Re-design of the distribution network of Skil Europe B.V.

An analysis of the design of the physical distribution network using a generic framework towards a network with lower supply chain costs

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Preface

'A great opportunity and ultimate chance' were my first thoughts when I received the message that I could apply for a Master of Science program on a technical university. This master thesis is the final course of the master of science program Transport, Infrastructure and Logistics.

It was also the hardest course for me to pass. My family and friends know, from earlier experiences, that it takes me a lot of effort to bring a thesis to a final end. Many times they have asked me "When are you ready" and every time I had to postpone the approximated period. And yes, this time again it took me a lot of effort, time and thoughts to bring this thesis to a good end.

This period was hard and not in the last place for my wife. Despite my changes in state of mind, now and then, she always was positive and kept me pushing which I am grateful of.

'Thanks for your continued support, Anouk.'

I want to thank Skil Europe B.V. for the opportunity they gave me to execute my research at their company and in particular the colleagues of the logistic department for the nice time and pleasant days I had at Skil. A special thank to Rik Visscher who introduces me too Skil and guide me through the company and first phase of my research and Marijn van der Hoofden to continue the guidance of the research at Skil.

I would also like to use this opportunity to express my thanks to my university supervisors, Marcel Ludema and Frans Sopers for their willingness to be my supervisors and for providing me with valuable and critical remarks during the meetings we had. Next to them, I would like to thank professor Van Wee, chairman of the committee, for his short, clear and bullet wise remarks and suggestions which helped me during me research.

It was indeed 'A great opportunity and ultimate chance' to earn a Master of Science degree under the circumstances that I had.

Now it is time to move on to a new challenge.

Arno Brinkman
Breda, January 2010
Summary

Skil Europe B.V. was established in the early 1920s as a producer of the electrically powered handsaw, also known as the Skilsaw. In 1992 there was a joint venture with Robert Bosch GmbH which led to a takeover of Skil by Robert Bosch GmbH in 1996. The main office is located in Breda, The Netherlands. Skil Europe B.V. is nowadays a manufacturer of a wide range of power tools with their main factories in China.

Globalization of the market, open markets in Europe, increasing fuel prices, economic recession and increasing prices of raw materials set pressure on the market. Outsourcing of non value added activities and increasing customers demand in quality and customer service levels make that companies need to keep evaluating their strategy continuously to keep their competitive position in their markets.

One of the important processes in reaching the customers and the customer's satisfaction is due to excellence in supply chain management. The supply chain is very important for many companies in order to structure their logistic process, because the supply chain performs in most cases as the value added activity and fulfils the customers demand, but the supply chain also represents a significant amount of the costs for a company. This is also the case for Skil. The profit of Skil is under pressure and they need to keep up and eventually increase the profit.

Skil has a complex supply chain with 26 suppliers and many different inventory locations and customers in 37 European countries. The current logistic organisation has grown over the years with an increase of customers in different countries and is integrated with the Bosch organisation when Skil became a business unit of Bosch. During these years adjustments have been made on the physical distribution network to lower certain supply chain costs when it turned out that a distribution to a warehouse could be done with lower costs.

But a complete analysis of the whole distribution network from all 13 warehouses to all customers in 37 countries hasn't been made yet. What would be the outcome when looking at all these actors and factors in the physical distribution network? It should give insight in possibilities to change the whole network in order the gain cost reduction in the supply chain.

Skil divides their supply chain costs into three phases depending on the place of the product in the supply chain. The source side which is the distribution from the supplier to the main warehouse in Breda / Meer. The make side, which is the value added activity in postponement that takes place in the main warehouse. The last is the deliver side in which the final distribution takes place from the main warehouse to the customers in the countries. Because this research aims at the possibilities of an alternative lay-out of the physical distribution
network the focus of this research is on the outbound side of the supply chain. This last phase represents the biggest amount of supply chain cost in Skil’s logistic organisation, about 9.7% of the Total Net Sales.

To lower the supply chain cost Skil wants to adjust their physical distribution network for the future, (period of 3 to 5 years). This means that it will need decisions mainly on strategic level.

This research uses a generic framework to analyse the physical distribution network of Skil in order to look for a possible ways to lower the supply chain costs. It gives an indication of possible ways to locate-allocate warehouses and customers of Skil. It gives no solutions on tactical or operational level of actions to be taken to lower the costs, but it gives a strategic direction of (re-)designing the physical distribution network in order to lower the supply chain costs and to meet the service level requirements of Skil.

The objective of this research is to re-design the physical distribution network for Skil Europe B.V. for the next 3 to 5 years, towards lower the logistic costs.

To propose an alternative physical distribution network design is it import to gain knowledge about the current logistical structure of a company. Many authors already discussed possible ways to analyze a physical distribution network. But these theories didn’t covered completely the wanted analysis for this research. The core aspect to analyze a company is in the most theories the same only the connection between the information after the analysis with the use of the location-allocation theory was missing. Therefore a new generic framework (see Figure 1) is made, based on these theories, which can and will be used to analyze an organization. A stepwise research based of this generic framework provides the necessary information that is used as an input to come up with a possible physical distribution network design with the lowest supply chain costs.
This generic framework is used as a criterion in this research. The steps given in this framework are executed to analyze the organization of Skil and gain the information needed to propose an alternative design. It can also be used for other companies to better understand the organization in depth in order to gain a clearer overview of their logistical procedures. When looking for an alternative network design this information is needed to be able to change aspects of the organization in order to adapt to the future.

First it will be important that it is clear what the corporate strategy is of the company because this will be the starting point in structure the logistic basic form. The competitive strategy matrix of Porter’s is used to get the strategy clear. Skil uses a strategy which lies in between the focus and differentiation. This is remarkable because the theory gives that the best way of...
getting a good market positioning for their products a clear corporate strategy must be chosen. In this case Skil doesn’t make a clear choice regarding the integrated costs. They don’t want to be the lowest because that will mean less service or lower marketing budgets. But it can’t get higher costs because than they will enter the Bosch tool markets. The logistic target Skil has, is to eventually get a service level of 98 % with the supply chain costs [% of Total Net Sales] below 13 % in 2011.

The next step is to get a clear overview of the as-is organization. Skil uses different warehouses in Europe to distribute their products from the main warehouse in Breda / Meer to the customers in the 37 countries. These warehouses are affiliated to the customers in the countries. Skil keeps inventory in these warehouse at a level that the service level will be met. Therefore the CODP are lying at these warehouses. The products between the warehouses are transported by a carrier which uses mainly truck loads. The transport of products is divided in rough distribution (warehouse to warehouse) and fine distribution (warehouse to customer) and done in all cases by a 3PL. Due to the fact that the lead times are rather long (65 - 75 days), the CODP lies that far in the logistic chain the costs and the service level target is 98 % it means that a lot of costs are at transport and inventory. The strategic value of the product of Skil and their complexity aren’t that high, which means that Skil is keen on meeting the customers demand.

The supply chain cost for the physical distribution network are calculated by using general calculation methods. A calculation model has been made in excel using different equation for different activities. These activities are the basis of making supply chain costs more transparent within a network. An overview of the cost drivers derived from theory research and applied on the situation of Skil is generated (see Figure 2).

![Figure 2 Cost drivers overview for Skil (derived after field and desk research at Skil)](image)
With use of this costs diversion within Skil equations to calculated the costs are formed based on the main Equation 1. These equations are making it possible to calculated the different costs within the physical distribution network.

**Equation 1 Physical distribution costs**

<table>
<thead>
<tr>
<th>Physical distribution Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>( TC = T + I + W )</td>
</tr>
<tr>
<td>( TC ) = Total costs in physical distribution (euro/year)</td>
</tr>
<tr>
<td>( T ) = Transport (euro/year)</td>
</tr>
<tr>
<td>( I ) = Inventory cost (euro/year)</td>
</tr>
<tr>
<td>( W ) = Warehouse &amp; handling cost (euro/year)</td>
</tr>
</tbody>
</table>

The demand of each part number pro month pro country for the years 2007 and 2008 is used to calculate the different costs in the physical distribution network. In Table 1 an overview is given of these calculated costs for the year 2007 and 2008.

**Table 1 Physical distribution costs calculated with use of the equations**

<table>
<thead>
<tr>
<th></th>
<th>Transport costs</th>
<th>Warehouse &amp; Handling costs</th>
<th>Inventory costs</th>
<th>Overall Total Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>own calculation</td>
<td>own calculation</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2007</td>
<td>2008</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transport costs</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transport costs rough distribution</td>
<td>€2,155,688</td>
<td>€1,526,950</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transport costs fine distribution</td>
<td>€28,723,726</td>
<td>€22,747,537</td>
<td></td>
<td></td>
</tr>
<tr>
<td>total</td>
<td>€30,279,414</td>
<td>€24,274,486</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Warehouse &amp; Handling costs</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Handling costs, Goods In</td>
<td>€167,816</td>
<td>€105,931</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Handling Costs, Goods Out</td>
<td>€2,183,237</td>
<td>€1,537,284</td>
<td></td>
<td></td>
</tr>
<tr>
<td>storage costs</td>
<td>€1,218,483</td>
<td>€900,834</td>
<td></td>
<td></td>
</tr>
<tr>
<td>total</td>
<td>€3,569,537</td>
<td>€2,674,055</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inventory costs</td>
<td>€2,303,760</td>
<td>€1,911,407</td>
<td></td>
<td></td>
</tr>
<tr>
<td>total</td>
<td>€2,303,760</td>
<td>€1,911,407</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overall Total Costs</td>
<td>€36,152,711</td>
<td>€28,859,948</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

From this table can be concluded that the biggest share of costs is in the fine distribution of the part numbers from the local warehouses to the costumers in the countries.

