store the material until needed. Hence, the LC will make sure that the production gets the right material in the right time. To be sure that the material is there when needed in production, it is often stored for weeks or even months before going to the manufacturing unit, where it is only used for a few hours. The Lean philosophy states inventory as one of the seven wastes (Liker, 2004) and means that it is very important to try to reduce it as much as possible. However, some stocks are actually necessary for running the production smoothly, but also due to that supplies can be delayed and there is often a missmatch between the incoming and outgoing quantities (Baudin, 2004). Furthermore, the products are not always produced exactly when the customers needs them. Consequently, the centralised resource could act as a distribution warehouse that bridge the gap between production and consumption (Lewis, 1968). Another big challenge in the globalised world today is that products are produced in one part of the world and consumed in another. Hence, a LC can help the production unit to control the outgoing material and bridge the gap to the customers.

Consequently, a LC should deal with both in- and outbound flows and can thereby have many different tasks. It will be a challenge to integrate these activities and handle the material flow in an efficient way. This report will investigate how to develop a LC in order to improve the material flows to and from production.

1.2 Company description

ABB is one of the world's leading engineering companies within power and automation technologies (ABB, 2013a). They provide solutions for energy efficient generation, electricity distribution, transmission and for increasing productivity in commercial and industrial operations. Some general information can be seen in Table 1. In 2012, the company operated in about 100 countries, employed about 146 thousand people and had $39,3 billion in revenue (Annual report, 2012).

Table 1. General information about ABB. Source: Annual report (2012).

ABB Group	
Founded	1988
Headquarter	Zürich, Switzerland
Merge	ASEA & BBC
CEO	Joe Hogan
Revenue	$39,3 billion
Net income	$2,704 billion
Employees	146,100 people

It all started 1883 in Stockholm, when Ludvig Fredholm establishes Elektriska Aktiebolaget as manufacturers of electrical lighting and generators (ABB, 2013a). Seven years later the company merged with Wenströms & Granströms Elektriska Kraftbolag and formed Allmänna Svenska Elektriska Aktiebolaget, later shortened to ASEA. For almost hundred years, ASEA had great success with a strong product development and innovation. Among others they developed and commercialised the first three-phase transmission system in Sweden, they were the first company in the world to manufacture synthetic diamonds and they launched one of the first industrial robots. All together, ASEA was a big participant in the development within the industry. In 1988, ASEA merged with a Swiss company called Brown, Bovery & Cie (BBC). Together they formed ABB, which from the beginning was a short for ASEA Brown Bovery.

With the long history and knowledge of power and automation technologies, ABB has grown into one of the world's largest organisations within their field. Today, ABB is the biggest supplier of industrial motors and drives, the biggest provider of generators to the wind industry and the biggest suppliers of power grids worldwide (ABB, 2013b). ABB is mainly operating in two key markets: power and automation. In the power market, ABB operates with products, systems and services that are designed to deliver electricity in various forms. In the automation market, on the other hand, ABB works with and improves product quality, energy efficiency and productivity in industrial and manufacturing applications.

1.2.1 Divisions

ABB is organised in five global divisions; Power Products, Power Systems, Discrete Automation & Motion, Low Voltage Products and Process Automation (Annual report, 2012) and can be seen in Figure 1. All divisions are in turn divided into certain business units that are concentrated on particular industries and product families (ABB, 2013c).

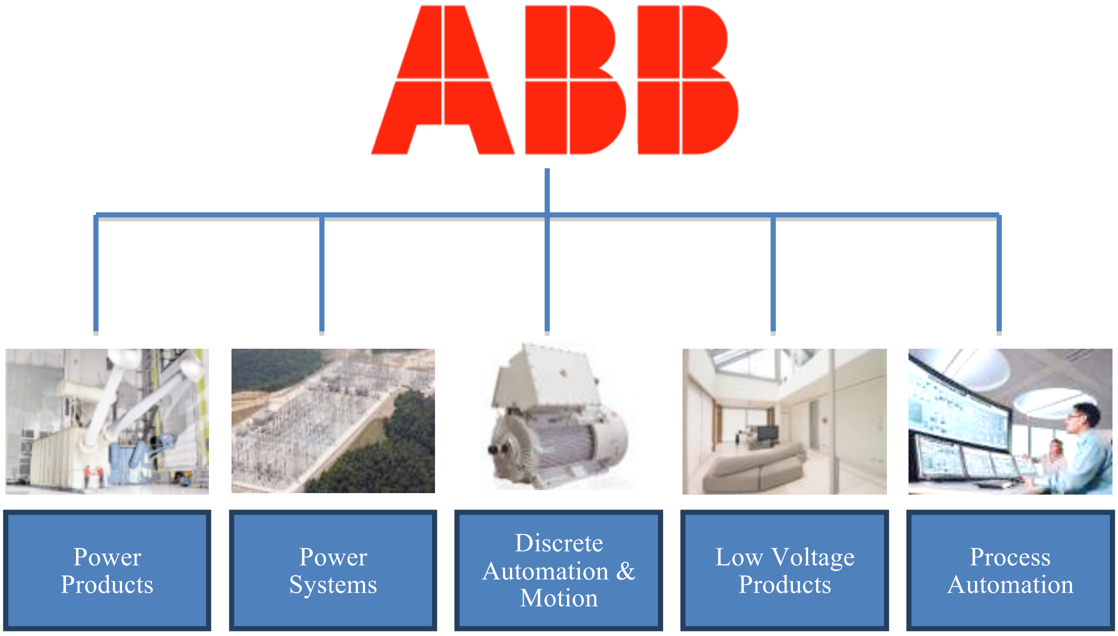


Figure 1. The five divisions of ABB; Power Products, Power Systems, Discrete Automation & Motion, Low Voltage Products and Process Automation. Source: Annual report (2012).

Power Products (PP) is the division that operates electric, gas and water utilities as well as industrial and commercial customers and offers products like high voltage products and systems, transformer products and medium voltage products and systems. ABB PP is actually the world's biggest supplier of transformers and stood for about 25 per cent of ABB's total revenue (Annual report, 2012). This is actually the highest revenue per division, see Figure 2.

Power Systems (PS) offers traditional energy systems that plays a big role in the optimisation of electricity generation. These products could be power generation plants, transmission grids and distribution networks. ABB PS actually has more than half of the world's installed base (ABB, 2013c). In 2012, the division had 18 per cent of the total revenue of ABB (Annual report, 2012), see Figure 2.

The Discrete Automation & Motion division delivers products, solutions and services that increase industrial productivity and energy efficiency (ABB, 2013d). The products can for example be motors, generators, drives, programmable logic controllers and power electronics. These products help customers to improve productivity, save energy, improve quality and generate energy (Annual report, 2012). The division is in a leading position in wind generators and a growing offering in solar inverters and is the world's biggest supplier of industrial electric motors and drives. Figure 2 show that the division had 22 per cent of ABB's total revenue last year, which is the second biggest division.

The Low Voltage Products offers products and solutions that are suitable for multiple electrical applications from residential home automation to industrial buildings, including low-voltage circuit breakers, switches, control products, wiring accessories and cable systems designed to ensure safety and reliability (ABB, 2013c). The main applications are in industry, building, infrastructures, rail and sustainable transportation and e-mobility applications

(Annual report, 2012). This division actually ships over 1 million products worldwide every day and has 16 per cent of ABB's total revenue.

The division of Process Automation offers solutions to optimise the productivity of industrial processes, e.g. turnkey engineering, control systems, measurement products, and life-cycle services. The customers can be industries in oil and gas, power, chemicals and pharmaceuticals, pulp and paper, metals and minerals, marine and turbocharging (ABB, 2013e). ABB Process automation actually delivered the world's first power-from-shore solution for an offshore rig. In 2012, the division stood for 19 per cent of ABB's total revenue, see Figure 2.

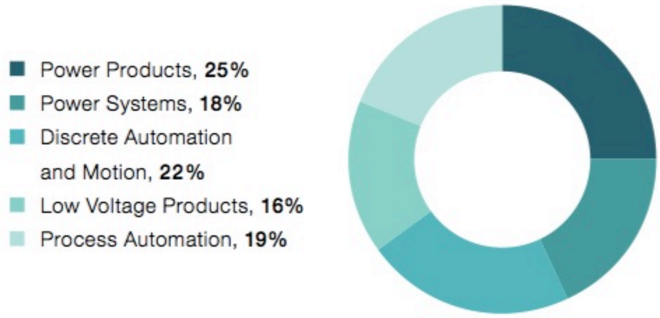


Figure 2. Revenue per division, 2012. Power Products stands for the biggest share of the revenue, while Low Voltage Products stands for the smallest share. Source: Annual report (2012).

1.3 The new Logistic Centre

ABB's production facilities in Ludvika have been located at the same position for more than hundred years. Over the years, the company has grown and so have the facilities. Consequently, the space is very limited today and at the same time the production is planning to expand as the demand is increasing[1]. The situation is not sustainable in the long run, why the management group has planned to move the handling of material and storage of products to an external area close to the production plant, see Figure 3. The external area is in total 56 000 square meters and is today an empty zone without any buildings, but surrounded by public roads. Within this area, a new LC will be built. The LC will support ABB Ludvika to coordinate and optimise the material flow and logistical processes, but also to improve the control of the flow.

Furthermore, the management group has formed a project group that will plan, design and develop the new LC. The project group consists of people from several departments at ABB Ludvika, e.g. Transport department, Facility Investment and external architects. The group has begun a planning phase and is now looking to settle on more specific plans for the area as far as both requirements and design. The project started in May 2013 and is supposed to be finished in 2015.

[1] Kurt Nordahl (Department manager, Transport department, ABB Ludvika) Interviewed 14 Mar. 2013.

Figure 3. The production facilities in Ludvika, which are located in the middle of the figure. The part that is marked in red is the planned area where the new LC will be build, just across the street from the production facilities. The area is in total 56 000 square meters and is today a non-used zone. Source: Google (2013).

1.3.1 Stated arguments for the new LC

ABB have many reasons for building the new LC, where the five main reasons can be seen in Table 2 (presented upon priority). The first and most important argument is Safety Issues. The limited space results in that trucks and machines are driving close to where personnel are working. Hence, the material flow becomes very complex with a lot of congestion, safety issues where an accident will happen soon. Thereby, ABB want to move the storage of material and the material flow outside of the production facilities.

A second argument for building the new LC is that there is a very limited control of the material flow. The material is handled manually with human readable text, i.e. without any scanning or any help from automatic processes. As a result, the forklift drivers need to remember where they store the goods, even when it comes to thousands of pallets. Of course, this requires a lot of work and becomes very time consuming for large material volumes. The concrete reading of the labels can also be an issue when the workers manually read the information, due to the human error. In many cases it can happen that the workers read the labels wrong or misunderstands the information. This can for example lead to that the products are stored in the wrong place or shipped to a wrong customer. Thereby, goods within ABB Ludvika are lost on a regular basis worth millions of dollars[2]. ABB Ludvika believes that by building the new LC it will lead to better control of the material flow. Mainly due to that a scanning system will be implemented at the same time as the material handling will be moved to the LC. But also because all logistics processes will be done at the same place and thus it is believed that the control will increase.

Also, the volume produced in ABB Ludvika is expected to increase in the future, which is the third argument. Only in 2012, the volume increased by 20 per cent and during 2013 the volumes are expected to increase by 35 to 45 per cent next year, which will result in more frequent deliveries and additional material handling.

[2] Kurt Nordahl (Department manager, Transport department, ABB Ludvika) Interviewed 14 Mar. 2013.

Fourthly in connection with this, the production units are today having a lack of capacity[3] where the storage space is very limited. Thereby it is needed to move the dedicated storage area to an external facility. The production units plans to expand their manufacturing area in order to cope with the increased volume. Hence, the total area today of 44 000 square meters is not going to be enough for more storage of goods.

The last reason for building the new LC is that a lot of material is stored outside and are disseminated over the productions facility, e.g. in temporary tents and outside in the cold. Hence, there is a risk that the quality of the material will be reduced. This is not a sustainable solution for ABB due to that the customers require that all material should have the highest quality. Hence, the material that needs to be stored inside should do that, while other material can be stored outside.

Table 2. ABB Ludvika has identified five main arguments for building the new LC presented in priority order.

Reasons for LC	
1. Safety issues	The limited space results in that trucks and machines are driving close to where personnel are working. Hence, accidents may occur.
2. Lack of control	The material is handled manually without any scanning or any help from automatic processes. Thereby, goods within ABB Ludvika are lost on a regular basis worth millions of dollars.
3. Increasing volumes	During 2013 the material volumes are expected to increase by 35 to 45 per cent, which will result in more frequent deliveries and additional material handling.
4. Lack of capacity	Today there is limited space for storage and movement of material, why it is needed to move the material to an external facility.
5. Outside storage	The material is stored all over the productions facility, in temporary tents and outside in the cold, which results in reduced material quality. Hence, the storage of some material needs to be moved inside.

1.3.2 Stated requirements for the new LC

The LC project group has discussed some requirements and functions for the new LC. The requirements and functions are not definite and have only been discussed according to what has been believed to be important and possible to achieve within the company. These are displayed in Table 3, along with some details.

Table 3. Function suggestions for the new LC.

Requirements	**Motivation**
Freight office	Office space where truckers may announce their arrival.
Loading zone	Space for both loading and unloading of trucks.
Office space	Room for 10-20 employees, incl. conference room, changing rooms, restrooms, dining etc.

[3] Kurt Nordahl (Department manager, Transport department, ABB Ludvika) Interviewed 14 Mar. 2013.

Property cover roof	Protecting goods from water and snow, a large cover of around 20.000 sqm is wanted.
Terminal building	A terminal building is needed for more long-term storage as well as to protect goods from outside conditions like cold and water. The building is planned to require around 3000-5000 sqm.
Truck parking	An area where to keep handling trucks that are not used.
Truck waiting lanes	A truck waiting area with room for the all trucks during the busiest hours.
Empty packaging handling	Space to handle finished goods packaging. Possibly by an outside actor.
Heavy load racks	A place to put heavier outgoing goods on top of each other.
High level storage	Storage of arriving goods of smaller sizes that are to be shared across several production departments.
Pallet handling zone	Space dedicated for handling pallets.
Queue screen	Line-up systems showing truckers when to enter the area.
Forklift workshop	Indoor space dedicated for forklift repair. Here, the plans are to receive external forklifts from other companies as a side business, in order to make more money.
Trucker restrooms	Restrooms and possibly also dining for truckers
Washing hall	Indoor space dedicated for washing forklifts.

A freight office is believed to be preferred in order for the trucks to register their arrival, exchange documents and communicate with the company. The terminal building is planned to host both office space and indoor storage for goods shipping off with requirements on temperature conditions and so on. This facility is also possibly a good place for a truck workshop. A loading area as well as handling truck parking is believed to be necessary in order to ensure the loading. Bad weather conditions are also believed to be reduced using a big property cover roof. An empty packaging and a pallet-handling zone would relieve the old areas for this and collect these activities more centrally. A high level storage would possibly allow arriving items used in several production facilities to be unpacked and sorted straight away. A queue screen could perhaps decrease confusion for awaiting trucks on the parking lanes giving them some extended information.

Geographical requirements are viewed in Figure 4 beneath. The LC area (A) represents around 55000 sqm. and this part is today covered with forest as well as a small gas station in the upper north, which is to be moved. These negotiations are on going. The left part (B) of around 3000 sqm., an old football field, is meant to become a truck waiting area where incoming trucks can park awaiting a loading process. This area has recently been covered with concrete in preparation for the LC. The square dimensions are about 40*80 meters. The third area (C) is already used by the company and separated by a road and a company security fence. This square, called “E-Plan” is today a storage area and loading zone for shipments going out from the transformers production. All three areas are now separated by roads but the one between area A and C is planned to be removed, leading the traffic up north southeast of area A instead. The company property will through this be extended using an entrance gate between area C and A. This passage is also a small hill of about 3 meters in height.

Besides geographical requirements, the project is also limited by present company wide procedures like shipping arriving goods straight to the production facilities which will be done also in the future. Storage is primary meant for finished dispatch products except for the possibility of a shared high-level storage, which currently is under examination. Another project input is the external area by the town of Grängesberg approximately 15 km away where supply washing and long-term storage is planned.

The project is also planned to introduce slot times for arriving traffic delivering goods. These time frames are to be delivered to each transporter at their announcement of arrival in order to smoothen out the flow and reduce the dips from the unloading areas.

Even though there are a lot of wonderings and plans for the project there are still a lot to do within these frames. An area design is still far from settled as well as flow decisions and functions to include. The project is currently evaluating these areas, partly with an input from this Master Thesis.

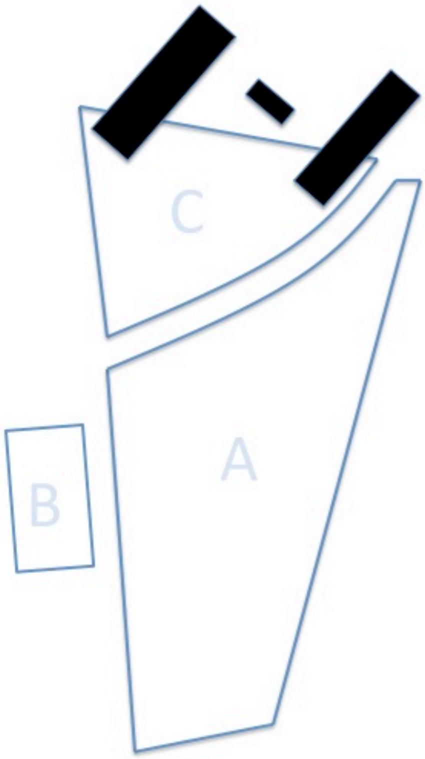


Figure 4. Geographic sketch of the LC area and its surroundings. Note that this is only a sketch; dimensions are not according to real life scales.

Another project parallel to the Logistic Centre implementation is a barcode initiative where a group of representatives from different ABB areas work together to create a future solution with better tracking and tracing control around the area. The future barcodes are meant to be standardised and used all over the company area so that material can be followed and less steps are required saving receiving and searching for items efforts among the personnel[4].

1.4 Purpose

The purpose of this report is to explore and evaluate the material flows to and from the production site at ABB Ludvika and investigate how these could be improved and controlled in the new Logistic Centre.

1.5 Problem analysis

To reach the purpose of this thesis, one main research question has been stated:

How can the material flow be most efficiently improved to and from the production divisions at ABB Ludvika through a Logistic Centre?

In order to answer the main research question, three research questions (RQ) have been formulated. By answering these RQ, it will be possible to answer the main research question and thereby fulfil the purpose of this thesis.

[4] Filip Bengtsson (Project manager, Facilities department, ABB Ludvika) interviewed 19 Jul. 2013.

RQ 1. What is the current logistic situation at ABB Ludvika and what issues are present?

First of all, the current logistic situation needs to be examined in order to identify problems that need to be reduced.

RQ 2. What main factors are affecting the performance of a Logistic Centre?

Secondly, what factors that affect the performance of a LC needs to be investigated and if it is possible to categorise these factors in some main areas.

RQ 3. What performance factors are critical in developing the new LC at ABB Ludvika?

Thirdly, the factors that were found in RQ 2 should affect the development of a LC in different ways. But how does these factors affect the development of the LC in the current logistic situation of ABB Ludvika together with the identified problems.

1.6 Demarcation

From Baudin's (2004) definition of logistics: "Logistics is comprised of all the operations needed to deliver goods or services, except making the goods or performing the services", this thesis will focus on the logistic activities outside production. When processes within the production units are found as having a clear key connection or potential valuable connection with the outside logistic flow and management, they may be taken into consideration. Further, material flows are considered supporting the five production divisions at ABB Ludvika, even though each of these divisions has their own subdivisions.

The thesis focus will include the issues developing the system and what areas to focus on within the walls of the LC where material flows, monitoring and control will become key. The initial current situation study will resolve in qualitative interview data as well as a limited quantitative approach based on data collection and observations. This field study phase will be restricted to a limited time set by the company. Flow observations will be made within certain standardised product categories covered in the methodology section within the reach of the company system.

While delivering the solution, the thesis will propose strategic non-economic guidelines to future developments. As illustrated in Figure 5, the project will focus on developing the flows locally at the new logistic centre.

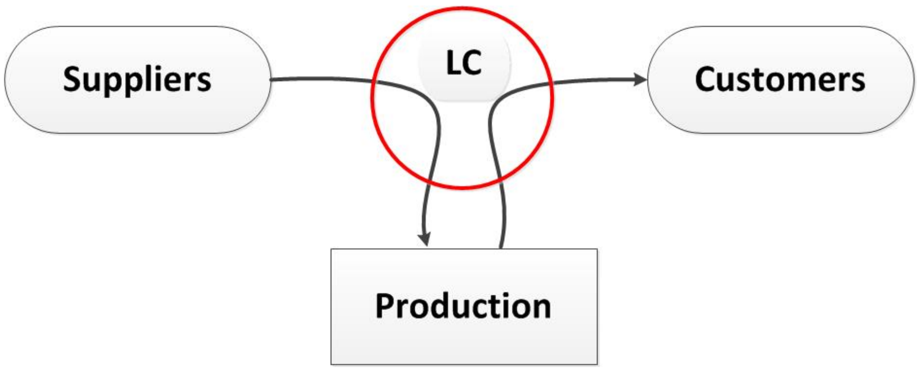


Figure 5. Illustration of the demarcation of this thesis, which will analyse the material flow to and from the production through the LC.

1.7 Outline

The outline of this thesis consists of eight main chapters, starting with Introduction and proceeding with Methodology, Theoretical framework, Empirical findings, DHL Torslanda Terminal, Analysis, Conclusion and Discussion and further research. A short explanation of the chapter follows:

Methodology – The methodology is explained in chapter two together with a reflection on the quality and reliability of the study. The methodology uses an inductive and deductive approach that matches theory and empirical findings.

Theoretical framework – The findings from the literature study will be presented in the theoretical framework, chapter 3. In order to find out what factors that are affecting the development of a LC, many logistic areas needs to be evaluated. The theoretical study will start wide with the terms of logistics and supply chain management and continue by the three pillars of a material network system: actors, activities and resources. In the end of the chapter a Logistic Centre Concept Model is presented, which summarises and describes the factors that affect the design of a LC. The theory study will then be populated in the analysis chapter using the data from the empirical findings.

Empirical findings – This chapter describes the current logistical situation of ABB Ludvika, divided in the four constraints from the LC Concept Model; Context, Production, External material flow and Internal material flow. The data collected was conducted through observations and interviews with ABB Ludvika employees.

DHL Torslanda Terminal – This chapter presents a benchmark of the previous Volvo Car's LC in Torslanda, now run by DHL. The section starts with some general information and then further describes the material flow and control. Finally, facility outline and further observations are examined.

Analysis – This chapter combines the empirical findings with the theoretical framework together with the benchmark. The chapter discuss and analyse the main observed logistical problems at ABB Ludvika and how to mitigate these problems in the LC. The chapter is organised in the four main constraints, coming from the LC Concept Model.

Conclusions – The chapter will answer the research questions and thereby answer the purpose of this thesis.

Discussion and further research – The finishing chapter will cover the reliability and validability of the thesis as well as highlight suggestions upon continued LC preparations.

2 METHODOLOGY

The methodology chapter will describe how this Master Thesis has been conducted. It starts with discussing an overall research strategy and continues with how the work process has been undertaken, used methods for data collection and finishes with a methodology reflection where chosen methodologies and their reliability and validity are discussed.

2.1 Research strategy

The research strategy of a thesis defines a framework for the whole report where suitable ways of work progress and analysis are discussed. According to Kovacs and Spens (2006), a research approach can be either deductive, inductive or adductive. While the deductive focuses on a theoretical collection with comparisons and a inductive study bases the research on practical knowledge, the rarely used adductive study focuses on totally new hypotheses. As the thesis was conducted at a real business case at an existing firm, the strategy was be inductive in the sense of empirical data collection but further also deductive analysing and making theoretically based conclusions based on this collected material.

2.1.1 Research approach methods

Having the general framework set, Ejvegård (2009) comments on nine even more defined and separated research approaches where six in this thesis chosen and followed methods are presented beneath:

A **description** and **Case Study** research approach will initiate the thesis conducting an empirical study and presenting a current state analysis where the project can lift off. The description process is quite simple in theory but may become rather challenging when it comes to the systematisation and sorting of the collected data in a way that is structured. Further challenges come with the selecting of proper data to use as well as the presentation of the material. The description method is here used as a way to prepare the analysis. As suggested by Ejvegård (2009) a Case Study will complement the description method using a case to describe the reality and making dividing problem definitions into smaller parts.

Collected information also have to be classified in order to be presented well and used for the analysis. This **classification** approach requires the researcher to carefully consider reliability, valid ability, exhaustive approach, clearness and usage among the selected data. These guidelines will inquire a section hierarchy where company resources, environment and material flow will be separated and considered as parts of the problem examinations.

Theory formation and **Model Building** worked to create a framework for the analysis of the current data. The theory formation originated from simple facts that resulted in hypothesis that later were investigated and discarded. Hypotheses were then derived along with newfound facts creating a new network so called Theory Formation. These ideas along with Model Building creating a theory based concept model where the analysis can be applied, providing a picture of reality under conditions chosen, wrapped the project into a structured conclusion.

Another large concern in research setups is whether to use a **qualitative or quantitative approach** in the data collection and observations. Blaxter, Hughes and Tight (2006) defines quantitative research as a systematic, scientific investigation of quantitative properties and their relationships. Quantitative research is verification oriented, objective and aim at finding causes. Qualitative research on the other hand, is defined as more subjective in nature and aiming at understanding a phenomenon from the respective reference frame. It is described as being more discovery-aimed providing a more holistic view on results. Kumar (2011) defines the aim of a qualitative research as to understand, explain, explore, discover and clarify situations, feelings, perceptions, attitudes, beliefs and experiences of a group of people. In order to reach a solution for the project objectives, this Master Thesis used a research approach that was both qualitative and quantitative. Quantitative data initially had to be collected in order to gain a current situation perspective where material flow processes could be recognised and measured upon theoretically established parameters. Qualitative data was further used through interviews and benchmark in order to connect quantitative measures and gaining a deeper understanding before evaluating possible system improvements. A reason for this is the size and time of the project framework, which was estimated to inquire certain limitations (see section "Demarcation"), and in order to provide a more holistic view for the company. Another impacting factor is the availability of quantitative data that is found to involve certain limitations.

All areas where results were gained from observations and interview material was compared to recent theory within the subject and interpreted with a critical view. The more important output was backed up with at least two sources. The research aim was to identify and bring general company wide problems of the system to the surface and to explore ways of solution to these.

2.1.2 Methods for data collection

Befring (1994) comments on the two data types, primary and secondary, where primary refers to measurements and quantifications based on interviews, observations and surveys. Secondary data refers to information collected for other purposes. Ejvegård (2003) underlines the importance of an overall literature study following written material like articles, books, essays, reports etc. The author also mentions the importance of reference use and the possibilities of studying the reference list of secondary data.

Both primary and secondary data was used and gathered in the fieldwork and analysis. The primary data collection methodology using interviews as well as the usage of secondary sources of information will be covered beneath.

Primary data was gathered from interviews and observations during the field studies. Questions asked and observations made were prepared in an initial phase of the situation analysis. The questions was stated in order to examine supplier and customer relations, distribution and 3PL usage, delivery and pickup routines, inventory flow, available resources and production departments using question forms in each area (see Appendix). Secondary data was collected and used mainly in the theory search. This information was taken mainly from the Internet, articles and literature.

As mentioned by Hartman (2004), interviews can be both quantitative and qualitative in the sense that they can be set out to bring in ”yes” or “no” answers on certain parameters, opinions on value scales or gather data material as well as serve to gather qualitative open answers from the interview objects. A qualitative interview should further not involve leading questions. The author also underlines the importance of choosing whom to interview as well as the preparation and note taking before and during the interview. Following these guidelines interviews in the thesis was carefully prepared and all preparation material was presented in appendix. Interviews were conducted both gathering quantitative and qualitative data as well as handling it differently accordingly in the work process.

Even though it may be time consuming, observations can be very useful complementary to interviews. An advantage of observations is the reality facts gathered that could be much different from those mentioned in an interview. Memory and perception issues may make information invalid or inaccurate (Hartman, 2004). Thus, observations of the material flow were made in parallel with interviews with the aim of covering the same areas and testing the covered performance.

Lekvall and Wahlbin (2001) underline the importance of a literature review and to create a theoretical framework before the task is fully formulated. Halvorsen (1992) states the importance beginning the project establishing a rather clear picture of the problem area so that the literature search wont be too time-consuming. Rumsey (2008) mentions two key points when doing literature search. The subject needs to be well defined and the purpose and scope should be clear.

The theoretical framework in this thesis followed a situation analysis where the problem was examined and company demands were gathered but problem analysis research questions sometimes was altered as the theory is reviewed in accordance to theory recommendations.

2.1.3 Process Mapping

Even though there are numerous process definitions, they all carry some likeness as far as describing activities and links interfering in networks (Ljungberg & Larsson, 2012). Taylor (1997) further explains how supply chains consists of many processes including information, standards and decisions taken at different times. Thus process maps are an essential start while analysing logistic flows and supply issues. Anupindi et al. (2012) highlights the use of process flowcharts as valuable graphical representation tools. The authors also comments on the value of an overview image in optimisation work where the correlation between different processes can be controlled and measured. Gardener and Cooper (2003) values the effectiveness of a map depending on how well it represents its system. Thus in the end, the appearance and understanding by the author really decides on the tool value.

In order to assist the reader and deliver a more clear solution, gathered information in the empirical findings as well as suggested solutions in the analysis were supported by material flow maps in accordance to suggestions stated above. Guidance to symbols and methods used were presented in Appendix.

2.1.4 Benchmarking

In order to reach a deeper understanding as well as a more practical view of possible system improvements, benchmarking was used as a main tool in the project. Benchmarking is defined as (APQC, 1993):

“The practice of being humble enough to admit that someone else is better at something and being wise enough to learn how to match them and even surpass them at it”

Since the core competences of ABB rather lies in technology solutions and know-how than logistic management there are reasons to believe that many winnings could be made using these ideas. Studies have shown an importance of benchmarking reaching so called breakthrough improvements as shown in Figure 6 beneath (Andersen & Pettersen, 1995).

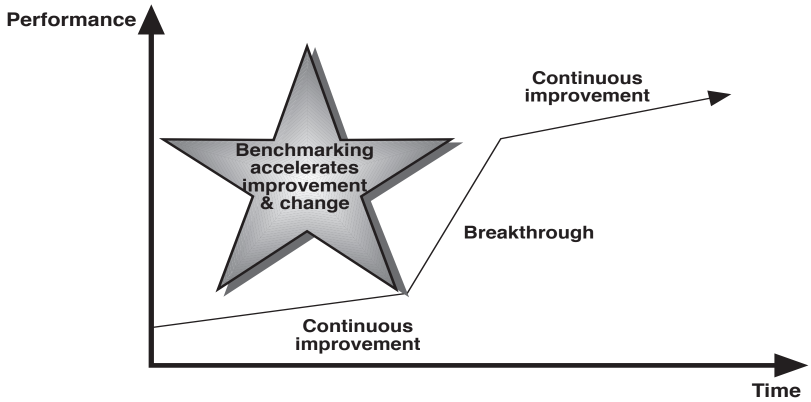


Figure 6. Illustration of the importance of benchmarking. Studies have shown an importance of benchmarking reaching so called breakthrough performance improvements. Source: Andersen and Pettersen (1995).

Kumar (2011) suggests a "case study" as suitable when exploring an area where little is known and a holistic view and understanding is desired using several methods collecting data. The research strategy will follow these ideas and aim to gather accurate material using diversified data collection methods in a situation analysis.

Interviews and observations were covered in empirical sections in order to make it possible to trace issues and questions in the further work process.

2.2 Work Process

The work process preparing the analysis was divided into three phases that partially was conducted simultaneously. A situation analysis of ABB Ludvika, a theory search on the subject and a benchmark together shaped an analysis and later a conclusion as shown in Figure 7.

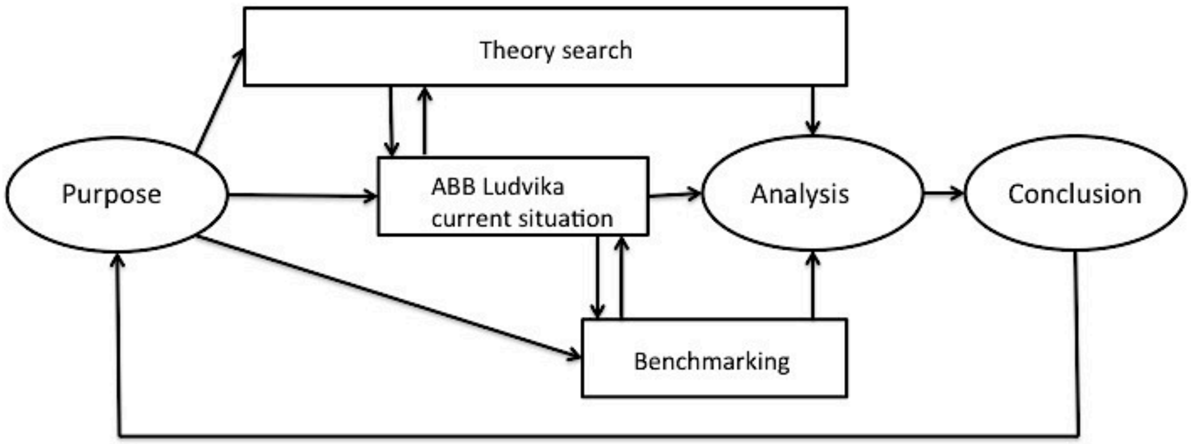


Figure 7. Illustration of how the Master Thesis should be conducted. In order to answer the purpose of this project, the research will be divided in three main areas; a theoretical search from scientific research and articles, a survey of the current situation in ABB Ludvika regarding the material flow and a benchmarking on how other companies has solved the situation. These three areas will then be analysed, which will result in some conclusions, which will answer the purpose of this thesis.

The thesis was initiated through the establishment of a planning report. This report specified an agreement of the given assignment with ABB Ludvika. The task was concretised with help from an introducing plant visit at the production site and logistic management department in Ludvika and with guidance from the supervisor Per Medbo at Chalmers. The planning report worked as a project plan and specified the task through areas like problem background, method and project time schedule. The report was then sent to the logistic department at Ludvika for verification and feedback.

The planning report was followed by a current state analysis exploring the company situation and the existing inbound and outbound logistic flows at the production site in Ludvika. This was done through field study data collection. The material was collected at the purchasing and transporting departments during a site visit in June. The data was gathered through both interviews and observations at this stage. In order to understand the present activities, and processes undertaken geographical illustrations were used showing on the outline of the existing material yards. Statistic numbers received on the present flow were illustrated through charts and graphs. Observations made following received and delivered items then gave input for current state value stream mapping images made in Microsoft Visio. The outline of the empirical section was structured in accordance to the concept model created from the theoretical framework on the subject.

The creating of a theoretical framework, suitable for the evaluated logistic setup, followed the current state analysis work in July. Theory was collected from course literature, articles available at the Chalmers library and web-based research on the subject in accordance to guidelines from the section above. The structure and development of the chapter was chosen in accordance with a theory organisational framework presented in the beginning of the chapter. This chapter was finished by a summarised theoretical concept model that later were used as a framework deciding on the improved material flow and warehouse development, as well as a structure for the whole report.

Theory studies were used as guidance in an evaluation of the plans and resources available for the new Logistic centre. A future state analysis was now initiated and these activities were conducted with help from another plant visit during late July with emphases on the new Logistic centre. This visit was used collecting information regarding planned and possible changes in the current logistic layout and the assigned area for the improved logistic operations. Here Microsoft Viso was used once again drawing future state material flow maps in order to overview and illustrate suggested changes in both the information and material flow. The fieldwork at this stage inquired meetings with the investment and logistics departments at the plant.

The work resulted in a complete project report with conclusions including concrete guidance and ideas for the development of the new Logistic Centre. The thesis will be presented through a project report and a presentation at Chalmers as well as one in ABB Ludvika.

2.3 Methodology Reflection

Ejvegård (2003) highlights the importance of reliability of gathered material through observations and interviews in order for the analysis to be successful. Criticism is viewed as very important as well as the controlling of questionable numbers in the data. Davidson & Patel (2003) further agrees promoting an important aspect of qualitative research as being the quality of the data collected, which will be very dependent on the degree of certainty of the material collected. Kumar (2011) underlines obstacles reaching validity and reliability when research interview questions are explored using multiple methods and evolving procedures. These issues were addressed using careful examination of all answers and their interpretation in order to reach trustworthiness. Guba and Lincoln (1985) suggests frequent reviews making sure that questions are being asked according to preparations as well as controls to secure that answers are perceived the same by both researchers. These authors also comments on the importance of visit and interview documentation in order to make traceability possible in the analyse-phase. This documentation was ensured keeping journal notes along the work.

3 THEORETICAL FRAMEWORK

The theory section starts with a general description of logistics and material flows, which are composed of a material system. Furthermore, other logistic terms will be described, such as distribution, route planning, lean production, centralisation, logistics service providers and tracking & tracing. The section ends with a model of how to develop a LC, which in turn summarises the main theories being used in this thesis.

3.1 Theory introduction

According to Baudin (2004, p. 10) logistics involves all the operations needed to deliver material, but not making it, which in turn includes different flows. These flows are part of a material system, or a supply chain (Chopra & Meindl, 2012), and are composed of the activities making the flow possible, the resources needed for the activities and the operators performing the activities. This means that the material system can be divided in three main areas; actors, activities and resources (Håkansson & Johanson, 1992). The actors performs the material flows activities needed between firms in the supply chain (Ford et al., 2003). These activities adds value to the end customer and could be everything from transporting, material handling, manufacturing or just bridging gaps to the customers. In order to perform the activities, resources are needed. The resource structure can be formed in many different ways, including decentralisation and centralisation (Abrahamsson, 1993). Warehouse design deals with the question of how to design the resources in order to perform the activities needed by the actors in the material system. Figure 8 shows the theory path towards the Logistic Centre.

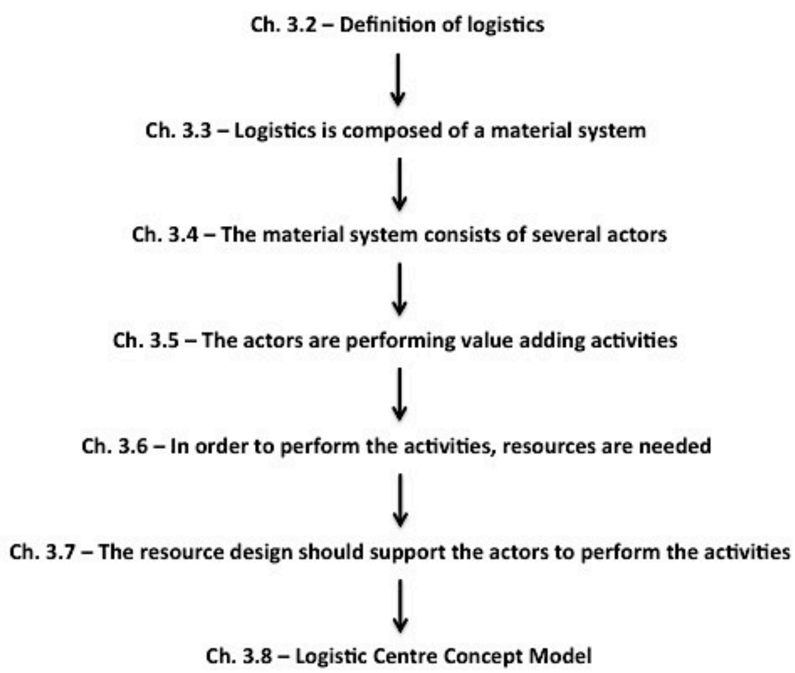


Figure 8. How the theory chapter is organised.

