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Success factors when ramping up the production and transport coordination between suppliers

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Executive Summary

IKEA is facing increasing challenges due to the required production Ramp-Up within the next years. The fact that the Consolidation Point close to Vilnius is being closed this summer of 2015 requires deeper collaboration with the current suppliers. They need to invest together as well as share previous gained knowledge about production Ramp-Up, especially from internal sources are key.

The 28 suppliers in Lithuania should start to Co-Load shipments in order to raise the transport performances and to cut cost. To do so, two good optimization options are available. Either to Cluster optimize the supplier, which refers to suppliers within the distances limitation of 100 km, or to Off-limit optimize by going beyond this distance limitation and allowing Co-Loads with suppliers outside the limitation.

Over 1500 shipments were studied and the Cluster optimization and the Off-limit optimization methods can reduce the shipments by 7.2% and 8.6% respectively. In parallel the gross volume utilization will increase by 8.5% and 9.4 %. If the management chose to keep the strict distance limitation, the supplier area around Kaunas and the area around Šiauliai must be prioritized. More, the Cluster method facilitates a simple supplier set-up, in contrary a more complex supplier set-up is needed with the Off-limit method. Yet, better performances and more Co-Loads can be achieved with the Off-limit method. The trade off between the two options is close supplier cooperation or cost reductions.

In order to increase the performances in the shipments even more, IKEA should loosen up the distance limitation of 100 km and keep it as an aim instead. The should start working with Co-Loads with suppliers close to Šiauliai and Kaunas and to provide them with clear loading instructions is important for future Co-Loads. Decrease the size of the DWPs and/or produce more top fillers, which allow a more dynamic loading, facilitate lower ordering sizes and reduce stock costs for the suppliers and for IKEA.

Preface

This master thesis was written for the fulfillment of my Master of Science degree in Mechanical Engineering with specialization in Logistics and Production Management at Lund University, Sweden. The thesis was written during a time frame between January 2015 and July 2015 and was a collaboration between the author, Lund University and IKEA.

Acknowledgments

The main part of time spent was at the office of the IKEA Purchase Organization Area North Europe in Kaunas, Lithuania. During the thesis project I have used previously gained engineering knowledge and now I have also enriched myself with new knowledge and techniques.

First, I would like to give Per Birgander and Tord Skoog big thanks for giving me the opportunity to write the thesis together with IKEA and especially in a foreign country. I would like to give a warm hug to all the people at the office in Kaunas, Lithuania, especially to the "Swedish clan" with Christian Johansson in the front and Aurimas Rudzionis, for making me feeling welcome every day during those months.

Throughout the thesis, several people were contributing with valuable input and information, but I would especially like to thank Jurgita Kijauskiene for guiding me and helping me. This also applies for my supervisor from Lund University, Jan Olhager and the supervisor from IKEA, Tord Skoog.

Finally, I cannot thank my family enough for always being supportive and helping me during these years of studies in three different countries.

Samuel Olsson, Lund, July 17, 2015

Abstract

The importance to cut costs and to be as efficient as possible has never been as important as it is today in order to stay competitive in the market. IKEA are currently facing increasing challenges with the production growth due to a high demand from the market and goals for 2020. This large growth will affect the bottom line of the supply chain, the suppliers. The necessary production growth also requires that collaboration with new suppliers is of vital importance in order to meet the demand from the market. Both the current supplier base and new possible suppliers must have the capacity and capability to achieve a production Ramp-Up from one level to another. The purpose for this part of the thesis is to find success factors related to production Ramp-Up that can facilitate the work with current and new suppliers in order to be efficient and cut costs. More production from the suppliers leads to more goods transport between the supplier and the end receiver. Consequently the transportation frequency of goods will be widely affected. Since the current utilization of the unit loads is not yet satisfactory, IKEA would like to investigate the possibilities of performing Co-Loads of shipments with two or more suppliers in order to cut transportation costs. This is the second part of the thesis and the purpose is to find possible supplier set-ups that will enable Co-Loading of shipments so that higher equipment utilization is obtained. The production Ramp-Up and Co-Loading were investigated through literature and interviews, which lead to the following conclusions. To manage a large production Ramp-Up, IKEA should focus on the current supplier base and by a closer cooperation use gained experience from previous suppliers Ramp-Up. Sharing knowledge is beneficial, both for IKEA and their suppliers. At the same time the Co-Loading issue was investigated and the conclusions are that between suppliers it is to a large extent possible to perform Co-Loads. Two different scenarios were studied; Cluster optimization, which is limited by a 100 km distance between suppliers, and Off-limit optimization, which is an observation outside the limitation of 100 km. Both scenarios increased the average volume of the shipments in the loading unit types by 8.5 and 9.4 % respectively. At the same time the number of shipments was reduced by 7.2 and 8.6%.

Sammanfattning

Det har aldrig varit så viktigt att minska kostnader och vara effektiv för att vara konkurrenskraftig på marknaden som det är idag. IKEA står inför stora utmaningar gällande produktionsökning på grund av ökad efterfrågan från marknaden och mål inför 2020. Denna massiva ökning kommer att påverka leverantörer, hjärtat i varuflödet. Den nödvändiga produktionsökningen kommer även att innebära att samarbete med leverantörer och är av större vikt för att möta efterfrågan. Både nuvarande och kommande leverantörer måste ha möjlighet och förmåga att öka produktionen. Syftet med denna del av uppsatsen är att finna faktorer som kan förenkla arbetet med nuvarande och nya leverantörer så att de kan vara effektiva och minska kostnader vid en produktionsökning. En högre produktionsvolym från leverantörerna leder till en ökning av transporten av gods från leverantör till mottagare. Eftersom den rådande utnyttjandegraden i transporten inte är helt tillfredsställande ämnar IKEA undersöka vilka möjligheter som finns för sam-lastning mellan två eller flera leverantörer för att optimera denna utnyttjandegrad och reducera transportkostnader. Detta är den andra delen av uppsatsen vars syfte är att hitta leverantörer som är lämpliga för samlastning så att en högre utnyttjandegrad uppnås. Produktionsökning och samlastning studerades utifrån litteratur och intervjuer. För att hantera en stor produktionsökning bör IKEA fokusera på och investera i nuvarande leverantörer i så hög grad som möjligt samtidigt som en närmare relation är att föredra. Kunskapsutbyte och kännedom från tidigare projekt är också viktigt och gynnsamt för både leverantör och IKEA. Samtidigt analyserades samlastningen mellan leverantörerna och det framkom att samlastning är i hög grad möjlig. Två scenarier togs fram där samlastning kan ske antingen via optimering av de kluster som begränsas av ett avstånd på 100 km mellan leverantörer, eller en optimering som inte tar hänsyn till denna distansbegränsning. Båda visar dock positivt resultat för medelvolymen i de olika transporttyperna med 8.5 och 9.4 % vardera. Parallellt minskas antalet transporter med 7.2 och 8.6 % enheter.

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Abbreviations

3PL	Third Party Logistic provider
CDC	Customer Distribution Center
CP	Consolidation Point
DC	Distribution Central
DD	Direct Delivery
DM	Distance Matrix
DWP	Dimension Weight Package
EQU	Equipment Utilization
FILO	First In Last Out
FTL	Full Truck Load
FY	Fiscal Year
IKEA	Ingvar Kamprad Elmtaryd Agunnaryd
JIT	Just-In-Time
KPI	Key Performance Indicator
LSC	Local Service Center
LTL	Less Than Truck Load
LUT	Loading Unit Type

NPD	New Product Development
PO	Purchase Organisation
POANE	Purchase Operation Area North Europe
RDU	Retail Distribution Unit
RFP	Request For Proposal
RFQ	Request For Quotation
ROI	Return Of Investment
RPN	Risk Priority Number
SCM	Supply Chain Matrix
SPI	Supply Information List
STO	Store
TP	Transit Point
TTM	Time-To-Market
TTV	Time-To-Volume
VBA	Visual Basic for Applications

CHAPTER 1

Introduction

This chapter provides the basics of the thesis in which background information and a short company description are presented. It is then followed up by problem discussion, aim and purpose. Finally, the last part of this chapter covers delimitation, stakeholders and thesis outline.

1.1 Background and Company Description

The dissolution of the Soviet Union in the late 20th century became a turning point for the trading for the countries from the former Soviet Union i.e. Latvia, Estonia and Lithuania. Due to the deep professional knowledge that these countries had gained in the areas of wood, steel and textile, they became more and more important for businesses in Europe. Sweden saw the business potential that rose in the East and the country of Lithuania became one of the most attractive ones.

Today, Sweden is the major investor in Lithuania with a total share of approximately 33 %, according to PricewaterhouseCoopers (2014). This is supported by Sweden (2015) and it is first of all due to the great professional knowledge that exists, but also the fact that the cost of labour is, in comparison to other parts of Europe, much lower. EuroStat (2015) clearly indicates the differences of labour where the average labour cost per hour, measured in EUR is 6,2 in Lithuania and in average in European Union it is 23,7 EUR. However, Lithuania is a economic that is growing stronger and stronger and the engineering industry, where Ingvar Kamprad Elmtaryd Agunnaryd (IKEA) is operating, have been expanding in average with 17 % since 2009, (PricewaterhouseCoopers, 2014).

The supplier base of IKEA is growing bigger for every year and currently IKEA has more than 1030 suppliers in over 50 countries. These suppliers are separated into 25 material areas and 36 different categories with around 9 500 products. Figure 1.1 below, indicates how the range of these products are supplied and each year, more than 30 Million cubic meters of goods are transported between the suppliers and the customers. More than half of the products that are sold in the stores are transported immediately from the suppliers to the IKEA stores, (Holmberg, 2015).

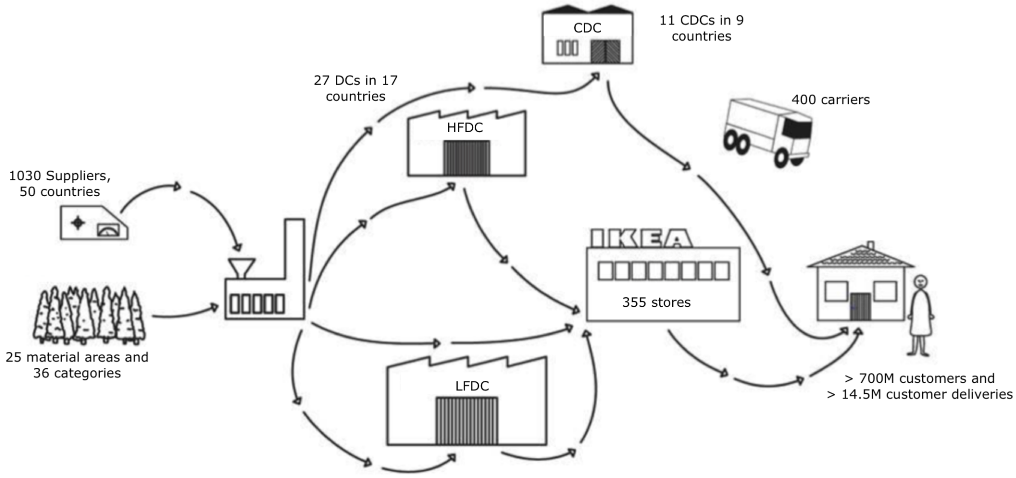


Figure 1.1: How the range of products are supplied, (Holmberg, 2015)

Nevertheless, the market situation today at IKEA can change fast. The range of products is wide and, for example, one product can exist in many different colors and dimensions. In addition to a wide range, new products are developed and the producers, i.e. the suppliers, need to adapt to this fast changing market to meet this demand. This drives IKEA and the suppliers to be efficient throughout the whole supply chain to tackle a fluctuating demand from the market. According to (Holmberg, 2015) IKEA will be facing big challenges within the next years and the goals are to reach 500+ IKEA stores globally and 50 billion EUR in sales in 2020. It requires a huge production Ramp-Up and it will affect the bottom line of the supply chain, which is the supplier.

This growth will impact the suppliers and their production significantly and it cannot be ignored that the Ramp-Up from the current produced volume to a much higher one, is a fact in a couple of years. For many suppliers the base of the range that they are producing is fairly stable. Yet, every year new products are established which forces the suppliers to manufacture the products in a timely manner, with the right quality and at the right cost, with the latter being the main focus. Also new suppliers have to be sourced in order to meet the demand.

The process for developing a new product is well known and is called New Product Development (NPD). NPD consists of different stages, which are described differently depending on which book and author is used. However, Matta et al. (2007), Minderhoud et al. (2005), and Surbier et al. (2014) among many, find that one of the most important phases in the NPD is the Ramp-Up because it is where money and time can be saved. Still there are more important aspects when considering the NPD or the Ramp-Up and according to Glock et al. (2000) and Kampker et al. (1992) a lower Ramp-Up cost can be obtained with the right knowledge among the personnel.

Every industry strives to be more effective and more efficient. By developing the NPD processes and especially the Ramp-Up, costs can be cut and higher profits will be the results.

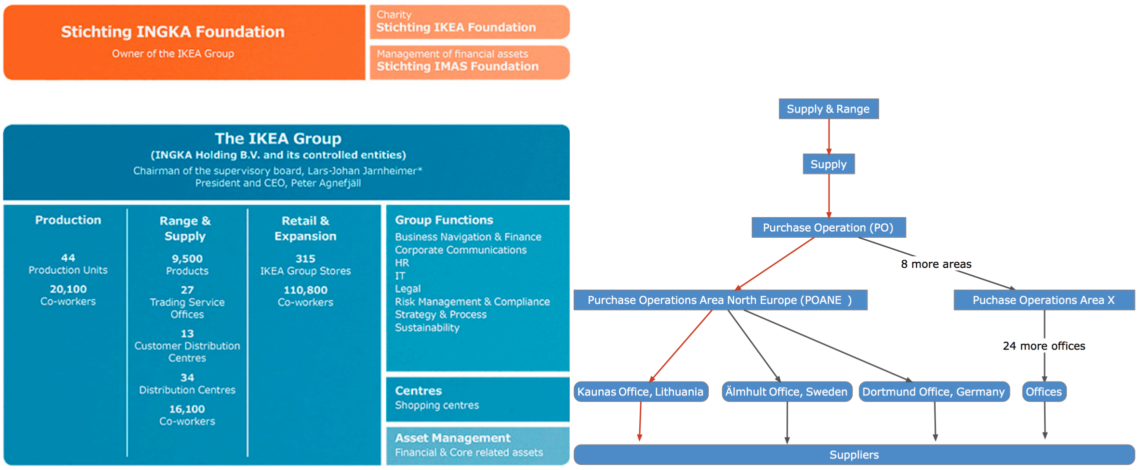
Since the suppliers will have a higher output volume, the need for a good supply chain, and especially good transportation, is vital. In the last few years IKEA has had low utilization of the Loading Unit Type (LUT). Now when the production from the suppliers will increase, so will the transportation. Subsequently low utilization leads to unnecessary costs related to the transportation. If a higher utilization can be obtained much money can be saved.

During the last year, IKEA has been focusing more on the utilization in the transport because it has many beneficial effects, not only related to costs. One of them is the lower pollution of carbon dioxide. This is also high on the agenda for the management at IKEA. The topic of efficiency in the transportation has now been allocated to a new area, coordination of transports between suppliers to lower the transportation costs.

"To offer a wide range of well-designed, functional home furnishing products at prices so low that as many people as possible will be able to afford them"
- Business idea IKEA

IKEA is a home furnishing company founded in 1943 by Ingvar Kamprad at an age of 17 years. Ingvar was born and raised in Elmtaryd in the village of Agunnaryd in Sweden and thereof the company name, (IKEA, 2015a). 1958 the first IKEA store opened in Älmhult, Sweden and since then, more than 355 new stores have opened and IKEA are now operating in over 38 countries all over the world, (IKEA, 2015e). Fiscal Year (FY) 2014 ended up with 28.7 billion EUR in sales and the goals for FY 2020 is to increase the sales to 50 billion EUR, (IKEA, 2015d).

The IKEA Group organization is presented below in Figure 1.2(a) and it is within the Range & Supply that this thesis will be conducted.



(a) The IKEA Group organization **(b)** Simplified chart for Supply organization

Figure 1.2: Organization chart for the IKEA Group

By illuminating the path with a red line, the stakeholders will have a better understanding where the thesis was conducted, and in which part of the organization, see Figure 1.2(b).

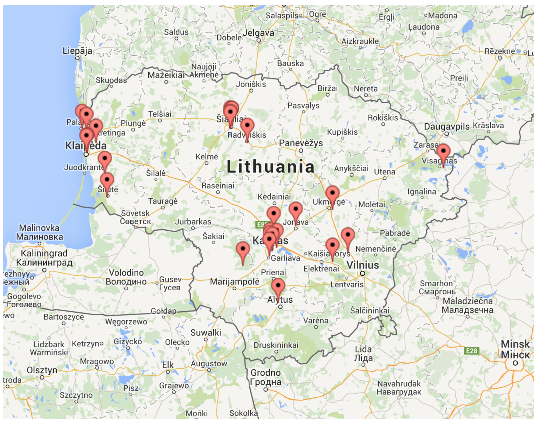
Within Supply there are nine organizations and one is the Purchase Organisation (PO) which is divided into nine areas where each area refers to a part of the world. Their primary task is to support and develop the suppliers on a day-to-day basis. They should also provide products that are available when the customer wants it, with high quality and with the right cost. Purchase Operation Area North Europe (POANE) has three offices located in Kaunas, in Älmhult and in Dortmund. These three offices have around 175 employees and manage 130 suppliers in total, (IKEA, 2015f).

1.2 Problem Discussion

Lithuania is located in the Eastern Europe, see Figure 1.3(a), and POANE has the responsibility of 28 suppliers located in Lithuania, plus a few more located in the adjacent countries and the location of these 28 suppliers can be seen in Figure 1.3(b).

The problem this thesis will address is two-headed. One part will focus on the production Ramp-Up related to the suppliers and IKEA. The second part will focus on the transportation and how to increase the equipment utilization by consolidate shipments between different suppliers.

(a) Location of Lithuania, (Institute, n.d.)



(b) Location of suppliers in Lithuania

Figure 1.3: Location of Lithuania and the suppliers

1.2.1 The Ramp-Up issues

The current set-up for the suppliers in Lithuania works fine but within a time frame of three to four years the production, for some of the suppliers, will increase up to 600 %, according to IKEA's forecasts and goals. This corresponds to a production growth from 1.5 million units to approximately 9 million units. A Ramp-Up of that degree cannot be ignored and consequently questions need to be raised. There are uncertainties on whether suppliers could manage a Ramp-Up of this magnitude and how a positive Ramp-Up can be achieved. One research questions for the Ramp-Up issues was stated:

RQ1: What factors are important when ramping up the production?

1.2.2 The Co-Loading issues

The transportation of the products, from the suppliers to its End Receiver i.e. Consolidation Point (CP)s, Store (STO)s or Distribution Central (DC)s will be affected. The transportation performances are currently lower than expectations from the management due to changes of LUT and suppliers. This leads to unnecessary transportation, extra costs and influences the environment in a bad way and therefore does not revive to the goals according the guidelines stated by IKEA (2015e).

Today, a Third Party Logistic provider (3PL) is managing the distribution of goods from each supplier to its End Receiver by either intermodal transportation with trucks and vessels or only by truck. Most of the transportations are with truck. Intermodal transportation refers primarily to the area around Klaipėda but also, with lower transportation rate, from the area around Šiauliai and the central area around Kaunas. More, only tuck is used for transportation from the central area, around Kaunas, and the area close to Šiauliai for transportation abroad. Also here, two research questions were stated:

> RQ2: Are there possibilities for coordination of transport between suppliers in order to increase the Equipment Utilization?
> RQ3: Which suppliers have the best opportunity to perform Co-Loads?

1.3 Objectives

- State what is important for the suppliers and for IKEA, when ramping up the production
- Investigate the suppliers for finding possible Co-Loads
- Find set-ups for the suppliers to increase the Equipment Utilization
- Show calculations and results of the Co-Loads
- Recommend IKEA how to increase the Equipment Utilization

1.4 Purpose

The purpose is to identify importance factors when ramping up the production and, at the same time, develop a suitable transport set-up, for some of the suppliers, so that a higher Equipment Utilization[1] will be obtained.

1.5 Focus And Delimitations

The Ramp-Up issue will focus on providing the host company with relevant facts for how to manage the Ramp-Up between the buyer (IKEA) and the suppliers from two levels, strategically and tactical level.

The Co-Loading issue will be narrowed down due to the time limitation of the thesis (20 weeks). It is also of high importance that the delimitation of suppliers will not affect the other suppliers in a negative manner. In other words, the investigation must have an overall perspective so that it will not be a sub optimization of a specific supplier.

Aspects such as loading restrictions, country specific regulations are excluded, as well as agreements between suppliers in order to perform Co-Loads. Also only shipments from the suppliers to their End Receiver (final destination) are considered due to the high complexity if distribution centers, consolidation points etc. are included.

1 Internal transportation measurements

1.6 Stakeholders

There are a number of stakeholders for this thesis who have a great interest in understanding and knowing about these topics. The Ramp-Up issue will be of most concern for IKEA's Technicians, Production Developers and their managers. Moreover, the suppliers will have an interest since it can affect their profit widely.

The second issue, the Co-Loading, is of great interest for the Transportation department, Business Developers, Supply Planners and the Logistic Department since it is related to shipments and transports.

Lastly, other stakeholders are supervisors from the university and the host company, together with other companies who are facing a big Ramp-Up within the next few years, as well as companies with many local suppliers with high transport frequency.

1.7 Thesis Outline

Chapter 1 Introduction

This chapter provides the basics of the thesis in which background information and a short company description are presented. It is then followed up by problem discussion, aim and purpose. Finally, the last part of this chapter covers delimitation, stakeholders and thesis outline.

Chapter 2 Methodology

This chapter gives insight about the different research approaches, strategies and their characteristics. Followed up by the classification of data, how to collect it and how to analyze it. The two last sections enlighten the reader about the trustworthiness of the data and finally the chosen research path for this thesis.

Chapter 3 Theoretical Framework: Ramp-Up

This chapter consists of the theoretical framework regarding the phenomenon Ramp-Up. It covers how Ramp-Up is related to the New Product Development process and Ramp-Up definitions and characteristics. Moreover, several sources from secondary data regarding Ramp-Up from different angles are described.

Chapter 4 Theoretical Framework: Co-Loading

This chapter consists of the theoretical framework for the phenomenon Co-Loading. It gives insight about how the physical transport is performed in three general delivery/pick-up methods.

Chapter 5 Empirical Data: Ramp-Up

Empirical information collected from primary data together with non-published sources covering the issue of Ramp-Up, is presented in this chapter.

Chapter 6 Empirical Data: Co-Loading

This chapter consists of empirical data collected from the host company. Here it is highlighted how the suppliers have been investigated. The transport of goods is explained as well as how the current physical distribution is managed. Last, how the Co-Loading process is managed with measurements and examples is explained.

Chapter 7 Results: Co-Loading

This chapter consists of calculations and results based on previous chapters regarding the phenomenon Co-Loading. First the suppliers are divided into clusters. Then two scenarios are used to illuminate the possibilities to perform Co-Loads. Last, information gathered from current and previous chapters determines the best supplier set-up for one cluster and one supplier.

Chapter 8 Analysis: Ramp-Up

This chapter integrates the theoretical and empirical data of the phenomenon Ramp-Up. The chapter is divided into two subsections, which describes the success factors from two levels, Strategic- and Tactical Level.

Chapter 9 Analysis: Co-Loading

In this chapter the key for performing Co-Loads and thereby increasing the Equipment Utilization is described as well as how to increase it even more by performing changes.

Chapter 10 Conclusions

The last chapter states the recommendations to the host company related to both the Ramp-Up issue and the Co-Loading issue. A brief implementation plan for the Co-Loading issue is also presented as well a discussion.

CHAPTER 2

Methodology

This chapter gives insight about the different research approaches, strategies and their characteristics. Followed up by the classification of data, how to collect it and how to analyze it. The two last sections enlighten the reader about the trustworthiness of the data and finally the chosen research path for this thesis.

2.1 Research Approaches

There are two general research approaches, inductive (qualitative) and deductive (quantitative), where each of them is suitable for different types of research. Sometimes the use of one approach is not sufficient to obtain necessary outcomes or results. Thus, one more approach exists, the abductive (mixed) approach, which is a mix between the inductive and deductive approaches. It gives the researcher an extra spectrum to combine the strengths from each approach. These three approaches are described below.

2.1.1 Inductive approach

The inductive research approach, or qualitative research approach, is used when the researcher has to take his opinion into account after considering the collected data, (Kothari, 2009). More, Saunders et al. (2009) summarizes the major differences between the inductive and the deductive approaches, where an inductive approach needs a closer understanding to the phenomenon that is being investigated. It also requires a more flexible structure that allows changes during the research. Typical data collections for inductive approach are methods that are non-numerical ones, for example, interviews, movies or observations, (Saunders et al., 2009).

2.1.2 Deductive approach

In contrast to the data collection methods for the inductive approach, the deductive approach is typically numerical. The data is normally collected from questionnaires, statistics or databases, Kothari (2009). Characteristics of the deductive approach or commonalty speaking, quantitative research is enumerated by Saunders et al. (2009) and emphases a highly structured way of pursue the research. Moreover, they declare that it is important to explain relationships between variables. They conclude that this approach is more scientific than the inductive approach.

2.1.3 Abductive approach

The abductive research approach is also called the mixed approach and is a rational research approach where the researcher uses both the inductive and the deductive method, for collecting and finding data. Creswell (2003) states that this mixed approach does not require that the data collection is performed at a single occasion, instead data preferably should be collected simultaneously throughout the research.

2.2 Research Strategies

There are different strategies to use to certify that the research will end up with satisfactory in terms of outcome. Saunders et al. (2009) highlights seven types of research strategies that could be used, and are appropriate for different occasions. In addition, Seuring et al. (2005) describes a more narrow range of strategies, which are more suitable for supply chain management, ending up with five strategies. Kothari (2009) describes some of the strategies that Saunders et al. (2009) and Seuring et al. (2005) mentioned. Below seven strategies are described.

2.2.1 Experimental

Saunders et al. (2009) describes the method as a study for finding possible correlations between two or many different objects. In general, hypotheses are stated at an early stage, which means that you guess the outcome. Hypotheses are predictions that the research is meant to answer whether they are true or not. It often results in a statistic analysis where the hypotheses are accepted or rejected depending upon correlation between the collected data. The data consists of a sampling of a population, which can be collected at random, or collected carefully, depending on the type of research and existing population. Experimental research is recognized by the high control of the research variables and is therefore typically used in laboratories.

In addition, Kothari (2009) describes that an equal sign between experimental studies and hypothesis testing research could be drawn. Because generally speaking they mean the same thing. If the research is performed well, it is a very powerful method for drawing conclusions about previously unclarified assumptions.

2.2.2 Survey

This research strategy is used when a large amount of data should be collected from many respondents. The respondents are normally people who answer questions or are participants of a structured observation, (Saunders et al., 2009).

More, Kothari (2009) states that it is a highly descriptive research strategy often used in the social science areas where the researcher has no influences on the outcome of the answers. He or she can only observe the answers and summarize them by using statistical methods and thereby draw conclusions about the investigated phenomenon.

In addition, Saunders et al. (2009) finds that it is a deductive method, i.e. a quantitative method where the data can be collected with different techniques, such as interviews, mailed questionnaires, or general questionnaires.

Lately, the use of questionnaires has grown due to online possibilities, which simplifies the data collection process and allows opportunities to reach a broader set of people. In general the online programs are easy to use, and since their existence give the possibility of dynamic questionnaires, making them a very powerful tool. Nevertheless, if the survey consists of many respondents and dynamic complexities, analyzing the data can be very time consuming, (Olhager, 2015)

2.2.3 Case study

A case study is a deep investigation or observation of a defined phenomenon. Case studies are seldom used in control groups, which forces the researcher to promote his or her own opinion. Even though the phenomenon is a single observation that should be investigated, it is common to use several different sources to collect the data, called triangulation. Thus, the problem, i.e. the phenomenon, could be examined from different views and consequently be more accurate and holistic, (Saunders et al., 2009).