To validate the calculation model a comparison is made with the costs calculated by the financial department of Skil (see Table 2)
Table 2 Comparison own calculation with Skil's calculation

<table>
<thead>
<tr>
<th></th>
<th>own calculation 2008</th>
<th>financial department 2008</th>
<th>absolute differences 2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transport costs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transport costs rough distribution</td>
<td>€1,526,950</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transport costs fine distribution</td>
<td>€22,747,537</td>
<td></td>
<td></td>
</tr>
<tr>
<td>total</td>
<td>€24,274,486</td>
<td>€3,964,000</td>
<td>€20,310,486</td>
</tr>
<tr>
<td>Warehouse &amp; Handling costs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Handling costs <em>Goods In</em></td>
<td>€105,931</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Handling Costs <em>Goods Out</em></td>
<td>€1,577,261</td>
<td></td>
<td></td>
</tr>
<tr>
<td>storage costs</td>
<td>€990,864</td>
<td></td>
<td></td>
</tr>
<tr>
<td>total</td>
<td>€2,674,055</td>
<td>€2,128,000</td>
<td>€546,055</td>
</tr>
<tr>
<td>Inventory costs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>inventory costs</td>
<td>€1,911,407</td>
<td></td>
<td></td>
</tr>
<tr>
<td>total</td>
<td>€1,911,407</td>
<td>€2,176,000</td>
<td>-€264,593</td>
</tr>
<tr>
<td>Overall Total Costs</td>
<td>€28,859,948</td>
<td>€8,268,000</td>
<td>€20,591,948</td>
</tr>
</tbody>
</table>

From this comparison can be concluded that mainly the fine distribution costs are showing a big difference. This can be explained due to the fact that normally Skil gets a discount for the fine distribution rates or the prices used in this research from UPS vary much from the real prices that are charged at Skil. When taken a fine distribution discount of 90% on the current rates of UPS the prices are more in line with the data calculated by the financial department. The diversion of the costs with this discount rate can be seen in Figure 3.

![Figure 3 Diversion logistic costs](image)

A more in depth analysis of the costs gives more insight in possible ways to lower these costs and what will be the subjects for further research. From this analysis it became clear that few cost savings can be achieved by using operational decisions, like changing pallet stacks or shortening the lead times. But the transportation cost are the biggest share of the total supply chain costs. This activity can be influenced by changing the physical distribution network. But by changing this network also the costs for inventory and warehouse & handling will be influenced.
The bottleneck in this research that it is not clear what the results on the supply chain costs will be when changing the lay-out of the physical distribution network.

The change of the layout of the physical distribution network gives an alternative design. This alternative design is made by using a location-allocation model. This model is constructed to optimize the logistic structure of Skil in terms of costs. For the situation of Skil a model is constructed which uses the ADD heuristic. It is a model that will fits the best for this research to look for alternative designs in order to lower the transportation and facility costs. The ADD heuristic is one of the most widely known heuristic and is still strong foundation for much of the location theory research done. Although in case of heuristic no guarantee exists that it would find an optimal solution, using exact methods is not a feasible option either. First, exact solution methods require more knowledge of linear programming and more sophisticated programs to solve those problems. Secondly when the problem becomes too large exact methods may not be computationally feasible.

For the situation of Skil the ADD heuristic will be a strong and usable tool to solve easily location problems if there are relatively few possible locations. The ADD heuristic is a location-allocation model that also could be used for other companies. The only change that will be needed is that the input variables have to be adjusted to this other company.

The target for this model is to: Optimize the transportation and facility costs for a centralized physical distribution structure through mitigating local distribution centres to a few distribution centres in Europe.

The important input parameters needed to minimize the transportation costs and warehouse costs are the demand of part numbers and from these derived the number of parcels and pallets or weight of a shipment between or within a country. The relation between the parameter in the model are given in Figure 4.
Figure 4 The relation between the parameters of the model

The relation diagram is used to calculate all costs of the physical distribution network. The model is designed in excel in which the demand of the part numbers per month per country will be the input. By opening and closing warehouses (one at a time) and allocate countries to these warehouses the costs can be calculated. When the steps are executed the warehouses are sorted in a decreasing order of total savings. For every step a warehouse will be assigned to a country (allocate). This allocation is done based on the lowest total cost of the open warehouse when distributing to that specific country.

When looking at the original situation of the layout of the network compared to a calculated 'optimized' lay-out of the network, with fine distribution rate discount of 90%, the following result is obtained (see Figure 5)
Figure 5 Comparison optimum model with original situation

The total cost decrease and the share of the fine distribution costs increases a lot. This means less warehouses and more fine distribution from the warehouse in the Netherlands.

To be sure that the ADD heuristic gives a good solution a validation is made of the heuristic. From this validation can be concluded that the ADD heuristic will give the lowest total costs for all situation when adding warehouses to the network to obtain the lowest costs, but the sequence of adding warehouses differs between the two used methods.

To look how robust the network is and what has the biggest or least impact on the network when changing the parameters a sensitivity analysis is performed. With this sensitivity analysis the consequences for the network design, in terms of costs, is analyzed when the input parameters of the model are changed. The model has two categories of control variables. These are: the demand of part numbers of each country and the costs aspects.

The demand of the part numbers are changed by using a forecast of each individual part numbers based on the demand pattern of the year 2007 and 2008. Two forecasts are made. The first one is when the demand of part numbers increases with 20 % to a total net sales of 100 million euro’s. The second is when the demand of part numbers decreases with 20 % to a total net sales of 66 million euro’s.

The costs aspects are divided into transportation costs and warehouse costs. Within these costs another diversion is made between the different cost drivers. This is done to gain a complete understanding of the costs developments in the model when changing parameters in the model. To vary the parameters the fine distribution rates were set a starting point. These turned out to produce the biggest impact on the network. So this parameters was changed ten times every time with 10 %. This is done to have a full understanding of the effects of this major parameter. Because steps of 10 % were taken for this parameters a look has been made to the change of absolute values of this rate. To be sure that the changes of the different parameters were in line with each other these absolute changes must be kept more or less the same. This meant
that the other parameters should change also with 10% with the exception for the interest rate. This should change with 2%.

For the year 2008 34 different scenarios are analyzed and for the situations that the demand increases or decreases with 20% 26 different situation are analyzed.

From these different analyses the following results from the change of the costs parameters are obtained. When the prices of the parameters increases the total costs of the network increase and vice versa. The warehouse in Latvia will always be redundant and the warehouses in The Netherlands, Poland, Romania and Hungary are always needed in the network. The other warehouses are depending on the rate of the fine distribution. The number of warehouses needed highly depend on the fine distribution rate. The rates for the warehouse costs don't have a big effect on the relative differences of the decrease of the total costs in a network.

The change of fine distribution rate sorts the biggest effect on the decrease of the total network costs when adding warehouses. It turns out that when adding a warehouse in most cases only the customers in the same country are allocated to this warehouse. An exception in all cases is the warehouse of in The Netherlands. This warehouses is allocates in all cases to the most countries.

From the analysis of the change in demand can be concluded that an decrease of the demand has an negative effect on the KPI supply chain costs. An increase of the demand has a positive effect of this KPI. This means that the network costs benefit when the total demand is increased.

A lot of analyses' are done in this research. A new generic framework is developed which can be used in general to analyse a design of a physical distribution network. A calculation model in excel is developed to calculated the lowest supply chain cost of the physical distribution network by adding each time a warehouse. Eventually a complete sensitive analysis is made to investigate the robustness of the network and the effects of the change of parameters to the network. In this case it meant that the parameter of fine distribution has a major effect on the layout of the network and therefore also on the supply chain costs of the network.

At last the conclusions that are drawn for this research are that:

- Implementing operational changes, like increasing pallets load, will have a positive effect on the supply chain costs.
- Changing the rates in a way that the activities will become cheaper the total network costs will also be lower.
- The warehouse of Latvia is not necessary in all alternative designs.
In the physical distribution network the warehouses of The Netherlands, Poland, Romania and Hungary are always needed.

Changing warehouses rates have less effect on the costs and lay-out of the network than changing transport rates.

The warehouse in the Netherlands takes the most fine distribution to the country. The other warehouses are used mostly for only domestic shipments.

Increasing the demand will lower the KPI Supply Chain cost.

It is very important to know exactly the fine distribution rate to decide to change the layout of the network.

The new introduced generic framework to analyse the design of the physical distribution network is a useful tool. This tool provides a clear overview of the procedure to follow from starting to analyse a company in order to suggest a possible (re-) design of physical distribution network with lower supply chain costs.

This research has no clear end solution and it gives a very good starting point for further research at Skil. Therefore the recommendations for Skil are:

- Further research is absolutely necessary for the subject of the fine distribution costs to be able to make a good decision how to change the layout of the physical distribution network.
- Further research on operational decisions can contribute to lower supply chain costs.
- Further research on how the big fluctuation in the demand pattern can be smoothened is needed to gain extra cost reduction over the complete supply chain.
- Further research is necessary to investigate if the combination of the logistic targets of 98% service level and the supply chain costs of < 13% (Total Net Sales) can be reached for the physical distribution network of Skil.
- Divide the different cost activities as a subject each when further research will be performed by others for the benefit of time.
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9.1 Conclusions

9.2 Recommendations

9.3 Limitations

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Abbreviations

A Appendix: Organization Robert Bosch GmbH

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C Appendix: Country Sales organization overview

D Appendix: number of part numbers sold in 2007, 2008 and 2009

E Appendix: LDC delivery to costumers in countries and own or rent by

F Appendix: Cost supply chain

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K Appendix: Product characteristics narrow terms

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Introduction Skil Europe B.V.
Skil is part of the Robert Bosch GmbH company (appendix A). Robert Bosch GmbH has three sectors which are divided into four divisions, which among the division Power Tools. The division Power Tools is divided into twelve business units in which Skil Europe B.V is one of the business units of the division Power Tools (PT).