Each of the steps in Figure 8 will further be described in each section, starting with logistics and continues with material system, actors, activities, resources, warehouse design and finally it ends with the Logistic Centre Concept Model.

3.2 Logistics

Baudin (2004, p. 10) defines logistics as:

“Logistics is comprised of all the operations needed to deliver goods or services, except making the goods or performing the services.”

In turn, logistics includes the three following flows:

- Material flows: Shipping, transportation, receiving, and storage and retrieval between plants and between production lines within a plant.
- Information flows: Transaction processing associated with the material flows, analysis of past activity, forecasting, planning, and scheduling future activity.
- Funds flows: Payments triggered by the movements of goods and information.

This definition means that logistics includes all activities that is needed to give the customer what they want, except from the pure production activities, i.e. transformation of materials through machining, fabrication, or assembly. Figure 9 shows the meaning of logistics as everything that happens outside the production boarders. The production needs materials from a network of suppliers, while the finished products go out to a distribution network before it reaches the end customers (Baudin, 2004). Both of these networks affects the production, even though the company management often do not see further than the first tier.

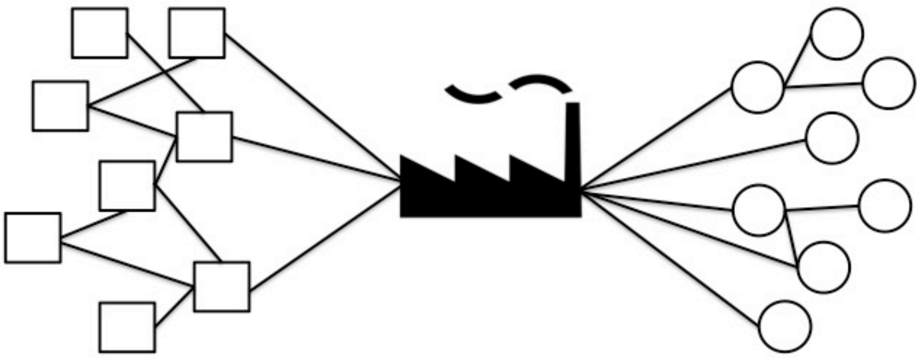


Figure 9. Logistics from a production perspective. The plant needs materials from a network of suppliers, while the finished products go out to a distribution network before it reaches the end customers. Source: Baudin (2004).

In- and outbound logistics are handled and coordinated by multiple independent actors, including multiple tiers of suppliers and distributors, trucking companies, railroads, and air and sea freight companies (Baudin, 2004). This means that in- and outbound logistics includes all activities that are conducted outside of the company in focus. Hence, the boundary is that between the company boarder and the rest of the world. The in- and outbound logistics will affect the total material flow due to that the external actors handles the activities needed to ship, transport, receive and storage between companies.

In-plant logistics, on the other hand, is under the control of one organisation. The in-plant logistics separates the in- and outbound logistics by all activities that are performed within the company boarder, except from the production. The in-plant logistics will affect the internal material flow within the company, when the own organisation controls the activities such as internal shipping, transporting, receiving and storage between internal divisions.

The logistics/production boundary could some times be hard to define. Production is everything that transforms the material through machining or other similar processes. Of course, packing the products in shipping could be seen as transforming them, but it is still considered part of logistics because it is often done by a department called “materials handling”. Where the logistics/production boundary is placed could thereby be seen as a managerial decision. Actually, production preparation by Logistics can overlap with materials handling by Production, which means that the handover can take place at many points. But, even though the boundary could be hard to find one thing is still sure; logistics performance is largely determined by what happens in production.

3.3 The material system

According to Baudin (2004) logistics is composed of a material system, or as Chopra and Meindl (2012) states; a supply network. Furthermore, the flow of materials through a materials system is composed of the activities making the flow possible, the resources needed for the activities and the operators performing the activities (Håkansson & Johanson, 1992; Håkansson & Snehota, 1995; Ford, Gadde, Håkansson & Snehota, 2003). Hence, the material system can be divided in three main areas; actors, activities and resources, see Figure 10 beneath.

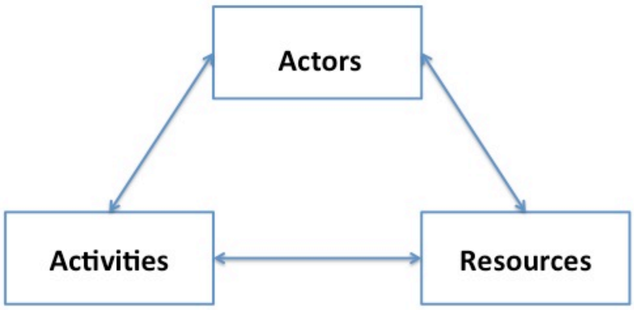


Figure 10. A material system is divided in three main areas; actors, activities and resources. All three areas give their particular perspective on the system. The activity dimension could be transportation, material handling and warehousing. The resource dimension could be rails, roads, terminals and warehouses. Finally, the actor dimension organises activities and resources in order to economies and generates value to the customer. Source: Håkansson and Johanson (1992).

All three areas give their particular perspective on the material system. The actor dimension consists of the different actors that that need to coordinate activities and combine resources in order to deliver the product to the customer in the most efficient way (Gadde, 2004). The activity dimension consists of all activities needed to get the materials to the customer, which could for example be transportation, material handling, warehousing, inventory handling and operations in terminals (Ford et al., 2003). The resource dimension consists of all resources that is needed for the particular activities and could be the physical infrastructure that the company has access to; rails, roads, terminals, ports and warehouses, but also competencies and capabilities of people in the company.

3.3.1 Supply chain management

In order to consider the whole material system, from supplier to the end customer, together with the three main areas, logistics have developed to include several companies in the network. In the early 1980s, consultants introduced the expression Supply Chain Management (SCM) (Oliver & Webber, 1992), which has developed from being a wider term of logistics to a whole new view area of integrating and managing key business processes across a supply chain (Cooper, Lambert & Pagh, 1997). Authors agree on the increased attention of the area and a recent switch of management viewpoint from an state where single companies are viewed as competing against one another towards an understanding where the true advantages only can be reached grasping a wider concept of whole supply chains competing (Chopra & Meindl 2012; Lambert & Cooper, 2000). The chain outcome performance is here seen as a total supply chain surplus, which should be proportionally shared between the actors. Lumsden (2012) underlines the importance of cooperation between the suppliers and customers, which should create a “win-win situation”. Thus, local optimisation may lead to problems at other ends of the chain causing final setbacks in the eyes of the consumer.

What is then the actual meaning of a Supply Chain? Christopher (2005, p. 17) defines a supply chain as:

“a network of organisations that are involved, through upstream and downstream linkages, in the different processes and activities that produce value in the form of products and services in the hands of the ultimate consumer”.

The author also presents different views of how these actors can be seen, either as different parts of a giant company internally and as tiers of companies externally. Lumsden (2012) illustrates this presenting how a focal company is surrounded upstream, by tiers of suppliers where orders, power and planning becomes central, and downstream, by tiers of customers where demand, adaption and service becomes vital, see Figure 11.

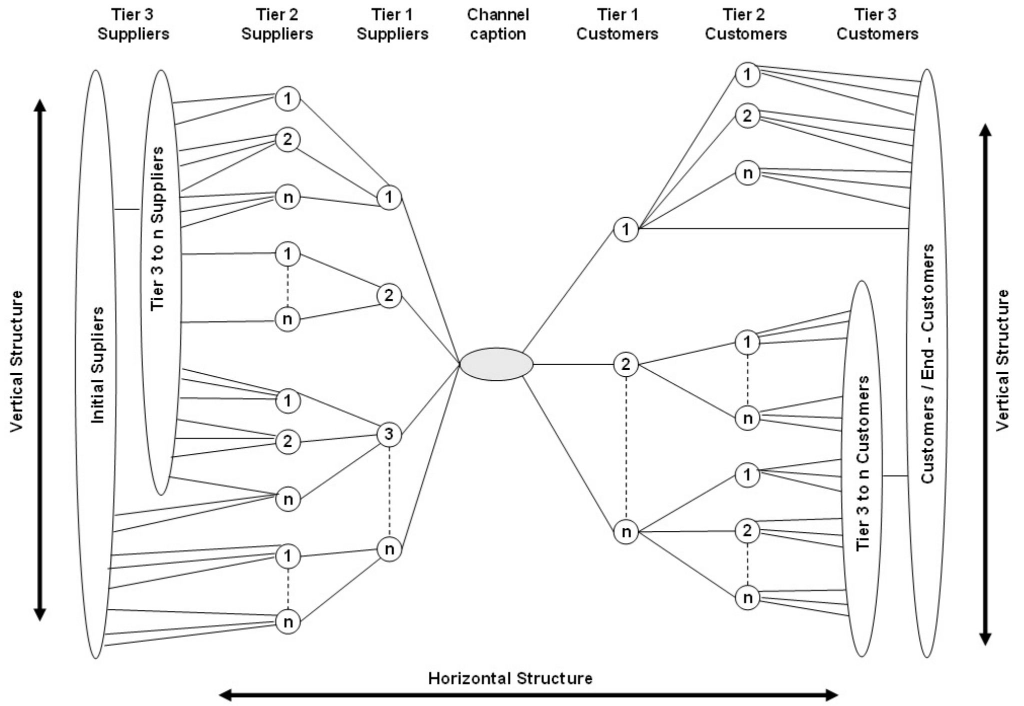


Figure 11. The Supply Chain network. Source: Giner Alor-Hernandez, A., Aguilar-Laserre, Guillermo Cortes-Robles and Cuauhtemoc Sanchez-Ramirez (2011).

Each link between these tiers is established through the flow of goods, information and funds. These become vital in the SCM work where common objectives involve the coordination and integration between the different actors. An important challenge here is to reach a suitable “Strategic Fit” for the company understanding the customer demand uncertainty and the supply chain capabilities. These kinds of design strategies evaluate the need for responsiveness in order to satisfy the customer, weighing the trade-off between an efficiently aimed chain and a more responsive one (Chopra & Meindl, 2012).

Stadtler (2008) agrees on the view of the two important SCM areas integration and coordination. This author illustrates the SCM concept with a house where these two key ingredients become pillars holding the roof. Integration is here communicated partly as an appropriate choice of partners creating a suitable design allowing network inter-organisational collaboration. The later possibilities to adapt the chain continuously in response to changes in the target market may involve big advantages here. Correct and shared leadership across the chain is also stated to be an important integration ingredient. Coordination of information, material and financial flows are presented to increase through a well-established use of communication and technology across the chain. Process orientation is also seen as encouraging this.

According to Chopra and Meindl (2012), management decisions are categorised on the basis of design, planning or operation depending on the time horison during which the decisions made apply. The outcome performance can be measured as supply chain achievements within the following drivers:

- **Facilities** (location of ex. production sites, storage sites)
- **Inventory** (raw material, WIP and finished goods within the chain)
- **Transportation** (ex. network setup choices)
- **Information**
- **Sourcing** (who will perform the different SCM activities)
- **Pricing**

In a research article by Beamon (1999), the author highlights a lack of metrics of SCM performance metrics and the importance of a complete and wider view in order to grasp SCM performance. The work concludes in the identification of a framework with three necessary performance measures; **Resource**, **Output** and **Flexibility**.

3.3.2 Material system investigation

According to several lean authors (Liker, 2004; Womack & Jones, 2003; Rother & Shook, 1999), many organisations are facing large material flow problems with long lead-times, long storage times and many numbers of activities. The essential problem is an ineffective supply and distribution system throughout the entire organisation, when at the same time the firms does not know if the systems are good or bad, what fits in what context and how to design it[5]. To mitigate these problems, many organisations focuses on separate activities and try to improve them as isolated issues. But, the functions are many times interdependent with each other (Ford et al., 2003), why there is a need for an overview of all problems in the whole system.

Rother and Shook (1999) came up with a method that illustrates and helps to understand the material and informational flow as the products goes through the production system. This method is called Value Stream Mapping (VSM), which maps the material and information flow and provides a common picture of the current situation as a foundation for discussion of how to create a more effective flow with the purpose of minimise wastes. During the recent years, VSM has become a standard methodology when organisations desire to improve production (Gardner, 2003; Hines & Rich, 1997; Womack & Jones, 2003). The VSM method tries to categorise the activities in three main groups; pure waste, non-value-adding and value-adding (Monden, 1998) and focuses on decrease the lead-times, minimise the wastes and increase the share of value added activities (Rother & Shook, 1999). By doing so, it will be possible to focus on the value-adding activities and remove the non-value-adding activities. Thus the current situation will be improved to a better future situation.

The main problem with VSM is that it only considers the production system and not the material supply and distribution system, which means that it is of big interest to develop the VSM methodology further (Ramesh & Kodali, 2012). But, if the material supply and distribution system should be investigated in the same manner as the VSM methodology, it will be hard to categories activities as value-adding or non-value-adding. According to the lean philosophy (Liker, 2004), an activity is only considered as value adding if it adds value to the customer. This means that unloading a truck can not be considered as a value-adding

[5] Lars Medbo (Senior Lecturer, Technology Management and Economics, Chalmers University of Technology) interviewed 7 Aug. 2013

activity according to the lean philosophy, even if considered as value for the production system. Also, Domingo, Alvarez, Pena, and Calvo (2007) mean that the VSM methodology does not cover material handling. Mathisson-Öjmertz (1998) has actually shown that material supply systems activities are essential for the production activities, even if considered non-value-adding. Hence, production activities can benefit from logistic activities before and after production. Consequently, organisations within supply chains need something more than the VSM methodology in order to improve the material flows within and between firms, not only in production but in all kind of material handling.

Material Flow Mapping (MFM) is a comprehensive methodology to describe and improve material flows, within and between organisations (Medbo, 2013). This methodology is under development at the Logistics and Transportation department at Chalmers University of Technology in Gothenburg, Sweden[6]. Among others, the main benefits of a MFM is that it helps the company to visualise concrete problems bigger than just a single activity, it links the material and informational flow, it provides a blueprint for implementation and it results in an overview of the system, which is easy to understand. The method reveals what is going on in the whole material system through a mapping of all the different activities. Through the mapping, several performance indicators can be investigated, e.g. the number of processes, the total lead-time, the storage time and the non value adding activities. The MFM can also be conducted at different levels in the supply chain, such as process level, single plant level, multiple plants and across companies. Normally, the first step is to start with a VSM of a single plant, from door to door, and then continue further with multiple plants and across company boarders. Furthermore, the MFM methodology can be divided in three main steps; current state mapping, future state mapping and plan & implementation. These steps are very similar to the VSM methodology, but as VSM considers production processes, MFM tries to identify and improve all kinds activities related to managing the material flows.

Medbo (2013) states four main activities in material flows, which are needed to be considered in a MFM; Material handling, Administrative activities, Transportation and Storage. Firstly, material handling activities involves movement in the material flow (excluding transportation), such as lifting, sorting, putting down and packing of the material. Secondly, administrative activities are events that maintain and control the material flows, such as scanning bar codes, entering information in a computer or stamp goods document. Thirdly, transportation is the relocation of material and is used to physically move material from one place to another (Lumsden, 2012). These activities can occur both inside the company boarders and externally between firms. Finally, storage activity is to store material in buffers, supermarkets or long-term storage until it is needed in another activity.

3.3.2.1 Current state

The first step in the MFM methodology is to understand how things currently operate, by doing a current state drawing of the material and informational flow (Medbo, 2013). A product or a product family should be chosen and then walk along the flow and collect actual facts. What performance measurements that should be evaluated needs to be decided before the methodology can begin. Slack, Chambers & Johnston (2007) means that all operations need some kind of performance measurement as a prerequisite for improvement. The performance measurements are highly related to the objective of the methodology together with the company goals. It is important to clock all the different operations time by hand and not take standard operations time. The current state will be the baseline of the further investigation.

[6] Lars Medbo (Senior Lecturer, Technology Management and Economics, Chalmers University of Technology) interviewed 7 Aug. 2013

3.3.2.2 Future state

The second step is to analyse the current state and design a future situation, by doing a future state drawing (Medbo, 2013). Rother & Shook (1999) means that there is always an opportunity for a better future situation, which will be the vision of the method. A guideline for the future state map of the material flow could be as what was stated by Rother & Shook (2003):

"A smooth flow without detours that generates the shortest lead time, highest quality and lowest cost".

In order to analyse the current situation, Medbo (2013) stated some guideline questions, which will help to achieve a future state. The seven questions are as follows:

1. What is the real customer demand?
   Demand, takt-time, physical design or the requirements from production need to be settled.

2. To what degree can we achieve a continuous material flow?
   - As few process steps as possible.
   - As few storage/buffers as possible.
   - As few handling operations as possible.
   - As small batchers as possible, preferably one-piece flow. Here, consideration must be taken to transports and then adjust the packages to small batches.

3. How can we achieve a pull controlled material flow?
   - Let the customer pull value from the producer and only produce what is needed.

4. How can a levelled material flow be achieved?

5. How can the material flow be synchronised with the takt of customer production flow?

6. Which process improvements are needed? (training, reductions of disturbances, quality improvements, reduction of changeover time etc.)?

7. How can the material flow be further improved?
   - Pursue perfection.

3.3.2.3 Plan & implementation

The final step in the MFM methodology is to plan and implement the improvements. Here, an action plan has to be decided of how to implement the future state. It is important to create a realistic plan to achieve the goals settled in the future state map. Also, the goal should not be implemented all at once, it is better to implement it step by step (Medbo, 2013). The improvements should also be tested and evaluated before implementation.

3.4 Actors

As stated by Chopra and Meindl (2012), a supply chain consists of several actors, from raw material supplier to manufacturer, retailer and finally end customer. All actors are creating value to the customer by performing different activities. The increasing needs and demands from the customers have made the actors more and more specialised over the years. As a result, the traditional supply chain has developed into a network of actors (Ford et al., 2003).

The actor dimension consists of the different actors that that need to coordinate activities and combine resources in order to deliver the product to the customer in the most efficient way (Gadde, 2004). Hence, actors organise activities and resources in order to economies and generate value to the customer. In this scattered structure, when companies rely more and more on outside suppliers, there is a need for additional and neutral actors to perform and coordinate the activities wanted between organisations (Bitran, Gurumurthi & Sam, 2007). These actors, which are called logistics service providers (LSP), are the ones that perform the material flows activities needed between firms in the supply chain.

Different LSP manages different functions in the material system. Berglund (1997) separates the functions into to main logistics activities, which can be performed by these actors. The first is referred as "Basic logistics" and includes activities like transport, warehousing, consolidation and labelling. The other is stated as "value-added logistics" and could be activities like order processing, kitting, network design and inventory management.

LSP are trying to achieve economy of scale by handling, coordinate and consolidate a big amount of material, which can be done due to the fact that LSPs provide logistics services to a number of clients simultaneously (LaLonde & Cooper, 1989; Ellram & Cooper, 1990; Bardi & Tracy, 1991). The more material volume that is handled by the actor, the more economy of scale can be accomplished. By doing so, the cost of logistics operations can be decreased. Andersson (1997) states that the cost of logistic operations is lower for logistics service providers than both for small and large firms. An explanation could be that LSP has a network of resources, such as terminals that can be coordinated to achieve a fast material flow with a low cost per unit.

3.4.1 Categorisation of LSP actors

The different actors can also be categorised by what functions they performs between the seller and the buyer (Lumsden, 2012). One party logistics (1PL) means that either the seller or the buyer takes care of the logistical functions (Lumsden, 2012).

Two party logistics (2PL) can be seen as a traditional collaboration between two parties involved in the logistical operations. In order for the logistic performance to be called 2PL, either the seller or the buyer should perform the transportation.

The most common situation is that three parties are involved in the logistics performance, which is called third party logistics (3PL). Here, three parties are involved: the seller, the buyer and an external party, which handles functional areas between the two other parties. PROTRANS (2003, p. 32) defines 3PL as:

"activities carried out by an external company on behalf of a shipper and consisting of at least the provision of management of multiple-logistics services."

A 3PL provider can of course carry out the physical movement of goods, but as the definition states, a 3PL provider can perform and manage other logistics services like storing, sorting or other value adding activities. Lumsden (2012) states that in order to get an efficient 3PL function between the two other parties, the commitment should imply closer and more long-term cooperation.

A 4PL, on the other hand, should effectively coordinate processes in the whole supply chain, manage logistics and material flow through many organisations and control other 3PL providers (Gattorna, 1998).

3.4.2 Relationships with LSP

When a firm contracts a LSP, then they become dependent of this external actor. Over the years, the relationship with the external actor has evolved from adversarial to cooperative. Gadde (2004) compares the traditional network with todays network and states that the relationship characteristics have developed from an arm's length approach to a collaborative relationship. Also, the relationship atmosphere has evolved from confrontation, where only money and power mattered, to a closer cooperation, where the parties develop together with trust and write long-term contracts. As a result, the cost for having a close cooperation is high, but on the other hand the benefits that can be achieved is much higher than in a traditional network.

Van Weele (2010) also comments on the relationship importance and means that a reduction of suppliers can result in a better relationship atmosphere with the remaining ones. This can result in trust between the parties with better cooperation. Hence, the 3PL providers together with the suppliers have very important roles to play in the external material flow.

3.5 Activities

The material system and the supply chain are today characterised as networks of specialised actors. As stated by Chopra and Meindl (2012), the actors perform several value adding activities in order to satisfy the demand from the end customers and consists of all activities needed to get the materials to the customer, which could for example be transportation, material handling, warehousing, inventory handling and operations in terminals (Ford et al., 2003). Activities in the supply chain are related and thereby interdependent to each other (Gadde, 2004). Hence, these activities need to be coordinated in order to create value to the customer, which is often done with information. The developments in information technology makes opportunities for a better performance, as well as productivity (Ross, 2002). When different activities make use of the same resources, they are similar. If the similarity increases, then the resource utilisation also increases, which results in economies of scale.

3.5.1 Production

Production is the activity that transforms and shapes the material to something that adds value to the customer. Production systems are often designed in order to perform as much value-adding activities as possible in the lowest amount of time (Baudin, 2004; Liker, 2004). To be able to achieve this, the material flow to and from production have a number of requirements. To be sure that the material is there when needed in production, it is often stored for weeks or even months before going to the manufacturing unit, where it is only used for a few hours. The Lean philosophy states inventory as one of the seven wastes (Liker, 2004) and means that it is very important to try to reduce it as much as possible. However, some stocks are actually necessary for running the production smoothly, but also due to that supplies can be delayed and there is often a missmatch between the incoming and outgoing quantities (Baudin, 2004).

Baudin (2004) states that logistics performance is largely determined by what happens in production. Thus the material flow has to support the production systems by fulfilling production requirements, which means that production has a very large affect on the material flow. The problem is that the production system and material flow system are often designed independently and with little consideration for each other. Consequently it will lead to a separate performance optimisation (Neumann & Medbo, 2009).

3.5.1.1 Lean production

The concept of lean production originated from the Toyota production system in the middle of the 19th century and has now spread all over the world. The principles of lean production is that it uses less of everything compared with ”traditional production”, such as less inventory, less manufacturing space, less investments in tools, less engineering hours to develop a product in a much shorter time (Womack, Jones & Roos, 1990). Organisations all over the world often misunderstand lean for being a simple model, consisting of a certain fixed tools and concepts that can be implemented over night (Liker & Meier, 2006). Instead, lean is a philosophy or a goal that company should strive towards. The lean thinking believes promotes company efficiency through both useful development tools and an improvement aimed atmosphere that should be shared company wide in order to secure quality at the right time using the minimum resources (Sayer & Williams, 2007).

Liker (2004) means that any processes that do not add value to the end customer should be considered waste and avoided if possible. The seven most common wastes has according to the Toyota production system been identified as overproduction, waiting, unnecessary transport, over- or incorrect processing, excess inventory, unnecessary movement, defects and unused employee creativity. A few other well-known lean tools and believes are the 5S (organising the work area), Kaizen (continuous improvement), JIT (Just in time principles) or SMED (reducing changeover times) (Liker, 2004).

A traditional production system can be considered as a push system, where the material is pushed through the system (Jonsson & Mattsson, 2009). When a process is finished the material is moved or pushed to the next process, even though the next process is busy. Then the material will be put in queue. In this kind of system, the production is using batches and the production plans are used for ordering.

On the other hand, in a pull system the material is pulled through the system and replenished only when the downstream operation needs material from upstream processes. Thus, processes in one work centre are initiated by a signal from the following work centre. In this kind of system no central production scheduling are necessary, besides capacity planning. A prerequisite to use a pull system is to work with small batch sizes.

Liker (2004) states unnecessary inventory as waste, but at the same time the author also means that not all kinds of inventory are waste. Actually, buffers are sometimes needed and can not be removed totally. In a pull environment, these buffers are called supermarkets, which are replenished by kanban system.

Another way to achieve a pull system is by applying First-In-First-Out (FIFO) principles (Lean Instituut, 2013). A FIFO system is usually used in a sequential pull system when there are many part numbers to hold inventory in between each process. Production is initiated by a production list and units are dragged through the system leaving each process in the same order as they arrived. These systems require short and predictable lead-times but are usually simple and efficient to operate.

3.5.1.2 Material feeding and replenishment principles

Several material feeding principles may be applied in production depending on the part selection exposure and sorting at assembly stations, which according to Johansson (1991) may be continuous supply, batch supply or kitting. While continuous supply offers all parts available at each workstation, batch supply goes for a limited number and kitting an even smaller selection sorted for one assembly object. Another feeding technique widely used is sequencing which not only suggests material to be delivered just in time, but also to have it received in a specific sequence suitable for the production line (Svensson, 2006).

A limited number of materials exposed at the assembly stations, or prepared material following sequences or kits can offer advantages like space, less tied up capital, control and visibility and also quality when there are fewer and more pre-chosen actions for the assembler to take. On the other hand, setbacks can be the time-consuming process of preparing kits (Bozer and McGinnis, 1992).

Having the material fed and the production line running, Johnson & Mattson (2009) further defines several techniques while replenishing the system with new material. Four methods mentioned are listed beneath:

- Re-order point systems
- Pull-based system
- Kanban
- Two-bin systems

Re-order point systems are commonly used for items with independent demand. This system triggers a re-order when the stock level reaches a certain predetermined value. Pull-based systems, on opposite to push systems, have got initiating actions further downstream dragging production upstream into replenishment. These systems can many times be used together with the kanban system, which is a method in the lean philosophy for authorising material movement or production based on a visual signal (Jonsson & Mattsson, 2009). When replenishment is needed, some communication is necessary between the downstream stock and the upstream operation. Hence, the kanban is the signal that tells that a replenishment is necessary. In this way the material is pulled through the system and there are not more material than needed at every station. The method is based on the use of kanban cards. The kanban cards can be used in different environment and for different purposes, why there are many different sorts of kanban cards; production kanban, move kanban, supplier kanban etc. Move kanban is used to order movement or transport and it specifies that the material can be removed from stocks and transported to a predetermined destination, i.e. the consuming unit. Browne et al. (1996) state that the main benefits of using the kanban method is that it decreases overproduction, eliminates unnecessary inventory of work-in-progress, shorting of the lead time and is a simple and cheep materials planning and production control.

3.5.1.3 Production preparation activities

In many cases, the material needs to be prepared in some way before it goes to production. This section describes three of the most common production preparation activities; sorting, kitting and sequencing.

Lumsden (2012) mentions sorting as one of the most common production preparation activities that can be done either at the production site or perhaps earlier upstream at terminals or warehouses. Sorting can simply work to divide inbound flow into many different criteria's.

Johansson (1991) presents kitting as preparation mechanism that works to support following production actions in the supply chain. The function collects kits, sets of parts required for one assembly object. The kits can be made out to boxes that are wrapped or production containers that are supplied from other supply chain actors. Benefits of the warehousing tool involve preparation that can work to increase parameters like quality and flexibility during production (Bozer & McGinnis, 1992).

A widely used production preparation activity is sequencing, which not only suggests material to be delivered just in time, but also to have it received in a specific sequence suitable for the production line (Svensson, 2006). According to Baudin (2004) these principles build upon the lean thoughts of just in time management preparing deliveries for arriving at the right time in the right place. The actions may be undertaken either at the suppliers end, in a warehouse or in the initial stages of the production facility.

3.5.1.4 Planning and scheduling

Several planning and scheduling principles exist and are suitable in different situations. A Master Production Schedule, MPS, is usually used for manufacturing planning purposes but can also be valuable in staffing or inventory matters (Johnsson & Mattsson, 2009). The production schedule, commonly controlled through computer software, can be seen as an estimation of the available demand, an information sharing system presenting inventory quantity on hand and a guide to future production during a certain period of time. Having such an important role driving factory activity, the accuracy and viability of the MPS usually has a great impact on profitability. System outputs guiding decision making rely on inputs many times coordinated from an Enterprise Resource Planning system (further described beneath) often working as a link between a sales department and the production.

Enterprise Resource Planning systems, ERPs, work in real-time to integrate business functions and departments within an organisation as well as externally to outside stakeholders. Being one of the most common IT-investments in recent history, the systems manage a wide range of information flow sharing available for almost all platforms (Bidgoli, 2004; Adam, Kotze & van der Merwe, 2011).

ERP modules generally support company functions like Financial Accounting, Management Accounting, Human Resources, Manufacturing, Supply Chain Management, Project Management, Customer Relationship Management and Data Services. As ERP systems usually are based on best practices and these frames commonly are intend to be kept by vendors, they seldom become customised and most often look very alike between different companies. (Vilpola, 2008)

Another planning and scheduling principle is Materials Requirements Planning, MRP, which is a production inventory planning software system used managing manufacturing processes (Johnsson & Mattson, 2009). The system is meant to plan manufacturing activities and insure materials as well as finished products availability while maintaining as low inventory levels as possible. Common system outputs involve "Recommended Production Schedule" and "Recommended Purchasing Schedule" (Waldner, 1992).

3.5.2 Distribution

A very important activity within the material system is distribution, which has been widely discussed and described by many authors (Lewis, 1968; Alderson, 1957; Bucklin, 1972; Gadde, 1989; Rosenblom, 1991; Ford et al., 2003; Gadde, 2004; Lumsden, 2012), ever since marketing became an accepted business area for about hundred years ago (Shawn, 1915). A channel of distribution was defined already in 1968 by Stanton (1968) as:

"…the route taken by the title to products from the point of production to the point of consumption…".

Hence, one can say that it is the activities that bridge the gap between production and consumption. Even though it was defined a long time ago, distribution is still a very important topic and maybe even more central today. Nowadays, the globalisation has made firms more crucial to make sure that the consumers get the product when they want it and where they want it. Of course, this is not an easy subject. To be able to deliver what the costumer wants, the distribution channel has become a network, consisting of many specialised companies that all adds a small part of value to the end costumer (Ford et al., 2003).

3.5.2.1 Distribution discrepancies

In order to bridge the gap that exist between producer and consumer, several distribution functions need to be performed. According to Rosenblom (1995) there are four discrepancies that need to be bridged; quantity, assortment, time and space.

The discrepancy in quantity is referred to as the high number of product quantities that is manufactured to accomplish economy of scale are often to big for a single customer to use. Hence, intermediaries act as a buffer and store big volumes of products so that customers can buy exactly the amount of products wanted.

The discrepancy in assortment means that products are often produced by specialised manufacturers, due to higher production efficiency. On the other hand, customers want to have an efficient consuming and need many different products at the same place. Hence, an intermediary can group items together from many producers that will add value to the end customer. Thereby, manufacturers can continue to produce specific products while intermediaries takes care of the grouping of different products and made them available for the end customer.

The discrepancy in time refers to that products are often not produced exactly when the costumer wants the product. Thereby, distribution functions are needed to store the products from the time they are manufactured until the customers need it. Intermediaries can add value to the end customer by store products in time.

The discrepancy in space means that the products are not produced on the same location as where it is used. On top of this, the globalization has increased the space between the production and consumption. The site of manufacturing is often affected by factors such as labour, history and price, which is often not the same site as where the costumers are located. It is not unlikely today that the production takes part on the other side of the world as where the consumption takes part. Hence, distribution functions and activities are needed to move the product from the place of production to the place of consumption. Actors that coordinate these activities adds vale to the end customer by transporting the products to where it is needed.

3.5.2.2 The importance of distribution

To deliver what the customers requires has been more and more important over the years (Ford et al., 2003; Lumsden, 2012). The discrepancies and gaps between producer and consumer, that needs to be bridged, has grown bigger and more varied, which in turn puts more requirements on the actors in the distribution network. Also, companies in the network has become more specialised and scattered over a larger geography. Hence, global manufacturers need to supply locally, which often involve deliveries to many countries or even continents. As a result, the cost to coordinate all the distribution activities has increased significantly. Distribution costs are large today and it is not unusual that the distribution costs can stand for as much as one-third of the total cost of the product. By achieving an efficient distribution it is possible to reduce costs. Distribution can also be a way to improve revenues. By offering the customer a variety of services and aftersales, the revenues will increase. Another reason that distribution is important is that the requirements of the customers have increased during the last decades. Today, customers require distribution solutions adapted to their particular problems. This means that manufacturers have gone from suppliers of products to providers of solutions. Hence, companies have become problem solvers. An additional argument for why distribution is important is the continuous technical development. The development could for example be increased manufacturing flexibility, increased systems for information exchange like the Internet and improvements in transportation and the physical handling of the products. The distribution network needs to adapt to these development, which offers chances for new and more efficient distribution arrangements.

All together, it is possible to identify four main reasons why distribution is important:

1. Need to reduce costs
2. A way to improve revenues
3. Increasing customer demands
4. Technical improvements makes new distribution solutions available.

3.5.3 Route planning

The scheduling and routing of service vehicles are an important activity for many companies involved in the distribution of goods, where the result of bad planning can be costly (Haksever, Render, Russell & Murdick, 2000). The design of how to distribute the goods from the terminal to the customers can be done in a numerous ways (Lawrence, Golden, Assad & Ball, 1983; Lumsden, 2012). Problems of how to plan the routes appear when the number of customers, goods and vehicles varies. However, when one vehicle only makes one delivery per route the problems are limited, but of course this is not the most efficient way to deliver goods. Hence, many frequent deliveries have to be made, which can be very time consuming. Normally, the vehicle makes many deliveries on each route that increases the complexity of how to know which route is the most efficient one for this specific case.

Lumsden (2012) states that if a vehicle will deliver goods to a number of customers (k), then the number of possible routes (n) will increase with the function of k. The customer that will be delivered firstly can be chosen in k different ways, the second in k-1, the third in k-2, etc. until all customers has got their delivery. If consideration is done according to minimise the transportation distance, then the number of possible route combinations is given with the following formula:

$$n = k!$$

If many vehicles and several routes are involved in the planning, then the complexity will increase even further. Hence, to find the optimal solution for how to perform the distribution routes are very hard, if not almost impossible. Instead, heuristic methods for how to design the routes have developed that are founded on experience or intuition rules. These methods will not find the optimal one, but it will give useful results.

The route planning could also be scheduled to reach the customer within a predefined time window (Lawrence et al., 1983; Haksever et al., 2000). Hence, the trucks will get a delivery-time restriction, where the material needs to be delivered within. The main benefit to use scheduled time windows is that the customer can plan according to the times the delivery should be made within and thereby gets a smother flow of trucks arriving at the depot. The main drawback on the other hand is that the delivering company gets one more restriction that needs to be kept. Of course this makes the complexity of the distribution even harder, which often results in that the cost of the delivery increases. The time window can either be two-sided or one-sided. If the truck gets a two-sided time window, then the truck needs to deliver the goods within a specific interval, e.g. between 10:30 and 11:00 A.M. A one-sided time window on the other hand specifies that the delivery needs to be made before a certain time.

The delivery of goods can be performed by many different vehicles, such as trucks or forklifts (Lusmden, 2012). The main benefits of using a truck for delivery is that more pallets can fit in a truck then on a forklift. Also, a truck can drive much faster than a forklift. On the other hand, a forklift can deliver goods directly without loading or unloading it, which is needed in a truck. When infrastructure allows it, the author describes the use of trains as a potentially valuable alternative. The mean of transport will though need distance in order to be economically viable because of the large transhipment costs while loading and unloading the goods.

According to several authors (Lumsden, 2012; Lawrenceet al., 1983; Haksever et al., 2000) there are many methods to plan the routes, where these three may be considered as the most common:

- Loops
- The sweep method
- Method to solve the general route problem

3.5.3.1 Loops

One of the most basic route planning methods is called loops, which are when the distribution vehicles have solid routes regarding some particular criteria, e.g. the load capacity of the vehicle (Lumsden, 2012). Hence, the vehicle will get the route so that its capacity is completely used. Another criteria could be the time where the vehicle will depart during some times, even though the load capacity is not fully used. An advantage of this method is that it is very easy and fast to use and it can be combined with other activities, such as collecting goods when at the same time delivering, if there is free load capacity. But, on the other hand, a drawback is that it will not give an optimal distribution. Figure 12 beneath shows an example of two permanent loops, where the vehicles deliver to the customers from the terminal regarding a specific criterion.

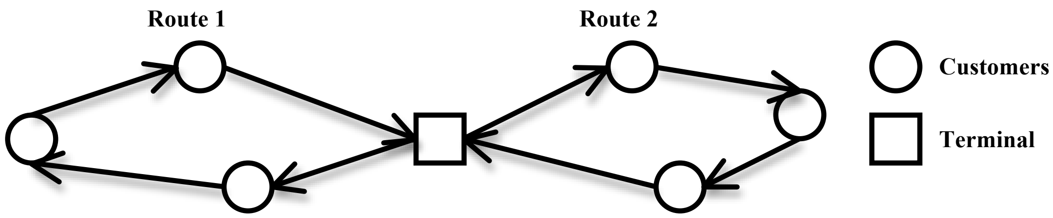


Figure 12. Illustration of how the route planning method loops works. This particular example consists of two loops where a vehicle distributes goods to six different customers regarding a certain criterion, e.g. time or load capacity.

3.5.3.2 The sweep method

Another usual way to distribute the goods to several customers is the sweep method, which is a method where the customers are divided through there geographical location related to the terminal. The customers are often divided so that the vehicle can drive for example clockwise from the terminal. The vehicle will depart from the terminal when a specific limit is fulfilled, e.g. when the loading capacity is full or optimum driving time. Just as for the loops, this method will not get the best distribution, but is simple and easy to use and understand.

3.5.3.3 Method to solve the general route problem

Clarke and Wright (1964) came up with an effective technique for how to design a route according to savings value, which today is a well-known method that is used in many companies (Lumsden, 2012). The method builds on decisions, which shall be taken in a consecutive order. As a result, the route solution will progressively be built on the best design according to many small steps. The method builds on the following progressive order:

1. The first thing to do is to see if there are some customers that require more than one vehicle to get the goods distributed. If so, these customers should fill out the vehicles

needed and if there are some material over, this material shall be included in the further route planning.
2. Secondly, each customer shall be supplied through a separate route directly from the terminal.
3. Thirdly, a measurement of priority (savings value) should be calculated, which will show how good it is to connect to customers in a single route instated of supplying them on their own. The customers that shows the highest savings value will then be connected to different routes including two customers. This is done until all customers is involved in a route, with the priority of the highest savings value first.
4. Fourthly, more customers should be included in the routes. This is done given the pair of customers that has the highest savings value is linked to another pair of customers that has the second highest savings value, but must include one of the customers from the first pair. This is repeated until all customers are connected with another pair, so that each route now involves three customers. Also, one has to keep in mind that every new route must be tolerable according to some prerequisites, e.g. capacity and route length. Another requirement is that the biggest vehicles should be filled up first, so that the lowest cost can be achieved.
5. Finally, the routes can continue to evolve into bigger routes with more customer pair. As for the fourth step, the procedure must be kept according to the highest savings value.

