MASTER

Cost insights in a retailer's supply chain for multiple sourcing possibilities

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Cost insights in a retailer's supply chain for multiple sourcing possibilities

by

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"The secret of change is to focus all of your energy,

not on fighting the old, but on building the new"

Socrates

Abstract

Companies in the retail sector environment face many challenges in this era of technological evolutions. In order to justify choices and to control operations proper cost insights are necessary to make profit, be efficient and survive under highly competitive circumstances. This master thesis addresses the problems relating to this cost topic for the real situation present at Company X. At first, analyses are carried out on the current situation to get a precise overview of all factors influencing the actual cost picture for the company. After evaluation of the standard way of operating at the company, a new model is developed to create a clear vision on costs present in the supply chain and which factors are important to consider when making decisions on sourcing products. A tool is created to evaluate all possible items and is leading in the discussion whether a product is profitable and how it should be delivered to the local warehouses. Outcomes based on examples show that acquisition prices, currency exchange rates, transportation costs by road and inventory levels have large impact on the sourcing issues. Finally, based on the modelling and analysis in combination with the developed tool, we provide directions on how future decisions should be made and where more analysis would provide some more valuable information.

Preface

This report is the final piece of my master thesis project carried out at Company X. Moreover, after 5 years it also marks the end of being a student at the Eindhoven University of Technology. It concludes my master study Operations Management and Logistics and the wonderful time that came along. The study brought me knowledge and experience on many subjects and I met fantastic people that made the time worthy.

I would like to thank a number of people who helped me during this project. First of all, I would like to thank Marco Slikker. Marco, your knowledge, your ability to help me structuring the project, your honest comments and sharing your view on the project was of a great value to me. You got me back on track where needed and reminded me to keep focusing on what was really important. It was very nice to have you as my supervisor. Secondly, I want to thank Arun Chockalingam, my second supervisor. Arun, your support, feedback and suggestions were very useful during the project. You helped me in approaching challenges from another perspective. Thank you both.

Furthermore am I very grateful to Michel Ophelders and Harald Vullings, my supervisors at Company X. Michel, you gave me the opportunity to execute the project and were very helpful in defining the scope of the project and finding out what the problem was for the company. Harald, your interest in the project, your unconditional support and the meetings where we exchanged thoughts are highly valued by me. You provided me with freedom within my own project. It was a pleasure to work with you. Moreover I want to thank all my colleagues at Company X. You were, without exception, all very welcoming and supporting. Thanks for listening, answering my questions and providing me with the necessary data.

Special thanks go to my friends that made the time I was a student such a great one. Both in Eindhoven and Oosterhout I enjoyed my time with you during the past 5 years. Hugo and Jaap in particular, together we had a fantastic time. A negative tradeoff between achieving great results and having a lot of fun was not present in our situation and I am very grateful to both of you for that. Roel, thank you for all the fun we had at home and your willingness to help me at every possible moment when I needed it.

I would like express my gratitude to my family. Marcel, Lian, Daan and Veerle, your love and support have brought me where I am today. Especially at the tougher moments, your positive and relaxing attitude kept me going and brought me the necessary optimism to continue and make you proud. I am a lucky person to be surrounded by you.

Last but certainly not least, Carlijn. It is hard to express in words what you mean to me and what you have done for me over the past years. I am very thankful for the support, the patience, understanding and optimism during the past time.

Thomas Wijnberg

Management Summary

Problem Statement

This report studies the costs incurred in the supply chain of a retailer. Based on cost insights the company can determine whether they source a product in the Far East or at a European supplier. Choosing the correct supplier seems to be a significant problem for companies since it has a large impact on costs incurred for a long term period. Especially low flexibility and long lead times seem to influence inventory levels and transportation costs that in combination with acquisition prices form a big part of the costs and thereby ensure or erase profit opportunities. Cost phenomena in supply chains have been extensively studied in literature, but mostly only based on a qualitative basis or focusing on a small part of the whole supply chain. This creates often a vague overview or too narrow application of costs insights, thereby not fulfilling the need of companies to have a relative simple overview of all related costs at once. In order to provide a solution to the company, the actual state of the as-is situation had to be clarified and provided the following problem statement:

"Current decision making is not optimal since it does not take all relevant factors into account. Because of the lacking insight in costs related to the various supply chain variants (i.e. direct and direct shipments) root causes of unprofitable products are hard to determine".

In order to come up with satisfying outcomes of the report the following question had to be answered:

"What cost factors are relevant to take into account for sourcing decisions and how can they be included in a more accurate cost model?"

Analysis

In order to understand what cost factors are important to consider, both in creating an appropriate cost determination model and for sourcing decisions, we first analyzed the current situation to see what was currently done by Company X. By combining this knowledge and insights with scientific research, we were able to identify lacking components of the current cost determination model. After having identified important cost factors that were present in this case study for the company, had a significant impact on the total costs figure and were within the scope of this project, all factors were checked both on completeness and correctness. This means that was checked for the current model whether all factors were included and if so, whether they were modeled in a way that reflects the real situation in a more or less accurate way. The outcome of the analysis was that many cost buckets had to be adapted in order to prevent that items were mispriced and thereby providing incorrect input for sourcing decisions for the management.

The following list of cost buckets was formed that would become a guideline in determining cost factors in the supply chain. It also indicates whether a cost bucket is changed compared to the current model used by the company:

Purchase price	*Changed?*	*(Yes/No)*
- Acquisition price		No
- Taxes and duties		No
- Currency exchange rate		No
Logistics		
- Physical transportation		Yes
- Handling costs		Yes
Inventory		
- Physical storage		Yes
- Inventory opportunity costs		Yes
- Obsolescence		Yes

New cost drivers were used in order to determine the magnitudes of all costs involved. For physical transportation operations, costs are now depending on the final location of shipped goods. It was found to be insufficient to treat all destinations equally, since large cost differences appeared to be present. For handling operations at the CDC, a standard uplift percentage was found to be far off modeling reality in a fair way. Not taking into account product characteristics in an environment where costs are incurred based on activities that require product characteristics as input tends to lead to large deviations between determined costs and actual costs. The new model proposes a situation where those product characteristics are used for all operations, including inbound and outbound activities.

In contrast to handling operation costs that were (incorrectly) included in the current cost determination model, no inventory costs were part of the model yet. Main drivers for inventory costs are uncertainty in demand, MOQs, lead times and the correctness of forecasts. These factors differ for European and Far East vendors and are therefore relevant to include.

Conclusion

A newly created model is able to come up with solutions on multiple questions. Not only does it per item tell whether it is beneficial to sell at all, it also answers this question for the different warehouses. In case of a profitable item, the cheapest sourcing variant is highlighted. The model is transferred into an Excel tool which makes it possible to find answers to sourcing questions and to determine cost tariffs based on multiple input variables. This is not only useful for cost determinations but it also creates an environment where simulations can be done and to execute what-if analysis given some changed circumstances. Some sensitivity analyses were already carried out. It taught us that some elements had more impact than others and the main contributors in the total cost tariffs were:

- Road transportation
- Currency exchange rate
- Inventory levels
- Coefficient of Variance/Standard Deviation in demand
- Acquisition price

The tool compares the different delivery variants and shows the differences between those variants. For a direct or indirect delivery, the best option is directly retracted from the tool that answers whether the European or Far East vendor would be the best option. Note that the tool at first comes with a single answer about the cost determination tariff. For many items it would however be good to evaluate this cost tariff based on varying input parameters in order to do some risk analysis. For high-risk items (large uncertainties in forecasts, demand) the initial cost tariff might be the best option, but in order to reduce risks Company X can choose to reduce this risk, which means sourcing locally. This depends on the cost differences present between the costs at European or Far East vendors and the risk level of a given item. For less risky products, the Far East proves to be a cheaper option in most cases.

Recommendations

Recommendations are made on different subjects, but all with the goal to increase efficiency, optimize decision making and reduce risks. The model provided insights that can be related to action within the company, that lead to actual cost savings. It also showed where future analyses should be about in order to gain even more insight about costs within the company. Amongst others is spoken about collaboration both internally as externally. Creating alignment between departments and other stakeholders reduces the presence of large demand variations, better forecasts are made and impact of MOQs is reduced. Being transparent about data improves efficiency within the chain. Furthermore the role of the CDC should be analyzed in greater detail with the tool. Findings indicate high costs for valuable products and costs of road transportation form a large part of total costs. Many products are hardly to not profitable in case of delivery via the CDC.

Inventory levels have a big impact. Current inventory control is at a low level of sophistication and combined with bad forecasts and high MOQs a theme that needs improvement. Using another IT tool, making LDCs responsible for forecasted items and reducing MOQs where possible can be steps in the desired direction.

Road transportation is one of the components that have a large impact on costs. Ensure FTLs, even if they lead to higher inventory levels, and differentiate per warehouse. Some warehouses are so expensive to visit from CDC that a local supplier option should be examined with greater interest.

The final recommendation deals with currency exchange rates. A heavily varying exchange rate has an enormous impact on both profit margins and risk levels. Agreements with suppliers about payments and fixing acquisition prices can reduce risks by much.

List of Abbreviations

General	
3PL	Third Party Logistics
ABC	Activity Based Costing
CDC	Central Distribution Center
DACHBNL	Germany, Austria, Switzerland, Belgium, Netherlands, Luxembourg
DDP	Duty Delivery Paid
EV	European Vendor
FCL	Full Container Load
FEV	Far East Vendor
LCL	Less than Container Load
LDC	Local Distribution Center
MOQ	Minimum Order Quantity
OB	Own Brand
OEM	Original Equipment Manufacturer
RDC	Regional Distribution Center
SKU	Stock Keeping Unit
SCED	Supply Chain Europe Department
TEU	Twenty foot Equivalent Unit

Model

In order of appearance, extendable with indices a, b and c to add necessary details

T_i	Total costs tariff per SKU
P_i	Purchase costs per SKU
L_i	Logistics costs per SKU
I_i	Inventory costs per SKU
AE_i	Acquisition price in Euros
D_i	Duties and Taxes per SKU
CUR	Currency exchange rate
F_i	Physical transportation costs per SKU
H_i	Handling costs per SKU
PS_i	Physical storage costs per SKU
IO_i	Inventory Opportunity costs per SKU
O_i	Obsolescence costs per SKU
Q_i	Quantity of item i fitting in a sea container
S	Sea transport tariffs per 40ft container
R	Road transport tariffs per 40ft container
FR	Fill rate sea container
r	Overhead costs of road transport (decimals)
l	Overhead costs of direct handling (decimals)
m	Overhead costs of indirect handling (decimals)
ps	Overhead costs of physical storage (decimals)
σ_i	Standard deviation demand per SKU
z	Inverse normality factor
μ_i	Average mean demand per SKU
TSL	Target Service Level
CV	Coefficient of Variance
$\overline{IOH}$	Average inventory level on hand
$\overline{IT}$	Average inventory in transit
C_i	Carton boxes per pallet per SKU
N_i	Quantity per box per SKU
RP	Road transport tariff per pallet
Z	Average pallets transported per week
B_i	Average outbound batch per SKU per warehouse
TT	Transit Time
LT	Lead Time
RV	Review Time
PT	Production Time
s	Reorder level
SS	Safety stock level
ST	Safety Time

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1 Introduction

This chapter provides an introduction to Company X and especially the European division of it, since the focus of this project is on this branch of the organization. The supply chain is analyzed; flows of both goods and information come to light.

1.1 Company X Inc.

The company is a relatively young American company, founded in 1986 in Boca Raton, Florida. Total sales per year lie around $17 billion (Company X, 2014) having 60,000 associates active in 58 countries and 2,000 physical stores. Furthermore they are placed 6th on the list with world's largest e-tailers. The core business of Company X is selling office products and providing service to companies. The product range includes paper, chairs, computers and furniture. For services one could think of printing, copying and maintenance for computers. Company X uses multi-channel selling (e.g. catalogue, internet and phone are examples of ways to sell products).

The company can be split in some distinct divisions, each responsible for their own business unit. 'Europe and the Middle East' is highlighted, since this unit forms the focus unit for this research and can be found in Figure 1.

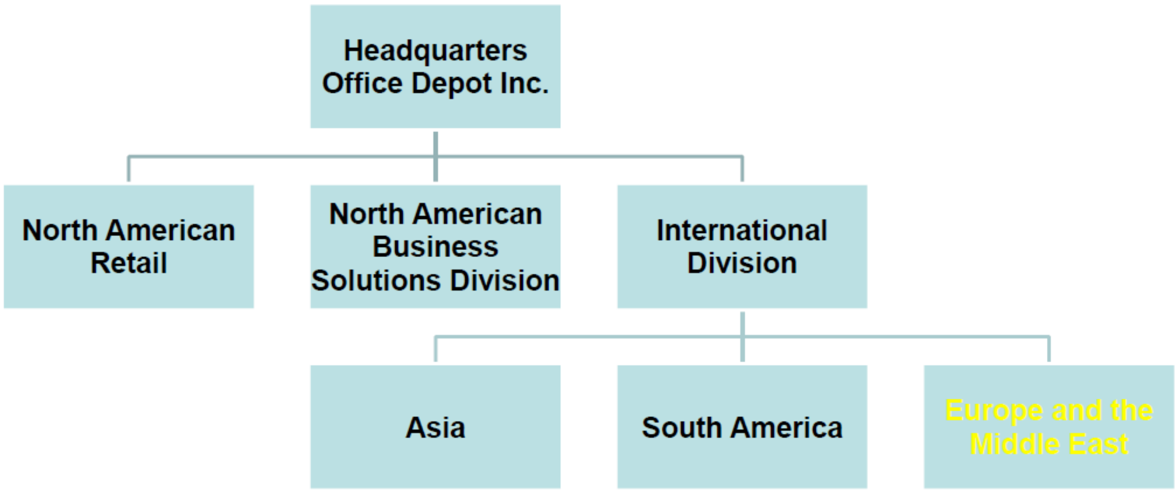

Figure 1 Organogram Company X (Company X, 2014)

1.2 Company X Europe

The International division regional headquarters is located in Venlo. For Europe and the Middle East, Company X sells office products and services through catalogs, contract sales, internet sites and retail stores. The company wants to meet the customers' needs by both offering nationally branded office products (Original Equipment Manufacturer, OEM), and own brand products and services (Own Brand, OB). Company X offers own brands including Company X®, Foray®, and Ativa®. Physical retail stores can be found in France, Sweden, Hungary, Israel, Kuwait, Saudi-Arabia and the United Arab Emirates. Those stores can be operated directly or in collaboration with a local partner.

1.3 Own Brand

For this project, the focus is on the Own Brand assortment. Products of OEMs are sourced directly at OEMs, and the location of their plants is of no concern for Company X and can be seen as given facts. The situation is different for OB products.

Those own brand products are purchased directly from manufacturers, located in Europe and China. The introduction of the OB line of products implied consequences for the manner the supply of goods is organized. OB products can be interesting to the company as they achieve a cost reduction per unit, especially when volume throughput levels are met. Merchandising groups per continent are responsible for managing life cycles and inventory levels. For Europe, a standard for all countries is therefore desirable to gain synergy in efforts and costs, and on this basis the headquarters in Venlo operates.

The flow of those products from the vendors is managed via a central distribution center (CDC) to support the activities of those OB products, completely operated by 3PL AB. The next chapter elaborates on this flow and how decisions about orders to vendors are placed.

2 Supply Chain conditions

This chapter elaborates on the current supply chain for Company X. It elaborates on how products flow from supplier to customer and activities related to smooth the process.

2.1 Locations

Company X Europe operates independently of the global company. The European supply chain handles incoming goods; afterwards the products are distributed all over Europe. Products can be sourced both locally as well as the Far East, where consolidation centers ensure filled containers shipped towards Europe.

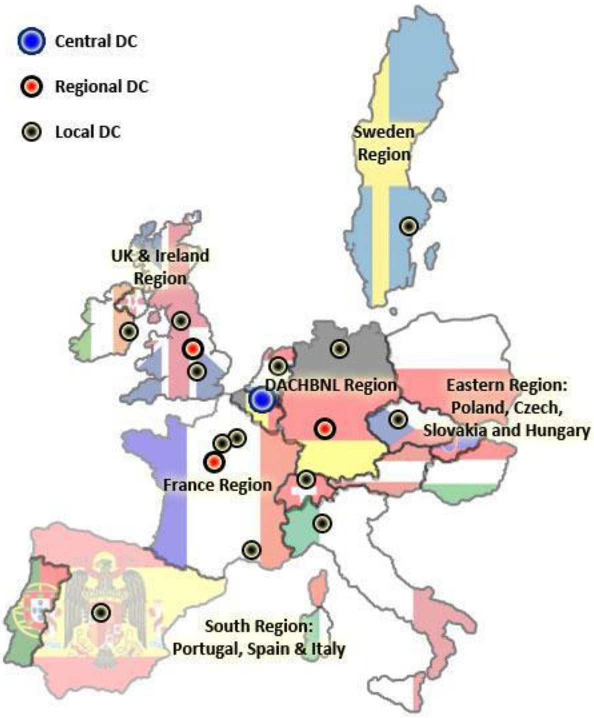

Figure 2 Warehouses Company X

For distribution to clients and retail stores, Company X has 16 distribution centers located across Europe (Appendix A) and is displayed in Figure 2. For ocean freight transport, a Central Distribution Centre (CDC) in Eindhout (Belgium) is used for handling incoming goods, picking, repacking and distribution towards Regional & Local Distribution Centers (RDC & LDC). It supports activities related to import of Own Brand (OB) products and acts as a distribution channel and stock buffer for the LDCs. Almost 20% of the order volume flows via the CDC. The rest is directly expedited, as will be explained in 2.2. RDCs are special variants of LDCs, since they are able to act as a cross dock warehouse for LDCs nearby.

The CDC is located in Eindhout (Belgium); The RDCs are in Grossostheim (Germany), Leicester (UK) and Meung-Sur-Loire (France). All processes are coordinated by the department 'European Supply Chain & Inventory Planning' in Venlo, being responsible for shipments (both direct and indirect) from Far East vendors. A total list of all warehouses can be found in Appendix A. Because the supply chain department is only responsible for shipping goods from supplier to local warehouse, the operations at the LDCs are left out of scope in this project.

2.2 Physical flow of products

Company X has multiple variants in which products are physically transferred towards the different warehouses in Europe. Decisions on which variant is chosen are elaborated on section 2.3. For the Own Brand products, a distinction can be made between two categories: products sourced in Europe and in the Far East. Company X Europe uses around 10 European Vendors (EV) and approximately 40 Far East Vendors (FEV). For both supplier categories the possibility exists to ship products directly or indirectly to the local warehouse. Graphical visualizations of the supply chains would look as follows for the Far East vendor (Figure 3) and European vendor (Figure 4):

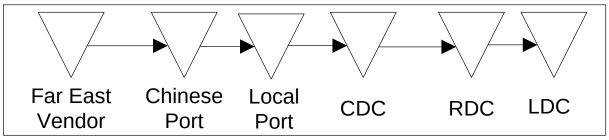

Figure 3 Supply Chain Far East Vendor

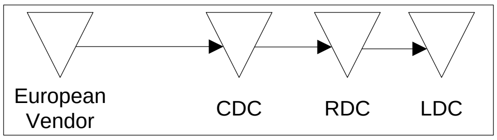

Figure 4 Supply Chain European Vendor

Note the presence of the Chinese port and the local port in the supply chain for a Far East vendor. Often, Company X has to consolidate a container with goods in the harbor in the Far East. As soon as this process is completed, the flow will continue towards Europe. The European port afterwards only functions as a receiving point from where products are transported to the warehouses. For European vendors, there is no such consolidation and products are immediately shipped to the warehouses. For European vendors, transportation is done over road. For Far East vendors, shipment towards a port in Europe goes overseas; the final delivery is done by truck over road. Note that the local port is not a place for inventory storing, but since the mode of transportation changes, it has to be included for splitting processes and its impact on the costs.

The visualizations above show the longest possible supply chain with all actors involved. For some products however, the chain length can be decreased by surpassing elements of the total supply process. At Company X three different applications can be distinguished. They are discussed below. The Far East suppliers are taken as an example, but in general the same logic applies for the European scenario, without the presence of the Chinese and local ports.

2.2.1 Direct shipments

Direct shipments depart in China and arrive at ports closest to the final warehouse. These harbors for the different warehouses can be found in Appendix A. At the port of destination, containers are loaded on a truck that finishes the delivery process by transferring the goods to the local warehouse. The inbound process can start and products are stored, ready to fulfill customers' orders. This process is presented in Figure 5.

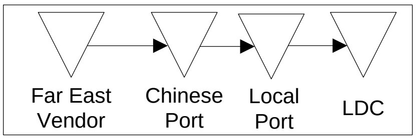

Figure 5 Direct Shipping to LDC

2.2.2 Shipment via RDC

The second method to ship is another variant to deliver goods immediately to the different countries without intervention of the CDC as can be seen in Figure 6. This way of transportation is available for the regions DACHBNL, France and the UK & Ireland, since they possess the mentioned RDCs. The RDC can function as a cross dock location like the CDC, but closer towards the final destination. The same logic applies for the direct shipment option, with arrival of the containers at the port close to the regional warehouse. After all products have reached the RDC, linked LDCs can have their orders fulfilled. Note that this is out of scope for the supply chain department, since they are not responsible for shipments between local warehouses. The possibility however is present and might be interesting to be the subject of future analysis.

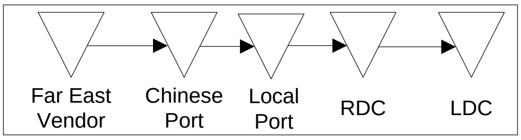

Figure 6 Shipping via RDC to LDC

The possible RDC constructions are in place at Meung sur Loire, Grossostheim and Leicester. The example for Meung sur Loire is exposed in Figure 7. Examples for Grossostheim and Leicester can be found in Appendix J.