The main office of Skil is located in Breda. In Figure 6 the organization chart of the main office in Breda is given. Under the finance department several groups are located among which the logistic group.

![Organization Chart Skil Europe B.V.](image)

Figure 6 Organization Chart Skil Europe B.V. (Skil, 2008A)

The logistics group is located in Breda and responsible for all logistic processes regarding the Skill power tools and accessories except the procurement, marketing and sales of these goods. The logistics group is divided into three subgroups; back office, operations and supply chain management. The main responsibility of back office is making appointments about transportation and crediting these to the customers. Operations mainly performs warehouse and handling activities and the supply chain management group is responsible for the logistic process of ordering pre-cuts at the suppliers until the delivery from the product to the right customers at the right time in the right quantities. This last group is divided into centre logistic planners (CLP) who are responsible for the product on the inbound side and the distribution managers (DM) who have the responsibility on the outbound side.

1.1 Products and customers

Skil has a lot of different power tools for the DIY and the smaller professional users. For the pragmatic DIY they have as many as 25 different PTs and within a single PT there are different model numbers which are referred as part number (example in appendix B).
Skil sells tools that are "easy to use, no-nonse tools with the best price/ quality ratio and that provide an extra level of convenience that ensure a hassle free, quick result" (Skil, 2008A). The customers' buying motives are easy to describe. Every tool needs at least two or three of the buying motives that Skil identifies. These buying motives are Ease to use, Safety, Problem solver, Convenience, Get's the job done, Price and Versatile (Skil, 2008A).

1.2 Business logistics

Skil has an international logistics organization with suppliers in China and Hungary, main warehouses in Belgium and The Netherlands and customers all over Europe. This paragraph describes the business process of how the product from the supplier will end up in the right way at the right customer. In Figure 7 an overview of the material and information flow of Skil is given.

![Material and information flow Skil](image)

**Figure 7 Material and information flow Skil**

The sale organization has an important role in the supply chain. The sales organization is divided into country sales organizations (CSO) which are responsible to sell tools of Skil in their region. In Appendix C an overview of the CSO is given with their regions of responsibility. Each region is represented by a brand manager who makes a forecast of the part number needed for their region. The logistic department study these forecasts and checks with the information system if the right part number will be available when asked by the sales manager. When the finished goods isn’t available they look if this part number could be produces within postponement by re-organising old part number and items so that the right part number will
become available. When this isn’t a possibility in postponement the logistic departments places a purchase orders at the suppliers. This supplier will produce the right part number and will send it with use of carriers to the Netherlands. When the brand managers actually sell the part number to the customers they place sales orders and the logistical department makes sure that the right part number will arrive at local warehouses. The CSO take care of the distribution from the local warehouses to the customers.

1.3 Markets and sales products

Skil sells their products to home improvement centres or in some countries to specific power tool shops. These customers are supplied by the distribution centres which are located in different countries. The number of tools sold in the different countries appears to differ a lot from each other. In Figure 8 the number of part numbers sold in the period from Jan 2007 till Mar 2009 to customers in different European countries is given. The total amount of tools sold in this period is around the 4.2 million tools. In appendix D the number of tools sold in 2007 and 2008 is given. The customers in the different European countries which are provided with tools by the specific distribution centres are given in appendix E. The number of tools sold via the different distribution centres to the home improvements centres or power tool shops is given in Figure 9 as a percentage of the total number of tools sold.

![Figure 8 # total items sold to customers in European countries (Jan 2007-Mar 2009)(own analysis)](image-url)
Figure 9 of total # tools sold via distribution centre (Jan 2007-Mar 2009) (own analysis)

From these figures can be concluded that the largest amount of tools is sold mainly via the warehouse in Germany. The most items are transported via the warehouse in Germany to the customers in the Western Europe countries. The other distribution centres have a share between the 2% to 7% of the total volume sold items.

1.4 Logistic costs

Skil has a complex supply chain with 26 suppliers and many different inventory locations and customers at wide spread geographical locations. To fulfil the customers demand Skil uses different ways of distributing their products to these customers. Skil uses a part of the logistic chain of Bosch. Bosch has an extended logistic organisation which Skil uses to distribute their products from the factory to the customer. In certain cases as for carriers Bosch makes call-off contracts with those carriers for all business units of Bosch. Skil can make use of these agreements with the carriers. Also Bosch has made agreements with distribution centres about the use of their services and spaces. When a business unit uses these distribution centre on behalf of Bosch, Bosch will get charged for this service and the business unit is charged by Bosch for the used services and / or space. So when Skil uses these ‘Bosch’ distribution centre Skil has to pay the BOSCH organization for using these logistics service. Bosch is leading these negotiation and makes these agreements on behalf of the Bosch organisation, including the business units. Therefore Bosch is looking for an optimal situation which serves the most business unit the bests.

Within Skil the thoughts arose if the use of these service provided by Bosch is the cheapest way of distributing their product to the customers. It could be that the price charged for using this
service is too high for the product that Skil need to get at the customers via the physical
distribution network. Skil has the freedom of looking for possibilities to lower the supply chain
costs for the physical distribution network, even when this could mean that parts of the Bosch
network will not be used.

The profit of Skil is under pressure and they need to keep up and eventually increase the profit.
The way to make more profit is by increasing the sales with the same supply chain cost per
activity or to lower the supply chain cost per activity. Increasing the sales is hard for Skil
because the number of tools sold doesn't increase but even drop at the moment so the prices
for the tools would have to be higher. But Skil operates in the power tool sector in which
Robert Bosch also sells power tools. The Bosch Power tools are of higher quality against relative
higher price. So if Skil wants to increase their prices they will enter the market segment of
Bosch and this is not allowed for Skil. So increasing prices to get higher sales is not possible. So
Skil has to lower the supply chain cost per activity to make more profit. The supply chain costs
amount to approximately 17% of the total net sales in 2008 (Appendix F).

So Skil is looking for possibilities to lower their supply chain costs. Skil already is at operational
and tactical level looking for possibilities to lower their supply chain costs. They do that by
looking at: different packaging materials; increasing pallet loads, more efficient use of
transport capacity. On strategic level Skil likes to find out what the effects will be on a change
in the lay-out of their physical distribution network. Therefore this research aims at a search
for possible ways to lower the supply chain costs for the physical distribution network by
looking at alternative lay-outs of their network.

1.5 Report structure

The report structure can be described as follows. In chapter 2, the research goal, the research
questions and the methodology of this research are explained. Chapter 3 discusses a generic
framework and the location-allocation models of designing a physical distribution network. This
generic framework is applied on Skil Europe B.V. in chapter 4. The costs structure that comes
with a physical distribution network are explained and worked out for Skil in Chapter 5. Based
on the calculation of the cost done in chapter 5 the bottlenecks in costs are derived in chapter
6. Based on the analysis made in previous chapter the requirements for a 'new' distribution
network for Skil are set out in chapter 6. In chapter 7 a location-allocation model, based on the
ADD Heuristic, is presented to search for the most 'optimal' model based on the lowest costs.
The location-allocation model from chapter 7 is used in chapter 8 to make a sensitivity analysis
of the parameters used in the model. The conclusions, recommendations and limitations of this
research are addressed in chapter 9.
Problem description
2.1 Research introduction

Globalization of the market, open markets in Europe, increasing fuel prices, economic recession and increasing prices of raw materials set pressure on the market. Outsourcing of non value added activities and increasing customers demand in quality and customer service levels make that companies need to keep evaluating their strategy continuously to keep their competitive position in their markets.

One of the important processes in reaching the customers and the customer's satisfaction is due to excellence in supply chain management. The supply chain is very important for many companies in order to structure their logistic process, because the supply chain performs in most cases as the value added activity and fulfils the customers demand, but the supply chain also represents a significant amount of the costs for a company.

This is also the case for Skil. The profit of Skil is under pressure and they need to keep up and eventually increase the profit. As mentioned in the introduction Skil is looking for a way to lower their supply chain costs on strategic level. Their aim is to look for the effects on the supply chain costs when a alternative lay out of their physical distribution network is suggested.

Skil has a complex supply chain with 26 suppliers and many different inventory locations and customers in 37 European countries. The current logistic organisation has grown over the years with an increase of customers in different countries and is integrated with the Bosch organisation when Skil became a business unit of Bosch. During these years adjustments have been made on the physical distribution network to lower certain supply chain costs when it turned out that a distribution to a warehouse could be done with lower costs.

But a complete analysis of the whole distribution network from all 13 warehouses to all customers in 37 countries hasn't been made yet. What would be the outcome when looking at all these actors and factors in the physical distribution network? It should give insight in possibilities to change the whole network in order the gain cost reduction in the supply chain.