2.2.4 Action research

The action research is a strategy to use for exploring an existing problem. A problem that could be specific or general, and existing in an industry or an organization, Kothari

(2009). To tackle the problem, Saunders et al. (2009) highlights the action research spiral. This is a technique that aims to solve the problem by an iterative method that repeats itself until satisfaction is obtained. The technique starts with defining the context and purpose and then the four phases begins. The first phase is *diagnosing*; finding facts and analyzing them. This phase is the foundation for the second phase, *planning*, in which planning the research is the objective. It is followed up by phase three, *taking action* i.e. doing something to solve the problem. The final phase is the *evaluation* where the process and the outcome are evaluated. If the outcome is not sufficient enough, the researcher can restart from phase one and go through the process again until satisfied.

2.2.5 Grounded theory

Is an inductive approach but can also be seen as an abductive approach. The method requires the researcher to collect and analyze data while reading and developing the theory. Also, the data should be presented at a conceptual level in order to draw well-founded conclusions. This is a strategy for the researcher to develop a self-critical approach for the data, (Saunders et al., 2009).

2.2.6 Archival research

Archival research is a strategy where existing data i.e. secondary data is investigated. A well-known problem for archival research is that no new data can be extracted. A typical researcher using this strategy is an historical researcher, where the researcher observes existing data, (Saunders et al., 2009).

2.2.7 Modelling

Modelling or in other words, quantitative strategy is, according to Olhager (2015) a highly structured method that is mainly used in the areas of mathematical modelling and simulations researches.

2.3 Research Questions

More, Saunders et al. (2009), Seuring et al. (2005), and Yin (2007) defines questions that should be raised for the different research strategies. These strategies and correlated questions that are appropriate to ask, when conducting the research are presented below in Table 2.1.

Table 2.1: Research strategies and corresponding questions

Research	Research questions	Mentioned by
Experiment	How, why?	(Saunders et al., 2009; Seuring et al., 2005; Yin, 2007)
Survey	Who, what, where, how many, how much?	(Saunders et al., 2009; Seuring et al., 2005; Yin, 2007)
Case study	How, what, why?	(Saunders et al., 2009; Seuring et al., 2005; Yin, 2007)
Action research	How	(Saunders et al., 2009; Seuring et al., 2005)
Grounded theory	N/A	
Archival research	Who, what, where, how many, how much	(Yin, 2007)
Modelling	N/A	

2.4 Data Collection Types

There are two types of data collection types, primary and secondary. Primary data is data that does not exist before the researcher has collected it. On the other hand, secondary data already exists and is collected from sources by the researcher, (Saunders et al., 2009). Below, both data collection types are described in more detail and typical examples of data that is referred to each type, is presented.

2.4.1 Primary data

Primary data is data that is collected for the first time by the researcher, meaning that this data then cannot be found anywhere before collecting it. The three most used data collection methods for primary data are described by Kothari (2009), and these three are:

- Observation
- Interview
- Questionnaires

Observation

Observation method contains of two main different observation methods, the first one, structured observation is, according to Saunders et al. (2009), quantitative and Kothari

(2009) points out that the most appropriate area for using this method is in descriptive studies.

Next, the second method for observation is qualitative and refers to the participant observation, where the role of the researcher is important. Saunders et al. (2009) describes two different roles where, the researcher takes part in the activity, or just where they observe the activity. In addition, the researcher can either reveal his identity or not. The role the researcher takes is depending on the topic of the research and if the participation should be preserved or not.

Interview

The interview method can be divided into two parts and according to Kothari (2009) these two techniques are either by a personal interview or by phone. Using the phone makes the interview method more trivial than the other two due to the simplicity. However, the questions in an interview are more than likely structured beforehand, for preparation purposes, and so that the correspondent knows what type of questions will be asked. Saunders et al. (2009) goes deeper into how the interview can be conducted, see the hierarchical tree in Figure 2.1.

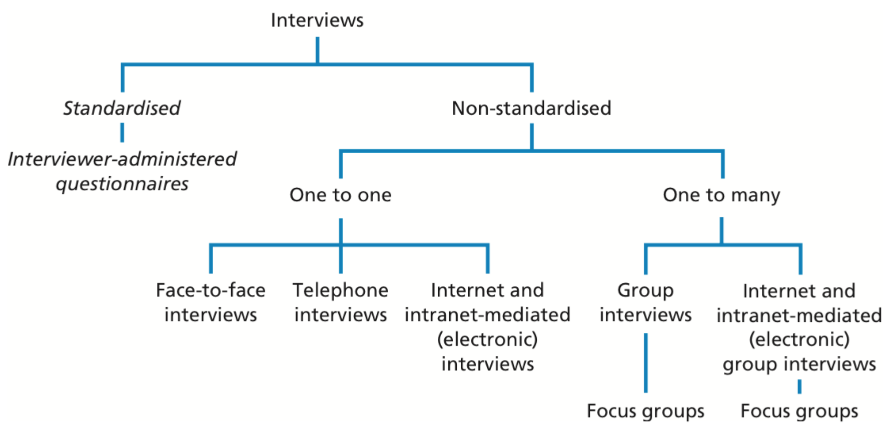


Figure 2.1: Collecting data with interviews, (Saunders et al., 2009)

The most used interviews are non-standardized interviews, which primarily refers to Face-to-face interviews and telephone interviews.

Questionnaires

Finally the last primary data collection method is questionnaires. Figure 2.2 presents how different questionnaires could be collected.

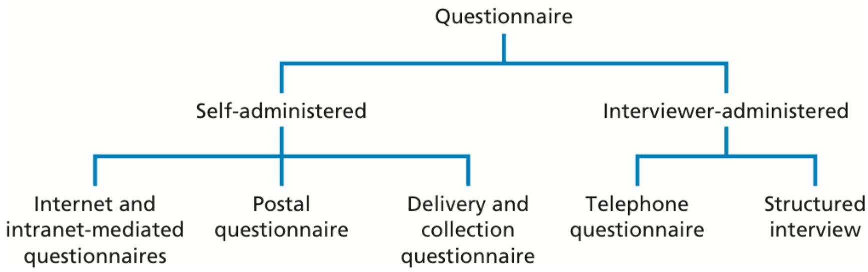


Figure 2.2: Collecting data via questionnaires, (Saunders et al., 2009)

The most common questionnaires are today managed online due to the great simplicity. However, both telephone questionnaires and postal questionnaires are also used but with a lower frequency.

2.4.2 Secondary data

Secondary data is data that already exist and published somewhere. It is necessary to pay attention and to be extra careful, when collecting this type of data. There is a risk that the data is not trustworthy, not collected in an objective manner, reliable or valid, (Kothari, 2009). The trustworthiness will be described further in section 2.6.

More, data from companies or organizations can be difficult to obtain. This may be due to the confidentiality that may occur in some companies in order to protect information from being leaked to competitors.

Kothari (2009) suggests that secondary data can be of two types, raw data or compiled data. Raw data is data that is not changed or where very little has changed, while the compiled data is data that is processed from the original. Typical compiled data could be, sorted, summarized or changed in any matter.

Saunders et al. (2009) presents that the secondary data can be divided into three main categories:

- Documentaries
- Multiple Sources
- Surveys

These categories include data that can be both qualitative and quantitative and can be collected from different sources. Saunders et al. (2009) also presents a hierarchical map of different categories of secondary data and shows different collecting examples, see Figure 2.3.

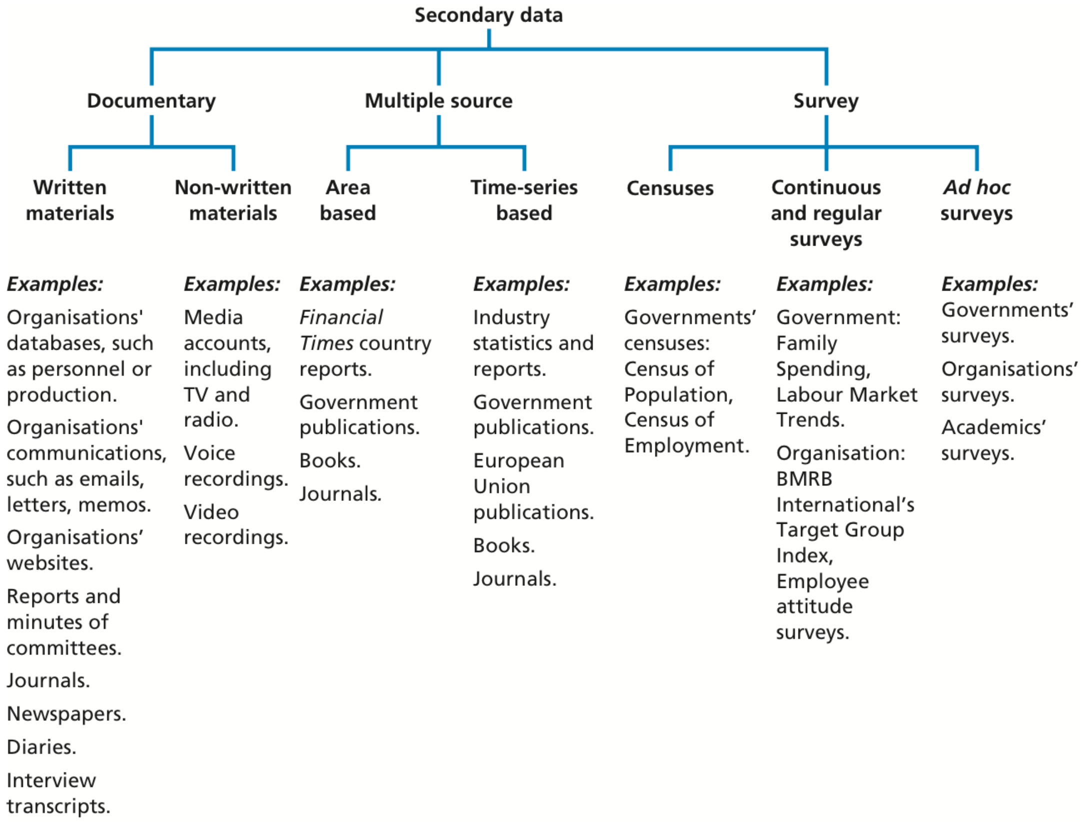


Figure 2.3: Methods for collecting secondary data, (Saunders et al., 2009)

2.5 Analyzing The Data

In the subsections below, the analyzing of quantitative and qualitative data is described.

2.5.1 Analyzing quantitative data

Processing the collected quantitative data into more user-friendly data is essential in order to reach, and eventually present, reasonable results. Therefore many good techniques exist to process the data and many of these techniques are related to statistical programs, (Saunders et al., 2009). They stress the importance of being structured and organized when collecting, configuring and presenting the data. Another important aspect is to always look at the data with critical eyes so that the risk of processing bad and biased data will be reduced.

2.5.2 Analyzing qualitative data

Qualitative data is more difficult to process since it is non-numerical and it allows the researcher to build a theory, based on the data. The gathered data may be of complex nature, and in general the data will need to be summarized, grouped or reconstructed so that the data can be presented in a meaningful way, (Saunders et al., 2009).

2.5.3 Differences between quantitative and qualitative data

By presenting Table 2.2 below, the differences between the qualitative data and the quantitative data are illuminated.

Table 2.2: Distinctions between quantitative and qualitative data, (Saunders et al., 2009)

Quantitative data	Qualitative data
Based on numbers	Based on words
Results in numerical	Results in non-standardised data
Standardised data	Requires classification
Analyzed by diagram, statistical methods etc.	Analyzed by conceptualization

In general, quantitative data is collected from numbers while the qualitative data is collected from words. The collected quantitative data will end up in standardized results and the qualitative data must be classified and organized. Finally the analysis is conducted, where the quantitative data will be analyzed through statistics or diagram. In addition, the qualitative data are analyzed through the use of conceptualization, (Saunders et al., 2009).

2.6 Trustworthiness

Throughout the thesis data have been collected from both primary data and secondary data. To ensure that good data has been collected, the author has primarily used acknowledged sources for the data collection for the theoretical parts of the thesis. Most of the articles have been collected from databases, which are available for students from Lund University. The following databases were used during the thesis to find information: Science Direct, JSTOR, Emerald, Elsevier and Web of Science. The mentioned databases are labeled as high quality, and are considered and acknowledged by a committee of professors, peer-reviewed, before being published.

2.6.1 Key Words

The key words used to find data related to the Ramp-Up was a mixture/or of a single search with the following words: Ramp-Up, New Product Development, NPD, Scale, Production, Increase, Time-To-Market, Time-To-Volume, Process, Management, Risk, Supplier, Involvement, Cost, Savings.

Key words used for the transport issue: Increase, Utilization, Performance, Transport, Management, Distribution, Techniques, Fill Rate, Coordination, Co-Loading, Joint, Collaboration, Suppliers.

2.6.2 Validity

Saunders et al. (2009) describes validity as how the findings are used and what they are about. Validity establishes whether the sources and data that are used in the research reflect what the researcher is searching for. Yet, there are threats to validity, such as bad contribution from the test population. Another threat is that persons or tests cannot be performed due to dropout of personal or restrictions from a company.

2.6.3 Reliability

Reliability, in the context of research, can be referred as the extent in which data techniques are used in research to yield consistent findings, (Saunders et al., 2009). According to the same authors, there are three main issues related to reliability. The first one is associated with subjects, or participant's error, which can occur if data collection is pursued at the wrong time. As an example Saunders et al. (2009) suggests that a questionnaire will give different results on Monday mornings and Friday afternoons, than on other days, due to the lack of concentration and human error. The second issue is the subject of participant bias. Meaning that lack of honesty or misleading answers can be given to the researcher. The third issue is the observer's error, which is the result of the researcher misleading the subject, or giving leading questions. The last issue is observer bias, which is related to the researchers interpretation of answers.

2.6.4 Objectivity

The knowledge of the author comes from previous education and previous professional experiences, which has been an asset when writing the thesis. Knowledge combined with the collected data and the external sources used, make the author responsible in terms of objectivity in the conclusions drawn. To ensure that no personal opinion, tampering with data, or misunderstandings of interviews or any data collection, the author presented the documentation and data with a corresponding person, or third party, for authorization. An example of this is when an interview was conducted the results, in terms of documentation, were presented to the participant to guarantee the reliability and validity, so that the interpretation was correct.

2.7 Chosen Research Path

By following a certain method, the thesis can be separated into smaller, more manageable parts. It is beneficial to follow a proven method for how to conduct research the correct way. Saunders et al. (2009) suggests that planning the time carefully is important for secure that the tasks will not end up with shortage of time, especially the literature search, which could be very time consuming. The planning part should be outlined before starting up the thesis. In general a Gannt chart is a good option to visually when each task will start and end. More, deadlines could be illuminated which will provide the stakeholders with a clear view of the procedures of the thesis. Thus, approaching a thesis of this scope correctly are essential for secure that the questions will be answered accurately.

The most suitable research strategy for this particular thesis, of the seven strategies discussed in section 2.2, is the Case Study strategy. The reason for this is that two phenomena, *Ramp-Up and Co-Loading* were identified and will be investigated further. The single case study type was selected for both of the phenomena, which enables a greater depth of the studies but has a limit on generalizability of the conclusion.

Several sources were used to secure that the phenomena were covered from many different aspects. Moreover, the abductive approach was used since all data could not be gathered initially, instead it was an ongoing process in which data was evaluated and examined throughout the thesis.

2.7.1 Sources

Data collection of secondary data is mainly related to articles and books were articles were mainly collected from the sources labeled in section 2.6.

Throughout the thesis, primary data has been collect through several sources. One source that continuously has been used is the non-standardized interview method, which primarily consisted of day-to-day conversations with colleagues and co-workers. Interviews with open questions, brainstorming and discussion were also used. More primary data was collected from participation in meetings, discussions at supplier meetings, phone calls and through mail correspondence. The following sets of persons with corresponding titles have been taken an active participation in above mentioned data collection methods, see Table 2.3.

Table 2.3: Involvement of persons and connected phenomena

Person	Title	Discussed phenomena
Jurgita Kijauskiene	Supply Developer	Co-Loading
Tord Skoog	Business Development Manager/ Site Manager	Co-Load and Ramp-Up
Darius Jucys	Production Developer	Ramp-Up
Lukas Liepis	Technician	Ramp-Up
Britt-Marie Jonsson	Technician	Co-Load and Ramp-Up
Lars-Åke Adaktusson	Supply Planner	Co-Load and Ramp-Up
Carl-Erik Silow	Operations Developer	Co-Load
Egle Velykyte	Supply Planner	Co-Load
Ida Göransson	Transport Business Developer	Co-Load
Mantas Jurgutis	Supply Planner	Co-Load
Magnus Nilsson	Transport Planner	Co-Load

The wish of anonymity among the involved persons so that specific statements should not be possible to track to a person, was accepted by the author and the host company. Therefore, in this thesis, the author together with the persons involved, decided that no citations will occur related to any persons statement.

Hence, other information sources have been used for collecting written, but non-published data. In this sentence it is data, which cannot be find in any official records. It refers mainly to secondary data in terms of internal documents from the host company, IKEA.

2.7.2 Thesis Structure

The structured way to perform a master thesis and its process are described by Regnell et al. (2008) in a short conference paper. They stress the importance of conducting the thesis in steps to secure the quality and the outcome. Below, in Figure 2.4 the process, adapted from the original from Regnell et al. (2008), is illuminated. It was this process that was followed during the thesis.

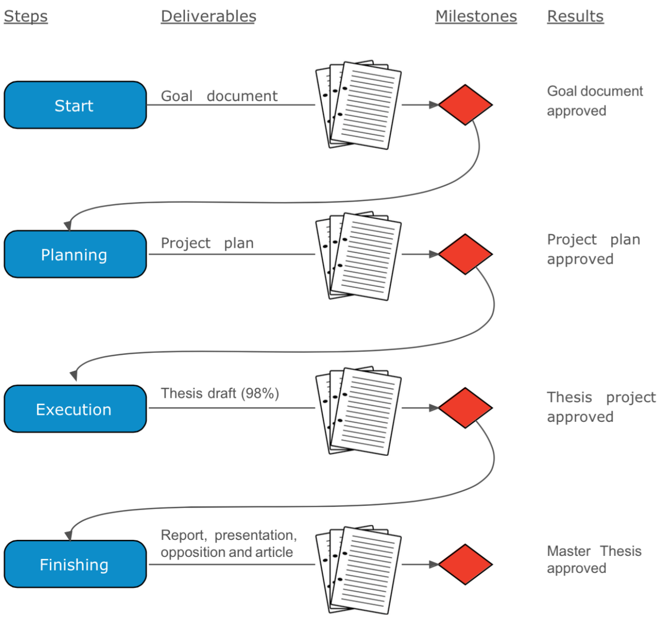


Figure 2.4: The process of a thesis, (Regnell et al., 2008)

After getting the approval to conduct the thesis with the host company, a goal document was written and approved. It consisted of general thesis information as well as practicalities. Around three weeks into the thesis the project plan was written and consisted of a in-depth description of the thesis, purpose and the predicted outcome. This part especially covers a Gantt chart, which illuminates the master thesis plan. Figure 2.5 shows that the thesis was divided into three parts.

In Figure 2.4, the execution part ended with a thesis draft, also called a 98-per-center containing an almost finished thesis. The last part ended with an article related to the thesis project, the fulfillment of the thesis, the presentation, and the opposition of another group.

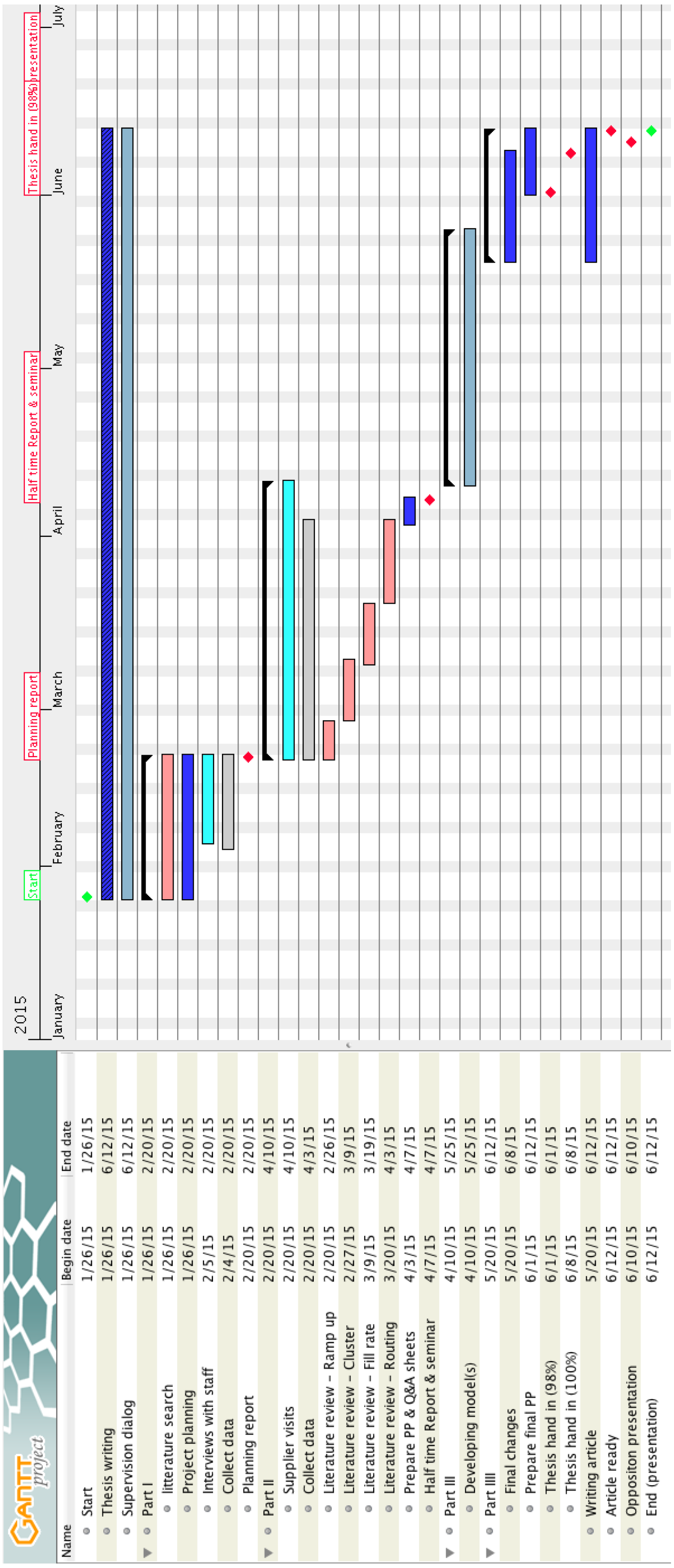


Figure 2.5: The project plan

CHAPTER 3

Theoretical Framework: Ramp-Up

This chapter consists of the theoretical framework regarding the phenomenon Ramp-Up. It covers how Ramp-Up is related to the New Product Development process and Ramp-Up definitions and characteristics. Moreover, several sources from secondary data regarding Ramp-Up from different angles are described.

3.1 New Product Development Process

During the last decades, companies in the manufacturing industry have been more enlightened regarding cost efficient manufacturing. A manufacturer always strives to lower the costs in the manufacturing process to be more competitive in the market. One major cost is the NPD, which is described by Ulrich et al. (2008) as a five-phase process which begins with phase zero, see Figure 3.1.

The *Planning* phase is the phase in which the general strategy is stated and possibilities are illuminated in regards to the market. Phase zero should result in a mission statement that specifies the targeted market, defines business goals, purposes and limitations.

In phase one, *Concept Development*, the demand from the market is identified together with alternative product concepts. A concept is a description of the form of the product that is knowledgeable for that specific product and is often used together with product specification. The concepts are evaluated and new possible concepts are taken into account for further investigation and concept tests.

System Level Design is the third phase consisting of definitions of the product such as the architecture, parts and components. The assembling of the product system is normally specified in this phase. The outcome from this phase is the geometrical layout and its' functionalities, which are clearly specified before entering the third phase.

The third phase is *Detail Design*, an in-deep specification of the product, covering all the areas such as geometry, material and parts that must be purchased from suppliers. The final documentation in this phase is drawings, tool description, manufacturing, assembling specifications. But also the most critical aspects, production costs and performances.

Figure 3.1: New Product Development Process, (Ulrich et al., 2008)

Phase four, *Testing and Refinement* is a period in which the product is tested and possible product improvements are made. Prototypes are manufactured and tested to the extent that the certain specifications are met. The first prototypes are usually called alpha types, and then when all conditions are met, beta types are tested internally by specialists and externally by customers. The objective in phase four is to illuminate necessary improvements to be made for the final product.

The last phase, is the *Production Ramp-Up* and is by far the most critical phase. It is in this phase the product is launched into regular production. This includes training the personnel and the elimination of problems that still exists. During this phase the volume increases until the right volume is obtained. However, it is here where problems easily can occur, which could be devastating for the company.

Surbier et al. (2014) describes that there are several vital aspects to take into consideration during the Production Ramp-Up phase. The four most important aspects are described further. *Time*, in terms of entering the market for the first time is crucial, especially in the high-tech industry where the lifecycle of the products are getting lower. By launching the product late, profits may be lost due to lower market share. C. Terwiesch et al. (2001) points out that the product, in an early stage at the market, can generate higher revenue due to a decline of the price of the product over time. In some industries the prices are declining 20-50% per year, which makes the difference of entering the market quickly, fundamental for maximum profit and revenue.

The next aspect is *Costs*, which is mainly related to the product launch and the Ramp-Up phase is considered as the major cost driver. Surbier et al. (2014) also states that research has revealed that among the best performing firms, up to 49 % of the sales are directly related to the introduction of new products.

Hence, the *Complexity* is due to products growing, the main reason being low life cycles and outsourcing, pushing the supply chain to be more complex. The outcome of the Ramp-Up is highly related to how well integrated the supply chain has managed to become, (Surbier et al., 2014). Furthermore, C. Terwiesch et al. (2001) describes the complexity as a growing trend towards the higher tolerances of products and techniques in the manufacturing.

The final vital aspect is the *Uncertainty* because, in many cases, the whole set-up is new in terms of supply chain and production systems. This leads to difficulties in predicting the yield and outcome.

In addition to the already mentioned aspects C. Terwiesch et al. (2001) argues that the importance for fast production Ramp-Up will decrease the payback time and has a positive effect on the Return Of Investment (ROI). However, to be able to get a satisfactory payback time and ROI, the volume and the quality for the product must be met, in time. C. Terwiesch et al. (2001) takes it one step further and says that the introduction of new products quickly into the market is more of a general rule than an exception.

3.2 Definitions Of Ramp-Up

Many authors define the Ramp-Up differently depending on the area of research or delimitations, but yet they are agreed that Ramp-Up is a part of the NPD process. Below are some definitions of the production Ramp-Up existing in the literature:

- Christian Terwiesch and Bohn (2001) - *"The period between completion of development and full capacity utilization"*
- Fjällström et al. (2009) - *"Production Ramp-Up is the initial period of commercial production, when product development should be finished"*
- C. Terwiesch et al. (2001) - *"The period when the normal production process makes the transition from zero to full-volume production, at or near the targeted levels of cost and quality"*
- Kampker et al. (1992) - *"The term production Ramp-Up describes the phase in product and production development processes, in which the prototype production is converted into the series production"*
- Koren et al. (1999) - *"The time interval it takes a newly introduced or just reconfigured production system to reach sustainable, long-term levels of production, in terms of throughput and part quality, considering the impact of equipment and labor on productivity"*

- Krüger et al. (2010) - *"The term Ramp-Up is the transition from product development to a mass production process"*

As recognized of the definitions above, the Ramp-Up is mostly defined in the NPD process where the process starts from scratch. The literature lacks the explanation of production Ramp-Up from current steady volumes to new higher volumes.

3.3 Production Ramp-Up Process

The production Ramp-Up is the last phase, illuminated in red in Figure 3.1, in the NPD process described in section 3.1.

There are two types of production Ramp-Ups. The NPD production Ramp-Up and Ramp-Up of the existing production. There are many sources explaining the NPD production Ramp-Up but on the contrary the Ramp-Up of the existing production is poorly covered in the literature. Yet, similarities can be drawn from the literature of NPD Ramp-Up since it is addressing the phenomena Ramp-Up and several familiar terms are equivalent. These terms are:

- Time-To-Market (TTM) are mentioned by Carrillo et al. (2004), Surbier et al. (2014), and Christian Terwiesch and Bohn (2001) as the time between the decision for producing a new product until this product is launched on the market for the customers.
- Another important term is the Time-To-Volume (TTV) which is related to the time between the decision for producing a new product until the right volume is obtained, (Carrillo et al., 2004; Surbier et al., 2014; Christian Terwiesch and Bohn, 2001).
- The last term is mentioned by Christian Terwiesch and Bohn (2001) as the Time-To-Payback which refers to the time it takes to meet the financial goals of the product.