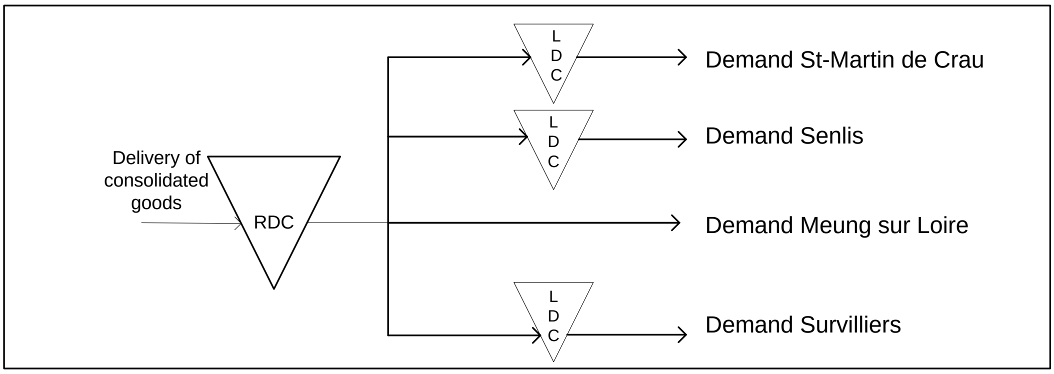

Figure 7 Shipping via RDC (MSL)

To get an idea about the quantities shipped to the different warehouses, the number of containers shipped in 2014 is shown in Table 1. Comparing these volumes to indirect flows (section 2.2.3) gives a hint about the magnitude of direct and indirect flows coming from Far East suppliers. Twenty foot Equivalent Units (TEU) is a common measure to determine order volumes for containers shipped overseas.

Final destination	Total TEU
Madrid	92
Ashton	563
Dublin	29
Elemenhorst-Lanken	32
Grossostheim	323
Hostivice	81
Leicester	624
Lenzburg	32
Meung sur Loire	268
Northampton	14
Siziano	46
Strangnas	4
Survilliers	56
Zwolle	76
Total	2.838

Table 1 Shipping frequencies Direct 2014 (Company X Supply Chain Europe, 2015)

2.2.3 Indirect shipment via CDC

Containers can also flow first to the central distribution center in Europe for Company X, located in Eindhout (Belgium) as shown in Figure 8. The CDC only serves as a stock point for supplying products of the OB assortment to all DC's in Europe and is not used for fulfilling direct customer orders or retail stores for Company X. The vessel with containers unloads at the port of Antwerp. From here the freight is taken to the CDC. Here it is stored on pallets, separated per SKU and waiting for final distribution. After an order is placed by an LDC, which will be explained in section 2.3, products are loaded in trucks and delivered at the local warehouse that placed the order.

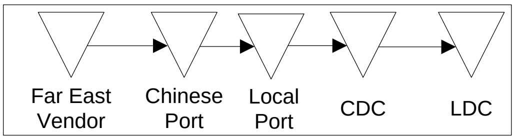

Figure 8 Indirect Shipping via CDC to LDC

2.2.4 Indirect shipment via RDC

In theory, a product can also flow via the CDC towards the local warehouses with again an intermediate stop at one of the RDCs (**Error! Reference source not found.**). Again the greements on shipments between RDC and LDC are out of scope for the supply chain department. In those situations, the supply chain is modeled as in Figure 3.

Shipping frequencies towards the CDC related to this indirect shipment possibility in the supply chain over 2014 were (Table 2):

Final destination	Total TEU
Eindhout	598

Table 2 Shipping frequency Indirect 2014

These four possible shipping routes can be modeled in a total overview as follows, each color representing a supply method, both for Far East and European vendors (Figure 9 & Figure 10):

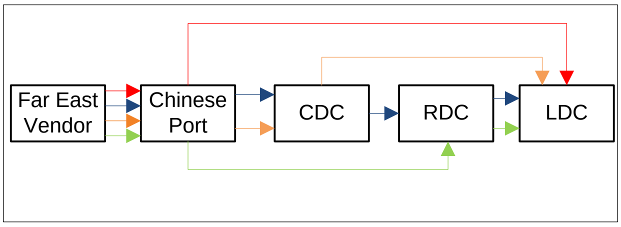

Figure 9 Possible product flow alternatives Far East

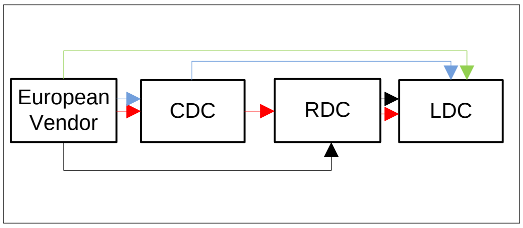

Figure 10 Possible product flow alternatives Europe

For this project, the focus is on the two flows they fully control: The direct shipment and the indirect shipment via CDC only. Flows via the RDCs are operated based on agreements between RDCs and LDCs directly and not in scope for this project. Therefore RDCs are treated like LDCs from here and seen as final destination.

2.2.5 Responsibilities

Up to now section 2.2 has provided insight on physical flows for the products of the OB for Company X. The transportation is carried out by different parties that take a part of the supply chain under their control. Here a clear distinction takes place between European and Far East vendors. Costs incurred by the different partners used in the process will be treated in section 2.4.

European Vendor

This is the simplest scenario. The vendor is responsible for bringing in the goods to the specified warehouse. This is often directly the local warehouse. In case of delivery at CDC or RDC, the final distribution is taken care of by the 3PL AB.

Far East Vendor

In this scenario the supplier ensures goods arrive at a port in China. In approximately half of the cases consolidation is possible and necessary to bring in completely filled containers. This takes up to a couple of days before the ship leaves towards Europe. The consolidation is handled by AB. As soon as the vessel leaves the port, it takes around 35 days to reach the port of destination. Ships of Maersk are most often contracted by the 3PL AB to accomplish this transportation overseas. From the port on, regardless of the port of arrival, AB ensure delivery by truck at the warehouses across Europe. From there on, responsibility of the goods lies with the warehouse of subject.

2.3 Control decisions

Decisions on inventory review and actually ordering is handled at different levels. This part provides insight in those processes, which form the starting point of actual delivery processes, like the physical flow of products as elaborated on in 2.2. An overview of the process is given in Appendix C.

2.3.1 Forecasting

Local supply chain team

Local demand planners make a forecast about the demand they expect for the products to sell in the near future. They have to collaborate with the merchandising, procurement and sales departments to get an eye on new products, products that will be phased out and promotions for the next period in order to come up with a reliable forecast. As soon as these forecasts are created, the supply chain team in Venlo, responsible for Europe as a whole takes over. Those forecasts can be seen as given and do not fall in scope of this project.

European supply chain team

As soon as all local warehouses have created forecasts, the Supply Chain Europe department consolidates all forecasts, aggregates them and uses these numbers as input values for actual purchase orders with the vendors. The forecasts are combined with actual information about inventory levels at the warehouses, lead times for the different suppliers and inventory available in the CDC to come up with items that have to be ordered at suppliers to prevent stock outs in the future. The lead times mainly depend on the location where the supplier is based. In section 2.3.2, the impact of suppliers is analyzed in more detail. Afterwards, a container plan is created to check for enough volume to ship efficiently and finally, orders are sent out to the different suppliers. Communications on the order quantities and confirmations from suppliers' side are necessary and this process is shown in Appendix D.

Note that both a direct and an indirect process overview is provided, which depends on the possible intermediate stop in the CDC in Eindhout. From this point on, Company X is done with forecasting and ordering and is awaiting suppliers' production time and delivering to the harbor.

2.3.2 Supply chain variants

The fastest way of transportation takes place via direct shipments. This is the most direct way of supply, where transportation costs are low. This option, however, is only an efficient one if the requested volume per warehouse is enough to fill the containers. Empty containers lead to high transportation costs per product and are not desirable for the company.

Direct shipments

If many items are ordered by an LDC the direct shipment is used to send Full Container Loads (FCL) to the distribution center. This is merely for FEV, if consolidation is possible in ports in China and for the European vendors that deliver smaller quantities by truck.

This type of shipment is possible for all LDCs, if they are able to place an order with enough volume to ensure profitability of direct shipments. This relates to the container plan created earlier on.

The difficulty of those shipments is the long lead time, which means that safety stock is quite high and should be stored at the LDC. At the moment, this method is used for some regions for a large part of the assortment, and for all regions with respect to the delivery of chairs, which logically fill containers quite fast due to their shape. Even with relatively small order sizes, containers can be filled fully.

Indirect Shipments
The main reason for indirect shipping is the combination of high Minimum Order Quantities (MOQ) and low demand rates, which results in extremely high inventories if they were shipped directly to the LDCs. In those cases, demand for these warehouses is stocked at the CDC, from where actual orders per LDC are shipped out as soon as necessary.

Based on the demand rates, MOQs and consolidation issues, the supply chain department makes a decision based on intuition which products per LDC will be shipped directly and which will be shipped via the CDC.

2.3.3 Replenishment schedules

A longer lead time has its impact on the way the supply chain is organized. Longer lead times require tidy decision making related to ordering products and observing the inventory levels.

Review periods
For the CDC, products are reviewed once a month and ordered in case current inventory levels are insufficient to cover the upcoming period till the next possible delivery moment afterwards.

Lead times
The biggest difference to be noted if comparing the supply chain construction of a Far East vendor with a European one lies in the lead time. The transportation time for a European vendor is a couple of days at most, whereas the combination of consolidation and shipping overseas most of the time sums up to approximately 40 days. For products flowing via the CDC towards the LDCs, an extra week is added on top of the lead time.

For all vendors a production time agreement is set at 30 days, but this number is equivalent for both vendor types and only needed to come up to a justified total lead time. This production time is the time in which a supplier should be able to deliver goods at the port. Because this time is incurred after order placement, it should be included in the total lead time to get a product from supplier to the warehouse.

2.4 Cost Structure at Company X

The department responsible for the supply chain handling is a facilitating center that acts as a non-profit department that makes operations possible between warehouses and suppliers. Between the suppliers delivery at the port up to delivery at the LDCs, multiple cost factors are found, which will be discussed in more detail. The major cost factors are:

- Inbound (CDC)
- Outbound (CDC)
- Storage (CDC)
- Distribution costs towards the LDCs
- Sea freight charges

The starting point of each tariff determination however is the acquisition price. This price is not caused by the Company X supply chain, but notable since it is the biggest component of the total price per product. Suppliers receive the first costs made by the Supply Chain Department. Suppliers produce the different products and make sure that they reach the harbor in the country of origin. This is shown in Figure 11.

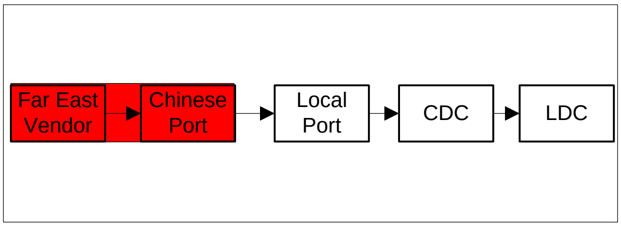

Figure 11 Purchasing price

2.4.1 Sea Freight Rates

Products sourced in the Far East have to be shipped to Europe. As mentioned before the destination of those freight transports can in theory be all DCs. The tariff to ship a container depends on this destination and the type of container used. Those rates include several handlings like actual transportation, handling at the terminals, insurances and security issues (Figure 12).

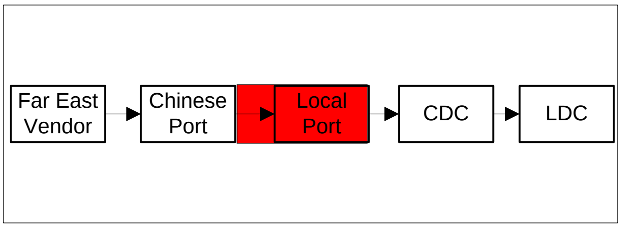

Figure 12 Sea Freight rate

Next to the sea transport, the goods have to arrive at the distribution centers (Figure 13 and Figure 14). This port-to-door transport is outsourced as well, to AB and included in the transport invoices.

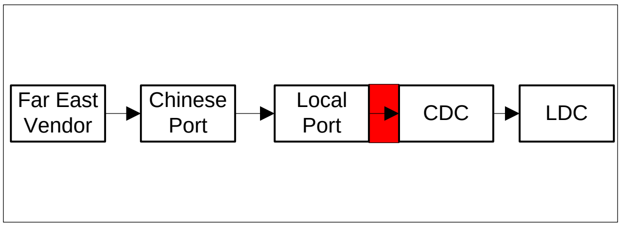

Figure 13 Port to door CDC tariff indirect

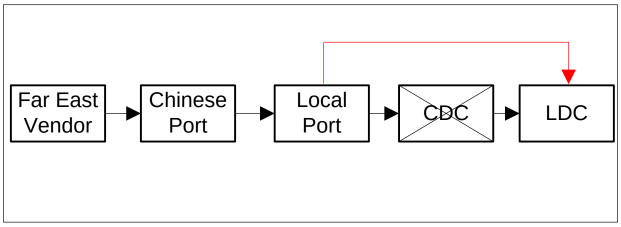

Figure 14 Port to door LDC tariff direct

2.4.2 CDC Warehousing costs

As soon as the goods have arrived in the central warehouse, a number of handlings take place.

The containers have to be unloaded, stored and eventually shipped to the final location of the products. Note that those handlings for now only occur in the CDC. For direct shipments and shipments from the CDC afterwards, handling at the final destination is explained later on. The combination of all costs incurred here form a direct cash flow towards the 3PL every month, based on volumes handled (Figure 15).

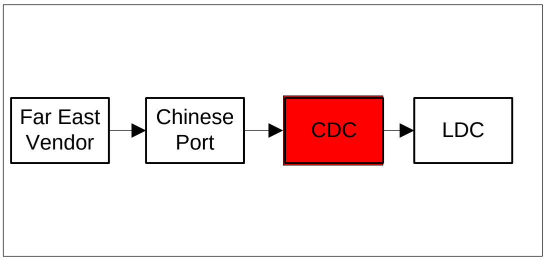

Figure 15 Warehouse costs

2.4.2.1 Inbound Logistics

Goods arrive fully stacked and separated in carton boxes in the sea containers. Those items have to be unloaded and palletized afterwards. For storage convenience, each SKU gets its own pallet. When a pallet is filled, it gets information labels and is stored in the warehouse. Based on the inventory order cycle, the design in the DC is organized. Costs for inbound are driven by the number of pallets created and number of packages handled.

2.4.2.2 Storage

Pallets are stored per SKU and split per order. This implies possibly multiple storage positions for the same SKU, but is done because of reduced complexity and thereby handling time is reduced. The costs depend on the pallet type and have a daily cost rate for occupation.

2.4.2.3 Outbound Logistics
As soon as an order is placed the outbound operations start at the CDC. Incoming orders are handled by the system that decides whether a complete pallet is needed to fulfill the order. In case of loose cartons picking a consolidated pallet is built. In such case costs are incurred per SKU. Pallets are packed, sealed in plastic, labeled and expedited to the LDC that placed the order. Orders that are too small to form a layer on a pallet are expedited as parcels. Those packages are charged per carton and a parcel packing rate is applied for sealing and labeling. As all pallets and packages are completed, they are loaded on a truck, where a cost rate per pallet or parcel is charged.

2.4.3 Transport CDC to LDC
The costs to reach an LDC are based on fixed prices. Those prices depend on the final destination and the number of pallets that are carried towards the LDC. The truck loading is the last step in the outbound process for the CDC, afterwards, as soon the doors of a truck are closed, the transportation process starts. It ends as soon as the destination is reached (Figure 16).

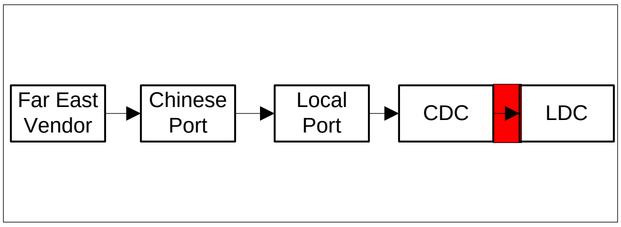

Figure 16 Transport

2.4.4 LDC Inbound costs
LDC inbound costs are out of scope for the supply chain Europe department (SCED). Generally they follow roughly the same cost structure as described for the CDC in 2.4.2. Note that here received goods actually end up at the balance of the company. The CDC can be seen as 'foreign country' and duties have not been paid yet. Those have to be added for the LDCs (Figure 17).

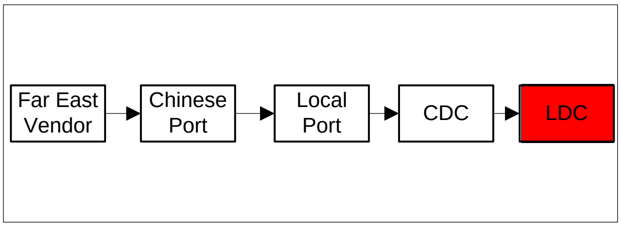

Figure 17 LDC handling

2.5 Landed Cost model

Based on the different cost places and mainly taking into account the cash flows, Company X at the moment uses a landed cost model to calculate the costs of a product at the moment it reaches the LDC. These costs, found in bills by suppliers and logistics partners, are calculated and divided over the different products based on item characteristics. The landed cost model related includes those costs and can be split in the categories:

- Purchase price
- Sea container freight rate (based on volume and destination)
- Duties
- Partner allowance
- Possible usage of handling and storage at the CDC

2.5.1 Cost specification

In order to understand the full cost model, all cost buckets will be examined in more detail. The purchase price is the first cost place. The supplier is paid costs for the product and thereby included his responsibility to deliver the products at the harbor. For European Vendors it means delivery to the warehouse that ordered the product.

If the product is delivered by the supplier and ready for shipment, the transportation process starts. A fixed cost rate per container is included for the products and is determined by the total costs divided by the volume of the product that fits in the container. For example, if the container price is €2000 and 400 items of a product fit in, each product gets an €5 added to the purchase price to cover the transport costs.

Duties and partner allowances are fixed rates as set by the government and negotiated with the shipping company. The duties depend on country and shipping route, where partner allowances are equal for all suppliers. The percentages multiplied by the initial purchase price determine the actual costs. Percentages differ per product.

Possible usage of handling and storage at CDC is only included if the indirect delivery shipping method via the CDC is used. Again, fixed percentages of the purchase price are taken to determine actual costs.

The sum of all determines the final costs of a product that is presented to the LDC and can be seen as their purchase price, different from the original one. An example of such calculation can be found in section 5.1.1. The model includes several cost factors and is used mainly for two purposes. First, it determines the costs to be accounted to local warehouses in order to cover costs made during flow of products from supplier to final destination. The second purpose lies in splitting direct and indirect supply chain costs.

Note that the mentioned cost places and processes mainly hold for the Far East vendors. For European vendors, price agreements are Duty Delivery Paid (DDP), meaning that all intermediate processes are not extra charged for. European vendors are relatively easy to analyze costs for decision making since the costs up to goods arrival at the local warehouses are included in the purchase price. For Far East vendors, as shown, many transportation and handling costs should be added before being able to make statements about true costs incurred.

3 Research questions

This chapter discusses the setup and design of the project. Information obtained from interviews at the company, former research projects, combined with gained insights from the Company X environment lead to research questions. The initial scope is fenced off to specify the problem area to be analyzed. The research project will focus on the supply chain decisions from a cost perspective.

3.1 Problem identification

The Supply Chain Europe department has identified opportunities for improvement of the actual decisions taken on sourcing and how the supply chain should look like. One of the most important gaps in knowledge and insights lies in the costs incurred in the supply chain for having products delivered from the supplier to the different distribution centers. At the moment, the company uses a landed cost model to determine prices that should be used for transactions towards the different countries that order products. This model was explained before. Many products are sourced in the Far East since purchase prices are lower compared to European vendors. However, combined with high transportation and handling costs, it might well be the case that such far away sourced products are not profitable. Some senior managers have their worries about the consequences of Far East sourcing and whether the actual costs allocated can be perceived as fair when they differ for the different warehouses. To judge such a situation, financial insight is needed. Research on this topic can be highly relevant because the 3PL partner AB that currently manages the CDC at the moment is paid a large amount of money.

By having two general scenarios (i.e. using the CDC or not) the difference in purchase price at the supplier gets an uplift to cover intermediate costs. The uplift percentages determined for the LDC is roughly 10% for the direct shipping method and 20% for the shipping method via the CDC. These percentages cover the issues mentioned in the landed cost models. This implies quite a significant difference on the margin that can be obtained. In order to justify sourcing in the Far East, this project focuses on gaining insights from a cost perspective on the impact that Far East sourcing has on the operations needed to ensure service target levels to be met This insight should provide the actual situation to determine differences between the two sourcing methods and related to that the influence it has on inventory levels, transportation and operations at the various DCs.

3.1.1 Ignored costs

Costs incurred by Company X were mentioned before and the landed cost model showed how different cost factors were taken into account and used as input for the sourcing decision. This is a nice starting point in determining costs that a given supply model incurs but these are only visible, physical costs. However, invisible costs (e.g. inventory opportunity costs) play a role and have their influence on the profitability of the sourcing method used. PWC wrote an article on these invisible but definitely present costs coming up with the following costs as being most important and mentioned by companies for analyzing alternative supply options for products, highlighting the difference between sourcing nearby and looking for products in the Far East (PWC Retail & Consumer, 2008):

- Transportation
- Customs Duties
- Warehousing
- Currency risks
- Regulatory compliance
- Quality
- Incremental inventory

Note that the transportation, customs duties and warehousing are included in Company X's cost model used for decisions on sourcing at suppliers. The other factors mentioned are not taken into consideration at the moment a decision has to be made on what supplier has to be chosen, as well the location of this particular supplier. Partly because factors are hard to quantify in a model and are only subject of discussion during meetings and qualitatively treated, sometimes because of limited knowledge or insight of the responsible decision maker.