Skil divides their supply chain costs into three phases depending on the place of the product in the supply chain. The source side which is the distribution from the supplier to the main warehouse in Breda / Meer. The make side, which is the value added activity in postponement that takes place in the main warehouse. The last is the deliver side in which the final distribution takes place from the main warehouse to the customers in the countries (appendix F). Because this research aims at the possibilities of an alternative lay-out of the physical distribution network we focus on the deliver side of the supply chain. This last phase
represents the biggest amount of supply chain cost in Skil's logistic organisation, about 9.7 % of the Total Net Sales.

To lower the supply chain cost Skil wants to adjust their physical distribution network for the future, (period of 3 to 5 years). This means that it will need decisions mainly on strategic level (Min & Zhou, 2002; Van Goor et al., 1999; Smith, 2003; Van der Weegen, 1989).

This research will be a search for a possible ways to lower the supply chain costs of Skil by looking at the physical distribution network. It will give an indication of possible ways to locate-allocate warehouses and customers of Skil. It gives no solutions on tactical or operational level of actions to be taken to lower the costs, but it gives a strategic direction of (re-) designing the physical distribution network in order to lower to supply chain costs and to meet the service level requirements of Skil

2.2 Objective and research model
The main objective of this research will be to (re)-design the physical distribution network for Skil Europe B.V. for the next 3 to 5 years in towards lower the supply chain costs.

For the structure of this research the method described in Verschuren et al. (2004) is used. In this method the start of a research is first to set the objective of the research. Based on this objective aspects for literature research are set and a research model is formed. With this research model a good overview is given of the structure of the report. Based on this research model the main question and central questions can be derived to support the objective of the research.

The goal of this research is to present an alternative design of the physical distribution network with the scope of lowering the supply chain cost.

For this report three different research views are used:
Literature research: study of scientific literature/articles;
Desk research: reports, journals, internet and data analysis;
Field research: interviews.

The research object will be Skil Europe B.V. which is situated in Breda. It will be a research at Skil in which the aim is to search for the logistic bottlenecks, in terms of costs, of Skil in order to present options to lower the logistic costs.

In order to perform this research the objective can be analyzed and three important subjects for literature research can be identified: the analysis of a company needed to design a physical
distribution network, the supply chain cost and positioning of warehouses / distribution centres in a network. These three subjects will be the main topics for the literature research given in Table 3. In this table the subjects and sources of the desk and field research, done in the research, are also given.

Table 3 main topics and subjects of the research views

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Theoretical framework</th>
</tr>
</thead>
<tbody>
<tr>
<td>Literature research</td>
<td>Distribution network design</td>
</tr>
<tr>
<td>Designing physical distribution network for 3-5 years</td>
<td>Cost diversion</td>
</tr>
<tr>
<td>Logistic costs</td>
<td>Location-allocation</td>
</tr>
<tr>
<td>Positioning warehouse / distribution centre</td>
<td>Source</td>
</tr>
<tr>
<td>Desk research</td>
<td>SAP sales figures countries</td>
</tr>
<tr>
<td>Demand pattern</td>
<td>Price tables Skil</td>
</tr>
<tr>
<td>Parameters costs</td>
<td>Table overview SC costs</td>
</tr>
<tr>
<td>Skil's logistic costs</td>
<td>Internet and program software</td>
</tr>
<tr>
<td>Key performance indicators</td>
<td>Robert Bosch BmbH intranet</td>
</tr>
<tr>
<td>Forecasting</td>
<td>Robert Bosch BmbH intranet</td>
</tr>
<tr>
<td>Logistic procedures Skil</td>
<td>Source</td>
</tr>
<tr>
<td>Field research</td>
<td>Interview financial department</td>
</tr>
<tr>
<td>Costs diversion Skil</td>
<td>Interview marketing department</td>
</tr>
<tr>
<td>Strategy Skil</td>
<td>Interview Logistic department</td>
</tr>
<tr>
<td>Logistic objectives Skil</td>
<td>Logistic organisation Skil</td>
</tr>
<tr>
<td>Logistic organisation Skil</td>
<td>Logistic department</td>
</tr>
</tbody>
</table>

When knowing and understanding these subjects better the next step is to analyze the strategy of Skil and its logistic structure regarding their products and customers. This research is done with desk research and field research. After the current situation at Skil is analyzed certain bottlenecks in their structure will appear. These bottlenecks are used as a focus to search for alternative designs of the physical distribution networks to lower the supply chain cost.

These designs are analyzed with a sensitivity analysis in order to determine the robustness of the proposed design with its parameters. Eventually the different designs with their different parameters are discussed and evaluated by their scores for KPI's and supply chain cost and will be the subject of a discussion of the possibility to implement a design.

This can be summarized in a research model which is given in Figure 10.
Verbalizing:
(a) A literature review, covering logistic costs, an analysis to design a physical distribution networks and the location-allocation of warehouses and customers (b) will lead, in combination with an extended desk and field research, (c) in the bottlenecks of the current logistic situation at Skil. With the use of literature covering location-allocation policy, different designs of physical distribution networks are made regarding these bottlenecks. (d) These designs are evaluated for lowest costs and their robustness for Skil which (e) will lead to a discussion and recommendation about the possibility to implement a designs.

2.3 Research questions

In order to achieve the objective of this research, the following question will be the main question:

What is the optimal physical distribution network design for Skil regarding the logistic costs?

To be able to answer this main question, information on different subjects is needed. This information is generated by answering different central questions. By using the research model a diversion can be made into the different questions.

1. What are the criteria for an analysis to design a physical distribution network?
To answer this question the methods in Table 4 are used. The answer is described in paragraphs 3.1, 3.2 and 5.1.

Table 4 Research method used for question 1

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Theoretical framework</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Literature research</strong></td>
<td><strong>Designing physical distribution network for 3-5 years</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Distribution network design</strong></td>
</tr>
<tr>
<td><strong>Logistic costs</strong></td>
<td><strong>Cost diversion</strong></td>
</tr>
<tr>
<td><strong>Positioning warehouse / distribution centre</strong></td>
<td><strong>Location-allocation</strong></td>
</tr>
</tbody>
</table>

2. How is the physical distribution network of Skil currently organised?

To answer this question the methods in Table 5 research methods used for question 2 are used. The answer is described in chapter 4 and paragraph 5.2.

Table 5 research methods used for question 2

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Desk research</td>
<td></td>
</tr>
<tr>
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<tr>
<td>Key performance indicators</td>
<td>Robert Bosch GmbH Intranet</td>
</tr>
<tr>
<td>Logistic procedures Skil</td>
<td>Robert Bosch GmbH Intranet</td>
</tr>
<tr>
<td>Rapid research</td>
<td>Source</td>
</tr>
<tr>
<td>Costs diversion Skil</td>
<td>Interview financial department</td>
</tr>
<tr>
<td>Strategy Skil</td>
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</tr>
<tr>
<td>Logistic objectives Skil</td>
<td>Interview Logistic department</td>
</tr>
<tr>
<td>Logistic organisation Skil</td>
<td>Logistic department</td>
</tr>
</tbody>
</table>
3. What are the results of the analysis of Skil’s current physical distribution network in terms of bottlenecks?

To answer this question an analysis is made of the costs and their impact. The answer on this question is given in paragraph 6.1

4. What are the requirements for an alternative design of the physical distribution network of Skil?

To answer this question the analysis of the theory from chapter 3 and 4 and the bottleneck analysis is used. The answer on this question is given in chapter 6.2

5. What are the alternative designs for the physical distribution network for Skil regarding the location-allocation policy?

To answer this question the theory of location-allocation is used. The answer on this question is given chapter 7.
6. Which parameters can be used to verify the robustness’s of the physical distribution network of Skil?

To answer this question the impact of the parameters on the network is analyzed. The answer on this question is given in chapter 8.

7. What is the result of the analysis of the robustness’s of the different designs of the physical distribution network?

To answer this question an sensitivity analysis is made and the Key Performance indicators are analyzed. The answer of this question is given in paragraph 8.2.

2.4 Assumptions and constraints

This report researches possible designs for the physical distribution networks for Skil. It will be a search at strategic level and certain consequences for tactical level in which the focus will be on the logistic costs of these designs. For strategic level the discussion will be on decisions regarding logistic network structure decisions and distribution channel planning (Van der Weegen, 1989, Min & Zhou, 2002). The decisions regarding production allocations, opening or closing factories, outsourcing and logistic information systems will be out of the scope of this research. The tactical level decisions are of no real subject in this research and are left out of this research (Van Goor et al., 1999; Smith, 2003; Van der Weegen, 1989; Min & Zhou, 2002). For an overview of possible decisions regarding the different levels see Appendix G.
For this research the focus will be on the logistics department and the processes which are important for this department. The processes of demand and distribution and properties of the different kind of products determine for a great deal how the distribution network of Skil is organized (Schary et al., 2001) and are therefore taken into account. Only the distribution of bulk tools and finished goods within Europe are within the scope of this research. The procurement and suppliers choice are not considered in this research. Although postponement is a process with the logistical department, this process as a whole will not be considered in this research.

The first idea was to look at the physical flow of goods between the suppliers, central distribution centres and the local distribution centres. Hereby the last stage of distributing products from the local distribution centre to the customers in the countries was not taken into account. After thorough research of the costs and possibilities to (re)-design the physical distribution network a shift of this demarcation has taken place. The last stage of the distribution to the customers in the countries is taken into account and the first stage from supplier to central warehouse in Breda / Meer is left out. This is done because of the possibilities to include the demand of the different countries in the location-allocation models. The savings that probably could be made with the delivery side of distribution is one of another kind of problem, looking more into other transportation companies, or try to aggregate certain volumes together in order to have scale benefits of the transportation. The current demarcation of the distribution flow is visualized by Figure 11.