Dissimilar descriptions of production Ramp-Up's consists of different stages during the life cycle of the product. There are several authors describing these stages and Carrillo et al. (2004) describes a five stage model which include the introduction, growth, maturity, saturation and decline of a product. Whereas Minderhoud et al. (2005) only mentions three steps in their product life cycle stages; embryonic, growth and maturity. In addition, Matta et al. (2007) also presents a three stage model; installation & setup, Ramp-Up, and regular production capacity. Another example is presented by Surbier et al. (2014), and they highlights a four stages model; development, Ramp-Up, maturity and decline.

Finally, Pufall et al. (2012) states a two stage model, Ramp-Up preparation and Ramp-Up execution being the two steps.

From the literature mentioned above a six stage graphical illustration was created to illustrate the essential steps that exists in the Ramp-Up process. This six-step illustration covers the main context and stages described above. Also the three itemized terms are presented graphically and shows how they are lapping over time in comparison to the production volume, see Figure 3.2.

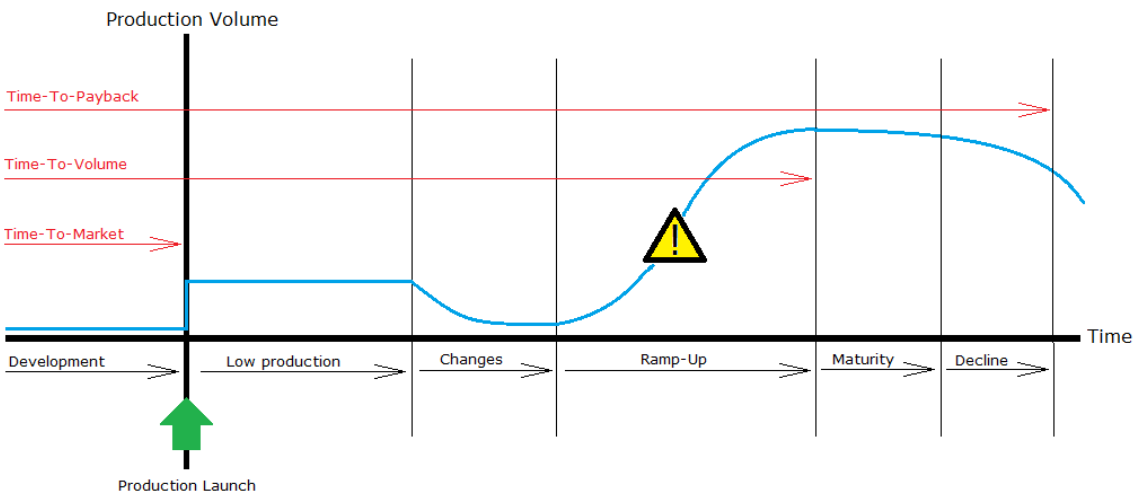


Figure 3.2: Production Ramp-Up process; steps and terms, (Olsson, 2015)

A short description of each stage based on the literature, is presented below:

- Development: The product is developed during a certain period along with planning, risk analysis and test production.
- Low Production: The production is launched and the product reaches the market for the consumers. Low volume of production is a characteristics of this initial phase.
- Changes: In many cases, small or large construction changes have to be made on the product or machinery before the large Ramp-Up.
- Ramp-Up: Where the volume of products is increased drastically in a short time period. It is in this step that the risk is very high.
- Maturity: When the predicted volume is reached and the production is good with low quality issues. In between the maturity phase and the decline phase is where the investments is paid back.

- Decline: The demand from the market is declining and consequently the necessary production volume.

3.4 Characteristics Of Ramp-Up Process

The characteristics of a Ramp-Up process were summarized by Surbier et al. (2014). They collected information from several articles, which resulted in the following characteristics. A low level of knowledge about the product and the processes in the initial phase, which leads to a slow, but progressive, learning process that is difficult to manage. At this point the production output and the production capacity are in general not satisfactory. The cycle time of a product is high as there are disturbances in the process, supply chain or in the quality of the product. There is a lack of reliable planning before the Ramp-Up and Pufall et al. (2012) points out that the planned yield never ends up with true production outcome.

Since much of the investments are made before the production will begin, late engineering changes can have a huge negative effect and delay both the TTM and the TTV, (C. Terwiesch et al., 2001).

3.5 Ramp-Up Management

Krüger et al. (2010) finds that managing the whole Ramp-Up process is central to success in the market, and the key is to obtain knowledge about the Ramp-Up capabilities of the productions system that will be used. The foundation is established in the development stage which includes all activities and measures for planning, management and implementation of the startup. The essential task of Ramp-Up management is the coordination of all necessary tasks as to guarantee timely production and the right quantity.

In addition, Schuh et al. (2005) shows that launching more and new products forces the producers to learn the Ramp-Up process for cost savings purposes. Schuh et al. (2005) present a holistic Ramp-Up approach in three steps which will be described in the three next subsections, they are: *Ramp-Up Strategy*, *Ramp-Up Planning* and *Ramp-Up Evaluation and Benchmarking*.

3.5.1 Ramp-Up strategies

The Ramp-Up strategy is divided into two main strategies, which depends upon variety, Ramp-Up time, utilization and decoupling level, see Figure 3.3. The first strategy mainly focuses on accomplishing a high volume of production and profit. This strategy is described as turning-scale-into-profit and is a volume-first strategy, which is most suitable for producers with low variation of products but with a high volume. Moreover, this strategy focuses on low production downtime in order to maintain high utilization of the machinery and equipment in the factory.

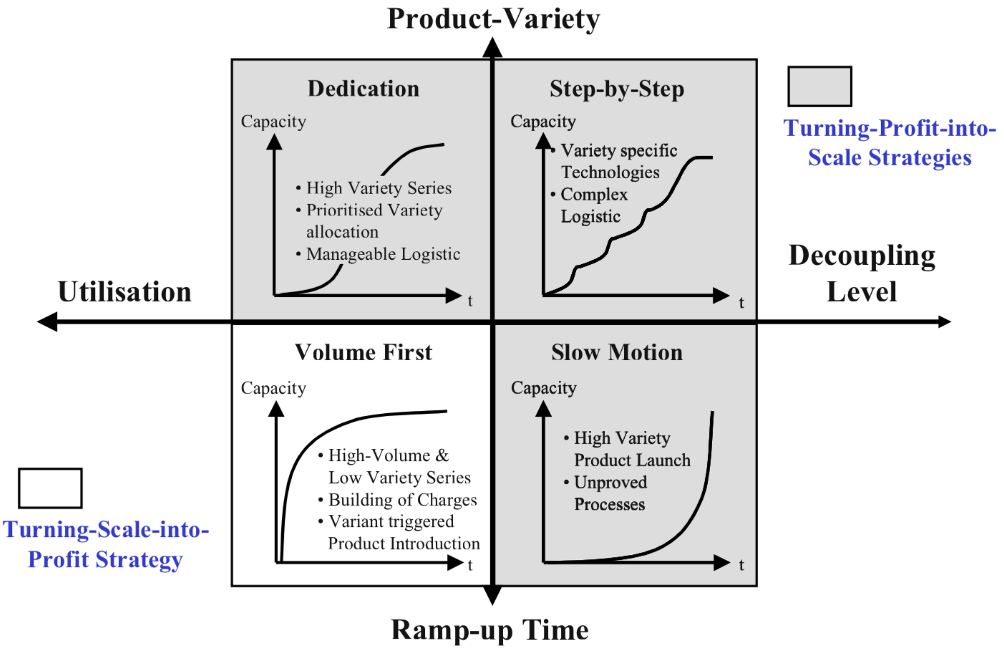


Figure 3.3: Ramp-Up strategies, (Schuh et al., 2005)

The second main strategy is primarily focused on making profit on the product, and then when the product yields profit, ramping up production to a higher level. This strategy is described as turning-profit-into scale and consists of three sub-strategies; *Dedication strategy*, *Step-By-Step strategy* and *Slow Motion strategy*.

The Slow-Motion-strategy is most applicable for a production with a high variety of products in highly automated systems. The Ramp-Up of the products is executed parallel and then kept on the same level during a longer period of time. *The Step-By-Step strategy* is most applicable when the products are categorized as high tech products, with large variety and complex logistics. *The Dedication strategy* is most appropriate for final assembly requirement.

3.5.2 Ramp-Up planning

The Ramp-Up planning is parallel to the development process but it is challenging to do forecasting in an early stage due to the high uncertainty before production starts. Thus, planning strategy must take an new innovative design and concepts into consideration in order to fulfill the requirements for the equipment in the production. In order to control the Ramp-Up planning there are four planning determinants, and two operative planning parameters in each planning determinant are described, these are:

- Volume – Described by the quantity accretion and utilization
- Variety – Described by variant mix and assorting lots
- Process chain – Described by overlapping to Ramp-Up and decoupling level on process stage
- Quality/maturity - Described by process fluctuations and rejections

These four areas are called the tomography and by implementing them into the Ramp-Up planning activities, a more aggressive production launch can be planned in the long-term perspective. It will also be more adjustable in the short-term with operative Ramp-Up parameters. The tomography is central for the internal and external supplier performance of the Ramp-Up evaluation and benchmarking, (Schuh et al., 2005).

3.5.3 Ramp-Up evaluation and benchmarking

The evaluation and benchmarking strategy covers important areas to ensure that both internal and external suppliers can guarantee that the requirements from the Ramp-Up planning strategy will be met, (Schuh et al., 2005).

As mentioned in the subsection above, the foundation of the Ramp-Up evaluation and benchmarking is the Ramp-Up tomography. The benchmarking concept is divided into two areas, *benchmarking process* and *fields of action*, see Figure 3.4.

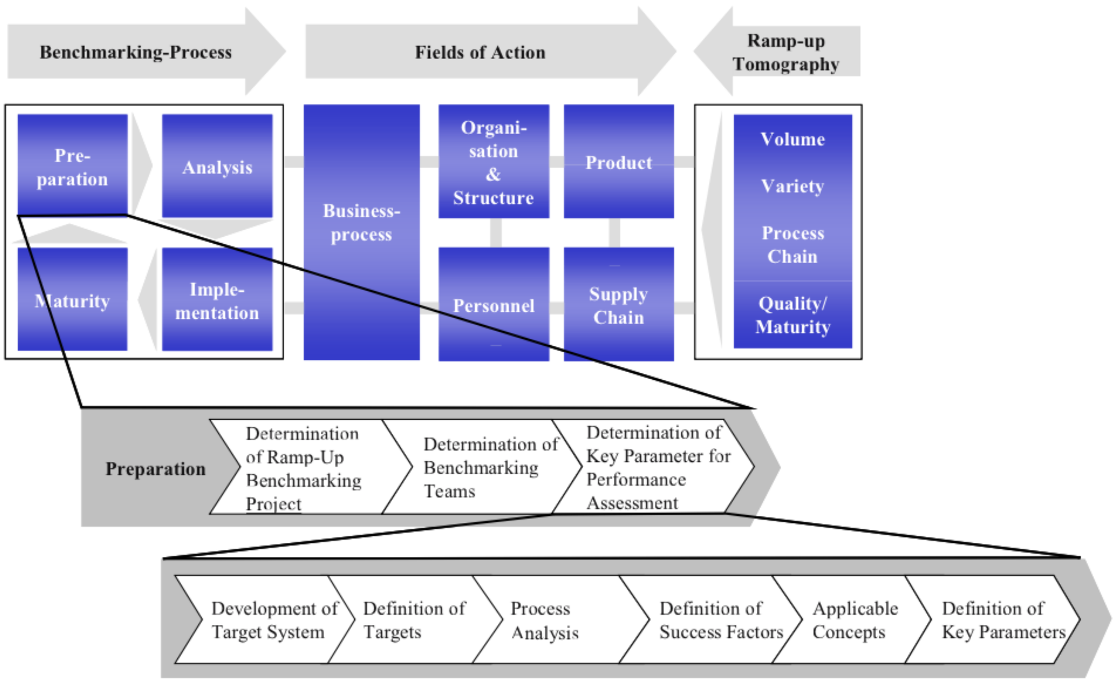


Figure 3.4: Details of Preparation phase within the Ramp-Up Benchmarking Concept, (Schuh et al., 2005)

Thus, the preparation phase is key in the Ramp-Up planning phase and is divided into three stages, where the first stage covering which projects can be studied. The second stage is where the benchmarking team is established and roles are divided. The last stage consists of determination of key parameters for performance assessment and includes both quantitative and qualitative key parameters. This last stage is divided into six sub-stages described in the list below, (Schuh et al., 2005):

- Development of the target system: Defined for the requirements of a Ramp-Up benchmarking.
- Definition of target: The target for the production Ramp-Up has to be defined and classified.
- Process analysis: In general, the defined target above is afflicted with problems and are, in this stage, investigated and identified.
- Define success factors: Based on the identification of the problems, success factors for the production Ramp-Up are specified.
- Applicable concepts: Useable concepts are developed and integrated.

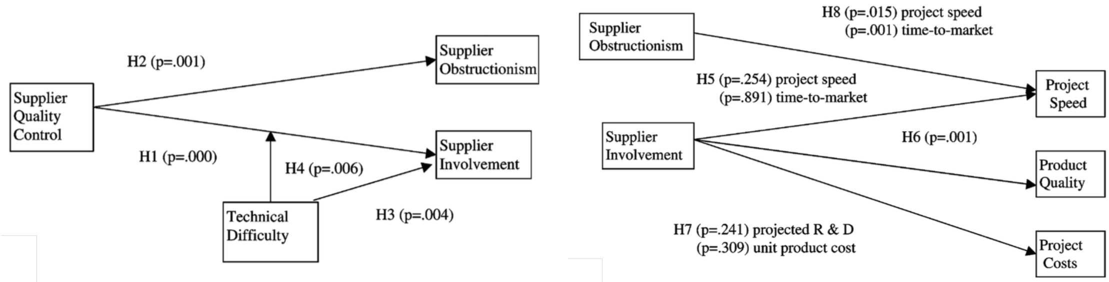
- Definition of key parameters: Measureable values for performance measurements are established from the success factors.

A well-performed evaluation and benchmarking can result in optimized measures, which can be implemented in the Ramp-Up process faster, (Schuh et al., 2005).

3.6 Factors Affecting The Production Ramp-Up

3.6.1 Supplier involvement

Primo et al. (2002) presents and analyzes the relationship between the supplier's involvement and the outcomes in a NPD project by investigating and testing eight hypotheses related to the supplier involvement, where they studied two approaches to the supplier involvement. The first approach was the buyer-supplier relationship, which ended up in four hypotheses, see Figure 3.5(a). The second approach was related to the outcomes in the NPD, also here, four hypotheses were tested, see Figure 3.5(b) below.



(a) Buyer-supplier relationship **(b)** Effects on the outcome

Figure 3.5: Model and hypotheses for supplier involvement, (Primo et al., 2002)

H1: *Supplier quality control positively affects supplier involvement*, proved it has a strong positive effect of supplier quality control on the level of supplier involvement. Based on H1, two more hypotheses were stated and these ones are related to the technological difficulties and how they affect the supplier involvement.

The result shows that H2: *Supplier quality control negatively affects supplier obstructionism*, was supported.

H3: *Technical difficulty is positively related to the level of supplier involvement* and H4: *Technical difficulty negatively moderates the effect of supplier quality control on supplier involvement*, was supported. This led to the conclusion that projects that require new technological capabilities, the importance of supplier quality control as a predictor for supplier involvement, is reduced. For H3 it means that when the projects have a high level of difficulty, the more important is the involvement of the suppliers.

The results from the second approach showed that H5: *the supplier involvement is positively related to project development time i.e. project speed and TTM*, did not have strong enough support to draw good conclusions. However, H6: *Supplier involvement is positively related to product quality*, was moderately supported. More, H7: *Supplier involvement is positively related to project costs*, could not be supported.

Lastly, H8 *Supplier obstructionism is negatively related to project development time* had a strong negative effect, which supported the hypothesis.

Primo et al. (2002) concludes that it is greatly beneficial to involve suppliers in order to achieve better quality products. If there are any technical difficulties, involving suppliers can be an advantage.

3.6.2 Supplier integration

In addition to the authors above, Petersen et al. (2005) also investigated the involvement of suppliers but through the scope of when the suppliers should be integrated into the NPD, what level of responsibility is to be given to the suppliers, and if the supplier involvement can improve the economics.

When to integrate the suppliers in the five different NPD phases (see section 3.1) and into *what* extent can the suppliers be integrated and what this means, are defined below in a four-levels-scale of integration, see Table 3.1.

Table 3.1: Levels of supplier integration, (Petersen et al., 2005)

Integration level	Description
None	No supplier involvement
White	Suppliers and buyers have discussions about specifications and requirements but the buyer makes all the decisions regarding design and specification decisions
Grey	The supplier and the buyer sometimes make joint development and efforts. It can include sharing information in terms of technology or taking joint decisions regarding design specifications
Black	The suppliers are informed of the requirements and then have, in large extent, the responsibility to source material and components so that those requirements will be fulfilled

The questions about *when* the suppliers should be integrated into the NPD process and what level of responsibility is to be given to the suppliers and if the supplier involvement can improve the economics, are stated and answered by six hypotheses. The first three hypotheses covering the involvement of the suppliers in the project team and its effectiveness, see H1, H2 and H3 below for hypotheses and results.

H1: *Selecting the right supplier for integration is positively associated with improved NPD effectiveness.* This hypothesis was supported, which proves that a careful and complete analysis of potential suppliers with the right prerequisites is positively affecting the decision-making in the project teams in the NPD process.

Thus, H2: *Joint buyer-supplier effort regarding technical goal and target setting is positively associated with improved NPD team effectiveness.* This hypothesis was also supported and verifies that involving the suppliers in setting the technical performance objectives for the project effectiveness, was positive.

However, H3: *Joint buyer-supplier effort regarding business performance goal and target settings is positively associated with improved NPD team effectiveness*, was not supported.

The next two hypotheses are covering the areas of the outcome in terms of financial performance and design performance if the project team is effective, see H4 and H5.

H4a: *Improved NPD team effectiveness is positively associated with improved firm financial performance* and H4b: *Improved NPD team effectiveness is positively associated with improved firm design performance*, both were supported and thereby confirms the importance of effective decisions making will result in a better design and financial performance. See the results from the hypotheses H1, H2 and H3 in Figure 3.6.

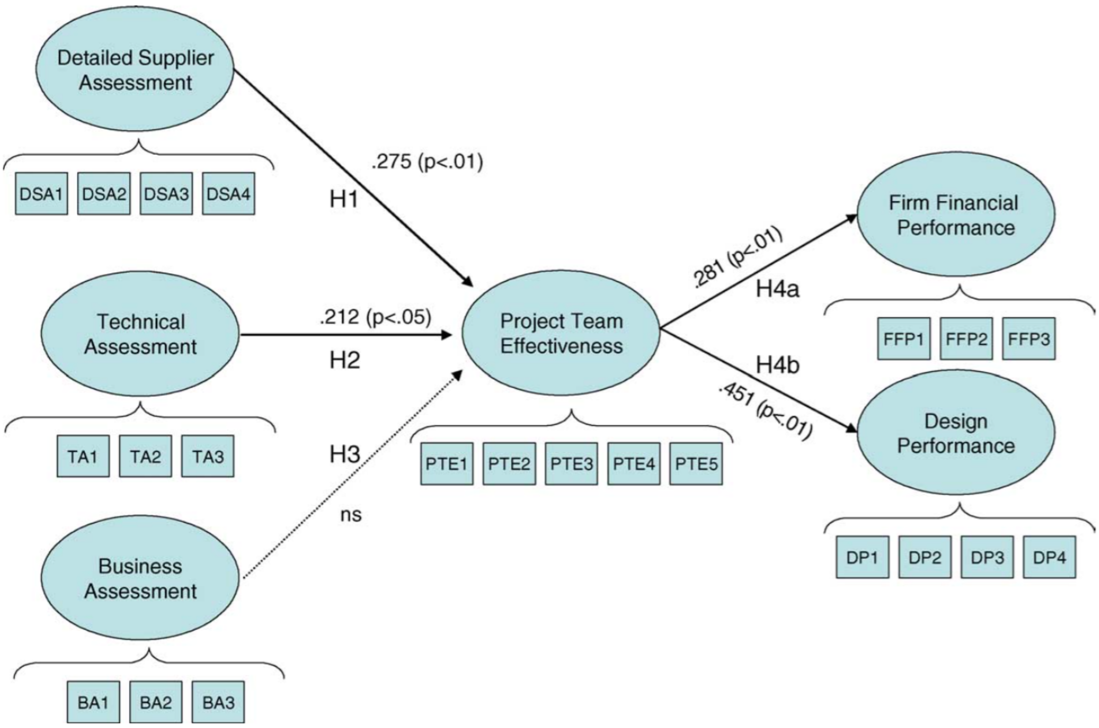


Figure 3.6: Results of the full model H1-H4, (Petersen et al., 2005)

H5 covers the relationships between the above stated hypotheses i.e. H1-H4, and where in the NPD process the suppliers should be integrated. H5: *The relationships stated in H1–H4 are decreasing by the phases at which the supplier is brought into the NPD process*, see the NPD phases in Figure 3.1 and the levels of supplier integration in Table 3.1. The results showed that only the hypothesis H4b was supported, which indicates that the earlier in the process the suppliers are integrated, the more likely there will be positive effects on the design performance. See the results in Figure 3.7 below. Nevertheless, no matter if the supplier are integrated early or late in the NPD process, it will not affect the firms financial performance noteworthy.

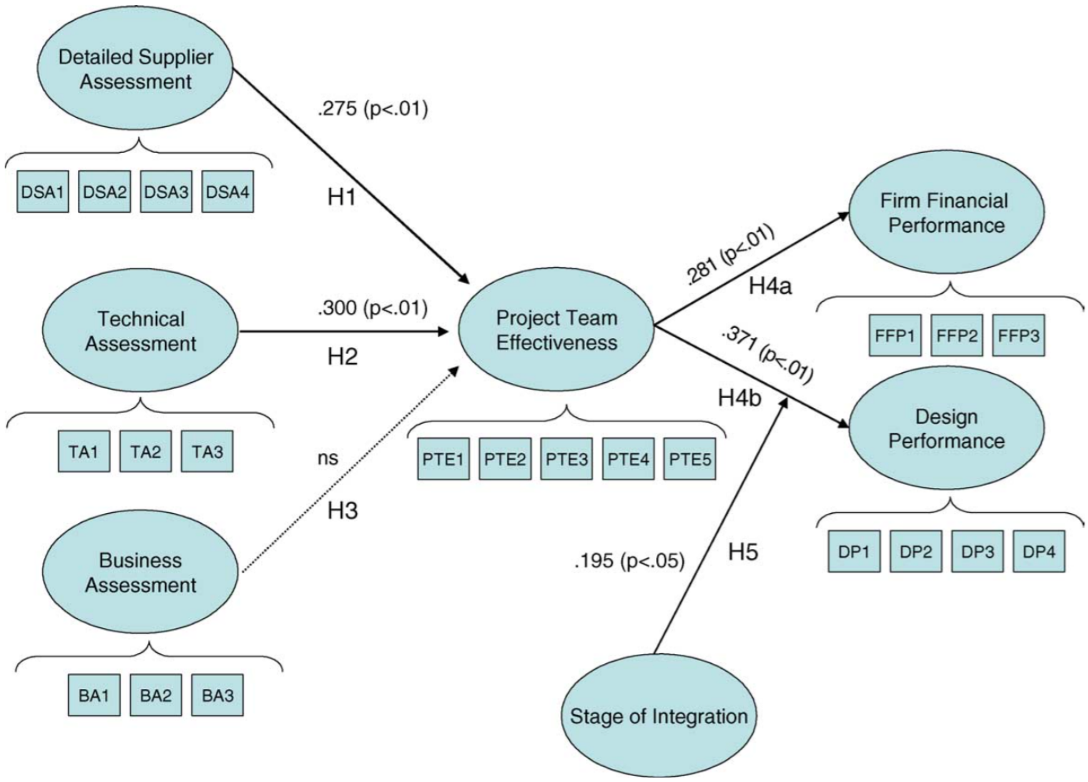


Figure 3.7: Results of stage of integration with H5, (Petersen et al., 2005)

Lastly, H6 covers the level of responsibility that should be given to the suppliers and re-tests the hypotheses H1-H4. H6: *The relationships expressed in H1–H4 are moderated by the level integration of responsibility assumed by the supplier in the NPD process.* The results supported that black box integration is better than grey box integration for H2. H3 was supported, which revealed that the supplier involvement is positive if the responsibility is lower and negative if the responsibility is high. Also a strong positive relation between project team effectiveness and design and financial performance, regardless of the supplier responsibility (H4a and H4b), see Figure 3.8.

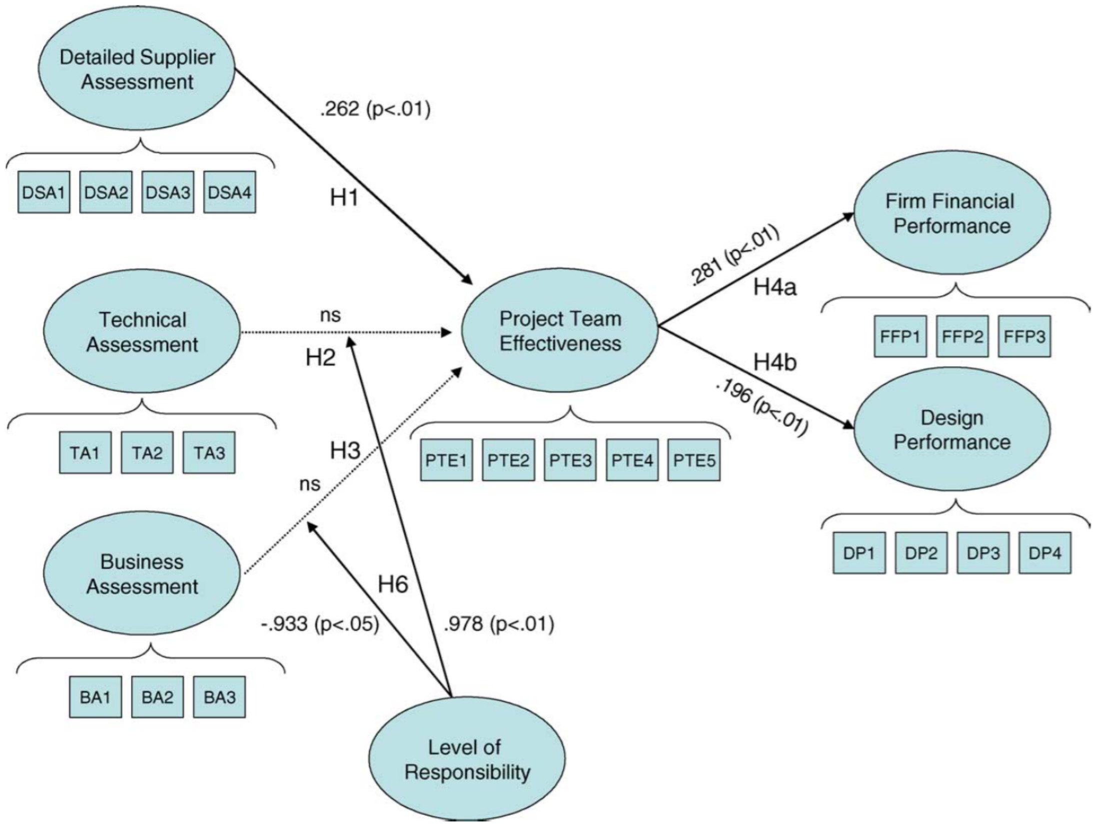


Figure 3.8: Results of the responsibility hypotheses H6, (Petersen et al., 2005)

Moreover, Ragatz et al. (1997) made a questionnaire in which 83 companies responded to questions regarding integration of suppliers in the NPD process. The responses indicated that one third had achieved results that were below their expectations causing them to come to the conclusion that the suppliers should be involved in a much earlier stage. The research also showed that today the companies are involving their suppliers much more, in comparison to the year 2000, and that soft aspect, such as trusting, long-relationship, access to supplier knowledge, joint development and communication is beneficial to supplier integration. Also, knowledge and expertise from the suppliers probably ends up in a higher and better design and manufacturing. Another positive effect of supplier involvement was that problems were addressed in an early stage, which lead to time and cost reductions. However, supplier involvement is difficult to manage, especially the barriers regarding sharing sensible information, and they need to be overcome. Sharing is caring, but the main concern usually is that valuable information can be leaked to competitors. Another barrier is the proudness of the company. New ideas coming from the suppliers are, in some cases, rejected immediately due to the not-invented-here culture. To break down these barriers stated above Ragatz et al. (1997) presents a model for achieving good supplier integration, see Figure 3.9 below.