As a consequence, the method will give an efficient and close to optimal solution for the distribution of goods. But, on the other hand, it is time consuming and requires calculation skills or help from automatic processes, which can be costly.

3.5.4 Tracking and tracing

A crucial activity within the material system is to control the material flows. Given the recent development of specialisation and increased freight transport between companies today, the transporting times with tied-up capital are not being reduced as many other activities but sometimes even increased (Chopra & Meindl, 2012). Stefansson and Tilanus (1998) underline the importance of following these transport activities. They highlight the fact that process maps many times involves storage points and production processes as figures ignoring transporting paths that are only referred to as connecting lines taken for granted and request further insight into these areas where tracking and tracing systems are presented. Hulsman and Windt (2007) suggest a recent greater complexity of logistics systems and a high incidence of disruptive factors to be factors creating the need for improved implemented control technology systems.

To track means to follow an item from point A to point B while tracing refers to finding an item on this path (Stefansson & Tilanus, 1998). As transporting activates aren't perfect a rise of controlling information systems has been present recently giving these following and finding opportunities for chosen parties. The systems has received much attention and improved several supply chains correctly implemented. Fritz and Schiefer (2009) identify improvements within areas like asset management, resource management, security and safety.

Tracking and tracing systems provide numerous advantages for many supply chain actors. The availability of the information improves general freight administration, carrier maintenance, and enable tracking and tracing demanded by transport customers (Mirzabeiki & Sjöholm, 2012).

Enabling tracking and tracing possibilities may be done in many ways. Stefansson and Tilanus (1998) suggest eight classification attributes customising a system for the present needs. Initially, one has to decide on how the data should enter the system. This could be through manual input from readable tags, barcodes or perhaps radio frequency tags, RFID, which are scanned automatically. A proper scope will further setup the structure through a simple transport line-up, also including storage or perhaps even conversation processes. One must also determine where the information should be input throughout the chain and on what hierarchical level, e.g. tracing batches of larger loads or every single item sent. Then one has to settle on what data to enter, choosing product parameters as well as who will access the information and be able to view the future flow. Finally the system will be shaped through the timing of the updates producing an active or passive system. According to the authors, these all attributes together work to define a tracking and tracing system and should all be weighted and considered once the development is underway.

3.5.5 Activity agreements

The activities that are performed in the material system often need some sort of agreements between the buyer and the seller. The International Chamber of Commerce, ICC, providing standards known as Incoterms was founded back in 1919 as an organisation that would represent business everywhere. The association is meant as a forum for guiding businesses to comprehend and follow world economy shifts. One of the organisations most well-known products are the Incoterms developed in 1936 (ICCWBO, 2013).

Business Dictionary (2013) defines Incoterms as:

“International commercial terms. Thirteen terms of sale accepted worldwide in assignment of costs and responsibilities between the buyer and the seller. Proposed, updated, and copyrighted by the International Chamber Of Commerce (ICC), they serve as global standards for uniform interpretation of common contract clauses in international trade”.

The developer defines them as (ICCWBO, 2013):

“internationally recognised standard and are used worldwide in international and domestic contracts for the sale of goods”.

This international association highlights the functionality of the rule set as guidance to avoid costly misunderstandings by clarifying the responsibility sharing between a seller and a buyer on an international or domestic market. The organisation also provides the latest set of rules (recent updates 1990, 2000, 2010) available with for common usage at their website.

As mentioned, the set of standards contain several rules that may be contracted depending on the active circumstances. The chosen standards serve to define obligations for both the seller and buyer of a good flow transaction. The different partial rules that may be chosen involve combinations an extreme state where the seller delivers only leaving the goods at the disposal for the buyer to collect (Ex-Works, EXW) and an opposite state where the sellers delivers leaving the goods at the disposal of the buyer (Delivered Duty Paied, DDP) (ICCWBO, 2013). Lumsden (2012) illustrates the different buyer-seller responsibility combinations as mixtures of the three dimensions; Cost, Risk and Insurance, that may be contracted to different points/locations along the good flow in the transportation from a seller to a buyer, see Figure 13.

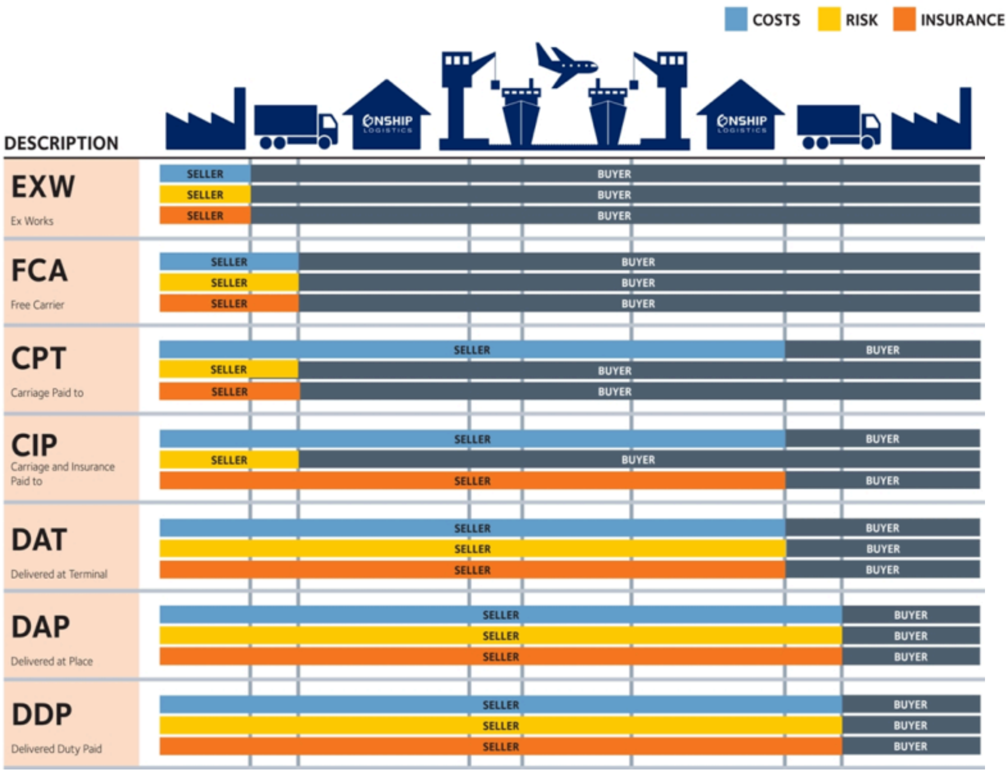


Figure 13. Incoterms 2010 - Combinations chart. Each agreed term category represents a different combination of cost (blue), risk (yellow) and insurance (orange) between a supplier and customer. Source: Icontainers (2013).

The Incoterm standards are proved to be widely used in several industries, a survey published by the industry organisation, Original Equipment Suppliers Association, OESA, reveals a frequent Incoterm usage around automotive companies like BMW, Chrysler, Honda and Hyundai/KIA (Bruno, 2013). Each of these actors was found to operate Incoterm standards at their purchasing department. One and the same user also managed several rule combinations depending on the transaction stakeholder. These combinations may depend on many factors like stakeholder interests or world economy and has developed and been changed over the years. Lumsden (2012) for instance, highlights a switch from previously commonly used rule sets like Free on Board, FOB and Cost, Insurance and Freight, CIF (excluded from Figure 20), concentrating more risk into freight transhipment phases, that now are applicable to waterway transportation only towards more generally usable methods. This author explains a recent freight transport containerisation development as a key driver in this change of Incoterm usage.

3.6 Resources

In order to perform the activities, various resources are needed. The resource dimension consists of all resources that is needed for the particular activities and could be the physical infrastructure that the company has access to; rails, roads, terminals, ports and warehouses, but also competencies and capabilities of people in the company (Ford et al., 2003). The value of a resource is not predetermined, it depends on how it is used and combined with other resources (Gadde, Håkansson, & Persson, 2010). Some resources lies within the boundaries of a firm and some are not. In a distribution network, firms needs access to each other's resources to be able to deliver what the customer wants. Companies try to utilise the resources as much as possible and combine them in the most efficient way. It could be that the route of many different products goes through the same resources often through consolidation, in order to utilise the specific resource as much as possible.

3.6.1 Resource structure

The material can flow in many different ways on its path towards the customer. Thus the channel structure can be formed in a numerous different ways, as the product flows through many resources. A distribution channel structure is often referred to as the shape the channels takes to make the products available to the customers (Rosenblom, 1991) and consists of all parties involved in performing these activities, from the producer to the wholesaler, retailer and the consumer.

The form of these channels can vary a lot, both in with regard to the length of the channel and the types of intermediaries involved (Rosenblom, 1995). Concerning the length of the channel, it varies from two stages where the manufacturer sells directly to the consumer and up to several intermediaries between the producer and the consumer. These intermediaries can consist of buffers or retailers, with the purpose of bridge the gap between producer and consumer, as what is demanded by the customer. Figure 15 shows an illustration of the distribution channel structure variation.

There are many factors that influence the length and shape of the channel where the most important ones are the product characteristics, the power of the manufacturer and the customers (Rosenblom, 1995). Firstly, the characteristics of the product that affects the channel in terms of the products weight, perishability, bulk, value and technical complexity. This means that high-tech products often needs a short channel between production and consumption, so that the costumers can get a high level of technical services directly from the manufacturer. Secondly, the power of the manufacturing company is a factor that can affect the length of the distribution channel, mainly in terms of the size of the manufacturer, its financial capacity and desire for control. Thereby, a big and rich producer has a bigger chance to distribute directly to costumers, which results in a higher degree of control. Thirdly, the customers have a very big impact on the length of the distribution channel, mainly in terms of the location of the customers, the number of customers, the needs of the customers. As a result, distribution channels can vary a lot, which is illustrated in Figure 14.

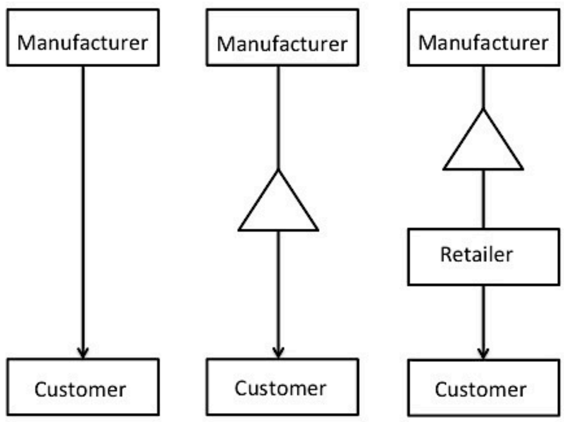


Figure 14. Illustration of the variation of channel structures. The lengths of the channels varies due to different ways of bridging the gap between producer and customer. The distribution channel to the left shows a direct channel, where the producer sells directly to the customer with no intermediaries in between. The middle one has a buffer or a storage between the manufacturer and the costumer. A distribution channel can also consist of several intermediaries such as retailers. Source: Rosenblom (1995).

3.6.2 Centralisation vs. decentralisation

The resources could be scattered in a decentralised manner at many different locations. On the other hand, the resources can be centralised in a single spot, where all activities and actors are located. Centralisation could be defined as (Management Study Guide, 2013; All Business, 2013):

“the process of a systematic and consistent reservation of authority at central points in the organisation, a system where little delegation of authority is made.”

Cambridge Dictionary (2013) defines it as:

"to remove authority in a system, company, country, etc. from local places to one central place so that the whole system, etc. is under central control"

These definitions could apply to many areas and processes of a company but the logistic dimensions of distribution an warehousing which has an obvious and strong connection and a recent attention within centralisation (Abrahamsson, 1993) will here receive focus. Figure 16 roughly illustrates the differences between the two mentioned common setup structures:

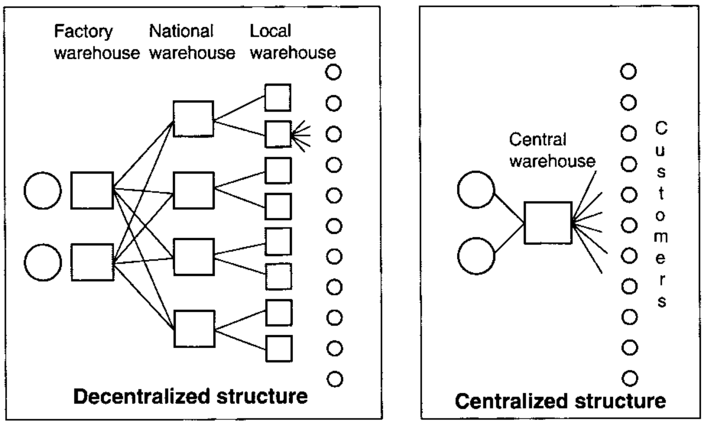


Figure 15. Centralised and decentralised distribution structures. The figure to the right shows a decentralised distribution structure, which involves many smaller warehouses. The figure to the right, on the other hand, shows a centralised distribution structure, where all products goes through a single big warehouse and then directly out to the customers. Source: Abrahamsson (1993).

Benefits gained through a developed and maintained centralisation process within distribution could be numerous. Cooper (1991) highlights advantages from less tied up capital (with an emphasis on inventory), lower operating costs and a decrease in expenses for physical distribution administration. In an article "Time based distribution" by Abrahamsson (1993), effects on three international Swedish companies has been analysed. The author concludes his results presenting benefits within inventory costs, distribution costs, lead-time, availability, delivery performance, warehousing and labor costs. On the other hand, setback factors could be a higher burden on decision makers like CEO's, Staff morale, staff skill development and obstacles to implementing diversification (Management Study Guide, 2013). Campbell et al. (2011) highlight centralisation risks like business rigidity, reduced motivation, bureaucracy and distraction.

Even though centralisation activities many times are recommended, few actions and developments has been recognised in the area during the last few decades (Cooper, 1991; Gadde, 1989). Traditional decentralised models with many tiers between the producers and consumers are still widely used. According to Gadde (1989), reasons for this could be the uncertainty of effects on cost savings and customer service.

Abrahamsson (1993) presents two different distribution structure theories were a **marketing channel model** suggest a decentralised structure when the company is dealing with standardised products, a large geographically spread out client base with relatively small actors and has competent middlemen available. He also comments on another **logistic theory model** focusing on coordination between physical distribution and material management. An important point here is that an increased cost in one area may involve even more of a cost decrease in another. This is illustrated in Figure 16 beneath.

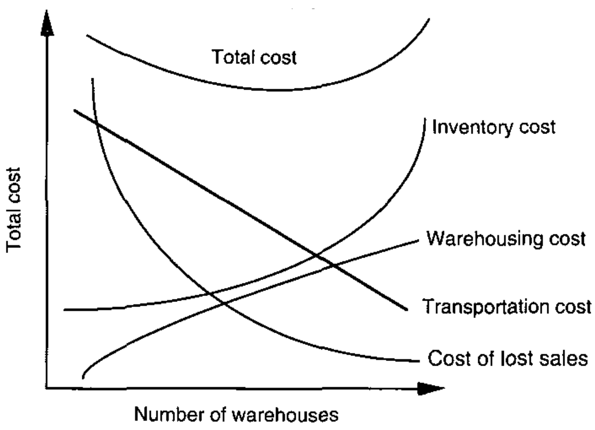


Figure 16. Illustration of how the various costs are changing, depending on the number of warehouses. When a single warehouse is used, then there will be low inventory and warehousing cost, but high transportation cost and cost of lost of sales, compared to if many warehouses are used. Source: Abrahamsson (2013).

Speh (2009) highlights difficulties in allocating warehousing costs and the importance of them being measured, which usually could be done monthly. The warehousing costs are divided into Handling, Storage, Operations administration (systems required running the unit) and general administration expenses (general costs not possible to allocate to a certain decentralised unit).

Abrahamsson (1993) further highlight changes in company goals where decision makers' beliefs in how to bridge the "gap" between the customer and producer have switched over the years. Traditionally customers and producers were seen as rather independent, separated by this gap measured in distance. Today, the gap is measured in lead-time instead stating the importance of accurate and quick delivery and integration among the actors. Abrahamsson (1993) refers to this as "Time-based distribution", and he announce the lead-time focus as an important ingredient in future distribution structure and centralisation decisions. Lead-times are many times seen as increasing with centralisation but the authors analysis show that they may even decrease so this is not certain.

Campbell, Kunisch and Müller-Stewens (2011) found centralisation decisions to origin from a widespread of processes, not developing from standardised procedures. Incentives were by many managers found to be benchmarks, politics or simply just trends or fashion. In absence of guidance, these authors developed a general guiding framework useful in this process, see Figure 17. The framework involves three simple questions regarding if the development is mandated, if it adds value or if it involves little risk. If the proposal does not survive at least one question, the authors recommend abandoning it.

Figure 17. The centralization decision, divided in three main questions. If all questions, more clearly described in the boxes, are answered "No" the model suggest not to centralise. Source: Campbell et al. (2011).

Speh (2009) identifies the four most common reasons for warehouses to be moved as the following:

1. The facility is to small and cannot be expanded
2. The customer base is changed and the present location does not adequately serve the new market
3. The supplier base has changed and the current location is not ideal
4. Because of mergers and acquisitions, your company has now to many warehouses

The author also underlines the importance of factors like location (for transportation purposes), risk management, cost and availability of labour as well as present taxes at the potential sites.

Given competitive advantage possibilities through cost reductions, centralisation may many times benefit the selling company as agreed by most, but not necessarily reduce customer value. Centralisation may even increase customer value through delivery accuracy, availability and reduced lead-times for the buyer (Abrahamsson, 1993; Stalk, 1988). Abrahamsson (1993) also found that transportation costs that he viewed as generally believed to increase with centralisation activities actually decreased in his results. Concluded effects of time-based distribution covering both the seller and buyer side are stated in Table 4 beneath.

Table 4. Effects of time-based distributions. Effects may be seen in many categories as illustrated beneath. Source: Abrahamsson (1993).

Logistics cost leadership	Logistics buyer value
Fixed distribution costs: - Decreased costs for personnel, warehouses and administration	**Lead times:** - Shorter and more reliable lead times for all markets and for all products
Variable distribution costs: - Reduced inventory costs - Constant transportation costs	**Delivery performance:** - Increased on-time deliveries - Complete orders to the customers
Savings in integration/separation: - Sales function separated from the materials flow - Centralised control of the materials flow – economies of scale - Integrated distribution functions	**Differentiation:** - Customised distribution to different groups of customers - Increased flexibility
Savings in learning costs: - Faster introduction of new products in the assortment	**Customer information:** - Faster and more reliable information to the customers about discrepancy

Another aspect of the centralisation decision is the so called transaction costs (van Weele, 2010). Transaction costs are always connected to these kinds of structural changes of an organisation. Important factors limiting results are communicated to be for instance the level of transaction-specific investments as well as the external and internal uncertainty.

3.6.3 Strategic management

Business dictionary (2013) defines strategic management as:

"The systematic analysis of the factors associated with customers and competitors (the external environment) and the organisation itself (the internal environment) to provide basis for maintaining optimum management practices."

Axelsson and Agndal (2010) further covers the subject as being used by upper management driving the company towards stated missions and objectives. The author further presents the surrounding environment as one of the key inputs to this management. Bains, Fill and Page

(2008) agrees on this and divides the environment interpretation work into three areas that all should be considered separately:

- Internal environment
- Performance environment
- External environment

As the Internal and performance environment cover direct affecting atmosphere inside the company borders and in regard to competitors and other stakeholders within the current market, the external environment goes beyond these border including areas more indirect, distant and complex. Environmental scans in all these areas are required in order to ensure performance through planning especially in development phases of new ideas.

Dealing with business unit, business proposition planning, or surrounding market environment analysis Bains, Fill and Page (2008) presents the SWOT- and PESTLE- (originally PEST) models as the most frequently used tools. The SWOT- model (involving Strengths, Weaknesses, Opportunities and Threats), mainly used within business unit planning and idea development, is meant to guide the company in identifying strengths and weaknesses within the company and matching these to opportunities and threats in an external macro environment. A key here is then to identify how the strengths can be used to take advantage of opportunities as well as in order to reduce the risk of threats as well as how weaknesses should be overcome reaching for opportunities and preventing threats. The PESTLE- model, many times used together with a SWOT, focuses on the market external environment where the opportunities and threats are shaped and is often a valuable input to the SWOT-analysis. The tool includes Political, Economic, Socio-cultural, Technological, Legal and Environmental factors that all affect this macro environment, see Figure 18. The external environment involves elements without a direct impact on the organisation performance but factors that may interfere in the future. Another characteristic is the fact that these forces are hard for the company to control.

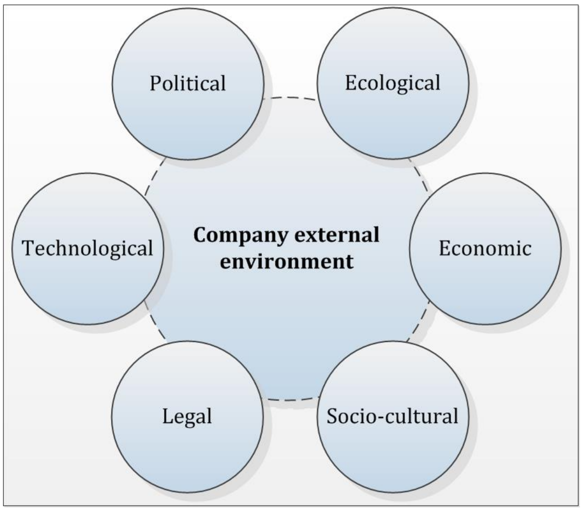


Figure 18. PESTLE environment-affecting factors. The surrounding forces displayed all work to shape the environment of the company and must be taken into consideration while examining the company situation.

Bains et al. (2008) and Armstrong and Kotler (2007) present the six forces shaping the external environment of the company:

The **political** environment refers to interaction between business, society and government. Forces here involve areas like tax policies or political stability as well as matters that are yet only in pipeline but have the potential to change the company situation in the future. The **economic** environment has to do with factors like the economic growth, current interest rates or inflation. Scenario analyses are useful here in determining possible future effects. **Socio-cultural** factors refer to ex. demographic trends, merging attitudes or emphasis on safety. The **technological** forces involve recent surrounding technological change that may change the company situation. It could be R&D developments or new automation progress. **Legal** factors go for all legislation limiting the company operation and demand. **Ecological** factors involve areas like climate change as well as awareness and demand from customer and society securing sustainability etc.

3.6.4 Warehousing yard outline

The usage of road transportation and truck traffic has been highly increasing through the last century (Lumsden, 2012). This trend can be explained through benefits gained through small-scale quantities, flexibility, safety, reliability, service and adaptability. Other reasons for the positive development can be the growing truckload volumes, allowed to be transported on public roads. Today, national legislation allows different truck/trailer combination in different sizes. In Sweden, a maximum truck length of 24 meters (width 2,6 m and height 4 m) is allowed but in most European countries the maximum length is set to 18.35 meters (width 2,6 m and height 3,65 m). Through the years, the trucks have become even longer and many sources points on a continued trend. Wilcox (2013) presents a recent statement by the European Commission, EC, in April 2013 where longer trucks are announced to be planned for the near future, as this would enhance aerodynamics and safety establish fuel savings of about 5-8%. These thoughts are also encouraged at the website of the Swedish road traffic controlling organisation Trafikverket (2002), where even longer (32 m) trucks are under trial in preparation for future legislation concerning vehicles on Swedish roads. This would include freight loads of around 80 ton. Possible fuel savings and carbon dioxide emissions of about 20 per cent per tonnage freight transported here motivate this initiative. Lumsden (2012) underlines that increased vehicle length almost always increased efficiency. The author continues commenting on different requirements from different vehicles and underlines the needs of proper support of longer trucks by suitable handling equipment and infrastructure. In the report *Trafiksituationsmodell* by Trafikverket (2002, TABELL 3.5.4-1), it is stated that the largest vehicle combinations require up to 14,5 m turning radius measured from the back axis middle point during a 90-degree turn. Lumsden (2012) estimates a turning radius required of at least 11 m.

3.7 Logistic Centre Concept Model

From the previous theory chapters it is stated that the material flow is affected by several requirements, coming from many different areas, e.g. production, context, actors, material system and its activities. Furthermore, the customers also state some requirements, which decide what should be accomplished by the material flow. Also, the requirements from the information flow make the material flow possible (Vollman, Berry, Whybark & Jacobs, 2005).

Harwell et al. (1993) defines requirements as:

“If it mandates that something must be accomplished, transformed, produced or provided, it is a requirement.”

According to Carr (2000) requirements has a close similarity to design solutions, but a requirement should specify needs rather than design solutions. Consequently, the theory chapters in this thesis will all give their particular requirements on the material flow and in turn, how to develop the new LC.

Summarising the theoretical section with background from the situation covered in the introduction, there are several requirements involving both potential and limitations restricting a Logistic Centre development. The expansion will also depend upon the situation of material flow which could include both a hub with one-way-type flows, supporting either supply or distribution activities, or as stated by the thesis introduction a production supporting centre where multiple-type flows are handled (ex. from suppliers to production or from this production further to its customers).

As stated by All Business (2013) and Cambridge dictionary (2013) centralisation is about the reservation of authority to central points in order to retain central control, which according to Cooper (1991) and Abrahamsson (1993) brings benefits within areas like tied-up capital, operating costs or administration or lead-time. Thus, reaching for these benefits, a centralised logistic centre can be developed. The development of a logistic centre with common features like storage, sorting, packing, kitting should according to Rushton, Croucher and Baker (2006) and Rowley (2000) be undertaken through a sequence of steps all inquiring certain constraints and guidance to the development. Gathered input from several areas will then lead the development.

The requirements are summarised in four main areas; Context, Production, External material flow, Internal material flow. These four areas are from now on called constraints, which will give their particular perspective and provide their specific emphasises of how to develop the LC. The four different constraints shape together the development of a Logistic Centre Concept model, which is shown in Figure 19 beneath. The model will help to improve the understanding of a complex reality with many factors involved affecting the LC development. The last central part will be the actual operative design that will be guided from the four constraints.

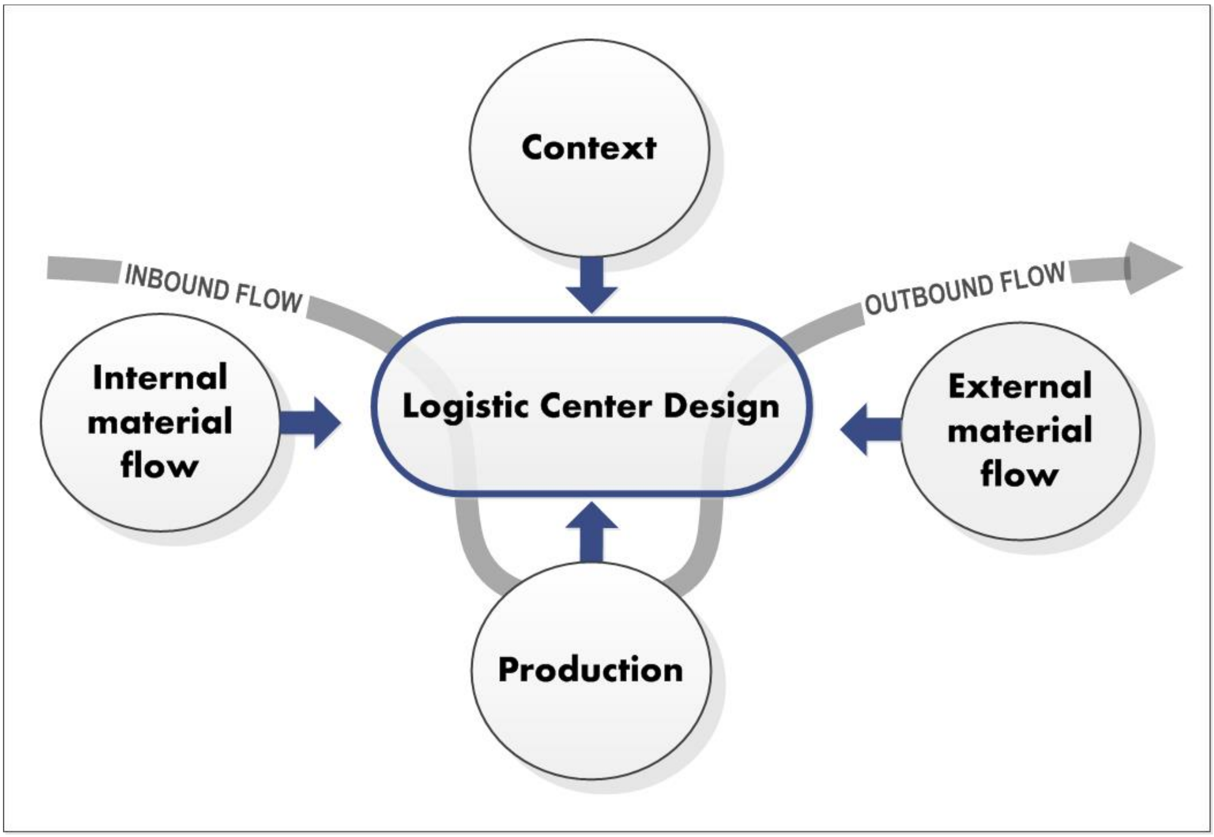


Figure 19. Four constraints shaping the development of a logistic centre supporting production with both in- and outbound material flows. The four constraints all give their particular perspective and provide their specific emphasises of how to develop and design the LC.

3.7.1 Context constraint

The context constraint concerns both the situation of the business and the external environment. The business area is more about the company characteristics and the product assortment, while the external environment area deals with more outside factors, such as rules, regulations, society, customers, suppliers etc.

Rushton et al. (2006) highlights the importance of initially identifying business constraints. These constraints involve several levels. In a larger perspective, it becomes highly important to have a shared plan for the development aligning with the policies and interest of the company or companies supported. What factors are driving the change? These could be both simple economical like cost cutting initiatives (as suggested by Abrahamsson (1993)), perhaps increasing the level of integration and relationships to neighbouring actors in the supply chain as suggested by Lumsden (2012) or increasing the level of customer service. As stated by Campbell et al. (2011) it also becomes valuable to question whether the decisions are mandated, whether they add value and whether the risks are low (Figure 17).

Other important inputs for the LC development are the resources available for the change. One will here also have to consider transaction costs and future scenarios that may interfere with development. Hassan (2002) suggests forecasting and analysing future demand and Emmett (2005) underlines the importance of a system suitable for the goods to be handled in this phase. Product characteristics like shapes, sizes, volumes and weight all needs to be considered.

As part of defining system requirements and project planning, Rushton et al. (2006) also presents the company environments as important input to warehouse development. Baines et al. (2008) states how the introduction of business expansion propositions benefit from an all-over overview of the company environment. Having included a business and performance environment aim within the business constraint, a dimension beyond the direct effects and situation is needed. Armstrong and Kotler (2007) suggest an external environment approach where surrounding Political, Economic, Socio-cultural, Technological, Legal and Environmental factors are weighted.

3.7.2 Production constraint

Production systems are often designed in order to perform as much value-adding activities as possible in the lowest amount of time (Baudin, 2004; Liker, 2004). To be able to achieve this, the material flow to and from production have a number of requirements. To be sure that the material is there when needed in production, it is often stored for weeks or even months before going to the manufacturing unit, where it is only used for a few hours. The Lean philosophy states inventory as one of the seven wastes (Liker, 2004) and means that it is very important to try to reduce it as much as possible. However, some stocks are actually necessary for running the production smoothly, but also due to that supplies can be delayed and there is often a missmatch between the incoming and outgoing quantities (Baudin, 2004).

Baudin (2004) states that logistics performance is largely determined by what happens in production. Thus the material flow has to support the production systems by fulfilling production requirements (constraints), which means that production has a very large affect on the material flow. The problem is that the production system and material flow system are often designed independently and with little consideration for each other. Consequently it will lead to a separate performance optimisation (Neumann & Medbo, 2009).

3.7.3 External material flow constraint

Through Stadtler's (2008) definition of SCM, all companies are involved in some sort of network to deliver what the costumer wants. Due to this, Gadde (2004) means that the activities of the actors become very interdependent on each other, even though they are performed in different company. Hence, the activities performed by external actors affect the activities made by the focal company. Consequently, there is a need for coordination and integration among the actors. Lumsden (2012) states the importance of collaboration between the actors in the network, which should create a "win-win situation" for all actors involved.

Baudin (2004) states in- and outbound logistics as all activities that are conducted outside of the company in focus. Hence, the boundary is that between the company boarder and the rest of the world. The in- and outbound logistics will affect the total material flow due to that the external actors handles the activities needed to ship, transport, receive and storage between companies. The in- and outbound logistics will further be called external material flow. This constraint will investigate how the external logistics, logistical processes outside the company boarders, affect the development of a LC.

3.7.4 Internal material flow constraint

Womack & Jones (2003) means that many companies are struggling with large internal material flow problems with long lead-times, long storage times and many processes (Womack & Jones, 2003). Furthermore, the basic problem might be an ineffective material system throughout the whole company (Rother & Shook, 1999). In order to solve these problems, the functions are separated as isolated siloes and try to improve them one by one (Liker, 2004). What many companies does not know is that the activities many times interdependent with each other (Ford et al., 2003), why there is a need for an overview of all problems in the whole internal system.

According to Baudin (2004), in-plant logistics is under the control of one organisation, which separates the in- and outbound logistics by all activities that are performed within the company boarder, except from the production. The in-plant logistics will affect the internal material flow within the company, when the own organisation controls the activities such as internal shipping, transporting, receiving and storage between internal divisions. The in-plant logistics will further be called internal material flow. This constraint will investigate how the internal logistics, i.e. logistical processes within the company boarders, affect the development of a LC.

4 EMPIRICAL FINDINGS

In this chapter, a review of the current situation of ABB Ludvika will be described. The chapter starts with some general information and then continues with a more deeply explanation about the material flow and control. Furthermore the situation analysis will examine the five constraints from the LC model through observations and interviews.

4.1 Context

ABB Sweden has approximately 8950 employees and is located in about 30 places all over the country. The headquarter can be found in Västerås, which employs approximately 4200 people (ABB, 2013f). In 2012, ABB Sweden had a revenue of 34 billion kronor, where 80 per cent was sold on export[7].

ABB Ludvika is the second biggest production site in Sweden and is concentrated on high voltage solutions. ABB Ludvika is located in the middle of Sweden in the province of Dalarna. The city is inhabited by 14000 people, which means that 33 per cent of the inhabitant works at ABB Ludvika. Ludvika is actually the headquarter of power generation in ABB globally and is the world leader of development of systems and products for high voltage. Here, the biggest testing facility for high voltage products in the world is located. The production site is divided in five main areas; Power Transformers, High Voltage Breakers, HVDC, High Voltage Components and Components. ABB factories assemble most products customised on make-to-order basis having clients all over the world. As ABB Ludvika is the world-leading site within production of high voltage products and components, most of the items are shipped abroad. Nearly 80 per cent of the output goes to other ABB in-house facilities around the globe where they become parts of giant solutions for the end customers[8]. Some of the product assortment that is made at ABB Ludvika can be seen in Figure 20 beneath.

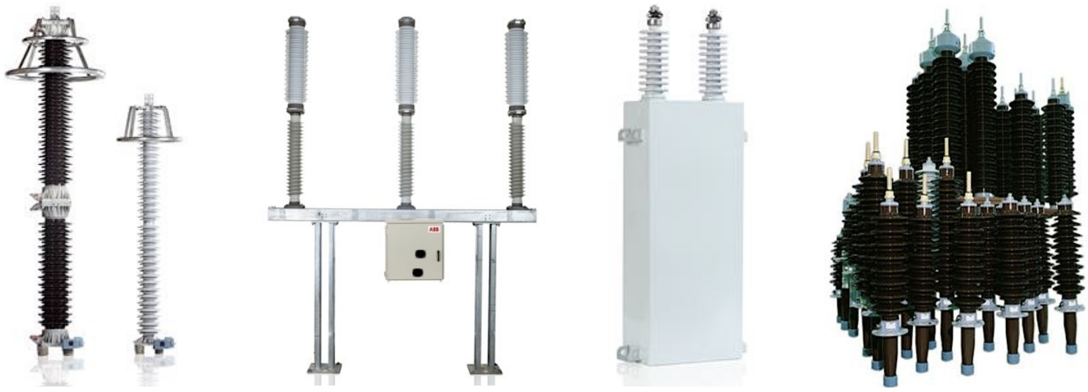


Figure 20. A glimpse of the product assortment manufactured in ABB Ludvika; Diverters, High voltage breakers and Capacitors. The production is divided in five main areas; Power Transformers, High Voltage Breakers, HVDC, High Voltage Components and Components. Source: ABB (2013f).

Figure 20 shows some of the products that are produced in Ludvika. Each of these are valuable tools in power transmission solutions where diverters and breakers protects the system from voltage changes, capacitors block direct current while allowing altering current and transformers transferring the energy flow. Most of the products manufactured at ABB Ludvika are very large, bulky and heavy.

ABB Ludvika has always focused on their core competence, such as pure production activities, innovation and product development. On the other hand, the logistics activities have

[7] Filip Bengtsson (Project manager, Facilities department, ABB Ludvika) interviewed 12 Jun. 2013.

[8] Karl-Bertil Westman (Distribution manager, Power Products dist., ABB Ludvika) Interviewed 20 Jun. 2013.

had a secondary priority, which has resulted in large inventories and long lead-times for the material before and after production. Even if ABB Ludvika over the years has had complications with the logistical activities, it has not been seen as a major problem. As a matter of fact, there exist no logistic department within ABB Ludvika and thus there are no one in charge of the logistical problem for the entire company. ABB Ludvika has always made a big profit and there has been little concern over the logistics.

4.1.1 Structure

ABB Ludvika is divided in a hierarchal company structure and consists of the two main divisions Power Product (PP) and Power Systems (PS), see Figure 21. In turn, PP involves the two business units High Voltage Products (HV Products) and Transformers, while PS only involves the business unit Grid Systems. These business units are in turn divided into five different subdivisions, which normally is called the five divisions of ABB Ludvika where HV Products consists of the two divisions High Voltage Components (HVC) and High Voltage Breakers (HVB), while Transformers consists of Power Transformers (TR) and Components (COM). PS only includes the High Voltage Direct Current (HVDC) department, locating in the north of the company facilities, see Figure 19. HVDC constitutes of one production unit as well as one systems unit. The systems department serves making project solutions for clients where parts from both suppliers, own production and PP are delivered and assembled together on spot. PS is actually the most important PP client generating about a big share of the annual turnover[9].

Each of the five divisions are viewed as separate companies and covered by internal revision. The different sites all negotiate transaction terms, order supplies and arrange most of the transport separately. They also use different business systems for arrangements and ordering that are not fully integrated across the firm. This lack of integration might mitigate benefits of scale while dealing with suppliers and customers and may also drive a development towards consolidation issues and congestion among the transportation gateways within ABB Ludvika[10].