An important factor to check for its impact on operations at Company X is the incremental inventory. The company should be stimulated to carry as less inventory as possible, as long as it meets the required service level. The costs of carrying inventory are therefore a cost place as well. The company desires return on invested money and too much stock is therefore a waste of money. The consequence of having a longer lead time will be reflected in the inventory levels and is therefore likely to be important for decision making on suppliers and their location as indicated by PWC (2008). Also the impact of currency risks may be big and have influence. Regulatory compliance and quality are not directly seen as having large impact on costs made in the supply chain, but should be monitored for proper cost determination.

Next to the fact of not having inventory carrying cost included in the model to determine costs, way transportation costs are treated at the moment is somewhat curious. Some improvement might pop up here, since after first analysis, some decisions on allocation factors do not seem totally reliable, neglecting the influence of destination of products on the total costs made.

3.1.2 Scope

The European supply chain department manages the OB stream from FEV and EV. Based on the current cost model used, findings from literature and expert opinions, the costs of sourced products will be analyzed to get an idea of the profitability of products. The scope covers from the port in China, where suppliers deliver products and Company X becomes responsible for the items and ends at the doorstep of local warehouses (Figure 18). The latter is point of discussion since for the company as a whole you want to check impact of supply chain choices for local warehouses as well, but the European supply chain department has no control on these warehouses and looks at those warehouses as given instances. The company should be aware of this impact since inventory cost are incurred at the local warehouses and differ for direct and indirect deliveries. For indirect deliveries inventory is partly stored at the CDC, ensuring a shorter lead time for LDCs when ordering products via the indirect delivery option. This is a reason why direct and indirect delivery cost calculations cannot directly be compared.

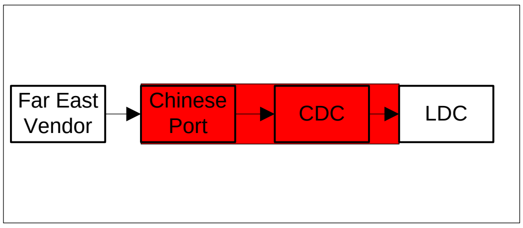

Figure 18 Scope Master Thesis

The objective of the thesis is to provide insights in the effects of choosing a certain supply method, depending on the vendor. It should create awareness at various stakeholders and departments within the company about how and why to take certain decisions related to supply chain activities. A more detailed cost structure explanation and consequences for the different actors in the supply chain can help the company in doing so.

We assume vendors and products as given and suggestions about changes can be given afterwards, when a final overview of costs and details is provided and shows possible benefits as a result of future changes.

3.1.3 Involved parties

The business units involved in this master thesis project, are the Supply Chain Europe department, the European procurement department and Finance. The European Supply Chain department takes care on the planning and supply of 17 central, regional, and local warehouses in Europe and is for sure the most important entity to focus on. However without input from the other two departments, information would be insufficient and biased, so they are included for a complete overview of processes and data.

3.1.4 Link towards literature

Previous research executed at Company X was mainly focused at inventory optimization, sometimes directly, sometimes indirectly linked via strategic decisions. In that respect, a new topic will be explored in this project, although not fully new. Previous theses at Company X (Coppens, 2011; van Deijck, 2013) have mentioned clear cost insights as limitations and gaps for their work. They did analyses on inventory aspects for Company X, thereby improving service levels and reducing inventory levels, but they noted that not taking into account transportation costs did have quite an impact. According to Coppens (2011), transportation costs form the majority costs related to Company X's financial expenses and therefore extra information is needed to provide relevant solutions to problems. Thereby this project would contribute to their findings as well, since a more sophisticated explanation can be added to their analyses.

Literature about costs and especially Activity-Based Costing has been reviewed for the Literature Search and the knowledge and findings relevant for this topic will be included. This literature also helps in analyzing of the problem, without being too specific or too broad. Tried is to find a nice balance between rigor and relevance. Contributing to scientific literature and assisting Company X in decision making.

This Activity-Based Costing seems to contribute in some cost accounting issues that play a role in the company and can provide valuable information for the decision making. Interesting is the role of the 3PL in this case where activities are, next to estimations, harder to change and more or less a fixed situation to deal with. This will have its implications for the applicability of the tool as a decision support model. It nevertheless will provide valuable insights in all activities and their related cost, so using the ABC method at least gives the company food for thought. Mainly for the warehouses, activities are important to get insights about what is going on. Relating them to the costs associated seems to be no more than a logical completing step.

3.2 Specification

Here is elaborated on the main research questions and the importance of the analyzed topic based on the drawn attention to it. Afterwards, via more specific sub questions, details of the main research question are discussed.

3.2.1 Main research question

At the moment, Company X is in the middle of a transformation phase that includes all departments. One of the essential parts of the process is to map and structure actual processes going on. Getting insights in costs is one of them. Therefore the Thesis should contribute to this transformation plan as well as via the insights in costs lead to actual cost savings in the daily operations in the future. Savings can be found in reduced inventory levels, less transportation costs and less operational expenses in the warehouses.

Literature provides opportunities and frameworks for optimization in e.g. performance of the upstream supply chain, reduction of levels of inventories, and the harmonization of business processes across various departments. This seems to be an issue for inventory optimization, but it can be broadened to the discussion of cost insight with respect to logistics as well. When having insights in costs of the supply chain, their consequent actions can be influenced in order to decrease costs.

Company X has many vendors in the Far East due to the lower purchase price for products, which is beneficial for the profit margin. However the consequences of sourcing in the Far East are high stock levels and low demand responsiveness. The reasons for these consequences are the long lead times that come with sourcing far away. The replenishment lead time can be defined as the time from order placement up to being present to deliver as soon as customer demand comes in (Silver, Pyke, & Peterson, 1998). For Company X, this lead time exists of production times at suppliers (30 days) and the shipping times towards Europe. One can understand that those shipping times can be quite different when comparing them to European Vendors. The shipping time is approximately 30 days, where consolidation at the port is neglected up to now. Furthermore, for Far East vendors, the review time equals a month, which has to be taken into account as well.

Next to long lead times, Minimum Order Quantities (MOQs) set by vendors have an impact on inventory levels for supply chain issues. For many vendors, those MOQs are specified per SKU and Company X faces additional costs due to the restriction made per order. Note that this can reduce the impact of lead times, since you are less triggered to order your products too often.

In chapter 2.4 was already shown what costs factors can be found that have an impact on the total costs for Company X. Costs are often volume- or item related and in the final cost splitting taken into account in such a way. However, after a first brief analysis, a gap is identified in the allocation of costs for the CDC. The main gap in operations lies in pricing method used for the handling of products. At the moment, Company X uses a fixed percentage to all of its products in order to make up for these costs. However 3PL AB bills Company X for all incoming, stored and outgoing pallets, so by analyzing SKUs coming in and going out, an exact calculation should be an option, although it is hard to obtain all data to complete the task. By doing so, transfer prices towards local warehouses will change. In the end all costs have to be covered, since SCED only facilitates handling for the countries. Unjustified tariff determination can lead to mispricing of goods, which result in too favorable or unfavorable pricing for customers. To illustrate this with an example, two carton boxes with the same handling, storing and outbound processes are charged totally different, only because of the value within the carton. This has a big impact on the product price, without having good arguments to do so. This situation is taken as a start to eventually continue the evaluation of different sourcing options, which only can be done if costs are treated properly. Next to the curious cost allocation for costs incurred at the CDC, increased inventory values for products with a long lead time are not taken into account, when the procurement department decides about a supplier for a product. To summarize and conclude the problem statement, the final problem description is:

"Company X does not have a proper cost insight model to determine where products have to be sourced. Current decision making is not optimal since it does not take all relevant factors into account. Because of the lacking insight in costs related to the various supply chain designs (i.e. direct and direct shipments) root causes of unprofitable products are hard to determine"

In order to tackle this problem statement, research questions have been stated that should help Company X to go after this problem and come with solutions that lead to better decision making. The following main question is therefore formulated:

"What factors are relevant to take into account for sourcing decisions and how can they be included in a more accurate cost model?"

3.2.2 Sub Research Questions

To gain insights in costs, several sub questions are needed to split the bigger process in smaller pieces. Costs occur at several places in the chain and an overview of them is needed to make justified statements. In this context where focusing on the CDC cost structure is included, we want to analyze operations, inventory and transportations. Variables having major influences are related to demand magnitude, lead times, product values and order frequencies. Those will be treated when analyzing the situation. Initial questions subject of investigation would be:

1) How does the actual cost structure model look like regarding supply chain costs?
2) What cost drivers are important to consider in analyzing costs from supplier to distribution center?
3) What is the impact of different cost drivers on total costs in the supply chain?
4) How should the cost drivers be included in the sourcing decisions?

3.2.3 Approach

The method to answer the questions as stated before and to give useful insights and recommendations for Company X has to be clear in order to achieve a structured continuation of this report. The general goal is to make clear how supply chain costs can be modeled, both for the current and the future state, and where the main differences are present. This is used to provide Company X with information about critical cost components where focus should be on and that are important to consider during the sourcing debate. As mentioned, Company X has multiple options in order to get a given item towards a warehouse and the different costs related to all those options are modeled. Generally, 4 different variants will be discussed, where the cheapest option gives the answer on the question where and what to source.

Important cost components will be taken from literature and applied to the current situations for Company X. Incorrect and incomplete cost measures will be adapted in the future model to reflect real costs as good as possible. From the new model, the variant leading to the lowest cost for Company X will be recommended as the sourcing method that should be pursued in order to achieve the best result for the company.

The new model will be incorporated in an Excel tool that compares multiple scenarios. This Excel tool will include all combined insights about cost factors needed to determine the cost tariff per product and is based on multiple input variables. Those input variables can be retracted from internal information available in the company. The outcomes are input for both strategic discussions as well as for operational costs that are billed towards local warehouses that order products via the ESCD.

4 Cost factors and notation

*This chapter provides insight about the qualitative components for cost models to be taken into account according to literature. The current situation is analyzed and checked against the qualitative components. Missing links are subject for discussion and eventually implemented in chapter 6. Afterwards the results and sensitivity of the models will be treated in chapter 7 (*Figure 19*). This will be particularly interesting since it includes the main differences between the current and a future design of the cost insights and are leading in the discussion on conclusions and recommendations towards Company X.*

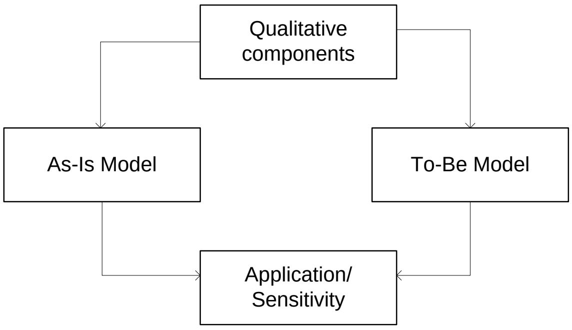

Figure 19 Analysis framework

This chapter provides first insights on cost buckets that are relevant in case of assessing costs for different supply chain variants. Based on insights on cost factors and by looking at the method Company X currently uses to assess the costs in the supply chain a model will be proposed that takes into account all relevant costs in the sourcing discussion for the company. For some items it will be beneficial to be supplied from the Far East against low acquisition price agreements, for others it will be more complex and costly, where a European supplier would be a more suitable option.

The question to source a product in Europe or the Far East should be answered based on output of the model. To generate this output the model should take into account several input parameters leading to the output which is expressed as cost per SKU sourced. The remainder of this report will elaborate on the input, model and output parameters to end up with a justified choice on the sourcing variant possible (Figure 20).

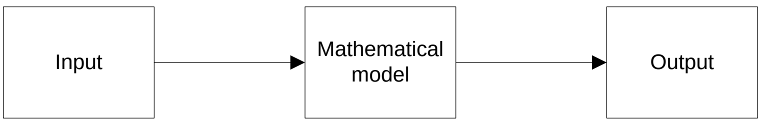

Figure 20 Model for analysis

4.1 Identifying relevant cost factors

Over the last decades, quite some research has focused on sourcing all over the world to gain strategic benefits. Main reason for the global sourcing of products in countries like China is the perceived cost saving possible (Servais & Overby, 2005; Quitens, Pauwels, & Matthyssens, 2006). In order to assess whether perceived cost savings are truly decreased cash flows a total overview on the costs is necessary (Bergman, 2006).Purchase prices are indeed in almost every situation lower compared to suppliers located in more developed countries (Gilley & Rasheed, 2000), but other costs can create a situation where savings are less obvious as at first sight might appear.

Literature on this topic covers a broad range of topics, starting at the supplier and ending at the consumer; from product design to an obsolete item. Meredith Smith (1999) looked for factors that helped in the choice what items where interesting to consider for global sourcing, Burpitt & Rondinelli (2004) performed research on the ideal location a supplier should be based for successful sourcing and many researchers analyzed the case where global sourcing could actually be used as a strategic tool to beat competitors in pleasing customers against favorable costs in the supply chain (Samli, Browning, & Busbia (1998); Murray, Kotabe, & Wildt (1995).

In this research, where focus lies on impact for supply chain operations, some advantages and disadvantages are more important than other. Several research publications taught us that communications with suppliers are different based on their geographical locations and related cultures. Nassimbeni & Sartor (2006) mention the presence of Guanxi (personal relations) to do successful business with Chinese suppliers, but such factors are hard to quantify and model. The presence of such factors is of crucial importance to keep in mind, but will not return in the remainder of this paper.

Meixell & Gargeya (2005) discuss the fact that next to an increase in transportation costs for supplying products overseas, decision making is complicated as well because of inventory tradeoffs due to the long lead time of the products. The difference in culture and language lower the effectiveness of business activities like forecasting and material planning compared to dealing with European suppliers. The decisions on supplier selection for products therefore are a constant tradeoff between lower production costs far away (Mol, van Tulder, & Beije, 2005) and low transportation costs locally, taking into account all side effects popping up.

Eberhardt et al (2004) mention the fact that quality issues should not be neglected. They suggest that the lack of technological expertise, quality fluctuations and poor delivery performance are major reasons to avoid the country as base for suppliers. It has its impact when a supplier is chosen by the company and important to discuss, although the type of industry has major influence on the magnitude of the impact.

This section has provided us some input for thoughts about issues that contribute in the discussion about why and where items should be sourced. Based on this qualitative input and in combination with quantitative input remarks can be made in chapter 5 and 6 about the correctness and completeness of the current decision making process.

4.1.1 General cost factors

Literature shows issues that determine the total profitability of items which can be sourced locally or in the Far East. To structure cost elements as far as possible and be able to assess supplier options in an objective manner, a framework from literature is taken as basis for elaboration on cost elements embedded in the supply chain. Platts & Song (2010) mention a total list of cost buckets, composed of findings in literature and interviews with industrial managers to gain insight in the different costs which can be combined to a framework to assess the total acquaintance costs of global sourcing from China.

At a high level, the following costs are mentioned to be present in industry:

1. Set up
2. Purchase price
3. Administrative
4. Logistics
5. Inventory
6. Quality
7. Supplier Management
8. Other

These cost buckets consist of multiple facets which will be elaborated on in the next sections. Since this is a general list for suppliers, not all drivers are applicable for the case of Company X. A first selection therefore is made to focus on items that actually are important for the company's case.

4.1.2 Specific cost factors in this project

Since the project is carried out for the supply chain department, the focus is on cost buckets related to this department. Also costs that are considered as insignificant due to the limited impact on total operations are no longer taken into account. The list is thereby reduced, since some mentioned buckets are left out from now. Criteria to assess the items to be included are:

- Supply chain department related
- Significant impact

Based on these two criteria, a number of cost buckets will no longer be considered in this project. However keep in mind that such costs are still relevant and present in other contexts. The reasons of dropping other costs are as follows:

Set up costs involve costs for collecting information on suppliers, investment made up front and training of personnel. The costs are only made at the beginning of the project and are considered to be an issue for the procurement.
Administrative costs are costs for forecasting, billing and back charges, but considered to be insignificant to include for final cost comparisons.
Supplier Management is hardly done by Company X at the moment. The influence and efforts of the department are very small.
Quality issues are present, but only to a limited amount. Since Company X deals with relative 'simple' products, the costs on quality issues are negligibly small.
Other costs relate to impact of negative associations with 'Made in China' products, corruption risks and dealing with local guidelines are considered to be insignificant as well.

The three other costs are after discussion with managers and some initial cost insights considered to be relevant and used as input for the coming chapters.

The updated list consists of the following main elements to continue with:

- Purchase price
- Logistics
- Inventory

4.1.3 Elaborated cost factors

The previous section showed the three major cost buckets that were used to compare supply chain costs for different variants. Here this selection is expanded by mentioning sub buckets that show a more narrow part of the major components. These sub buckets will be found in analyses related to the total costs of the supply chain variants used by Company X.

Elaborating on these main elements provides more insight on the costs involved to analyze profitability of the different suppliers. The article of Platts & Song (2010) continues with some more detailed analysis on relevant cost buckets and do split these in subcomponents. These subcomponents will be subject to analysis to as-is and to-be situation as proposed in the beginning of this chapter. The resulting outcomes of this initial analysis will be used as variables to consider for models in the coming chapters dealing with cost analyses.

Purchase price

- Acquisition price
- Taxes and duties
- Currency exchange rate

Logistics

- Physical transportation
- Handling costs

Inventory

- Physical storage
- Inventory opportunity costs
- Obsolescence

These subcomponents coincide with literature findings where price, warehousing, transportation, obsolescence, expediting and duties are mentioned as most significant cost drivers to take into account for decision making.

4.1.4 Notation of parameters and variables

To achieve the goal of having the possibility to compare the cost of multiple supply chain variants, these variants have to be modeled in a consistent way. Therefore notation is introduced for the different major and sub buckets to clarify cost components. All products get indices attached in order to distinguish the different supply chain variants and see what factors are relevant for the given conditions analyzed. Note that this notation with indices a, b and c works consistently for all cost buckets and are introduced here once. The indices can reflect the following parameters and their definitions:

$a \in \{F, E\}$ with $F = Far\ East, E = Europe$

$b \in \{d, i\}$ with $d = direct,\ i = indirect$

$c \in \{1,2,3 \dots 16\}$ with each number reflection warehouse location

We now continue with analyzing different cost buckets in greater detail and by having a given set of parameters reflection a sourcing option for Company X.

Total costs

Every product i gets a tariff that can be linked to one of the options. All options are compared to one another by taking together the total costs made during the supply chain activities and handlings that took place to move the product from supplier to local warehouse. Therefore we see the following notation:

$T_i^{a,b} =$ Total tariff costs per SKU, depending on location a of vendor and supply chain variant b

As an example, $T_i^{F,i}$ would reflect the tariff for a SKU sourced in the Far East and being transported indirectly via the CDC.

If we return to the identified cost buckets we can calculate the total tariff costs per SKU by summing the major components leading to the following formula:

$$T_i^{a,b} = P_i^{a,b} + L_i^{a,b} + I_i^{a,b}$$

$P_i^{a,b}$ = Purchase costs

$L_i^{a,b}$ = Logistic costs

$I_i^{a,b}$ = Inventory costs

Since clear differences in chapter headings are sufficient to directly see whether we deal with the old models or the new, we do not explicitly mention differences between the current and a new model yet.

Purchase costs

Purchasing items is the first cost component that is taken into account. Suppliers are paid for producing a given item and deliver it at an agreed location. This location can be a local port in the Far East for vendors far away, as well as directly to the local warehouse in case of a European supplier. Purchase costs only differ for the difference in location of the supplier, the way in which Company X it delivers to its local warehouse does not influence these costs. Therefore the $P_i^{a,b}$ is replaced by P_i^a from here onwards. Purchase costs can be split in three different relevant elements: Acquisition price, duties & taxes, and currency exchange rate. These will be denoted by:

AE_i^a = Acquisition price in Euros

D_i^a = Duties & taxes

CUR = Currency exchange rate

The application and impact of the different components can be found in the elaborations hereafter, based on the different supplier's locations.

Logistic costs

Transporting goods from supplier to warehouse leads to costs and depends both on supplier's location a and the chosen supply chain variant b. Sub buckets for this major component are the physical transportation of items and the possible handling costs at the central warehouse in Belgium. The physical transportation costs both depend on location a and supply chain variant b, whereas handling costs only depend on whether a product goes indirectly via the CDC or not.

$F_i^{a,b}$ = Physical transportation costs

H_i^b = Handling costs

Inventory costs

Keeping inventory has partly to do with the location of the supplier, since the lead time involved to bring products from the supplier to Company X impacts the total inventory levels, both locally as well as in transit. The same holds for the direct and indirect transportation variants. We therefore continue with the variable $I_i^{a,b}$ for inventory costs. Sub components follow the same logic as applied for the grand cost bucket of inventory and will therefore be denoted as follows:

$PS_i^{a,b}$ = Physical storage costs

$IO_i^{a,b}$ = Inventory opportunity costs

$O_i^{a,b}$ = Obsolescence costs

5 Current model

This chapter provides an overview of the current cost determination at Company X and continues with discussions about the completeness and correctness of this way of operating. The outcomes of these discussions lead to a new cost determination model that can be used to assess costs incurred by a product during the supply chain. The approach chosen to analyze the appropriateness and completeness of the current situation is based on the following set up.

5.1 As-is situation Company X

This chapter continues in the use of notations as introduced before. It shows the current cost analysis as used by Company X in setting tariffs and take decisions on sourcing. Note that these are not based on any scientific methods mentioned before. A split is made in vendor type, since they will use different accumulations and formulas to come up with the costs of the separate major and sub buckets as identified before. Input parameters are available within the company, both in internal product related documents as in costs set by third parties for instance at the logistic activities.

5.1.1 Cost Analysis Far East Vendor

In order to analyze the current situation, a model is exposed that shows Company X's actual cost determination. The following input parameters are needed to eventually reach the outcome.