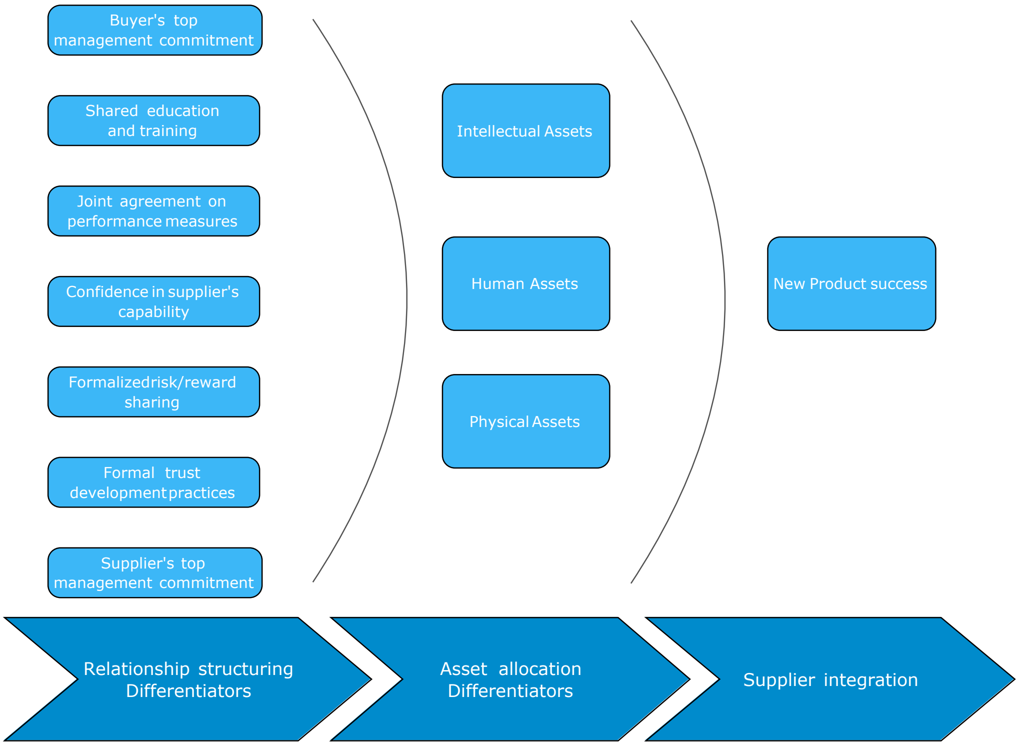


Figure 3.9: Supplier integration and new product success, (Ragatz et al., 1997)

Two important themes regarding how companies can overcome or reduce the barriers are presented. The first theme is *Relationship Structuring*, which helps the company to break down barriers. Relationship structuring involves education and training together with confidence and formal trust. These are the most essential aspects for creating good supplier integration. The second theme is the *Asset Allocation*, which includes intellectual assets, human assets and physical assets. Sharing intellectual assets results in better decision-making so that customer requirements can be met. Sharing human assets provides both sides with valuable knowledge about the personnel, which lead to better problem solving and better interactions. Last, sharing the information about the physical assets will ensure that the right tools and resources are available and certify that design and development activities will ensue in order to meet the requirements, (Ragatz et al., 1997).

3.6.3 Successful production Ramp-Up

Gross et al. (2010) found that there is a lack of research related to the importance of coordination and cooperation in the production Ramp-Up in the NPD process. They performed a survey addressing 71 manufacturing companies in European countries where questions were asked to people with good insight in the firms, in order to answering their six hypotheses, described further below. See Figure 3.10 presenting the results from the survey and where the non-supported hypotheses are marked as dotted lines. The first three hypotheses are associated to coordination of the production Ramp-Up.

H1: *The degree of cooperation with suppliers during the first phases in the NPD process is positively affected by the implementation of a Ramp-Up strategy*, was not supported, which implies that working with suppliers and deciding upon how often and with what intensity during the production Ramp-Up is not important.

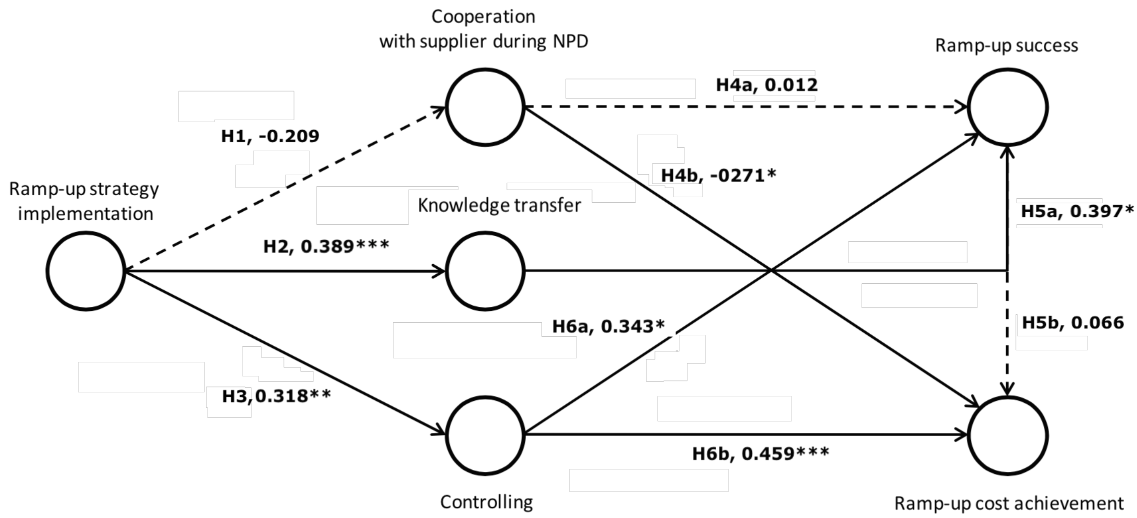


Figure 3.10: Production Ramp-Up in the New Product Development process, (Gross et al., 2010)

On the contrary, H2: *The degree of knowledge transfer during and in between production Ramp-Up projects is positively affected by the implementation of a Ramp-Up strategy* and H3: *The degree of controlling in production Ramp-Up projects is positively affected by the implementation of a Ramp-Up strategy* which is both supported, meaning that it is of importance to implement a production Ramp-Up strategy where knowledge and experience from older projects is taken into account. Thus, deciding on how to manage the controlling in product Ramp-Up projects and defining milestones are also important for the coordination of the production Ramp-Up process.

The next three hypotheses are related to the Ramp-Up success factors such as time, quality and cost achievement. Since there is a distinct difference between Ramp-Up success and Ramp-Up achievement, they where subdivided into two parts where (a) refers to success Ramp-Up and (b) to Ramp-Up cost achievement.

H4a/b: *The success of production Ramp-Up is positively affected by the degree of integrating supplier in the early phases of the NPD process.* H4a was not supported but H4b was supported saying that cost achievement is positively affected by the degree of supplier integration.

H5a/b: *The success of production Ramp-Up projects is positively affected by the capability of transferring knowledge from previous Ramp-Up projects to current projects and in between the project team.* Sharing information and knowledge during the production Ramp-Up process was successfully supported in terms of timing and quality (H5a). Nevertheless, H5b, sharing information and knowledge in terms of costs levels, was not supported.

The last hypothesis, H6a/b: *The information flow created by cooperation and communication needs to be planned and controlled. Thus the success of production Ramp-Up projects is positively affected by utilization of a controlling system.* Both 6a and 6b was supported meaning that controlling the system in terms of cost aspects, timelines and quality increases the production Ramp-Up achievements.

By increasing the production from a certain level of units to a higher one will force the supplier to Ramp-Up up the tempo in the production. This will stress the machines, personal and the management to oversee all parts that will be affected, (C. Terwiesch et al., 2001). Furthermore, Langowitz (1986) states that there are two major ways for making a successful Ramp-Up. The first one is to match the current competence and machine park to the coming models. The second way is to prepare for the forthcoming challenges. In addition, he also argued that by overseeing current working techniques problems could be observed and eliminated at an early stage.

3.7 Learning And Knowledge

Ramping up the production from one level to another higher level requires the workforce to adapt new techniques, or work in another ways, to accomplish a higher volume. Knowledge is power and many authors, among them being Almgren (2012), Kampker et al. (1992), Surbier et al. (2014), and Christian Terwiesch and Xu (2004), have highlighted the importance of having the right prerequisites in order to perform satisfactorily when ramping up the production. It is acknowledged that learning is a task that will be improved by practice and experience. The typical learning curve represented by a slow beginning with low output, thereafter the curve accelerates and the output increases until high knowledge and experience is gained and the curve begins to mature, (Glock et al., 2000).

Moreover, the learning processes in the manufacturing industry have, over the years, been studied thoroughly. It is acknowledged that in the initial phase of a manufacturing sequence, an assembler needs more time per unit produced, than after experiencing the sequence. In the manufacturing industry, practice makes perfect and to achieve a high time-per-unit produced, experience and knowledge are essential.

Kampker et al. (1992) examined the production Ramp-Up in low-volume context and declares that it is beneficial to strive for high qualification among the employees to achieve a successful Ramp-Up, especially when much of the work is performed by hand. The complexities of the product range are strongly related to the effort and training of the employees. An existing four-step model, with the added step of *gamification*, increases the qualification of the workers. The main reason for adding another step was that the original four steps did not cover the all channels of information. *Demonstration* covers observation and verbal information gathering, while the *execution* and the *completion* steps are covering the active information. However, the lack of mental information is present without the *gamification* step, why it is of high importance to cover that information channel. The five-step-model is presented below in Table 3.2.

Table 3.2: The gamification approach, (Kampker et al., 1992)

Step	Description
1. Preparation	The first step, *preparation*, is the introduction to the workplace where no physical activity, related to the manufacturing, is performed. More, it is not a part of the process due to the non-working agenda.
2. Demonstration	In the *demonstration* step the worker will be introduced to the work and the supervisor will demonstrate and describe how the tasks should be completed.
3. Gamification	Step three, *gamification*, addresses the worker to be motivated and focused.
4. Execution	Is the step where the work is performed on routine.
5. Completion	Is where the worker assembles correctly and with excellence at the right time.

Consequently, Kampker et al. (1992) states that after adapting this model, Ramp-Up time can be decreased which leads to a better Ramp-Up performance. More, the gamification approach can also reduce the Ramp-Up cost for the assembling systems.

According to the research by Christian Terwiesch and Xu (2004), they show that freezing the process for some time, without making changes, is favorable for the Ramp-Up process and learning among the personnel. This is the case, especially when the level of knowledge is initially low and the life cycle of the products are low. Surbier et al. (2014) finally confirms that Ramp-Up efficiency depends heavily on learning curves.

CHAPTER 4

Theoretical Framework: Co-Loading

This chapter consists of the theoretical framework for the phenomenon Co-Loading. It gives insight about how the physical transport is performed in three general delivery/pick-up methods.

4.1 Physical Transportation

The distribution systems, how the products are distributed are described by Lumsden (2007) as the fundamentals of how goods are supplied. Suppliers can be located in different locations in different countries and still have to supply the stores in time. Nevertheless the time and cost are important subjects that need to be lowered in order to stay competitive in the market and to save money. In the last decades, companies have been changing politics from a push-approach to a pull-approach, which goes in line with the Just-In-Time (JIT) thinking. For that reason, the frequency in the transportation has been increasing to meet the JIT evolution. A major drawback of this, according to Lumsden (2007), is that it is lowering the filling rate in transportation.

Hall (1987) states that by examining the characteristics of the situation, such as:

- Flow patterns
- Transportation charges
- Time value of freight goods

gives a better insight about what type of loading and distribution methods are to be used. This means that manufacturer should determine the number of goods to be delivered each week to anticipate the need for extra terminals (see section 4.1.3). On the contrary, large volumes may also indicate the need to eliminate terminals in order to only ship with Direct Delivery (DD). Also, Fleischmann (2005) points out that large shipments can go directly to the End Receiver, if Full Truck Load (FTL) is possible, while smaller shipments can be Co-Loaded.

Hence, Hall (1987) describes the importance of knowing where the destinations are because, if the distances between the destinations are close enough, pick-up with a vehicle for Co-Loading can be considered. Last essential aspect is the time, if the value of time is large, the best option may be not to Co-Load at all since it is more time consuming.

Sürie et al. (2005) states that transportation costs can be reduces if FTL is used but should not depend upon increased batch sizes. Instead the 3PL companies should simplify for companies that making small batches by Co-Loading from multiple suppliers near each other and thereby economics of scale with FTL. In line with what's stated above, 3PL companies may use assortments to FTL when delivering goods, which would decrease the safety stock without compromising the service level or increased transportation costs.

A network of transportation can be described as the links between the suppliers and the stores. However, the networks are, in many cases, not that simple and need to be expanded with terminals. Reason for using terminals include being able to supply stores in time, with the right amount of products, or to consolidate transportation from different suppliers to increase the filling rate in transportation, (Lumsden, 2007).

In this context a network is represented by a graphic figure and lines. With a corresponding denotation, see below in Table 4.1, the transportation relation can be calculated. The relation will represent the complexity of the network where a high transportation relation number is more difficult to manage than a low number.

Table 4.1: Denotation of transportation relation

Object	Figure	Denotation
Relation	N/A	R
Suppliers	Rhomb	m
Terminals	Squares	t
Stores	Circle	c
Flow of products	Line with arrow indicating the direction	

4.1.1 Direct Deliveries (DD)

DD enables the simplest form of consolidation of the goods before the distribution of the goods to the End Receiver, namely inventory consolidation. This consolidation form works in practice by holding the shipment until the right amount of goods are produced i.e. the minimum loading quantity is reached, or, when the predetermined date for the shipment to dispatch is reached, (Hall, 1987). However, inventory consolidation cannot be achieved if the goods cannot be stored until they should be dispatched, and consequently the inventory will increase with time, and the holding cost respectively.

According to Lumsden (2007) the delivery method DD is a fast transport method for delivering goods to the stores. Yet, he declares that if the distribution systems consist of many nodes, DD can be very resource demanding in terms of low utilization in the transportation. However, this method does not require any times restriction, meaning that there is no connection between any other nods than to the final destination node, which leads to a higher degree of freedom for the purchaser. With DD, the transportation relation is calculated by multiplying the number of supplier nodes with end nodes. Thus, if three suppliers are delivering to four stores the relation will be $R = 3 * 4 = 12$, meaning that the more suppliers or stores, the bigger relation, which enhances the risks of delivering failures, see Figure 4.1.

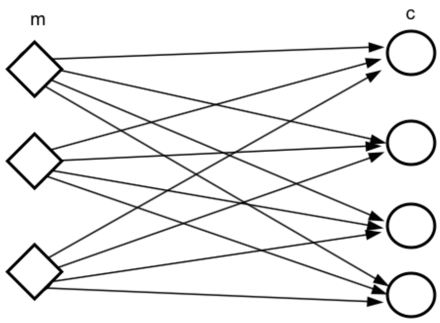


Figure 4.1: Distribution with Direct Delivery, (Lumsden, 2007)

The pros and cons for DD are presented below in Table 4.2 which is a summarizing of Carboneras (2014) and Chopra et al. (2007).

Table 4.2: Pros and cons for Direct Delivery

Pros	Cons
No extra storage in warehouses	Higher inventory due to size of orders
Easy to manage	High cost of transport and reception
Low facility costs	Long response time due to distance
Fast TTM	Expensive backorders

4.1.2 Vehicle Co-Loading

Yet, in many cases, the volume of goods is not enough to fill a full truck and, consequently, the shipment has to departure with low vehicle utilization. This is a known problem in the transportation industry and since the beginning of the 21st century the empty run of the trucks has been around 20%. At the same time, the truck utilization is varying around 56 % according to Cruijssen (2012).

Vehicle Co-Loading addresses the involvement of picking up and dropping of goods from different locations and destinations by using a milk-run technique with only one truck, see Figure 4.2 below for a simplified illustration, adopted from Hall (1987).

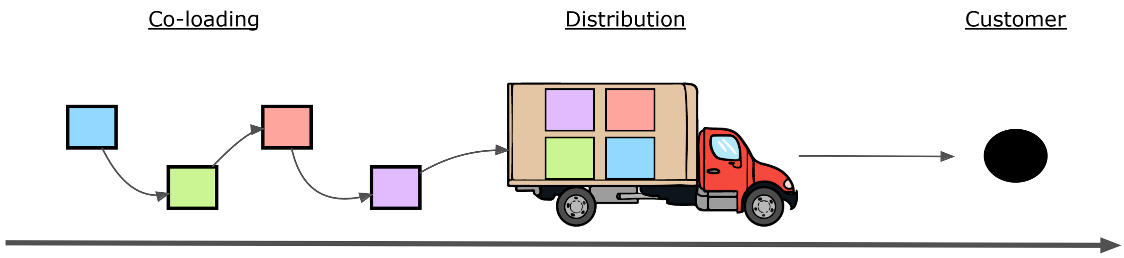


Figure 4.2: Vehicle Co-Loading technique

Moreover, Hall (1987) states clearly that trade-offs have to be made when using the transportation method Co-Loading. This method needs more stops along the way to the customer i.e. End Receiver which leads to a longer lead time due the stops and due to the fact that the total amount of kilometers will increase because of longer routes. However, it is essential to take advantage of the lower transportation charges that come from larger load sizes.

Vehicle Co-Loading needs clear sizes of transportation units, i.e. pallets. Each of the suppliers need to either round up, or round down, the quantity to a whole pallet. They also have to adjust the size of the shipment so that the FTL is reached with the given truck type, (Fleischmann, 2005).

Based on Fleischmann (2005), Hall (1987), and Lumsden (2007) the pros and cons for using vehicle Co-Loading are highlighted in Table 4.3.

Table 4.3: Pros and cons for vehicle Co-Loading

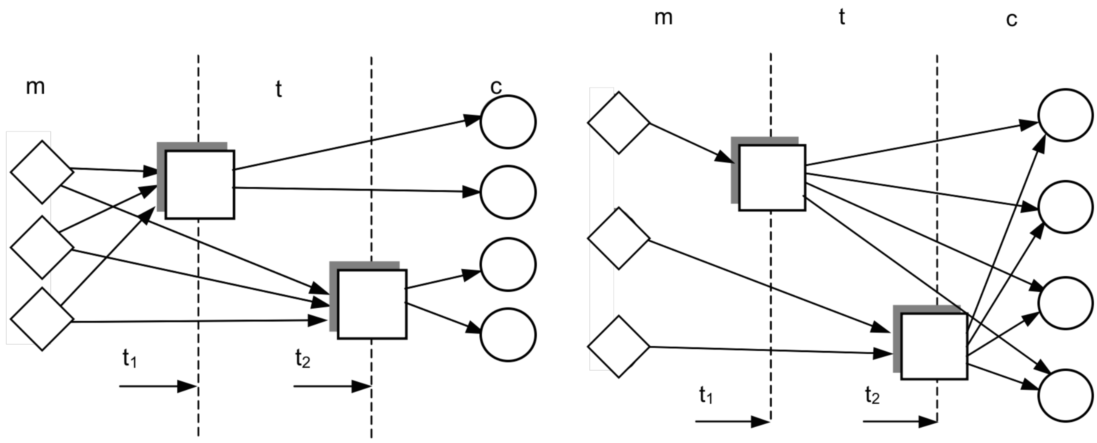
Pros	Cons
Higher utilization in the truck	Longer routes
Lower total transportation costs	Coordination of pick-up points
Higher transportation frequency	Deeper planning
Lower inventory	Longer lead time

4.1.3 Deliveries with terminals

Multi-Terminal system

Lumsden (2007) describes the multi-terminal system as a system for consolidating shipments or reducing the number of shipments that occur with the previously described method. With a multi-terminal system the products will pass through one or many terminals before ending up at the store. Many suppliers and stores can be connected to one terminal. Notable is that the flow of the products is only in one direction, i.e. from the supplier to the terminal and then to the end location, the stores. There are two types of multi-terminal systems, one that is focusing on the stores and one focusing on the suppliers.

The multi-terminal network system that is focusing on the stores is designed so the stores always are supplied from one terminal, see Figure 4.3(a). The relation in this case is calculated by the number of suppliers multiplied with the number of terminals added with the number of stores. With three suppliers, two terminals and four stores the relation are equal to $R = 3 * 2 + 4 = 10$, see Figure 4.3(a). This method has a slightly higher transportation time than the supplier-focused terminal. This is due to all the goods from the corresponding suppliers that must arrive at the terminal before the shipment from the terminal can dispatch.



(a) Multi-terminal - Store focus **(b)** Multi-terminal - Supplier focus

Figure 4.3: Distribution with multi-terminals, (Lumsden, 2007)

Contradictory, the supplier-focus network system is designed so each supplier delivers to one terminal, which will increase the efficiency, slightly, in contrast to the store-focused system. The relation is calculated as follows: $R = 3 + 2 * 4 = 11$, see Figure 4.3(b). The pros and cons are presented below in Table 4.4, summarized from Carboneras (2014) and Chopra et al. (2007).

Table 4.4: Pros and cons for Multi-terminal network

Pros	Cons
Lower transport distance	Need for extra inventory
Fast response time	Longer time-to-market
High punctuality	More schedule planning

One-Terminal system

Lumsden (2007) argues that to be even more cost efficient, and if possible, to reduce the number of terminals, the transportation relation will decrease which leads to a higher utilization of the resources. Yet, it means that a higher transport frequency will be necessary to meet the demand. The one-terminal system is also limited due to time constraints of all products having to arrive before the transportation can dispatch from the terminal to the stores. Hence, there are two ways for handling this time limitation. The first option is to let the transport dispatch without the corresponding products, which could lead to discrepancies further up in the chain. The other approach would be to wait until the next delivery arrives from the supplier, and then let the products dispatch in that cycle.

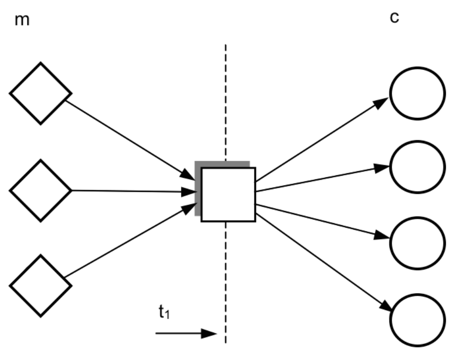


Figure 4.4: Distribution with one-terminal, (Lumsden, 2007)

The relationship for the one-terminal system is calculated as the number of suppliers plus number of stores i.e. $R = 3 + 4 = 7$, see Figure 4.4.

The pros and cons of this method are in line with the multi-terminal system stated above in Table 4.4.

4.1.4 Increase Co-Loading efficiency

In order to utilize the LUT as much as possible and to simplify the unloading process, different techniques to load the LUT exists. There is one general rule when loading a LUT, that the first loaded goods will be unloaded last, meaning that an appropriate rule is, First In Last Out (FILO), (Lumsden, 2007).

A vital aspect of loading the LUT is safety. This includes loading procedure, the way that the goods are stacked and placed according to regulations, and the limitations of the LUT.

A common used technique to increase the efficiency when loading the LUT is to prepare by placing in a specific area. It is called pre-loading and according to Lumsden (2007) the advantageous are:

- The goods does not have to be pre-loaded in the same sequence which they later will be loaded
- The carrier LUT does not have to arrive until the pre-loading is finished
- The loading time, and carrier LUT wait, is reduced

CHAPTER 5

Empirical Data: Ramp-Up

Empirical information collected from primary data together with non-published sources covering the issue of Ramp-Up, is presented in this chapter.

5.1 Starting Up A Supplier

Before the NPD can be initiated and the production can start, an extensive planning needs to be completed. The planning phase is essential in order to select the right suppliers and determine if they have the right prerequisite to produce products for IKEA. New products are in general developed during a period between 12-24 months with an average of 18 months. The development time is highly related to the complexity of the products and its characteristics.

Starting up a new supplier is a time-consuming process, which is necessary to ensure that factors for the supplier and sub-suppliers are fulfilled. The process for starting up a new supplier is presented below in Figure 5.1 and is a part of the NPD process until the launch of the product.

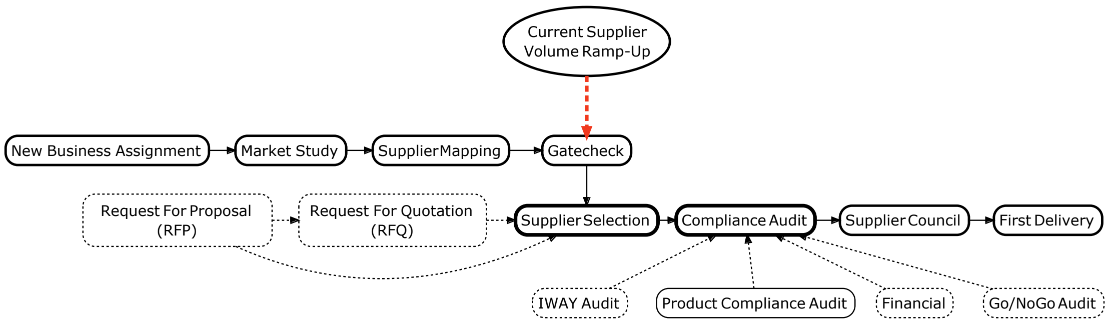


Figure 5.1: Start up of new supplier

The new business assignment describes the contents of what needs to be sourced and what capacity is needed for starting up new suppliers. Then a market study is performed which ends up with answers of what role the market can play to define the sourcing needs. Next, potential suppliers are contacted and a first insight about the corresponding supplier is established by relevant information gathering from the supplier.

The gatecheck is a milestone for the suppliers where each potential supplier is evaluated to ensure that both capacity and capability will be met if the supplier will be selected for further analysis. In this stage an existing supplier can be investigated when there is a need for a production ramp-up in terms of volume of an already existing product.

In the next stage the best suppliers are selected for further analysis. First, the current supplier base has to be investigated as to whether there is any supplier who has the preconditions to adapt another product. If no supplier is suitable for this product, the spectrum is broadened and new suppliers have to be found. IKEA therefore requests information from the suppliers i.e. Request For Proposal (RFP) and/or Request For Quotation (RFQ), which enables the comparison of information from the suppliers, structurally and deeply.

In the supplier selection stage one supplier is, in general, selected as a primary supplier, and will get the majority share of the total volume that needs to be produced. This is a well-known strategy of spreading the risk by sourcing several suppliers to the same product (dual/multiple sourcing). Understanding this leads to the topic, risk assessment in production, which will be discussed later in section section 5.3.

During the compliance audit the supplier(s) are investigated deeply and IKEA makes sure that:

- The suppliers are working according to current laws in regards to social conditions, working conditions, child labor and environment, stated in IWAY.
- That the product meets the requirements, new products often require new technology and education of personnel in order to be able to manufacture the products according to the technical specifications. The number of machines and staff must be balanced so the desired volume can be met. However, the most important factor is the quality, because if the requested quality cannot be met, the production cannot start. Likewise if quality issues occur during existing production, the production will be held until the issue is solved.
- That the supplier(s) are financial stable and have the financial muscles to do necessary investments.

- That the supplier(s) having the right working methods for quality and compliance standards, secured by the Go/NoGo audit.

When the compliance audit is finished, the audit is presented for the suppliers and other stakeholders in the supplier council. Here the final decision to start up the production is determined along with goals and deadlines. Last the production is carried out, and if necessary, small calibrations are made before the product reaches the consumer market. Before the products reaches the market the products are tested, both by IKEA laboratories and suppliers in order to validate if the product reaches the requirement stated in the production requirement documents.

5.2 Supplier Balancing

When the capacity from the suppliers is not enough to meet the demand from the market of a specific product, the current supplier must be phased out (closed), or the current supplier must be balanced with other/new suppliers to meet the demand. Reasons for phasing out the supplier may be unwillingness to develop, price conflicts or quality issues. Another reason may be supplier cannot produce several products, which can result in another problem such as transport inefficiency. However, finding new suppliers, as well as phasing out a supplier is very time consuming processes, why balancing the suppliers are a better option.