The five divisions are currently operating on a rather high degree of capacity and the company is looking to expand this capacity in the traces of a 20 per cent output volume increase during the last year and an expected increase of 35 to 45 per cent during 2013[3]. This is creating space issues around the plants that will increase in a near future. The output goods are many times stored quite some time on company property, many times waiting for other products and components that are to be shipped together. There are three large material yards and also other freed up space used for this storage (see Figure 22). Problems

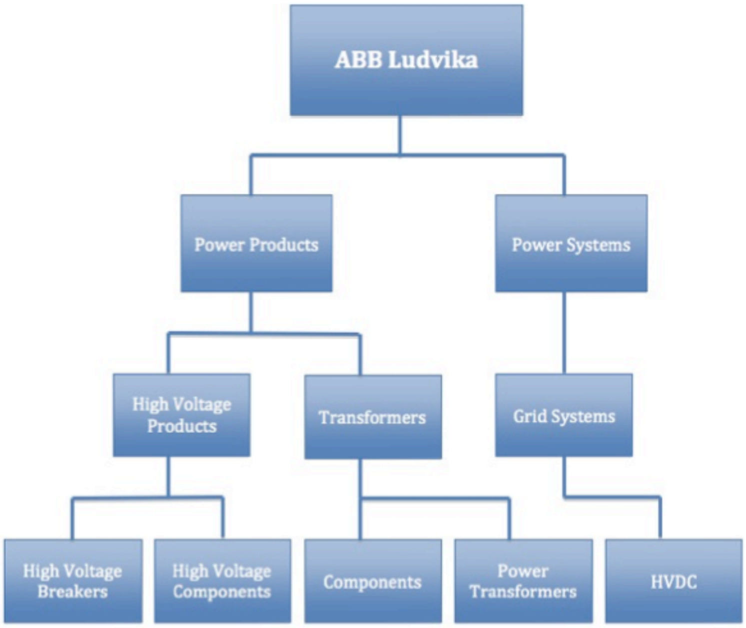


Figure 21. The company structure of ABB Ludvika, which consists of the two main divisions PP and PS. The five subsystems is also shown, which normally is called the five divisions of ABB Ludvika.

[9] Jan Bergfeldt (Distribution manager, HVDC Systems, ABB Ludvika) Interviewed 19 Jun. 2013.
[10] Kurt Nordahl (Department manager, Transport department, ABB Ludvika) Interviewed 12 Jun. 2013.

sometimes arise when these products are hard to find which makes transportation and assembling work increasingly time-consuming. The only guidelines on the goods locations are vivid positioning references like material yard and such made verbally by the responsible trucker and put into a computer system by transport administration, this makes them hard to find[11]. Other concerns here are raised by the fact that each production unit negotiates different logistic terms (usually incoterms) with their clients, sometimes making the buyer responsible for fetching the shipments (Ex-Works). In this case the goods may be stored for long and sometimes would not even be shipped at all. These facts create some confusion and trouble the processes even further[12].

4.1.2 Facilities

The production facilities in Ludvika are spread across several blocks centrally located in Ludvika. The production site area of around 500.000 m^2, enclosed by security fences, is limited by surrounding living neighbourhoods in the east, a giant lake in the north, a neighbouring non-competitor production company site in the west and a 56.000 m^2 company-owned uninhabited forest strip in the south (see introduction section map, Figure 3). The site is today divided into two parts with a public road separating the area. The used company properties involve indoor production facilities, both company owned and managed by others, for the largest part and secondly around 20 per cent roofless material yards. The rest of the area includes a small share of storage tents, parking spots and infrastructural resources like roads and pathways. The major production facilities and storage areas can be viewed in Figure 22.

Within ABB Ludvika there are three main material yards, which has the purpose to store finished products[13]. The storage time at a material yard can vary a lot. Some products are shipped to customer within a week, while other products have to be stored for about six months to a year[14]. The average long-term storing time is estimated to be approximately 3 weeks. There are many reasons for ABB Ludvika to store the finished products and why the storage time varies.

Firstly, most of the produced products are shipped internally within ABB to special projects all around the world. These projects often apply Just-In-Time (JIT) and want to have the products when they are needed in the project[15]. The production divisions at ABB Ludvika do not take consideration of this and just start to produce the products when an order is received. As a result, many products are stored for a long time before going to the projects thus the projects are not integrated with the production.

Secondly, according to special agreements some customers are responsible for the pick-up of the products, so called Ex-works. Hence, ABB does not know when the customers will come and collect the products and have to store products until then. Today, ABB Ludvika store these products for free. There are examples within the company that some products have been stored for as long as ten years. ABB Ludvika does not know what to do with the products, due to that the customers already paid for them.

[11] Linnea Grönvold (Freight administrator, Transport department, ABB Ludvika) interviewed 17 Jun. 2013.
[12] Peter Åsmo (Supply chain manager, Power Prod. Supply chain, ABB Ludvika) interviewed 14 Jun. 2013.
[13] Karl-Bertil Westman (Distribution manager, Power Products dist., ABB Ludvika) Interviewed 20 Jun. 2013.
[14] Anna-Carin Malmberg (Distribution Manager, Components, ABB Ludvika) Interviewed 17 Jul. 2013
[15] Filip Bengtsson (Project manager, Facilities department, ABB Ludvika) interviewed 19 Jul. 2013.

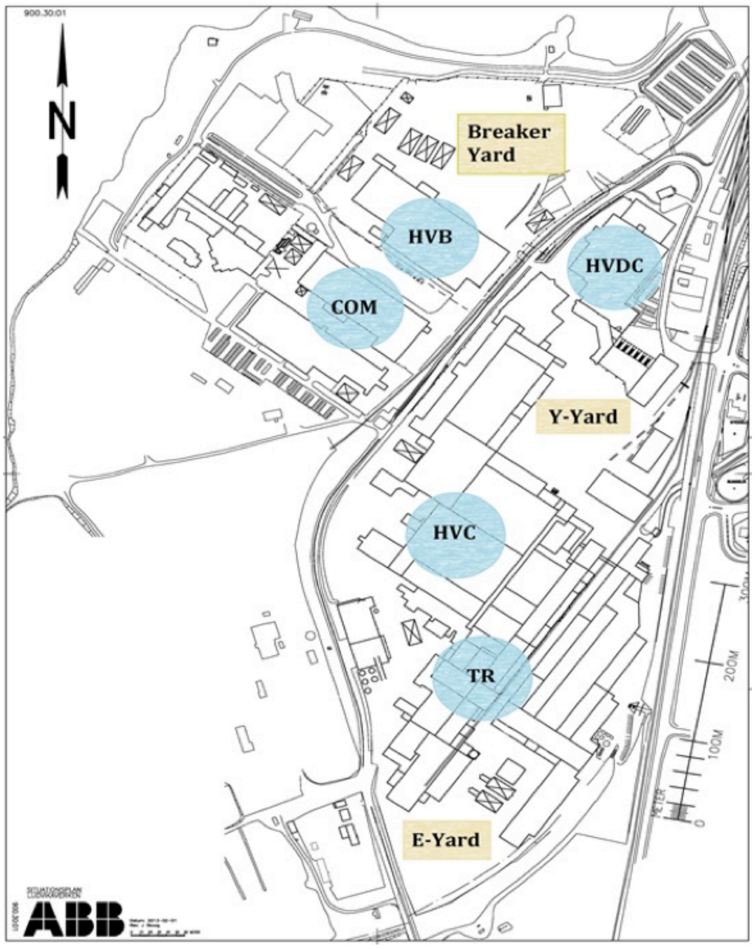


Figure 22. Production facility group and material yard layout. The facilities are separated in the five main divisions; HVDC, HV Breakers, HV Components, Power Transformers and Components. There are also three material yards; Breakers-yard, Y-yard and E-yard, which have the purpose of storing finished products on long- and short-term.

Thirdly, some customers want to have all products shipped at the same time, even though some products are ready before others. This means that the products that are ready first needs to be stored until the manufacturing order is completely finished.

As a consequence, ABB Ludvika needs a lot of space to be able to handle all this storage of finished products. Today the material yards are always full of products.

One material yard is devoted to the division Power transformers and is called E-yard, see Figure 23. Another material yard is dedicated to HV Breakers and is called Breakers-yard, see Figure 24. A third material yard is comprehensive for all the other departments and is called Y-yard, see Figure 25. All material yards are divided into two sections, where one is for long-term storage and the other for goods that should depart in one or two days. These sections are in turn divided into different zones, often one for each destination.

4.1.2.1 E-yard

Figure 23 shows the material yard called E-yard. The E-yard is located in the south area of ABB Ludvika and is dedicated for the division of Power Transformers[16]. In the right upper corner, there is a zone that the division of Power Transformers can do whatever they want with. Here, they can store semi-finished items for example. The TRP is responsible for the rest of the area. This section is divided into a number of different zones; GP-1, GP-2 and GP-3, where finished parts from the division of Power Transformers are stored. These zones are

[16] Fredrik Graaf (Freight administration, Transport department, ABB Ludvika) interviewed 20 Jun. 2013.

dedicated for long-term storage. When a truck notifies its arrival one day before, the forklift drivers just sort out the right goods and puts them close to the loading area.

The arriving truck is entering the area from the right, see the arrows in Figure 23. When the truck reaches the loading area, it stops and gets loaded by the forklift driver. Then the truck enters the same way it came from.

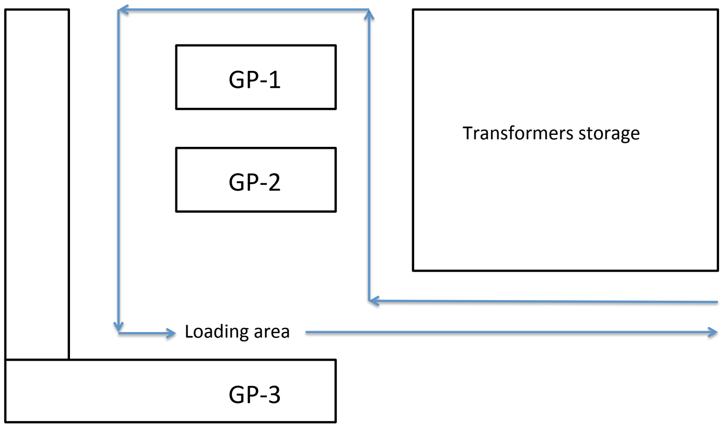


Figure 23. The material yard called E-yard, which is divided into four main zones; Transformers storage, GP-1, GP-2, and GP-3, which are all dedicated for long-term storage of finished products. When a truck notify its arrival a day before, the forklift drivers sort out the right goods and puts them close to the loading area.

4.1.2.2 Breakers-yard

Figure 24 shows an illustration of the Breakers-yard. The Breakers-yard is located in the north part of ABB Ludvika and is completely devoted to the division of HV Breakers[17]. This area has multifunctional tasks and is divided into incoming material, storage and outgoing material. The upper part of the Breakers-yard is dedicated to the incoming material, while the lower part is for storage and outgoing material. The upper arrows (marked in blue) show the material flow of the trucks that are delivering packages to the production at HV Breakers. The lower arrows (marked in red) show the flow of the trucks that are arriving for pickups of finished products. The different boxes in the image show sections where the TRP store goods, mainly in order to be consolidated going out. The area and different sections are necessary in order for the different employees to find the goods. The crossed boxes are tents. As seen in Figure 24, there are a lot of different zones for storage of goods, which makes it very hard for the forklift drivers to control manually where are the products are stored.

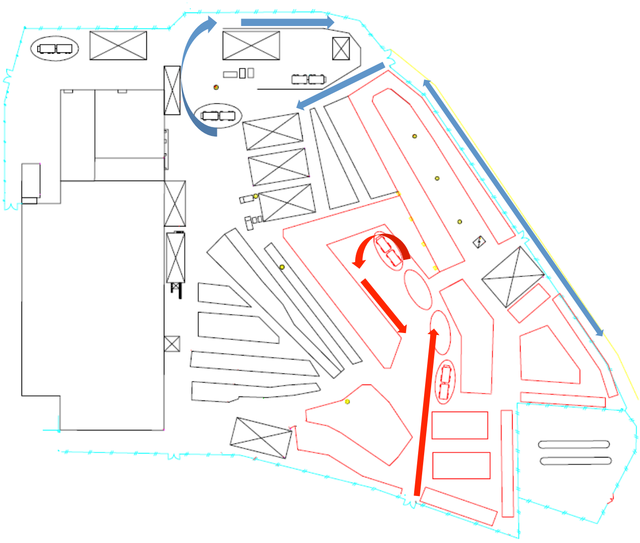


Figure 24. The material yard called Breakers-yard, which is completely devoted to the division HV Breakers. This area has multifunctional tasks and is divided into incoming material, storage and outgoing material. The blue arrows shows the incoming material flow, while the red arrows shows the outgoing material flow.

[17] Conny Ehlin (Freight handling, Transport department, ABB Ludvika) interviewed 19 Jun. 2013.

4.1.2.3 The Y-yard

The Y-yard is divided into even more zones than the other two material yards. Here are all finished parts from the divisions HV Components, Components and HVDC are stored[18]. The zones Y1, Y2, Y3 and NP are long storage zones and the time that the products are stored in the material yards can vary very much. Some products have to wait for other products to be finished, so that ABB can consolidate the goods and send them to the customer in one delivery. The zone P, which stands for "Plattan", is an area where packages is placed that are leaving ABB Ludvika within the next couple of days. The Y-yard also includes a special zone for both the goods going to the Port of Gothenburg (marked "Gothenburg") and the goods going to Arlanda with airfreight (marked "Airfreight"). The truck is entering from the right and drives to the loading area. After the goods are loaded the truck leaves through the same way it came from. Figure 25 shows an illustration of the material yard called Y-yard.

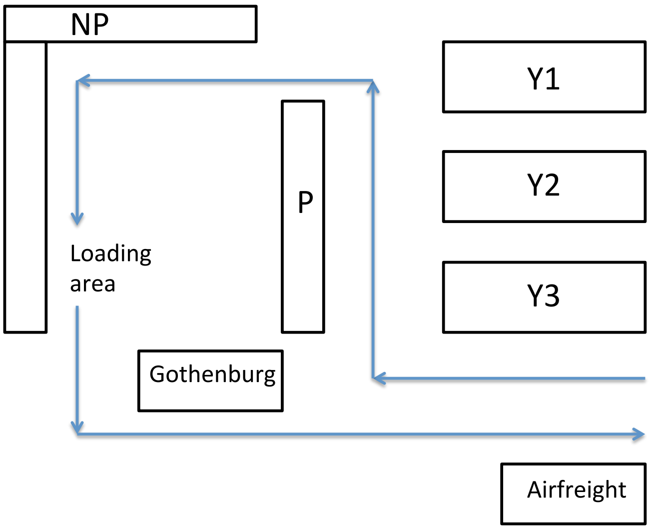


Figure 25. The material yard called Y-yard where finished parts is stored from the three divisions HV Components, Components and HVDC. Y1, Y2, Y3 and NP are all zones for long-term storage, while P ("Plattan"), Gothenburg and Airfreight are zones for goods that are supposed to be shipped within the next couple of days.

4.2 Production

Most products manufactured at ABB Ludvika are done according to Make-To-Order (MTO) or even Engineer-To-Order (ETO) principles[19]. This means that a product is only manufactured if a customer has ordered the specific product. Hence, there is no production towards a finished goods inventory. Each of the five divisions produces different products and the divisions show on different procedures as far material feeding goes and thus somehow different requirements upon the new LC. They all have a first separate department storage area that TRP delivers to. Having received these items, they do volume amount checks, quality checks and a system data input (usually without barcode scanning) into an ERP system. Items do many times also require unpacking in order for the staff to identify their destination, a tagging system of some kind would reduce these issues and make this flow more efficient[20]. After these actions, the supplies are taken further into the production and this is where some of the departments go separate ways.

At the Components facilities for instance, a Master Production Schedule (MPS) is frequently updated, with input from monthly sales meetings, forecasts, orders and quantity on hand, plans the production as well as the supply orders with a time horizon of 12 months (Brankl & Wu, 2010). Received shipments are all checked, counted and sorted upon geometry

[18] Fredrik Graaf (Freight administration, Transport department, ABB Ludvika) interviewed 20 Jun. 2013.
[19] Karl-Bertil Westman (Distribution manager, Power Products dist., ABB Ludvika) Interviewed 20 Jun. 2013.
[20] Håkan H Andersson (Purchasing Manager, Transformers Department, ABB Ludvika) Interviewed 16 Jul. 2013.

parameters within the production facility. A purchasing department follows this plan and make orders frequently taking the quantity on hand as well as a Materials Requirements planning, MRP into account trying to adapt to just in time principles. Apart from the replenishment from these orders, the production department uses Re-Order Point systems for small items like bolts or nuts (that are ordered manually) and 2-bin systems internally for larger items and components in production. No point of use inventory is built, the assemblers has to fetch the materials per operation. The department then produces numerous end products that are used both internally and externally.

The Transformers department on the other hand only making about 70 units each year with higher lead times, about 2-6 months and a takt-time of about a week, sometimes over a year from order to delivery, processes many of the parts in parallel to begin with and then assemblies these parts[21]. This production unit uses kitting both within the production and also outsources these actions to suppliers[22]. Kits here referred to as Mechanical Kits are prepared in the early production stages and then taken along with the products on yellow trolleys through the factory. All units here are produced on make to order basis and the purchasing department is able to follow this since orders are received as much as a year in advance. The products are also customised and different for each client. The department uses a five-day buffer storage on incoming material.

Final differences can also be seen at the HVDC department where shipments meant to be parts of HVDC systems are assembled out of products from mainly other internal departments like Transformers and Breakers, without going through production, together with own products and sent directly to the customers. These offerings mainly require internal transportation.

The general production vision aims for a decreased lead-time, through increased productivity, for the following years that are forecasted to raise sales numbers (with as much as 40 per cent at the transformers department)[23] without loosing quality, which has to be superior within ABB. Company-wide catchwords are summarised in Figure 26 beneath with the highest priority on top:

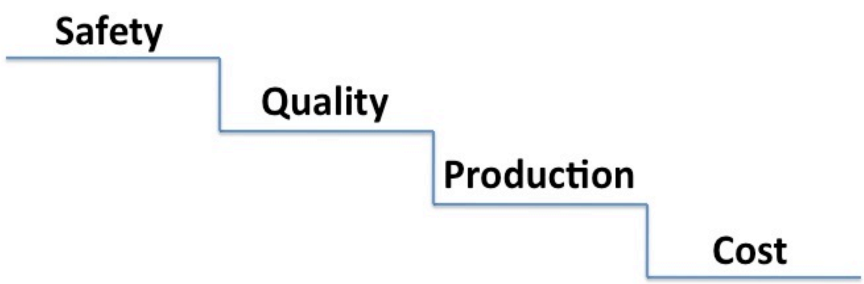


Figure 26. ABB Production vision catchwords. The catchwords are meant as to be enriching and aiming the company culture and atmosphere, covering all production units. Safety should always be on top making sure production employee accidents are kept low. After that, one should favour quality before productivity, efficiency in production and cost. Source: Daniel Wikberg[23]

[21] Daniel Wikberg (Test-Room Manager, Transformers Department, ABB Ludvika) Interviewed 16 Jul. 2013.
[22] Håkan H Andersson (Purchasing Manager, Transformers Department, ABB Ludvika) Interviewed 16 Jul. 2013.
[23] Daniel Wikberg (Test-Room Manager, Transformers Department, ABB Ludvika) Interviewed 16 Jul. 2013.

4.3 External material flow

The external material flow deals with the flows to and from ABB Ludvika. Hence, it starts with the material flow from the supplier base to the company boarders and then continues from the company boarders to the customers. In order to efficiently handle and coordinate the material flow to and from ABB Ludvika, the company uses external actors; LSPs.

4.3.1 Logistics service providers

LSPs handles the external material flow to and from ABB Ludvika. This involves some logistics functions from the supplier base to ABB Ludvika, as well as from the company to the customer base. The LSP handles the following value adding activities for ABB Ludvika:

- Transportation
- Storage
- Consolidation
- Air freight security preparation
- Logistic planning

Even though the physical transportation of goods stands for the biggest activity that the LSP providers perform, they also handles some other value adding activities like storage of finished products and logistic planning. The LSP company AA-logistik store finished products in Västerås, mainly for the division HVDC[24]. AA-Logistic is also involved in airfreight security preparations required for the shipping, involving airplane-proofing standards like x-ray etc. The reason for this is mainly due to lack of capacity in Ludvika. LSP providers can also be involved in some extent of the logistic planning of how to get the products as efficient as possible to the customer. It could be that the customer wants to have the products shipped to the middle of the Amazon rainforest in Brazil, where it could be necessary to build new roads. The large logistic planning that is involved in these projects are handled by each divisions shipping department[25]. But, in some cases they need help from the LSP providers, who have a lot of competences and capabilities in these questions. But these competencies are rarely used. Instead, ABB Ludvika tries to do as much as possible in-house.

The central division of ABB Group has made some central agreements with a few LSP providers, which are supposed to handle all kinds of external activities for the entire ABB[26]. Dependent on what transportation mode that is the dominating one for this specific shipping and what destination, ABB can choose from some LSP in this particular matter. For example, if ABB Ludvika is supposed to ship some products to Kenya in Africa, there are agreements with a some LSPs that are supposed to handle the transportation to and from Kenya. Then, depending on which transportation mode that will be the most dominating one, in this case it will be sea freight, maybe there are now only two LSP companies left to choose from. Now, these two companies will be compared mainly by price, but also if both of them are possible to perform the required transportation. In many cases it could be that the products are very bulky and heavy, which needs to be considered for the LSP.

DHL is considered as one of the biggest LSP providers for ABB Ludvika. DHL has a terminal in Borlänge, located approximately 50 km from Ludvika, where several value-adding activities are performed for many customers[27]. If only considering ABB Ludvika, DHL Borlänge consolidates material from suppliers all over the world and delivers them each day to ABB Ludvika. DHL Borlänge uses milk rounds in order to deliver the material to several

[24] Hans Messing (Production manager, HVDC Products Production, ABB Ludvika) Interviewed 19 Jun. 2013.
[25] Karl-Bertil Westman (Distribution manager, Power Products dist., ABB Ludvika) Interviewed 20 Jun. 2013.
[26] Karl-Bertil Westman (Distribution manager, Power Products dist., ABB Ludvika) Interviewed 20 Jun. 2013.
[27] Vehbi Shkreta (Terminal manager, Freight, DHL Borlänge) Interviewed 18 Jun. 2013.

customers. Sometimes these trucks have a very low fill rate and this is often the case with the incoming trucks to ABB Ludvika. According to DHL Borlänge, it is a result of a bad planning due to the bad communication between the two parties.

A lot of the tasks taken care of by DHL could possibly be managed more effective if the companies had a closer relationship. If DHL had a better vision into processes at ABB, value-adding activities could probably be made more efficiently. DHL believed that it is crucial for them to get information as early as possible in order to plan their routes and activities in the best possible way. Today, DHL Borlänge get information from ABB Ludvika one day before the shipment shall be executed, which is not considered to be enough in order to plan the shipments in the best possible way. DHL Borlänge actually means that if they could get information long time in advance, they could plan the routes much better and achieve a higher fill rate. DHL Borlänge has actually tried for a long time to develop a more collaborative relationship, but ABB Ludvika wants to keep them on an arm's length approach. DHL Borlänge believes that if they get more responsibility they can plan the material flow much better and achieve economy of scale and it would be a win-win situation for DHL and ABB Ludvika. On the other hand, ABB Ludvika means that they have always kept the LSP on an arms length approach and has always send the transportation information a day before the shipment shall be executed. Therefore, ABB Ludvika has never experienced this as a problem[28].

4.3.2 The material flow

The external material flow starts when the production division order supplies from the supplier base, which consists of around 4000 suppliers, PP and PS have approximately 2000 each[29]. When the suppliers should book the deliveries to ABB Ludvika, it is common that the company is involved in this process. ABB Group has made agreements with some LSP that should handle the external material flow. About 15 per cent of the suppliers generate 80 per cent of the bought volume. Suppliers are classified as A-suppliers who are considered more important due to volume or quality, B-Suppliers and C-Suppliers. Supply material and components can also be grouped into three groups; C1, C2 and C3. C1 are standardised products that can be sourced from a lot of places. C2 are more complicated ones and C3 are key supply material and components. Supplier relationships are usually handled according to these categories, where the A-suppliers are handled on a long-term basis with a high degree of trust and close collaboration. The B- and C-Suppliers on the other hand, are not handled that close.

The LSP handles the incoming material flow from all the suppliers to ABB Ludvika, where the central agreements apply. Here, the logistics services of the LSP are mainly focusing on the physical movement of goods, i.e. transportation. When the purchasing departments at each division buy the supplies necessary, they also need to state which LSP provider that will handle the transportation to ABB Ludvika. Consequently, the suppliers need to adapt to ABB's agreements.

When products are produced and ready to be shipped, it leaves ABB Ludvika and are transported to the customer base, which consists of thousands of customers located all over the world. A big part of these customers are internal customers, i.e. other ABB divisions. When shipping terms should be negotiated with the customers, the standardised methodology called incoterms is often used. The agreed framework used may vary from transaction to transaction depending on the circumstances. Leaving the shipping in the hands of suppliers

[28] Karl-Bertil Westman (Distribution manager, Power Products dist., ABB Ludvika) Interviewed 20 Jun. 2013.
[29] Peter Åsmo (Supply chain manager, Power Prod. Supply chain, ABB Ludvika) interviewed 14 Jun. 2013.

and customers can sometimes serve to reduce the control as well as consolidation of the goods. This may cause delays and handling issues sending and receiving shipments.

The LSP helps ABB Ludvika to distribute the finished products to the customers. ABB Ludvika can choose between a number of different LSP, as what is stated in the centrally agreements from the company group. Which LSP provider that is chosen is decided through what transportation mode that should be used, the destination, the characteristics of the product and the agreements with the customers. In general, ABB Ludvika holds the LSP on an arms length approach and believes that getting the cheapest LSP provider for each situation is the most important criteria. Information about the LSP that is used for the finished products to the customers can be seen in Table 5 beneath:

Table 5. Information about the 3PL that are used for the finished products in ABB Ludvika. Road transportation is used most frequently as most destinations lies within Europe and central asia. Sea freight through Gothenburg and airfreight are used for longer distances and in timely critical occasions.

Transportation mode	3PL Providers	Share	Destination	Other information
Road	DHL Schenker Bring DSV	57,9 %	Europe, Russia, Central Asia	Represents the biggest share of all shipping from ABB Ludvika. 78% are pickups by the customers, so called Ex-Works.
Sea freight	DHL Geodis-Wilson Kuldne & Nagel Agility	33 %	Other continents	Sea freight is mainly shipped from the Port of Gothenburg. DHL is always used for the road transport to Gothenburg. The Port of Norrköping is used for the transformers.
Airfreight	DHL Geodis-Wilson Kuldne & Nagel Agility	9 %	Globally	Airfreight from Arlanda, where AA-logistik is driving the goods, is used for the express cargo, when something needs to be delivered as quickly as possible.
Railway	ABB owned train	<0,1 %	Norrkoping	Railway is used for very heavy products like the transformers and only approximately 30 products a year, which are sent to the Port of Norrköping.

For road transport, each distribution division can choose between DHL, Schenker, Bring, and DSV, which is mainly used for transportation to customers in Europe, Russia and Central Asia. Of all number of packages leaves ABB Ludvika, 57,9 per cent is transported to the customer with truck. 78 per cent of all this truck transportation is pickups by the customers themselves, on so called Ex-Works terms. This means that the shipping department at each division books only 22 per cent of all outgoing products taken by truck.

Sea freight, on the other hand, is handled by DHL, Geodis-Wilson, Kuldne & Nagel and Agility. This option is sometimes used when products should be shipped to other continents such as Asia, North and South America. Most of the sea freight is shipped from the Port of Gothenburg, which represents approximately 33 per cent of all outgoing packages from ABB

Ludvika, about three to four full truckloads a day[30]. The truck transportation to Gothenburg is always handled with DHL, regardless of the shipper who then ships the goods to the end customer. The only sea freight that is not shipped from Gothenburg is the heavy transformers products, which are sent by trains to the Port of Norrköping, mentioned further beneath.

Airfreight, however, is only used for the express cargo, when products need to be delivered as quickly as possible[31]. Airfreight stands for 9 per cent of all the numbers of packages going out from ABB Ludvika. These packages are often very small in size, weight and volume. When calculating just the total weight going out from ABB Ludvika with Airfreight, the number is only 3 per cent. The express products are picked up once a day at 11:45 by a transportation company called AA logistics, which drives the goods to Västerås where they are sorted. Then, a truck drives the goods to Arlanda Airport, where an airplane can lift with the goods in the evening. Here, some of the 3PL companies DHL, Geodis-Wilson, Kuldne & Nagel and Agility takes over and handles the transportation to the end customer.

Railway shipped products, transformers, are so heavy that road transport cannot be used. Further problems arise carrying these shipments on the railroad to Gothenburg, so instead the Port of Norrköping is used[32]. Approximately one train with one transformer is leaving ABB Ludvika each week, which is the only time when railway is used, due to that it is considered to be inefficient and it takes too long time[33].

4.4 Internal material flow

The internal material flow deals with the flow within ABB Ludvika, which starts when the material enters the company boarder until it reaches production. When the product is completed, the internal material flow continues until it leaves the company boarders. In order to handle the internal material flow in the most efficient way, ABB Ludvika uses a centrally located division called the transport department (TRP).

4.4.1 The Transport department

TRP is a central division within ABB Ludvika, which is an internal actor that handles the internal material flow for all the five production divisions. The TRP may be seen as an internal logistics service provider, which serves the production with material and takes care of the finished products within the company boarders. The main logistics functions of TRP is listed beneath:

- Internal transportations
- Warehousing
- Sorting
- Storing
- Booking of some external transportations

These logistics activities may be seen as more basic activities. Actually, TRP would like to perform more “value-adding” activities, such as production preparation, logistic planning, consolidation and sequencing. Even though many of these activities are very similar for all divisions, they are actually performed internally at each division and there is a strong tradition to keep it this way. The five divisions only see TRP as an actor that should deliver and collect

[30] Anita Hultgren (Transportation coordinator, Transport department, ABB Ludvika) interviewed 19 Jun. 2013.
[31] Karl-Bertil Westman (Distribution manager, Power Products dist., ABB Ludvika) Interviewed 14 Jun. 2013.
[32] Edy Jernberg (Production manager, Transformers department, ABB Ludvika) Interviewed 18 Jun. 2013.
[33] Karl-Bertil Westman (Distribution manager, Power Products dist., ABB Ludvika) Interviewed 14 Jun. 2013.

the material, i.e. material movement. Hence, there are not much cooperation or communication between TRP and the five production divisions.

In order for TRP to perform the basic activities, the department carries resources of 23 employees (where 5 handle administrative tasks and 18 the physical material flow), 18 handling-trucks in different sizes and storage yards with and without roof cover. TRP is open daily Monday to Friday, between 06:30-12:00 and 01:00-3:30 pm even though many of the production facilities are running all night and the site gates are staffed with security personnel until 9 pm. This fact generates a lumpy material flow with high peaks, especially in the morning time[3]. If trucks arrive during weekends, they will have to wait in an assigned parking spot until Monday morning. The weekend backlog creates a high burden on the transport department each Monday morning.

There are two delivering spots as well as three pick-up spots on the company property where goods are sent off to different departments as well as prepared in order to be shipped, see Figure 22.

Space problems also occurs when trucks, arriving on TRP closed hours many times has to be let in to the site just because they cannot turn around outside the gate. This brings confusion to the drivers that seldom speak Swedish and many times not even English. They often stop inside the site trying to announce their arrival anyway[34].

Table 6. Statistics from the transportation department. There are almost five times as many trucks with loaded finished products going to customers than trucks delivering incoming material to the production. On the internal transportation, the division Components stands for the highest share 25 per cent of all transported goods, while HVDC only represents a share of 5 per cent.

Statistics from the Transporting department

Calculated monthly averages from three registration months, rounded off values

External traffic			
	Inbound		
	Incomming trucks	**1320**	Trucks
	Goods received	**13670**	Pallets
	Pallets per truck	**10,4**	Pallets
	Outbound		
	Outgoing trucks	**276**	Trucks
	Goods shipped	**5212**	Pallets
	Pallets per truck	**18,9**	Pallets
Internal traffic TRP			
	Total deliveries	**7245**	Deliveries
	Amount of goods handeled	**18882**	Pallets
	Goods per delivery	**2,6**	Pallets

Transport work shares divided on each division

Calculated on the internal TRP delivery amount share (inbound and outbound)

Components	**25%**
High voltage breakers	**12%**
High voltage components	**24%**
HVDC	**5%**
Transformers	**21%**
Other	**13%**

[34] Anonymous (Security Guard, "Norra porten" ABB Ludvika) interviewed 17 Jun. 2013.

ABB Ludvika is currently struggling with a lot of internal and external material flows, see Table 6. A company hosted survey made in November 2011 and November and May 2012 points on an average of 44 delivered truckloads each day and around only 13 going out. An insight here is the average amount of pallets going in and out per truck (10,4 vs. 18,9), showing on a varying fill-rate. The railway is only used about once each week. The table also reveals the delivery (inbound and outbound) delivery share divided on the different departments visited by the TRP as well as the amount of trips made and packages delivered. These facts are used as references for TRP while sending internal invoices to the client departments each month. The invoices are measured from the amount of deliveries only and written out to monthly amounts each year. The amounts are then weighted between the different departments after check-ups during registration months (usually May and November) each year. Note also that there are other departments buying services from TRP as well. Most of these are other companies renting buildings from ABB Ludvika.

As the TRP material planning is made according to empirical studies of amount of units received, the statistics (partly shown in Table 6) within these areas become important to the future efficiency of the department. Statistics are made based on daily manual data input from items handled by the separate truck drivers. At ABB Ludvika, there seem to be some confusion to what data to calculate within these forms. Pallets are sometimes made up of several packages with several wrapped units into each, which tend to make the counting somewhat problematic. Basing the future development upon these inputs might through this bring several sources of errors into investment calculations.

Apart from truck deliveries and pickups there are about 250 internal deliveries each day, creating congestion. A quick peek at Table 6 and a few rough calculations reveals around 180 trucks passing's outside the TRP office each hour (3 passing's each minute). The further fact that this spot is a crossing where a big share of production employees has to pass at least twice each day highlights the congestion issues as severe security issues[35]. The trucks loading from the Breakers facilities at the very north have to pass through the same flow as the others in order to get correct information and announce their arrival at the TRP department[36].

All this traffic involves giant problems at the offloading location where TRP staff are working to remove goods from the trucks as fast as possible. Congestion causes delays in this process when empty trucks or filled trucks going out have to pass by in front these open trucks. There are only two lanes here and the train-tracks that also server to bother the flow, has to be unblocked[37]. Figure 27 beneath illustrates this.

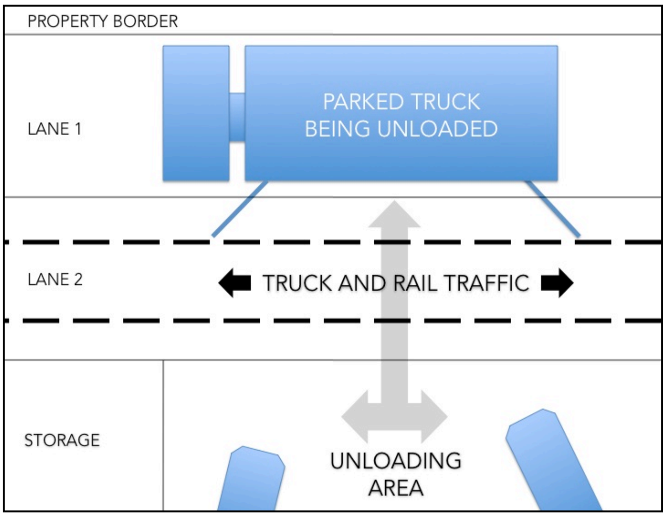


Figure 27. Unloading congestion issues at ABB Ludvika. Heavy traffic involves giant problems at the unloading location where TRP staff are working to remove goods from the trucks. Congestion causes delays in this process when empty or filled trucks going out have to pass by in front these open trucks. There are only two lanes here and the train-tracks that also server to bother the flow, has to be

[35] Kurt Nordahl (Department manager, Transport department, ABB Ludvika) interviewed 12 Jun. 2013.
[36] Conny Ehlin (Freight handling, Transport department, ABB Ludvika) interviewed 19 Jun. 2013.
[37] Tommy Andersson (Freight handling, Transport department, ABB Ludvika) interviewed 17 Jun. 2013.

The trucks that are being unloaded usually do not arrive full. Employees at the unloading area estimate the average fill-rate to about 50 per cent[38]. Personnel at TRP administration also claims that it is extremely rare that the trucks delivering also pass to the loading area bringing goods in return during the same trip[39].

4.4.2 Material flow investigation

A material flow mapping (MFM) has been conducted of the current state within ABB Ludvika and can be seen in Figure 28, where a bigger figure is provided in Appendix C. The purpose of Figure 28 is not to show what kind of processes that should be performed, but instead just to get an overview of the whole picture. The MFM shows both the material and the informational flow, from the components enters the company until it reaches production. After production, the MFM continues until the material leaves the company.

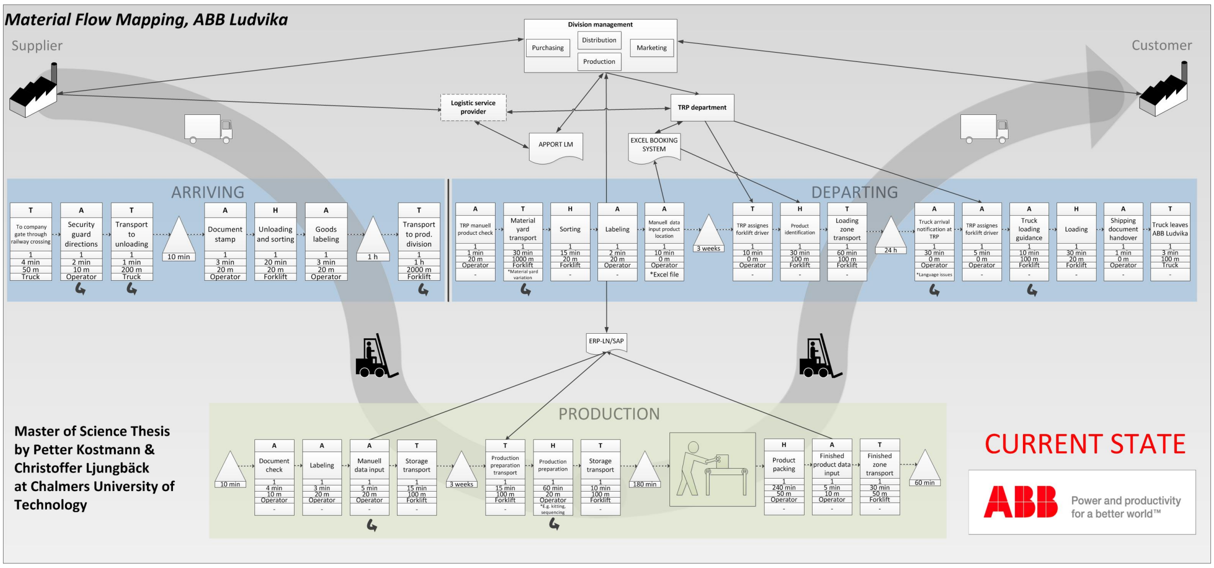


Figure 28. The current state overview map of the internal material and informational flow. Each column of boxes represents one process of the flow. A larger version of the image is displayed in Appendix C. Each of the three illustrated department flows in this overview figure will be covered more closely beneath. These parts will be illustrated with separate zoomed-in images taken from this map.

The investigation was made on 16 Jul. 2013 and followed the logistical processes to and from production. The study did not follow a specific material flow, instead it examined the processes that most of the materials flows have in common. Even though the material and informational flow can be very separated within the production, the logistical processes are very similar outside of production. The logistics activities can be divided in three main areas; arriving, production and departing. The TRP department is handling the activities for the arriving and the departing, while each production divisions are handling the production activities. Note that the pure production activities have not been examined, hence when talking about production activities they are referred to the logistics activities before and after production that is made by the production personnel.

[38] Bengt Olof Karlsson (Freight handling, Transport department, ABB Ludvika) interviewed 17 Jun. 2013.
[39] Anita Hultgren (Freight coordinator, Transport department, ABB Ludvika) interviewed 19 Jun. 2013.