Input parameters (on SKU level):

- Quantity of item i fitting in a sea container (Q_i)
- Acquisition price in dollars($) (A_i^F)
- Duties/Partner allowances (decimals) (D_i^F)
- Sea transport tariffs per 40ft container (S)
- Road transport tariffs per 40ft container (R)

- Currency Exchange Rate dollar/euro (CUR)
- Fill rate sea container (FR)
- Overhead costs of road transport (decimals) (r)
- Overhead costs of direct handling (decimals) (l)
- Overhead costs of indirect handling (decimals) (m)
- Overhead costs of physical storage (decimals) (ps)

Purchase costs

Purchasing in the Far East means an agreed price with the vendor in dollars to start with. Combined with taxes, duties and partner allowances, which depend on this acquisition price and a given currency rate, the total purchase costs are determined as follows:

$$AE_i^F = \frac{A_i^F}{CUR}$$

$$P_i^F = (1 + D_i^F)AE_i^F$$

Logistic costs

Logistics will be split again to model the differences in supply chain variant b used. For Far East vendors the first part, overseas, is the same for both variants, but the road transport and handling afterwards are treated in different ways.

$$L_i^{F,b} = F_i^{F,b} + H_i^b$$

Physical Transportation

Physical transportation ($F_i^{F,b}$) can once more be gathered by an accumulation of both sea freight (SF_i^F) and road transport ($RT_i^{F,b}$).

$$F_i^{F,b} = SF_i^F + RT_i^{F,b}$$

Sea Freight

$$SF_i^F = \frac{S}{Q_i * FR}$$

Road Transport

1) $RT_i^{F,d} = \frac{R}{Q_i * FR}$
2) $RT_i^{F,i} = \frac{R}{Q_i * FR} + r * (P_i^F + SF_i^F + \frac{R}{Q_i * FR})$

Handling

Handling only depends on supply chain variant used. Therefore we again make a split in calculations. The origin of a product is not of influence on the total handling costs.

1) $H_i^d = l * (P_i^F + F_i^{F,d})$
2) $H_i^i = m * (P_i^F + F_i^{F,i})$

Inventory costs

Inventory costs in general do not depend on the type of a product or the way it ends up in the warehouse. However, it is indirectly linked since throughput times and average days of inventory in stock are linked via the location of the supplier and how products arrive at their final location. Currently, a fixed overhead cost factor is used to determine the physical storage costs. Inventory opportunity and obsolescence costs are not taken into account.

$$I_i^{F,b} = PS_i^{F,b} + IO_i^{F,b} + O_i^{F,b}$$

Physical storage

1) $PS_i^{F,d} = 0$
2) $PS_i^{F,i} = ps * (P_i^F + F_i^{F,i})$

Inventory Opportunity

$IO_i^{F,b} = 0$

Obsolescence

$O_i^{F,b} = 0$

Multiple cost buckets depend on acquisition price (duties and partner allowances) or accumulated cost of purchase price and physical transportation cost (Handling, indirect road transport and storage). For calculations, these buckets accumulate to 10,8% and 1,8% respectively for indirect and direct shipping methods and will be used accordingly in the following example. These percentages are currently used according to internal documents (Company X Supply Chain (2015); Company X, 2014).

Example Far East vendor

We compare three SKUs with different characteristics (Table 3). We only observe products that have a purchase price negotiated. The SKUs follow the same indirect shipping methods. Note that a similar example can be provided for the direct shipping method. Company X uses the cost determination method as described before, with the following input values:

- Sea transport tariffs per 40ft container (S) €1900
- Road transport tariffs per 40ft container (R) €525

- Currency Exchange Rate dollar/euro (CUR) 1,14
- Fill rate container (FR) 0,85
- Overhead costs of road transport (decimals) (r) 0,041
- Overhead costs of direct handling(decimals) (l) 0,018
- Overhead costs of indirect handling (decimals) (m) 0,036
- Overhead costs of physical storage (decimals) (ps) 0,031

Input	SKU	Highlighter	Chair	Hole Puncher
	Q_i	103790	491	10809
	A_i^F	$1,91	$74,85	$13,62
	D_i^F	0,053	0,016	0,038
Acquisition		€1,68	€65,66	€11,95
Duties		€0,06	€0,00	€0,26
Partner Allowances		€0,03	€1,05	€0,19
Sea Freight		€0,02	€4,55	€0,21
Road Transport to CDC		€0,01	€1,26	€0,06
Overhead costs direct		€0,04	€1,30	€0,23
Overhead costs indirect		€0,20	€7,83	€1,37
Total costs direct		€1,83	€73,89	€12,90
Total costs indirect		€1,99	€80,42	€14,04

Table 3 Example current model Far East vendor

5.1.2 Cost Analysis European Vendors

European vendors differ from Far East vendors with respect to the purchase price costs. Suppliers in Europe are paid in euros and based on DDP. This means that no duties, allowances or transportation have to be paid, in contrast to products sourced on the other side of the world. Suppliers take care of all costs up to delivery at CDC for indirect shipments and LDCs for direct shipments. In general the same model can be applied as done for Far East vendors, multiple cost buckets however can be skipped since they are already included in the acquisition price. Important to mention here is that European prices are generally higher than Asian acquisition prices, otherwise it would never be beneficial to buy in the Far East. We assume a 15% acquisition price difference compared to Far East Vendors. Not that this differs per item in reality. Hereafter, only changed factors will be discussed. Other cost components are treated in the same way as they were for the Far East variant.

Purchase costs

Purchasing in Europe means an agreed price with the vendor in euros to start with. The price is Duty Delivery Paid (DDP) so no extra charges come into scope.

$$P_i^E = AE_i^E$$

Logistic costs

$$L_i^{E,b} = F_i^{E,b} + H_i^b$$

Physical Transportation

Physical transportation ($F_i^{E,b}$) only consists of possible road transport ($RT_i^{E,b}$).

Road Transport

1) $RT_i^{E,d} = 0$
2) $RT_i^{E,i} = r * (P_i^E + \frac{R}{Q_i * fill\ rate})$

Handling

1) $H_i^d = l * (P_i^E)$
2) $H_i^i = m * (P_i^E)$

Inventory costs

$$I_i^{E,b} = PS_i^{E,b} + IO_i^{E,b} + O_i^{E,b}$$

Physical storage

1) $PS_i^{E,d} = 0$
2) $PS_i^{E,i} = ps * (P_i^E)$

Inventory Opportunity

$IO_i^{E,b} = 0$

Obsolescence

$O_i^{E,b} = 0$

Multiple cost buckets depend on acquisition price (duties and partner allowances) or accumulated cost of purchase price and physical transportation cost (Handling, indirect road transport and storage). For calculations, these buckets accumulate to 10,8% and 1,8% respectively for indirect and direct shipping methods and will be used accordingly.

Example European vendor

The same three SKUs with different characteristics are highlighted (Table 4). We only observe products that have a purchase price negotiated on DDP agreements. For DDP products, all transportation costs and duties are already included. The SKUs have different shipping methods.

- Road transport tariffs per 40ft container (R) €525
- Fill rate container (FR) 0,85
- Overhead costs of road transport (decimals) (r) 0,041
- Overhead costs of direct handling(decimals) (l) 0,018
- Overhead costs of indirect handling (decimals) (m) 0,036
- Overhead costs of physical storage (decimals) (ps) 0,031

Input	SKU	Highlighter	Chair	Hole Puncher
	Q_i	103790	491	10809
	A_i^E	€2,02	€76,72	€14,26
Acquisition		€2,02	€76,72	€14,26
Overhead costs direct		€0,04	€1,38	€0,26
Overhead costs indirect		€0,22	€8,29	€1,54
Total costs direct		€2,06	€78,10	€14,52
Total costs indirect		€2,24	€85,01	€15,80

Table 4 Example current model European vendor

5.2 Correctness and completeness

Debates about correctness and completeness of cost models are subject to assumptions, practicalities and desired level of preciseness. Company X is not interested in costs insights up to five decimals, but at least assumptions made leading to final figures, conclusions and recommendations should be correct. The model should reflect reality in such a way that it is useful but not too complex as well. This should be taken into account when judging a model, without being too subjective in addressing errors and mistakes in the cost accounting method used. However if a more precise allocation is possible, without adding much complexity, it should be executed. In case of wrong assumptions and incorrect allocations, the complexity is less of an issue and improvements are necessary to be made. Furthermore cost buckets found to be significant in literature should be included in the final model as well.

Purchase price
Purchase price is the building block for all costs to be allocated. Generally speaking, this is a matter for procurement to negotiate about and a given fact to use for supply chain analysis and optimization. However, as can be seen in the example provided, some supply chain costs are directly calculated based on this price. A logic continuation explains that a decrease in acquisition price has its consequences for handling cost allocations. The question arises whether this is the case.
Duties and partner allowances are given figures, which have to be taken for granted, but do not have major impact nor are to be influenced. These are dealt with properly.
The same holds for the currency exchange rate. During this project, we do not dig deeper on the influence of exchange rates and related risks. A short sensitivity analysis will be provided in order to show the impact of fluctuations on the total costs.

Logistic costs
Sea Freight is a fixed price per container and handled as such in the model. For cost calculations the volume of products is compared to the 85% capacity loading volume of containers. Since cartons are loose loaded without pallets, this seems to be a fair allocation. Relative simple improvements can be made for direct shipments to the different countries, since in the current model a standard price per container is used for all harbors. Cost differences do however exist and can be found in Appendix A.

Delivery at warehouse costs is the first cost component bucket where large differences can be expected. The current model always chooses the transportation costs to the CDC in Eindhout, regardless of the actual destination. For indirect shipments flowing via the CDC this is a correct model of the flow. For direct shipments it is not. Direct transshipments are not charged enough currently, which gives them too much of an advantage for shipping costs over land. For some countries, the difference is rather small, for some very big. Actual road transportation costs can be found in Appendix A.

Probably the biggest improvement in accurate modeling can be gained in handling cost components. Overall costs are known that are paid to the 3PL and in order to cover them, fixed percentages are used for paying those bills. Product features and cost drivers of actual costs are not taken into account, which tends to lead to incorrect cost overviews. Knowledge of handling, storage and outbound costs at the 3PL is present. Although a lot of data is needed for correct calculation, an allocation that approximates true costs closer than the current model would be a large improvement in accurateness.

Inventory
Physical storage costs are included in the uplift percentage. Product characteristics are not taken into account. Inventory opportunity cost and obsolescence are not included.

6 New model

To generate useful output, the new model should take into account different and more input parameters. The remainder of this report will elaborate on the input, model and output parameters to end up with a justified choice on the sourcing variant possible. Instead of using uplift percentages to cover handling, transportation and storage fees, costs now will be allocated to the products based on related activities and processes where items are charged relative to the costs they actually cause.

6.1 Improvement opportunities

When comparing the as-is situation (i.e. the current model) with the relevant cost factors as found in chapter 4 and combine these with the analysis in section 5.2 we can derive improvement opportunities that will help Company X in coming to a more accurate process costs insight leading to better decision making in the end.

First, improvements in cost allocation are made at the physical transportation level. Cost of road transportation from port to local warehouse and the variant of transportation via CDC and ultimately reaching the local warehouses are based on payments to 3PL as well. Since big differences occur in transportation prices, this can have a big impact on the price, especially for products of which only limited number of items fit in trucks. Cost drivers for delivery at warehouse that cover total costs are based on the combination of volume, destination and direct/indirect shipment. At the moment, all final destinations are treated the same way and therefore some warehouses take cost hits that are made due to delivery to other warehouses. Those incorrect input values should be taken out and warehouses pay in the future for the true costs caused. Therefore the future cost model has to include distinct values to differentiate product costs per final destination.

The second improvement is more complex and will be in the direction of inbound handling, storage and outbound handling costs that are now covered by a fixed percentage. Starting from scratch would mean an activity-based costing setup, requiring cost drivers to be found for the different processes related to the handling in warehouses. However, 3PL partner AB actually uses cost drivers in their warehouses to calculate costs to be billed towards Company X. This information is shared with Company X and it might be interesting to find a way to incorporate these cost drivers in the internal cost model.

Inbound costs are related to creating new pallets to store products on and the number of carton boxes picked filled with items. The costs are twofold: Per SKU coming in, a fee is paid for creating a pallet to store the products. Afterwards, per carton box additional costs are charged. Cost driver for ordered SKUs is the number of cartons filled with products and the number of pallets created. As the number of items per box are known, prices for inbound can be allocated per SKU. Activity cost drivers look the same as for the outbound process. Picking SKUs from stock racks lead to costs and eventually shipping per pallet does as well. The combination of the two makes up the costs for outbound activities. Cost drivers are the SKU location visited in the warehouse and the number of pallets created for outbound. Thereby a more activity-based cost price method is to be used instead of the standardized percentages to cover total costs. At the moment activity-based costing is only implemented to a very limited extent. Data for handling cost calculations are obtained via product characteristics. A Product Data Sheet (PDS) contains information needed on characteristics of products.

A third improvement is found in inventory costs. The supply chain is not penalized yet for high inventory levels, although awareness is present that the total inventory is decreased in an ideal situation. This holds for both the inventory opportunity costs and obsolescence. For costs calculations however it was not included up to now.
Opportunity costs relate to the 'punishment' for all invested money that cannot be spent elsewhere. Company X internally works with a 10% to assess investments related to inventory. Up to now, this was however not included in the cost models related to sourcing. Cost drivers for this bucket are average inventory value held per SKU and the average time an item is kept in stock before it is sold.

To summarize, the following changes will be seen in this chapter with respect to the current model. We provide an overview with relevant cost factors (as in 4.1.3) that will show up in the new model in a different way compared to the current model.

	Changed? (Yes/No)
Purchase price	
- Acquisition price	No
- Taxes and duties	No
- Currency exchange rate	No
Logistics	
- Physical transportation	Yes
- Handling costs	Yes
Inventory	
- Physical storage	Yes
- Inventory opportunity costs	Yes
- Obsolescence	Yes

The purchase price bucket will not be treated differently in the new model. Therefore the same conditions and assumptions hold as seen in chapter 5. The cost buckets Logistics and Inventory will change and was already indicated before. The coming sections will elaborate on these components that eventually lead to the new model.

6.2 Inventory levels

Company X keeps track of its inventory levels and uses it for reorder policies. This knowledge however is not translated to the cost model subject to this project.

Considering inventory control at one or multiple stock locations is related to three main parameter settings around three important decisions (de Kok, 2011): the review time for inventory control, the reorder level when an order is placed and ultimately the quantity ordered. Four basic inventory control methods could be identified as shown in Table 4.

	Continuous Review	Periodic Review
Variable Lot Size	(s,S)	(R,s,S)
Fixed Lot Size	(s,Q)	(R,s,Q)

Table 5 Inventory control policies

Applying the mentioned frameworks on the situation for Company X, in particular the situation for the CDC reordering policy, we consider the mentioned parameter settings.

Orders

Inventory in the CDC is controlled by the European Supply Chain Department (ESCD). Every month the ESDC decides on the quantities order at the different suppliers, nowadays mainly located in Asia. This indicates a monthly review period, which can be seen as one of the characteristics of inventory management. Whenever the inventory position falls below the reorder level s, a fixed batch size Q (or a multiple of Q) will be ordered to get the inventory position above the reorder level. This means that the inventory policy can be defined as a (R, s, nQ) policy, where n is the minimum integer needed to bring the inventory position after ordering back to or above the reorder level (van Donselaar & Broekmeulen, 2013). The **review period** at the CDC in Eindhout for the items which are ordered directly at the vendor is one month for Far East Vendors. For European vendors, items are reviewed twice a month.

Another important decision is the **order quantity**. There are two possibilities: an order can be of any size to raise the stock position above the reorder level s or the size of an order should be equal to (when (R,s,nQ): multiples of) a predetermined lot size Q. At Company X, vendors are required to supply in:

- a complete pallet
- a pallet layer
- a complete carton/package.

The third parameter setting is the **reorder level**, present in any of the four variants. In periodic review systems, demand fulfillment is required over the time period which covers the review period plus lead time (R+L). For example, assume that an order is placed at time t, which is received at time t+L. A second order is placed at time t+R, which is received at time t+R+L. This means that, when the first order is placed, no other orders could be received until the arrival of the second order from now. This implies that the reorder point at t should be chosen such that the demand during a period of R+L could be covered. However, a stock out can still occur when the demand during R+L exceeds the reorder point. Therefore, the reorder point should include some value of safety stock which allows for the uncertainty of demand and uncertainty of supply in the short run.

The reorder level is determined as the sum of the expected demand during the lead time and the safety stock level. The safety stock level is defined as a sufficient level of inventory to ensure delivery for a given time period. When looking at the database with items 2 months demand coverage is frequently seen as safety stock. The safety stock level (ss) is based on the safety time (ST) and the average daily demand (μ):

$$SS = ST * \mu$$

The reorder level (s) is determined based on the safety stock level and the replenishment lead time (LT):

$$s = SS + L * \mu$$

The usefulness of having insight in inventory levels is to determine both service level and related inventory investment costs. We assume service level to be a constraint that should be met against lowest costs possible. Inventory working capital is the capital that is tied up in inventories, i.e. the value of inventories. The relevant inventory for working capital is the inventory that is kept on hand at a location plus the inventory in transit to a location. Only at the local warehouses, service level (probability that a stock-out doesn't occur) is explicitly taken into account when calculating safety stock levels. For the CDC more rough assumptions are made and safety stock levels are set as months of demand that can be extra fulfilled. For many products it is the case that 1, 2 or 3 months of inventory are taken as safety stock, next to the regular stock used to fulfill forecasted demand, like the formulas above show.

For now, we continue with the Company X inventory control mechanisms when transforming inventory variables into cost outcomes subject of this research project. Mentioned should be that this is a very basic way of keeping control of inventory. In the near future it might be interesting to use literature on fill rate to improve current results and this will be used when modeling the inventory policies. A fill rate measure gives the most complete view on the performance of the system and therefore it is the most appropriate service measure to use. It not only shows the number of stock outs per period but also gives indications about the magnitude and impact of a stock out. Safety stocks need to be determined in such a way that the expected fill rate for each month is equal to the desired fill rate.

Company X inventory model

A graphical representation of the mathematical model input and output is presented in Figure 21. The input and output for are slightly different for the two models that will be discussed, and will therefore be further specified in this section. For now, we assume that all required model input is available. How the input parameters are transformed to output variables will be mentioned in this section. Differences between the models are found in the safety stock levels.

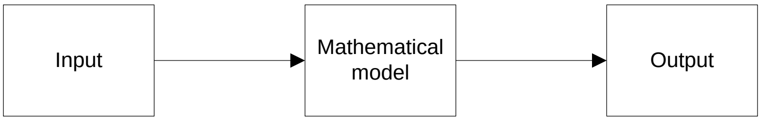

Figure 21 Model set up

Input parameters

- Transit time (TT)
- Production time (PT)
- Review period (R)
- Expected daily demand per SKU (μ_i)
- Safety time per SKU (ST_i)
- Service Level (SL)
- Coefficient of variance (CV)

Output parameters

- *Average inventory level on hand* $(\overline{IOH})$
- *Average inventory in transit* $(\overline{IT})$

Model

The model combines multiple parameters and based on formulas output parameters will be derived. Different sub components are present in the model and are mentioned hereafter.

Lead time

Lead time is the combination of production time and transit time:

$$LT = PT + TT$$

This split is necessary since the total lead time is needed to calculate correct safety stock levels. For cost calculations however, applying from the moment items come in Company X's possession, the TT is needed.

Demand during lead and review time

Assuming the forecasts for the coming months as fixed and purely based on the expected average monthly demand, the expected demand during the lead time and review period is obtained via the following formula:

$\mu_{L+R,i} = \mu_i * (LT + R)$

Safety Stock
Current situation
Safety stock levels are fixed and set at 2 times the expected demand for the same month. This therefore is different per month and an average should be taken to come up with general conclusions. Note that the chosen strategy is not in line with recognized literature and therefore an extended model will be presented afterwards. However, to judge the current situation of cost placements, it is reasonable to continue the line of logic for Company X:

$$SS_i = ST_i * \mu_i$$

Note that the average formula is the same as the formula for the safety stock in an arbitrary month, since we assume that only an indication of demand is given upfront during negotiations with suppliers. This will hold as long as this μ_i is used as decision input. For future cost considerations with current suppliers forecasts can be used to get a more accurate and realistic indication on the as-is situation.

Future situation
The desired service level is necessary to determine the correct corresponding safety level. The service level input, leading via the inverse function of the normal distribution to the variable z_i, assumes a normal distribution of demand. This is not entirely the case since negative demand is not possible in a real situation, but negligible for most products. Even for products with a low demand it gives a quick insight in the inventory situation of the product. In worst case it skews normality leading to an overestimation of safety stock.
In the more scientific approach is chosen to determine safety stock levels, we come up with the formula:

$$SS_i = z_i * \sqrt{E[LT]\sigma_D^2 + (E[D])^2\sigma_L^2}$$

Since lead time is assumed to be rather fixed, without large variabilities, and demand to be more varying over time, the formula is simplified for Company X to:

$$SS_i = z_i * \sqrt{E[LT]\sigma_D^2}$$

Input needed for this approach compared to the previous model includes the coefficient of variance (CV) since the σ_i will largely depend on the average demand value. This can be determined accordingly:

$$\sigma_i = CV * \mu_i$$

Note that the lead time needed for input here consists of both production time and transportation time. For costs issues elsewhere in the report, only the transportation time is considered for the inventory in transit, since no payments are made till production time has passed.