![Figure 11: Demarcation Research](image)

For this research the central warehouses of Breda and Meer are seen as one central warehouse. This is done to simplify the goods flow from this central warehouse to the other warehouses.
2.5 Research methodology

The research will be conducted at Skil. It will be a research in which different designs for Skil are developed and by means of an assessment set in order of lowest logistic costs.

This research will start with a literature study of performance metrics, distributions network designs and location-allocation models. From this study the criteria are formed. When these criteria are known, field- and desk research is needed to get clear how Skil can meet these requirements and how they can fill in the criteria. From this analysis bottlenecks in the organisation are made clear which are used to make new designs with the use of location-allocation theory. Different designs of physical distribution networks can be made. These designs are assessed with a look at the logistic costs and their robustness. After this assessment there will be a discussion of the possibility to implement this design.
A generic framework to analyse a design of physical distribution network
One of the important processes in reaching the customers and the customer's satisfaction is due to excellence supply chain management. The supply chain is very important for many companies because the supply chain performs in most cases the value added activities and represent a significant amount of the costs for a company. The supply chain is divided in different main processes in which Min & Zhou (2002) distinguishes material management and physical distribution and Van Goor et al. (1999) adds two, physical supply and reverse logistics.

The aim in this research is to look at the physical distribution. In short this is the effective and efficient control of good flow and information between the producers and customer in order to get the finished goods on the right time, right place and the right quantity at the customer (Van Goor et al., 1999).

But how to build a physical distribution network so that it fits the company, their products and serves the customers demand? This chapter provides the theory to analyse a physical distribution network. It gives a generic framework that will be used for Skil but also could be used could be used also for other companies. This chapter is used to analyse the physical distribution network of Skil and it provides a starting point in this research to narrow the research further on more to the supply chain costs of the physical distribution network of Skil.

The first paragraph of this chapter provides a generic framework that will be used to analyse the physical distribution network consists of, which different methods there are to design a physical distribution network and what kind of information is needed to make different kind of decisions for the physical distribution network. From this theory a framework is made that will could be used to analyse the physical distribution network of a company to understand it and to provide the starting point for making possible changes within a company regarding the physical distribution network.

Paragraph 3.2 provides an insight in location-allocation models that will be used as a decision supportive tools to locate-allocate warehouses and customers in the network. These models could be used also for different companies and for Skil a choice is made based on their companies characteristics.

An schematic overview of the generic framework with the location-allocation models is shown in paragraph Error! Reference source not found.. This will be the criteria to be met in general to analyse a physical distribution network and start a process of changing a distribution network.

In the last paragraph the sub-conclusions of the chapter are given.
3.1 How to analyse the design of a physical distribution network?

There are different methods to analyse a design of a physical distribution network. In this paragraph a short analysis is made of literature from different authors who describe a procedure of how to analyse a design of a physical distribution network.

Van der Velde et al. (2002) has his way of analysing a physical distribution network in order to change it. The first step is to analyze and determine the as-is strategy and the future strategy of the concern regarding supply chain management. Then there is a need to analyze and map the processes of the as-is organization (the structure, products, material and information flow and the decoupling point). Then select the key costumers and select with a Pareto analysis the gross product of important and map theses features to the key customers. Finally compare this strategy with the as-is strategy and look whether and where there are possible tensions and changes these processes.

For Huizinga et al. (2000) the development of a logistic basic form stands central in order to find a balance between good logistic performance and an optimal use of resources. The basic form describes the physical arrangement, the control, the organization and the information supply. In order to work with success in the design stage it is necessary to have insight in: the current situation, good flow, logistic costs, business characteristics, current markets and the customer demand, the future situation; the wishes of customers, the market development, the business plan, the wanted direction with logistical guidelines and the alternative infrastructures.

In order to design a model a scope has to be developed, this scope consists of the description which decisions will be supported by the model, whereupon the alternative designs should be compared in terms of evaluation criteria, which links of physical distribution will be looked at, which area will be looked at, which sales markets will be looked at and which products will be discussed. In Figure 12 an example of a scope is given.
Scope

1. Decisions
   a. Number of warehouses
   b. Location of warehouses
   c. Which customers go to which warehouses
   d. Location factory is a given fact

2. Evaluation criteria
   a. Operation logistic costs
   b. Inventory costs in warehouses and pipeline
   c. Handling costs in warehouses
   d. Transport costs
   e. Customer service criterion
   f. Customer order cycle time

3. Logistic chain
   Logistic chain which takes care of the distribution
   of finished products from start of factory
   
   Factory -> Warehouse -> Customer

4. Geography
   Western-Europe

5. Markets
   All direct and in-direct consumer markets.
   Business to business market will be looked at
   separately because they can be seen separate from
   each other

6. Products
   Products in productgroups A, B and C.

Figure 12 Scope example (Huizinga et al., 2000)

Mourits et al. (1995) describes that the first step in the development of a distribution plan is a
good understanding of the corporate objectives and strategic plans. This distribution plan
should link the corporate objectives to the specific components of the goods distribution
network. For this distribution plan insight is needed in the marketing plan, financial plan, sales
volume plan and the customer service plan. This distribution plan includes specifications on
inventory, warehousing, transport and customer communication. To design a distribution plan
four phases are distinguished:

- Clarification of the task: In this phase a description of the problem is needed. This
description should contain the product types and assembly structure, characteristics of
the customer and supplier market and specification of the current situation including
facilities and equipment.

- Conceptual design: For the conceptual design the description of the main logistical
function that need to be perform by the network is needed, followed by a selection of
one or several solutions principles for a general arrangements. It gives an indication of
the geographical distribution of the logistical functions. The main purpose is to
emphasize the importance of considering the structural aspects of the network.

- Embodiment design: In the embodiment design the number and location of all facilities
and the good flow between each of them can be worked out into several general layout
designs. There will be an estimation of costs involved by each of the alternative lay-out designs.

- Detailed design: The detailed design should contain the details specification of one or more of the embodied designs.

Coyle at al. (2003) uses a method of six steps to design and determine an optimum design of a logistic network, see Figure 13. The first step is to get clear what the corporate strategy is. In this step it is also important to establish the parameters and objectives of the logistics network. The second step is to gather important information that could be used in further step of the design. Hereby could be thought about, customer requirements, key logistic goals and objectives, the current logistics network, values for logistic costs and key performance measures. In Figure 14 the number of steps that should be included in a logistic audit is given. The third step of the design of a logistic network is to examine possible alternatives. This is to gain insight in possible solutions and not to give a final answer. The fourth step should give an idea of possible facility locations on which will be decided, together with the network plan in the fifth step. The last step is about developing an implementation plan.

Figure 13 Key steps in the logistic network design process (Coyle at al., 2003)
Van Goor at al. (1999) also uses a framework to get the right information for designing a physical distribution network. This framework is given in Figure 15. Before a physical distribution network can be designed it is needed that it is clear what the company wants to achieve, the strategy of a company and the beneath laying target, by the logistic network. The strategy of a company is the start of making a choice for the basic logistic form. For our research the choice of the basic logistic form is important because that handles mainly the question of the layout of the physical distribution network. The most important elements of the basic logistic form are the primary processes of producers to customers, the locations of the inventory and the good flows between the process and the inventories. Depending on the strategy, target and basic logistic form the choices for the other systems are made sequentially like Figure 15 presents. On the end of the complete process the wanted performance indicators of the company should be become clear.
A way of defining a competitive strategy is with the use of Porter's competitive strategy matrix, (Van Goor et al., 1999; Van der Velde et al. 2002) given in Figure 16.

![Porter's competitive strategy matrix](image)

**Figure 16** Porter's competitive strategy matrix (Porter, 1985)

When the strategy and target becomes clear the choice for the basic form can be made. The most important elements of the basic logistic form are the main processes of inventory control, warehouse management and external transport. Besides this strategy it is also important to know the product characteristics because they determine the way these three main processes, warehouse management, inventory control and external transport, will be filled in. How these product characteristics relate to the physical distribution can be seen in Figure 17.

![Relation marketing, logistics and product characteristics](image)

**Figure 17** Relation marketing, logistics and product characteristics (Goor et al., 1999)
With use of these product characteristics, the corporate strategy and the target, choices can be made in terms of trade-offs, between logistic costs and service level, in designing the physical distribution network.

Now there is an understanding how the information could be arranged to analyse a physical distribution network the next questions is which decisions have to be made and what kind of information is needed for these decisions.

Within making these physical network designs different levels of decisions can be distinguished. Van Goor et al. (1999), Van der Weegen (1989) and Smith (2003) distinguish three different kind of decision levels in which different decisions have to be made. These levels are strategic, tactical and operation level. Some examples of decisions on the different levels are on strategic level decisions about the physical structure of the logistic organization; opening and closing of warehouses and outsourcing of logistic processes. On tactical level it is about where to put the Customer-Order-Decoupling-Points (CODP), inventory and warehouse management. The operational level concerns decisions related to the operational processes, like transport routes and warehouse lay-out. In appendix G an overview is given of these three authors of whom decisions on which levels should be made.

Smith (2003) states that depending on the decisions on the levels respectively from strategic, tactical and operational level de decisions can be made further on. In Figure 18 an overview of information needed for the different kind of decisions is given.