Table 7 beneath summarises the investigation regarding the throughput time, time in storage and transport distance.

Table 7. Summary of the MFM investigation regarding time and distance within ABB Ludvika.

Material flow mapping	Throughput time	Time in storage	Transport distance
Total	**43,7 days**	**43,25 days**	**4280 m**
- Arriving	0,1 days (2,4h)	0,05 days (1,2h)	2320 m
- Production*	21,4 days	21,2 days	480 m
- Departing	22,2 days	22,0 days	1480 m

*Before and after the production process.

Table 7 shows that the total material throughput time is in total 43,7 days, where the material is stored as much as 43,25 days (a day has been calculated as 24 hours). The material flow at the arriving has only a throughput time of 0,1 days with a storage time of 0,05 days. The material flow at the production department has a throughput time of 21,4 days with a storage time of 21,2 days. Finally, the material flow at the departing has a throughput time of 22,2 days with a storage time of 22,0 days.

Furthermore, Table 7 shows how big distance the material is transported throughout the company. The total transport distance is 4280 m, where the material flow is transported 2320 m at arrival, 480 m at production and 1480 m at departing.

The MFM also explains the number of processes throughout the company, which is shown in Table 8. The table divides the processes in four main categories: Transport, Handling, Administrative and Storage.

Table 8. Summary of the MFM investigation regarding the number of processes, which is divided in four main categories: Transport, Handling, Administrative and Storage.

Number of processes	Total	Arriving	Production	Departing
- Total	**39**	**9**	**14**	**16**
- Transport	11	3	4	4
- Handling	6	1	2	3
- Administrative	14	3	4	7
- Storage	8	2	4	2

Within ABB Ludvika there are in total 39 different processes, where arriving consists of 9 processes, production of 14 processes and departing 16 processes. Administrative activities accounts for the largest share, with in total 14 processes. Transportation and Storage activities have 11 and 8 processes, while Handling activities stands for the smallest share with only 6 processes.

The following chapters will describe more in detail how the material and informational flows goes through the company and how it is controlled, divided in the three main areas; arriving, production and departing.

4.4.2.1 The material flow at arriving

The material flow at arriving starts when it enters the company borders and continues until the material is delivered to each production division. The material flow has a throughput time of 0,1 days (2,4 h), where 0,05 days are just storage (see Table 7) and consists of 9 different processes (see Table 8). The material flow at arriving is handled and coordinated by the TRP. The MFM at arriving can be viewed in Figure 29 beneath.

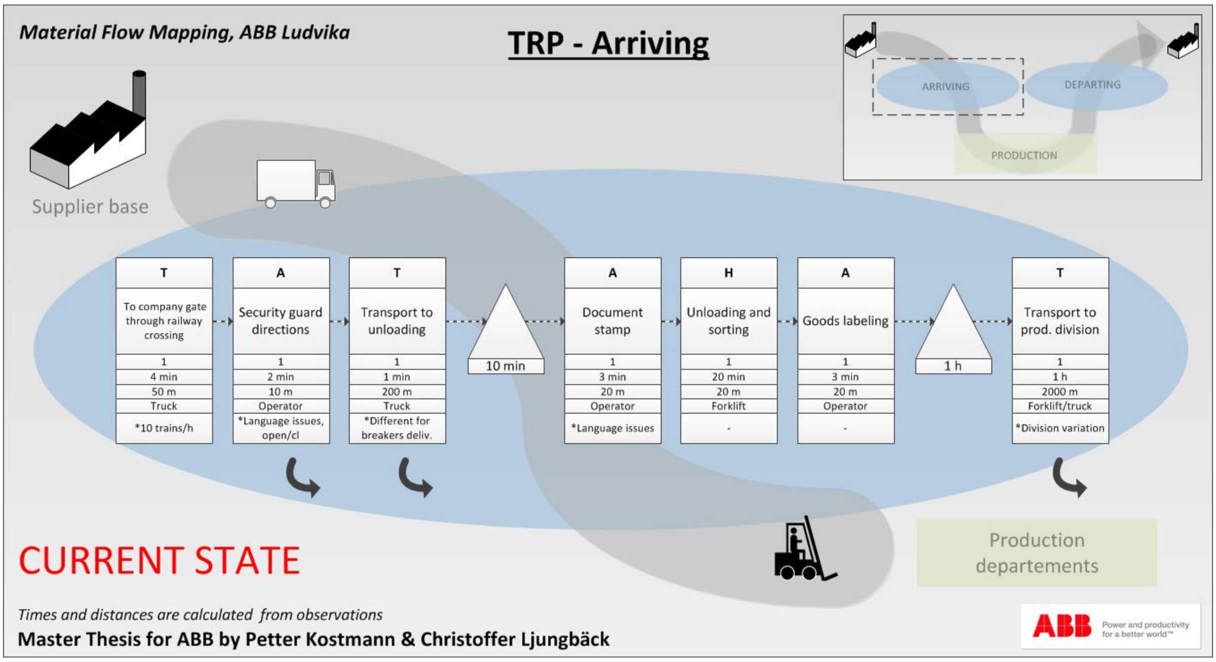


Figure 29. MFM of the arriving side of the transporting department. Incoming truck deliveries at the upper right are taken further to each production division, down left. The arrows underneath the processes mark points where alternative flows may be attained depending on shipment.

The first step in the material flow is that the truck has to cross the railway right before the company gate. This railway is frequently used both by goods and passenger transports and can be blocked as much as 12 times each hour creating congestion and delays outside the site[40]. Most of the trucks entering ABB Ludvika are not scheduled for a certain time. TRP only knows how many trucks that will arrive each day, but not what specific hour. As a result, the trucks enter ABB Ludvika with large variations. Most trucks are entering in the morning, while fewer are entering in the afternoon[41]. Consequently, this is not an optimal solution for the staff at TRP, which has a very stressful work in the morning and less to do in the afternoon. In cases where the trucks arrive during closed hours (TRP closes at 15:30 and the company gate closes at 21:00), the trucks need to be allowed into the company area anyway to be able to turn, due to that the space is very limited in front of the gate. This creates confusion when the truck drivers often think they are allowed into the area for loading of goods[42]. Many truck drivers also do not know that the TRP is closed on evenings and weekends, and may therefore become angry when they had planned to pick up the goods. The trucks have to drive to a parking lot south of ABB and wait for the TRP to open, which can take many hours and even days if it is on a weekend. Trucks that should pick up products for the customers, so called ex-works, also has to park at the same parking spot, while all administrative is handled before loading can occur[43].

During a normal situation, when a truck is arriving during the opening hours the truck needs to announce their arrival in the security booth at the gate. Here, they will be assigned to enter the area and drive to the right zone[44]. For unloading trucks there are now two options, which can be seen in the list beneath:

1. The truck should drive to the unloading area called T65, if the truck should deliver material to one of the four production divisions; HV Components, Components, Transformers and HVDC.

[40] Filip Bengtsson (Project manager, Facilities department, ABB Ludvika) interviewed 12 Jun. 2013.
[41] Tommy Andersson (Freight handling, Transportation department, ABB Ludvika) Interviewed 17 Jun. 2013.
[42] Anonymous (Security guard, "Norra porten", Securitas Ludvika) Interviewed 17 Jun. 2013.
[43] Kurt Nordahl (Department manager, Transport department, ABB Ludvika) interviewed 12 Jun. 2013.
[44] Anonymous (Security guard, "Norra porten", Securitas Ludvika) Interviewed 17 Jun. 2013.

2. The truck should drive to the unloading area called Breakers-yard, if the truck should deliver material to HV Breakers.

The first, and the most common one, is that the truck has goods to either one of the four divisions; HV Components, Components, Transformers and HVDC. If so, the truck will get directions to drive to the unloading area called T65. The other option is that the truck has goods to the division HV Breakers. In that case, the truck needs to drive to their own material yard, the Breakers-yard, see Figure 24.

When the truck is in the right zone, the unloading can begin. At T65 there are three forklift drivers, while at the Breakers-yard there are two workers for the incoming material. These workers will then unload the goods, mark them and sort them into piles so that other TRP staff can fetch these goods right away and drive them out to further storage at the production units[45]. The unloading storage area capacity is quite limited so the goods have to be brought out right away to each division, which normally is done with forklifts at different sizes. As a result, TRP needs to drive a large number of runs each day to be able to deliver the goods at each division, mainly due to the limited loading capacity of a forklift. Additionally, a milk-run truck is also used for more heavy material and for divisions located further away. This truck leaves T65 on specified hours, three times a day, where it delivers goods and at the same time picks up finished products.

4.4.2.2 The material flow at production

The material flow at production starts when the material is delivered to the production division and continues until the finished product are put outside the production division. The pure production activities are not examined here, but only the logistics activities before and after production. The material flow has a throughput time of 21,4 days, where 21,2 days are just storage (see Table 7) and consists of 14 different processes (see Table 8). The material flow at production is handled and coordinated by the production staff at each division. The MFM at production can be viewed in Figure 30 beneath.

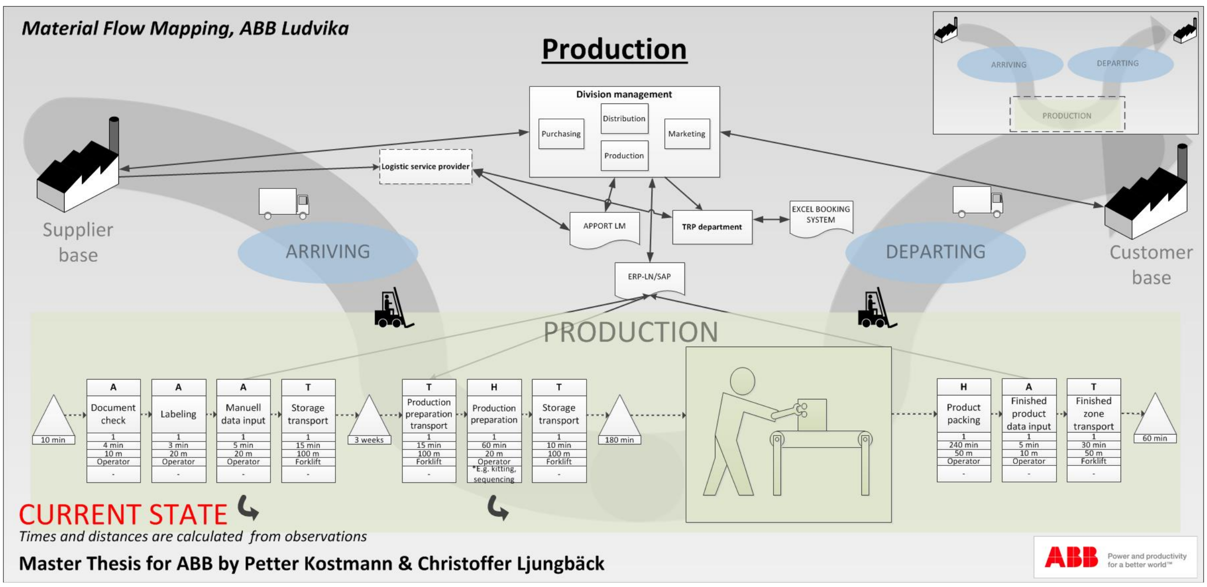


Figure 30. MFM of the production. Notify that these activities only consider the logistics activities within the production divisions and not the pure manufacturing activities, such as material transformation.

[45] Tommy Andersson (Freight handling, Transportation department, ABB Ludvika) Interviewed 17 Jun. 2013.

Once the goods are delivered to the separate departments, it is stored outside each department for some hours. Personnel at each division receive the material and transport them further to a long-term storage, where it is stored for about 3 weeks. When production needs the components, personnel transport the material to some value adding activities. All production divisions are doing some sort of production preparation activities. For example, the division Components sort and kit the material before it goes to production, while HV Breakers just sort the material in a special sequence for production. These value-adding activities are done in each division just before production. Then it is transported to a short-term buffer close to the production site, which is the last step in the inbound material flow.

The lead-time for the production is not examined in this thesis, but may vary from a few days to about six months, depending on the product and what division that is performing the manufacturing[46]. For example, the lead-time for Power transformers is about six months, while other divisions have much shorter time (see section 4.2 Production).

After production, the products need to be packed, which is handled at each production department. To be able to deliver the product to the customer, the products have to be put on pallets. These pallets are often special made by external suppliers for the customised products in various sizes. The special made pallets are often stored at a material yard, waiting for the product to be manufactured. This can sometimes takes very long time and the pallets just stands there and takes up a lot of the limited space. After the product is packed in a pallet, it is then discharged into the finished goods storage on a so-called square, which is located outside of each division's production facility.

4.4.2.3 The material flow at departing

The material flow at departing starts when the product is finished and put out on the finished goods storage and continues until the product leaves the company boarders. The material flow has a throughput time of 22,2 days, where 22,0 days are just storage (see Table 7) and consists of 16 different processes (see Table 8). The material flow at production is handled and coordinated by the TRP. The MFM at departing can be viewed in Figure 31 beneath.

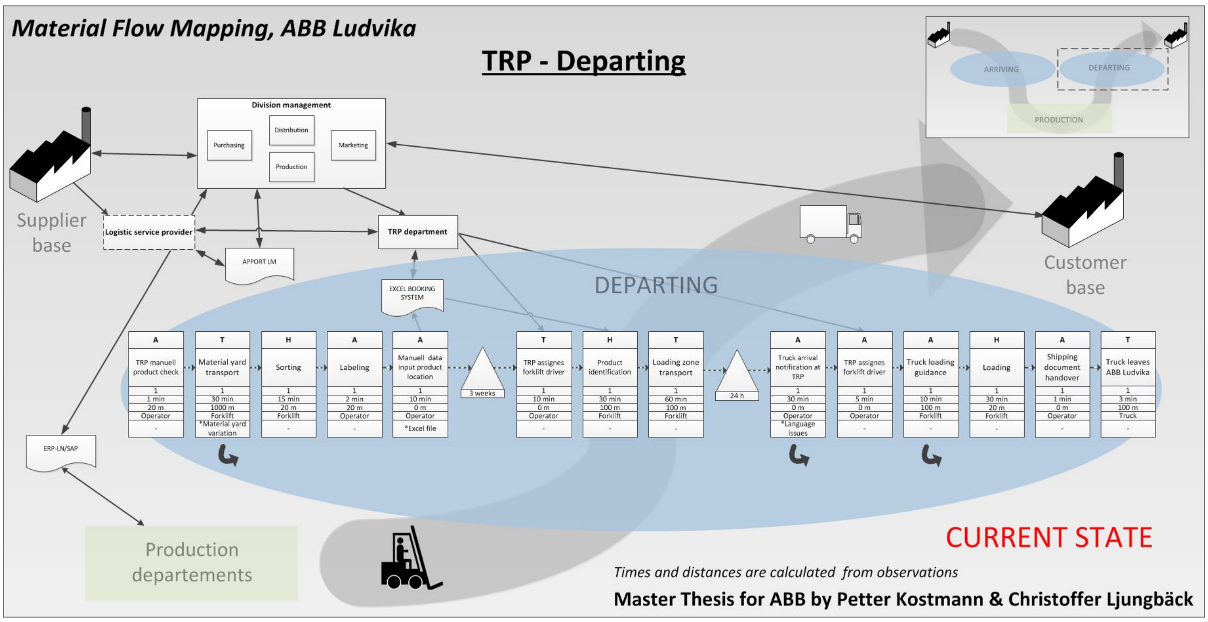


Figure 31. MFM of the departing side handled by the transportation department. Finished goods are picked up by each production division and taken further to storage before 3PL pickups. The arrows underneath the processes mark points where alternative flows may be attained depending on shipment.

[46] Karl-Bertil Westman (Distribution manager, Power Products dist., ABB Ludvika) Interviewed 20 Jun. 2013.

TRP drives around the entire ABB area and keeps an eye on the different squares for finished products. When the production department has set out finished products into the square, TRP picks them up and transport the goods to a material yard for long-term storage until the order is complete[47]. The storage time at a material yard can vary a lot. Some products are shipped to customer within a week, while other products have to be stored for about six months to a year. The average long-term storing time is estimated to be approximately 3 weeks. Reasons for the long-term storage can be seen in section 4.1.2 Facilities.

When the products are ready to be shipped to the customer it is often handled by a LSP that will come and collect the products. The LSP arrives at ABB Ludvika by crossing the railway, turn left and drive towards the company gate, which is the same entrance as for the unloading trucks. The driver announces the arrival at the gate and gets instructions from a security guard on where to drive[48]. Trucks with the purpose of loading finished products is supposed to drive into a specific parking area located in Y-yard, which is composed of two lines with the capacity of three trucks in each line.

A forklift driver at TRP drives to the parking area and thereafter guide the truck to the right loading zone. Depending on the reasons for loading there are five options for the truck, summarised in Table 9 beneath.

Table 9. The five options of a loading truck in ABB Ludvika.

Options	Reason for pickup	Material zone
1.	Loading products from one of the divisions: • HV Components • Components • HVDC	Y-yard
2.	Sea freight going to the Port of Gothenburg	Gothenburg Zone
3.	Airfreight going to Arlanda	Airfreight Zone
4.	Loading products from Transformers	E-yard
5.	Loading products from HV Breakers	Brytare-yard

Firstly, if the truck will pick up goods from one of the three divisions HV Components, Components and HVDC, the truck drives to the unloading zone at Y-yard. Secondly, if the truck comes from DHL and going to the Port of Gothenburg, the truck needs to drive to the special zone for Gothenburg goods. Thirdly, if it is the truck coming from AA-logistics that will pick up goods to Arlanda, the truck needs to drive to the special zone for airfreight. Fourthly, if the truck is supposed to pick up goods from the division of transformers, the truck has to drive to the E-yard. Fifthly, if the truck is going to load products from HV Breakers the truck needs to go to the Breakers-yard. As a result, there are five different options for a pick up truck entering ABB Ludvika, which effects in complex material flows, trucks and personnel. If the products are located on E-yard or Breakers-yard, the guiding from the forklift driver can take a while due to that it is pretty far.

When the truck arrives at the right loading zone, the driver goes out from the truck and prepare the loading by opening the side of the truck. Thereafter, a forklift driver loads the packages on the truck. These packages are already sorted the day before to this particular

[47] Gustav Norman (Freight handling, Transportation department, ABB Ludvika) Interviewed 14 Jun. 2013.
[48] Anonymous (Security guard, "Norra porten", Securitas Ludvika) Interviewed 17 Jun. 2013.

truck arrives[49]. When all packages are loaded, the truck drives out from ABB Ludvika through one of the various gates depending on what material yard the truck has been loaded on, see Figure 22.

4.4.2.4 The information flow

As stated before, most products manufactured at ABB Ludvika are done according to MTO or ETO principles[50]. This means that all the departments need to get an order before production can begin, which is the first step in the inbound informational flow. A customer order may involve different products and different pieces of each product. When the customer has set an order, a contract between ABB and the customer needs to be written. These actions are handled separately by the marketing department at each division. In the contract, all necessary information is stated like conditions of carriage (Incoterms), delivery date, price, etc. For example, the agreement between ABB and the customer may set one or several delivery dates depending on if the customer wants to have the products delivered at the same time or divided in several shipments.

Thereafter, the marketing department sends a signal to a management information system. ABB uses different systems at different divisions, e.g. PP uses a system called ERP-LN, while PS is using the system SAP, which is more commonly used across the whole organisation. When the order is in the system, the production department receives the order and the process of preparing the customised solution begins, as they know what should be produced until what date.

The customer order input to the management information system triggers the different purchasing departments at each division to order required parts from their suppliers. When the components needed for production are bought from the suppliers, the delivery announces the arrival to ABB Ludvika one day before. The TRP then knows how many trucks and how many packages that are coming the next day and can plan according to this.

When the truck with incoming material arrives at ABB Ludvika, the truck driver hands over freight documents with the actual order number, containing information about what is delivered and to what production division it is going[51]. The TRP will stamp the documents, and keep one copy for themselves. After unloading the goods, the TRP workers deliver the packages to each division and hand over the document from the truck driver. Each division checks that the goods document are correct, put on labels and then enters the information from the document into their system. Now the production unit knows that the components are ready for manufacturing.

Once the complete product is produced, packed and ready, a signal is sent to the system indicating that the item is complete. Then the production workers put out the products in a finished zone. The TRP staffs does not see this signal and have to circle around the area and manually see if there are some packages in the finished zones[52]. If so, the forklift driver transports the package to a material yard for storage. The location of the specific zone for the storage of the product is communicated to the administrative department of TRP. The forklift driver walks to the office and leaves a handwritten note with information containing what zone the specific product is located. The administrative department types in the information in an excel file, containing all stored packages and what zone they are located on. Due to the large number of stored products, the excel file becomes very big and hard to find relevant data. All packages are marked with an order number or a case number and the forklift driver

[49] Gustav Norman (Freight handling, Transportation department, ABB Ludvika) Interviewed 14 Jun. 2013
[50] Karl-Bertil Westman (Distribution manager, Power Products dist., ABB Ludvika) Interviewed 20 Jun. 2013.
[51] Anita Hultgren (Transportation coordinator, Transport department, ABB Ludvika) interviewed 19 Jun. 2013.
[52] Gustav Norman (Freight handling, Transportation department, ABB Ludvika) Interviewed 14 Jun. 2013.

keeps track of where the packages are stored, see Figure 32. If the truck driver would be sick for a day, it can take a very long time to find the products with the help from the excel document[53].

Figure 32. Outgoing package marking at ABB Ludvika. All packages are marked with an order number or a case number and the forklift driver keeps track of where the packages are stored. The forklift drivers needs to manually keep track of all packages themselves, though no scanning or automatic processes is conducted.

Once the products has been driven away from the production department and stored in a material yard, the specific division's shipping department is ordering the transportation. A certain transportation program is used for the calculation of the shipping, which calculates which 3PL provider is the cheapest depending on the destination, type of product and volume. HVDC on the other hand has already written a contract with one 3PL that should handle all transportation[54]. If the product is going to be exported by sea freight, then the TRP books the truck transport to the Port of Gothenburg. This booking is done each day for all divisions simultaneously, with the purpose of achieving a high fill rate by consolidating products from all divisions. TRP sends a list to DHL every week with all shipments needed to be transported to the Port of Gothenburg. A "list of packages" is attached in the booking and DHL compile all the lists and send the amount of trucks that are necessary for all products to be shipped. When the DHL truck arrives to ABB Ludvika, the truck driver just notifies that they are from DHL and that they want to pick up goods. Typically these drivers are familiar with the "ABB Ludvika concept" and goes directly to the TRP administrative department, so that they can get a forklift driver assigned. Then, a TRP forklift driver loads the truck in a way that he thinks is the best, without necessarily taking specific packages. For each shipment that TRP has loaded in the truck, the driver gets a "list of packages" for this particular load.

When each division's shipping department has decided on which LSP that will transport their products, a signal is sent to a web based system called APPORT Logistic Manager (APPORT LM), where ABB has direct contact with the LSP and a reservation is made. Information in this system tells the LSP of what kind of products that should be transported and when they are going to be delivered to the customer. The LSP will then send a confirmation to the division through an Estimated Time of Arrival (ETA), which indicates when the products can be collected and when it is delivered to the customer. A message is then sent to the customer when the delivery will take place.

Thereafter, the division's shipping department sends a signal to the TRP. The signal includes a "list of packages", which shows the number of packages, weight, volume, destination and

[53] Linnea Grönvold (Freight administrator, Transport department, ABB Ludvika) interviewed 17 Jun. 2013.
[54] Jan Bergfeldt (Distribution manager, HVDC – Systems Distribution, ABB Ludvika) Interviewed 19 Jun. 2013.

which LSP that should manage the transportation. Normally, the LSP announces its arrival at least a day before. Then, TRP prints the “list of packages” and set a forklift driver to collect all the packages together in the right zone. If the forklift driver cannot find the particular packages, the worker needs to get information from the administrative department at TRP, which has an excel file containing all stored packages and what zone they are located on. This sorting activity is often carried out within the same material yard, e.g. long-term storage to the loading zone. In Figure 15, this example can be from zone “Y1” to zone “Plattan”.

When the truck arrives to ABB Ludvika it will notify arrival at TRP. Here, the driver shows a specification number of what products that should be picked up. Thereafter, the truck driver has to wait for a forklift driver that will guide the truck to the dispatch area. It occurs most often problems with communication, as many drivers are of foreign descent and do not speak English. The “List of packages” for the specific shipment is then moved manually to another person on the TRP, which hand overs the papers and delegates the work to a forklift driver. The forklift driver knows what zone the goods are stored from the sorting activity the day before and shows the truck driver to the right zone for dispatch.

When the loading is complete, the truck driver gets a “list of packages”, which shows what products that are loaded on the truck. Thereafter the truck leaves ABB Ludvika and delivers the products to the customers. Often, the LSP sends a signal to the customer, with information that the products has been picked up at ABB Ludvika and now is on the way for delivery.

Consequently, the information flow is very complex, consisting of many different steps and is mostly handled manually in lack of an efficient IT-system.

5 BENCHMARKING - DHL TORSLANDA

The following empirical chapter regarding the DHL operated Torslanda terminal providing the automotive company Volvo Cars with logistic activities will discuss the current situation at the site. As mentioned in the methodology, this situation will then be used for best practice benchmarking activities input within the following analysis section. All information provided was gathered through site visit observations and an interview with the Operation Supervisor Jan Larsson[55]*.*

5.1 History and general information

The DHL terminal in Torslanda was established only a few years ago. The activities now provided by DHL were earlier undertaken in-house by Volvo Car's employees in the production facilities but the system was recently changed for two reasons. Firstly, as production volumes increased in the beginning of the 20th century, the automotive company started to grow out of its facilities and were in many senses forced to take action. A second factor motivating the changeover was logistic performance like resource efficiency. Electronic high level storage compartments that sometimes caused the line to stop as they broke controlled the earlier terminal actions. As line stops are very costly (roughly about 5 million SEK per hour), these inefficiency and risky issues needed to be solved. The changes finally agreed upon resulted in an outsourcing of primarily receiving and sorting activities to DHL and a new terminal owned by Prologis in Torslanda. The earlier setup used a receiving hub, Volvo Logistic Centre in Arendal (VLC Arendal), a couple of kilometres away for cross-docking and storage actions which now still handles certain items but also ships through the Torslanda terminal where items are sorted. The relationship with VLC Arendal is partly competitive and sometimes problematic, but the contact with Volvo Cars on the other hand is described as close. Several staff meetings are established to ensure performance and stability in the flow.

In order to fulfil resource utilisation the terminal also supply another actor, Nordic Lubricants within the British Petroleum (BP) organisation, with logistic services mainly storing finished goods bound for customers in outside and inside storage. Thus the facility is divided into two parts where the one supporting Volvo Cars will receive focus within this section. Table 10 provides some short facts about the new terminal in Torslanda, where information concerning the Volvo Cars logistics only are marked in grey.

Table 10. General information about the Torslanda terminal. Information specific for Volvo support is marked in grey.

Torslanda terminal	
Facility owner	Prologis
Logistic operator	DHL
Customers	Volvo (about 55%), Nordic Lubricants (45%)
Employee cover	11 + Staffing agency coverage
Warehousing functions	Short storage, sorting and consolidation
Supply	Around 20-30 trucks/day from VLC Arendal (about 50%) and other Volvo suppliers (50%)
Average throughput time	3 days/pallet
Pallets handled	Around 1500 / day

[55] Jan Larsson (Operation Supervisor, Supply Chain Management, DHL Göteborg) Interviewed 21 Aug. 2013.

5.2 Material flow and control

The Torslanda terminal, together with Volvo Logistic Centre in Arendal (VLC Arendal) handles most of the regular sized material flows entering Volvo. VLC Arendal also provides longer time storage when needed and then delivers to Volvo or further to the Torslanda terminal counting for about 50 per cent and 13 trucks of the shipments received at Torslanda dedicated for Volvo. The rest of the Volvo inbound material comes from thousands of other suppliers and third party logistic providers all over the world. Thus, there is no flow of finished goods from Volvo (see flow in Figure 33 on the following page). Pallets received at the terminal spend an average of three days in storage and no wrapping is removed. As the terminal staff doesn't break the packages the site is mostly free of guilt when it comes to damaged supply and this is a way for Volvo to increase quality in their supply chain. Outbound deliveries for Volvo departs every half hour on schedule, in two Volvo owned trucks, dropping of goods at two dedicated delivery points around the production facilities less than two km away from the Torslanda terminal.

As each car consumes a little over 2,5 pallets and roughly 800 cars are produced each day (usually 51 each hour), the pallet turnover is about 2000 each day. Most of these go through the Torslanda terminal. The fill rate of the outgoing trucks bound for Volvo is usually below 80 per cent allowing flexibility at busy times. These outbound trucks as well as the inbound ones coming from VLC Arendal are equipped with spacers, a wheeled mechanical floor structure, increasing the speed of freight loading and unloading. Unloading actions using spacers can be made within two minutes while dock unloading from the truck back or side may take more than a half an hour. The flow is controlled by Volvo who makes orders directly from their suppliers on electronic bases when the production needs refill as the storage in the factory is very limited. Computer based applications are used to view inventory measures both in the factory and at the Torslanda terminal through vendor managed inventory principles. Through this, the Torslanda terminal decision makers have no say about their own inventory. Volvo has a locked production schedule for eight days, but the order of the production may vary.

When the goods first enter the terminal, each pallet is scanned during unloading so that the system knows it has arrived. The pallets arriving on spacers can be scanned immediately while goods from other suppliers has to be unloaded and put into piles that then are scanned before the material is carried further. When the employees make the scanning, a computer tells them what compartment section to leave the goods in the terminal automatically. This way the terminal filling can be controlled and optimised while the crew knows where the units are stored for future loading outbound activities. When the freight reaches Volvo it is scanned again on receiving and many times also stored. When goods are ordered from Volvo, the system creates a picking list for each half hour shipments at the Torslanda terminal. When the orders are picked, the employees follow this list as well as scan each pallet in order to confirm that the right items are shipped. Over the last few years, all pallets leaving Torslanda have been correctly delivered. A separate flow of emergency deliveries is also possible when the production plant suddenly needs something really fast. DHL then have got only 15 minutes to fetch this item and deliver it using own trucks and at the moment they can meet these measures. There is also a reverse flow of damaged goods handled separately at the terminal where suppliers arrive to inspect or fetch material that is going back. This flow is not so rare in the automotive industry as the quality aspects are very important and the production lines have got little tolerances for even small errors. DHL sends monthly invoices to Volvo and the services are charged using both the amount of shipments prepared and the amount of pallets handled for the whole factory.

As the orders are made, the terminal receives lists of arriving trucks regularly. Through this, they know what trucks should be arriving in the near future but only the ones coming from

VLC Arendal are booked in certain slot times. The other half of the shipments may show up whenever in the near future making the planning a little bit harder for the crew. The inbound deliveries are viewed in schedules so that the days can be planned. The workload of unloading arriving as well as departing trucks is carried out by a usual number of eight employees dedicated for Volvo at the Torslanda factory. Flow peaks are handled both from the use of staff supporting the Nordic Lubricants flow, which is not as time critical, and also with help from staffing agency coverage. Four employees are managing the inbound flow and four are concentrating on the outbound activities in the usual flow of goods. The warehousing functions provided are only these short storing, sorting and consolidation. No production preparation activities are performed even though the goods many times are delivered straight onto the production lines when they reach the factory.

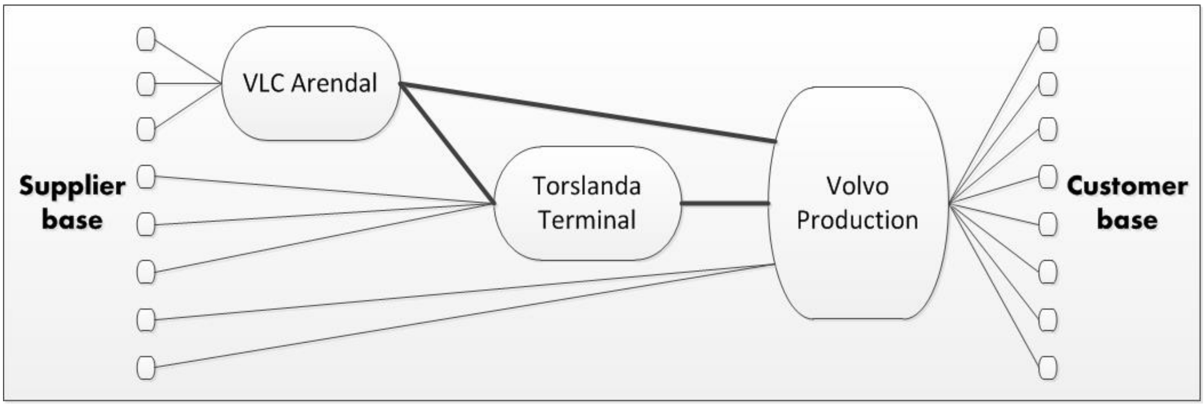


Figure 33. A simplified sketch showing the external material flow surrounding Volvo and the Torslanda terminal. More frequent flows involving trucks equipped with spacers has been marked with thicker black lines. The supplier and customer base are symbolised by a narrowed down number of actors.

5.3 Facility outline and further observations

The DHL managed Torslanda terminal involve resources as far as the staff for both the Nordic Lubricant branch as well as eleven employees dedicated for Volvo. The terminal also uses around ten smaller forklifts to control the flow as well as a few trucks available for emergency deliveries to Volvo. The site also involves high-level storage compartments for different pallet sizes as well as IT-systems and scanning devices supporting the flow. The facility is entered through four receiving docks where two are equipped with spacers for faster unloading purposes and one with a loading bridge so that certain trucks can be unloaded sideways. The outgoing side only involve two spacer-equipped docks.

The storing compartments dedicated for Volvo include eight racks, around 50 meters long and fourteen meters high, including storing compartments for six different pallet sizes. A distance allowing two forklifts working at rather great speeds at the same time separates the isles. The isles are filled using a computer system telling the employees where to store the goods and the no dedicated filling except for the different pallet sizes is made. The closest isles are used first leaving the further isles open for increasing goods volumes and so on as Volvo is controlling the inventory levels. The site has only been full twice causing trucks to wait and rearrangements to be made.

As of the beginning of 2014, Volvo logistics handling the flows at VLC Arendal will loose their contract with Volvo and a new actor will enter the supply chain. With this change, Volvo will also in source some of the logistic activities to their own plant. According to Larsson, in-sourcing activities are becoming more popular establishing a better control managing quality.

6 ANALYSIS

This chapter will discuss and analyse the current state of ABB Ludvika separated by each constraint in the LC model; Context, Production, External Material Flow and Internal Material Flow. An introduction section will present how this chapter is structured.

6.1 Analysis introduction

The LC Concept Model revealed that there are four main constraints affecting a LC development. By investigating ABB Ludvika according to the four constraints it was possible to identify several problem areas. According to the LC Concept Model, it was also stated that each constraint affects the development of a LC in different ways. The identified problems and how the constraints affect the development of the new LC are discussed and analysed. The theoretical framework together with the benchmark of Volvo Car's LC (the DHL Terminal) will function as a baseline for the analysis. Furthermore, each section will end by a short summary of the main conclusions from each constraint, involving the main logistical problems of the current state of ABB Ludvika and how each constraint affects the development of the LC.

6.2 Context constraint

An important constraint limiting the warehouse development is the context current situation and setup of ABB Ludvika. The context constraint is divided in two main views, Business and External environment. The Business view deals with the company characteristics, product assortment etc. The External environment on the other hand, takes consideration of rules and regulation, economic times, external geography etc.

6.2.1 The Business view

ABB Ludvika is not built around logistics, having a core competence aim rather on technology and innovation, causing activities of the TRP contradictive to mission tasks and vulnerable to fall out of focus, so also the new Logistics Centre.

The transport department at ABB Ludvika is currently managing a somehow decentralised system. Decentralised in the sense that the material flow is initiated by two inbound gateways (Y-Yard and Breakers-Yard) as well as three outbound gateways (Y-Yard, E-Yard and Breakers-Yard). Each of these gateways has separate staff, handling equipment as well as truck flows, but within the same organisation.

As stated by Abrahamsson (1993) and Lumsden (2012), the present rather decentralised state of the transport department tends to raise warehousing costs (Figure 16), which becomes vital in the case of ABB. Starting with the handling equipment that will be required at each gateway as suggested by Speh (2009). This factor tends to raise the cost of resources and tied up capital within the transport branch. Forklifts of many kinds will here be needed at each gateway in order to handle each load, and as the incoming truckloads arrive at unnoticed time intervals, a sharing of the equipment will be hard to maintain. The staffing will also be needed to be higher in order for the department to be prepared for shipments arriving at different time intervals at different places throughout the day. Other factors that tend to raise the warehousing costs compared to a more centralised system become the material handling activities performed by the staff. At the moment these goes as far as tagging and sorting which both could reduce the time and employee requirements if they were undertaken together at once. The same goes for other production preparation activities like kitting or sequencing that possibly could be introduced in several future scenarios and these will be covered in the production section further down in the analysis. Tagging equipment enabling future tracking and tracing will also be needed in greater numbers in the current decentralised situation.

Speh (2009) also communicates storage cost as a vital part of the warehousing costs. The resource facilities will be required to meet storage demands on several locations at today's layout at ABB. The large amount of suppliers as well as the customised make-to-order products inquires numerous types of goods geometries requiring certain storage parameters like for instance roof, temperature, shelf variants or multiple small compartments within high-level storage for small articles on inbound supplies. These all storage variants are today needed on many locations both among the company material gateways as well as within the production departments, within the decentralised layout, reduces possibilities of scale benefits as suggested by Chopra and Meindl (2012). Speh (2009) continues presenting Operation administration and general administrative expenses as further properties of the warehousing costs. Factors like supervision of the staff which is now done separately at each branch as well as information technology and its sharing which is both more expensive upon each system and limited as for sharing goes across the production departments today. As centralisation increases the similarity in resources, which will increase the interdependence among activities, Garcia & Lambert (2003) highlights the importance of these activities being coordinated by information. But, close coordination can be very expensive. If the costs are higher than the cost of "inefficiency", then it could be better to not coordinate.

A more centralised structure usually also decreases the cost of inventory (Abrahamsson 1993), view Figure 16. Centralisation, compared to decentralisation, lowers the inventory levels and increases the service level, but only if the same article is consumed in many places. Having a wide product line as different across the production department as ABB does today, this setup tend to reduce these benefits during a centralisation even though there are areas of smaller components and modules that are consumed at several places inbound. Looking at the outbound structure there are little to be saved as far as inventory tied up capital since each department produces different products.

On the other hand, Abrahamsson (1993) reveals an increase in transportation costs and lost sales through centralisation. As the departments now will be located a bit further from the storing position and gateways there will be an increase in transportation but as the consolidation potential raises with merged shipment these drawbacks could be reduced through economies of scale benefits (Christopher 2005). Cost of lost sales is estimated to be arid since the product availability will be the same in the eyes of the customer.

As the change would involve major investments developing new storage capabilities, handling equipment, loading/unloading areas and such, the decision will also be affected by transaction costs covered by van Weele (2010). Driving the change, these will increase and also involve risk as of future uncertainty to the progress outcome.

A final view of the general cost potential developing the Logistic Centre is illustrated in Figure 34. The theory model by Abrahamsson (1993) in the theory section is hereby modified to illustrate a simplified cost development throughout a centralisation process with inputs from other articles. The green arrow represents the cost development as centralisation activities are undertaken. Contradictive to theory by Speh (2009), Operation and Administrative costs has been removed from the warehousing costs and is here presented separately.