5.3 Ramp-Up Risk Assessment

When launching a new product, or ramping up current production, problems always arise and need to be solved. Problems may occur in many different areas such as technical, organizational or process related. Some may be easy to manage and some are more difficult. To be able to predict problems at an early stage in the production, risk assessments are made to address possible issues, problems, bottlenecks and risks. The purpose for doing a production risk assessment is to improve the over all quality, decreasing the cost of poor quality products, and to increase customers satisfaction. The production risk assessment process is divided into nine steps, see Figure 5.2. First, the process is investigated and documented in detail with a process flow chart where operations, transportations, inspections, delay and storage are determined. The reviews are performed physically by walking through the production process.

In step two, potential failures for each part of the process are highlighted, and preferably generated by a fishbone analysis, which will hopefully illuminates what triggered the problem. Now the root cause is determined and the next step is to define what caused the problem by asking why, step three.

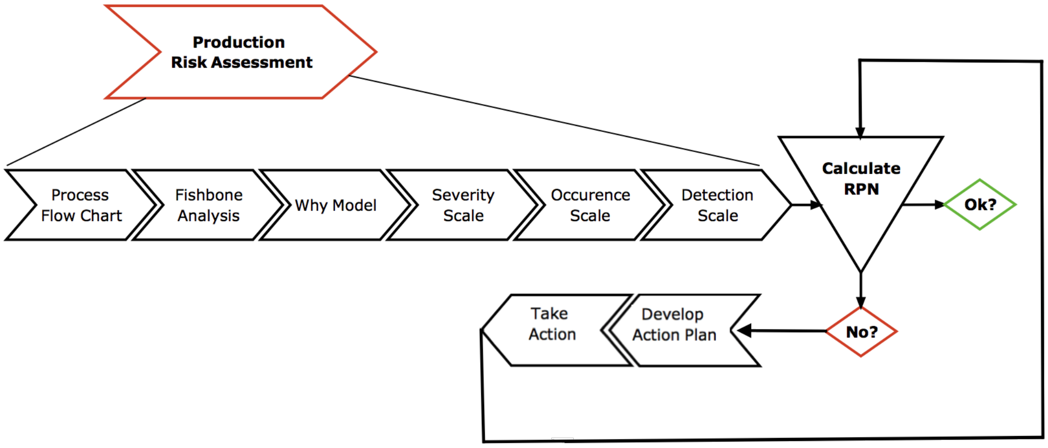


Figure 5.2: Production Risk Assessment Method

Step four is to rank how serious the effect will be if the problem occurs on a scale from one to ten, where ten means that the effect may cause hazards without warning and could injure customers or employees, and, one meaning very low severity, causing no noticeable effect on customers or employees.

Next, step five is to rank how frequently the problem may occur on a scale from one to ten, where one is very low frequency of problem occurrence, and ten is a very high frequency of problem occurrences.

The reason for step six is to identify the process, or product related controls, in place for each problem and then to assign the ranking to evaluate the current process controls. Again, a ranking interval from one to ten, where one is certainty of a problem, where the problem occurs and how to solve it. Ten is absolute uncertainty of a problem, and where the problem occurs is not determined or predictable.

Step seven is to calculate the Risk Priority Number (RPN) by multiplying the Severity scale, the Occurrence scale and the Detection scale. If the RPN are not satisfactory, action plans are developed (step 8) to solve the problem and then implement, step nine.

Production development is a process that has to be monitored throughout the whole life cycle and, hence the process is monitored by a method called constant production improvement; an ongoing process where the technicians from IKEA work closely with the suppliers in order to find and implement methods or techniques to make the product better and cheaper than before.

5.4 IKEA Ramp-Up Characteristics

When a big company, such as IKEA, opens the doors for collaboration with new suppliers it is, in many cases, economically advantageous for suppliers since IKEA will buy large volumes, yet the suppliers tend to be overconfident regarding their capacity in production. Thus, to ensure that new suppliers can meet the production volume that they claim they will, the suppliers are given a low volume to produce in the beginning. If they can meet the smaller volume within the right requirements and framework, larger volumes can be initiated and produced. Suppliers which need to increase the production volumes by a couple of hundred percent, tend to be fairly manageable. The difficulties are not only related to the production or the personnel, instead problems with sourcing raw material or finding sub-suppliers are even more frequent and difficult. In regions where raw material lacks, it must be sourced from other parts of the world leading to uncertainty in lead times.

A major problem related to production volume ramp-up of existing production is resources. If the production needs to be doubled it is not necessary that it require double machinery or double personnel. In most cases, smaller investments, together with the right resources, can be enough. Or another approach is to reschedule the labor from one shift to more shifts. Certainly it is highly related to what kind of product that needs to be ramped up, what the limitations in the production are and where the bottlenecks are located.

The ramp-up phase is without questions the most critical stage in the NPD process. It is during the volume ramp-up where hidden problems will occur and could contribute to small production stops or large downtime.

Also many suppliers are overconfident regarding the volume of planned produced units and therefore IKEA employees have, in some situations, needed to correct the planned outcome to be more reliable.

The production ramp-up for current suppliers from one volume output to a higher volume output has lower risks of failure and problems than new suppliers. A new supplier tends to have more issues with quality and production risks along with uncertainty regarding time (TTM and TTV). The specific and most critical characteristic, and risk that impregnate the interviews, is time. To solve time issues one must partake in in-deep planning.

5.5 Example Of Production Ramp-Up Issue

A supplier has had a steady production for a couple of weeks before and was going to ramp-up the production when a quality issue of the exterior of the products was found. The production was stopped and an investigation was initiated. The investigation confirmed that the problem was caused by uv-light generated from the lamps. It leads to a change of all the corresponding lamps in the manufacturing site, however, the problem occurred again after a short time. The lamps were sent to a laboratory where a chemistry expert examined the lamps. The report turned out that the lamps had a thin layer on the surface of the lamp. That layer, covering the entire lamp, consisted of small particles of sand, which changed the uv-light to infrared light, leading to exterior problems on the products. The sand came from the machines operating in that specific manufacturing plant. It all ended up with a downtime of the production for almost one year and a change of the entire ventilation system in the manufacturing plant in order to get rid of the sand particles and to meet the requirements on the product.

5.6 Supplier Development

The supplier's knowledge about the production is central to the production output. IKEA has a close relationship with their suppliers in which they constantly meeting to discuss problems, product improvement possibilities, or just to report the situation and share measurements and KPIs. Yet, there exist discrepancies between suppliers and IKEA employees; they are expressed as communication difficulties, due to language barriers or lack of knowledge about processes or techniques. To eliminate these discrepancies IKEA can provide education covering these areas. Educating and informing the personnel would also decrease the risk of production failures or interruptions.

In general, suppliers are trustworthy and the knowledge of the employees is adequate. But, for instances, can a professional machine operator be outstanding in managing the machine and obtain a high output and simultaneously lack knowledge in other vital areas such as quality. This can impact the production rate negatively and delay the production launch or the TTV significantly.

When the design for a product is established by IKEA and all legal documents are signed, the supplier and IKEA start a deep collaboration to determine what is the best way to produce the product. The supplier and IKEA work closely during the development phase where techniques and knowledge are shared widely and joint decisions are made.

A supplier can buy material and/or components from internal (IKEA Components) or external (sub-suppliers) sources. If external sources are used the material and/or components must meet the same requirements as the main supplier. Hence, the final supplier is completely responsible for the product in terms of quality and function.

5.7 Information Sharing

Much information is considered as sensible and IKEA has a strict policy regarding information sharing. Trivial information in order to help deploy the supplier is shared, such as production requirements, how IKEA evaluates their suppliers and how much to produce.

CHAPTER 6

Empirical Data: Co-Loading

This chapter consists of empirical data collected from the host company. Here it is highlighted how the suppliers have been investigated. The transport of goods is explained as well as how the current physical distribution is managed. Last, how the Co-Loading process is managed with measurements and examples is explained.

6.1 Supplier Investigation

To be able to draw any conclusion of the suppliers and find possible set-ups to perform Co-Loads, the suppliers had to be investigated from different aspects. Three aspects were established to find relations and possibilities between the suppliers, these are:

- The Supply Chain Matrix (SCM) - Information of where each supplier is delivering goods.
- The Distance Matrix (DM) - Information of distances between every supplier
- Weight classification - Every LUT has weight and volume limitation, which preferably should be reached in order to get a FTL. If the suppliers reach this limitation depending on the goods. The suppliers will be classified as Heavy, Light or Heavy/Light supplier in order to find possibilities to Co-Load supplier from different classifications.

In order to narrow down the scope of the project the suppliers had to be investigated deeper. To do so, the suppliers and their End Receivers had to be found and matched with the other suppliers. Meaning that each supplier has locations to where they send the goods. To be able to consolidate transportations between suppliers, the same end location i.e. End Receiver is desired for optimal Co-Loading and simplicity.

Secondary data (excel files) from each of the 28 suppliers was downloaded internally. Each supplier had one excel sheet consisting of between 80-9000 rows and with 73 columns of data. Among the data was irrelevant data, which would not contribute with any valuable information. For that reason, cleaning and sorting the data was vital. Two options to clean and sort the data existed, either manually, which would take a tremendous amount of time and would increase the risk of making mistakes (human factor mistakes). The other option was by using Visual Basic for Applications (VBA) programming which would lower the time spend on cleaning and sorting, but also, decreasing the risk of mistakes. The latter option was selected.

6.1.1 Definition of End Receiver

An End Receiver is a string consisting of three-variable; Type (what type of storage place, can be CDC, DC, STO etc.), City (is a country specific code, for example, Sweden is SE) and a Code (a unique number since there could be many CDC in a specific country). Below, in Table 6.1 two examples of End Receivers are presented.

Table 6.1: Description of End Receiver

Type	City	Code	End Receiver	Description
STO	DE	139	STO,DE,139	Store located in Germany with unique code 139
CDC	GB	269	CDC,GB,269	Customer Distribution Center located in Great Britain with unique code 269

6.1.2 Finding the Supply Chain Matrix

The SCM is a square matrix containing an equal number of rows and columns. Yet, to obtain a SCM, all the data has to be processed and correlations need to be found, which means effort is needed to design a VBA code that can solve the issue, preferably in a step-by-step method.

Since the host company strives to increase the EQU in all areas, the VBA code that was developed was written so that it can be reused to examine other suppliers in other areas just by modifying the VBA code slightly. The step-by-step method for finding the SCM was divided into seven steps i.e. seven macros, where each macro solves and simplifies the problem.

The first macro cleans each sheet of supplier information so that only the relevant data will be left and it also removes possible duplicates of End Receivers.

The second macro merging three columns so that a string presents the End Receivers, as described in Table 6.1. Therefore, instead of having three variables in three columns in mind, only once column with one string is necessary to keep in mind.

The third macro is calculating how many End Receivers each supplier has and printing that number at the top of each sheet.

The fourth macro is taking the sorted and cleaned End Receivers for each supplier, in each sheet, and presenting them in one sheet.

The macro with the most complex code is the fifth macro where each End Receiver for each supplier is matched using the built in function in excel, Vlookup. This information is stored in a new sheet.

The sixth macro is printing the supplier information, i.e. supplier data into the new sheet with the matched End Receivers. All the End Receivers are now addressed and exist in one sheet, however this sheet consists a lot of data so it is difficult to draw conclusions without knowing the structure of the data.

The last step is to copy all the data in the current sheet (scm) and paste into a pre-written excel template. By doing so, the data, which seems unstructured, is presented in a structured format in a $28x28$ square SCM.

In order to reproduce the steps to get a SCM a step-by-step method is presented below and can be adapted for other regions at IKEA, see Table 6.2.

Table 6.2: How to get the Supply Chain Matrix for the suppliers

Step & Description
1. Open a new Excel Workbook
2. Download and save the SPI for the supplier
3. Copy all the SPI data for the supplier
a) Paste the data into the Workbook in a new Sheet
b) Rename the Sheet to the supplier number
4. Repeat Step 2-3 until all SPI data for each supplier are in different Sheets
5. Click on the developer tab
6. Import the following .bas files:
a) *sortMainSourceFile1*
b) *mergeCells2*
c) *getUniquePos3*
d) *supplierUniqueLocations4*
e) *matchLocationsWithVlookUp51*
f) *printSupplierInformation6*
g) *fixSCMatrix7*
7. Run macro: *sortMainSourceFile1*, see Appendix A.1
Cleaning the data and eliminating unnecessary data
8. Run macro: *mergeCells2*, see Appendix A.2
Merging cells so that the End Receivers are in one column for all suppliers
9. Run macro: *getUniquePos3*, see Appendix A.3
Counting how many End Receivers each supplier has
10. Create a new Sheet and name it to "sum" and return to the first Sheet
12. Run macro: *supplierUniqueLocations4*, see Appendix A.4
Printing all the End Receivers for each supplier in the sum sheet
13. Create a new Sheet and name it to "scm" and return to Sheet "sum"
14. Run macro: *matchLocationsWithVlookUp51*, see Appendix A.5
Matches each End Receiver for each supplier with all the other suppliers
15. Run macro: *printSupplierInformation6*, see Appendix A.6
16. Copy all the data in Sheet "scm"
17. Open the Workbook "SCTemplate"
18. Paste the copied data into the first Sheet in "SCTemplate"
19. Run macro: *fixSCMatrix7*, see Appendix A.7
20. The last sheet now contains the Supply Chain Matrix

6.1.3 The Distance Matrix

However, it is not enough to sort out and to draw conclusions of the suppliers based on the SCM where relations are presented. Other aspects needs to be taken into account and one of them is the distances between the suppliers, which is a limitation set by the company to lower the carbon dioxide pollution. This distance limit is set to be 100 km. Thus, distances from each supplier to every other supplier needed to be established.

To measure the distances between the suppliers realistically the longitude and latitude coordinates (GPS position) was found by entering the address of the suppliers into Google maps. Thereafter, the distances between the suppliers could be discovered and ended up with a square matrix with the dimensions $28x28$ and where each intersection a distance is displayed in km (1000 meters).

6.1.4 Weight classification of the suppliers

Since many of the suppliers are producing different products it is difficult to find a clear distinction between heavy or light suppliers. The weight classifications were determined by questioning the Supply Planners and studying what type of products the suppliers are producing. The classification is presented in Table 6.3 below.

Table 6.3: Weight classification of the suppliers

Classification	Supplier
Heavy (H)	SUP1, SUP2, SUP3, SUP4, SUP5, SUP6, SUP9, SUP10, SUP15, SUP17, SUP18, SUP19, SUP21, SUP24, SUP26, SUP27 and SUP28
Light (L)	SUP7, SUP11 and SUP25
Heavy/Light (H/L)	SUP8, SUP12, SUP13, SUP14, SUP16, SUP20, SUP22 and SUP23

As illuminated above, there are 17 suppliers that are considered as heavy, three as light and eight, which are a mix between heavy and light. Further on the suppliers abbreviated as Light and Heavy/Light are presented as **bold text** in the tables and matrices for simplicity.

6.2 Goods Transports

6.2.1 Types of transportation equipment

The transportation of goods from the suppliers, in the Baltic region, to its End Receiver are carried out by a LUT which could be a truck or a container depending on the need and where the goods will be sent. However, in the Baltic region the most used transportation mode is truck were two types are the most frequently used. There is different weight limitations depending on the carrier (IKEA uses many different carriers), however there are two general truck types used, see Table 6.4 below.

Table 6.4: Characteristics of the carriers LUTs

Type	Length (m)	Capacity (m^3)	Weight limitation (ton)
T90	13,4	80	$20 \leq ton \leq 25{,}5$
T90L	13,6	90	$20 \leq ton \leq 25{,}5$

The goal is to utilize the LUT as much as possible in order to lower the costs, however, when the LUT cannot be loaded so that the volume or the weight limitation is reached, the LUT must dispatch with less than optimum conditions. When this occurs, a Less Than Truck Load (LTL) is ordered from the transport carrier. Nevertheless, both the buyer and the carrier are striving to obviate from bad utilization in the LUTs. If the LUTs is utilized as much as possible i.e. that no more goods can be loaded or that the weight limitation is reached, the LUT is considered as a full LUT and a FTL is ordered from the carrier.

6.2.2 The goods

To be able to plan and maximize the transportation equipment in a safe way, the goods and their characteristics have to be known. The corresponding height of the goods depends on what type of pallet is used and is therefore measured with or without the pallet. The length and the width of the goods are measured normally, see Figure 6.1 for the dimension of measurements of a non-EUR or IKEA wooden pallet.

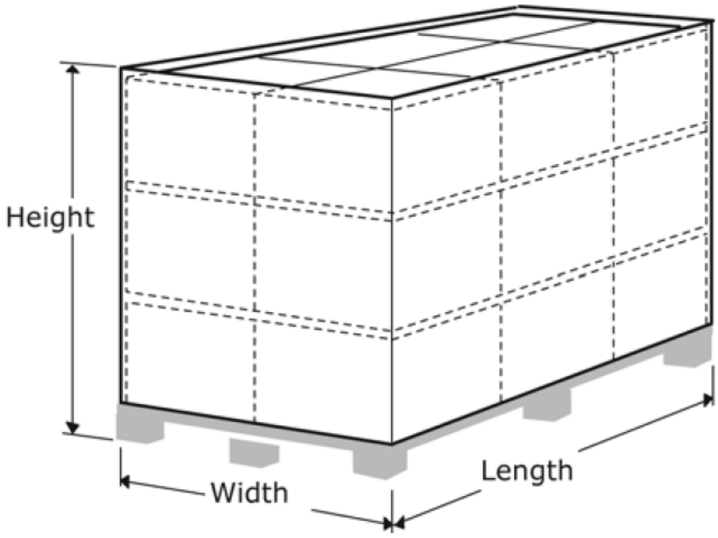


Figure 6.1: How to measure the pallet

The suppliers are responsible for providing IKEA with the details about the Dimension Weight Package (DWP) data for all the goods. The DWP consists of deep data of every product and package such as dimensions, weight, material etc. The DWP is very important because the data is used throughout the whole supply chain; loading, warehouses, stores, and transport booking are some examples of units at IKEA that are using the DWP data. Therefore it is of high importance that the suppliers are providing IKEA with accurate DWP data. In some cases it can be difficult since external factors can affect the goods and especially the weight. For example, the weight of wood depends on the humidity, if the whole LUT is loaded with wood the weight deviates from time to time.

6.2.3 Loading the Loading Unit Types

A way to increase the EQU and to secure that the goods will be transported safely is by loading the LUTs efficiently. Doing it right from the beginning will decrease the risks of damages and claims from the receivers. For planning the loading units the DWP data is used by the transportation planners. They are using advanced optimization tools to calculate how to place the goods in the best possible way for every unique shipment. The key is to reduce air or empty space since it will decrease the transport costs and damage problems.

Another way to increase the EQU dramatically is to use top fillers with goods, meaning that smaller units of goods are placed where there is empty space in order to utilize the volume of the LUT as much as possible. Consequently, some suppliers are producing goods intended for top filling only, see Figure 6.2 for a possible placement of top-fillers.

Figure 6.2: Top fillers in a Loading Unit Type

Yet, there exists suppliers producing products with rare dimensions leading to difficulties to fill the LUT efficiently and as a result have to use filling material, such as airbags, to secure the goods.

Sometimes it happens that the carrier sends the wrong LUT, for example a T90 instead of a T90L. A very experienced forklift operator can see the difference between these LUT, nevertheless, there are many that cannot see the difference. This leads to goods that are supposed to fit in the LUT not fitting or to unsatisfactory utilization. The suppliers therefore have an important responsibility of securing the right LUT from the carrier, if not, they should report it and refuse to load that LUT. The most important aspect is the availability of the products, not the EQU. This runs the risk of the goods arriving late to the stores. A trade-off has to be made by the suppliers to choose to fill the LUT anyway or to let it leave without all the goods. Nevertheless, the suppliers are obliged to report irregularities to the transport management.

6.2.4 Co-Loading example

Good

In Figure 6.3(a) the Supplier has loaded the goods in the best possible way and secured them with a net to avoid the pallets from moving around during the transportation to the second supplier. The second supplier has removed/kept the net and the loaded their goods and thereafter secured it with a net for the same reason as the first supplier, see Figure 6.3(b).

(a) First supplier **(b)** Second supplier

(c) Third supplier **(d)** Third supplier

Figure 6.3: Good Co-Load example between three suppliers

The last supplier has also loaded according to the guidelines and secured the pallets, see Figure 6.3(c) and Figure 6.3(d). Now a high EQU is obtained and the LUT is shipped to the End Receiver.

Bad

The first supplier has loaded the pallets in a bad way without any security approach, which makes it impossible for the second supplier to load efficiently without damaging the goods, see Figure 6.4.

(a) First supplier **(b)** Arrived at the second supplier

Figure 6.4: Bad Co-Loading by suppliers

A lot of space is left between the pallets, which could cause the pallets to move and not allow the next supplier to load as planned.

6.3 Physical Distribution Methods

IKEA is currently using five different distribution methods to provide the goods from the manufacturing suppliers to their End Receiver.

The flow of the goods is presented in blue lines in the pictures below. The dark blue line represents the actual flow of goods while the lighter one represent possible paths. The figures are adopted from (IKEA, 2015c).

6.3.1 Customer Order

A method where the goods are ordered by the customers for home delivery. The customer orders the goods in either the store, by e-commerce or by mail. The goods, which are stocked in the Customer Distribution Center (CDC) or Retail Distribution Unit (RDU), are delivered to the customers address directly from CDC via a hub or from a RDU via a Local Service Center (LSC).

Figure 6.5: Customer Order

The CDC can be replenished in three different ways. The first one from a DC which in turn is supplied by the suppliers. Next, from a CP or directly from the suppliers. This is visualised in the Figure 6.5 with the light blue lines.

6.3.2 Direct Delivery (DD)

The goods from the supplier are transported directly to the end customer i.e. the store, see Figure 6.6. This method is a highly cost efficient method, but, to be able to reach a high EQU the transport mode should be as utilized as possible.

Figure 6.6: Direct Delivery

To reach a high utilization for the transportation mode, the transportation carrier must wait until a sufficient amount of goods can be sent. It will affect the inventory levels negatively since stores must have a higher stock level to compensate the longer lead times that are required, (IKEA, 2015c).

6.3.3 Via Consolidation Point (CP)

A CP is used when the suppliers does not have sufficient amount of order(s) so that they can fill a whole LUT to a sufficient level in terms of EQU.

Figure 6.7: Via consolidation point

For that reason the suppliers sends the goods to a CP for Co-Loading the goods together with other suppliers so that a LUT is filled i.e. Full Truck Load (FTL). The full LUT with goods is then transported to the final destination, which can be DC or an IKEA store, see Figure 6.7.

6.3.4 Via Transit Point (TP)

A type of one-terminal system where the suppliers send goods to the Transit Point (TP) which is located at a DC. Here, the goods will be received and reloaded into a new LUT for further transportation, with higher fill-rate, to the stores.

Figure 6.8: Via Transit Point

This method exists for increasing the fill-rate in the transportation mode and have positive effects, such as, fewer goods in the supply chain and less problems with the stock levels.

6.3.5 Via Distribution Center (DC)

The DC is a big warehouse that is used for stock-keeping goods from many suppliers.

Figure 6.9: Via Distribution Center

The goods arrive to the warehouse from the suppliers and are dispatched to a selling unit for example the STOs. The DCs are strategically placed at many locations all over the world and hence the DCs are organized so that each DC is responsible for replenishing a group of selling units.

6.4 Co-Loading Goods Between Suppliers

IKEA (2015b) states a limitation of maximum three pick-up addresses, meaning that maximum three suppliers can Co-Load goods in one LUT.

The Supply Planner has the responsibility to inform the Transport Planner the amount of goods, (volume and weight), that should be sent from the supplier. That information is provided at least ten days before the shipment must dispatch. In a case that the goods are not sufficient to fill a whole truck, a LTL is ordered from the carrier by the Transport Planner.

Two days later the Transport Planner notifies the suppliers about volumes, the pick-up date, and that their shipment must be Co-Loaded with another supplier.

No less than four days before the shipment is dispatched, the suppliers must inform the Transport Planner of their acceptance of the shipment. The same day the Transport Planner makes contact with the carrier and informs them about the pick-up locations and volumes, and provides the supplier with loading instructions.

As soon as the carrier receives the transport booking they contact the supplier for more information and confirmation. They day before dispatch the carrier contacts the supplier for reconfirmation of the shipment, and will be informed of any possible delays. If the transport carrier will be delayed they are responsible for informing the chain of suppliers about the delays.

If everything goes according to plan, the LUT arrives on the dispatch day for loading the LUT with goods. The principles are strict when loading the LUT. For instance, the second supplier is not allowed to unload or reload the already loaded goods from the first supplier. However in some cases there are agreements between suppliers so that they can unload and reload goods in order to increase the Equipment Utilization (EQU). Yet, these sort of agreements are difficult to negotiate and are seldom seen among these 28 suppliers in Lithuania.

Moreover, the physical loading procedure is different from company to company. Some forklifts drivers are using gained experience when loading the LUT and others are using advanced software to calculate how to optimize the loading procedure. Even though many suppliers possess the technique and the Transport Planner provides them with loading instructions, it is poorly used by the forklifts drivers because they believe they have acquired knowledge. Occasionally the loading results are even better than calculated. Though it still can contributes to problems later, when the next supplier has to load their goods. If the first supplier has not loaded according to the instructions, there is a high risk that it will not be possible to load all planned pallets at the next supplier.

6.5 Logistic Performance And Measurements

IKEA pays for the transport between the suppliers and the destination, where the carrier charges IKEA per cubic meter (m^3) goods and distance (km). By increasing the fill rate in the LUT, less frequent transportation is needed and, consequently, lower transportation cost as result.

During the last few years, IKEA has been measuring transport efficiency with filling rates as Key Performance Indicator (KPI). Last year (2014), a new approach for measuring the transport efficiency was redefined and introduced.

6.5.1 Equipment utilization (EQU)

EQU measures the efficiency in the transportation in terms of use of the equipment and is divided into three areas of measurement. Measuring these three areas gives a clearer picture of the situation, and each area complements the other areas well.

First, the EQU, which also now is the KPI, is measuring how much net goods in cubic meters that are sent every shipment, see (6.1).

$$Nm^3/shipm = \frac{\text{Net } m^3 \text{ Goods}}{\text{Number of shipments}} \tag{6.1}$$

The filling rate measures how well the volume is utilized meaning the fraction between net cubic meters of goods and the LUT volume i.e. truck container etc, see (6.2).

$$\text{Filling Rate (\%)} = \frac{\text{Net } m^3 \text{ Goods}}{\text{Loading Unit Type (LUT) volume}} \tag{6.2}$$

The last area of measuring the EQU is how well the LUT is used in terms of weight, see (6.3)

$$\text{Weight Utilization (kg)} = \text{Total weight of shipment} \tag{6.3}$$

6.5.2 How to measure the fill rate and EQU in the transportation

Fill rate and EQU are based on calculations for each and every consignment. The calculations are based on, when the consignment has arrived to the receiver, and is calculated with the Co-Loaded consignments total net volume and the LUTs volume.

Since a consignment can be connected to one or several shipments before arriving to the End Receiver the fill rate and EQU is only calculated on one of the shipments, either the first shipment or the last shipment. First and last shipment is described below in an illustration, see Figure 6.10.

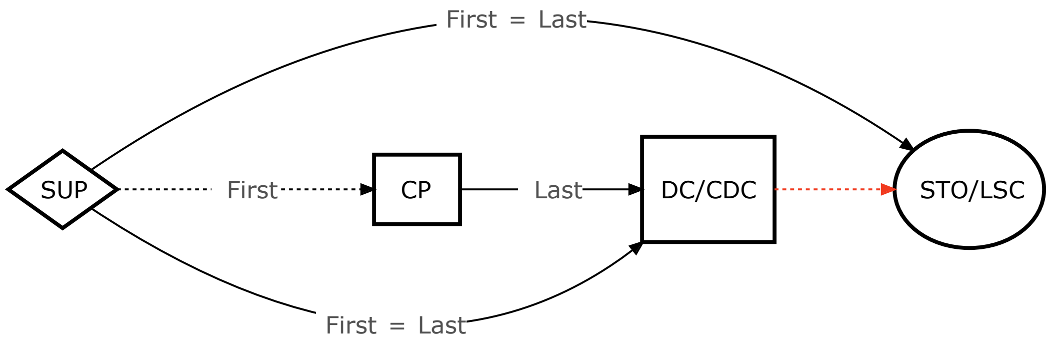


Figure 6.10: Explanation of first and last shipment

The last shipment is reflecting the main costs and is therefore considered in the calculation of the fill rate and EQU. However, the calculation of fill rate and EQU is simple when only one supplier is delivering, but in many cases many suppliers are delivering and consolidating goods along the supply chain and therefore these rules are the guidelines:

- Only consignments that have arrived to the End Receiver for a specific supplier are considered
- Only last shipments of these consignments are taken into consideration

To demonstrate how the fill rate and the EQU are calculated for inbound transportation, an example will be presented, see Figure 6.11.