Inventory on hand

We assume that fill rate is high and that the backorders are therefore negligible when assessing the inventory levels on hand (i.e. the impact on the inventory level is very low). For products ordered every month, the following formula holds to obtain the inventory level on hand:

$$\overline{IOH_i} = SS_i + \frac{\mu_i * R}{2}$$

Inventory in transit

Inventory in transit overlaps demand for multiple months in the near future. Every month one order is expected to be placed with a longer transit time, which means that multiple import orders are in transit at a given moment.

$$\overline{IT_i} = \mu_i * TT$$

Total inventory for cost consideration

$$\bar{I} = \overline{IOH} + \overline{IT}$$

In total we see three sub inventories present as part of the total inventory levels. Inventory can be still in production, it can be on its way towards the warehouse, or it can already be stocked. Inventory in transit and on hand is necessary for cost considerations for this project as can be seen in the formula above. Inventory still in production is relevant for safety stock levels that are on hand and therefore indirectly needed as input for inventory levels for the cost calculations.

6.3 Notation of parameter and variables

The previous chapter about the old model had already introduced some notation necessary to create clarity and structure; however some extra notation is needed to come to a final, improved model. Mentioned was already that specific destination (i.e. the location of local warehouse) has impact on the total costs and therefore the tariff charged per item. In order to do so, an extra superscript is added in order to distinguish between different warehouses. Note that for comparisons with the previous model, one should keep in mind that no earlier distinction was made related to the final destination. Each local warehouse will be numbered to make clear differences.

Total costs

Every product i gets a tariff that can be linked to one of the options. All options are compared to one another by taking together the total costs made during the supply chain activities and handlings that took place to move the product from supplier to local warehouse. Therefore we see the following notation:

$T_i^{a,b,c}$ = Total costs tariff per SKU, depending on location a of vendor and supply chain variant b

As an example, $T_i^{F,i,1}$ would reflect the tariff for a SKU sourced in the Far East and being transported indirectly via the CDC. The final destination would be Leicester (See Appendix A, for numbered warehouses). If we return to the identified cost buckets we can calculate the total costs tariff per SKU by summing the major components leading to the following formula:

$$T_i^{a,b,c} = P_i^{a,b,c} + L_i^{a,b,c} + I_i^{a,b,c}$$

Many components will be the same as in the previous model and will therefore not again be treated here. You find explanations in 4.1.4.

Purchase costs
Purchase costs only differ for the distinct in location of the supplier, the way in which Company X it delivers to its local warehouse does not influence these costs nor does the location of the local warehouse. Therefore the $P_i^{a,b,c}$ is replaced by P_i^a from here onwards.

Logistics costs
Compared to the old model, activities in local warehouse have become more important in order to determine the logistics costs. Product characteristics will be taken into account.

$F_i^{a,b,c}$ = Physical transportation

$H_i^{b,c}$ = Handling costs

Inventory costs
Warehouses are assumed to follow the same inventory policies but the average demand has an impact on the magnitude of the inventory costs. We therefore continue with the variable $I_i^{a,b,c}$. Sub components follow the same logic as applied for the total cost bucket of inventory and will therefore be modeled as follows:

$PS_i^{a,b,c}$ = Physical storage costs

$IO_i^{a,b,c}$ = Inventory opportunity costs

$O_i^{a,b,c}$ = Obsolescence costs

6.4 To-be situation Company X

This section shows the future cost analysis to be used by Company X in setting tariffs and make decisions about sourcing. A split is made in vendor type, since they will use different accumulations and formulas to come up with the costs of the separate major and sub buckets as identified before. Input is obtained from internal documents and cost specifications provided by the 3PL (Company X (2014); AB, December 2014).

6.4.1 Cost analysis Far East Vendors

Based on different cost drivers, final cost tariffs can be calculated. Some are rather simple to obtain and include in the model, others aspects can be more complex and heavily depend on operating decisions made that relate to the order frequencies and order magnitudes, which are results of chosen strategy in combination with the used replenishment strategy.

Input parameters (on SKU level):

- Carton boxes per pallet per item i (C_i)
- Quantity per box per item i (N_i)
- Sea transport tariffs per 40ft container per destination (S^c)
- Road transport tariffs per 40ft container per destination (R^c)
- Road transport tariff per pallet per destination (RP^c)
- Average pallets per warehouse per outbound activity (Z^c)
- Average demand per SKU per day per warehouse (μ_i^c)
- Coefficient of variance per SKU per warehouse (CV_i^c)
- Required Service Level (SL)
- Average outbound batch per SKU per warehouse (B_i^c)
- Minimum Order Quantity per SKU (MOQ_i)

- Currency exchange rate dollar/euro (Cur)
- Fill rate container (FR)
- Inventory opportunity cost (decimals) (IO)
- Obsolescence (decimals) (O)
- Lead Time per product per warehouse per variant ($LT_i^{F,b,c}$)
- Review time per product per variant (RV_i^F)

6.4.1.1 Purchase costs

Purchasing cost calculation has not been changed as discussed in 6.1.

6.4.1.2 Logistic costs

Logistics will be split an extra time to model the differences in supply chain variant b used. For Far East vendors the first part, overseas, is the same for both variants, but the road transport and handling afterwards are treated in different ways.

$$L_i^{F,b,c} = F_i^{F,b,c} + H_i^{b,c}$$

Physical Transportation

Physical transportation ($F_i^{F,b,c}$) can once more be gathered by an accumulation of both sea freight ($SF_i^{F,c}$) and road transport ($RT_i^{F,b,c}$). These rates can be found in Appendix A and B.

$$F_i^{F,b,c} = SF_i^{F,c} + RT_i^{F,b,c}$$

Sea Freight

$$SF_i^{F,c} = \frac{S^c}{Q_i * FR}$$

Road Transport

Note that the number of pallets shipped on average determines the impact on costs per product. It is more efficient to ship full truck loads instead of trucks with only a couple of pallets loaded. The average number of pallets shipped from the CDC towards the different warehouses can be found in Appendix E. If volumes change, the impact of this factor changes as well, since not the price per full truck is displayed.

For direct shipments, the charges relate to transport from local port to warehouse. For indirect deliveries it is a combination of transport to CDC and reaching the final warehouse.

1) $RT_i^{F,d,c} = \frac{R^c}{Q_i * FR}$
2) $RT_i^{F,i,c} = \frac{R^c}{Q_i * FR} + (\frac{RP^c}{C_i * N_i})$

Handling

Handling depends on the supply chain variant used and the final destination (volume related). Therefore we again make a split in calculations. The origin of a product is not of influence on the total handling costs. Instead of using fixed percentages as done in the current model, we want to allocate costs based on the activity necessary to get products via the CDC towards LDCs. To model the process in an accurate way, handling is split up in different parts as specified on bills obtained via the 3PL. This means a split in handling incoming and outgoing goods. No longer are costs based on a dated percentage, but on actual handlings.

1) $H_i^{d,c} = 0$

Inbound handling is summed over all warehouses' volumes and therefore costs for all warehouses can be accumulated since only one input value is needed to determine all incoming handling activities. For outbound, the volumes can and will differ and so will costs related. Therefore an extra superscript is used for this activity. Since these rates are obtained from a third party, assumed is that they are fixed in the scope of this project and therefore they are immediately used as part of the model. In other, future projects these values can be denoted as variables in order to have a deeper analysis on the influence of the different rates.

2) $H_i^{i,c} = IH_i^i + OH_i^{i,c}$

Inbound handling

Inbound rates are given for pallets and boxes. The input value necessary to determine costs is the average order volume for the CDC per incoming order. This leads to exact numbers of boxes and pallets inbounded. Cost rates for inbound are (Table 6):

Activity	Cost Driver	Rate
Pallet Inbound Handling	Pallet Inbound	€3,04

Table 6 Pallet inbound costs (Kuehne and Nagel, 2015)

Incremental costs per pallet are made for picking loose loaded cartons. These rates are (Table 7):

Activity	Cost Driver	Rate
1-10 cartons per pallet	Carton	€0,24
11-20 cartons per pallet	Carton	€0,19
21-30 cartons per pallet	Carton	€0,17
>30 cartons per pallet	Carton	€0,16

Table 7 Cartons inbound costs (Kuehne and Nagel, 2015)

$$IH_i^i =$$

$$\left(\left\lceil\frac{\sum_c \mu_i^c*30}{C_i*N_i}\right\rceil * \frac{3{,}04+I_i*0{,}24)}{N_i*\sum_c D_i^c*30}\right) \qquad If\ C_i \leq 10$$

$$\left(\left\lceil\frac{\sum_c \mu_i^c*30}{C_i*N_i}\right\rceil * \frac{3{,}04+I_i*0{,}19)}{N_i*\sum_c D_i^c*30}\right) \qquad If\ C_i \leq 20$$

$$\left(\left\lceil\frac{\sum_c \mu_i^c*30}{C_i*N_i}\right\rceil * \frac{3{,}04+I_i*0{,}17)}{N_i*\sum_c D_i^c*30}\right) \qquad If\ C_i \leq 30$$

$$\left(\left\lceil\frac{\sum_c \mu_i^c*30}{C_i*N_i}\right\rceil * \frac{3{,}04+I_i*0{,}16)}{N_i*\sum_c D_i^c*30}\right) \qquad If\ C_i > 30$$

Outbound handling

Outbound rates are treated roughly the same way as inbound is done. The rates are as follows (Table 8):

Activity	Cost Driver	Rate
Picking Carton	Picking location (SKU)	€2,37
Picking Full Pallet	Pallet Outbound	€2,37
Packing picked Pallet	Pallet Outbound	€3,35
Pallet Loading	Pallet Outbound	€2,08

Table 8 Outbound rates (Kuehne and Nagel, 2015)

$$OB_i^c = \frac{\left[\frac{\mu_i^c*7}{C_i}\right]*2{,}37+\frac{\mu_i^c*7}{C_i}*(3{,}35+2{,}08)}{N_i*\mu_i^c*7}$$

6.4.1.3 Inventory costs

Inventory costs in general do not depend on the type of a product or the way it ends up in the warehouse. However it is indirectly linked since throughput times and average days of inventory in stock are linked via the location of the supplier and supply chain variant used to deliver items at the final location. Physical storage costs are billed by the 3PL, like the handling part is done. For opportunity costs and obsolescence costs, a fixed percentage will be charged on the average inventory level. These factors were not taken into account in the current model. Inventory opportunity and obsolescence costs are not taken into account.

$$I_i^{F,b,c} = PS_i^{F,b,c} + IO_i^{F,b,c} + O_i^{F,b,c}$$

Physical storage

1) $PS_i^{F,d,c} = 0$

Storing items in the CDC is only applicable for the indirect method and average numbers of the item stored are needed as input to determine storage costs. Based on the number of pallets occupied by the SKU on average, total physical storage costs can be determined (Table 9).

Storage	Pallet in Storage	€0,197/calendar day

Table 9 Physical Storage Rates (Kuehne and Nagel, 2015)

2) $PS_i^{F,i,c} = \frac{\left\lceil \frac{\overline{IOH_i}}{C_i * N_i} \right\rceil}{\mu_i^c} * 0,197$

Inventory Opportunity

Capital investment is a new cost object in the allocation of prices. We take an inventory carrying cost rate of 10% to compensate for money invested upfront. For every SKU, one needs average inventory and average time an item is kept in stock to calculate how much costs are lost in keeping inventory.

Cost per SKU

$$IO_i^{F,b,c} = P_i * 1{,}10^{\frac{\left(\frac{\overline{TI}_i^{b,c}}{\mu_i^c}\right)}{365}}$$

Obsolescence

Obsolete products are no longer valuable to the firm, since they do not return any profits. In order to compensate for these products, 1% of the value of a product is added on top of costs to cover for losses. This is a percentage currently used at the company. For items that have stock to fulfill demand for more than 6 months, this percentage increases. For the current situation, we assume that inventory levels do not exceed 6 levels of demand to cover.

$$O_i^{F,b,c} = P_i * 0{,}01$$

Example

We compare three SKUs with different characteristics. We only observe products that have a purchase price negotiated. The SKUs follow the same indirect shipping methods. Note that a similar example can be provided for the direct shipping method. We provide an example for deliveries to the warehouse in Leicester. Note that other warehouse calculations can be derived in the same way (Table 10). The following input values are taken:

- Sea transport tariffs per 40ft container (S^1) €1800
- Road transport tariffs per 40ft container (R^1) €800
- Road transport tariff per pallet per destination (RP^1) €51
- Average pallets per warehouse per outbound activity (Z^1) 16
- Coefficient of variance per SKU per warehouse (CV_i^c) 1
- Required Service Level (decimals) (SL_i) 0,95
- Minimum Order Quantity per SKU (MOQ_i) 1

- Currency Exchange Rate dollar/euro (CUR) 1,14
- Fill rate container (FR) 0,85
- Inventory opportunity cost percentage (decimals) (IO) 0,10
- Obsolescence percentage (decimals) (O) 0,01
- Lead Time per product per warehouse per variant ($LT_i^{F,b,c}$) 70
- Review time per product per variant (RV_i^F) 30

Input	SKU	Highlighter	Chair	Hole Puncher
	Q_i	103790	491	10809
	A_i^F	$1,91	$74,85	$13,62
	D_i^F	0,053	0,016	0,038
	C_i	18	4	36
	N_i	60	1	6
	μ_i^1	7,9	7,67	6,53
Purchase price		€1,76	€66,71	€12,40
Sea Freight		€0,02	€4,31	€0,20
Road Transport		€0,05	€14,01	€0,29
Inbound handling		€0,01	€1,01	€0,02
Outbound handling		€0,01	€1,95	€0,09
Physical storage		€0,02	€3,70	€0,09
Opportunity costs		€0,07	€2,57	€0,48
Obsolescence costs		€0,02	€0,67	€0,12
Total costs		€1,97	€94,93	€13,69

Table 10 Example new model Far East vendor

6.4.2 Cost Analysis European vendor

Input parameters (on SKU level):

- Acquisition price in Euros (€) (AE_i^E)
- Carton boxes per pallet per item i (C_i)
- Quantity per box per item i (N_i)
- Road transport tariff per pallet per destination (RP^c)
- Average pallets per warehouse per outbound activity (Z^c)
- Average demand per SKU per day per warehouse (μ_i^c)
- Coefficient of variance per SKU per warehouse (CV_i^c)
- Required Service Level (SL)
- Average outbound batch per SKU per warehouse (B_i^c)
- Minimum Order Quantity per SKU (MOQ_i)

- Currency exchange rate dollar/euro (Cur)
- Fill rate container (FR)
- Inventory opportunity cost percentage (decimals) (IO)
- Obsolescence percentage (decimals) (O)
- Lead Time per product per warehouse per variant $(LT_i^{E,b,c})$
- Review time per product per variant (RV_i^E)

Purchase costs

Purchasing in Europe means an agreed price with the vendor in euros to start with. The price is Duty Delivery Paid (DDP) so no extra charges come into scope.

$$P_i^E = AE_i^E$$

Logistic costs

For European vendors we only deal with road transport. In case of direct delivery, no road costs are made since suppliers deliver products at the local warehouse. In case of indirect delivery, Company X makes costs from the central to the local warehouse.

$$L_i^{E,b,c} = F_i^{E,b,c} + H_i^{b,c}$$

Physical Transportation

Physical transportation $(F_i^{E,b})$ only consists of possible road transport $(RT_i^{E,b})$.

Road Transport

1) $RT_i^{E,d,c} = 0$
2) $RT_i^{E,i,c} = \frac{RP^c}{C_i * N_i}$

Handling

Handling costs are determined in exactly the same way as they were derived in 6.4.1. In case of direct deliveries, no handling at the CDC takes place. In case of indirect shipments, a truck appears at the door of the CDC from which the same activities take place and the same costs are incurred.

Inventory

Inventory is equally derived with respect to formulas as in the Far East variant. Note that variables will differ, e.g. the lead time, but the formulas are executed in the same manner. Therefore, for explanations and formulas, see 6.4.1.

Example

The same three SKUs are compared. We only observe products that have a purchase price negotiated. The SKUs follow the same indirect shipping methods. Note that a similar example can be provided for the direct shipping method. We provide an example for deliveries to the warehouse in Leicester (Table 11). The following input values are taken:

- Road transport tariff per pallet per destination	(RP^1)	€51
- Average pallets per warehouse per outbound activity	(Z^1)	16
- Coefficient of variance per SKU per warehouse	(CV_i^c)	1
- Required Service Level (decimals)	(SL_i)	0,95
- Minimum order quantity	(MOQ_i)	1
- Currency Exchange Rate dollar/euro	(CUR)	1,14
- Fill rate container	(FR)	0,85
- Inventory opportunity cost percentage (decimals)	(IO)	0,10
- Obsolescence percentage (decimals)	(O)	0,01
- Lead Time per product per warehouse per variant	($LT_i^{E,i,c}$)	30
- Review time per product	(RV_i^E)	15

Input	SKU	Highlighter	Chair	Hole Puncher
	Q_i	103790	491	10809
	A_i^E	€2,02	€76,72	€14,26
	C_i	18	4	36
	N_i	60	1	6
	μ_i^1	7,9	7,67	6,53
Acquisition		€2,02	€76,72	€14,26
Road Transport to LDC		€0,05	€12,75	€0,24
Inbound handling		€0,01	€1,01	€0,02
Outbound handling		€0,01	€1,95	€0,09
Physical storage		€0,02	€1,85	€0,06
Opportunity costs		€0,04	€1,36	€0,25
Obsolescence costs		€0,02	€0,77	€0,14
Total costs		€2,17	€96,40	€15,06

Table 11 Example new model European vendor

7 Results

The final chapter before coming to conclusions provides insight in magnitudes of the different cost buckets as identified during the research. One will encounter buckets that are of less influence than others and one will see the impact of variation among the buckets on the total cost pictures. This chapter shows influence of the buckets for the examples chosen during the past two chapters and eventually exposes some sensitivity analysis which is useful for determining where extra focus should be on from management perspectives in the near future.

7.1 Cost comparisons

The main goal in this section is to increase the understanding of relationships between input and output variables and the impact of one on another. It provides both theoretical information about the accuracy needed for the input variables and practical information about the variables where focus should be on in reality since they cause large cost impacts for the sourcing model. In combination with the sensitivity analysis it makes clear to management which factors are important and where focus should lie in order to make or keep an item profitable. Note that outcomes of total cost comparisons (i.e. checking the multiple scenarios) is twofold. On the one hand, it exposes which of the variants is most profitable under the given conditions and on the other hand it shows whether the items are profitable at all or should be ignored and denied at all because of losses in any given case.

Models

We start by examining the examples provided during the previous chapters. If we see the influence per cost bucket, a first idea is obtained about the influence of cost drivers. These findings are noted in Appendix G and Appendix H. We compare the current and new model to find differences in terms of output level for both methods of cost determination (Table 12 and Table 13).

Far East	**Highlighter**		**Chair**		**Hole Puncher**	
	Direct	*Indirect*	*Direct*	*Indirect*	*Direct*	*Indirect*
Current	1,83	1,99	73,89	80,42	12,90	14,04
New	1,84	1,97	74,84	94,93	13,06	13,69
Difference	1%	-1%	1%	18%	1%	-2%

Table 12 Cost differences current and new model Far East

Europe	**Highlighter**		**Chair**		**Hole Puncher**	
	Direct	*Indirect*	*Direct*	*Indirect*	*Direct*	*Indirect*
Current	2,06	2,24	78,10	85,01	14,52	15,80
New	2,06	2,17	78,09	96,40	14,51	15,06
Difference	0%	-3%	0%	13%	0%	-5%

Table 13 Cost differences current and new model Europe

We see large differences for indirect sourcing methods and small to none for the direct option. This is explainable since for the direct method, not a lot of cost buckets are of influence. The inventory opportunity and obsolescence cost play a role and they are comparable to the standard 1,8% that was added in the model currently used by

Company X. For the indirect method however, where Company X as well used a fixed uplift percentage to cover costs, large differences occur since multiple factors play a role here. To light comes the fact, as previously assumed, that some items are overpriced in order to compensate for underpriced products.

Sourcing consequences
Next to the differences between the current and new model, also differences between direct and indirect sourcing from both European and Far East vendors come forward. We see other ratios if we compare the options and those changed ratios (i.e. often gap between given options) are input for new discussions at the company about where to source. Some products will be steered heavily towards sourcing in the Far East, where other depend greatly on uncertainty factors that make the company decide to find products in the less volatile environment Europe offers. For many items the result will be that sourcing in the Far East is not the best option anymore. This is due to currency exchange rate changes, but also products that deal with large variations in demand and bad forecasts are better off when sourced in Europe. Up to now was often assumed that a vendor in the Far East was always the better option because of the low purchase price. New models however suggest that this logic is no longer valid and a more detailed analysis is needed per product. The precise impact of all different input factors is discussed in the sensitivity analysis. First conclusion drawn here is that adding an uplift percentage to determine total costs can be sufficient for the direct delivery variant. However, for the indirect variant, more effort and sophistication is needed to assess the profitability of products. Large variations in costs are found here compared to the current situation with the current model used. Where current models assumed an approximately 11% uplift to cover the costs and therefore a profit given the fact of low purchase price, new models lead to results showing the incorrectness of these assumptions.

7.2 Sensitivity Analysis

For companies like Company X, sourcing decisions are made at a single point in time for a given item and due to contracts and investment obligations, the decision on where to source is extremely important. Once a decision is finalized, its outcomes are fixed on the initial basis and they are highly impact by the risk sensitivity analysis measures. If there would be a change in one of the factors of the variables then it has the impact on the overall project and especially the outcomes which might be not achieved as initially desired and planned. We check influence of the different variables based on the following ranges. These ranges are chosen as being a possible real situation for Company X and the impact is checked on the total price and eventually sourcing decision. Here we discuss the components that differ more than 5% on output level in order to get a better understanding of the major cost buckets' influence. All factors are discussed in Appendix K. The most important variables are related to acquisition, inventory opportunity and road transport costs. Tables showing influence of less influential cost buckets can be found in Appendix L. If we distill this to large variations in total output levels, factors to focus on are:

- Road transportation
- Currency exchange rate
- Inventory levels
- Coefficient of Variance/Standard Deviation of demand
- Acquisition price

These factors are discussed here and show impact of variations on input level in output terms. For each of the items they show a comparable pattern where the given factor has sometimes more influence on an item than on another, depending on all product characteristics in total. Shown are the first items of all examples up to now, the highlighter and the chair. Outcomes for the hole puncher, can be found in Appendix L.