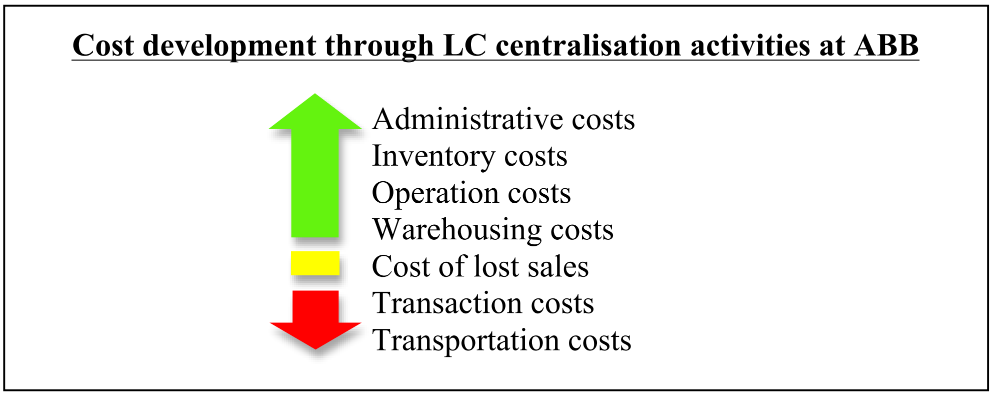


Figure 34. Simplified cost developments through centralisation actions at ABB Ludvika. Cost decreases are illustrated through the green arrow while the red show cost increases and the yellow represents no change. The list order is alphabetical.

Receiving gains within Warehousing, Operating and Administrative as well as inventory costs the total effect is predicted to be cost saving illustrated by the green total cost line.

Even though cost development plays a big role in these kinds of decisions there are other aspects that ABB needs to mind. Campbell et al. (2011) presents a framework where at least one of three the following three questions needs to be answered yes in order for the centralisation to be beneficial (Figure 17):

- Is it mandated?
- Does it add significant value?
- Are the risks low?

The change in Ludvika is not required by any outside stakeholders like customers, governments or suppliers even though it could make material flows more efficient bringing benefits to the whole supply chain. The only potential source forcing the change is found to be security concern for personnel working the areas among with heavy congestion from circulating trucks and forklifts possibly raised by laws or unions. Thereby the answer to the first question seems to be **NO**. Whether the development adds value or not is a trickier question. With background from the brief total cost analysis above, it seems to be cost reducing and this without interfering with the level of customer service. Stalk (1988) even highlight the potential of increased customer service level through decreased lead-times and increased delivery accuracy which could be slightly addressed at ABB. Less congestion through more efficient loading/unloading could really reduce lead-times at all ends. The decision will though not add the requested 10% of value to market capitalisation even though profits show potential to increase. The actions are value adding at many levels but the small gains are not viewed to be as significant as requested by Campbell et al. (2011). Given this, the second answer is also weighted as a **NO** in the larger picture. Finally the framework asks the question whether the risks connected to the centralisation are low. Common risks are believed to be increased bureaucracy, business rigidity, reduced motivation or distraction. Even though there may be some reduced motivation in the traces of authority centralisation and less self controlled branches at ABB Ludvika, these risk should be low due to the minimal change in the eyes of other supply chain actors and little local changes as suggested by Abrahamsson (1993). It may even go the other way and become more efficient due to the new setup. Given this, the last answer will be **YES**. Having one positive answer, this framework approves centralisation activities.

As mentioned, logistic activities are currently undertaken by both the TRP as well as the separate production departments. Centralisation in this matter could mean to bring activities into one actor, putting more logistic focus on the new LC. Another aspect are the current in- and outbound flows of materials where deliveries are made at two locations and loading, where pallets are stored all over the company property, is conducted at three. This could also be centralised, having only one gateway instead of these five in the Logistic Centre. At the moment, the gateway all has different crews with little communication.

Another area clearly affecting the context constraint and the new LC is found to be the company atmosphere and culture in Ludvika and the decentralised setup among the production sites. All orders are today made separately from each production department and even the information technology is handled different ways within different systems (SAP and ERP-LN). This fact reduces the possibilities of economies of scale while ordering and thus reduced prices. The shipping will also be harder to coordinate. In the field work conducted at the Torslanda terminal, a logistic actor supporting the automotive industry of Volvo, the production orders were made by one unit creating one production schedule in one system so that the logistic provider could plan and prepare roughly before their operations. As suggested by Stadtler (2008), key issues in improving SCM are the coordination and integration in the supply chains, and the contradictions are clear at this point. A lack of integration and coordination within the production departments also creates local optimisation among the sites, which can work to reduce the whole supply chain gain. The issues raised are mainly connected to inbound activities since many outbound flows involve customers within the same companies and shipments are sent together at fulfilment.

The setup with a separate transporting department sending invoices to each production department can also possible work as reducing this integration in some ways. The activities performed by TRP may be seen as “outside the company” in the sense that their warehousing activities performed are not evaluated or made accordingly to the production. The efficiency or ways of these may also not be questioned since they are made “within the company”. An example of this can be the TRP invoice system being based on number of deliveries only and not the amounts of goods, during two registration months each year. This may make shipping unevenly expensive for the production departments around the site, as a long large delivery with a big truck with many pallets is as expensive as a short delivery of one packet with one smaller forklift only. In the Torslanda terminal, supporting the Volvo production, invoices are produced monthly taking the amount of goods handled into consideration by the logistic actor DHL. The deliveries, here made consolidated on time schedules, are made by Volvo and seen as fixed costs separately.

The internal invoice system at ABB may also serve to increase bureaucracy, complexity and time effort among the work force at ABB Ludvika. One may also question this setup through the findings and statements of van Weele (2010) where core competence focus should be prior today as mentioned earlier. This is also agreed by Chopra and Meindl (2012) who recommends outsourcing in cases like these. As ABB is a deeply technological company, with sustainable advantages within technology and solutions, the creating, efficiency and development of an internal transport department may be questioned. A reason for doubting the TRP performance may also be traced to the fact that the company is doing well at the time being and producing strong numbers in sales on the core competence technology market which may make decision makers somewhat less observant of transportation optimisation issues. A quick peek at Volvo and a tight automotive market with a big share of logistic costs view a system where the logistic have been outsourced partly to DHL and Volvo Logistics group.

Another important factor shaping the business constraint is the current geographical company property limitation. The company is growing out of its area forcing TRP to place boxes on all empty spaces left possible to find. This causes misunderstanding and efficiency setbacks while arranging outbound shipping that many times aren't picked up buy the customer when ready. The company must look over responsibility sharing standards and make sure not to get completed shipments standing for long taking up space on company property. They must through this also allocate enough space in order to handle all these goods efficiently. Another concern in these handling procedures is the products that are flowing through the areas. The geometry and big sizes of the shipments require handling equipment and suitable vehicles as well. All these ingredients also serve to cause congestion that limit both efficiency and even employee safety. Today the entrance is easily overloaded with trucks waiting arriving the same hours.

6.2.2 The External environment view

The second view of the context constraint is the External environment, which includes rules and regulation, economic times, external geography etc. Axelsson and Agndal (2010) highlight the importance for management actors to understand the business environment when dealing with planning activities and new idea proposition developments through company expansion. As mentioned by Baines et al. (2008) a planning analysis like this one could benefit from covering the internal business environment and performance environment, covered in the previous section analysing the business constraint, as well as an external environment that are to be evaluated here.

The demands of the customers will always be a central factor pushing manufacturing companies towards efficiency and rationalising (Baines, 2008). A project group preparing future expansions like the one in Ludvika, needs to take the customer into consideration and try to foresee how the market will develop. This calls for engaging the marketing department and question whether and how the product development and assortment will change in the future. The key is to understand intentions by both suppliers and customers in order to develop the LC in response to this.

The warehouse development will be affected by surrounding environmental constraints that are not as clear and easy to predict or master. As stated in the theoretical section, this external environment can be interpreted through the understanding of the six dimensions in the PESTLE-model covered by Baines et al. (2008).

The political and legal environments that should be considered while developing the Logistic Centre show on some possible effects. Even though the current national political climate is rather stable there may be changes occurring in rather near future. One concern could be possible transport legislation changes in the future. If the maximum truck lengths allowed are extended for instance, the new LC must be dimensioned for this both considering turning area, parking and loading. Standardised procedures may also be affected if some trucks had to be loaded/unloaded from the back instead of the current sideway handling at ABB. Other concerns can possibly be raised by international freight tariffs. If dimensions are to be changed by haulers or toll price indexes modified by governments, packaging and preparation procedures at the Logistic Centre may have to be shaped somehow to include this flexibility. As products manufactured by ABB involve quite large and irregular geometries, this area becomes even more interesting. ABB also receives supplies including transformer oil samples and other fluids that are regarded as dangerous for the environment requiring special handling and packaging and perhaps changed legislation within these areas in the future. Another issue may be labour law that must be considered when construction workspaces for employees with appropriate rest rooms, safe entering and yard exits etc. The current situation involves a lot of congestion and traffic concern that also raises questions driving change initiatives. As found in empirical observations, there are several dangerous crossings interfering with personnel transportation today. Together with production emissions, this fact also involves issues within air quality on the company property. Other legal concerns may be the use of Incoterms and how these standardised trade regulations will develop in the next few years (ICCWBO, 2013). The usage of customer responsibility centred rule sets like Ex-Works causes problems today and this clearly show the importance of monitoring and complying with future terms so that company efficiency and revenue can be maximised (more about incoterms in the external and internal material flow sections). ABB currently has got loads of outgoing products stored on the site that are to be fetched by customers.

The economic external environment may also change in the future involving different interest rates, which can server to affect investment calculations. As stated in the empirical section, product demands are high at the moment and the company is looking to expand its production. Future downturns may include changing demands, which also will require flexibility in order for the new centre to stand ready and ensure efficiency. Freight handling and other warehouse functions as well as staffing could be areas to look into adjusting for changes. Gas prices may also continue to rise increasing the motivation for finding other means of transport. If railway freight transportation would grow in the future it may not be a good idea to block these tracks with for instance warehousing supporting buildings.

The socio-cultural as well as technological environment will also have to be considered. Emphasises on safety and worker environment raced by the public should be met in order to create a well respected place to work in the area as well as to reach expectations from the surrounding society. It may also be important to ensure the society with a smooth future infrastructure traffic solution around the centre, since roads has to be changed and rerouted through the new development. Designing the LC will also require research within handling and warehousing technology. Improved solutions in the future must be able to fit into the chosen setup of the Logistic Centre.

The ecological dimension to the external environment may also server to raise an increasing public awareness of world problems like emissions and climate change. This may force more environmentally friendly solutions on businesses in the future motivating train usage or ideas for less energy consuming material handling within the LC.

The dedicated area for the LC project is limited to its 56 000 square meters and as stated, there are many ingredients to include within this property (Table 3) that cannot be extended due to surrounding living areas and other company properties. These are also limitations set by the surrounding environment. The company does have other sites for logistic usage a couple of kilometres away that can be used. The current project plan has suggested using these for long-term storage and warehousing functions that are not as frequently made. As stated by Lumsden (2012), a satellite storage point like this would benefit from standardised usage of specific dedicated products. This will reduce the need for expensive flexibility within handling equipment or storage spots. Finding proper ways to handle these point standardised will require attention within contracting procedures by the different marketing departments. One will have to identify what products that are delivered through Ex-works standards and storage time statistics.

The surrounding infrastructure will also limit the structure of the new LC. Initially the centre will be limited to only truck transport due to the location and the fact that railroad would be too expensive to integrate. The new setup is also motivated by the passenger traffic used railroad tracks mentioned in the empirical section. This crossing does not have to be passed by deliveries or pickups anymore, saving a lot on efficiency and lead-time in the material flow.

The lack of space to expand the company gate also motivates a change. The current situation where turning trucks has to be let into the company property in order to turn around has to be met by the new solution through a proper dimension of parking and truck passages. As stated in announcements and reports by Trafikverket (2012) and Wilcox (2013), the legislation of truck lengths is increasing and these may grow in near future. This would change the requirements for handling equipment as well as the outline of the new LC, with roads, parking and loading/unloading spots. According to Trafikverket (2002) trucks may need as long as 14,5 m turning radius space which would also interfere with the development of the LC. Looking at the present expansion plans, the prepared area parking "Olympia" (Figure 4, area B) with its width of 40 meters would only make room for about four lanes and if trucks should be able to turn around and return on the outside street, even less (otherwise they would have to be let in to the company area). Counting for the maximum truck length allowed, this would mean about eight trucks (area length 80 m), which would not be enough during the current rush hours. Considering the suggested length increase (Wilcox, 2013), it might be something to think about.

6.2.3 Summary

The analysis of the context constraint identified several problems, seen in the list beneath:

- A decentralised company structure with separate production, purchase, material handling and distribution departments together with various business systems.
- Little or no cooperation and communication between the divisions decrease the use of scale benefits.
- Integration issues, while seeing TRP as "outside the company" regarding cooperation and "inside the company" when it comes to economics.
- A big part of the total selling volume is internal, which seems to be complex, bureaucratic and time consuming. Local optimisation.
- Transportation as a non core competence activity
- Space and congestion issues externally and internally.

In order to improve the material flows and develop the new LC as good as possible, it will be crucial to try to reduce the problems. While optimising the non-core competence it will be crucial to use the benefits of integration running the TRP close aligned with the rest of the company. A lot of improvements could be raised through information sharing and the creating of a team-atmosphere. Each activity that can be able to centralise should be considered as of the potential of adding value to future business. Centralisation can lead to several improvements within economies of scale through Administrative, Inventory, Operation and Warehousing costs. The LC will also most certainly deal with the raised issues concerning space and congestion. Further, expansion like these will need research and market understanding as to read of customers and suppliers future demands. Other important issues will be external surrounding ones that are not always as easy to influence. Political, Economic, Socio-cultural, Technological, Legal and Environmental environments should all be screened. Thus development of the LC will cross the context constraint in numerous ways.

6.3 Production constraint

Regarding the interdependency between the activities in the supply chain, highlighted by Gadde (2004), the coordination becomes highly important. Receiving and recording supply at several production gateways around the factory will inquire larger communication needs as far as to increase integration and information sharing across the chain. Separate ERP system input may decrease the rate of both lead-time, chain integration next to staff efficiency. Productivity could here be raised by through both centralisation activities and information technology investments (Ross, 2002). As stated by Neumann & Medbo (2009) there is a big risk of loosing efficiency while developing material flow systems and production separately with little consideration to each other. This is really also present and applicable on ABB Ludvika, where staff on separate departments has little understanding and insight into what others are doing, even though they work “on the same team” and in the same chain. The transport department delivers shipments as soon as they arrive to production divisions through uneven flows from upstream suppliers acting as if tier one suppliers and customers are non-changeable. Deliveries are made according to own measures and performance is reached through a high degree of local optimisation at all ends.

The separate storage and tagging systems can also work to decrease efficiency. As mentioned by Liker (2004), storage is one of the seven wastes of lean production where one should try to reduce inventory as much as possible. Separate storage also mean separate safety stocks, which will tend to increase overall inventory at ABB as there are many articles that can be used in several production units. Not to mention storage capacity where the company at this point cannot take advantage of each other and economies of scale in operation. Tagging systems that has been presented and lay in pipeline would certainly make the flow more efficient and reduce the degree of mistakes.

As stated by Liker (2005), just in time principles may work to reduce inventory while ordering and planning the material flow. The production divisions has got separate materials Requirements Planning system and orders on divisional purchasing departments which may many times work to reduce volume advantages through economies of scale.

One of the issues mentioned from start within the future expansion plans lies within the facility space. As production through last year has been running on a high degree of the active capacity, there are questions for the future about the room. Production managers at transformers has stated a planned takt-time increase with as much as 40 per cent, and unused shifts may be ran but if the volumes increase as expected the factory is most certainly looking at space issues. Regarding expansions within the current company area, little seem to be decided concerning the old logistic spaces that the transportation department currently is operating. The transport manager comments on them being used for less material intensive activities of the transportation department, but what really would be efficient and where they would be best of use is found to be left unsaid as far as this analyse has been undertaken.

Regarding production preparation activities, there are plenty of material management going on both at each of the production division material arrival but also at suppliers end. The transport department carries none of these actions out. The company uses sorting, sequencing and kitting at several divisions. According to Baudin (2004), sequencing could work to increase efficiency while decreasing expensive storage and buffer requirements within production. At the moment, the transportation department is delivering each inbound shipment as soon as possible to the production divisions. Whether this is the most efficient way for the company is a whole, is left to be unsaid. As stated by Bozer and McGinnis (1992), kitting can work to increase productivity, quality and flexibility during production. Having it spread out on different suppliers could danger the outcome of the preparation method. Thus, it could possibly be an opportunity looking into whether kitting could be centralised and the transporting department could certainly be a reasonable target for such a development. As a new Logistic Centre is being built, these actions should really receive attention in the nearest future. Is it possible to centralise these activities? Could the transporting department do it? What is needed, and what are the demands as far as production preparation from each unit? These are questions that need to be examined in the near future. This would also be decent input into the process of developing a new tagging system that currently is undertaken at the company. As stated by Johansson (1991), kitting and sequencing taken care of internally could work to increase control, efficiency and lead-time while improving the economic situation.

6.3.1 Summary

The main problem areas within the production constraint can be seen in the list beneath:

- Several material inbound gateways as well as separate material recording cause work and costly increased capacity requirements. Another setback here is company cooperation.
- The transportation department being seen as a non-changeable outside actor in the eyes of the production units causes local optimisation thinking with a low degree of resource utilisation.
- Separate storing and tagging systems are working to reduce efficiency and scale benefits.
- If the produced volume increases, there is little space capacity in order to manage the increase. Little consideration to future use of TRP areas.
- Large inventory before and after production.
- Production preparation activities being made separately and also externally reduces scale benefits, control and efficiency as far as lead-time.

When working with the development of new LC it will be important to mitigate these problems. Current production material efficiency issues that demand centralisation, integration and cooperation across the company will demand several functions on the new LC. Material recording, tagging, inventory and production preparation activities like sequencing or kitting will need to be examined and prepared for at the new LC. Even if operations wont be changed immediately, the future may hold transformations within these areas.

6.4 External material flow constraint

An important factor limiting the development of a LC is the external material flow. As stated before, it is the flow to and from the company boarders. Companies have become more and more specialized over the years due to the increasing needs and demands from the customers, which have resulted in a network of actors (Ford et al., 2003). This means that ABB Ludvika is actually part of such a network, even if they seem to think that they are alone having a focal role in the supply chain. As much as 4000 suppliers provides the production facilities at ABB Ludvika with material, which means that the company relies on this large amount of suppliers in order to give the consumers what they want. On the other hand, the customer base consists of thousands of customers all over the world. Hence, in order for ABB Ludvika to improve the material flows to and from the company boarders as efficiently as possible, there is a need for external actors to handle and coordinate the material flow in the network. Furthermore, if it would be possible for ABB Ludvika to decrease the number of suppliers delivering material to the production divisions it would affect the external material flow in a number of ways. Van Weele (2010) means that a reduction of suppliers can result in a better relationship atmosphere with the remaining ones. This can result in trust between the parties with better cooperation. Hence, the LSPs together with the suppliers have very important roles to play in the external material flow.

6.4.1 The roles of the external actors

Bitran et al. (2007) state that to perform and coordinate the activities needed in the network, there is a need for additional and neutral actors. ABB Ludvika is using many LSPs to efficiently handle the external material flow to and from the company boarders. Lumsden (2012) means that the most common situation is that three parties are involved in the logistics performance and that is actually the situation at ABB Ludvika, where 3PL providers handle the external material flow from the suppliers to ABB Ludvika and finally to the end costumers. These 3PL providers are actually handling the material flow throughout the whole supply chain where, according to Stadtler (2008), integration and coordination is two main important areas. Consequently, the LSPs are very important actors for ABB Ludvika in order to coordinate the activities needed and integrate the organisations involved in the supply chain.

The activities performed in the network affects the total material flow and have a great impact of the logistics performance. Ford et al. (2003) states that activities in the supply chain are related and thereby interdependent to each other. It is crucial for ABB Ludvika to realize this. Hence, the activities that are made by the suppliers or by the 3PL providers affect the later activities made in the production. The activities that are required are often referred to overcome the four discrepancies; quantity, assortment, time and space (Rosenblom, 1995). The discrepancies in quantity and assortment may not be relevant for the external flow in the case of ABB Ludvika, due to that they only produce according to MTO or ETO. On the other hand, the discrepancies in time and space are highly relevant. The discrepancy in time refers to that products are often not produced exactly when the costumer wants the product, which means that material needs to be stored. At ABB Ludvika, finished products are stored for weeks, or even months, before it is shipped to the customer. This area will be discussed in the internal material flow chapter. The discrepancy in space is another activity that needs to be bridged for the external material flow. Rosenblom (1995) state that the discrepancy in space means that the products are not produced on the same location as where they are used. Hence, there is a need for activities to move the product from the place of production to the place of consumption. ABB Ludvika has thousands of customers all over the world, where external actors should coordinate these activities and add value to the end customer by transporting the products to where they are needed. The LC could be the place where the actors leave and pick up the goods in order to overcome the discrepancy in space.

A stated argument for building the new LC is that the demand will increase the future. This will affect both ABB Ludvika and the entire supply chains, including the 3PL providers. There will be more material flowing around in the material system, why the 3PL gets an even bigger responsibility in order to serve ABB Ludvika and the end customers with material and finished products. But, if the demand increases and the cooperation between ABB Ludvika and the 3PL providers increases, then it would be possible for better consolidation. This means a more effective external material flow to and from ABB Ludvika.

6.4.2 What should be performed by the LSPs?

Today, the external LSPs perform several value-adding activities for ABB Ludvika, such as storage and airfreight security preparation. But, the transportation stands for the absolutely biggest share, which means that the LSP are mainly performing “Basic logistics” functions for ABB Ludvika, as stated by Berglund (1997). One reason that the LSPs do not perform more value adding activities can be that ABB Ludvika handles the LSPs on an arm’s length approach and only compares them by prices. Gadde (2004) means that the relationship characteristics have developed from an arm’s length approach and confrontation, where only money and power mattered, to a collaborative relationship where the parties develop together with trust and write long-term contracts. A fact is that ABB Ludvika does not comply with this development where they still just want to have the cheapest LSP for each shipping. Gadde (2004) also states that by having a closer cooperation, where the parties develop together with trust and write long-term contracts, many benefits can be gained compared to have an arm's length relationship with the LSP, even if the price can be higher. If ABB Ludvika could develop a closer relationship and start to cooperate with one, or a few LSPs, it would be very beneficial. Of course the price for this is higher, but given the very expensive products that are sold within the company, this price would be a very small share of the total price. Looking at the logistic situation at Volvo and the Torslanda terminal covered in the empirical section for benchmarking purposes, one can see an extended relationship following these principles. A LSP, in this case DHL, is conducting consolidation, warehousing and partly also sequencing feeding the automotive production lines at Volvo Car. Aligning with the earlier mentioned development towards networks and core competence focus, DHL carries out further services than just "Basic logistics" supporting the situation for Volvo Cars.

DHL Borlänge states that ABB Ludvika is their biggest customer, but they cannot plan the shipments far ahead because they never know what is supposed to be shipped until a day before. DHL Borlänge would like to develop a more collaborative relationship in this way, but ABB Ludvika wants to keep them on an arm's length approach. DHL Borlänge believes that if they get more responsibility they can plan the material flow much better and achieve a higher degree of economy of scale. This would establish something closer to a win-win situation for DHL and ABB Ludvika. One reason for limited collaboration could be that ABB Ludvika does not know the large potential that exists. Another could be that they keep the LSP on an arm's length approach with purpose. Either way, ABB Ludvika could gain from working more closely with their LSPs like in the situation at Volvo.

A closer relationship with the LSP could result in that more and more "Value-added logistics" activities could be performed by the LSP. Berglund (1997) means that "Value-added logistics" could be activities like order processing, kitting, network design and inventory management. Today, the different production divisions are doing their own "Value-adding activities" such as production preparation, even though they are very similar to each other. If ABB Ludvika could develop their relationship with the LSP then they could perform the value-adding logistics. But building long-term relationships and trust takes time, why this is not an option today. The suggestion would rather be to start developing a closer relationship with the LSPs and put more responsibility on these actors continuously as the relationships atmosphere improves.

Ford et al. (2003) means that distribution costs are large today and it is not unusual that the distribution costs can stand for as much as one-third of the total cost of the product. If ABB Ludvika would realize the importance of distribution, it would be possible to save a lot of money. Hence, by achieving an efficient distribution at ABB Ludvika it would be possible to reduce costs.

6.4.3 The role of the LC for the external material flow

Ford et al. (2003) means that in order for the actors to perform the activities needed, there is a requirement of different kinds of resources. For the external material flow, the new LC together with external warehouses and terminals can be seen as the resources needed to perform the external material flow. The LC will be an important asset in order to perform the activities needed. Gadde et al. (2010) means that the value of a resource is not predetermined, it depends on how it is used and combined with other resources. Hence, the LC needs to be combined with other external resources in order to get out as much value as possible of the centre. Here, it is very important to have a good relationship atmosphere with the external actors in order to get access to their resources. In this way, the value of the LC will be increased. The situation at Volvo can be viewed as an example of this. The resources of the logistic provider and facilities at VLC Arendal and the Torslanda terminal are combined in a way of specialisation and separated focus trough the material received and warehousing functions. The sites are further combined through investments in spacers within their unloading/loading docks so that transports between the facilities can be loaded and unloaded much more efficiently. According to Jan Larsson[56], a spacer-equipped transport can be unloaded as much as 50 times faster than one without spacers. By having a good relationship with the LSPs, it will be possible to get access to their resources. In this way, the LC could be combined in an enormous way and thus the value of the resource will increase. Furthermore Ford et al. (2003) states that when different activities make use of the same resources, they are similar. If the similarity increases, then the resource utilisation also increases, which results in economies of scale. Thus, different activities should make use of the LC in order to increase the similarity and achieve economy of scale. If the material flow should be improved, the LC must be a place where the external material flow integrates with the internal material flow.

According to the company hosted survey it was stated that the external truck with incoming material to the production enters the company boarders three times more then the ones that leaves with finished products. Consequently, ABB Ludvika needs a large group of staff to handle the incoming trucks and at the same time the trucks results in congestion on the already limited space, which in turn results in the safety issue. The problem may lie in ABB Ludvika’s bad relationship with the LSPs. DHL Borlänge states that it is very hard to plan the routes when they just know a day before what material that should be delivered or picked up. As a result, the trucks with incoming material have in general a very low fill rate. DHL Borlänge also means that if they could know what material that are supposed to be shipped to and from ABB Ludvika further in advance, they could plan the routes much better and achieve a higher fill rate. On the other hand, ABB Ludvika means that they have always informed the LSP a day before shipment, which has not been seen as a problem. Lumsden (2012) actually means that in order to get an efficient function between the two parties, the commitment should imply closer and more long-term cooperation. Hence, ABB Ludvika should start building a closer relationship with their LSPs.

Another explanation to the many trucks entering ABB Ludvika with incoming material is that many LSPs are using milk rounds to deliver their goods to several customers. This is a very common way of delivering material according to Lumsden (2012). This means that ABB Ludvika is only one of many places where the truck should deliver material. But, it could be that one LSP is delivering several trucks during one day. According to DHL Borlänge, it is a result of a bad planning due to the bad communication between the two parties.

A distribution channel can be formed in many different ways, with many different actors, activities and resources involved. One way is to have a direct link between the two parties, e.g. manufacturer and consumer, without any intermediaries or buffers (Rosenblom, 1995). Another way is to have several intermediaries and buffers between the two parties. ABB Ludvika does not have any intermediaries, such as wholesalers or retailers between them and the suppliers and customers. But, on the other hand, they have a three weeks long storage of components between the suppliers and the manufacturing and a several weeks long storage of finished products between the manufacturing and the customers. This cannot be considered to be a direct link. A future LC can help ABB Ludvika to get one step closer to a direct link, even though the LC in it self can be considered as an intermediary.

[56] Jan Larsson (Operation Supervisor, Supply Chain Management, DHL Göteborg) Interviewed 21 Aug. 2013.

6.4.4 Summary

The previous analysis revealed that the external material flow is a very important area for ABB Ludvika. Several problems were identified, which can be seen in the list beneath:

- Many actors involved in the external material flow.
- Little cooperation with the LSPs.
- Bad relationships with the LSPs.
- Low fill rate in the trucks.
- Several LSPs can be chosen for each assignment and normally the cheapest one gets the job.
- High variations of the in- and outbound material flow.

The LC needs to mitigate these problems, which will be an important input in the expansion. An essential conclusion is that the LC together with other external warehouses and terminals can be seen as the resources needed to perform the total material flow, in order to deliver what the customers requires. This means that the LC will be combined with other resources to get out as much value as possible of the centre. If this will work properly, it will be very important to have a good relationship atmosphere with the other actors in order to get access to their resources. In this way, the LC could be combined in an enormous way and thus the value of the resource will increase. Consequently, the LC needs to be developed in a way that encourages connections with other resources in the material network system. The trucks going between the resources needs to have an easy access to and from the LC area, with easy manoeuvrable infrastructure, no congestion from other trucks and with as little waiting time as possible. This will be crucial for the LC, in order to improve the material flows. Hence, the LC will be the interface between the internal and external material flows, which needs to be handled as efficiently as possible.

6.5 Internal material flow constraint

Many lean authors (Liker, 2004; Womack & Jones, 2003; Rother & Shook, 1999) means that it is not uncommon that many companies are struggling with long lead-times, long storage times and many processes in both the material and the informational flow. The material flow investigation discovered that this is just the case of ABB Ludvika. By applying the MFM method it can help ABB Ludvika to illustrate the material and informational flow in the internal material system (Medbo, 2013) and understand that the activities are many times interdependent with each other (Gadde, 2004).

The MFM revealed that ABB Ludvika has large problems with the internal logistics, both the material and the informational flow. The internal logistics consists of as much as 39 different processes with a throughput time of 43,7 days. On top of this, the material is stored for 99 per cent of the total throughput time at eight different storage places. Hence, ABB Ludvika needs to improve their internal logistics and material flow by reducing the number of processes together with the throughput time. If a future state should be achieved according to Rother and Shook's (2003) citation of a future situation ABB Ludvika has a lot to work with. Hence, the objective for ABB Ludvika should be to accomplish a direct and smooth material flow with the shortest throughput time and the lowest cost.

According to Medbo (2013), the analysis of the current situation can be done by answering the seven guideline questions, which will help to achieve an improved future situation.

6.5.1 What is the real customer demand?

Due to that this thesis is only considering the actual logistical processes and not the production, it is very hard to determine the real customer demand. On top of this, a product or a product family could not either be chosen due to that this thesis is considering all five divisions at ABB Ludvika, which are producing a large variety of product types. But, it is known that the demand will increase in the future, which is one of the stated arguments for the LC. When the demand increases there will be more material within the company boarders and thus more material to handle for TRP and the production divisions. As a result, the throughput time will probably increase even more. This means that it will be very important to try to reduce the number of logistical processes and the throughput time in the future. Consequently, a future state map needs to be created containing a minimum number of processes and as short throughput time as possible. The material handling will then be much more effective and less costly.

Even if the real demand or takt-time cannot be answered, there are some requirements coming from production, which can be seen as the customer for the LC. Also, Baudin (2004) means that logistics performance is largely determined by what happens in production. Some of the production requirements on the logistics activities could be that the material should be in production when needed, prepared and ready.

The MFM discovered that after the unloading and sorting activity, the material is delivered to each division within an hour. Thereafter, each division takes care of its own material where it is stored for about three weeks. The straight away receiving deliveries made by TRP to each production unit lack of consolidation and may many times include rather poor fill-rate. These transports are hard to plan since the delivering trucks arrive at uneven timeframes and without slot-times. This creates a very problematic flow. Comparing this to the Torslanda terminal, one can view some differences. Volvo has here got time-slots for half of the transportations and a sense of when the rest arrives. This allows DHL to receive more evenly and deliver the goods consolidated in Volvo-owned trucks running on time-schedules. This also helps the invoice system making it more fair and even since most deliveries are in even sizes compared to the more sporadic system at ABB. The TRP internal delivery system further makes the material flow more problematic and hard to plan at the receiving end by the production departments. Before the material goes into production, some “Value-adding activities”, or production preparation, are performed. Berglund (1997) means that “Value-added logistics” could be activities like order processing, kitting, network design and inventory management and are very similar at each division at ABB Ludvika. Hence, the production has some requirements on the material before it can enter the production. All production divisions are performing some sort of production preparation activities before the material is going to production, e.g. the division Components sort and kit the material, while HV Breakers just sort the material in a special sequence for production. Today, these value-adding activities are done in each division just before production. The main question here seems to be: who should perform the production preparation activities in an optimal future situation; each division, the LC, the LSPs or the suppliers?

A first option could be that each production division performs their own preparation activities, just as today. One big benefit of this option would be that the divisions already has a great experience in doing this due to that they have done it for a very long time. They also have personnel dedicated for these activities. On the other hand, the production preparation activities are very similar in the five different divisions. In this decentralised structure, ABB Ludvika loose a lot of the benefits of centralisation, such as lower lead-time and lower warehousing costs (Abrahamsson, 1993).

The second option would be that the production preparation activities could be performed in the LC. Today, TRP is only performing activities such as sorting, storing and transporting, i.e. “Basic logistics” activities (Berglund, 1997). This is done despite the fact that TRP would like to perform more “Value-adding” activities, like sorting, kitting and/or sequencing. TRP means that the production divisions just see them as a department that should deliver and collect the material and nothing more. Hence, TRP does not get the responsibility to perform more value adding activities. Gadde (2004) means that if the relationship atmosphere develops from confrontation, where only money and power mattered, to a closer cooperation, where the parties develop together with trust, both parties can gain a lot of benefits. This is definitely something that the production divisions together with TRP should start working with. If this is done, the two parties could start to cooperate and TRP could get more responsibility to perform more “Value-adding” activities in the LC. If the production preparation activities should be performed in a future LC the main benefit would be that the activities should be centralised. Similar activities could be done at one single place, with lower costs and fewer personnel. The workers with the job to execute these activities could move from each division to the LC. The main drawback of this option is that the transportation costs would increase (Abrahamsson, 1993). If these activities should be performed in the LC, then this could be done after the scanning of the material. A transportation of the material to the production preparation area has to be done at first. When the material has arrived, the “Value-adding” activities can begin.

A third option would be that the production preparation activities could be performed by the LSPs. A closer relationship with the LSP could result in that more and more “Value-added logistics” activities could be performed by the provider. As stated by LaLonde and Cooper (1989), if more responsibility could be placed on the LSP and they could handle, coordinate and consolidate more of the ABB Ludvika material, then they would be able to achieve economy of scale. This could be done because LSPs provide logistics services to a number of clients simultaneously. As discussed in the previous chapter (External material flow analysis), this would not be an option today due to the bad relationship, but would absolutely be an option in the future.

A fourth path could be to use the suppliers to further extinct than today. Looking at Volvo and the situation surrounding the Torslanda terminal, many of the articles received are already prepared for the production. If ABB were to take this route they would have to develop their relationships and coordinate the production sites so that the supplier number could be reduced, otherwise scale benefits would be hard to reach. Winnings from working like this could be reduced personnel at each production site, cost cutting, as well as a further development towards core competence focus like suggested by Chopra and Meindl (2012).

Consequently, looking at the current situation ABB Ludvika could benefit from performing a larger extent of their “Value-adding” activities, also the production preparation, in the LC. This option seems to involve a lot of benefits comparing with the two other options. Even if outsourcing the activities to a LSP could definitely be an option in the future. But then a better relationships needs to be settled.

6.5.2 To what degree can we achieve a continuous material flow?

ABB Ludvika needs to start working towards a continuous material flow with as few process steps, buffers and handling operations as possible. The main reason that ABB Ludvika is not doing this right now is that no actor has control of the entire material flow. Instead the internal material flow is controlled in a decentralised manner through many different actors and departments. As a result, ABB Ludvika are struggling with large buffers and many logistics activities.

Today, few activities are done by TRP. Instead, the material is sent directly to each division, which then take care of the material. As a matter of fact, all the divisions are handle the material in a similar manner and the logistical processes before and after production are very alike. If instead these processes could be done by one actor for all the different divisions, economy of scale could be achieved. This means that ABB Ludvika should try to do as much of the logistical processes in the LC, by the TRP department. If only talking the processes in consideration, this can be seen as switching from a decentralised structure to a centralised structure. If a centralised structure could be achieved, ABB Ludvika would gain a lot of benefits as less tied up capital, lower operating costs and a decrease in expenses for physical distribution administration (Cooper, 1991). Furthermore, Abrahamsson (1993) means that centralisation also can benefit the lead-time, availability, delivery performance and warehousing. All these benefits may be seen as a great improvement from a decentralised structure. But, the main benefit may be the increase of control. If ABB Ludvika could centralise their logistics activities to one resource instead of several, the control of the material flow would be increased. The two separated functions, arriving and departing, could be done in the same resource; the LC. Here, most of the material activities should be performed, see Figure 35 beneath.

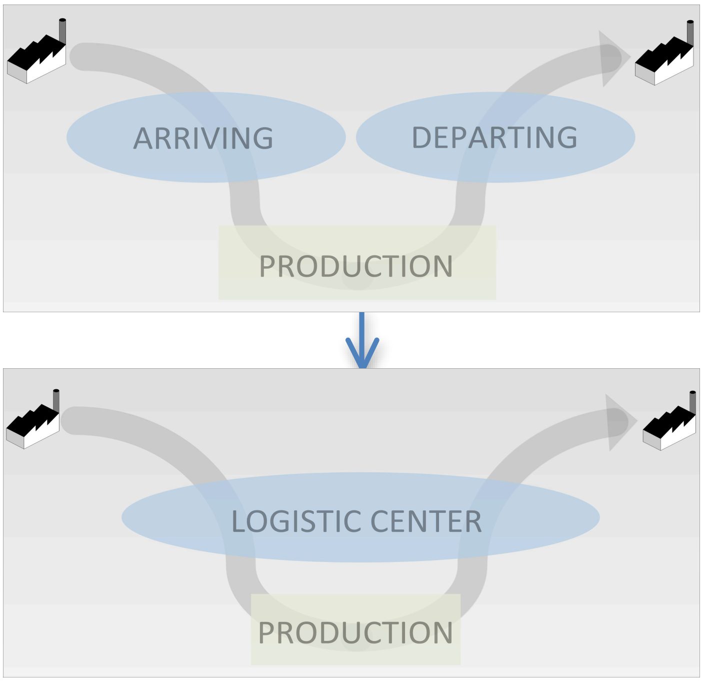


Figure 35. All logistics activities should as much as possible be performed in the LC. Here all coordination and handling of the material flow would be controlled. When one actor controls the material flow in a single resource it will be possible to achieve a continuous material flow, with as few process steps, buffers and handling operations as possible.

If all logistics activities for all the five production divisions could be performed in the LC the volume of the handled material would increase. Several authors (LaLonde & Cooper, 1989; Ellram & Cooper, 1990; Bardi & Tracy, 1991) state that if a LSP, such as TRP, can provide logistics services to a number of clients simultaneously, then economy of scale could be achieved. Furthermore, the more material that TRP can handle in the LC, the larger degree of economy of scale can be achieved. This would not only gain TRP, but the entire ABB Ludvika. As a result, a continuous material flow could be achieved, with as few process steps, buffers and handling operations as possible.

Furthermore, these benefits can partly be seen at the Torslanda terminal where DHL handles flows that are to be delivered to several departments at the same time. Volvo Cars has actually outsourced the logistical operations to DHL, in order to only focus on production. As much of the logistical processes should be done before the material comes to production. Hence, the material should only be delivered to production when needed, prepared and ready.