Figure 18 decisions made on different levels (Smith, 2003)
3.2 Location and allocation models

Which location and allocation models could be used to analyse and compute the supply chain costs for the physical distribution network of Skil? Several models are available in the literature, but which models fits best in this research and the situation for Skil? This paragraph gives in short a literature overview of different models and possible solution methods for location-allocation models. After this overview the situation of Skil in relation to these models is described and finally the reason of choosing a the model that will be used in this research is given.

3.2.1 Literature

3.2.1.1 Overview

In the field of facilities location and customer allocation, model formulation and solution algorithms vary widely in terms of fundamental assumptions, mathematical complexity and computational performance. The last decades a lot of research is done in location-allocation techniques which resulted in various model formulations which range in complexity from single linear, single stage, single product uncapacitated, deterministic models to stochastic models. Roughly there are three main subclasses in facility location (Daskin, 1995; Klose and Drexl, 2005).

- Continues location models (models in the plane).
- Network location models;
  - P-median problem (introduced by Hakimi (1964)),
  - Covering problem,
  - P-center.
- Mix integer programming;
  - Single- vs. multistage models;
  - Uncapacitated vs. capacitated models,
  - Multiple- vs. single-sourcing,
  - Single-, vs. multi-product models,
  - Static vs. dynamic models,
  - Deterministic vs. probabilistic models,
  - Models without and with routing options included.

One important way to measure the effectiveness of a facility location is by determine the average distance traveled by those who visit it: the P-median problems. So the focus is on minimizing only the travel distance or time for operating cost once a facility is located. A close relative to the P-median problem is the set of ‘fixed charge facility location problem’
that includes problems which have a fixed charge to locate each potential facility site and
the cost to run the warehouse. One model in this set the Uncapacitated fixed charge
Facility Location Problem’ (UFLP). The ULFP is formulated by adding a fixed cost to the P-
median objective function and removing the constraint that dictates the number of
facilities to locate and sites them so to minimize the total costs (so travel and running
costs).

Through facility location several questions should be answered:

- How should demand be allocated to the facilities?
- Is it allowed to split demand of a single point between several facilities?
- How many facilities should be sites
- Where should each facility be located?
- Which customers will be served by which facility?

The simplest model is the incapacitated, single-stage model (or ULFP). As mentioned in the
previous paragraph, this model considers the trade-offs between fixed operating and
variable delivery costs. The formulation of this problem mathematically is (Aikens, 1985):

\[
\text{Minimize } \sum_{i \in I} \sum_{j \in J} c_{ij} x_{ij} + \sum_{i \in I} f_i z_i
\]

Subject to

\[
\sum_{i \in I} x_{ij} = 1, \quad \forall j \in J
\]

\[
x_{ij} - z_i \leq 0, \quad \forall i \in I, j \in J
\]

or

\[
x_{ij} \in \{0,1\}
\]

\[
z_i \in \{0,1\}
\]

where

- \( x_{ij} \) = The proportion of customer j’s demand satisfied by facility i
- \( z_i \) = 1 if facility i is established, 0 otherwise
- \( c_{ij} \) = The total production and distribution cost for supplying all of customer j’s demand from facility i
- \( f_i \) = Fixed costs of establishing facility i
- \( I, J \) = The sets of candidate facility sites I and the set of customers J respectively

The UFL problem is to open a subset of facilities in order to minimize the total costs
(transportation costs and fixed costs of the facilities). Constraint set 1 requires that all demand
will be satisfied and constraint set 2 insures that customers are only served from open facilities. Furthermore constraint 3a or 3b can be chosen. Constrain 3a insures that customers can only be supplied by only one facility and when constrain 3b is chosen a customer can be supplied by several facilities. Finally constrain set 4 insures that the z value is binary, so a facility is or open or closed.

3.2.1.2 Solution methods

Linear Programming (LP) problems can be solved extremely efficient with methods and techniques available today (Hillier and Lieberman, 2001). A LP problem with abounded feasible region guarantee that a corner-point feasible solution exists that is optimal for the overall problem. This guarantee is the key to the efficiency of the simplex method. However the UFL and the Single Source Facility Location (SSFL) problems (is a special case of the capacitated facility location problem in which each customer can only be supplied from one facility) are generally more difficult to solve because some or all decision variables are integer or binary. Therefore for IP problems (Integer Problems) and BIP problems (binary variables, so only 0-1 variables) the ease of solving will decrease enormously because guarantee that a corner-point feasible solution exists that is optimal for the overall problem does not exists anymore. You might think that a pure IP or BIP problem with bounded feasible region has just a finite number of feasible solutions and therefore may seem to be solved relatively easy, but those finite numbers can be very large. For BIP problems with n-variables, there are only two choices for each decision variable: 1 or yes and 0 or not. Therefore for BIP problem with n-variables there are $2^n$ solutions to be considered ($2^n = \sum_{k=0}^{n} \binom{N}{k}$, with k the number of warehouses (Daskin, 1995)). Thus each time n is increased by 1, the number of solutions is doubled (called exponential growth). So facility location problems require exponential computation time $O(2^n)$ but when a number of facilities k will be fixed the problem reduces to $\binom{N}{k}$ possibilities (Owen and Daskin, 1998; Daskin 1995)) and will become solvable in polynomial time (this number is $O(N^P)$ for $P<<N$).Nevertheless this still requires high computation time for reasonable values of N and P. Such complexity issues have led to the development of sophisticated algorithms for solving this problem.

The solution methods to solve facility problems fall roughly into two broad classes, namely;

1. Approximations based on exact methods
2. Heuristics
The last five decades many researchers have worked both on exact algorithms and heuristic solutions problems. The problems UFLP and the capacitated CFLP problems (which have an extra capacity restriction for each warehouse) can be solved by exact algorithms and Branch and Bound methods but in some situations the exact methods may not be computationally feasible (especially large scale problems). In such case heuristic provide most of the time acceptable trade-off between computing effort and solution quality. In the next paragraph an overview of the exact methods to solve UFLP (and CFLP) will be given as the most important heuristics to solve easily and fast small problems or to solve large complex problems.

- **Exact methods**
  - Linear programming relaxation
  - Lagrangian relaxation
- **Heuristics**
  - Construction algorithms
  - Improvement algorithms

The heuristics can be subdivided into two groups: construction algorithms and improvement algorithms. A constructive algorithm attempt to build a good solution from scratch and an improvement algorithm tries to improve an initial solution again and again till no more improvements will be achieved.

There are two improvement heuristics that can be used for solving UFLP problems, namely the neighbourhood search heuristic and the exchange heuristic (e.g. the exchange heuristic begins with any set of facility sites and then search the best possible substitution before making any exchange (Daskin, 1995)) Those heuristics are used to solve efficiently P-median problems but for ‘fixed charge facility location problems’ those improvement algorithms will be less effective. The reason for this is that the improvement heuristic take an initial solution and therefore also the number of facilities given. If the number of facilities is sub-optimal it is possible to stick in a local optimum (in the P-median this could not happen because the number of facilities to locate was an input to the problem and not an output, this in contrast with UFL problems).

For UFLP problems better results can be obtained through using constructive algorithms. One of the earliest approaches (Aikens, 1985) to solve UFLP problems is heuristic development by Keuhn and Hamburger (1963). This approach consists of two parts: (1) the main program, which locates warehouses once at a time until no additional warehouses can be added to the distribution network without increasing total costs and (2) the ‘bump and shift routine’, entered after processing in the main program is complete, which attempts to modify solutions
arrived at the main program by evaluation the profit implications of dropping individual warehouses or shifting them from one location to the other. This algorithm employed the following three heuristics:

1. The best candidate locations will be near demand concentrations;
2. Near optimum results can be archived by opening warehouses once-at-a-time which produce the greatest costs savings for the entire system;
3. Only a small subset of all candidate locations needs to be investigated in order to determine the next warehouse to open.

So the idea behind the procedure of Keuhn and Hamburger is to locate warehouses once-at-a-time until no more warehouses can be opened without increasing total system costs. This result, and a few years later another heuristic was developed by Feldman et al. (1966) which works actually on the same method, in the two most well-known construction heuristics for facility problems:

- The ADD procedure (Keuhn and Hamburger, 1963) and (ADD stands for 'add')
- The DROP procedure (Feldmand, Lehrer and Ray, 1966). (DROP stands for 'drop')

Although the method to solve UFLP is a few decades old it still provides a strong foundation for much of the location theory research done to date. The only changes are that the complexity of the mix-integer problems increased to add more and more level of detail in the models.

In appendix H an complete overview is given of theory of the location and allocation models and their thought about these models with their pros and cons.

3.2.2 Skil's situation
The objective of most models found in the facility location literature is to minimize the total demand-weighted distance between customers and facilities. However this is not the driver for Skil. The 3PLs used to transport the tools to the end-customers use the country to deliver and the number of pallets or weight of a package to determine the price of a shipment. Therefore it is not needed, in the research, the exact location of each Skil end-customer to optimize the physical distribution structure and it will be possible to use the aggregation value on country level. The transportation costs will then only depend on the number of shipments between countries or within a country. As a result the total transportation costs and facility costs need to be minimized. So instead of minimizing the total distance, the transportation costs together with the facility costs have to be optimized.
3.2.3 Conclusions location-allocation model

To realize the optimization of a centralized structure for the situation of Skil a model is constructed which uses the ADD heuristic. The ADD heuristic is one of the most widely known heuristic and is still strong foundation for much of the location theory research done. Although in case of heuristic no guarantee exists that it would find an optimal solution, using exact methods is not a feasible option either. First, exact solution methods require more knowledge of linear programming and more sophisticated programs to solve those problems. Secondly when the problem becomes too large exact methods may not be computationally feasible.