Road Transportation

Delivering products from the central warehouse in Belgium towards a final local destination is one of the most cost causing activities for the company. Trucks are relative expensive and since all products are loaded palletized, space is often not efficiently filled compared to loose loaded transport in sea containers. Long distances with a low number of pallets are reducing profit, since road transport costs rise to levels that make margins fade away. An interesting finding is that sea transport is negligible compared to the road equivalent of transportation. It mostly influences the decision whether to transport direct or indirect. Outcomes for the highlighter and chair can be found in Figure 22.

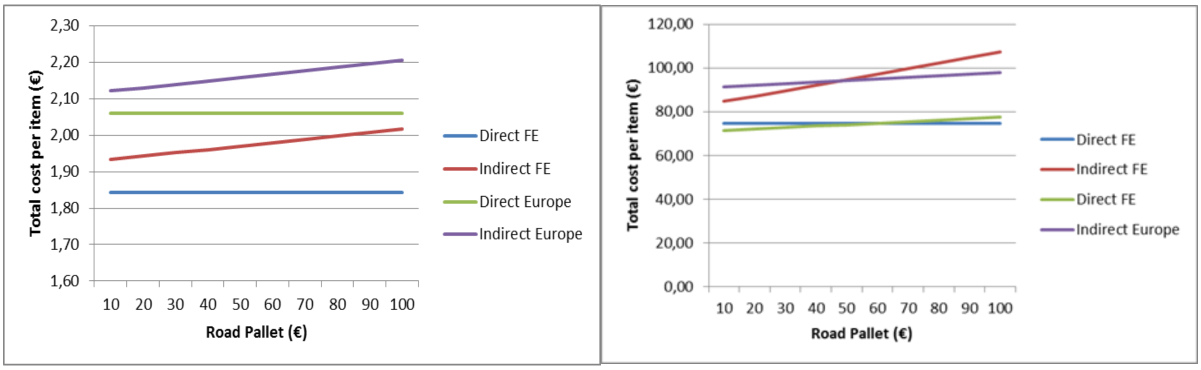

Figure 22 Sensitivity road pallet cost highlighter and chair

Currency exchange rate

The company deals with the influence of exchange rates in the sourcing dilemma since Far East vendors are paid in dollars (Figure 23). Over the last year the euro took a major drop and this leads to a less profitable situation in the case of buying in the Far East. To be more precise, this is the biggest cost hit for the company if we take a look at all factors. It is completely exposing the issue about the location of a supplier. The company should note that the exchange rates define the profit they make to a large extent.

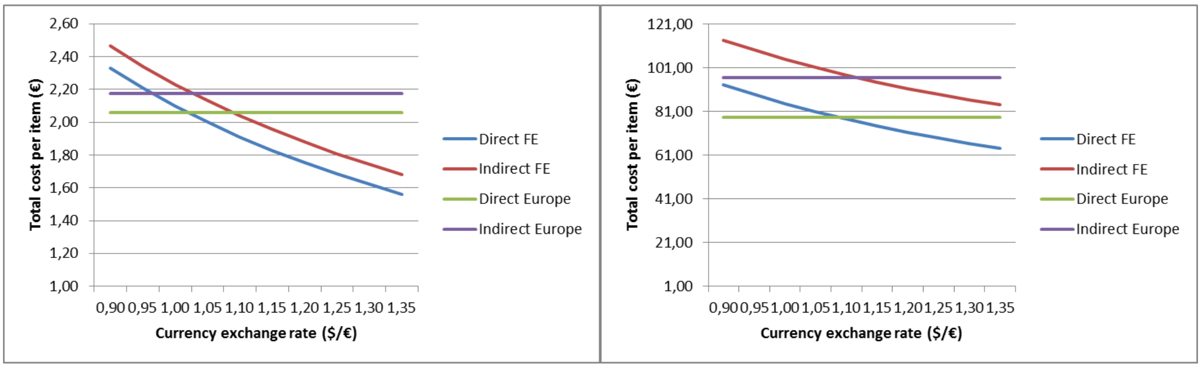

Figure 23 Sensitivity currency exchange rate highlighter and chair

Inventory levels

One of the most important tradeoffs in moving products from location A to B is the one between batch sizes and number of handlings. Each additional shipping moment requires extra money invested, but having too much inventory on hand is not more profitable. At Company X we see a lot of badly forecasted items, leading to too high levels of inventory. The graph shows the impact of additional inventory in the CDC. Note that this outcome is of less importance for the sourcing decision, but having insights is useful for operational choices related to batch sizes and order frequencies (Figure 24). Kinks that can be seen in the graph relate to additional pallets needed for storing more products as soon as a pallet is completely filled. Costs per product increase extra at those critical levels.

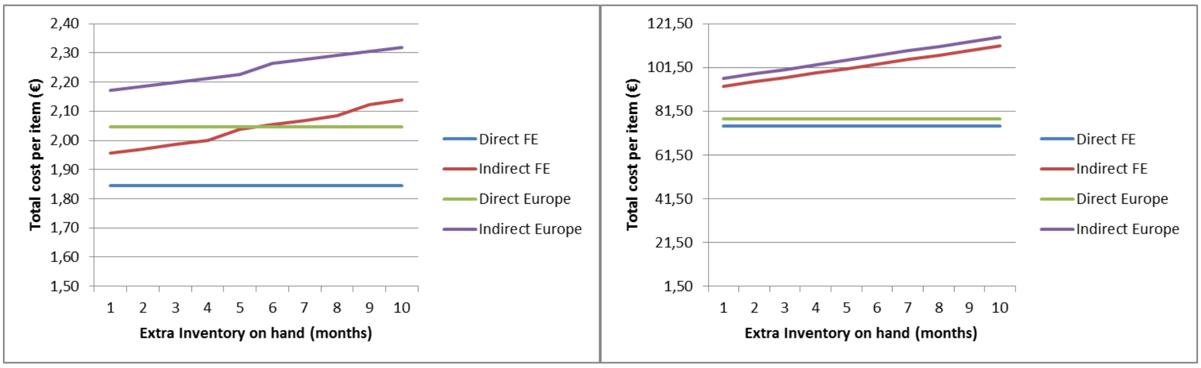

Figure 24 Sensitivity inventory highlighter and chair

Coefficient of Variance/Standard Deviation

The volatility has a large impact on the costs per product (Figure 25). It relates to the inventory levels as discussed before, but the influence here comes due to safety stock needed to cover for large variations in the demand pattern. The impact is larger for Far East vendors, since lead times are approximately twice as long as European vendors deliver ordered items. It shows the importance of good forecasts and being able to reduce variability if possible. In general, it pleads the case to order volatile products nearby and products that can be forecasted well and have a relative steady demand pattern can be sourced more easily in the Far East. Furthermore we have seen that a situation with a coefficient of variance equal to 1 is more or less comparable to the situation now for Company X, where a standard time in months of safety stock is used. Kinks can be explained in the same way as done for the extra inventory paragraph before.

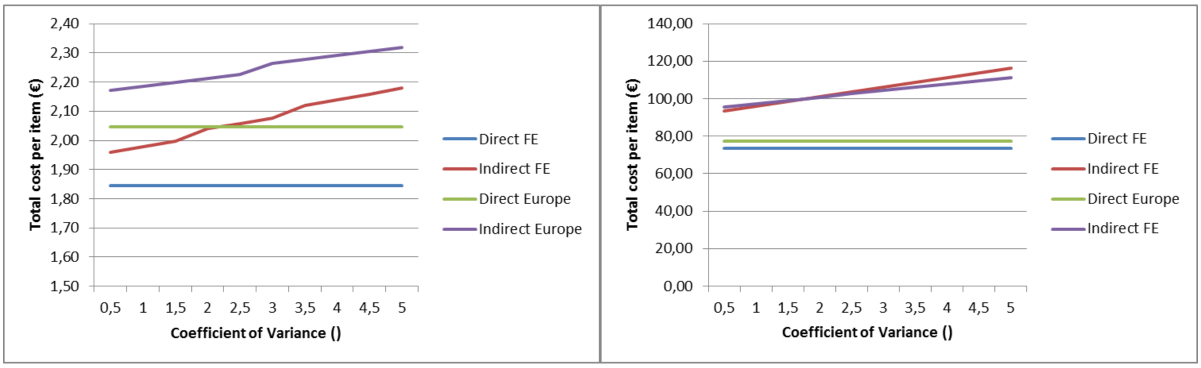

Figure 25 Sensitivity coefficient of variance highlighter and chair

Acquisition price

One of the most interesting questions in the total discussion is related to acquisition prices. Based on the cost price that a supplier sets to the company for buying a product, Company X can debate whether or not this leads to a beneficial situation for the company. Combining knowledge of all cost factors comes together in a final graph presenting if and when a given product brings profit along (Figure 26). The location of the supplier is here the subject of discussion; it does not further influence the transportation manner about direct or indirect deliveries. These graphs show a change in purchase costs at the Far East vendors. Similar graphs can be created for a change in purchase costs at a European vendor.

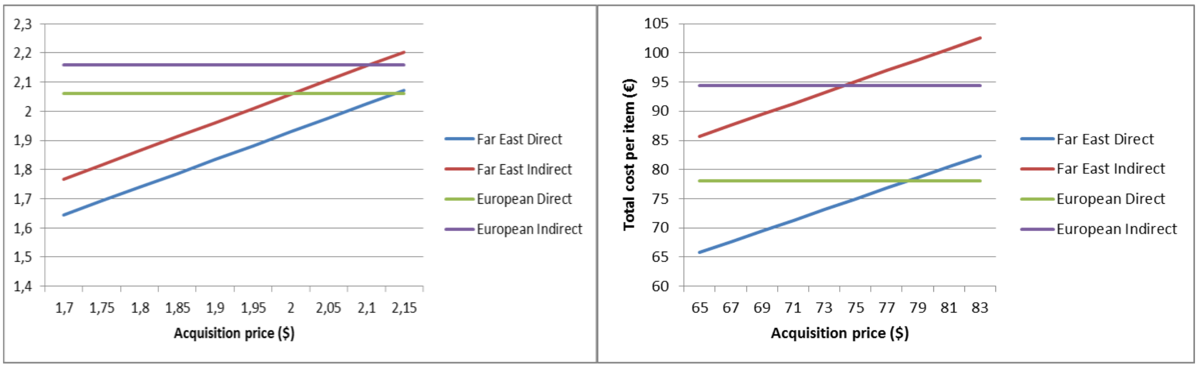

Figure 26 Sensitivity acquisition price in dollars for highlighter and chair

Discussed in this chapter are the major contributing cost factors to the total cost picture. Some factors mainly hold for the chair example, for instance indicating that products needing more space for transportation are more costly than smaller products to transship. Factors related to the acquisition price are recognizable at all products and are therefore very important to keep in mind related to the recommendations that will follow after the conclusion of this report. From managerial perspective, one wants to know how to avoid high cost if information is present about the cost factors and when they take place. This chapter roughly described the main factors having large impact on total costs, but one should keep in mind that the extent differs per specific item and a check per item is necessary to make statements about the costs related to an item and where to focus on in order to keep products profitable.

8 Conclusion

This concluding part consists of multiple sections. First, the most important findings and insights will be discussed based on the research done. Afterwards limitations are mentioned that should be kept in mind when analyzing the project as a whole and form a starting to point for further improvements. The final section provides recommendations to the company and possible future projects that help in improving the current situation for Company X.

This chapter starts with conclusions of the research study by answering the research questions that were stated in Chapter 3 of this report. The first chapters already taught us that costs are incurred at many places in the whole supply chain for the company. However at Company X it was not totally clear what cost factors were really present and how they affected the sourcing discussion. Those insights were needed in order to improve the profitability and efficiency of the business as a whole. After an explorative problem analysis and subsequent definition the following main research question was stated:

"What factors are relevant to take into account for sourcing decisions and how can they be included in a more accurate cost model?"

8.1 Research Questions

In this section we return to this question and provide answers to this main question by answering the sub questions that were stated along.

How does the actual cost structure model look like regarding supply chain costs?

In order to gain understanding which important factors play a role in the improvement of cost determinations, chapter 4 and 5 translated the qualitative situation for Company X in a quantitative model. Chapter 2 had already shown us where costs were incurred in the supply chain and afterwards was continued with the first analysis on the current situation. First results identified a lacking cost system that missed certain critical components resulting in a situation where mispriced items were present. In order to correct for these deviations, adaptions were identified to be useful in the logistics and inventory cost buckets.

What cost drivers are important to consider in analyzing costs from supplier to distribution center?

After combining scientific insights with the actual method Company X is using, we came up with the conclusion that a new model was needed in order to reflect the current situation in a more realistic way. The purchase price related costs were found to be adequately modeled and were not treated differently in the new situation. Other cost factors however did, and new cost drivers were used in order to determine the magnitudes of all costs involved. For physical transportation operations, costs are now depending on the final location of shipped goods. It was found to be insufficient to treat all destinations equally, since large cost differences appeared to be present. The influence is largest for the road transportation.

For handling operations at the CDC, a standard uplift percentage was found to be far off modeling reality in a fair way. Not taking into account product characteristics in an environment where costs are incurred based on activities that require product characteristics as input tends to lead to large deviations between determined costs and actual costs. The new model proposes a situation where those product characteristics are used for all operations, including inbound and outbound activities.
In contrast to handling operation costs that were (incorrectly) included in the current cost determination model, no inventory costs were part of the model yet. Main drivers for inventory costs are uncertainty in demand, MOQs, lead times and the correctness of forecasts. These factors differ for European and Far East vendors and are therefore relevant to include. Remember that the cost tariff determination is not a main goal but mainly an underlying explanatory phenomenon in the sourcing discussion.
In summary, the biggest change takes place in the definition of cost per item. This report has made clear that a more specific definition per warehouse is needed and that no single uplift percentage is sufficient to effectively model costs for every item.

What is the impact of different cost drivers on total costs in the supply chain?
The new model is able to come up with solutions on multiple questions. Not only does it per item tell whether it is beneficial to sell at all, it also answers this for the different warehouses. In case of a profitable item, the cheapest sourcing variant is highlighted. The model is transferred into an Excel tool which makes it possible to find answers to sourcing questions and to determine cost tariffs based on multiple input variables. This is not only useful for cost determinations but it also creates an environment where simulations can be executed and to execute what-if analysis given some changed circumstances. This was done in the sensitivity analyses in section 7.2. It taught us that some elements had more impact than others and the main contributors in variation of costs were:

- Road transportation
- Currency exchange rate
- Inventory levels
- Coefficient of Variance/Standard Deviation in demand
- Acquisition price

These cost factors were found to have a significant impact on total cost determinations. Choices relating to these factors are therefore of high importance not only on the tactical level of activities but also on the strategic level when choosing suppliers.

How should the cost drivers be included in the sourcing decisions?
All cost drivers are incorporated in the new model and corresponding tool. The tool eventually helps in the sourcing decisions by comparing the different variants and shows the differences between those variants. For a direct or indirect delivery, the best option is directly retracted from the tool that answers whether the European or Far East vendor

would be the best option. The choice about a direct or indirect delivery is somewhat more complicated since different inventory levels are in place at the local warehouses. Note that the tool at first comes with a single answer about the cost determination tariff. For many items it would however be good to evaluate this cost tariff based on varying input parameters in order to do some risk analysis. For high-risk items (large uncertainties in forecasts, demand) the initial cost tariff might be the best option, but in order to reduce risks Company X can choose to reduce this risk and source locally. This also depends on the differences present between the costs at European or Far East vendors.
Next to specific item cost determination related to sourcing decisions, some general analysis is useful for strategic sourcing decision making at Company X. By knowing what activities are most cost consuming and by knowing how to control the cost drivers causing costs Company X can ensure an efficiency improvement. Concepts related to reorder policies, MOQs, volatility and changing circumstances can all be simulated in order to know what the effect will be on costs and eventually the profit made. Furthermore insights in sophistication level are gained. Some factors have a minor influence on costs, so discussion on such items is less relevant compared to major influencers. Sometimes rough estimations ensure a sufficient level for cost determination, in other cases, the smallest deviation can have large impacts.

Overall, the report presents a complete overview of the current logistic situation for the company, with both scientific and practical components. The combination of both results in valuable insights for decision making in the company and provides a case for literature on how to translate scientific concepts into an application of literature for a company.

8.2 Limitations

During the project the costs in scope for this project are oriented up to the local warehouses. Costs at those local warehouses are the responsibility of these warehouses itself. However this can lead to sub optimization in the supply chain since batch sizes and order moments that are beneficial for the aggregated demand pattern of all warehouses may be not the ideal situation for each of the warehouses itself.

Another limitation relates to the sensitivity analysis and result section. Some first impressions were noted here based on a limited number of three examples. These items however were chosen based on different properties to have a diversified part of all items available checked against the different conditions. Although it only contains a couple of examples, all items can be calculated via the tool and therefore unlimited examples can be provided if needed. Note that the meaning of this project was to understand the current situation and gain insights related to the sourcing decisions, not a full validation for all items was needed here. Final remark is related to the reorder policies at Company X and the forecasts used in this report. In this research only simple averages are used to calculate inventory levels. It would be too complex to take all forecasts, forecasts and data errors and deviations in demand into account. By showing the impact of extra inventory, changes in demand deviations and influence of MOQ the impact of incorrect forecasts can be somewhat predicted in terms of costs, but it can never reflect reality in a perfect way. The way in which Company X determines safety stock levels and reorders is in general a limitation to which this project is adapted. Sometimes models are suited to reflect the real situation at Company X, in other situations more scientific approaches are used to optimize the situation and diminish the lacking operations at Company X on the cost cases as presented in this report. An example of this can be found in the safety stock level calculations and sensitivity analysis.

8.3 Recommendations

Based on the models, outcomes and analyses carried out in this project, some possible improvements come forward and combined with general remarks this section provides Company X with some valuable thoughts and suggestions in order to improve the current situation and what might be relevant to consider in the future.

Collaboration

One of the key factors is to have alignment within the company and create collaboration both internally as externally. Firstly the own departments (Supply chain, procurement, merchandising & sales) should make clear agreements. Examples are present where large discounts were obtained at the procurement department, without realizing that costs return as a boomerang at the supply chain department because of high MOQs coming with the low cost deal. By aligning objectives and deals, better forecasts can be made and operations run more smoothly.

Collaboration with other partners is important as well. If items change from vendor or transportation method due to the new model, it has its consequences for vendors (changed demand, consolidation and MOQs). The results should be clearly communicated with them and the future situation discussed in order to prevent for problems due to the new situation. For the 3PL the frequency of visiting warehouses might differ and the role of the CDC will be investigated even more.

Role of CDC

If the company would decide to change delivery frequencies and routes (depending on direct/indirect decisions) the role of the CDC should be evaluated. Now that a proper cost picture is in place, one can check whether all additional handlings lead to a more profitable situation than directly transporting items towards local warehouses. It is mainly a tradeoff between inventory levels and additional handling costs. In case the CDC will be visited less or more frequently, it will have its impact for other warehouses. Scenarios with regional warehouses serving as a CDC have been thought over. In these changed situations the inbound and picking volumes might change drastically and redesigns of these warehouses can be a result.

Focus on inventory levels

At the moment large differences are present with respect to inventory control for different product types. Own brand items are forecasted and ordered based on Excel schemes whereas products from OEMs are controlled via the IT tool of Prime. Not only can it be disadvantageous to have multiple inventory control in use, the way many items are handled is often inefficient and too simple given its product characteristics. The project has shown the major consequences of bad forecasting and too high inventory levels on the costs per item. Previous research carried out at the company is useful in setting up conditions and input needed for a more sophisticated inventory policy (Arts (2013); Vargas (2012)). Also the possibility of implementing the own brand items in Prime can be a large step forward.

Agreements LDC

One of the problems causing inventory levels to increase lies in the forecasts of LDCs. Forecasting is done up months upfront and this can deviate from the actual volume they need at the moment goods arrive. Warehouses are however not punished for setting too high forecasts and ordering way below the initial volumes. The consequence is that the CDC ends up with a bulk of inventory of a given item that would cover months in advance. A possible solution would be to make LDCs responsible for their forecasts and obligate them to order what they initially forecasted. In this way they feel the need of being more cautious when forecasting items and eventually inventory levels will decrease, leading to lower costs for the company as a whole.

Agreements Road transport

The new model taught us that the final miles of delivery are very cost consuming. Transporting a truck to Sweden is often way more expensive than delivering a full sea container from China to Europe. This is not directly a problem, but it exposes the need to transport the final part of the supply chain route efficiently. Ensure full trucks, combine visited locations and make for destinations that are very costly to visit agreements with local suppliers. This can make large differences in terms of costs as can be checked via the new tool.

Agreements with suppliers about currency

Over the last year, the exchange rate varied approximately 30%. This means an enormous impact on the profit margins that were in place when comparing products from the Far East and Europe. In order to prevent this, Company X can protect its business more against such threats by making agreements with suppliers. It can be the case that suppliers are willing to accept payments in euros. Other possibilities can be that prices are fixed for a larger period of time against an agreed exchange rate, or Company X investigates the possibilities of hedging.

Minimum order quantity

The recommendations to have another look at the MOQs set at the company hold for both the current and a future environment. Currently some items have a large MOQ set which obligates the company to buy items that have the result that inventory is available for the next months to years of demand. This will have its impact on costs and operations and should therefore be checked in a similar way as price discounts have to be checked. For the future situation the MOQs can have a large influence as well. In case that many items will no longer be transported via the CDC in Belgium, more items will be shipped directly. Do not underestimate the role of the CDC in breaking bulk and reducing the impact of MOQs for the company.

Future projects

This project is characterized by its broad scope. Many elements from supplier to local warehouse were incorporated to reflect the complete situation for the company. The consequence of a broad scope is then that not all activities, items and patterns can be studied in the tiniest detail. However, by having set up this project, many elements can be taken out for further research and coming up with more detailed results and conclusions. This project can be used as a hallstand where all the separate elements can be stacked together.