6.5.3 How can we achieve a pull controlled material flow?

Due to that ABB Ludvika is only producing according to MTO or ETO the first impression of ABB Ludvika is that they are using a pull system. But, only producing according to these principles is not the same as a pull controlled material flow. As a matter of fact, ABB Ludvika is actually handling the material in a push system, where all material are pushed from operation to operation. The MFM revealed that ABB Ludvika has a very long throughput time of the material with many buffers and a lot of steps included. Hence, ABB Ludvika are not letting the customer pull value from the producer, even if they only produce what is needed. In order to reduce the large amount of material within the company boarders, ABB Ludvika needs to pull material through the system and replenish only when the upstream operation needs material from downstream processes.

One option for ABB Ludvika to implement a pull system is to start using FIFO flows. The movement of materials should flow in a continuous stream, where the downstream processes only replenish from the upstream processes when needed. This would decrease the material volume in the flows and at the same time, the lead-time and the queues before each process would also decrease. Another way for ABB Ludvika to change towards a pull system is to start working with the kanban method. According to Jonsson and Mattsson (2009), kanban is a method in the lean philosophy for authorising material movement based on a visual signal. When replenishment is needed in the production, some communication is necessary between the downstream stock and the upstream operation and this is handled by the kanban signal. If this would be applied within ABB Ludvika, the production can send a signal to the LC whenever they need replenishment. Hence, the material will now be pulled through the system and there will not be more material than needed in the production. The main benefits for ABB Ludvika to switch towards a kanban system is that it eliminates unnecessary inventory of work-in-progress, shorting of the lead time and is a simple and cheep materials planning and production control (Browne et al., 1996). Even though Liker (2004) states unnecessary inventory as waste, there will always be some inventories that are needed. These small inventories that are replenished by the kanban method are called supermarkets. Furthermore, the production facility at Volvo Cars only replenish from the Torslanda Terminal when material is needed. They only sends a signal to the terminal indicating that replenish is needed, which can be seen as a kanban signal. In situations of emergency, DHL has only fifteen minutes to deliver the material to production. As a matter of fact, Volvo Cars and the Torslanda Terminal can be considered as a pull system.

Thus, the kanban signal will go to the LC, which will be received by the TRP staff. Now comes the problem for TRP of how to deliver the material internally according to the pull system. The work share divided by each division was shown in the TRP survey, where the production divisions COM, HV COM and TRS stood for approximately 21 to 25 per cent each, while HV BRE and HVDC stood for a much lower share. According to Lumsden (2012) the design of how to distribute the goods from the terminal to the customers can be done in a numerous ways, according to the formula $n = k!$. This formula state that if the number of customers are five, as within ABB Ludvika, then the number of possible route combinations are as much as 120, which can be viewed in the formula beneath:

$$k = 5 \Rightarrow n = 5! \Rightarrow 1x2x3x4x5 = 120$$

Hence, in the LC, the TRP needs to figure out a standardised way to efficiently deliver the material to the five production divisions. Lumsden (2012) state that this can be done in three main ways; loops, the sweep method and the method to solve the general route problem. Each of the three methods have their own benefits and drawbacks and is suitable in different environments. Firstly, the loops method is a very easy and fast method to use and it can be combined with other activities, such as collecting goods when at the same time delivering. The main drawback, on the other hand is that it will not give an optimal distribution. Secondly, the sweep method is also a simple and easy method to use and understand, but also here it will not give the best distribution. Thirdly, the method to solve the general route problem is more advanced way to find the way to distribute. It will give an efficient and close to optimal solution, but the method is time consuming and requires calculation skills or help from automatic processes, which can be costly. As a consequence, TRP needs a simple method, e.g. the loops method. Of course, the method to solve the general route problem would be optimal to choose but the TRP does not have the calculation skills, automatic processes or a lot of money, which is necessary. On the other hand, if the loops method would be used, then all personnel would understand the logic behind it. The truck could leave the LC when the truck is full, or every hour if the truck would not be full before that time. In the future, if TRP and the LC gets more resources and competences, then they could start using the method to solve the general route problem. At least, TRP should strive to get there one day.

6.5.4 How can a levelled material flow be achieved?

ABB Ludvika is today facing large variations in the material flow to and from the company boarders. The MFM revealed that some of the answers that the company does not have a levelled material flow are due to many reasons.

One reason is that the internal material flow starts with that the truck has to cross the railway right before the company gate, which is frequently used and thus also blocked. Here, trucks can stand and wait for about five minutes before it can enters the company boarders, which can not be considered as a levelled material flow. Also, Liker (2004) states waiting as a waste, which means that this step needs to be removed in a future situation. Consequently, it is important to consider that the infrastructure around the LC should be developed so that the external trucks going in and out from the LC can do that with a smooth flow without any waiting.

Another reason that a levelled material flow is not achieved today is that TRP only has limited opening hours, eight hours a day, even if many of the production facilities are running all night, which creates a lumpy material handling. On top of this, the external LSPs entering ABB Ludvika are not scheduled for a certain time, only what day the truck should arrive but not what specific hour. Furthermore, if trucks arrive during weekends, they will have to wait in an assigned parking spot until Monday morning. All of these reasons create large variations with high peaks, especially in the morning time. In order to smooth out the material flow, the Torslanda terminal has opened the same hours as production at Volvo Cars. This means that one option for the LC would be to have the same opening hours as production. But, the problem here is that the five production divisions at ABB Ludvika have different opening hours. Hence, the LC could be opened the same hours as production, but with a variety of personnel during these hours.

Lawrence et al. (1983) states that in order to plan the truck arriving and thereby smooth out the flow one option could be to implement time windows. On the other hand, a drawback with this option is that the delivering company gets one more criteria to follow, which often results in a higher price for the transportation. If time windows would be used, the LSP could get a specific time when it has to be at ABB Ludvika to deliver or pick up material, i.e. the LSP gets a delivery-time restriction. In this way, there will be no congestion and the variation will be more stable. Also, the trucks does not have to wait and stand in a line together with other trucks, thus Liker (2004) states waiting as one of the seven wastes. If time windows would be used in the future LC, then the trucks can drive directly to unloading area, where the unloading and sorting can begin. This would save a lot of administrative work and thereby also material waiting would be removed. Looking at the Torslanda terminal, one can easily see benefits gained from using time windows and receiving a way more steady flow. As a result, the benefits of using time windows for the 3PL providers entering the LC would be that the congestion of trucks would decrease, the lead time would decrease when the material does not have to wait before loading or unloading and the administrative work would also be less. All these benefits seem to be much higher than the drawback of getting a small increase in the transportation costs. Also, the time windows with incoming material could be settled by the production takt. This would result in a smoother internal material flow as well. All together, the benefits seems to be much higher than the drawbacks, why time windows would be positive for ABB Ludvika to use. Also, it could be feasible to have longer opening hours at the LC. As a result, it will lower the high burden on the TRP staff, serve the production with a better JIT arrangement and at the same time it will smooth out the material flow.

6.5.5 How can the material flow be synchronised with the takt of customer production flow?

Even if the takt-time was not investigated in this MFM, the result revealed that the material flow is not synchronised according to the customer demand. ABB Ludvika has today giant storages of three weeks before and after production. In order to achieve a material flow that are synchronised with the customer demand ABB Ludvika needs to start reduce the buffers before and after production.

Before production, each division have their own long-term storage of material for approximately three weeks production. If instead centralisation principles can be used in the LC, a lot of benefits can be achieved. Cooper (1991) states benefits with centralisation as less tied up capital, lower operating costs and a decrease in expenses for physical distribution administration, while Abrahamsson (1993) means that centralisation also can benefit the lead-time, availability, delivery performance and warehousing. This means that a centralised safety stock of material before production should be implemented in the LC, instead of having a decentralised storage structure at each production division. The Torslanda Terminal controls a safety stock of three days material to Volvo Cars production. Close to the production is a small buffer, or a supermarket, which is only replenished from the safety stock when needed. This could be something that ABB Ludvika should strive towards. Hence, the big inventory of three weeks could be reduced to a few days.

After production, the finished products are stored at one of the three material yards until it is shipped to the customers. The storage space is also today scattered over many different areas and the storage time varies a lot. ABB Ludvika needs a lot of space to be able to handle all this storage of finished products. According to Rosenblom (1995), the discrepancy in time refers to that products are often not produced exactly when the costumer wants the product, which means that material needs to be stored. At ABB Ludvika, finished products are stored for weeks, or even months, before it is shipped to the customer. Rosenblom (1995) continues by stating that intermediaries can add value to the end customer by store products in time. This is also what is done at ABB Ludvika, some products are stored at a material yard while HVDC store their products at AA-logistik in Västerås. On the other hand, according to the lean philosophy (Liker, 2004), the storage of finished products for several weeks can be considered as waste. At least four of the seven wastes can be identified; waiting, unnecessary transport, excess inventory and unnecessary movement. Consequently, the storage of finished products needs to be shortening down or removed.

There seems to be three main reasons for ABB Ludvika to store the finished products and why the storage time varies. One reason is that that most of the produced products are shipped internally within ABB to special projects all around the world, which applies JIT arrangements. This means that the products are produced before they are really needed in the projects. Hence, the production is not synchronised with the JIT projects. Another reason is the special transportation agreements between the customers and ABB Ludvika, called Incoterms, where some customers are responsible for the pick-up of their own products, so called Ex-works. The final reason is that some customers wants to have all products shipped at the same time, even though some products are ready before others. Taking all three reasons together, the underlying cause for the long storage time may come from less accurate production planning, different shipping agreements with the customers and limited integration and cooperation in the supply chains.

A reason for less accurate production planning may come from the decentralised setup of the production units where no Master Production Schedule overlooks the whole output volume in time. Bidgoli, (2004), Adam, Kotze & van der Merwe (2011) underlines the importance of Enterprice Resource Planning systems, ERP's, as a way of increasing integration and cooperation in the supply chain while developing information sharing across all tiers of actors. Varying lead-times and takt-times of the different shipment articles may also trouble the planning. As a result, ABB Ludvika should try to more efficiently produce the products when the customers need them.

The reason for bad shipping agreements with the customers may come from the frequent use of standardised trade regulations provided by the International Chamber of Commerce (ICCWBO, 2013). Rule combinations categories like Ex-Works where the buyer accept responsibility for the three parameters risk, cost and insurance mentioned by Lumsden (2012) may create issues like lack of good control and information at the end of ABB. As customers are responsible for the pickup it will be planned according their schedule neglecting the interests of a smooth truck flow or reduced inventory levels at the property in Ludvika. Agreements like these may cause freight to be stored at ABB for many years and in some cases the merchandise wont even be picked up at all due to customer problems like bankruptcy or depth.

As a result, the company should try to write agreements with the customers where ABB Ludvika together with a LSP is responsible for the transportation. Hence, the ex-works should be eliminated as far as possible due to the fact that it can work to create problems for the company. But, if the customer is determined to be responsible for transportation, there must be a cost of storing the products. As it looks now, there are few incentives for the customers to fetch goods. Boxes as old as ten years may be found in the yards, according to transport department employees sometimes as belongings to clients who are not even in business anymore.

If ABB Ludvika improves the production planning, the shipping agreements and the cooperation with other firms in the supply chains, the storage time of finished products could decrease from an average of three weeks to approximately a few days.

Thus if no long term storage are needed anymore, the products can be transported to the LC where a short term storage for finished products can be found. A future LC could centralise the storage of finished products to one single spot, which would decrease the tied up capital and the throughput time, lower operating costs and increase the delivery performance (Cooper, 1991; Abrahamsson, 1993). When the finished products arrive at the new LC they will be scanned and be put in a short-term storage before the LSP comes and collects the products and drive it to the customers.

6.5.6 Which process improvements are needed?

Stated by a TRP survey, the department handles on average 945 pallets and performs 363 deliveries to the five production divisions each day, with approximately 2,6 pallets per delivery. The deliveries to the production facilities are today mostly performed by forklift, which results in the low number of pallets per delivery. Also, the deliveries with forklift becomes very time consuming for the personnel at TRP when they have to make several deliveries to the same division in order to deliver a full truck load. This is a process that needs to be improved. At the terminal in Torslanda, one can see great differences here as the material is delivered to the factory in time schedule trucks. Here a way bigger volume can be delivered at once with much less driving.

Lumsden (2012) means that if a truck would deliver the material instead of a forklift, a much higher number of pallets per delivery could be achieved. Another option would be to use a truck train where even more units could be delivered and easily loaded and unloaded. A truck train could depart on schedule, working to increase integration throughout the divisions as slot times internally would make it easier to plan and efficiently load/unload at all ends. Not to mention environmental aspects that could be answered to using this option.

Therefore, in the LC, it would be much more feasible to deliver and pick up the material with internal trucks or truck trains going around the area, which would decrease the number of deliveries each day and at the same time increase the number of pallets per delivery.

6.5.7 How can the material flow be further improved?

In order to pursue perfection of the future material flow, it needs to be controlled in a much more effective way. TRP does not have any information system to help them coordinate the material. Ross (2002) states that the activities performed by the actors should be coordinated with information. Hence, ABB Ludvika should try to manage the activities with information as much as possible. If doing so, the number of administrative processes could be eliminated. Today, there are as much as fourteen administrative steps, which is a big reason for the very time consuming material system within ABB Ludvika.

In order for TRP to increase the handling and coordinating of the logistical activities, the control of the material flow must be improved. TRP should get access to ABB Ludvika's informational system so that they can communicate faster with the other divisions. According to Ross (2002), this will increase the performance of the activities. One situation where this can improve the logistics activities is when TRP are picking up the finished products at each production division. Today, the TRP forklift drivers drive around the area and look for finished products manually and is of course very time consuming. If instead TRP gets a signal indicating that the products are finished, TRP can handle and coordinate the activities much more efficient. For example, TRP can pick up the products with the loop truck at the same time as it delivers supplies to the supermarket. Lumsden (2012) means that the distribution method can be used both for deliveries and collect of material at the same time, but it needs to be planned. Hence, the signal with the information is crucial for the route planning. At the same time as the signal is sent to the TRP containing information that the product is finished, another signal should be sent to the LSP through the common information system APPORT-LM. The signal contains information with when the products should be picked up and what kind of products it is, i.e. weight, volume etc. If possible, this signal should be sent to the LSP as early as possible in order for the provider to plan their activities. DHL Borlänge means that it is crucial for them to get information as early as possible in order to plan their routes and activities in the best possible way.

Furthermore, a consideration to implement a tracking & tracing system needs to be investigated. Stefansson and Tilanus (1998) mean that it is of big importance to follow the logistical activities. This is also agreed by Hulsman and Windt (2007) that states that the logistical systems complexity creates a need for improved control by technology systems.

A tracking & tracing system is an informational system that can both follow and finding the material (Stefansson & Tilanus, 1998). If ABB Ludvika could implement such a system, Fritz and Schiefer (2009) means that they can improve areas like asset management, resource management, security and safety, which is just what ABB Ludvika and TRP needs. On top of this, benefits also affects other actors in the same supply chain, such as general freight administration, carrier maintenance, and enable tracking and tracing demanded by transport customers (Mirzabeiki & Sjöholm, 2012). Hence, if a tracking & tracing system is implemented by ABB Ludvika, then several other actors, i.e. the LSPs, can get a big benefit of this. This means that it will be a win-win situation between ABB Ludvika and the LSPs, which can result in a better control of the entire material flow, both the external and internal material flow. This can also improve the relationship atmosphere between Ludvika and the LSPs, which is really needed. Furthermore, all these benefits of implementing a tracking & tracing system may suggest that it will be a good idea. But on the other hand it can be a very expensive and may not be exactly what the company needs right now. Instead, ABB Ludvika needs a simple system in order to control the internal material flow better. The eight classification attributes, suggested by Stefansson and Tilanus (1998), can help the company to know what kind of system that is needed. These eight classification attributes need to be investigated deeply in order to get the right system for ABB Ludvika's needs, which will not be examined in this thesis. On the other hand, the discussion above revealed that ABB Ludvika is in a great need to implement some sort of control system. It may not need to be the most advanced system in this point of time. Instead, it is crucial for ABB Ludvika to increase the IT integration between TRP and the production divisions. The most urgent matter right now is to be able to scan the internal material in order for the production divisions to know that the material has entered the company boarders and is ready to for manufacturing. This can be done by a simple scanning system. The Torslanda Terminal always scans the incoming material before it is put in the safety stock. In this way, the production at Volvo Cars knows that the material is available in the terminal. The scanning system allows Volvo and the Torslanda terminal to reduce the number of administrative steps in the material flow as well as to gain control of the flow, knowing where the goods are. If ABB Ludvika would implement such a scanning system, the control of the material flow would increase and TRP would be able to perform the logistical activities much more effective.

In order to scan the material, there needs to be labels with barcodes on the material. When the material from the incoming truck has been unloaded and sorted, the TRP staff needs to label the pallets and then scan them. The signal from the scanning should go to a common IT-system, where the production divisions see that the supplies have arrived.

6.5.8 Future state map

As stated by Medbo (2013), the purpose of answering the seven questions is to conduct a future state from the current state. By taking the answers from each question and merge them together, it was possible to create a future state map, see Figure 36. This map shows how the material shall flow from the LC to production and then back to the LC again. It also shows what logistical processes that need to be performed and how they are controlled. Due to the big size of the map, it is also provided in Appendix D. The purpose of the overview sketch is not to show what kind of processes that should be performed, but instated just to get an overview of the whole picture.

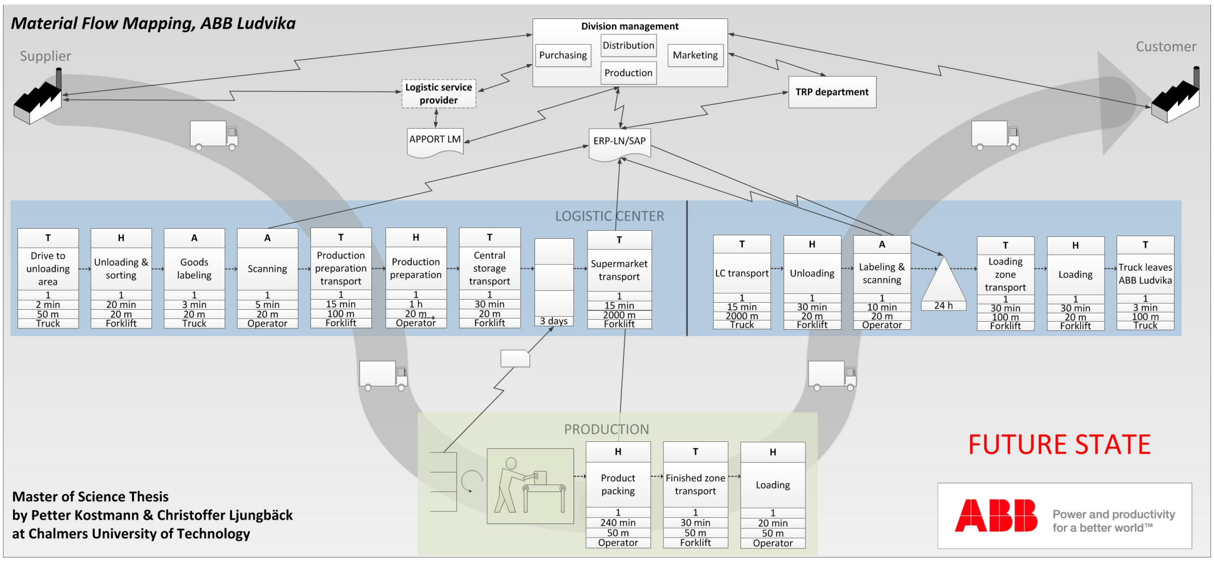


Figure 36. The future state map of the internal material and information flow. Note that the blue part of the Logistic Centre now has brought two actors into one. A larger version of the image can be seen in Appendix D.

6.5.8.1 The new material flow

Both the incoming and outgoing material flows will now be handled together in the LC. Here, the activities will be done together in order to achieve economy of scale and centralisation benefits. The LC will have longer opening hours that shall be adapted to production, so that a smooth flow can be achieved. When the truck with incoming material enters ABB Ludvika it will have a specific time window, which will reduce the waiting and the lumpiness. The first logistical process would be for the truck to drive to the unloading area. Here, a forklift driver would start to unload the truck and sort the material directly.

The previous analysis revealed that a scanning system is necessary in order to increase the control of the flow, but also to increase the communication between TRP and the production divisions. The next logistical process in the LC, after the unloading and sorting, would then be to label the material with specific bar codes. These bar codes would then be scanned, which directly sends a signal to a common IT-system. The production divisions can now see that the material has entered the company boarders.

Instead of driving out the material to each division, the material should be stored here until it is needed in production. But before the material goes to a central storage it will be prepared for production. Different divisions need different production preparation activities, e.g. sorting, kitting, sequencing. These will now be conducted in the LC. Hence, the next logistical process after the scanning would be to transport the material to the production preparation area within the centre. Thereafter, the production preparation activity would be executed. When the material is prepared and ready for manufacturing, it is transported to a central inventory. The inventory should only contain material for a few days production. If ABB Ludvika would have the same volume as the Torslanda Terminal, the inventory would last for three days of production.

In order to achieve a pull controlled material flow, the processes will use FIFO principles. To further achieve a pull system, the production will be replenished from the centralized inventory to a supermarket by sending a kanban signal to the LC. If ABB Ludvika would have the same volume as the Torslanda Terminal, the supermarket would last for only a couple of hours of production. An estimated time for the supermarket in the case of ABB Ludvika would be approximately three hours. When the LC receives the kanban signal, they start to load a carrier, perhaps a truck train, with the specific material. The material will be delivered to the production with the distribution principle "loops", which will deliver material at specific times.

When production personnel receive the material they will put it directly in a supermarket, thus the material is prepared and ready for production. The material will be used almost directly and will only be stored at the supermarket for a couple of hours.

When the product is completed, it needs to be packed, which will be the first logistical process after production. This needs to be done at each production division separately due to that the divisions produce very different products from each other. When this is done, a signal is sent to the common IT system, indicating that the products are ready for pick up. TRP sees this signal and knows what to pick up and where. Production personnel transport the products to a finished zone close to production where the products are loaded on a TRP truck or truck train. Thereafter, the products are transported back to the LC. The logistical processes that needs to be executed at the production divisions has thereby decreased from fourteen processes to only four. Hence, TRP and the LC shall perform as much of the logistical processes as possible, while the production divisions shall focus on the pure production activities.

When the finished products arrive at the LC they are unloaded from the carrier. Thereafter it is labelled and scanned, which thereby sends a signal to the common IT system indicating that the products has arrived to the LC and awaits transportation to the customer. The next process in the future state is that the products need to be stored for a short period of time, approximately 24 hours. This is due to all the preparation activities need to be done, including transport booking. The 24 hour inventory can also be seen as a buffer that makes sure that the products are there when the truck arrives for pick up. When the LSP notify its arrival, a signal is sent to the LC from the common IT system saying that the truck will come during a specific time window. Hence, when the truck arrives to the LC it can be loaded directly. The final process in the future state map is that the truck leaves ABB Ludvika and drives to the customer.

Consequently, the LC will conduct sixteen different logistics processes, while each production division only will execute four processes.

6.5.8.2 How good is the new material flow?

The future state only involves 20 processes and has a throughput time of 105,2 hours. Comparing with the current state, the number of processes has decreased by 49 per cent, while the throughput time has decreased by 90 per cent. This can be considered as a major improvement. A 90 per cent lead-time reduction means that there will be 90 per cent less material in the system within ABB Ludvika. Thereby, the basic need to move to an external LC due to space issues is no longer needed. As a matter of fact, if the company implement the future state they will be able to increase the volumes by 90 per cent before getting any space issues. Table 10 beneath summarises the future state regarding the throughput time, time in storage and transport distance.

Table 10. Summary of the MFM investigation regarding time and distance within ABB Ludvika.

Future state	Throughput time	Time in storage	Transport distance
- Total	**105,2 h**	**96 h**	**4660 m**
- Logistic Centre	100,4 h	96 h	4510 m
- Production*	4,8 h	0 h	150 m

*The logistical activities before and after the production process, within each division.

Table 10 shows that the total throughput time is in total 105,2 hours, where the material is stored for 96 hours. The material flow at the LC has a throughput time of 100,4 hours with a storage time of 96 hours. Hence, all material storage is done at the LC. The material flow at the production department has only a throughput time of 4,8 hours with no a storage time before and after the production process. This is because a supermarket is implemented instead of a buffer before production. Thus in a perfect world, according to the lean philosophy (Liker, 2004), the production need the material at the same time as it is replenished in the supermarket.

Furthermore, the total transport distance is 4660 m, where the material flow is transported 4510 m at the LC and only 150 m within each production division. Hence, the LC staff shall perform most of the transportation, while each production division shall focus on their core competence; production. This is the only performance measurement that has increased. A big reason for this is that the LC will be built on an external area outside the production facilities.

Table 11 shows the number of processes in the future state. The table divides the processes in four main categories: Transport, Handling, Administrative and Storage.

Table 11. The number of processes in the future state.

Number of processes	Total	LC	Production
- Total	**20**	**16**	**4**
- Transport	8	7	1
- Handling	6	4	2
- Administrative	3	3	0
- Storage	3	2	1

The future state has in total 20 different processes, where the LC handles sixteen of these and the production divisions only four 4. This means that 80 per cent of all the logistics activities should be performed in the centre, which can be compared with the current state where only 64 per cent of all logistics activities are performed outside of production. On top of that, these processes where before divided in arriving and departing. In the future state these two areas will be performed simultaneously in the LC.

The transportation activities have decreased from eleven to eight processes, while the handling activities have gone down from six processes to four. In the current state, the administrative activities accounted for the largest share, with in total fourteen processes. They have now decreased to only three, which are all performed in the LC. Thus, no logistical administrative processes will be done at each production division. A big reason for the big decrease of administrative processes is mainly due to the implementation of a better control and IT-system.

The number of storages has decreased from eight to three, hence a reduction of 63 per cent. Also, the three storages that are left consist of one centralised inventory, one supermarket and one short-term storage of finished products. The centralised inventory and the short-term storage will be located in the LC, while the supermarket needs to be close to the production. The current state map is compared with the future state map in Table 12. The table shows that the future state is a major improvement compared to the current state.

Table 12. Comparison of the current state and the future state of the MFM investigation, regarding time and distance within ABB Ludvika.

Material flow mapping	Current state	Future state
Throughput time	**43,7 days**	**105,2 h**
Time in storage	**43,25 days**	**96 h**
Transport distance	**4280 m**	**4660 m**
Number of processes	**39**	**20**
- Transport	11	8
- Handling	6	6
- Administrative	14	3
- Storage	8	3

Table 12 is summarized in Figure 37 beneath. The left chart compares the throughput-time of the current and future state, while the right chart compares the number of activities. The future state has decreased the throughput-time with 90 per cent and the number of activities with 49 per cent. The right chart shows that most of the activities that has decreased are storage or administrative activities which means that the future state contains a higher share of value-adding activities.

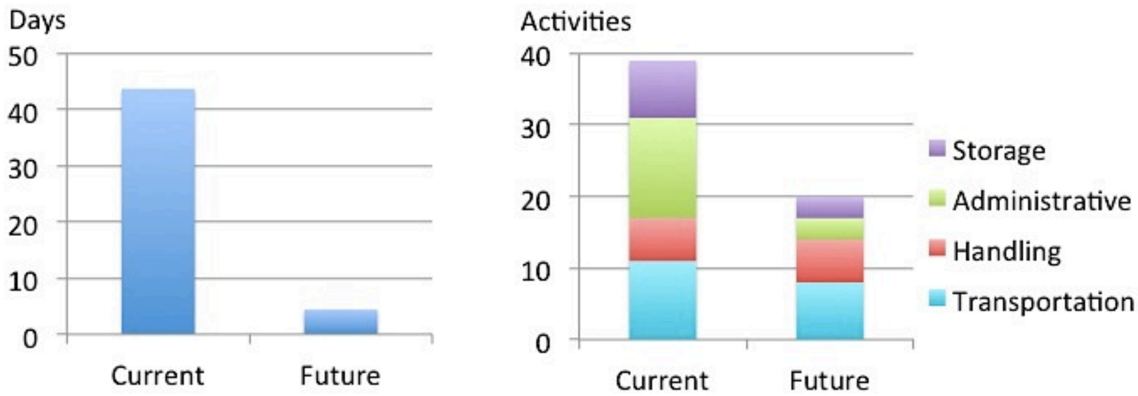


Figure 37. The left chart compares the throughput-time of the current and future state. The number of days has actually decreased by 90 per cent, from 44 days to approximately 4 days. The right chart compares the number of activities of the current and future state, which has decreased by 49 per cent, from 39 to 20 logistical activities.

The final step in the MFM methodology is to plan and implement the improvements. ABB Ludvika actually has a golden opportunity to implement the changes at the same time as the LC will be built. Hence, the future state map will give some requirement on the development of the future LC, which will need to be considered.

6.5.9 Summary

The analysis of the internal material flow revealed that ABB Ludvika is struggling with large internal logistical problems. The main problems can be seen in the list beneath:

- Very long throughput time
- Many number of logistical processes
- Many administrative steps due to lack of effective information technology
- Many buffers
- The material is stored in a scattered area all over the facility.
- TRP does not perform any value adding activities.

By implementing the future state map, most of the problems will be mitigated. As a matter of fact, the future state map has a 90 per cent better throughput time, involving 49 per cent less activities. This means that there will be 90 per cent less material in the system and thus the basic need to move to an external LC due to space issues is no longer needed. As a result of the future state, ABB Ludvika can increase the volumes by 90 per cent before getting any space issues. But, even if the Internal material flow constraint concludes that the LC is not necessary due to a less throughput time, there might be other large benefits coming from the other three constraints, which suggests that the new LC is positive for ABB Ludvika.

The future state map will of course be an important input in the development of the LC. The map tells what kind of activities that shall be performed in the LC and thus the developers must take consideration of these activities. The LC shall be able to perform sixteen different logistical processes within four categorises; transportation, handling, administrative and storage. The big change compared to today would be the switch from a push to a pull system. Hence, in the future state and in the LC the material shall be pulled through the system. This will be done by FIFO principles and kanban signals. One process shall never have material it does not need. If a pull system shall work properly, the control of the material needs to be improved. Hence, a scanning system needs to be implemented in order to increase the control and the communication within the company. Furthermore, the three weeks of inventory before production will be decreased to a three days centralised inventory in the LC. After production, the three weeks inventory of finished products shall also be decreased to only 24 hours. Consequently, the LC needs to be designed in order to manage a three days inventory before production and a 24 hours inventory of finished products after production. When the production needs to be replenished they shall send a kanban signal to the LC indicating that supplies are needed. The LC needs to invest in a more advance IT-system together with the rest of the company, which will help the LC to communicate and control the flow.

7 CONCLUSION

RQ 1. What is the current logistic situation at ABB Ludvika and what issues are present?

The investigation of the current logistic situation at ABB Ludvika, described in chapter 4, revealed that the company is struggling with many logistical problems in different areas. The main problems can be seen in Table 13 divided in the four constraints, in total 24 problems.

Table 13. The main issues of the current situation of ABB Ludvika, divided by the four constraints.

Context	Production	External material flow	Internal material flow
A decentralised company structure with separate production, purchase, material handling and distribution departments together with various business systems.	Several material inbound gateways as well as separate material recording.	Many actors involved in the external material flow.	Long lead-time.
Little or no cooperation and communication between the divisions decrease the use of scale benefits.	The TRP being seen as a non-changeable outside actor.	Little cooperation with the LSPs.	A large number of logistics processes.
Integration issues, while seeing TRP as “outside the company” regarding cooperation and “inside the company” when it comes to economics.	Separate storing and tagging systems.	Bad relationships with the LSPs.	Many administrative steps due to lack of effective information technology.
A big part of the total selling volume is internal, which seems to be complex, bureaucratic and time consuming. Local optimisation.	Little capacity for volume increase. Little consideration has been taken to future use of TRP areas.	Low fill rate in the trucks.	Many buffers.
Transportation as a non core competence activity	Large inventory before and after production	Several LSPs can be chosen for each assignment and normally the cheapest one gets the job.	The material is stored in a scattered area all over the facility.
Space and congestion issues externally and internally.	Separately made production preparation activities.	High variations of the in- and outbound material flow.	TRP does not perform any value adding activities.

Table 13 reveals that the production facility in Ludvika has got problems with the material flows. The five different company divisions located in Ludvika results in that there are a large amount of different components going in and out from the production sites. Hence, the main challenge for ABB Ludvika is to create a sustainable system with better control and coordination of the in- and outbound material flow that will last in the long term.

RQ 2. What factors are affecting the development of a LC?

This thesis revealed that there are many factors influencing the development of a LC and thus the material flows. The LC Concept model categorise four main constraints all providing their specific emphasises on a complex problem. The context constraint deals with the requirements coming from company characteristics, products assortment and the external factors, such as rules and regulations. The production constraint sets requirements as when the material is needed, how it is needed and if it should be prepared in some way. The external material flow constraint deals with the flow to and from the company boarders and sets some requirements on the external actors in the supply chain and the logistic service providers, which handles the material flows between firms in the network. The internal material flow constraint deals with the in-plant logistics processes, except from the pure production activities. All of these four constraints, illustrated in Figure 38, will affect the development of a LC in their specific way and set some boundaries for the design that needs to be kept.

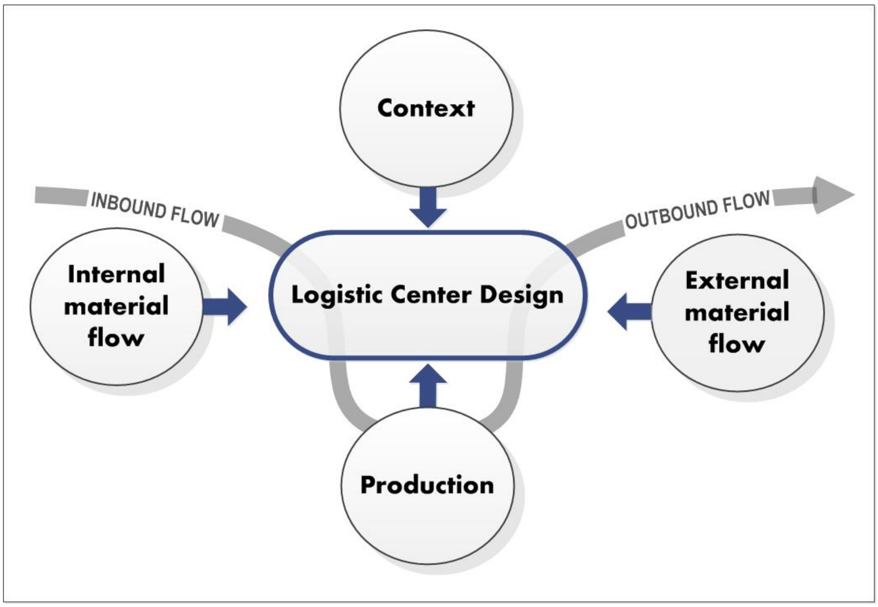


Figure 38. The LC Concept Model. Four constraints shaping the development of a logistic centre supporting production with both in- and outbound material flows. The four constraints all give their particular perspective and provide their specific emphasises of how to develop and design the LC.

RQ 3. What performance factors are critical in developing the new LC at ABB Ludvika?

The factors affecting the development of the LC have been concluded in the concept model responding to RQ 3. Each of the factors will, with input from the problems covered in RQ 1, generate guidelines for the expansion plans in Ludvika stated beneath:

The context constraint highlights the importance of cooperation, integration and communication throughout the company where a team-atmosphere needs to be attained. Centralisation activities need to bring similarities to one point in order for the company to reach scale benefits. Here one must look at each decentralised unit and identify how these could be managed together bringing down several categories of cost. In order to avoid narrow scopes and local optimisation, one must use tools like information technology and cooperation methods, which will a critical area of attention during the development of the new LC. As the TRP is an inhouse actor in a company where focus rather lies on technology one must be careful when using this benefit through attaining a vision where the company becomes one unit in the eyes of all employees. Another aspect will be to monitor changes in the future product assortment and development. One must here stay tuned with both suppliers and customers in order to foresee what will or may happen in the future. Scenario analyses and close supply chain integration will here be critical. Not only the connections in the chain but also the outside environment that may not always be so easy to influence must be considered. Thus, changes in politics, law or the environment should be regarded.

From the production perspective, one of the main messages is to prepare the expansion for future takeovers and centralisation of currently divisional work at each production site. The new facility needs to stand ready in order to handle further storage and recording. It is also important to integrate all divisions into the development and make sure to stand ready for future cooperation within the new facilities. Areas important to cover here will be future use of production preparation methods that could be centralised and made within the capacity of the new facilities. The new LC is also affected by the fact of information sharing importance across the whole company. Information channels like tagging must be taken into consideration as well as into the budget, where IT-technology will become a vital tool for the future success of the LC unit. All-and all the bottom line is to increase cooperation within the whole company as well as beyond the tier walls around the supply chain in order to create a “team-working” atmosphere.

The LSPs are very important actors in the role of coordinating the external material flows between firms in the supply chain and thus they are central for ABB Ludvika in order to handle the material to and from production. ABB Ludvika needs to realise that they are part of a big network of actors and start to cooperate with the other actors in the supply chain. Hence, ABB Ludvika does not see the potential with more cooperation between the companies today. In order to mitigate this, the company needs to stop handle the 3PL providers on an arm’s length approach and start with a collaborative relationship where the parties develop together with trust and instead help each other. When one or a few 3PL partners is chosen more responsibility can be placed on these firms that can start to perform more value adding processes than just basic logistics activities. When the 3PL providers gets more responsibility they can plan the material flow much better and achieve economy of scale. Hence, it will be a win-win situation for ABB Ludvika and the 3PL providers. Then, a higher fill rate can be achieved if the 3PL can plan better in advance. As a result, the handling of the incoming material at ABB Ludvika will be less time consuming and less costly. The new LC will be an important asset in order to perform the activities needed. By having a good relationship with the 3PLs, it will be possible to get access to their resources. In this way, the new LC could be combined in an enormous way and thus the vale of the resource will increase. The LC should overcome the discrepancy in time, where products can be stored until the customers needs it. Also, the LC will be the interface between the internal and external material flows.

The MFM revealed that ABB Ludvika is struggling with very ineffective material flows internally. By analyse the current state with the seven guideline questions a future state was conducted. The future state, compared with the current state, had a lead-time reduction of 90 per cent to only 105,2 hours. Furthermore, the number of logistics processes was also reduced tremendously with 49 per cent to only 20 processes. The main idea with the new LC is that as much logistical activities as possible shall be performed here and not at the production divisions. If a better relationship between the production divisions and the TRP could be established, more value-adding activities could be performed by TRP in the LC. If so, the LC will handle 16 processes inside the hub, while each production division will only handle 4 processes, which are absolutely necessary for running production smoothly. The future state map also shows that there are some small buffers needed. Before production, there will be necessary to have a safety stock of three days of material, which will be replenished to production through kanban signals. This means that there will also be a small buffer just before production, called supermarket. The purpose of these buffers is to be sure that the requirements from production will be satisfied thus the production never will be stopped. The future state also recommends longer opening hours in the new LC in order to it lower the high burden on the TRP and at the same time it will smooth out the material flow. Another suggestion to decrease the variations is to implement time windows for all material coming in or going out from ABB Ludvika. The main benefits with this would be that the congestion of trucks would decrease, the lead time would decrease when the material does not have to wait before loading or unloading and the administrative work would also be less. All these benefits outnumber the drawback of getting a small increase in the transportation costs. In order to deliver the material as efficient as possible a truck should be used instead of a forklift. This would decrease the number of deliveries each day and at the same time increase the number of pallets per delivery. Furthermore, the loops method should be used to distribute the material to the five production divisions. The method is simple enough so all personnel at TRP would understand the logic behind it. The truck could leave the LC when the truck is full, or every hour if the truck would not be full before that time. In the future, if TRP and the LC get more resources and competences, then they could start using the method to solve the general route problem. At least, TRP should strive to get there one day. The future state also shows that it is possible to reduce the enormous inventory of finished products. Better production planning and better agreement with the customer results in that finished products can leave the company boarders almost directly after production. This means that the storage of finished goods should decreased from approximately 3 weeks to about 24 hours, a reduction of 95 per cent.