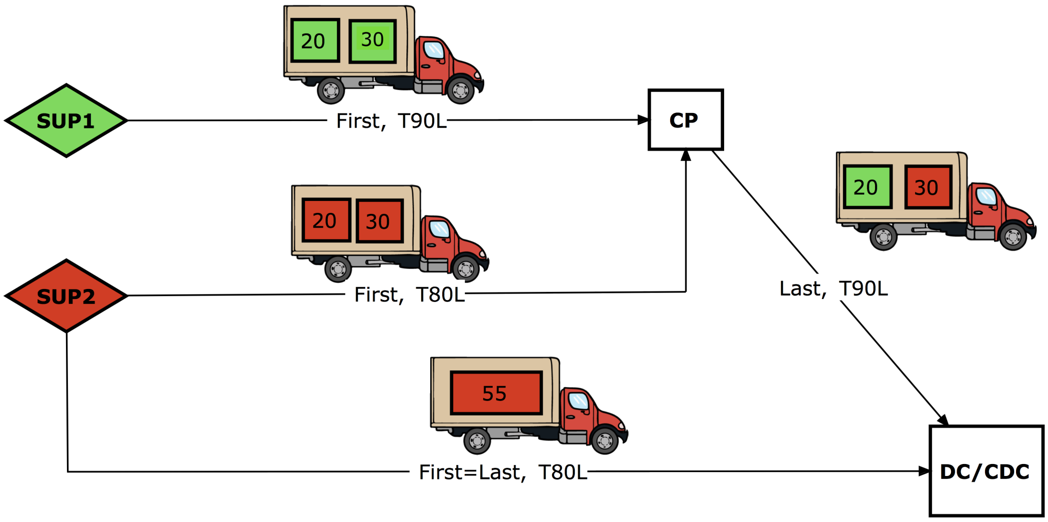


Figure 6.11: EQU for Inbound transportation

Studying Supplier 1 and 2 with two inbound shipments with given volume and LUT. Supplier 1 is delivering 50 m^3 (20+30) to the CP for consolidation with Supplier 2 who is delivering 60 m^3 (20+40) respectively. The CP consolidates 20 m^3 from Supplier 1 and 30 m^3 from Supplier 2 and then the new shipment goes to the DC. In parallel Supplier 2 sends 55 m^3 directly to the DC, What is the fill rate and EQU for Supplier 1 and Supplier 2? By considering the guidelines we get the result presented in Table 6.5.

Table 6.5: Example: Fill rate and EQU for inbound transportation

	SUP1	SUP2
Number of last shipments	1	2
Total volume (m^3) of LUT involved	90	$90 + 80 = 170$
Total net volume for all consolidated consignments	$20 + 30 = 50$	$20 + 30 + 55 = 105$
Fill Rate (%)	$\frac{50}{90} = 55{,}6$	$\frac{105}{170} = 61{,}8$
EQU (nm^3/shp)	$\frac{50}{1} = 50$	$\frac{105}{2} = 52{,}5$

Another example for illustrating Direct transportation of the goods is presented below in Figure 6.12. Here, three suppliers are investigated and fill rate and EQU are illuminated.

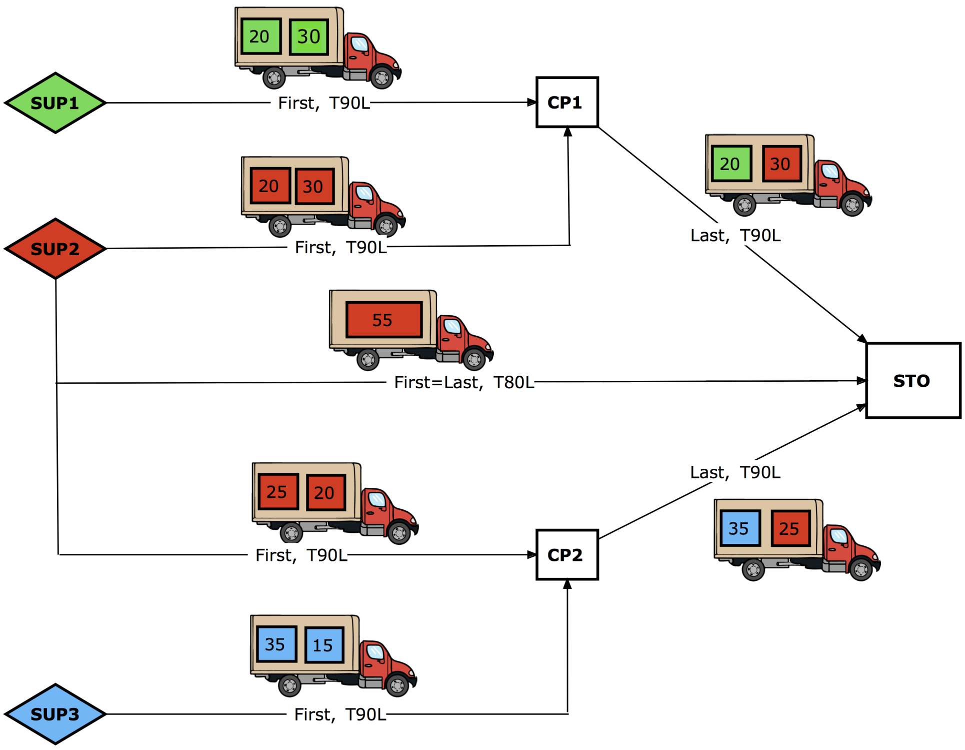


Figure 6.12: EQU for Direct transportation

The calculations of fill rate and EQU as before gives the results in Table 6.6 below.

Table 6.6: Example: Fill rate and EQU for Direct transportation

	SUP1	SUP2	SUP3
Number of last shipments	1	3	1
Total volume (m^3) of LUT involved	90	$90 + 80 + 90 = 260$	90
Total net volume for all consolidated consignments	$20 + 30 = 50$	$20 + 30 + 55 + 35 + 25 = 165$	$35 + 25 = 60$
Fill Rate (%)	$\frac{50}{90} = 55{,}6$	$\frac{165}{260} = 63{,}4$	$\frac{60}{90} = 66{,}7$
EQU (nm^3/shp)	$\frac{50}{1} = 50$	$\frac{165}{3} = 55$	$\frac{60}{1} = 60$

CHAPTER 7

Results: Co-Loading

This chapter consists of calculations and results based on previous chapters regarding the phenomenon Co-Loading. First the suppliers are divided into clusters. Then two scenarios are used to illuminate the possibilities to perform Co-Loads. Last, information gathered from current and previous chapters determines the best supplier set-up for one cluster and one supplier.

7.1 Identified Supplier Clusters

The DM shows the distances between the suppliers in kilometers, see the DM in Appendix B.1. The DM is the foundation when clustering the suppliers for facilitating finding possible Co-Loads.

Two approaches were used to show the clusters. The first approach used was a clustering technique which is well known in the in the industry where it is used for clustering machines according to order in which components should be processed. The clustering was based on distances, where a distance below 100 km between two suppliers was abbreviated as number one (1), in order to smooth out the clustering process. It was performed manually by arranging the suppliers position until distinguish clusters appeared, see Figure 7.1.

	SUP1	SUP3	SUP6	SUP9	SUP10	**SUP11**	SUP24	SUP2	SUP4	**SUP8**	**SUP13**	**SUP16**	SUP17	SUP18	**SUP20**	SUP21	**SUP23**	SUP26	SUP27	SUP28	SUP5	**SUP7**	**SUP12**	**SUP14**	SUP15	SUP19	**SUP22**	**SUP25**
SUP1		1	1	1	1	1	1																					
SUP3	1		1	1	1	1	1																					
SUP6	1	1		1	1	1	1																					
SUP9	1	1	1		1	1	1																					
SUP10	1	1	1	1		1	1																					
SUP11	1	1	1	1	1		1																					
SUP24	1	1	1	1	1	1																						
SUP5																												
SUP2									1	1	1	1	1	1	1	1	1	1	1	1								
SUP4								1				1	1		1	1	1		1	1								
SUP8								1			1	1		1	1		1	1	1									
SUP13								1		1		1	1	1	1	1	1	1	1	1								
SUP16								1	1	1	1		1	1	1	1	1	1	1	1								
SUP17								1	1		1	1		1	1	1	1	1	1	1								
SUP18								1		1	1	1	1			1	1	1	1	1								
SUP20								1	1	1	1	1	1				1	1	1									
SUP21								1	1		1	1	1	1			1	1	1	1								
SUP23								1	1	1	1	1	1	1	1	1		1	1	1								
SUP26								1		1	1	1	1	1	1	1	1		1							1		
SUP27								1	1	1	1	1	1	1	1	1	1	1		1								
SUP28								1	1		1	1	1	1		1	1		1									
SUP7																							1	1	1	1	1	1
SUP12																						1		1	1	1	1	
SUP14																						1	1		1	1	1	1
SUP15																						1	1	1		1	1	1
SUP19																		1				1	1	1	1		1	1
SUP22																						1	1	1	1	1		1
SUP25																						1		1	1	1	1	

Figure 7.1: Clustered suppliers according to the DM

Three clear groups are illuminated (Blue, Green and Red) and a bold supplier name means that the suppliers are considered as Light or Heavy/Light.

In the next approach the DM was executed in Matlab as a dendrogram[1]. The corresponding dendrogram, see Figure 7.2, shows clearly the relations between the suppliers in terms of distances. The height of the vertical lines tells to what extent the suppliers are related or not related to each other's where a high line means low relation and vice versa.

1 Finds correlations between objects and then displays the relations in a diagram called dendrogram

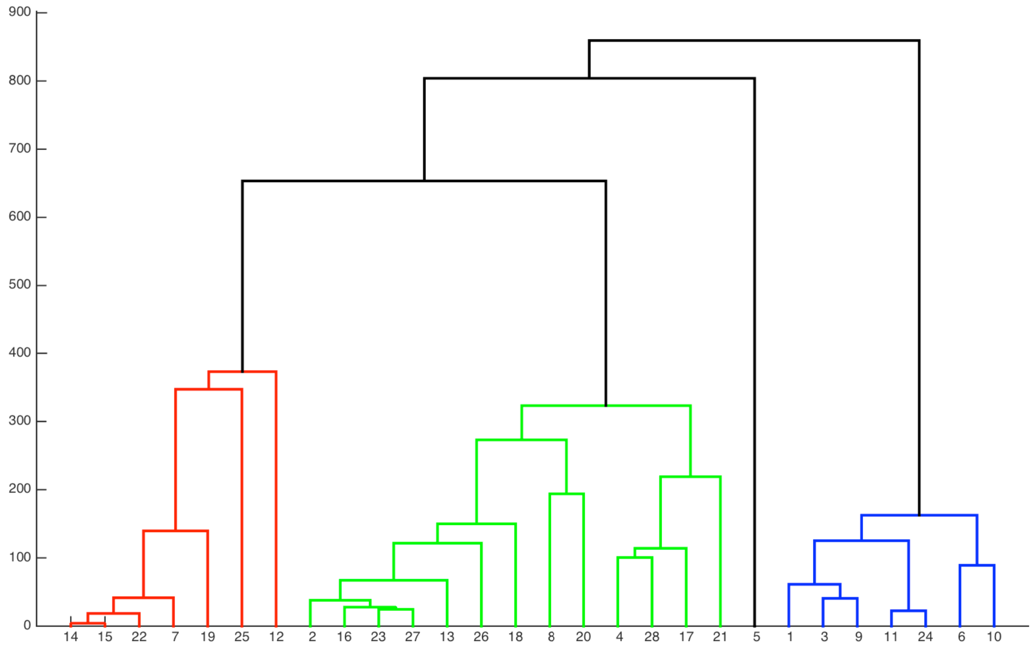


Figure 7.2: Dendrogram based on the Distance Matrix

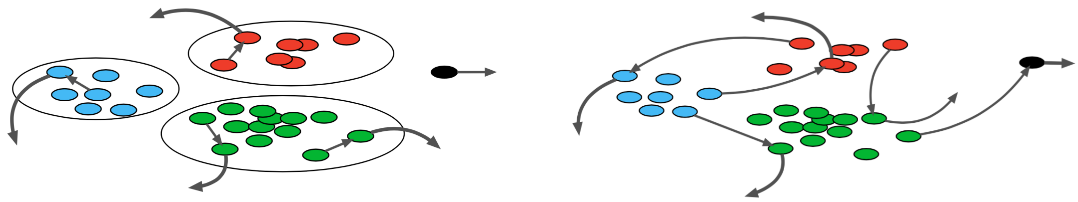
By studying the clusters in Figure 7.1 and/or Figure 7.2 it becomes clear that supplier five does not have any relation to any other supplier i.e. no relation to any supplier within 100 km. However, it is the only supplier that does not have any distance relation to the other suppliers.

The mixture of heavy and light suppliers is important for increasing the possibilities to perform Co-Loads between the suppliers. The Blue cluster does have a poor mixture of heavy and light suppliers, where only one supplier is considered as Light/Heavy (SUP11), which means that the suppliers in the Blue cluster will struggle to find Co-Loads because the weight limitation tends to be reached before the volume limitation in the LUTs. Consequently the LUT will be poorly utilized.

However, the Red and the Green clusters have a good combination of heavy and light suppliers which consequently enables these suppliers, in these two clusters to be more efficient and Co-Load more.

7.2 Scenarios

Two scenarios were developed to increase the EQU. The first scenario is to optimize each cluster individually within the distance limitation of 100 km. In the next scenario we study how to increase the EQU by thinking outside the box and allowing the shipments to travel more than 100 km. These two scenarios do allow Co-Loads to different extents. Cluster optimization covers one set of suppliers to perform Co-Loads. The off-limit optimization covers another set of suppliers, which cannot be addressed in the first scenario. The set-up for those two scenarios are illuminated in Figure 7.3, where the three rings represents where the three clusters (Red, Green and Blue) are located. The coloured dots represent the suppliers in the clusters and the lines indicated the Co-Loading.



(a) Cluster optimization **(b)** Off-limit optimization

Figure 7.3: Illustration of the scenarios

Four weeks of shipments, which corresponded to 1547 shipments, were observed to perform analyzes. Of these shipments only the delivery *first=last* shipment was observed because otherwise shipments from each CDC, DC or equivalent had to be collected, which would have been to complex.

The scenarios were compared with the current situation and the performances of those shipments. These scenarios also have the following requirements to perform a Co-Load:

- Must have the same End Receiver
- Must dispatch on the same day
- Must not exceed a volume utilization in the LUT of 80%. This limitation is set based upon observations of the current performance and what is realistic.
- Must not exceed the weight limitation of the LUT

In order to find Co-Loads with the above presented prerequisites a macro was written and used to sort out and find Co-loads among the large set of data. The conceptual method for finding these Co-Loads are simplified below in Figure 7.4 and the macro can be seen in A.9.

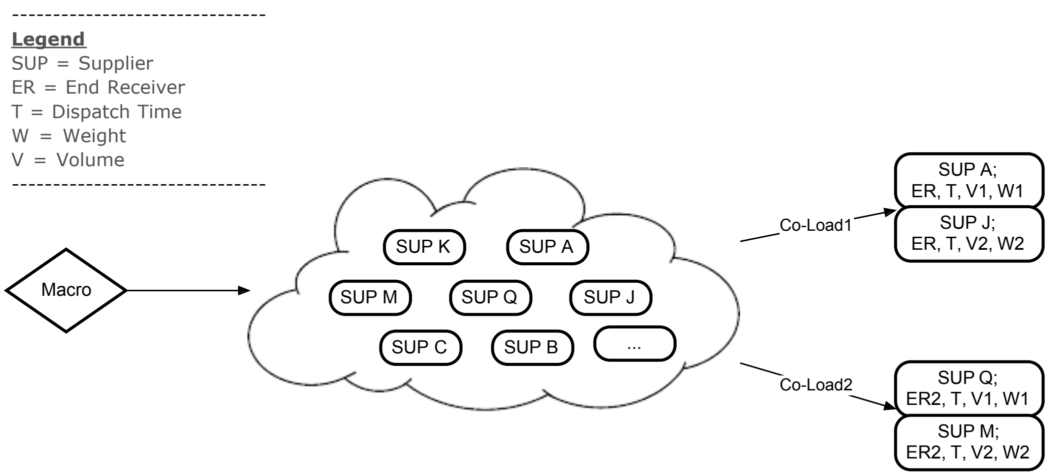


Figure 7.4: Conceptual method for finding Co-Loads

The cloud represents the suppliers and the shipment data for each supplier. The shipment data is sorted with the macro based on the End Receiver and the dispatch date. Then the macro investigates which suppliers have the same End Receiver, dispatch time and if they do not exceed the limitations of the LUT. If that is fulfilled the shipment are merged into one shipment and a Co-Load between two suppliers are established. Due to the low possibilities to perform Co-Loads with more than two suppliers and outer circumstances such as regulations complexity, the macro was written to manage Co-Loads, only between two suppliers.

7.2.1 Cluster optimization

The shipments before and after the Cluster optimization method are presented below in a histogram. The outcome before, contra after the Co-Loads are presented below, see results in Figure 7.5.

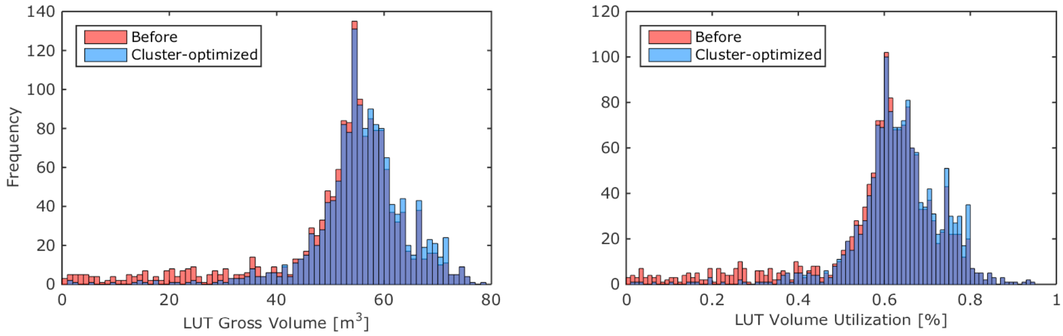


Figure 7.5: Histogram for the Cluster optimization

As we can see, the tails and the gravitation of the center has been moved further right towards a higher average gross volume in the shipments as well as the volume utilization in the LUT. More detailed results are presented below in Table 7.1.

Table 7.1: Results from Co-Loading within clusters

Cluster	Red	Green	Blue	SUP5	Total
Shipments before	172	565	718	92	1547
Gross Volume [m^3]	46,93	52,41	52,84	56,13	51,92
Gross Vol Utilization [%]	0,53	0,60	0,59	0,59	0,59
Gross Weight [kg]	7 269,26	15 931,53	19 253,48	20 980,32	17 042,44
Gross Weight Utilization [%]	0,30	0,66	0,78	0,86	0,69
Co-Loads	32	49	30	0	111
Gross Volume [m^3]	60,70	61,12	63,41	N/A	61,74
Gross Vol Utilization [%]	0,69	0,69	0,72	N/A	0,70
Gross Weight [kg]	10 071,15	19 355,63	22 925,92	N/A	17 450,90
Gross Weight Utilization [%]	0,41	0,80	0,93	N/A	0,71
Shipments after	140	516	688	92	1436
Gross Volume [m^3]	58,04	57,39	54,46	56,13	55,93
Gross Vol Utilization [%]	0,66	0,66	0,61	0,59	0,63
Gross Weight [kg]	8 968,21	17 444,40	20 582,58	20 980,32	18 359,78
Gross Weight Utilization [%]	0,37	0,72	0,83	0,86	0,74
Difference/Change					
Shipments reduction	-18,6%	-8,7%	-4,2%	0,0%	-7,2 %
Gross Volume Utilization [%]]	23,7%	9,5 %	3,1 %	0,0 %	8,5 %
Gross Weight Utilization [%]	23,4 %	9,5 %	6,5 %	0,0 %	7,0%

Noteworthy is that the Red cluster does have a very large share of possible Co-Loads in comparison to the number of total shipments. The reason for that is that the LUT shipments are very poorly utilized, which is bad, but leads to a great possibility to perform Co-Loads.

SUP5 had to be handled separately since it does not addressed to any cluster due to the distance limitation and therefore no Co-Loads can be made with this supplier.

Overall, by optimizing each cluster respectively, the shipments in total can be reduced by 7.2 % which corresponds to a 8.5% higher gross volume utilization and 7 % higher weight utilization in the LUT.

7.2.2 Off-limit optimization

When not taking the distance limitation into consideration, the following histogram, before and after Co-Loading, illuminates the differences, see Figure 7.6.

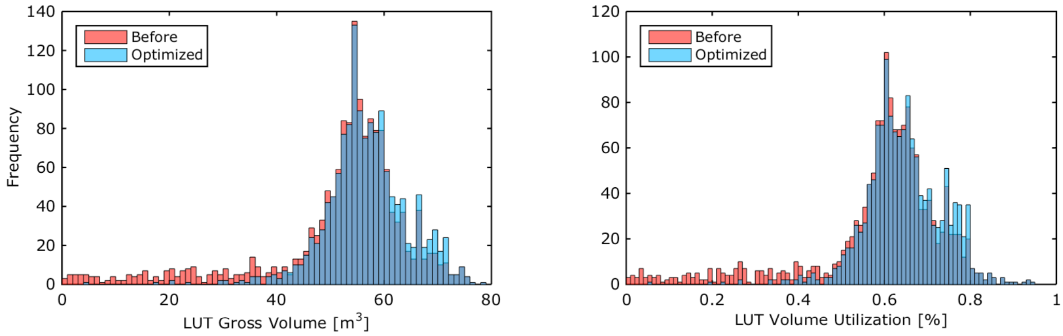


Figure 7.6: Histogram for the Off-limit optimization

With the off-limit optimization method enables Co-Loads beyond the distance limitation, but also within the limitation. Yet, few Co-Loads are made within the limitation and thereby within the clusters. Approximately 25% are performed with the clusters and the rest beyond the distance limitation.

Table 7.2: Results from Co-Loading with Off-limit

	Shipments	Gross Volume $[m^3]$	Gross Vol Utilization [%]	Gross Weight [kg]	Gross Weight Utilization [%]
Before	1547	51,92	0,59	17 042,44	0,69
Co-Loads					
Red	3	63,99	0,74	11 704,73	0,47
Green	27	63,77	0,72	21 545,84	0,89
Blue	17	62,88	0,71	24 089,45	0,97
SUP5	3	61,76	0,69	21 105,69	0,88
Off-Limits	83	63,33	0,72	21 946,94	0,90
After	1414	56,80	0,65	17 590,85	0,76
Difference	-133	4,88	0,06	548,41	0,07
Percentage	-8,60%	9,41%	9,41%	3,22%	9,41%

However, this method does reduce the number of shipments with 133 units and increase the performances for every other measures, see Table 7.2.

7.2.3 Scenario comparison

Co-Loading between suppliers will reduce the number of shipments, increase the volume and weight utilization in the LUTs regardless of using the Cluster or Off-limit method. These two scenarios were compared in order to see the difference, see Table 7.3 below.

Table 7.3: Scenario comparison

Scenario	Cluster optimization	Off-limit optimization	Difference
Shipments before	1 547	1 547	
Co-Loads	111	133	
Red	32	3	-29
Green	49	27	-22
Blue	30	17	-13
SUP5	0	3	3
Off-limit	0	83	83
Shipments after	1 436	1 414	-22
Gross Volume [m^3]	56,51	56,80	0,30
Gross Vol Utilization [%]	0,63	0,65	2,3%
Gross Weight [kg]	16 993,88	17 590,85	596,97
Gross Weight Utilization [%]	0,69	0,76	9,3%

The pros of using the Cluster optimization method are working closer with a small set-up of suppliers contra working and perform Co-Loads with a large set of suppliers which is inevitable with the Off-limit optimization method. However, more shipments can be Co-Loaded with the Off-limit method than the Cluster method, which lowers the total transportation costs as the total transport distance.

7.3 Supplier set-up and Co-Loading for one supplier

The suppliers within the clusters have different possibilities to accomplish a Co-Load with other suppliers, this is why finding the suppliers which have a good potential is important in order to merge shipments into a Co-Load.

Finding the cluster and the supplier that has the best possibility to perform Co-Loads was determined by combining the DM, the SCM and the Weight Classification for the suppliers into one matrix, the Combination Matrix.

7.3.1 Establishing the Supply Chain Matrix

First, the SCM was determined by executing the macros in the order represented in Table 6.2 and for informational purposes, the time it took for executing each macro was measured and the results can be seen in Table 7.4 below.

Table 7.4: Time for execute the macros

Macro name	Time (s)	Inspiration Source
1. sortMainSourceFile1	45.64	(Analysistabs, n.d.; Easy, n.d.; Walkenbach, 2007)
2. mergeCells2	0.93	(Analysistabs, n.d.; Easy, n.d.)
3. getUniquePos3	0.47	(Easy, n.d.)
4. supplierUniqueLocations4	1.69	(Analysistabs, n.d.; Easy, n.d.)
5. matchLocationsWithVlookUp51	1013.01	(Analysistabs, n.d.; Stackoverflow, n.d.; Trick, n.d.)
6. printSupplierInformation6	1.61	(Analysistabs, n.d.; Easy, n.d.)
7. fixSCMatrix7	12.92	(Analysistabs, n.d.)
Sum:	**1076,27**	17.94 min

Notable is that it almost took 17 (16.88) minutes to execute macro number 5, *matchLocationsWithVlookUp51*. The reason for this is the fact that each End Receiver had to be matched against every other End Receiver for every supplier. However, good things comes to those who wait and the SCM was established showing to what extent the suppliers have similarities in terms of same End Receivers and to what degree (in percentage) the End Receivers are the same. The whole SCM is presented in Appendix B.2.

Hence, for clarification one example is described. Lets study a snapshot from the SCM in Figure 7.5 and lets investigate the intersection between supplier SUP5 and SUP2 (highlighted in yellow).

Table 7.5: Snapshot of the Supply Chain Matrix

Supplier		SUP1	SUP2	SUP3	SUP4	SUP5	SUP6
	End Receivers	136	279	338	391	291	194
SUP1	136	0/0	86/0,63	130/0,96	136/1	70/0,51	75/0,55
SUP2	279		0/0	249/0,89	279/1	220/0,79	127/0,46
SUP3	338			0/0	337/1	242/0,72	157/0,46
SUP4	391				0/0	288/0,74	194/0,5
SUP5	291					0/0	130/0,45
SUP6	194						0/0

Supplier SUP5 has 291 End Receivers and SUP2 have 279 End Receivers, where 220 End Receivers for supplier SUP2 is the same as for supplier SUP5, which corresponds to 79%.

7.3.2 Establishing the Combination Matrix

Now when the SCM was established, the SCM, the DM and the Weight Classification were combined with a single macro, see Appendix A.8. It lead to the full Combination matrix, see Appendix B.3.

Hence, to narrow down the set of possible suppliers two decision variables were set as fixed, variables that modifies the outcome. The first variable was the relation between different suppliers from the SCM, where a value in per cent in the interval $0 \leq \text{value} \leq 1$ was chosen, where 0% means zero relation between the suppliers in terms of End Receivers and 1 represent 100% correlation.

In order to sort out some suppliers to investigate deeper and to not have to large set of data, the first decision variable was set to be 50%. A lower selected percentage would increase the number of possibilities and leading to a large set of connections. A higher percentage is decreasing connections between the suppliers and consequently leading to a smaller set of suppliers to investigate.