As mentioned as a limitation, costs at LDCs were out of scope for this project. To make the puzzle complete, extra information about handling orders and inventory levels at LDCs are useful pieces to gather. By doing so, a further step in the direction of optimizing the complete chain is set.

Another recommendation of a future project would be to check the possibilities of changing a vendor. At the moment, a vendor is chosen upfront for items and afterwards the situation is assumed to be fixed. However circumstances change and it might become beneficial to transfer the location of a vendor from far away to nearby, or the other way around. A more dynamic check on vendors can be created and more profit can be made in case the company is faster able to adapt to changed conditions.

“Everything should be made as simple as possible, but not simpler”

Einstein

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Appendix A

This appendix provides an overview of all local warehouses for Company X in Europe. The port of arrival is reflected, which is necessary input or determining both sea transport costs and road transport costs afterwards. Sea freight charges are shown in this table as well (Table 14)

	LDC	Country	Harbor	Sea freight charges and administration
1	Leicester	UK	Felixstowe	€1800
2	Ashton Moss	UK	Felixstowe	€1800
3	Dublin	Ireland	Dublin	€1950
4	Northampton	UK	Felixstowe	€1800
5	Meung-sur-Loire	France	Le Havre	€1800
6	St-Martin de Crau	France	Fos sur Mère	€2800
7	Survilliers	France	Le Havre	€1800
8	Senlis	France	Le Havre	€1700
9	Grossostheim	Germany	Antwerp	€1800
10	Lanken	Germany	Hamburg	€1800
11	Lenzburg	Switzerland	Antwerp	€1800
12	Zwolle	Netherlands	Antwerp	€1800
13	Siziano	Italy	Genova	€2800
14	Madrid	Spain	Valencia	€2800
15	Hostivice	Czech Republic	Bremerhaven	€1800
16	Strängnäs	Sweden	Stockholm	€1900

Table 14 Distribution Centers Europe (Kuehne and Nagel, December 2014)

Appendix B

This appendix shows road transport costs (Table 15). Note that for the direct transport, costs are per container, since the complete container is loaded on a truck and directly expedited to the warehouse of destination. For the indirect transport costs, extra information is needed. Costs depend on volume shipped from CDC to local warehouse and based on this volume (i.e. number of pallets) exact cost calculations can be done. These average number of pallets can be found in Appendix F.

LDC	Port	Direct Transport Costs (per container)	Indirect Transport Costs from CDC to LDC (per pallet)
Leicester	Felixstowe	€ 800	€51
Ashton Moss	Felixstowe	€ 870	€54
Dublin	Dublin	€ 425	€51
Northampton	Felixstowe	€ 928	€94
Meung-sur-Loire	Le Havre	€ 900	€27
St-Martin de Crau	Fos sur Mère	€ 565	€51
Survilliers	Le Havre	€ 750	€21
Senlis	Le Havre	€ 750	€22
Grossostheim	Antwerp	€ 1290	€23
Lanken	Hamburg	€ 495	€35
Lenzburg	Antwerp	€ 1600	€52
Zwolle	Antwerp	€ 605	€11
Siziano	Genova	€ 700	€41
Madrid	Valencia	€ 915	€58
Hostivice	Bremerhaven	€ 900	€34
Strängnäs	Stockholm	€50	€68
CDC Eindhout	Antwerp	€525	-

Table 15 Road transport LDC (Company X Supply Chain Europe, 2015)

Appendix C

This appendix provides insights about how orders are created and which activities are needed to do so (Figure 27).

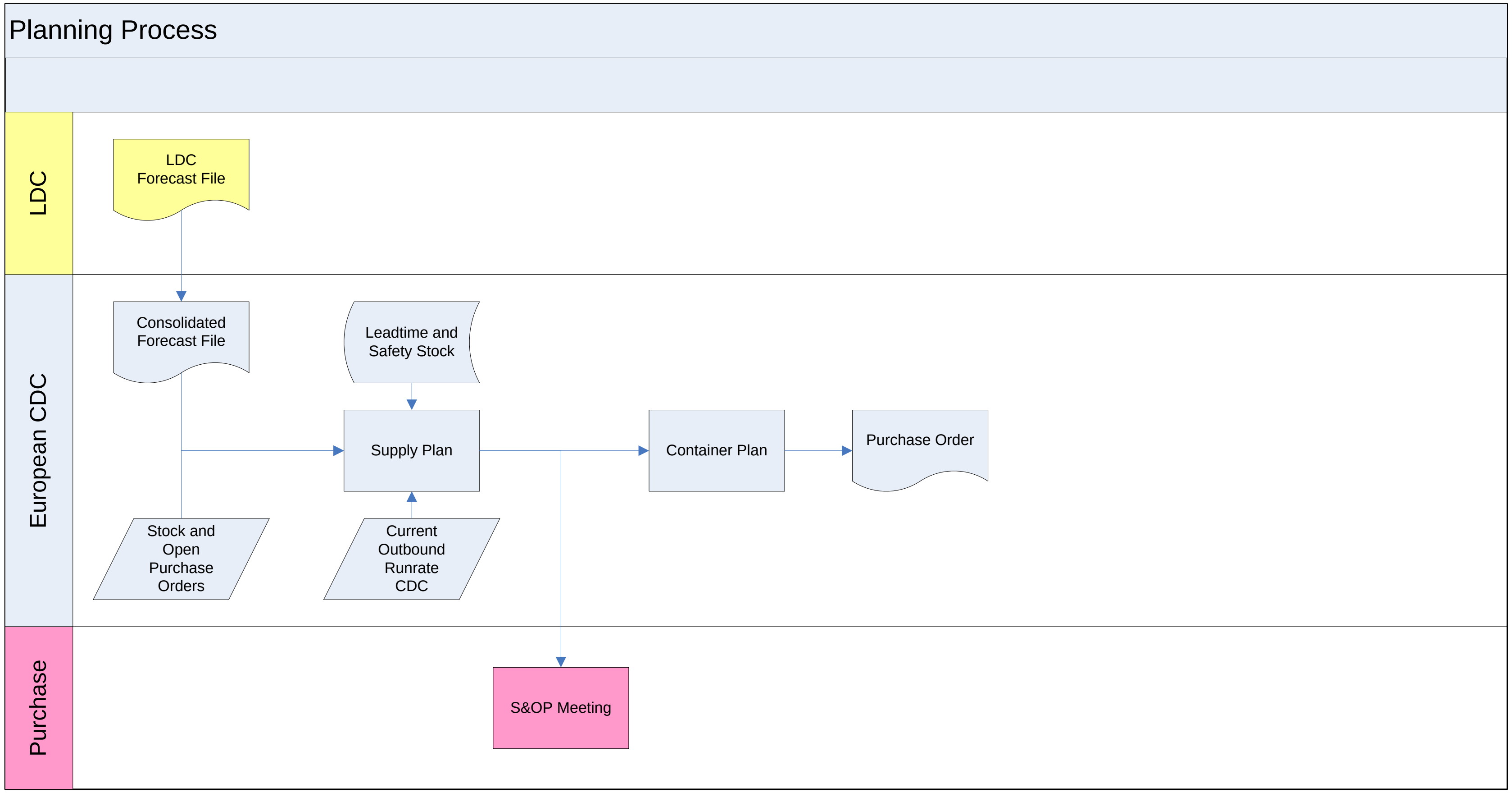

Figure 27 Planning Process

Appendix D

This appendix reflects the approach followed in order to ensure that an order is placed at both the vendor and 3PL for direct shipments (Figure 28) and indirect shipments (Figure 29)

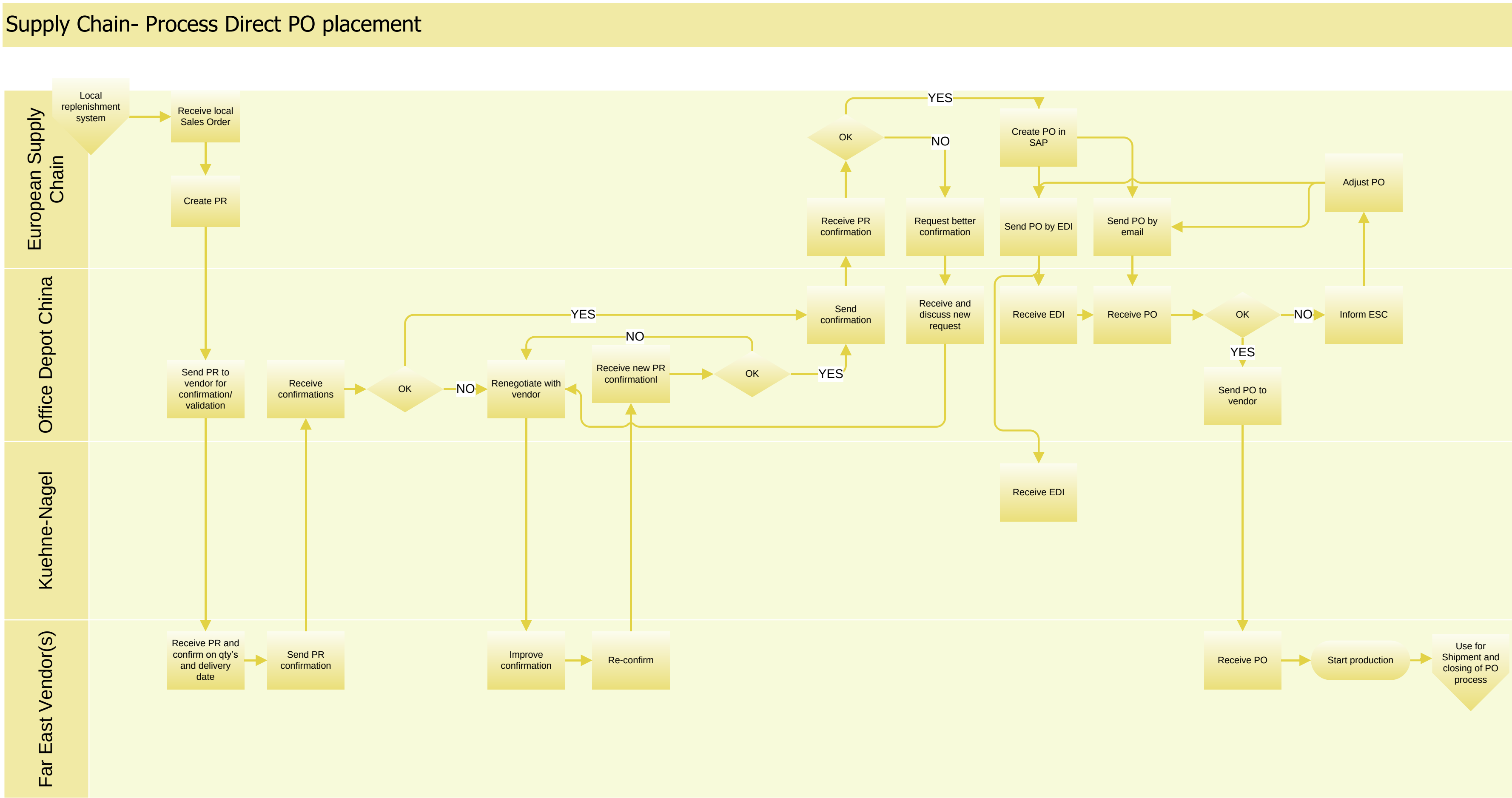

Figure 28 Supply Chain- Process Direct PO placement

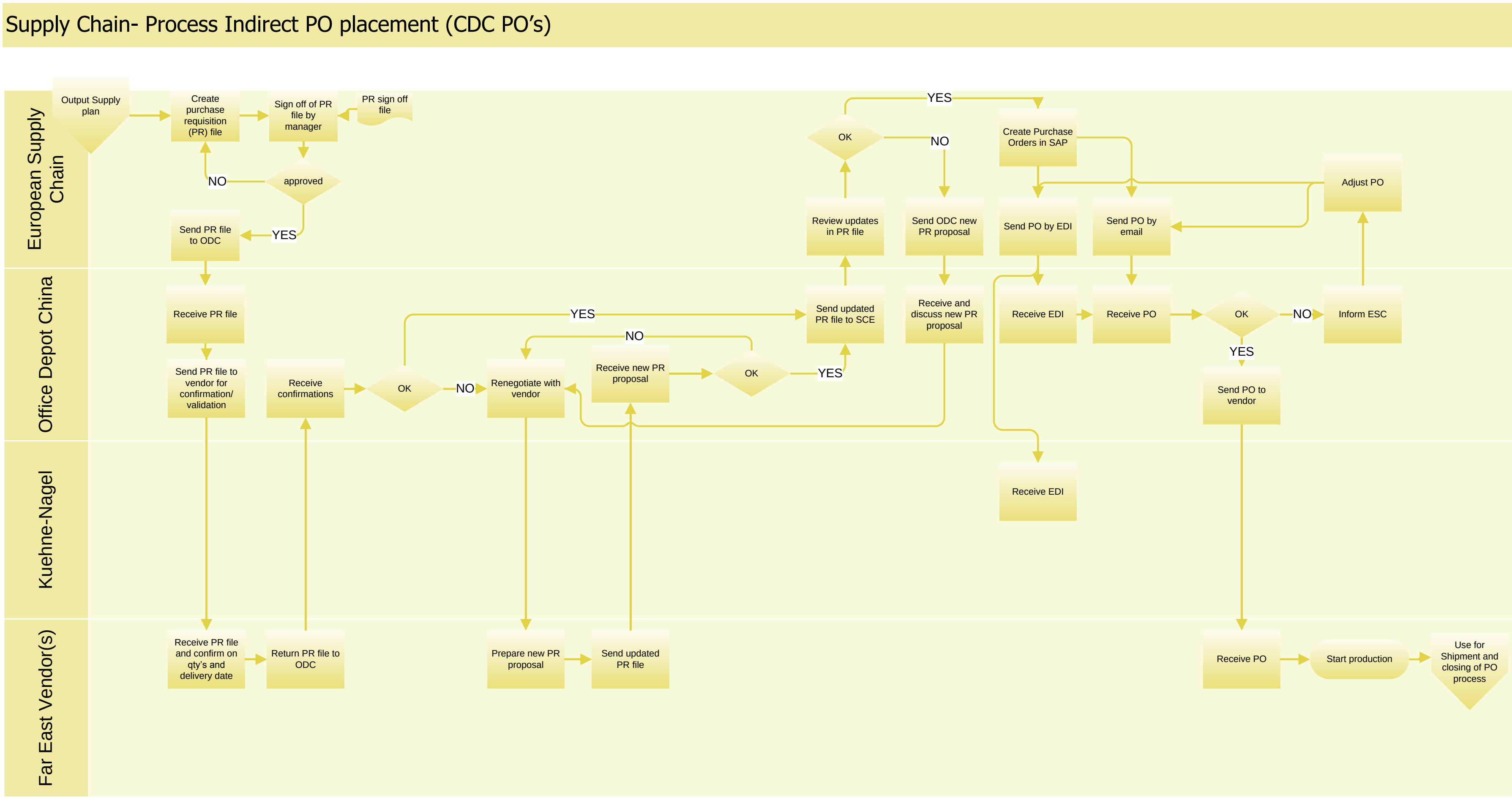

Figure 29 Supply Chain- Process Indirect PO placement

Appendix E

The average number of pallets per week is shown here. This information is needed for calculation of costs per pallet for the indirect shipping method (Table 16)

LDC	#Pallets/week
Senlis	167
Zwolle	78
Strängnäs	36
Leicester	16
Ashton	15
Northampton	3
St-Martin-de-Crau	41
Survilliers	30
Meung-sur-Loire	64
Großostheim	39
Lanken	15
Lenzburg	13
Siziano	28
Madrid	41
Hostivice	30

Table 16 Average pallets shipped per week from CDC to LDC

Appendix F

In order to come up with an inventory model, the following assumptions are made in order to justify formulas and simplify the real situation.

Assumptions inventory model

1. Demand for consecutive periods and demand for different locations and products are stochastic and independent.
2. Average demand is equal for each month of the year, no distinctions are observed.
3. All demand that cannot be satisfied directly from stock is backordered.
4. Suppliers always deliver orders immediately after production and production time is never exceeded.
5. Demand is stationary on the daily level per month.
6. There are no constraints regarding storage capacities.
7. Transshipments between local stock points are not allowed.
8. All lead times are constant and deterministic. Therefore they have no influence on inventory levels via extra safety stock.
9. Products are non-perishable.
10. Product values are constant.

Appendix G

For all examples, costs are translated in percentages to find out which cost component contributes most to total costs for the Far East vendor (Table 17) and European vendor (Table 18).

Cost	Highlighter		Chair		Hole Puncher	
	Direct	*Indirect*	*Direct*	*Indirect*	*Direct*	*Indirect*
Acquisition	96%	90%	89%	70%	95%	91%
Sea Transport	1%	1%	6%	5%	2%	1%
Road Transport	0%	3%	3%	15%	1%	2%
Inbound	0%	1%	0%	1%	0%	0%
Outbound	0%	0%	0%	2%	0%	1%
Storage	0%	1%	0%	4%	0%	1%
Inventory carrying	2%	3%	2%	3%	2%	3%
Obsolescence	1%	1%	1%	1%	1%	1%
Total	100%	100%	100%	100%	100%	100%

Table 17 Cost buckets in percentages per example Far East vendor

Cost	Highlighter		Chair		Hole Puncher	
	Direct	*Indirect*	*Direct*	*Indirect*	*Direct*	*Indirect*
Acquisition	98%	92%	98%	78%	98%	94%
Road Transport	0%	2%	0%	13%	0%	2%
Inbound	0%	1%	0%	1%	0%	0%
Outbound	0%	0%	0%	2%	0%	1%
Storage	0%	1%	0%	3%	0%	1%
Inventory carrying	1%	2%	1%	2%	1%	2%
Obsolescence	1%	1%	1%	1%	1%	1%
Total	100%	100%	100%	100%	100%	100%

Table 18 Cost buckets in percentages per example European vendor

Appendix H

Per analyzed cost component, sensitivity analysis outcomes are shown. The left column denotes the variation of input parameter, whereas other columns reflect the outcome variables for Far East and Europe. The graph pictures the visual example for the hole puncher. Graphs containing information about the highlighter and chair can already be found in the main text in 7.2.

Road Transportation

	Highlighter		Chair		Hole Puncher	
RP	Direct FE	Indirect FE	Direct FE	Indirect FE	Direct FE	Indirect FE
10	1,84	1,93	74,84	84,68	13,06	13,50
20	1,84	1,94	74,84	87,18	13,06	13,55
30	1,84	1,95	74,84	89,68	13,06	13,60
40	1,84	1,96	74,84	92,18	13,06	13,64
50	1,84	1,97	74,84	94,68	13,06	13,69
60	1,84	1,98	74,84	97,18	13,06	13,74
70	1,84	1,99	74,84	99,68	13,06	13,78
80	1,84	2,00	74,84	102,18	13,06	13,83
90	1,84	2,01	74,84	104,68	13,06	13,88
100	1,84	2,02	74,84	107,18	13,06	13,92

Table 19 Road Transportation sensitivity analysis Far East

	Highlighter		Chair		Hole Puncher	
RP	Direct Europe	Indirect Europe	Direct Europe	Indirect Europe	Direct Europe	Indirect Europe
10	2,06	2,12	78,09	84,08	14,51	14,73
20	2,06	2,13	78,09	86,58	14,51	14,78
30	2,06	2,14	78,09	89,08	14,51	14,82
40	2,06	2,15	78,09	91,58	14,51	14,87
50	2,06	2,16	78,09	94,08	14,51	14,92
60	2,06	2,17	78,09	96,58	14,51	14,96
70	2,06	2,18	78,09	99,08	14,51	15,01
80	2,06	2,19	78,09	101,58	14,51	15,05
90	2,06	2,19	78,09	104,08	14,51	15,10
100	2,06	2,20	78,09	106,58	14,51	15,15

Table 20 Road Transportation sensitivity analysis Europe

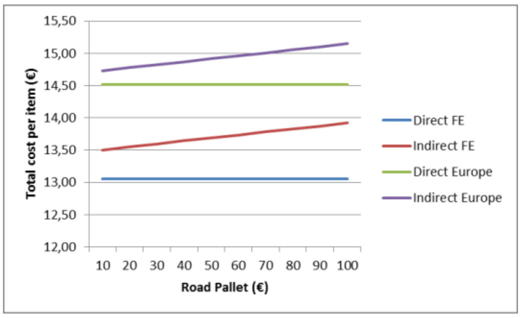

Figure 30 Road transportation sensitivity analysis hole puncher

Currency exchange rate

Cur	Direct FE	Indirect FE	Direct FE	Indirect FE	Direct FE	Indirect FE
0,90	2,33	2,46	93,13	113,58	16,46	17,16
0,95	2,21	2,34	88,56	108,92	15,61	16,30
1,00	2,10	2,23	84,44	104,72	14,84	15,52
1,05	2,00	2,13	80,72	100,92	14,15	14,81
1,10	1,91	2,04	77,33	97,47	13,52	14,17
1,15	1,83	1,95	74,24	94,32	12,95	13,58
1,20	1,75	1,88	71,41	91,43	12,42	13,04
1,25	1,68	1,81	68,80	88,77	11,93	12,55
1,30	1,62	1,74	66,39	86,32	11,49	12,09
1,35	1,56	1,68	64,16	84,04	11,07	11,67

Table 21 Currency exchange rate sensitivity analysis Far East

	Highlighter		**Chair**		**Hole Puncher**	
Cur	Direct Europe	Indirect Europe	Direct Europe	Indirect Europe	Direct Europe	Indirect Europe
0,90	2,06	2,17	78,09	96,40	14,51	15,06
0,95	2,06	2,17	78,09	96,40	14,51	15,06
1,00	2,06	2,17	78,09	96,40	14,51	15,06
1,05	2,06	2,17	78,09	96,40	14,51	15,06
1,10	2,06	2,17	78,09	96,40	14,51	15,06
1,15	2,06	2,17	78,09	96,40	14,51	15,06
1,20	2,06	2,17	78,09	96,40	14,51	15,06
1,25	2,06	2,17	78,09	96,40	14,51	15,06
1,30	2,06	2,17	78,09	96,40	14,51	15,06
1,35	2,06	2,17	78,09	96,40	14,51	15,06