Concluding, the 24 identified problems are interrelated which means that ABB Ludvika needs to consider all four constraints at the same time when developing the new Logistic Centre. If this can be achieved, there are large opportunities for logistics improvement. Our mitigation strategies suggest recommendations that can reduce the throughput time of 90 per cent. This means that there will be 90 per cent less material in the system, which of course will have large effects on the entire Ludvika site. Firstly, there will no longer be any capacity limitations and thou no more safety issues. Secondly, the bounded capital in the inventory will largely be reduced which will save costs for the company. As a result of the reduced material in the system, the control of the new material flow will be increased together with the investments in the IT-system. Furthermore, ABB Ludvika will have a higher degree of cooperation, both internally and externally.

Finally we would like to notify that the production within ABB Ludvika is a very important area for the development of the LC. Hence the production needs to be investigated thoroughly in order to find what kind of requirements the production will put on the logistics. If more activities and inventories could be centralise in the LC, the entire company can switch from MTO to ATO. Standardised products could be pre-assembled in the LC, which will result in faster throughput times and shorter production time.

8 DISCUSSION AND FURTHER RESEARCH

The purpose of this report was to explore and evaluate the material flows to and from the production site at ABB Ludvika and investigate how these could be improved and controlled in the new Logistic Centre. An empiric situation analysis where current company issues were brought to the surface and a wide theory search resulted in the development of a guidance framework, the LC Concept Model. The concept model was then applied with the result of several guidelines for the future LC development. In order to assure validability and reliability within the given solution, a comprehensive literature search, next to benchmarking, numerous company interviews and several observations where conducted. The strategic aim of the result may include some setbacks within the actual operative details as far as process and lead-time estimations that will need practical testing in order to verify.

As for further research, one of the main things will be to gather necessary input from the separate divisions of ABB Ludvika. Future production plans ad demands as well as current ways of tracking, storage and production preparation needs to be examined and weighted with help from divisional input. A key here will be to identify similarities that can gain lead-time and budget through scale benefits. As highlighted in the analyses, centralisation activities like these require a deeper understanding of the actual operative business at all ends. This also goes for the information sharing and the IT-Technology needed in order to assist it with the expansion plans. The question here will be how to actually strengthen transparency and cooperation within the new developments.

Further, when plans are clearer, one must look at the economic perspective in order to decide on LC layout and functions as well as to make priorities in the development. Environmental and sustainability aspects will also be important within this decision-making stage. Another area to cover here will also be how to assist the employees and traffic within the new facilities. These developments need to be carefully examined and in line with laws and regulations as well. Last but not least, when functions and requirements have been established, one must take the actual warehouse design into consideration. How can the strategic guidelines become reality in the actual building layout design.

REFERENCES

ABB (2013a) *History*. http://new.abb.com (4 Jun. 2013).

ABB (2013b) *Who we are - ABB in brief*. http://new.abb.com (4 Jun. 2013).

ABB (2013c) *Our businesses*. http://new.abb.com (5 Jun. 2013).

ABB (2013d) *Discrete Automation and Motion division*. http://new.abb.com (5 Jun. 2013).

ABB (2013e) *Process Automation division*. http://new.abb.com (5 Jun. 2013).

ABB (2013f) *Välkommen till ABB*. http://www.abb.se (7 Jun. 2013).

Abrahamsson, M. (1993), Time-Based Distribution, *The International Journal of Logistics Management*, Vol. 4, No. 2.

Adam, R., Kotze, P., & van der Merwe, A. (2011), Acceptance of enterprise resource planning systems by small manufacturing Enterprises. In: In: Proceedings of the 1tth International Conference on Enterprise Information Systems, Vol.1, edited by Runtong Zhang, José Cordeiro, Xuewei Li, Zhenji Zhang and Juliang Zhang, SciTePress. , p. 229 – 238.

Alderson, W. (1957), *Marketing Behavior and Executive Action,* Homewood, Illinois: Richard D. Irwin.

All Business (2013) *Business glossary, centralization*. http://www.allbusiness.com/glossaries/centralization/4950372-1.html (12 Jun. 2013).

Andersen, B., & Pettersen, P.-G. (1995), The Benchmarking Handbook: Step-by-Step Instructions, Chapman & Hall, London.

Andersson, D. (1997), *Third Party Logistics - Outsourcing Logistics in Partnerships*, Linköping Studies in Management and Economics, Dissertations No. 34, Department of Management and Economics Linköping University.

Annual report (2012), ABB Annual report

Anupindi, R., Chopra, S., Deshmukh, S. D., Van Mieghem, J. A., Zemel, E. (2012) *Managing Business Process Flows, 3rd ed.*, New Jersey: Pearson Education Inc.

APQC (1993), Basics of Benchmarking, American Productivity and Quality Center, Houston, TX.

Armstrong, G., & Kotler, P. (2007), *Marketing: An introduction*. 12th ed. New York: Prentice Hall.

Axelsson, B. & Agndal, H. (2005), *Proffisionell Marknadsföring*, Second edition, Lund, Studentlitteratur.

Baines, P., Fill, C. & Page, K. (2008), *Marketing*, Oxford: Oxford University Press.

Bardi, E., J. & Tracey, M. (1991), "Transportation Outsourcing: A Survey of US Practices", *International Journal of Physical Distribution & Logistics Management*, vol. 21, No. 3.

Baudin, M. (2004), Lean Logistics: the nuts and bolts of delivering materials and goods, Productivity Press, New York

Beamon, B. (1999),"Measuring supply chain performance", *International Journal of Operations & Production Management*, Vol. 19 Iss: 3 pp. 275 - 292

Befring, E. (1994), *Forskningsmetodik och statistik*. Lund: Studentlitteratur. Pp.64-72

Berglund, M. (1997) Third-party logistics providers — towards a conceptual strategic model, Licentiate Thesis, No. 7, LiU-TEK-LIC.

Bidgoli, H. (2004), *The Internet Encyclopedia*, Volume 1, John Wiley & Sons, Inc. p. 707.

Bitran, G. R., Gurumurthi S. and Sam, S. L. (2007), The Need for Third-Party Coordination in Supply Chain Governance, *MIT Sloan Management review*, Volume 48, No 3.

Blaxter, L., Hughes, C. & Tight, M. (2006), *How to research*, 3rd ed., Open University Press, Berkshire, UK.

Bozer, Y. A. & McGinnis, L. F. (1992), "Kitting versus line stocking: A conceptual framework and a descriptive model", *Int. J. Production Economics*, Vol. 28, pp. 1-19

Brankl, S. & Wu, Z. (2010), Materials Supply System Design: Development and Application of a Model to Support Materials Support Materials Supply at ABB Components. Goteborg: Chalmers University of Technology. (Master Thesis within the Department of Technology Management and Economics. Division of Logistics and Transportation).

Bruno, J. C. (2013), Legal implications and current use of incoterms. Butzel Long for *Original Equipment Suppliers Association*. http://www.oesa.org/Doc-Vault/OESA-Digest-not-surveys/2013/Butzel-Long-LIC-Presentation-May-2.pdf (5 Jul. 2013).

Bucklin, L. P. (1972), *Competition and Evolution in the Distributive Trades,* Englewood Cliffs, New Jersey: Prentice-Hall.

Business Dictionary (2013) *INCOTERMS*. http://www.businessdictionary.com (5 Jul. 2013).

Cambridge Dictionary (2013) *centralize*. http://dictionary.cambridge.org (12 Jun. 2013).

Campbell, A., Kunisch, S., & Müller-Stewens, G. (2011), To centralize or not to centralize?, *McKinsey & Company - Insights & Publications*. http://www.mckinsey.com (12 Jun. 2013).

Carr, J. J. (2000), Requirements engineering and management: the key to designing quality complex systems. *The TQM Magazine*, 12(6), 400-407.

Christopher, M. (2005), Logistics and supply chain management, creating value-adding networks, Financial Times Prentice Hall, 3rd ed.

Chopra, S., & Meindl, P. (2012), Supply Chain Management, Strategy, Planning and Operation, Fifth Edition, England: Pearson Education Limited

Clarke, G., & Wright, J. (1964), "Scheduling of vehicles from a central depot to a number of delivery points", Operations Research, 12 #4, pp. 568-581.

Cooper, M. C., Lambert, D. M., & Pagh, J. D. (1997), Supply Chain Management: More Than a New Name for Logistics. *The International Journal of Logistics Management* 8(1), 1–13.

Cooper, J. (1991), "The Paradox of Logistics in Europe", *International Journal of Logistics Management*, Vol. 2, No. 2, pp 42-54.

Davidson, B., & Patel, R. (2003), Forskningsmetodikens grunder – Att planera, genomföra och rapportera en undersökning. Lund: Studentlitteratur.

de Koster, R., Le-Duc, T., & Roodbergen, K. J. (2007), Design and control of warehouse order picking: A literature review, *European Journal of Operational Research*, vol 82, iss 2, pp 481-501.

Domingo, R., Alvarez, R., Pena, M. M., & Calvo, R. (2007). Materials flow improvement in a lean assembly line: a case study. *Assembly automation*, 27(2), 141-147.

Ejvegård, R. (2003), *Vetenskaplig metod*. Third edition. Lund: Studentlitteratur.

Ellram, L. M. & Cooper, M. C. (1990), Supply Chain Management, Partnerships, and the Shipper-Third Party Relationship*, The International Journal of Logistics Management*, Vol 1, No. 2.

Emmett, S. (2005), *Excellence in Warehouse Management*. John Wiley, Chichester

Ford, D., Gadde, L-E, Håkansson, H., & Snehota, I. (2003), Distribution in Business Networks, *Managing Business Relationships,* Wiley, Ch. 6, pp. 119-150.

Fritz, M., & Schiefer, G. (2009), Tracking, tracing, and business process interests in food commodities: a multi-level decision complexity, *International Journal of Production Economics*, Vol. 117, No. 2, pp.317–329.

Gadde, L-E. (1989), "Understanding Distribution – Channel Development", *Marketing at the Gothenburg School of Economics*, Göteborg: Proceedings BAS, 1989.

Gadde, L-E. (2004), Activity Coordination and resource combining in distribution networks-implications for relationship involvement and the relationship atmosphere, *Journal of Marketing Management,* 20, 1-2, pp. 157-184

Gadde, L.-E., Håkansson, H. and Persson, G. (2010), *Supply Network Strategies*, John Wiley & Sons, second edition.

Garcia-Dastugue, S.J., Lambert, D.M. (2003), *Industrial Marketing Management*, vol. 32, pp. 251–263.

Gardner, J. T. (2003), Strategic supply chain mapping approaches. *Journal of Business Logistics*, 2482), 37-64.

Gardner, J. T. & Cooper, M. C. (2003) Strategic Supply Chain Mapping Approaches, *Journal of Business Logistics*; Vol. 24 Issue 2, pp.37-64

Gattorna, J. (1998), Strategic supply chain alignment: Best practice in supply chain management, Gower Publishing Ltd

Giner Alor-Hernandez, A., Aguilar-Laserre, Guillermo Cortes-Robles and Cuauhtemoc Sanchez-Ramirez (2011), Improving E-Procurement in Supply Chain Through Web Technologies: The HYDRA Approach, *Supply Chain Management - New Perspectives*, Prof. Sanda Renko (Ed.)

Google Maps (2013) *Ludvika*. https://maps.google.com (7 Jun. 2013).

Guba, E. G., & Lincoln, Y. S. (1985), *Naturalistic inquiry*. Newbury Park: Sage Publications.

Haksever, C., Render, B., Russell, R., & Murdick, R. (2000), Service Management and Operations, 2nd ed. Prentice Hall: Upper Saddle River, NJ, 476–497.

Halvorsen, K. (1992) *Samhällsvetenskaplig metod*, Lund: Studentlitteratur

Hartman, J. (2004), *Vetenskapligt tänkande – från kunskapsteori till metodteori*. Second edition. Studentlitteratur. pp. 205-209, 232-248, 272-288.

Hassan, M. (2002), A framework for the design of warehouse layout. *Facilities 20* (13/14), pp. 432–440.

Hines, P., & Rich, N. (1997), The seven value stream mapping tools. *International Journal of Operations & Production Management*, 17(1), 46-64.

Hulsmann, M., & Windt, K. (2007), Changing paradigms in logistics – understanding the shift from conventional control to autonomous cooperation and control, in Hulsmann, M. and Windt, K. (Eds.): *Understanding Autonomous Cooperation and Control in Logistics- the Impact of Autonomy of Management, Information, Communication and Material Flow,* Springer, Berlin, pp.4–16.

Håkansson, H., & Johanson, J. (1992), A model of industrial networks. In B Axelson & G. Easton (Eds.), *Industrial networks: a new view of reality*. London: Routhledge.

Håkansson, H., & Snehota (eds.) (1995), *Developing Relationships in Business Networks*, London, International Thomson Business Press.

ICCWBO (2013) *The Incoterms® rules*. http://www.iccwbo.org (5 Jul. 2013).

Icontainers (2013) *Incoterms 2010*. http://www.icontainers.com/ayuda/wp-content/uploads/2011/07/incoterms20108.jpg (5 Jul. 2013).

Johansson, M. I. (1991), "Kitting systems for small size parts in manual assembly systems"

Jonsson, P., & Mattsson, S-A. (2009), *Manufacturing planning and control*, McGraw-Hill, London

Keith F. Punch (2005), *Introduction to Social Research–Quantitative & Qualitative Approaches*. London: Sage

Kovacs, G. & Spens, K. M. (2006), A content analysis of research approachs in logistics research. *International Journal of Physical Distribution and Logistics Management*, 36 (vol. 5).

Kumar, R. (2011), *Research methodology*, third edition. London: Sage Publications Ltd. Vol. 2.

La Londe, B. J., & Cooper, M. C. (1989), *Partnerships in Providing Customer Service: A Third-Party Perspective*, Council of Logistics Management, Oak Brook, Ill USA.

Lambert, D. M. & Cooper, M. C., (2000), Issues in Supply Chain Management, Industrial Marketing Management, vol. 29, pp. 65–83.

Lawrence, B., Golden, B., Assad, A., & Ball, M. (1983), "Routing and Scheduling of Vehicles and Crews: The State of the Art." *Computers and Operations Research* 10, no. 2, 63–211.

Lean Instituut (2013) Pull Systems Must Fit Your Production Needs. http://leaninstituut.nl/publications/Pull_Systems_Must_Fit_Your_Production_Needs.pdf (20 Nov. 2013).

Lekvall, P., Wahlbin, C. (2001) *Information för marknadsföringsbeslut*, 4th ed., Göteborg: IHM Publishing

Lewis, E. (1968), *Marketing Channels: Structure and Strategy*, New York.

Liker, J. K. (2004), *The Toyota way: 14 management principles from the world's greatest manufacturer.* New York: McGraw-Hill.

Liker, J. K., & Meier, D. (2006), "The Toyota Way Fieldbook: A Practical Guide for Implementing Toyota's 4Ps". New York, McGraw-Hill.

Ljungberg, A., Larsson, E. (2012) *Processbaserad verksamhetsutveckling: varför - vad - hur?,* 2nd ed., Lund: Studentlitteratur

Lumsden, K. (2012), *Logistikens grunder*, Studentlitteratur, Third edition, Lund.

Management Study Guide (2013) *Centralization and Decentralization*. http://www.managementstudyguide.com (12 Jun. 2013).

Mathisson-Öjmertz, B. (1998), A value-adding perspective on materials handling *Materials handling from a value-adding perspective*. Göteborg: Chalmers University of Technology.

Medbo, L.; Senior lecturer Technology Management and Economics, Chalmers University of Technology, (2013), Case introduction, lecture 7 Feb. 2013.

Monden, Y. (1998), *Toyota production system: an integrated approach to just-in-time* (3. ed.). Norcross, Ga.: Engineering & Management.

Neumann, P., & Medbo, L. (2009), Ergonomic and technical aspects in the redesign of materials supply system: Big boxes vs. narrow bins. *International Journal of Industrial Ergonomics*, 40(5), 541-548.

Oliver, R. K., & Webber, M. D. (1992), Supply-Chain Management: Logistics Catches Up with Strategy. *Outlook (1982);* cit. Christopher, M. G.: *Logistics, The Strategic Issue.* Chapman and Hall, London.

Oswald, S., & Boulton, W. (1995), "Obtaining Industry Control: The Case of the Pharmaceutical Industry", *California Management Review,* Vol. 38, No.1, pp. 138-162.

PROTRANS (2003), The Role of Third party Logistics Services Providers and their Impact on Transport, European Commission, Deliverable no. 6, Final public report, p. 32

Ramesh, V., & Kodali, R. (2012), A decision framework for maximising lean manufacturing performance. International Journal of Production Research, 50(8), 2234-2251.

Rosenbloom, B. (1991), *Marketing Channels: A Management View,* 4th edn, Chicago: Dryden Press.

Rosenbloom, B. (1995), Channels of Distribution, *Companion Encyclopaedia of Marketing,* London, Routledge. p. 137-154.

Ross, A. (2002), "A multi-dimensional empirical exploration of technology investment, coordination and firm performance", *International Journal of Physical Distribution* & *Logistics Management,* Vol. 32, No.7, pp. 591-609.

Rother, M., & Shook, J. (1999), *Learning to see: Value stream mapping to Add Value and eliminate Muda*. Brookline, MA: The Lean Enterprise Institute.

Rother, M., & Shook, J. (2003), *Learning to see: Value stream mapping to Add Value and eliminate Muda*. Version 1.3. Brookline, MA: The Lean Enterprise Institute.

Rowley, J. (2000), *The principles of warehouse design*, second ed. The Institute of Logistics & Transport, Corby.

Rumsey, S. (2008) *How to find information: A guide for researchers*, 2nd ed., Berkshire: McGraw-Hill Professional Publishing

Rushton, A., Croucher, P., & Baker, P. (2006), *The Handbook of Logistics and Distribution Management*, third ed. Kogan Page, London.

Sayer, N.J. & Williams, B. (2007), *Lean for Dummies*, John Wiley & Sons, Indianapolis, IN.

Shaw, A. W. (1915), *Some Problems in Market Distribution,* Cambridge, Mass.: Harvard University Press.

Slack, N., Chambers, S., & Johnston, R. (2007). *Operations management* (5. ed). Harlow: FT Prentice Hall.

Speh, T. (2009), Understanding warehouse costs and risks. *Ackerman Warehousing Forum*, Vol. 24, No 7.

Stadtler, H. (2008), Supply Chain Management – An Overview Book chapter in Supply Chain Management and Advanced Planning Concepts, Models, Software, and Case Studies, Chapter 1, P 9-36.

Stadtler, H. (2005), Supply Chain Management – An overview, Supply Chain Management and Advanced Planning, pp 9-35, Springer Berlin Heidelberg.

Stalk, G. (1988), " Time - The next source of competitive advantage", *Harvard Business Review*, Vol. 66, No 4, pp. 41-55.

Stanton, W. J. (1968), *Fundamentals of Marketing,* second edition, New York: McGraw-Hill.

Stefansson, G., & Tilanus, B. (2000), "Tracking and tracing: Principles and practice", *Int. J. of Technology Management*, Vol. 20, No 3⁄4 pp. 252-271.

Svensson, G. (2006), "Sequential service quality in service encounter chains: case studies", *Journal of Services Marketing*, vol. 20, Iss: 1 pp. 51-58

Taylor, D. H. (1997) *Global Cases in Logistics and Supply Chain Management*, London: International Thomson Business Press

Trafikverket (2002) *Grundvärden Trafiksituationsmodell*. http://www.trafikverket.se (8 Aug. 2013).

Trafikverket (2012) *Test med långa fordon*. http://www.trafikverket.se (8 Aug. 2013).

Mirzabeiki, V., & Sjöholm P. (2012), "Sharing tracking and tracing data to improve operations of supply chain actors ", *International Journal of Logistics Systems and Management*, Vol. 13, No 1, pp. 81-95

Van Weele, A. (2010), *Purchasing and Supply Chain Management* (PSCM), South-Western Cengage Learning fifth edition.

Vilpola, I. H. (2008), "A method for improving ERP implementation success by the principles and process of user-centred design". *Enterprise Information Systems* **2** (1): 47–76.

Vollman, T. E., Berry, W. L., Whybark, C. D., & Jacobs, F. R. (2005), *Manufacturing Planning and Control for Supply Chain Management* (Fifth Edition ed.). Singapore: McGrawHill.

Waldner, J-B. (1992), *CIM: Principles of Computer Integrated Manufacturing*. Chichester: John Wiley & Sons. p. 46.

Wilcox, D. (2013), EC finally approves truck length increase. *Commercial Motor, 219*(5531), 6.

Womack, J., P., Jones, D., T., & Roos, D. (1990), The Machine that Changed the World, Free Press, Rawson Associates, New York, 323 pp.

Womack J. P. & Jones, D. T. (2003), *Lean thinking: banish waste and create wealth in your corporation*. Rev. and updated [ed.] London: Free Press Business

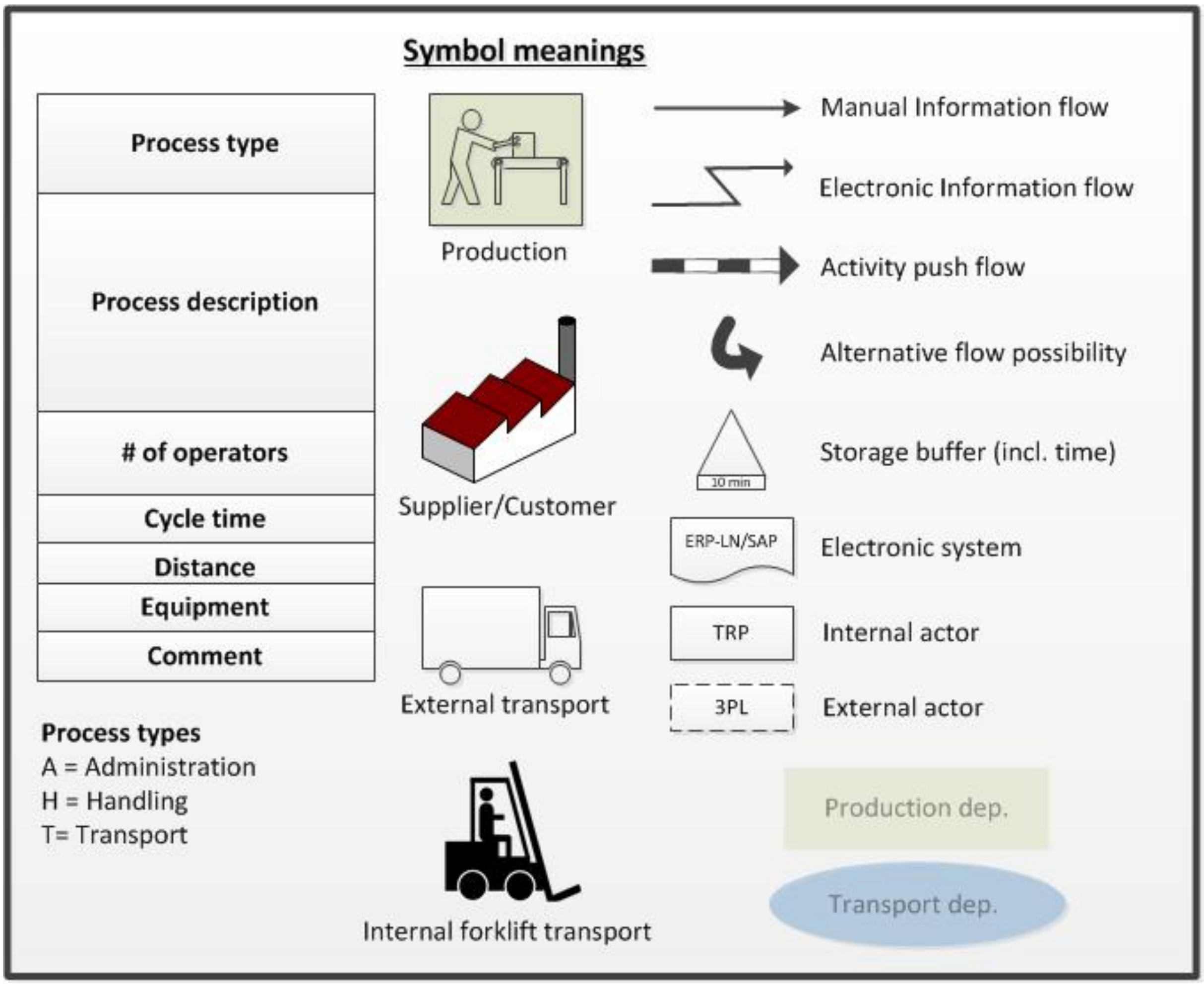
APPENDIX A

Interviews

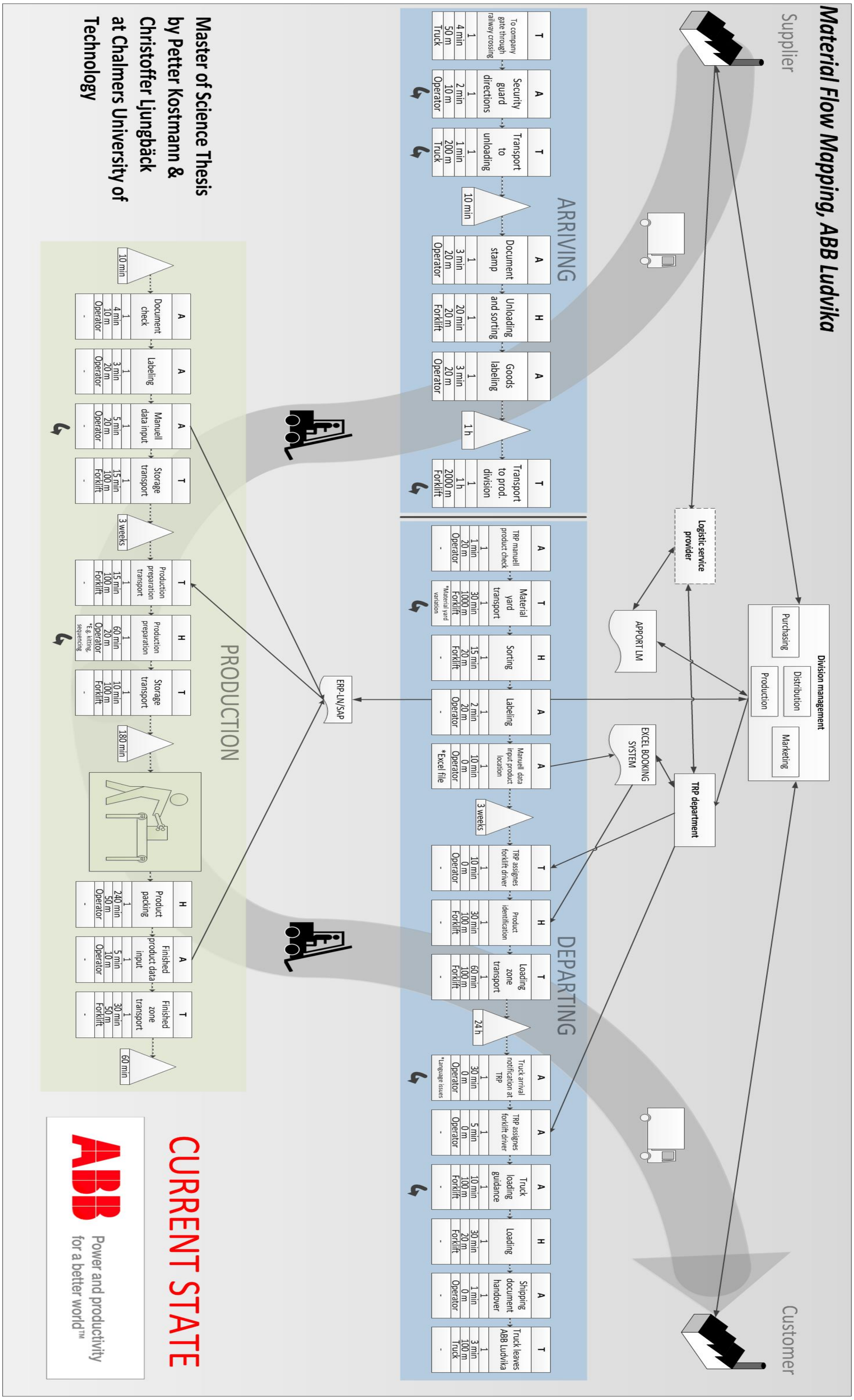
Name	Position	Department	Company	Interview type	Interview date
Andersson, Håkan H	Purchasing manager	Transformers department	ABB, Ludvika	Person-to-Person	16 Jul. 2013
Andersson, Tommy	Freight handling	Transportation department	ABB, Ludvika	Person-to-Person	17 Jun. 2013
Anonymous	Security guard	"Norra porten"	Securitas, Ludvika	Person-to-Person	17 Jun. 2013
Bengtsson, Filip	Project manager	Facility department	ABB, Ludvika	Person-to-Person	15 Mar. 2013, 12 Jun. 2013, 19 Jul. 2013
Bergfeldt, Jan	Distribution manager	HVDC – Systems Distribution	ABB, Ludvika	Person-to-Person	19 Jun. 2013
Ehlin, Conny	Freight handling	Transportation department	ABB, Ludvika	Person-to-Person	19 Jun. 2013
Ek, Mikael	Freight handling	Transportation department	ABB, Ludvika	Person-to-Person	17 Jun. 2013
Graaf, Fredrik	Freight administration	Transportation department	ABB, Ludvika	Person-to-Person	20 Jun. 2013
Grönvold, Linnea	Freight administration	Transportation department	ABB, Ludvika	Person-to-Person	17 Jun. 2013
Hultgren, Anita	Freight coordinator	Transportation department	ABB, Ludvika	Person-to-Person	19 Jun. 2013
Jernberg, Edy	Production manager	Transformers department	ABB, Ludvika	Person-to-Person	18 Jun. 2013
Karlsson, Bengt Olof	Freight handling	Transportation department	ABB, Ludvika	Person-to-Person	17 Jun. 2013
Larsson, Jan	Operation Supervisor	Supply Chain Management	DHL, Göteborg	Person-to-Person	21 Aug. 2013
Malmberg, Anna-Carin	Distribution Manager	Components	ABB, Ludvika	Person-to-Person	17 Jul. 2013
Medbo, Lars	Senior Lecturer	Technology Management and Economics	Chalmers University of Technology	Person-to-Person	7 Aug. 2013
Mäkelä, Kjell	Freight handling	Transportation department	ABB, Ludvika	Person-to-Person	19 Jun. 2013
Mässing, Hans	Production manager	HVDC – Products Production	ABB, Ludvika	Person-to-Person	19 Jun. 2013
Naess, Lars	Freight handling	Transportation department	ABB, Ludvika	Person-to-Person	17 Jun. 2013

Nordahl, Kurt	Department manager	Transport dep. manager	ABB, Ludvika	Person-to-Person	14 Mar. 2013, 12 Jun. 2013
Norman, Gustav	Freight handling	Transportation department	ABB, Ludvika	Person-to-Person	14 Jun. 2013
Shkreta, Vehbi	Terminal manager	Freight	DHL, Borlänge	Person-to-Person	18 Jun. 2013
Westman, Karl-Bertil	Distribution manager	Power Products Distribution	ABB, Ludvika	Person-to-Person	14 Jun. 2013, 20 Jun. 2013
Wikberg, Daniel	Test room manager	Transformers department	ABB, Ludvika	Person-to-Person	16 Jul. 2013
Åsmo, Peter	Supply Chain manager	Power products Supply chain.	ABB, Ludvika	Person-to-Person	14 Jun. 2013

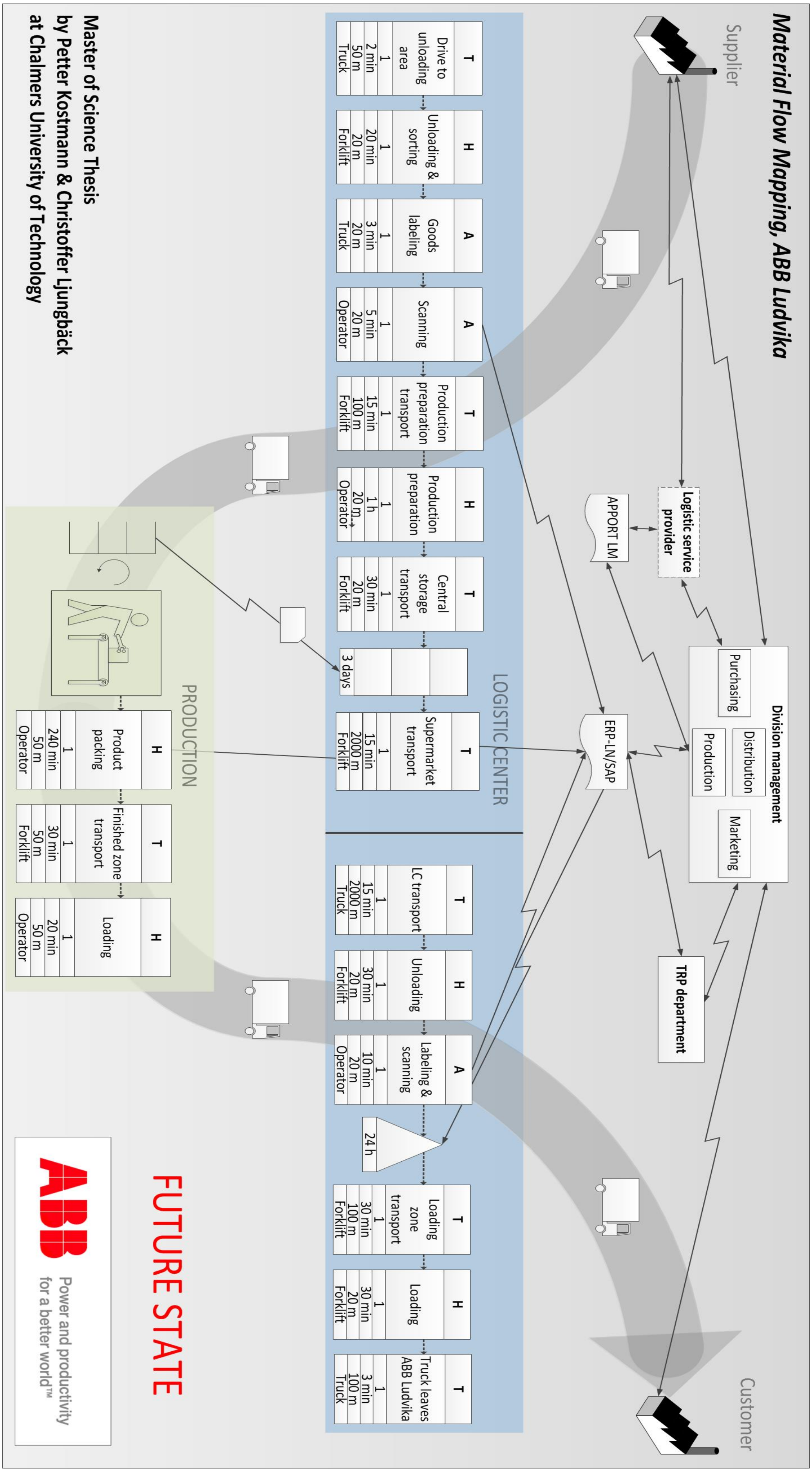
APPENDIX B


Symbol meanings
Process type
Process description
# of operators
Cycle time
Distance
Equipment
Comment
Process types
A = Administration
H = Handling
T= Transport
Production
Supplier/Customer
External transport
Internal forklift transport
Manual Information flow
Electronic Information flow
Activity push flow
Alternative flow possibility
10 min
Storage buffer (incl. time)
ERP-LN/SAP
Electronic system
TRP
Internal actor
3PL
External actor
Production dep.
Transport dep.

APPENDIX C


Material Flow Mapping, ABB Ludvika
Supplier
Customer
Division management
Purchasing
Distribution
Production
Marketing
Logistic service provider
APPORT LM
EXCEL BOOKING SYSTEM
TRP department
ERP-LN/SAP
ARRIVING
T To company gate through railway crossing 1 4 min 50 m Truck
A Security guard directions 1 2 min 10 m Operator
T Transport to unloading 1 1 min 200 m Truck
10 min
A Document stamp 1 3 min 20 m Operator
H Unloading and sorting 1 20 min 20 m Forklift
A Goods labeling 1 3 min 20 m Operator
1 h
T Transport to prod. division 1 1 h 2000 m Forklift
DEPARTING
A TRP manuell product check 1 1 min 20 m Operator -
T Material yard transport 1 30 min 1000 m Forklift *Material yard variation
H Sorting 1 15 min 20 m Forklift -
A Labeling 1 2 min 20 m Operator -
A Manuell data input product location 1 10 min 0 m Operator *Excel file
3 weeks
T TRP assignes forklift driver 1 10 min 0 m Operator -
H Product identification 1 30 min 100 m Forklift -
T Loading zone transport 1 60 min 100 m Forklift -
24 h
A Truck arrival notification at TRP 1 30 min 0 m Operator *Language issues
A TRP assignes forklift driver 1 5 min 0 m Operator -
A Truck loading guidance 1 10 min 100 m Forklift -
H Loading 1 30 min 20 m Forklift -
A Shipping document handover 1 1 min 0 m Operator -
T Truck leaves ABB Ludvika 1 3 min 100 m Truck -
PRODUCTION
10 min
A Document check 1 4 min 10 m Operator -
A Labeling 1 3 min 20 m Operator -
A Manuell data input 1 5 min 20 m Operator -
T Storage transport 1 15 min 100 m Forklift -
3 weeks
T Production preparation transport 1 15 min 100 m Forklift -
H Production preparation 1 60 min 20 m Operator *E.g kitting, sequencing
T Storage transport 1 10 min 100 m Forklift -
180 min
H Product packing 1 240 min 50 m Operator -
A Finished product data input 1 5 min 10 m Operator -
T Finished zone transport 1 30 min 50 m Forklift -
60 min
Master of Science Thesis by Petter Kostmann & Christoffer Ljungbäck at Chalmers University of Technology
CURRENT STATE
Power and productivity for a better world™

APPENDIX D


Material Flow Mapping, ABB Ludvika
Supplier
Customer
Division management
Purchasing
Distribution
Production
Marketing
Logistic service provider
APPORT LM
ERP-LN/SAP
TRP department
LOGISTIC CENTER
PRODUCTION
FUTURE STATE
T
Drive to unloading area
1
2 min
50 m
Truck
H
Unloading & sorting
1
20 min
20 m
Forklift
A
Goods labeling
1
3 min
20 m
Truck
A
Scanning
1
5 min
20 m
Operator
T
Production preparation transport
1
15 min
100 m
Forklift
H
Production preparation
1
1 h
20 m
Operator
T
Central storage transport
1
30 min
20 m
Forklift
3 days
T
Supermarket transport
1
15 min
2000 m
Forklift
H
Product packing
1
240 min
50 m
Operator
T
Finished zone transport
1
30 min
50 m
Forklift
H
Loading
1
20 min
50 m
Operator
T
LC transport
1
15 min
2000 m
Truck
H
Unloading
1
30 min
20 m
Forklift
A
Labeling & scanning
1
10 min
20 m
Operator
24 h
T
Loading zone transport
1
30 min
100 m
Forklift
H
Loading
1
30 min
20 m
Forklift
T
Truck leaves ABB Ludvika
1
3 min
100 m
Truck
Master of Science Thesis
by Petter Kostmann & Christoffer Ljungbäck
at Chalmers University of Technology
Power and productivity for a better world™