For the situation of Skil the ADD heuristic will be a strong and usable tool to solve easily location problems if there are relatively few possible locations. The prognosis is that not many warehouses are needed through Europe to meet European demand. It is expected that between the 4 and 7 warehouses are needed where the savings on transportation costs to locate a warehouse in a specific country will be larger than the fixed costs of the extra warehouse. It is clear that in an optimal situation the second distribution centre, after Breda / Meer, the warehouse with the largest savings will be chosen first. In contract, the situation will be radically different if 50 warehouses should be located over more than thousand locations through a greedy heuristic, where once a decision is made, it will not be changed anymore. This is not the case and through the possibility to validate the ADD heuristic performance through checking whether the result of the ADD heuristic will be optimal or not the ADD procedure will be a suitable tool to use.

3.3 A generic framework to analyse a design of a physical distribution network

To propose an alternative physical distribution network design is it important to gain knowledge about the current logistical structure of a company. Many authors already discussed possible ways to analyze a physical distribution network. But these theories didn't covered completely the wanted analysis for this research. The core aspect to analyze a company is in the most theories the same only the connection between the information after the analysis with the use of the location-allocation theory was missing. Therefore a new generic framework is made, based on these theories, which can and will be used to analyze an organization. A stepwise research based of this generic framework provides the necessary information that is used as an input to come up with a possible physical distribution network design with the lowest supply chain costs.

In the first paragraph different methods of analyzing a design of a physical distribution network are discussed and the decisions on different levels are discussed. In this paragraph a conclusive
overview is given of the method that will be used for this research to analyse a design for a physical distribution network.

All authors mentioned in the first paragraph describes that it is important to know what the corporate strategy of a company is because this determines the eventual structure of the logistic basic form. Because based on the strategy of a company certain trade-offs in the logistic structure can be made. For instance accepting higher costs for warehousing and transport when a company wants to achieve a high service level. Van Goor et al. (1999) and Van der Velde et al. (2002) uses the model of Porter (1985) to define the corporate strategy of a company. Other authors don’t use such a clear model. So to define the corporate stargey Porter’s model will be used. Van Goor et al. (1999) also mentions that the logistic target must be clear so give direction for implementing different facets of the physical distribution network. This logistic target will be in the framework because it gives a clear understanding of the specific logistic target of the company.

After the strategy and target are clear different ways to analyse a design of the physical distribution network are explained. The authors uses different key words to name their procedures. The core process in all procedures is to gain more knowledge about the current logistical organisation. There is a need to analyse the current organisation to be able to understand the current logistic procedures and lay-out of the logistic network. With use of this information the physical distribution network can be projected on the objectives that the company wants to achieve in the future. Coyle et al. (2003) describes it as ‘perfrom logistic audit’, Van der Velde et al. (2002) describes it as to ‘analyze and map the processes of the as-is organization’ and Mourits et al. (1995) mentioned it as a first phase ‘Clarification of the task’.

In our framework this will be mentioned as ‘describing the as-is organization’. It is about analyzing the current logistic organization to gain better understanding of the company and the way the logistic procedures are shaped. In this step the logistic structure, the product characteristics, key customers & markets and the costs of the logistics processes must become clear. Van Goor et al. (1999) uses the relation between marketing, logistics and product characteristics to give insight into the possible impacts that the facets can have on the logistical network. This graph is also used to analyze the as-is organization because it gives a better understanding of the products that a company uses and their possible impacts on the logistic network.

Van der Velde et al. (2002) and Huizinga et al. (2000) describes that based on the previous analysis it must become clear where there are tensions or possible bottlenecks in the network. Other authors don’t talk in a clear sense about generating these tensions or bottlenecks. To be
clear what in particular will be investigated further on in this research a choice is made to describe what the tensions or bottlenecks are based on the analysis of the current organization. So a clearer search can be made to lower the logistics costs.

Huizinga et al. (2000) uses a scope as a supportive tools to give a clear overview of the aspects that will be included in when looking for an alternative design of the physical distribution network. Mourits et al. (1995) uses a second phase 'conceptual design' to describe to functions that need to be performed by the network. Hereby also an indication of the geographical distribution of the logistical function is given. In this research first a scope is formed to know what the aspects will be that a new design must perform. This will give a clear overview. After that alternative designs are presented with an estimation of costs will be given. Mourits et al. (1995) describes this as phase three 'embodiment design'. Coyle et al. (2003) mentioned in his method these steps as 'examine logistic network alternatives' and 'network / location decision making'. The 'conduct facility location analysis' is not taken in the framework because the locations of possible facilities are fixed.

Finally Coyle et al. (2003), Mourits et al. (1995) describes the step that an analysis have to be made about the possibilities to implement a alternative design. In the generic framework this will be presented as a discussion of the possibility to implement an alternative design.

3.4 Sub-conclusion

The aspects mentioned above are used to generate a generic framework to analyze a design of a physical distribution network. This generic framework is used as a criterion that will be used to analyze the organization of Skil. It can also be used for other companies to better understand the organization in depth in order to gain a clearer overview of their logistical procedures. When looking for a alternative network design this information is needed to be able to change aspects of the organization in order to adept to the future.

First it will be important that it is clear what the corporate strategy is of the company because this will be the starting point in structure the logistic basic form. As earlier mentioned the competitive strategy matrix of Porter's (Figure 16) could be used to get the strategy clear. Depending on this strategy also the target or objective what the company wants to achieve with the physical distribution network must become clear.

The next step will be to get a clear overview of the as-is organization. In this overview the logistical structure must be examined with the goods and information flow. The product characteristics must become clear. The key costumers and markets must be given and the costs for the main processes must be known. This information is used to know the organisation and
their product so that the (re-)design of the physical distribution network also fits the company culture. The analysis of the costs is made to search for bottlenecks or main cost drivers of the products. This information can be used as a point of interest when looking at the costs for the (re-)design.

After the as-is organization has been researched, the description of the problem for the future situation must become clear so that there could be a scope written of what the company wants to achieve with their new design. When the scope and the idea of the new design are formulated, the conceptual designs can be made in which the relevant costs can be calculated. For this design, the theory written in paragraph 3.2 about the location-allocation policy is used. With this new design, also called a conceptual design, the warehouse locations, inventory levels, and ways of transport must become clear. After the calculation of the costs of these designs, a discussion with the company experts can be started with the questions what the feasibility will be of these designs for Skil in the future.

The procedure schematically is given in Figure 19.
Figure 19 Generic framework of procedure analysing a design of a distribution network
The generic framework applied on SKIL Europe B.V.
In paragraph 3.1 the theory of analyzing a design of a physical distribution network is discussed. From this research it became clear that it is important that the current organisation is being researched in depth. Chapter 1 gave an short introduction of the company Skil. In this chapter a more in depth overview of Skil is given. This is done in the way that is discussed in paragraph 3.3. First the strategy and logistic target of Skil are given. In paragraph 4.2 the as-is organisation of Skil is described. For the description of this paragraph research has been done within the organisation of Skil and interviews are taken with persons of the logistical, financial department and marketing department.

4.1 Strategy of Skil and their logistic target

'Everything you need' is the brand promise of Skil. They try to reach that with two different kind of tools in two market segments in which they operate; the Do-IT-Yourself (DIY) market and the professional market. For each market Skil has a clear vision what they want to achieve and how they want to do that. By introducing the "House of Orientation" Robert Bosch GmbH tries to better understand the changes in the business division to secure their sustained competitiveness (Bosch, 2008.).

The strategy that Skil has, is to aim at the price oriented and convenience oriented pragmatic for the normal power tools and to at the pragmatic professional for the master tools. Skil sells not only a tool but provides a complete package of service. There are possibilities to order spare parts, ask questions via dealers or on the internet and there is a lot off information on the Skil internet site for the end-users regarding the Skil products. They compete in the DIY market with brands like Black and Decker and X-craft and in the professional market they compete with brands like Sparky, Protool, Kress, Worx, Maktec en supplement (often regional) brands. Skil sells tools that are 'easy to use, no-nonsense tools with the best price/ quality ratio and that provide an extra level of convenience that ensure a hassle free, quick result' (Skil, 2008A). The buying motives of the products are easy to describe. Every tool needs at least two or three of the buying motive that Skil identifies. These buying motives are Easy to use, Safety, Problem solver, Convenience, Get's the job done, Price and Versatile (Skil, 2008A). The position of the tools is on another market than the Bosch tools, better to be seen in Figure 20.
Positioning of our brands

<table>
<thead>
<tr>
<th>Occasional usage</th>
<th>Daily usage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Good quality</td>
<td>High quality/accuracy</td>
</tr>
</tbody>
</table>

Figure 20 positioning of Skil Masters (left) and Skil (right) (Skil, 2008A)

The answer how Skil positions there tools can be given with the use of porter's generic competitive strategy matrix (Porter, 1985). Porter distinguishes three kinds of competitive advantages: low cost, differentiation and focus. On the vertical axis in Figure 21 the relative perceptive value has been placed. This is to say the (quality) value of the company relative to the competition; the higher the position, the stronger the value of the products, the brand or the company. The integrated costs, related to the competition, have been placed on the horizontal axis.