Table 22 Currency exchange rate sensitivity analysis Europe

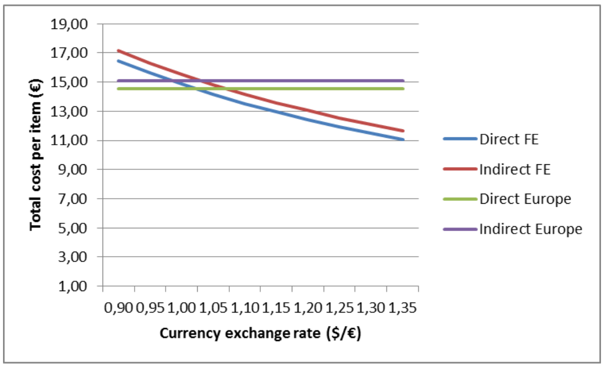

Figure 31 Currency exchange rate sensitivity analysis hole puncher

Inventory levels

	Highlighter		Chair		Hole Puncher	
ST	Direct FE	Indirect FE	Direct FE	Indirect FE	Direct FE	Indirect FE
1	1,84	1,96	74,84	92,92	13,06	13,56
2	1,84	1,97	74,84	94,93	13,06	13,69
3	1,84	1,99	74,84	96,96	13,06	13,83
4	1,84	2,00	74,84	98,97	13,06	13,96
5	1,84	2,04	74,84	101,02	13,06	14,06
6	1,84	2,05	74,84	103,04	13,06	14,20
7	1,84	2,07	74,84	105,09	13,06	14,33
8	1,84	2,08	74,84	107,12	13,06	14,47
9	1,84	2,12	74,84	109,18	13,06	14,60
10	1,84	2,14	74,84	111,25	13,06	14,74

Table 23 Inventory levels sensitivity analysis Far East

	Highlighter		Chair		Hole Puncher	
ST	Direct Europe	Indirect Europe	Direct Europe	Indirect Europe	Direct Europe	Indirect Europe
1	2,06	2,17	78,09	96,40	14,51	15,06
2	2,06	2,19	78,09	98,51	14,51	15,21
3	2,06	2,21	78,09	100,59	14,51	15,32
4	2,06	2,22	78,09	102,70	14,51	15,47
5	2,06	2,27	78,09	104,82	14,51	15,62
6	2,06	2,28	78,09	106,92	14,51	15,76
7	2,06	2,30	78,09	109,05	14,51	15,91
8	2,06	2,32	78,09	111,16	14,51	16,06
9	2,06	2,36	78,09	113,29	14,51	16,21
10	2,06	2,38	78,09	115,41	14,51	16,37

Table 24 Inventory levels sensitivity analysis Europe

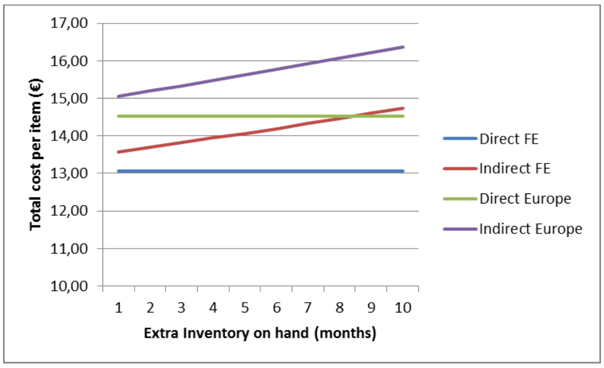

Figure 32 Inventory levels sensitivity analysis hole puncher

Coefficient of Variance

CV	Direct FE	Indirect FE	Direct FE	Indirect FE	Direct FE	Indirect FE
0,5	1,84	1,96	73,61	93,44	12,83	13,59
1	1,84	1,98	73,61	95,97	12,83	13,75
1,5	1,84	2,00	73,61	98,51	12,83	13,90
2	1,84	2,04	73,61	101,06	12,83	14,09
2,5	1,84	2,06	73,61	103,63	12,83	14,25
3	1,84	2,08	73,61	106,19	12,83	14,42
3,5	1,84	2,12	73,61	108,76	12,83	14,58
4	1,84	2,14	73,61	111,33	12,83	14,74
4,5	1,84	2,16	73,61	113,93	12,83	14,91
5	1,84	2,18	73,61	116,52	12,83	15,08

Table 25 Coefficient of variance sensitivity analysis Far East

CV	Direct Europe	Indirect Europe	Direct Europe	Indirect Europe	Direct Europe	Indirect Europe
0,5	2,05	2,17	77,55	95,68	14,41	15,01
1	2,05	2,19	77,55	97,39	14,41	15,14
1,5	2,05	2,20	77,55	99,10	14,41	15,26
2	2,05	2,21	77,55	100,85	14,41	15,36
2,5	2,05	2,23	77,55	102,57	14,41	15,48
3	2,05	2,26	77,55	104,29	14,41	15,61
3,5	2,05	2,28	77,55	106,05	14,41	15,74
4	2,05	2,29	77,55	107,78	14,41	15,83
4,5	2,05	2,31	77,55	109,51	14,41	15,96
5	2,05	2,32	77,55	111,27	14,41	16,09

Table 26 Coefficient of variance sensitivity analysis Europe

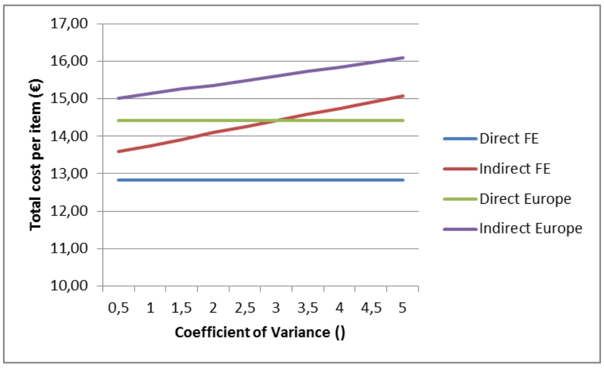

Figure 33 Coefficient of variance sensitivity analysis hole puncher

Acquisition price

	Highlighter	
A	Direct FE	Indirect FE
1,70	1,64	1,77
1,75	1,69	1,82
1,80	1,74	1,86
1,85	1,79	1,91
1,90	1,83	1,96
1,95	1,88	2,01
2,00	1,93	2,06
2,05	1,98	2,11
2,10	2,02	2,15
2,15	2,07	2,20

Table 27 Acquisition price sensitivity analysis Far East highlighter

	Chair	
A	Direct FE	Indirect FE
65	65,81	85,72
67	67,64	87,59
69	69,47	89,46
71	71,31	91,33
73	73,14	93,20
75	74,97	95,07
77	76,81	96,93
79	78,64	98,80
81	80,47	100,67
83	82,31	102,54

Table 28 Acquisition price sensitivity analysis Far East chair

	Hole Puncher	
A	Direct FE	Indirect FE
11,50	11,07	11,67
12,00	11,54	12,15
12,50	12,01	12,63
13,00	12,48	13,10
13,50	12,94	13,58
14,00	13,41	14,06
14,50	13,88	14,53
15,00	14,35	15,01
15,50	14,82	15,49
16,00	15,29	15,97

Table 29 Acquisition price sensitivity analysis Far East hole puncher

	Highlighter	
A	Direct Europe	Indirect Europe
1,70	2,06	2,16
1,75	2,06	2,16
1,80	2,06	2,16
1,85	2,06	2,16
1,90	2,06	2,16
1,95	2,06	2,16
2,00	2,06	2,16
2,05	2,06	2,16
2,10	2,06	2,16
2,15	2,06	2,16

Table 30 Acquisition price sensitivity analysis Europe highlighter

	Chair	
A	Direct Europe	Indirect Europe
65	78,09	94,33
67	78,09	94,33
69	78,09	94,33
71	78,09	94,33
73	78,09	94,33
75	78,09	94,33
77	78,09	94,33
79	78,09	94,33
81	78,09	94,33
83	78,09	94,33

Table 31 Acquisition price sensitivity analysis Europe chair

	Hole Puncher	
A	Direct Europe	Indirect Europe
11,50	14,51	14,92
12,00	14,51	14,92
12,50	14,51	14,92
13,00	14,51	14,92
13,50	14,51	14,92
14,00	14,51	14,92
14,50	14,51	14,92
15,00	14,51	14,92
15,50	14,51	14,92
16,00	14,51	14,92

Table 32 Acquisition price sensitivity analysis Europe hole puncher

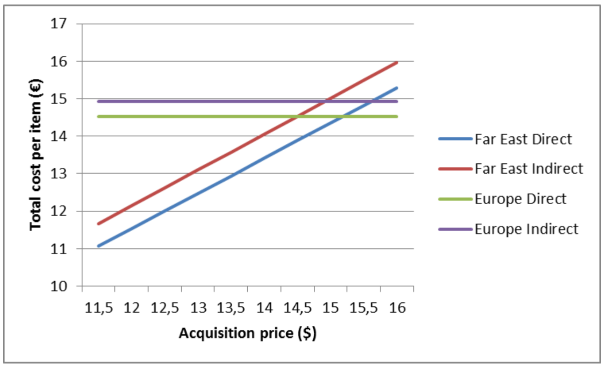

Figure 34 Acquisition price sensitivity analysis hole puncher

Appendix I

This appendix has the same set up as the previous appendix. This one however contains cost buckets that were found less relevant and are therefore not extensively discussed in the main text. Also no graphs are provided

Far East

	Highlighter		Chair		Hole Puncher	
S	Direct FE	Indirect FE	Direct FE	Indirect FE	Direct FE	Indirect FE
300	1,83	1,95	71,24	91,33	12,89	13,53
600	1,83	1,96	71,96	92,05	12,93	13,56
900	1,83	1,96	72,68	92,77	12,96	13,60
1200	1,84	1,96	73,40	93,49	12,99	13,63
1500	1,84	1,97	74,12	94,21	13,02	13,66
1800	1,84	1,97	74,84	94,93	13,06	13,69
2100	1,85	1,97	75,55	95,64	13,09	13,73
2400	1,85	1,98	76,27	96,36	13,12	13,76
2700	1,85	1,98	76,99	97,08	13,16	13,79
3000	1,86	1,98	77,71	97,80	13,19	13,83

Table 33 Sea freight charges sensitivity analysis Far East

	Highlighter		Chair		Hole Puncher	
R^1	Direct FE	Indirect FE	Direct FE	Indirect FE	Direct FE	Indirect FE
400	1,84	1,97	73,88	94,93	13,01	13,69
500	1,84	1,97	74,12	94,93	13,02	13,69
600	1,84	1,97	74,36	94,93	13,04	13,69
700	1,84	1,97	74,60	94,93	13,05	13,69
800	1,84	1,97	74,84	94,93	13,06	13,69
900	1,85	1,97	75,08	94,93	13,07	13,69
1000	1,85	1,97	75,32	94,93	13,08	13,69
1100	1,85	1,97	75,55	94,93	13,09	13,69
1200	1,85	1,97	75,79	94,93	13,10	13,69
1300	1,85	1,97	76,03	94,93	13,11	13,69

Table 34 Direct road transport sensitivity analysis Far East

	Highlighter		Chair		Hole Puncher	
R^{cdc}	Direct FE	Indirect FE	Direct FE	Indirect FE	Direct FE	Indirect FE
200	1,84	1,97	74,84	94,15	13,06	13,66
250	1,84	1,97	74,84	94,27	13,06	13,66
300	1,84	1,97	74,84	94,39	13,06	13,67
350	1,84	1,97	74,84	94,51	13,06	13,68
400	1,84	1,97	74,84	94,63	13,06	13,68
450	1,84	1,97	74,84	94,75	13,06	13,69
500	1,84	1,97	74,84	94,87	13,06	13,69
550	1,84	1,97	74,84	94,99	13,06	13,70
600	1,84	1,97	74,84	95,11	13,06	13,70
650	1,84	1,97	74,84	95,22	13,06	13,71

Table 35 Indirect road transport to CDC sensitivity analysis Far East

	Highlighter		Chair		Hole Puncher	
IO	Direct FE	Indirect FE	Direct FE	Indirect FE	Direct FE	Indirect FE
0,05	1,83	1,94	74,23	93,66	12,94	13,46
0,07	1,83	1,95	74,48	94,17	12,99	13,55
0,09	1,84	1,96	74,72	94,67	13,03	13,65
0,11	1,85	1,98	74,95	95,17	13,08	13,74
0,13	1,85	1,99	75,19	95,67	13,12	13,83
0,15	1,86	2,00	75,42	96,16	13,17	13,92
0,17	1,87	2,02	75,64	96,64	13,21	14,01
0,19	1,87	2,03	75,87	97,12	13,25	14,10
0,21	1,88	2,04	76,09	97,60	13,29	14,19
0,23	1,88	2,05	76,31	98,07	13,33	14,28

Table 36 Inventory opportunity sensitivity analysis Far East

	Highlighter		Chair		Hole Puncher	
LT	Direct FE	Indirect FE	Direct FE	Indirect FE	Direct FE	Indirect FE
30	1,83	1,95	74,13	94,21	12,93	13,56
35	1,83	1,95	74,22	94,30	12,94	13,58
40	1,83	1,96	74,31	94,38	12,96	13,59
45	1,83	1,96	74,39	94,47	12,97	13,61
50	1,83	1,96	74,48	94,56	12,99	13,63
55	1,84	1,96	74,57	94,65	13,01	13,64
60	1,84	1,97	74,66	94,74	13,02	13,66
65	1,84	1,97	74,75	94,84	13,04	13,68
70	1,84	1,97	74,84	94,93	13,06	13,69
75	1,85	1,97	74,92	95,02	13,07	13,71

Table 37 Lead time sensitivity analysis Far East

	Highlighter		Chair		Hole Puncher	
R	Direct FE	Indirect FE	Direct FE	Indirect FE	Direct FE	Indirect FE
5	1,84	1,96	74,84	94,08	13,06	13,62
10	1,84	1,97	74,84	94,26	13,06	13,63
15	1,84	1,97	74,84	94,43	13,06	13,67
20	1,84	1,97	74,84	94,60	13,06	13,68
25	1,84	1,97	74,84	94,78	13,06	13,69
30	1,84	1,97	74,84	94,93	13,06	13,69
35	1,84	1,97	74,84	95,10	13,06	13,70
40	1,84	1,97	74,84	95,27	13,06	13,71
45	1,84	1,97	74,84	95,45	13,06	13,72
50	1,84	1,98	74,84	95,59	13,06	13,73

Table 38 Review time sensitivity analysis Far East

SL	**Direct FE**	**Indirect FE**	**Direct FE**	**Indirect FE**	**Direct FE**	**Indirect FE**
0,9	1,84	1,97	73,61	94,85	12,83	13,69
0,91	1,84	1,97	73,61	95,03	12,83	13,70
0,92	1,84	1,97	73,61	95,24	12,83	13,71
0,93	1,84	1,97	73,61	95,45	12,83	13,72
0,94	1,84	1,98	73,61	95,69	12,83	13,73
0,95	1,84	1,98	73,61	95,97	12,83	13,75
0,96	1,84	1,98	73,61	96,29	12,83	13,76
0,97	1,84	1,98	73,61	96,71	12,83	13,81
0,98	1,84	1,99	73,61	97,24	12,83	13,84
0,99	1,84	1,99	73,61	98,09	12,83	13,88

Table 39 Service level sensitivity analysis Far East

Europe

	Highlighter		Chair		Hole Puncher	
IO	Direct Europe	Indirect Europe	Direct Europe	Indirect Europe	Direct Europe	Indirect Europe
0,05	2,05	2,15	77,79	93,96	14,46	14,85
0,07	2,06	2,15	77,91	94,11	14,48	14,88
0,09	2,06	2,16	78,03	94,26	14,50	14,91
0,11	2,06	2,16	78,14	94,40	14,53	14,93
0,13	2,06	2,16	78,26	94,54	14,55	14,96
0,15	2,07	2,17	78,37	94,68	14,57	14,99
0,17	2,07	2,17	78,48	94,82	14,59	15,01
0,19	2,07	2,18	78,59	94,96	14,61	15,04
0,21	2,08	2,18	78,70	95,09	14,63	15,06
0,23	2,08	2,18	78,80	95,22	14,65	15,09

Table 40 Inventory opportunity sensitivity analysis Europe

	Highlighter		Chair		Hole Puncher	
LT	Direct Europe	Indirect Europe	Direct Europe	Indirect Europe	Direct Europe	Indirect Europe
30	2,06	2,16	78,09	94,33	14,51	14,92
35	2,06	2,16	78,19	94,43	14,53	14,94
40	2,07	2,16	78,29	94,53	14,55	14,96
45	2,07	2,17	78,39	94,63	14,57	14,98
50	2,07	2,17	78,49	94,74	14,59	15,00
55	2,07	2,17	78,59	94,84	14,61	15,01
60	2,08	2,17	78,70	94,94	14,63	15,03
65	2,08	2,18	78,80	95,04	14,65	15,05
70	2,08	2,18	78,90	95,14	14,67	15,07
75	2,08	2,18	79,00	95,25	14,68	15,09

Table 41 Lead time sensitivity analysis Europe

	Highlighter		Chair		Hole Puncher	
R	Direct Europe	Indirect Europe	Direct Europe	Indirect Europe	Direct Europe	Indirect Europe
5	2,06	2,16	78,09	93,97	14,51	14,90
10	2,06	2,16	78,09	94,15	14,51	14,91
15	2,06	2,16	78,09	94,33	14,51	14,92
20	2,06	2,16	78,09	94,51	14,51	14,93
25	2,06	2,16	78,09	94,66	14,51	14,94
30	2,06	2,16	78,09	94,84	14,51	14,95
35	2,06	2,16	78,09	95,02	14,51	14,96
40	2,06	2,17	78,09	95,20	14,51	14,97
45	2,06	2,17	78,09	95,38	14,51	14,98
50	2,06	2,17	78,09	95,53	14,51	14,99

Table 42 Review time sensitivity analysis Europe

SL	Direct FE	Indirect FE	Direct FE	Indirect FE	Direct FE	Indirect FE
0,9	2,05	2,18	77,55	96,63	14,41	15,10
0,91	2,05	2,18	77,55	96,77	14,41	15,10
0,92	2,05	2,18	77,55	96,88	14,41	15,11
0,93	2,05	2,18	77,55	97,03	14,41	15,12
0,94	2,05	2,18	77,55	97,21	14,41	15,13
0,95	2,05	2,19	77,55	97,39	14,41	15,14
0,96	2,05	2,19	77,55	97,61	14,41	15,15
0,97	2,05	2,19	77,55	97,89	14,41	15,16
0,98	2,05	2,19	77,55	98,26	14,41	15,18
0,99	2,05	2,20	77,55	98,81	14,41	15,25

Table 43 Service level sensitivity analysis Europe

Appendix J

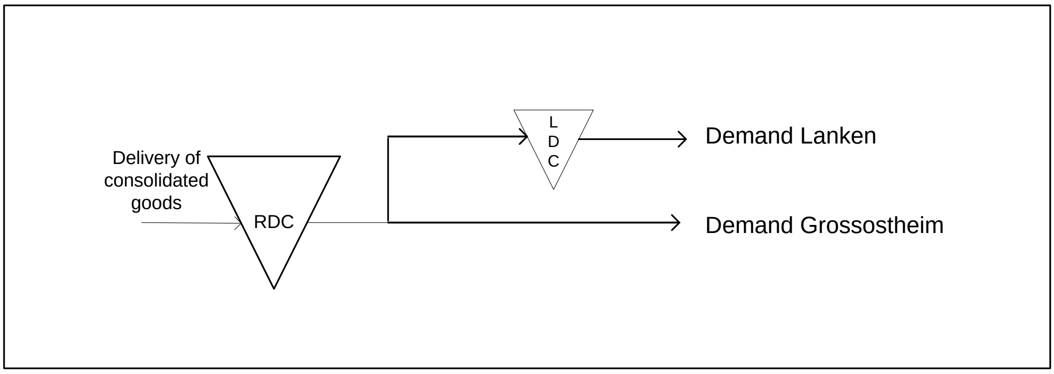

Figure 35 Shipping via RDC (Grossostheim)

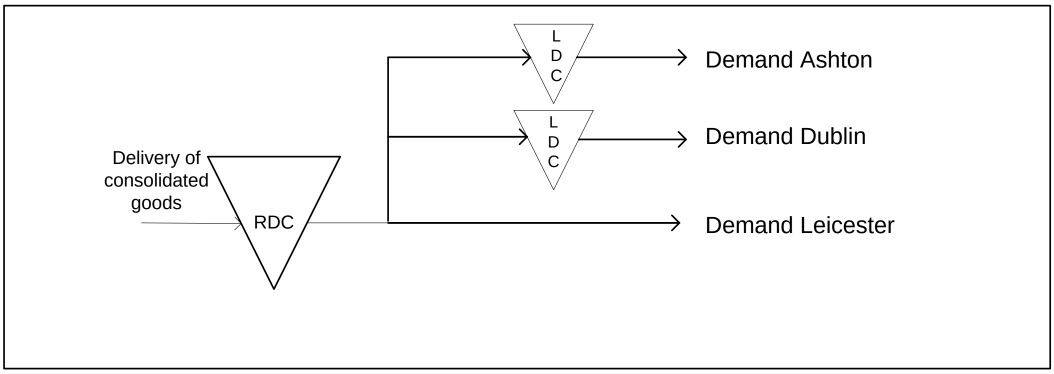

Figure 36 Shipping via RDC (Leicester)