The second decision variable was the distance, which was set to 100 km according to the current limitations. The results from the narrowed-down Combination Matrix are presented in B.4, where the suppliers also are grouped according to the clusters.

7.3.3 Cluster selection

Selecting the cluster was based on the following criterion:

1. The Combination Matrix
2. Mix of heavy and light suppliers
3. Number of supplier in the cluster
4. The shut-down of the CP during the summer of 2015
5. The observed shipments
6. Direction from the supervisor
7. Gut feeling

A mix of heavy and light supplier is central to find possible Co-Loads. The Combination Matrix gives a good indication of which suppliers sends goods to the same End Receiver and thereby increases the opportunity to find Co-Loads. The more suppliers within the cluster, the better chance to perform Co-Loads and increase the shipment dynamic. When looking into the Cluster optimization results in Table 7.1, the Red cluster can Co-Load significantly and therefore it cannot be ignored that it has a large Co-Loading potential. Yet, the Green cluster do require that more shipments be Co-Loaded in the future since the CP close to the Green cluster will be closed[1]. The cluster with the most potential due to high production growth within the next years is more relevant.

Based on above presented information and directions the Green cluster was selected. It has five suppliers abbreviated as light or heavy/light and has a large set of suppliers, explicitly 13 suppliers with 67 possible relations between each other's, within the 100 km limitation. Yet, not all of these 13 suppliers in the Green cluster have a sufficient End Receiver correlation (less than 50%). For that reason, these suppliers with not sufficient End Receiver correlation are not considered in the next step, selecting reference supplier and core-suppliers.

7.3.4 Select reference and core-suppliers

The Combination Matrix for the Green Cluster has one supplier that has many relations to the other suppliers, that is SUP20, which also is considered as heavy/light. For that reason SUP20 was selected as reference supplier. SUP20 has five core-suppliers closer than 100 kilometers away, while having a equality of End Receivers of 50% or more, see Table 7.6, which is based on the narrowed Combination Matrix (B.4).

Lets study the intersection between SUP20 and SUP13 as a short example for explanation. SUP20 is classified as heavy/light supplier with 209 unique End Receivers. SUP13 is also classified as heavy/light with 160 unique End Receivers. Of these 160 unique End Receivers 137 are the same as SUP20, which corresponds to 86%. The distance between SUP20 and SUP13 is 58 km.

1 This information was brought to me during the end of the stay in Lithuania

Table 7.6: The reference supplier and relations to the other core-suppliers

Supplier		**SUP20**
	End Receivers	209
SUP4	391	208/0,53/100
SUP8	361	200/0,55/71
SUP13	160	137/0,86/58
SUP16	86	61/0,71/70
SUP17	47	34/0,72/92

7.3.5 Current reference core-suppliers performance

Below in Table 7.7 the performances for the reference and the core-supplier in the green clusters are presented. The data is based of shipments of the fiscal year 2014.

Table 7.7: Supplier performance measurements FY 2014

Supplier	**SUP20**	SUP4	**SUP8**	**SUP13**	**SUP16**	SUP17
LUT share (T90,T90L)	92,5%	97,8%	92,9%	94,1%	100,0%	88,8%
Nm^3/Shp	51,2	52,4	47,8	54,3	53,4	44,8
Net FR	57%	58%	54%	62%	60%	50%
Gkg/Shp	13 672,9	16 525,6	21 465,1	14 126,1	5 005,7	13 142,9

Noteworthy is that only the LUT types T90 and T90L are taken into consideration even though other truck-types are used, however with a much lower frequency. This becomes clear when observing the Total LUT share, which for all suppliers does not end up with 100 per cent, except for SUP16, see Table 7.7. The information in this table is generated by Qlickview and shows the KPIs. Hence, it is of importance to notify that here the fill rate and Nm^3/Shp are established based on *net* cubic meters, not *gross* cubic meters. Nevertheless, if the performance measurements are performed in net or gross, has no importance, because performance raise in percentage yields the same results.

7.3.6 Co-Loading between the reference supplier and the core-suppliers

Two week of shipments from the Green Cluster and only shipment from the reference and core-suppliers, were investigated. During these specific weeks the reference supplier could perform five Co-Loads with the reference suppliers. The End Receiver is the major decision variable when deciding which supplier should do the first pick-up. For example if the End Receiver is located in Italy the first pick-up should be at the supplier furthest away from the End Receiver, in order to travel as little as possible.

As mentioned before it is not possible to reach a LUT utilization of 100%. Again, a realistic truth is that shipments with a LUT utilization above 80% are very, very rare. Consequently no Co-Loads exceeding a LUT volume utilization of 80 % were not allowed. Shipment data from shipments for the reference supplier and the core-suppliers were collected and in total 80 shipments could be allocated to these suppliers. Of these 80 shipments ten possible shipments could be Co-Loaded into five shipments, see Table 7.8.

Table 7.8: Co-Loads with the reference supplier, SUP20

	Co-Load 1	Co-Load 2	Co-Load 3	Co-Load 4	Co-Load 5
End Receiver	DT,IT,236	DT,ES,487	DT,FR,247	DT,FR,247	DT,IT,236
Date	21/04/15	22/04/15	27/04/15	27/04/15	03/05/15
Pick-up 1	**SUP8**	SUP4	**SUP20**	**SUP20**	SUP17
Pick-up 2	**SUP20**	**SUP20**	**SUP13**	**SUP13**	**SUP20**
Gross Volume [m^3]	65,35	61,2	71,51	72,32	67,75
Volume Utilization [%]	0,73	0,71	0,79	0,76	0,75
Gross Weight [kg]	24 138,82	17 886,44	21 981,24	22 383,24	15 534,5
Weight Utilization [%]	0,99	0,75	0,92	0,90	0,65

Only by studying the reference supplier and its shipments, five Co-Loads were possible with very good measurements. Many of the Co-Loads are made between light or heavy/light suppliers.

This finishes the supplier set-up for the green cluster and supplier 20. Supplier 20 should work deeper with the core-suppliers 4, 8, 13, 16 and 17.

7.3.7 Performance measures after Co-Loading with reference supplier

The shipment data was delivered with *gross* measures, which gave a high performance measures.

Table 7.9: Reference supplier performance

	SUP20
Number of last shipments	5
Total volume m^3 of LUT involved	90+90+90+90+90 = 450
Total Co-Loaded Gross volume involved	65,35 + 61,2 + 71,51 + 72,32 + 67,75 = 336,18
Fill Rate (%)	0,75
EQU (Gross)	67,2

By comparing with the current performance for SUP20 (see Table 7.7) the Co-Loaded performances are much higher. It is due to the fact that gross volume is used instead of net volume. The difference between the gross volume and net volume are the packaging material and mainly the pallets.

CHAPTER 8

Analysis: Ramp-Up

This chapter integrates the theoretical and empirical data of the phenomenon Ramp-Up. The chapter is divided into two subsections, which describes the success factors from two levels, Strategic- and Tactical Level.

8.1 Strategic Level

Key for delivering goods with the right quality is tracked down to the bottom line, the suppliers. They are, to large extend, responsible for delivering goods with the right quality and should therefore be considered and investigated deeply when selecting the right supplier for producing the goods, which goes in line with Ragatz et al. (1997). The current process for starting up a supplier are well established but can be improved by integrating the knowledge and experience from older projects and start-ups that the IKEA organization possess. This is also supported by Gross et al. (2010) who argues that it is of importance to implement a Ramp-Up strategy where knowledge and experience from older projects are key-stones for a successful production Ramp-Up. The current supplier base of over 1030 suppliers globally, mirrors the fact that deep knowledge of starting up a supplier exists but previous Ramp-Up experience is moderately used. Such a strategy would improve the supplier-start-up process and thereby the Ramp-Up efficiency.

The growth plans are set high and to reach the goals, existing suppliers must Ramp-Up the production. In order to succeed with the Ramp-Up and to be successful, the management and/or the decision takers must be committed and be willing to do investments and changes that can secure the supply. This applies both for the supplier and for IKEA and is one way to build a long-term relationship and cut costs for both parties. For many suppliers, only a small investment or change is needed in order to be able to double the production. The barriers that must be overcome for the suppliers are the unwillingness to perform changes and to be open for propositions from IKEA. In turn, IKEA must have trust in the suppliers which will give them motivation and focus to perform and deliver better.

No man is an island and the overall goal from the IKEA management is crystal clear - to grow together. Suppliers and IKEA should grow together and this is why collaboration between suppliers and IKEA are vital. However, today the suppliers have the level which refers to a level of integration between the white and the grey level. A supplier integration, closer to the *grey* level is wanted and according to Petersen et al. (2005) a *black* level of integration is even more favorable because an early supplier integration will contribute to a better product design. More, joint agreements on performance measurements also add value to the relationship.

When new suppliers have to be sourced it is of vital importance to take the Full Combination Matrix (see B.3) into account for simplify for possible Co-Loads in the future. Meaning that it is wise to source new suppliers so that the cluster will have a better mix of heavy and light suppliers. Clusters with many heavy suppliers should preferably be complemented with light suppliers in order to be more efficient regarding the Co-Loads.

Another approach to increase the collaboration is education, which could be used more towards the suppliers than it is today. Shared education and training are positive for structuring the relationship between IKEA and their suppliers. Sharing the human assets and primary the knowledge among the personal from IKEA and from the suppliers would lead to better problem solving. Further, barrier related to communication with the supplier's employee due to absence of knowledge of a common tongue. This is an issue that is very difficult to address and to solve. Information that needs to go through a third person might be changed, misunderstood and ultimately time inefficient. The solutions are education and time - generation change.

8.2 Tactic Level

The risks of ramping up the production of current suppliers are lower than ramping up new suppliers, and that is why the current supplier base should be prioritized. First this is because the relations with these suppliers are already established, which facilitates the whole Ramp-Up process because the suppliers know how IKEA works and vice versa. It leads to a faster TTM, TTV and if any joint-investments are made, a quicker Time-To-Payback is also a fact. Working closer with current suppliers also elucidate what strengths and weaknesses they have. Hence, previous working experience indicates whether the suppliers know their business. Knowing whether the suppliers know their limitations, capacity and capability are central, both for IKEA and the suppliers, which is in line with Ragatz et al. (1997), who declares that to be successful, the buying company (IKEA) need to have confidence in the capabilities at the supplier. This is also equivalent for the opposite direction and the supplier must feel confident in trusting promises from IKEA, such as volumes. Therefore an agreement exists where a penalty fee will strike if the volumes are not reached. Thus, the financial risks are shared and it is beneficial for the relationship, but setting joint business goals should be avoided (Ragatz et al., 1997).

The flow of information with an already established supplier is smoother and enables a better knowledge of what to share and what not to share with the supplier. Gross et al. (2010) argues that sharing information about timing and quality contributes to a successful Ramp-Up achievement. The latter, quality, should according to Primo et al. (2002) be controlled which is observed and highlighted in the Production Risk Assessment (see Figure 5.2) before the production launch but also throughout the lifecycle and has an positive effect of the supplier involvement. Hence, the higher level of integration the better the design performance will be, (Petersen et al., 2005).

When the suppliers should be integrated in the production Ramp-Up depends on the complexity of the process. Primo et al. (2002) states that the more complex the process are, the more should the suppliers should be involved in the process. Since every Ramp-Up project is very different a general answer of exactly when to integrate the suppliers is impossible. Nevertheless, the better the supplier are integrated the better will the cost achievements will be, (Gross et al., 2010).

IKEA contributes to the suppliers with technical knowledge in terms of human assets and information. They can also contribute with physical assets such as machines or modules that are brought into the process. Sharing assets are very positive according to Ragatz et al. (1997) since it has a positive effect on the supplier integration and lead to better success of production Ramp-Up.

CHAPTER 9

Analysis: Co-Loading

In this chapter the key for performing Co-Loads and thereby increasing the Equipment Utilization is described as well as how to increase it even more by performing changes.

9.1 Increase The Equipment Utilization

To be able to increase the EQU there are a set of aspects that need to be considered. The aspects are divided into two subsections, hard aspects and soft aspects. The hard aspects cannot or are difficult to change and the soft aspects are aspects that can be changed, with varying difficulty.

9.1.1 Hard aspects

Since the hard aspects cannot be changed, they will not contribute to an increase of the EQU. These aspects abbreviated as hard are:

- Geographical location of the supplier
- Capacity of the LUT
- Goods characteristics
- Loading restrictions
- Infrastructure
- Country-specific regulations

The location of the suppliers cannot be changed, only modified by sourcing new suppliers or changing supplier. The capacity in the LUTs are trivial as well as the characteristics of the goods. Loading restrictions are limited by the LUT and the country-specific regulations must be met. The infrastructure cannot be changed but the routing can be modified.

9.1.2 Soft aspects

- End Receiver
- LUT limitation
- Shipment volume
- Shipment weight
- Dispatch time
- Distance limitation of 100 km

However the soft aspects can be changed and therefore can contribute drastically to an increase of the EQU. The soft aspects and how to approach them so a higher EQU will be obtained, are described below: When the Transport Planners receives information about what to ship and to where, why it is important that they are selecting the right LUT. The difference of five cubic meters more or less is affecting the EQU a lot. In addition, the LUT does have a weight interval of 5,5 ton to consider as well, depending on carrier, and does likewise affect the EQU.

Hence, time is trivial since the goods must arrive in time to the end receivers. Therefore the lead-time, dispatch time and with what frequency must be considerate when planning the Co-Loads.

Routing the LUTs, in which order the LUT should transport and do the pick-up depends on the infrastructure, location of the pick-up-suppliers and which supplier is the first. The first supplier should be based on location, goods and LUT. It is important to be efficient and to do the things right when planning the route so that the next suppliers does not need to do any unnecessary unloading in order to load their goods.

Moreover, there exists different types of LUTs that allows different loading techniques, not only the traditionally way from behind, but also from the side. If the suppliers have the opportunity to load traditionally and from the side, less time will be needed to unload and load the LUT. It also decreases the risks of damages and legal issues between suppliers if the second supplier does not have to move any previous loaded goods.

The loading bay and how it is designed must be taken into consideration, especially if a LUT with loading possibilities from the side is selected, the suppliers must have a loading bay designed so loading from the side is possible.

Further, the loading preparation and loading procedure must be raised to a higher level at the suppliers. Today the loading procedures are working well, but with a more complex set-up with Co-Loads it demands a more structured way to work when loading the LUT if a higher EQU should be obtained. A pre-staging area for decreasing the loading time, which enables a higher possibility to perform Co-Loads within the right time frame, should be used at the supplier's plant. The loading procedure also covers how to load the LUT safely and correctly according to regulations such as axel weight and what the next supplier should load. The Transport Planners possesses sophisticated optimization tools for planning the loading of each specific LUT. This information must be communicated, and especially, used by the forklifts drivers. I cannot stress this issue of using this software hard enough since it is central in order to perform Co-Loads without interruptions, the next supplier cannot fit his goods if the loading is done poorly at the previous supplier(s).

The DWP sets the limitation of how the goods can be loaded onto the LUT. The DWP are based on the dimensions of the goods loaded onto a pallet. Today, different pallets are used, mainly EUR-pallet, IKEA-pallet and half-pallets are used for the suppliers in the corresponding region. In order to be more flexible in how to load the LUT, the DWP must be changed. One approach is, if possible, to store the goods on half pallets or only use top fillers on pallets. It would provide the chance to increase the EQU dramatically. The suppliers who are using top fillers do have better volume utilization and weight utilization than the suppliers who does not use top fillers. Smaller units of good do have more synergy effects such as:

- Simplified ordering flow, which enables the customers (stores, DC etc.) to order more frequently and keep a lower stock.
- Increase the dynamics according to the shipments. For example can one large shipment easily be split in order to perform Co-Load with other suppliers and thereby decrease the overall transportation costs and increase the EQU.
- Less damages in the transportation due to simplified handling.
- Less pollution

Yet, smaller units requires more goods handling and thereby higher labour cost.

Good communication between IKEA and the suppliers about correct volumes and timetables are very important to decrease risks with late deliveries or volumes. It should also include the loading configuration discussed above.

Last aspect that must be fulfilled in order to reach a higher EQU are the willingness and commitment from the supplier management to perform changes and contribute to the joint development, which will strengthen their competitiveness and facilitate Co-Loads with other suppliers.

CHAPTER 10

Conclusions

The last chapter states the recommendations to the host company related to both the Ramp-Up issue and the Co-Loading issue. A brief implementation plan for the Co-Loading issue is also presented as well a discussion.

10.1 Recommendations

Working together as one big unit is key for a successful Ramp-Up for the current supplier base where the focus should be on growing jointly towards the goals for 2020. To increase the volume output IKEA should concentrate on the current supplier base and do necessary investments or changes rather than sourcing new suppliers. In order to help the suppliers as much as possible IKEA should be more present at the supplier's production plants for increasing the collaboration, trust, education and experiences.

The supplier's top management must be more involved and have the willingness to perform changes. Lack of enthusiasm is dangerous since it easily can infect co-workers attitude. This is very important since the supplier must Ramp-Up the production and due to this Ramp-Up, more transportation of goods is a fact. More Co-Loading between suppliers must be planned and initiated in order to lower the costs and increase the transportation efficiency.

Regarding the Co-Load IKEA should work with the Green Cluster because those suppliers are favorable to preform Co-Loads because of the great mix of heavy and light suppliers. The Combination Matrix is a good foundation for getting a clue as to which supplier is suitable for each other.

In order to increase the number of Co-Loads the distance limitation should be loosened up and kept as an aim instead. Then a larger set of suppliers can be able to perform Co-Loads, which has been positively proven that it is beneficial. Even though large improvements are possible only by Co-Loading within the clusters it would open up even more possibilities to perform Co-Loads.

The DWP should be smaller so that a more dynamic loading in the trucks is possible. It also allows the customer (End Receivers) to order more frequently but with a lower volume, which will keep down the stock, both for the suppliers and for IKEA. With smaller DWP the goods will be ordered more frequently and pushes the suppliers to load quicker in order to dispatch in time, thus a pre-staging area is to consider since it allows a quicker loading. This is also beneficial, both for IKEA and their suppliers when many suppliers needs to Ramp-Up the production

Suppliers with top fillers have in general a higher LUT utilization than suppliers without top fillers, this is why suppliers that do not produces top fillers should strongly consider to produce top fillers.

IKEA should assist the suppliers with unquestionable loading procedures with 3D graphics that must be followed when loading the truck. This is central in order to load the truck so the next supplier can load their goods without interruptions.

Below are a short implementation plan to quickly increase the EQU:

1. Loosen up the distance limitation of 100 km and keep it as a aim instead
2. Establish supplier set-ups with the Combination Matrix as reference
3. Start working with Co-Loads with suppliers within the Green- and Red Cluster
4. Decrease the size of the DWPs, preferably onto a half IKEA-pallet, or, focus more on top fillers.

The second best alternative, if the management is not satisfied with loosening up the distance limitation, they should consider looking into splitting shipments and then perform Co-Loads and considering sourcing carriers that have trucks with loading possibilities from the side.

10.2 Discussion

Throughout the thesis the author has strived to make it as generalized as possible by writing clear instructions of how to process the information so that the SCM and the Combination matrix easily can be obtained. These matrices are to large extent generalizable for every IKEA Purchasing organization and could therefore be used to investigate if the suppliers should perform Co-Loads and with witch other suppliers.

The types of industry, in which the suppliers are operating, are not of main importance. Instead the focus should be on what type of goods they are producing and if the regular shipments reach full volume utilization or full weight utilization first.

In order to generalize the Co-Loading method to other organizations and companies the Combination matrix is a good foundation since it shows a lot of information. However, the VBA code written is probably only suitable for IKEA.

Ramping up the production is a very specific process that heavily depends on equipment, people and what type of product that should be produced. Observing 28 suppliers working within different industries, producing several products and draw general conclusions from them, is difficult. However, the author has tried to keep it as general and at as tactical/strategically level as possible where success factors were illuminated in order to have a successful Ramp-Up. Sources related to Production Ramp-Up in the high-tech industry are fairly easy to find. In opposition, the lack of relevant information regarding Ramp-Up of a current production level to a higher level is large.

If the knowledge about the shut-down of the CP close to Vilnius would be brought to the author in an earlier stage, the Red cluster would be investigated further instead of the Green cluster. This CP was very important for suppliers located in the adjacent areas close to Vilnius. Now, when this CP will be closed there exists an even higher need for performing Co-Loads between suppliers to keep down the costs and increase the EQU, why it is of vital importance to start working with the supplier negotiation (regulations of how Co-Loads should be performed, legal aspects, insurance etc.) and the suppliers set-up as soon as possible.

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APPENDIX A

VBA code

A.1 sortMainSourceFile1

```
Attribute VB_Name = "Module2"
Option Explicit

'Sorting out the important variables and removing irrelevant data from the source↩
 files

Sub sortMainSourceFile1()
'Defining variables
    Dim i As Integer
    Dim supplier As String
    Dim supplierNumber As String
    Dim summary As String
    Dim ws As Worksheet

For Each ws In ActiveWorkbook.Worksheets
    ws.Select
    'Clear information that will not be used
    Cells(1, 1).Clear
    Range(Cells(1, 7), Cells(10000, 150)).Clear

    'Store supplier number
    Cells(2, 1).Select
    supplier = ActiveCell
    supplierNumber = Right(supplier, 6)

    'Print supplier name, number and week
    Cells(1, 1) = "Supplier:"
    Cells(1, 2) = supplierNumber
    Cells(2, 1).Clear
```

```
    Cells(2, 2) = Right(Cells(3, 1), 6)
    Cells(2, 1) = "Week"
    Cells(3, 1).Clear

    'In column TYPE each row that consists of the index "summary" will be removed
    i = 1 'beginning value of the row

    'Looping until the column has a empty cell
    Do While Cells(6 + i, 4).Value <> ""
        summary = "Summary"
        If Cells(6 + i, 4) = summary Then
        'deleling the row and moving everything one step up
            Range(Cells(6 + i, 1), Cells(6 + i, 10)).Delete shift:=xlUp
        End If
        i = i + 1 'increasing the row nbr
    Loop

    'Moving the important columns with TYPE, CITY and CODE to Column A,B and C
    Range(Cells(5, 4), Cells(6 + i, 6)).Select
    Selection.Copy
    Range(Cells(5, 1), Cells(6 + i, 3)).Activate
    ActiveSheet.Paste
    Range(Cells(5, 4), Cells(6 + i, 6)).Clear

    'Remove duplicates from columns A, B and C to prevent that the same location ↩
exists twice
    Range(Cells(5, 1), Cells(6 + i, 3)).Select
    Selection.RemoveDuplicates columns:=Array(1, 3), Header:=xlYes
Next ws
'Return to first sheet
ActiveWorkbook.Worksheets("17775").Select
End Sub
```

A.2 mergeCells2

```
Attribute VB_Name = "Module21"
Option Explicit
'This sub will merge the cells in col A, B and C
Sub mergeCells2()

'Declares variables
Dim i As Integer
Dim ws As Worksheet

'Goes through every sheet and merging the cells
For Each ws In ActiveWorkbook.Worksheets
    ws.Select
    i = 6 'first values start in col 6
```

```

    'Looping until the cell is empty
    Do While Cells(i, 1).Value <> ""
        'Merging the cells
        Cells(i, 4) = Cells(i, 1).Value & "," & Cells(i, 2).Value & "," & Cells(i, 3).Value
        i = i + 1
     Loop
Next ws
'Return to first sheet
ActiveWorkbook.Worksheets("17775").Select
End Sub
```

A.3 getUniquePos3

```
Attribute VB_Name = "Module11"
Option Explicit
'Calculates how many unique locations each supplier have

Sub getUniquePos3()

'Define Variables
Dim counter As Integer
Dim row As Integer
Dim ws As Worksheet

'Goes through all worksheets
For Each ws In ActiveWorkbook.Worksheets
    ws.Select
    counter = 0
    row = 5
    Do While Cells(1 + row, 1).Value <> ""
        counter = counter + 1
        row = row + 1
    Loop
    Cells(3, 1) = "Unique locations:"
    Cells(3, 2) = counter

    'So that the window will be seen from the top in the sheet
    Cells(2, 2).Select
Next ws
End Sub
```

A.4 supplierUniqueLocations4

```
Attribute VB_Name = "Module121"
Option Explicit

'This sub will paste all the unique locations into a new sheet
Sub supplierUniqueLocations4()

'Define variables
Dim ws As Worksheet
Dim supplierNumber As String
Dim i As Integer
Dim week As String
Dim uniqueLocations As String


'Goes through every sheet and copy the merged cells into the sum sheet
i = 1
For Each ws In ActiveWorkbook.Worksheets
    'copy the range
    ws.Select
    Range(Cells(6, 4), Cells(2000, 4)).Select
    'Store supplier number
    supplierNumber = Cells(1, 2)
    'Store week
    week = Cells(2, 2)
    'Store locations
    uniqueLocations = Cells(3, 2)
    Selection.Copy

    'Pasting the above copied and stored into sheet scm
    Worksheets("sum").Select
    Cells(3, i + 1) = supplierNumber
    Cells(4, i + 1) = week
    Cells(5, i + 1) = uniqueLocations
    Range(Cells(7, 1 + i), Cells(2000, i + 1)).Activate
    ActiveSheet.Paste
    i = i + 1
Next ws
Cells(1, 1) = "Suppliers and their supply location"

'Removing the extra column that will be created due to go-trough every sheet
Range(Cells(1, 30), Cells(2000, 30)).Clear

End Sub
```

A.5 matchLocationsWithVlookUp51

```
Attribute VB_Name = "Module5"
Option Explicit

'Matching unique locations for each supplier to every other supplier and their locations
Sub matchLocationsWithVlookUp51()
'start sheet
Worksheets("sum").Select

Dim maxV As Integer
'Finding the max unique location for each supplier
maxV = WorksheetFunction.Max(Range(Cells(5, 2), Cells(5, 4))) + 6

Dim cell As Range
Dim result As String
Dim nextCol As Integer
Dim k As Integer
Dim r As Integer
Dim c As Integer
Dim col As Integer
Dim lookUpRange As Range

'initial values
r = 7
c = 3
k = 2
nextCol = 3
col = 2

On Error Resume Next
'Do until cells empty
Do Until IsEmpty(Cells(7, col))
  'Needs to have two loops
  Do Until IsEmpty(Cells(7, nextCol)) 'loops through the columns depening on how many suppliers
        For Each cell In Worksheets("sum").Range(Cells(7, col), Cells(maxV, col))

            'setting the lookUpRange so it can be adjusted later on
            Set lookUpRange = Range(Cells(7, nextCol), Cells(maxV, nextCol))

            'The vlookUp function used
            result = Application.VLookup(cell, lookUpRange, 1, False)

            'If the current cell exists in the lookUpRange then I save it to next sheet (scm)
            If result = "Error 2042" Then
                'nothing found
```

```
            ElseIf Not cell <> result Then
                cell.Select
                Selection.Copy
                Worksheets("scm").Select
                Cells(r, c).Activate
                ActiveSheet.Paste
                Worksheets("sum").Select
                r = r + 1 'incrementing the row count
            End If
        Next
        'increasing the counting variables
        nextCol = nextCol + 1
        r = 7
        c = c + 1
    Loop
    'if the cell is empty, proceed with next setup
    If IsEmpty(Cells(7, nextCol)) Then
        col = col + 1
        nextCol = col + 1
        c = c + 1
    End If
Loop

On Error GoTo 0

End Sub
```

A.6 printSupplierInformation6

```
Attribute VB_Name = "Module12"
Option Explicit

'Printing the supplier information into the scm sheet
Sub printSupplierInformation6()

'Variables
Dim i As Integer
Dim begin As Integer
Dim start As Integer
Dim finish As Integer

'Initial values
i = 1
begin = 2
start = 2
finish = 29
Do While i < 29
    'copy the information
    Worksheets("sum").Select
    Range(Cells(3, begin), Cells(5, 29)).Select
    Selection.Copy
    Worksheets("scm").Select
    Range(Cells(3, start), Cells(5, finish)).Select
    ActiveSheet.Paste

    'paste the information
    Worksheets("sum").Select
    begin = begin + 1
    start = finish + 1
    finish = finish + 28 - i
    i = i + 1
Loop
End Sub
```

A.7 fixSCMatrix7

```
Attribute VB_Name = "Module1"
Option Explicit

'Fix the "statistics" for the supplier to the matrix
Sub fixSCMatrix7()

'startsheet
Worksheets("Sheet1").Select

'Letting the user declare how many suppliers
Dim numberOfSuppliers As Integer

'Using a inputbox for storing the value
numberOfSuppliers = InputBox("How many suppliers?")

Dim maxV As Integer
'Finding the max unique location for each supplier
maxV = WorksheetFunction.Max(Range(Cells(5, 2), Cells(5, numberOfSuppliers))) + 6

'Variables
Dim locations As Integer
Dim col As Integer
Dim counter1 As Integer
Dim counter2 As Integer
Dim row As Integer
Dim columns As Integer

'initial values
counter1 = 2
counter2 = 2
columns = 2
row = 5

'Need to have to loops in order to keep track on the columns
Do While counter1 < numberOfSuppliers + 2
    counter2 = 2
    col = row - 3
    Do While col < numberOfSuppliers + 2
        Worksheets("Sheet1").Select

        'using the build in function countif
        locations = Application.WorksheetFunction.CountIf(Range(Cells(7, columns), Cells(maxV, columns)), "*")
        Worksheets("Sheet2").Select
        Cells(row, col + 1).Select
        Cells(row, col + 1) = locations

```

```
        'increase the counter variables
        columns = columns + 1
        counter2 = counter2 + 1
        col = col + 1
        Loop
        'Increase the counter variables
        row = row + 1
        counter1 = counter1 + 1
        Worksheets("Sheet1").Select
    Loop
End Sub
```

A.8 SCMandDM

```
Attribute VB_Name = "Module1"
Option Explicit

'Finds the relations between SCM and DM
Sub SCM_DM()

'Start sheet
ActiveWorkbook.Worksheets("SCM").Select

'Variables
Dim r As Integer
Dim c As Integer
Dim text As String
Dim percentage As String
Dim distance As Integer
Dim scmText As String
Dim dmDist As String

'initial values
r = 6
c = 4

'Double do-while for looping through all cells
Do While Cells(r, c) <> ""
    Do While Cells(r, c) <> ""
        'Store the scm-value
        scmText = Cells(r, c).Value

        'Takes out the percentage part
        text = InStr(1, Cells(r, c), "/")
        percentage = Mid(Cells(r, c), text + 1)

        'Analyze if the percentage part is bigger than a value
        If percentage > "0,50" Then
            'goes to dm matris
            Worksheets("DM").Select

            'checks if the distance is lower than the limit
            distance = Cells(r, c).Value
            If distance < 101 Then
                'if so, place the scm-values and dm-values in next sheet
                Worksheets("SCM_DM").Select
                Cells(r, c) = scmText & "/" & distance
            End If
        End If
        'increase the column count and returns to scm sheet
        c = c + 1
```

```
        ActiveWorkbook.Worksheets("SCM").Select
    Loop
    'increase the row count and sets the colcount to the intitial
    r = r + 1
    c = 4
Loop
End Sub
```

A.9 appcoLoad

```
Attribute VB_Name = "Module1"
Option Explicit

'Creating co-loads based on current end receiver, volume, weight and dispatch ↩
time

Sub coLoad()

'Declare variables

Dim supplier As String
Dim supplier2 As String

Dim er As String
Dim er2 As String

'RowCounters
Dim row As Integer 'current row
Dim nextRow As Integer 'nextRow
Dim loadRow As Integer 'keeping track on rows in sheet coLoad

'total volume and weight
Dim volume As Double
Dim weight As Double
Dim totV As Double
Dim totW As Double

'date variables
Dim t As Date
Dim t2 As Date
Dim dateDifference As Integer

'Row keepers which keep track on the rows when deleting rows
Dim rowKeeper As Integer
Dim rowKeeper2 As Integer


Worksheets("All2").Select

'initial values
row = 2
nextRow = 3
loadRow = 1


Do While Cells(row, 1).Value <> ""

```

```
    supplier = Cells(row, 1)
    supplier2 = Cells(nextRow, 1)

    er = Cells(row, 2)
    er2 = Cells(nextRow, 2)

    t = Format(Left(Cells(row, 4), 10), "m/d/yyyy")
    t2 = Format(Left(Cells(nextRow, 4), 10), "m/d/yyyy")
    dateDifference = Abs(DateDiff("d", t, t2))

    volume = Cells(row, 7) + Cells(nextRow, 7)
    weight = Cells(row, 8) + Cells(nextRow, 8)
    totV = Cells(row, 16) + Cells(nextRow, 16)
    totW = Cells(row, 17) + Cells(nextRow, 17)

    If er = er2 Then
        'Time interval where shipments can be coloaded within +-2 days
        If 0 < dateDifference < 2 Then
            'Being realistic and does not co-load over 80%
            If totV < 0.8 Then
                If totW < 1 Then
                loadRow = loadRow + 1
                    Worksheets("coLoad").Select
                    Cells(loadRow, 1) = "coLoad" & "," & supplier & "," & supplier2
                    Cells(loadRow, 2) = er
                    Cells(loadRow, 3) = t
                    Cells(loadRow, 4) = volume
                    Cells(loadRow, 5) = totV
                    Cells(loadRow, 6) = weight
                    Cells(loadRow, 7) = totW

                    rowKeeper = row
                    rowKeeper2 = nextRow

                    Worksheets("All2").Select
                    Range(Cells(row, 1), Cells(row, 20)).Clear
                    Range(Cells(nextRow, 1), Cells(nextRow, 20)).Clear

                    Range(Cells(rowKeeper, 1), Cells(rowKeeper, 20)).Delete shift:=xlUp
                    Range(Cells(rowKeeper2 - 1, 1), Cells(rowKeeper2 - 1, 20)).Delete shift:=xlUp


                    row = rowKeeper - 1

                End If
            End If
        End If
    End If
```

```

    If er <> er2 Then
        row = row + 1
        nextRow = row + 1
    Else
        nextRow = nextRow + 1
    End If
  Loop
End Sub
```

APPENDIX B

Matrices

B.1 The Distance Matrix

Table B.1: The Distance Matrix

Supplier	End Receivers	SUP1	SUP2	SUP3	SUP4	SUP5	SUP6	**SUP7**	**SUP8**	SUP9	SUP10	**SUP11**	**SUP12**	**SUP13**	**SUP14**	SUP15	**SUP16**	SUP17	SUP18	SUP19	**SUP20**	SUP21	**SUP22**	**SUP23**	SUP24	**SUP25**	SUP26	SUP27	SUP28
		136	279	338	391	291	194	310	361	154	316	226	304	160	295	15	86	47	59	99	209	26	204	129	7	26	8	7	5
SUP1	136	0	220	3,2	303	398	32,8	179	257	13,2	52,8	26,5	175	172	172	172	212	277	239	187	277	269	175	218	27	175	209	218	297
SUP2	279		0	219	96,4	206	222	188	44,2	222	208	243	164	8,9	159	160	6,7	70,1	37,2	126	61	77,5	163	7,4	243	164	28,3	2,2	89,9
SUP3	338			0	303	398	31,3	179	257	14,4	51,3	27,7	175	226	171	172	211	276	239	187	276	268	174	217	28,2	174	208	218	296
SUP4	391				0	157	305	220	146	305	291	326	219	103	219	219	96,8	34	104	194	100	75	218	92,3	326	218	111	99,4	31,4
SUP5	291					0	398	251	253	398	384	419	249	214	254	254	203	183	171	246	256	135	249	201	420	249	214	206	155
SUP6	194						0	180	189	41	23,4	54,6	176	227	173	173	213	278	240	188	278	269	175	219	55,1	176	209	219	297
SUP7	310							0	202	151	166	148	3,6	171	5,8	6	156	216	129	27,4	221	148	2,8	162	144	3,3	127	163	192
SUP8	361								0	260	168	281	202	38	198	198	51,8	119	85,3	164	70,6	126	201	51	281	202	66,5	44,1	139
SUP9	154									0	64,4	29,1	177	228	173	173	213	278	241	189	278	270	176	219	24,5	176	210	219	298
SUP10	316										0	74,6	161	213	158	158	198	263	225	173	263	255	161	204	75,1	161	195	204	282
SUP11	226											0	150	248	150	150	233	298	261	171	299	290	149	239	6	150	230	240	318
SUP12	304												0	170	9	5,3	155	214	127	26	221	146	1	161	146	350	126	162	190
SUP13	160													0	166	166	11,6	75,4	44,5	132	58	84,7	169	14,7	249	170	34,5	8,7	95,1
SUP14	295														0	1	151	214	127	25,4	216	146	4,3	157	146	4,7	125	157	190
SUP15	15															0	151	214	127	25,6	216	146	4,5	157	146	5	125	157	190
SUP16	86																0	68,7	34,2	118	70,5	74,4	155	6,4	235	155	19,8	4,5	88,5
SUP17	47																	0	75,9	182	91,7	63,5	206	64,2	298	207	83,4	71,4	24,6
SUP18	59																		0	102	103	42,3	126	31,4	257	126	43,3	36,5	85,4
SUP19	99																			0	182	121	24,4	123	167	24,8	100	124	165
SUP20	209																				0	150	220	65,8	300	221	85,5	63	111
SUP21	26																					0	145	72	290	146	83,9	77,1	47,2
SUP22	204																						0	161	145	1	124	161	189
SUP23	129																							0	241	161	26	8	83,7
SUP24	7																								0	145	221	230	309
SUP25	26																									0	125	161	190
SUP26	8																										0	25,7	105
SUP27	7																											0	91
SUP28	5																												0

B.2 The Supply Chain Matrix

Table B.2: The Supply Chain Matrix

Supplier	End Receivers	SUP1 136	SUP2 279	SUP3 338	SUP4 391	SUP5 291	SUP6 194	**SUP7** 310	**SUP8** 361	SUP9 154	SUP10 316	**SUP11** 226	**SUP12** 304	**SUP13** 160	**SUP14** 295
SUP1	136	0/0	86/0,63	130/0,96	136/1	70/0,51	75/0,55	136/1	133/0,98	81/0,6	114/0,84	136/1	135/0,99	95/0,7	135/0,99
SUP2	279		0/0	249/0,89	279/1	220/0,79	127/0,46	227/0,81	266/0,95	101/0,36	223/0,8	174/0,62	229/0,82	110/0,39	210/0,75
SUP3	338			0/0	337/1	242/0,72	157/0,46	256/0,76	310/0,92	143/0,42	270/0,8	193/0,57	257/0,76	152/0,45	255/0,75
SUP4	391				0/0	288/0,74	194/0,5	308/0,79	359/0,92	153/0,39	313/0,8	225/0,58	302/0,77	159/0,41	294/0,75
SUP5	291					0/0	130/0,45	214/0,74	259/0,89	118/0,41	245/0,84	139/0,48	208/0,71	75/0,26	220/0,76
SUP6	194						0/0	192/0,99	185/0,95	107/0,55	165/0,85	128/0,66	194/1	91/0,47	173/0,89
SUP7	310							0/0	296/0,95	150/0,48	256/0,83	225/0,73	297/0,96	159/0,51	271/0,87
SUP8	361								0/0	144/0,4	289/0,8	223/0,62	291/0,81	151/0,42	264/0,73
SUP9	154									0/0	145/0,94	126/0,82	152/0,99	101/0,66	152/0,99
SUP10	316										0/0	183/0,58	253/0,8	135/0,43	266/0,84
SUP11	226											0/0	223/0,99	146/0,65	203/0,9
SUP12	304												0/0	158/0,52	276/0,91
SUP13	160													0/0	138/0,86
SUP14	295														0/0
SUP15	15														
SUP16	86														
SUP17	47														
SUP18	59														
SUP19	99														
SUP20	209														
SUP21	26														
SUP22	204														
SUP23	129														
SUP24	7														
SUP25	26														
SUP26	8														
SUP27	7														
SUP28	5														

Supplier	End Receivers	SUP15 15	**SUP16** 86	SUP17 47	SUP18 59	SUP19 99	**SUP20** 209	SUP21 26	**SUP22** 204	**SUP23** 129	SUP24 7	**SUP25** 26	SUP26 8	SUP27 7	SUP28 5
SUP1	136	9/0,07	14/0,1	10/0,07	7/0,05	47/0,35	95/0,7	6/0,04	130/0,96	92/0,68	4/0,03	11/0,08	3/0,02	1/0,01	6/0,04
SUP2	279	15/0,05	84/0,3	47/0,17	58/0,21	54/0,19	127/0,46	26/0,09	124/0,44	73/0,26	7/0,03	23/0,08	8/0,03	7/0,03	5/0,02
SUP3	338	14/0,04	82/0,24	44/0,13	57/0,17	91/0,27	157/0,46	24/0,07	179/0,53	119/0,35	6/0,02	24/0,07	8/0,02	7/0,02	4/0,01
SUP4	391	15/0,04	84/0,21	47/0,12	58/0,15	98/0,25	208/0,53	26/0,07	204/0,52	129/0,33	7/0,02	26/0,07	8/0,02	7/0,02	6/0,02
SUP5	291	15/0,05	62/0,21	46/0,16	58/0,2	73/0,25	144/0,49	25/0,09	117/0,4	62/0,21	6/0,02	24/0,08	8/0,03	7/0,02	5/0,02
SUP6	194	9/0,05	39/0,2	33/0,17	18/0,09	56/0,29	119/0,61	24/0,12	134/0,69	81/0,42	6/0,03	13/0,07	7/0,04	1/0,01	1/0,01
SUP7	310	15/0,05	83/0,27	44/0,14	55/0,18	96/0,31	208/0,67	25/0,08	204/0,66	126/0,41	6/0,02	23/0,07	8/0,03	5/0,02	5/0,02
SUP8	361	13/0,04	84/0,23	38/0,11	57/0,16	97/0,27	200/0,55	19/0,05	197/0,55	127/0,35	6/0,02	23/0,06	8/0,02	7/0,02	3/0,01
SUP9	154	15/0,1	55/0,36	44/0,29	56/0,36	91/0,59	119/0,77	25/0,16	98/0,64	65/0,42	6/0,04	23/0,15	8/0,05	6/0,04	5/0,03
SUP10	316	15/0,05	63/0,2	46/0,15	58/0,18	99/0,31	199/0,63	25/0,08	156/0,49	124/0,39	6/0,02	24/0,08	8/0,03	7/0,02	5/0,02
SUP11	226	15/0,07	73/0,32	20/0,09	44/0,19	84/0,37	160/0,71	11/0,05	159/0,7	98/0,43	6/0,03	18/0,08	7/0,03	2/0,01	5/0,02
SUP12	304	15/0,05	83/0,27	46/0,15	59/0,19	98/0,32	200/0,66	26/0,09	195/0,64	128/0,42	7/0,02	24/0,08	8/0,03	7/0,02	5/0,02
SUP13	160	13/0,08	69/0,43	28/0,18	37/0,23	76/0,48	137/0,86	23/0,14	126/0,79	96/0,6	6/0,04	17/0,11	7/0,04	1/0,01	5/0,03
SUP14	295	15/0,05	63/0,21	46/0,16	59/0,2	98/0,33	193/0,65	26/0,09	169/0,57	127/0,43	7/0,02	25/0,08	8/0,03	7/0,02	6/0,02
SUP15	15	0/0	9/0,6	15/1	12/0,8	15/1	14/0,93	10/0,67	8/0,53	10/0,67	5/0,33	15/1	7/0,47	2/0,13	5/0,33
SUP16	86		0/0	20/0,23	44/0,51	40/0,47	61/0,71	16/0,19	44/0,51	16/0,19	4/0,05	9/0,1	7/0,08	1/0,01	2/0,02
SUP17	47			0/0	27/0,57	24/0,51	34/0,72	26/0,55	26/0,55	17/0,36	7/0,15	21/0,45	8/0,17	7/0,15	5/0,11
SUP18	59				0/0	51/0,86	49/0,83	14/0,24	12/0,2	16/0,27	7/0,12	18/0,31	8/0,14	7/0,12	3/0,05
SUP19	99					0/0	93/0,94	11/0,11	53/0,54	53/0,54	6/0,06	23/0,23	8/0,08	7/0,07	5/0,05
SUP20	209						0/0	24/0,11	140/0,67	101/0,48	6/0,03	18/0,09	8/0,04	1/0	5/0,02
SUP21	26							0/0	20/0,77	10/0,38	7/0,27	10/0,38	7/0,27	1/0,04	1/0,04
SUP22	204								0/0	100/0,49	5/0,02	12/0,06	5/0,02	1/0	2/0,01
SUP23	129									0/0	7/0,05	18/0,14	7/0,05	7/0,05	2/0,02
SUP24	7										0/0	5/0,71	4/0,57	1/0,14	2/0,29
SUP25	26											0/0	7/0,27	7/0,27	5/0,19
SUP26	8												0/0	1/0,13	1/0,13
SUP27	7													0/0	1/0,14
SUP28	5														0/0

B.3 The Full Combination Matrix

Table B.3: The Full Combination Matrix

Supplier	End Receivers	SUP1	SUP2	SUP3	SUP4	SUP5	SUP6	**SUP7**	**SUP8**	SUP9	SUP10
		136	279	338	391	291	194	310	361	154	316
SUP1	136	0/0/0	86/0,63/220	130/0,96/3	136/1/303	70/0,51/398	75/0,55/33	136/1/179	133/0,98/257	81/0,6/13	114/0,84/53
SUP2	279		0/0/0	249/0,89/219	279/1/96	220/0,79/206	127/0,46/222	227/0,81/188	266/0,95/44	101/0,36/222	223/0,8/208
SUP3	338			0/0/0	337/1/303	242/0,72/398	157/0,46/31	256/0,76/179	310/0,92/257	143/0,42/14	270/0,8/51
SUP4	391				0/0/0	288/0,74/157	194/0,5/305	308/0,79/220	359/0,92/146	153/0,39/305	313/0,8/291
SUP5	291					0/0/0	130/0,45/398	214/0,74/251	259/0,89/253	118/0,41/398	245/0,84/384
SUP6	194						0/0/0	192/0,99/180	185/0,95/189	107/0,55/41	165/0,85/23
SUP7	310							0/0/0	296/0,95/202	150/0,48/151	256/0,83/166
SUP8	361								0/0/0	144/0,4/260	289/0,8/168
SUP9	154									0/0/0	145/0,94/64
SUP10	316										0/0/0
SUP11	226										
SUP12	304										
SUP13	160										
SUP14	295										
SUP15	15										
SUP16	86										
SUP17	47										
SUP18	59										
SUP19	99										
SUP20	209										
SUP21	26										
SUP22	204										
SUP23	129										
SUP24	7										
SUP25	26										
SUP26	8										
SUP27	7										
SUP28	5										

Supplier	End Receivers	**SUP11**	**SUP12**	**SUP13**	**SUP14**	SUP15	**SUP16**	SUP17	SUP18	SUP19
		226	304	160	295	15	86	47	59	99
SUP1	136	136/1/26	135/0,99/175	95/0,7/172	135/0,99/172	9/0,07/172	14/0,1/212	10/0,07/277	7/0,05/239	47/0,35/187
SUP2	279	174/0,62/243	229/0,82/164	110/0,39/9	210/0,75/159	15/0,05/160	84/0,3/7	47/0,17/70	58/0,21/37	54/0,19/126
SUP3	338	193/0,57/28	257/0,76/175	152/0,45/226	255/0,75/171	14/0,04/172	82/0,24/211	44/0,13/276	57/0,17/239	91/0,27/187
SUP4	391	225/0,58/326	302/0,77/219	159/0,41/103	294/0,75/219	15/0,04/219	84/0,21/97	47/0,12/34	58/0,15/104	98/0,25/194
SUP5	291	139/0,48/419	208/0,71/249	75/0,26/214	220/0,76/254	15/0,05/254	62/0,21/203	46/0,16/183	58/0,2/171	73/0,25/246
SUP6	194	128/0,66/55	194/1/176	91/0,47/227	173/0,89/173	9/0,05/173	39/0,2/213	33/0,17/278	18/0,09/240	56/0,29/188
SUP7	310	225/0,73/148	297/0,96/4	159/0,51/171	271/0,87/6	15/0,05/6	83/0,27/156	44/0,14/216	55/0,18/129	96/0,31/27
SUP8	361	223/0,62/281	291/0,81/202	151/0,42/38	264/0,73/198	13/0,04/198	84/0,23/52	38/0,11/119	57/0,16/85	97/0,27/164
SUP9	154	126/0,82/29	152/0,99/177	101/0,66/228	152/0,99/173	15/0,1/173	55/0,36/213	44/0,29/278	56/0,36/241	91/0,59/189
SUP10	316	183/0,58/75	253/0,8/161	135/0,43/213	266/0,84/158	15/0,05/158	63/0,2/198	46/0,15/263	58/0,18/225	99/0,31/173
SUP11	226	0/0/0	223/0,99/150	146/0,65/248	203/0,9/150	15/0,07/150	73/0,32/233	20/0,09/298	44/0,19/261	84/0,37/171
SUP12	304		0/0/0	158/0,52/170	276/0,91/9	15/0,05/5	83/0,27/155	46/0,15/214	59/0,19/127	98/0,32/26
SUP13	160			0/0/0	138/0,86/166	13/0,08/166	69/0,43/12	28/0,18/75	37/0,23/44	76/0,48/132
SUP14	295				0/0/0	15/0,05/1	63/0,21/151	46/0,16/214	59/0,2/127	98/0,33/25
SUP15	15					0/0/0	9/0,6/151	15/1/214	12/0,8/127	15/1/26
SUP16	86						0/0/0	20/0,23/69	44/0,51/34	40/0,47/118
SUP17	47							0/0/0	27/0,57/76	24/0,51/182
SUP18	59								0/0/0	51/0,86/102
SUP19	99									0/0/0
SUP20	209									
SUP21	26									
SUP22	204									
SUP23	129									
SUP24	7									
SUP25	26									
SUP26	8									
SUP27	7									
SUP28	5									

Supplier	End Receivers	**SUP20**	SUP21	**SUP22**	**SUP23**	SUP24	**SUP25**	SUP26	SUP27	SUP28
		209	26	204	129	7	26	8	7	5
SUP1	136	95/0,7/277	6/0,04/269	130/0,96/175	92/0,68/218	4/0,03/27	11/0,08/175	3/0,02/209	1/0,01/218	6/0,04/297
SUP2	279	127/0,46/61	26/0,09/78	124/0,44/163	73/0,26/7	7/0,03/243	23/0,08/164	8/0,03/28	7/0,03/2	5/0,02/90
SUP3	338	157/0,46/276	24/0,07/268	179/0,53/174	119/0,35/217	6/0,02/28	24/0,07/174	8/0,02/208	7/0,02/218	4/0,01/296
SUP4	391	208/0,53/100	26/0,07/75	204/0,52/218	129/0,33/92	7/0,02/326	26/0,07/218	8/0,02/111	7/0,02/99	6/0,02/31
SUP5	291	144/0,49/256	25/0,09/135	117/0,4/249	62/0,21/201	6/0,02/420	24/0,08/249	8/0,03/214	7/0,02/206	5/0,02/155
SUP6	194	119/0,61/278	24/0,12/269	134/0,69/175	81/0,42/219	6/0,03/55	13/0,07/176	7/0,04/209	1/0,01/219	1/0,01/297
SUP7	310	208/0,67/221	25/0,08/148	204/0,66/3	126/0,41/162	6/0,02/144	23/0,07/3	8/0,03/127	5/0,02/163	5/0,02/192
SUP8	361	200/0,55/71	19/0,05/126	197/0,55/201	127/0,35/51	6/0,02/281	23/0,06/202	8/0,02/66	7/0,02/44	3/0,01/139
SUP9	154	119/0,77/278	25/0,16/270	98/0,64/176	65/0,42/219	6/0,04/24	23/0,15/176	8/0,05/210	6/0,04/219	5/0,03/298
SUP10	316	199/0,63/263	25/0,08/255	156/0,49/161	124/0,39/204	6/0,02/75	24/0,08/161	8/0,03/195	7/0,02/204	5/0,02/282
SUP11	226	160/0,71/299	11/0,05/290	159/0,7/149	98/0,43/239	6/0,03/6	18/0,08/150	7/0,03/230	2/0,01/240	5/0,02/318
SUP12	304	200/0,66/221	26/0,09/146	195/0,64/1	128/0,42/161	7/0,02/146	24/0,08/350	8/0,03/126	7/0,02/162	5/0,02/190
SUP13	160	137/0,86/58	23/0,14/85	126/0,79/169	96/0,6/15	6/0,04/249	17/0,11/170	7/0,04/34	1/0,01/9	5/0,03/95
SUP14	295	193/0,65/216	26/0,09/146	169/0,57/4	127/0,43/157	7/0,02/146	25/0,08/5	8/0,03/125	7/0,02/157	6/0,02/190
SUP15	15	14/0,93/216	10/0,67/146	8/0,53/4	10/0,67/157	5/0,33/146	15/1/5	7/0,47/125	2/0,13/157	5/0,33/190
SUP16	86	61/0,71/70	16/0,19/74	44/0,51/155	16/0,19/6	4/0,05/235	9/0,1/155	7/0,08/20	1/0,01/4	2/0,02/88
SUP17	47	34/0,72/92	26/0,55/64	26/0,55/206	17/0,36/64	7/0,15/298	21/0,45/207	8/0,17/83	7/0,15/71	5/0,11/25
SUP18	59	49/0,83/103	14/0,24/42	12/0,2/126	16/0,27/31	7/0,12/257	18/0,31/126	8/0,14/43	7/0,12/36	3/0,05/85
SUP19	99	93/0,94/182	11/0,11/121	53/0,54/24	53/0,54/123	6/0,06/167	23/0,23/25	8/0,08/100	7/0,07/124	5/0,05/165
SUP20	209	0/0/0	24/0,11/150	140/0,67/220	101/0,48/66	6/0,03/300	18/0,09/221	8/0,04/86	1/0/63	5/0,02/111
SUP21	26		0/0/0	20/0,77/145	10/0,38/72	7/0,27/290	10/0,38/146	7/0,27/84	1/0,04/77	1/0,04/47
SUP22	204			0/0/0	100/0,49/161	5/0,02/145	12/0,06/1	5/0,02/124	1/0/161	2/0,01/189
SUP23	129				0/0/0	7/0,05/241	18/0,14/161	7/0,05/26	7/0,05/8	2/0,02/84
SUP24	7					0/0/0	5/0,71/145	4/0,57/221	1/0,14/230	2/0,29/309
SUP25	26						0/0/0	7/0,27/125	7/0,27/161	5/0,19/190
SUP26	8							0/0/0	1/0,13/26	1/0,13/105
SUP27	7								0/0/0	1/0,14/91
SUP28	5									0/0/0

B.4 The Narrowed Combination Matrix

Table B.4: The Narrowed Combination Matrix grouped according to the clusters

Supplier		SUP1	SUP3	SUP6	SUP9	SUP10	**SUP11**	SUP24	SUP2	SUP4	**SUP8**	**SUP13**	**SUP16**	SUP17	SUP18	**SUP20**	SUP21	**SUP23**	SUP26	SUP27	SUP28	SUP5	**SUP7**	**SUP12**	**SUP14**	SUP15	SUP19	**SUP22**	**SUP25**
	End Receivers	136	338	194	154	316	226	7	279	391	361	160	86	47	59	209	26	129	8	7	5	291	310	304	295	15	99	204	26
SUP1	136		130/0,96/3	75/0,55/33	81/0,6/13	114/0,84/53	136/1/26																						
SUP3	338					270/0,8/51	193/0,57/28																						
SUP6	194				107/0,55/41	165/0,85/23	128/0,66/55																						
SUP9	154					145/0,94/64	126/0,82/29																						
SUP10	316						183/0,58/75																						
SUP11	226																												
SUP24	7																												
SUP2	279									279/1/96	266/0,95/44																		
SUP4	391															208/0,53/100													
SUP8	361															200/0,55/71													
SUP13	160															137/0,86/58		96/0,6/15											
SUP16	86														44/0,51/34	61/0,71/70													
SUP17	47														27/0,57/76	34/0,72/92	26/0,55/64												
SUP18	59																												
SUP20	209																												
SUP21	26																												
SUP23	129																												
SUP26	8																												
SUP27	7																												
SUP28	5									279/1/97	266/0,95/45																		
SUP5	291																												
SUP7	310																							297/0,96/4	271/0,87/6			204/0,66/3	
SUP12	304																								276/0,91/9			195/0,64/1	
SUP14	295																											169/0,57/4	
SUP15	15																										15/1/26	8/0,53/4	15/1/5
SUP19	99																											53/0,54/24	
SUP22	204																												
SUP25	26																												