Cost leadership means to aim at the lowest cost price and selling price possible for the product. A differentiation strategy aims at bringing a product to the market that in the eyes of the customer has unique values and differs from the products of the competition. These differentiation points are relative; relative to the competition and relative to the customers' needs. This strategy is always aiming at improving customers' satisfaction and customer loyalty. The last strategy is a differentiation or cost leadership strategy focused on a small group of customers only. This means that there is in depths focus on customers (often individual).
For Skil this means that after interviews with several persons of the marketing department and looking at the brand values for the Skil and Skil Master Tools and their product characteristics, Skil aims at a strategy in the middle of Focus and Differentiation. Their aim in the market is to set tools with specific differentiations, like easy hand-grips, and different kind of safety measures, for their tools but against relative low costs. They try to combine these two different market strategies. They say that their products are the most attractive A-brand products due to their admitted quality (Skil, 2008A) and relative low price.

The next issue to describe is what the logistic target of Skil is. For Skil it is important to keep the costs as low as possible but with a minimum service level target set by the management. To formulate the target Skil uses performance metrics. Skil has identified many different key performance indicators (Bosch, 2006). The most important drivers for the logistic department are four key performance indicators (KPIs). These KPIs are service level, the value of the finished goods inventory, the total coverage in days and the supply chain costs. These KPIs are set by the BOSCH group at higher managerial level. The management uses these KPIs as a tool to control and check the business units. In Table 6 the target values of these KPI’s are given till 2011.

Table 6 key performance indicators logistics organization Skil (Skil, 2008A)

<table>
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<tr>
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<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Service level 1: availability [%]</td>
<td>≥ 96,5%</td>
<td>97%</td>
<td>98%</td>
<td>98%</td>
</tr>
<tr>
<td>Finished goods; Avg inventory [Mio EUR]</td>
<td>18.970</td>
<td>19.100</td>
<td>19.680</td>
<td></td>
</tr>
<tr>
<td>Total Coverage (GEZ)(days)</td>
<td>74 days</td>
<td>70</td>
<td>67</td>
<td>64</td>
</tr>
<tr>
<td>Supply chain costs [% NGU]</td>
<td>≤ 14,6%</td>
<td>≤ 14,9%</td>
<td>≤ 13,6%</td>
<td>≤ 12,9%</td>
</tr>
<tr>
<td>NGU [Mio EUR]</td>
<td>100</td>
<td>97.0</td>
<td>102.0</td>
<td>110.0</td>
</tr>
</tbody>
</table>

The calculation of these metrics is done with use of the logistical information systems. This system generates the metrics conform calculation models. The management of Robert Bosch GmbH and Skil has the possibility to generate these KPIs when needed.
4.2 As-is organisation

In this paragraph the current situation of Skil will be described using the elements earlier mentioned in paragraph 3.3. The following elements will be handled in the next different sub-paragraphs, first the logistic structure of the company will be described in detail. Then the customers and where they are settled is described and finally the product characteristics are mentioned.

4.2.1 Logistic structure

For the physical distribution network the basic logistic form is one of the most important subjects. The basic logistic form describes the primary processes of producer to customer, the locations of the customer-order-decoupling-points and the goods flow between processes and inventory point (Van Goor et al., 1999). There are several basic forms that a company can have to structure a company (see Figure 22).

![Figure 22 seven basic forms (Van Goor et al., 1999)](image-url)
Skil combines different forms to structure their basic form. In Figure 23 this basic structure can be seen. Skil uses the warehouse in Breda / Meer as their main warehouse from which finished goods are distributed direct to local warehouses that performs in different countries. These warehouses are used in some cases as national warehouses for domestic shipments or as international warehouses that also distribute to customers in other countries. The warehouse in Breda / Meer is also used to perform value added activity that is called postponement. Their they transform part numbers with use of accessories to other part numbers. The warehouse in Germany also performs the task of international distribution centre. From this place distribution to customers or other local warehouses takes place.

![Diagram of warehouse structure](image)

**Figure 23 structure basic form Skil**

The three main processes in this basic form are inventory management, warehouse management and transport management. These three processes are described in the following sub-paragraphs.

4.2.1.1 Warehouse

Skil uses warehouses at different locations in Europe. Appendix I gives an overview of the used warehouses and the distribution flow from warehouse to warehouse and to which countries. The only warehouse that is owned by Skil is the warehouse in Breda. The other warehouses are owned by an external company, but are rent by the Robert Bosch GmbH group or the CSO. In Meer, Belgium, the warehouse is rent from an external company named Ouweland. The
warehouse in Romania, Greece, Latvia and Bulgaria are rent by the CSOs and the warehouses in Germany, Denmark, Spain, Italy, Great-Britain, Poland, Hungary and Finland are rent by the Robert Bosch GmbH company. These warehouses are mainly dedicated for the use of the Robert Bosch GmbH group or the CSOs. When Skil uses these warehouses they are charged for the service and space used.

The warehouses in Meer, Belgium, and Worms, Germany, are the main warehouses, also called rough distribution warehouses, from which the distributions of the most of goods to the local warehouses or costumers take place. The local warehouses, also called fine distribution warehouses, are used to distribute goods to the costumers in the different affiliated countries.

In the warehouse of Breda mainly bulk tools and accessories which are needed for postponement are stored. These goods are necessary to produce certain part numbers within a certain time period depending on the forecast of the part numbers. The finished goods are transported to the warehouse in Meer for further distribution or directly transported to local warehouses. In Meer there are finished goods but also bulk tools stored, which stand ready to be called for Breda for postponement. Meer is also a bounded warehouse were Skil can store goods for further distributions outside Europe. The reason to use a 3Pl for warehousing is that it gives Skil flexibility of storing tools in the warehouse when needed in Meer.

The warehouse in Worms is the international distribution warehouse of Robert Bosch GmbH from where most of the other business units sent there good through to local warehouses in Europe. The local warehouses owned by the CSO or Robert Bosch are used by Skil because they are connected to the fine distribution to the costumers.

4.2.1.2 Inventory

Inventory of goods are found in different locations. There is inventory at the local warehouses and Worms which are under responsibility of the distribution managers. They try to keep this inventory as low as possible with the use of an inventory management system. In order to control the inventory at local warehouse the distribution managers keeps a re-order point. The most important fact to keep inventory at this level is to assure that goods can be delivered and that it will not afflict the service level 1: availability.

The inventory in Meer and Breda are a responsibility of centre logistic planners. They control this inventory also with the use of inventory management system and make sure there is at least a safety stock available of certain part numbers that are fast moving so that these part numbers can be delivered to local warehouses when there is actual demand within lead time of these part numbers.
4.2.1.3 Transportation

Three modes are used to get the goods from the suppliers to the customers via the different warehouses. The first stage from supplier to the main warehouses in Breda and Meer mainly intermodal transport is used with sea transport from the ports in China to the port of Rotterdam and from there with road transport to the warehouses. Skil uses a forwarder who arranges this transportation and all additional regulations. This transport is done under FOB conditions. In exceptional cases air transport is used when certain goods are needed on short notice hereby forwarders are also responsible. The transportation from the factory in Hungary is done by road under ex works conditions.

The rest of the transportation between the warehouses is done by road transport. The transportation from Breda and Meer to Worms or local warehouses is arranged by Skil and outsourced to a selected 3Pl (rough distribution). The transportation between Worms and the local distribution centre is arranged by Robert Bosch GmbH and they charge Skil for incurrent costs (rough distribution). The final stage from the transportation from local warehouse to the customers is called fine distribution. This is also for some deliveries from IDC Worms to customers. Therefore Skil is also charged. This fine distribution is outsourced to a 3Pl, like TNT, DHL or UPS.

This way of producing and ordering means that the actual customer-order-decoupling-point lays at the warehouse were the specific finished goods are stored. in Figure 24 this COPD is put in the logistic structure of Skil. The reason that there are two CODP is that because the warehouse in Germany as well as other local warehouses distribute to customers in the countries. This means that the CODP lies at the warehouse from where the deliveries to the customers take place. Having a CODP at this place means that a safety and replenishment stock need to be kept at these places in order to meet the service level demand of Skil. Having stock at these places will result in higher costs for keeping inventory and handling part numbers at these warehouses.
Figure 24 Costumer Order Decoupling Point

The average lead time of these procedures will be seen in Figure 25. A remark for this figure is that the average lead time for transportation to local warehouse depends on the destination of the local warehouse. In appendix J an overview of the average lead times is given from the central warehouse to IDC or LDC. Lead time in this case is from ordering in the system till the order is booked into the system that the part numbers are received.

Figure 25 average lead time product (calculation MRP Lead time (working days)) (min 65 days / max 75 days)
4.2.2 Customers

The customers for Skil in this research are the stores who sell the products of Skil. Via these stores Skil tries to reach the end-users which are the clients with the buying motives Skil as set. An indication of how important the product for the customer is can be determined with the reversed version of the procurement matrix of Kraljic (Figure 26) introduced by Van der Velde et al. (2002).

![Figure 26 Reversed procurement matrix of Kraljic (Van der Velde et al., 2002)](image)

The strategic value is measured by criteria; like added value, percentage of value of delivered products on the cost price of the end product of the customer, influence of the products on the productivity of the customer. Market complexity is measured by criteria like the structural scarcity of the products on the market, the speed of technology development, the existence of entry barriers for new producers in the market, etc. Kraljic (2002) distinguishes four types of products: Commodity products, added value products, bottleneck products and strategic product. As earlier mention Skil has two target groups, the price oriented pragmatic and the convenience oriented pragmatics, which uses the tools to turn his / her house into a home. These product are 'hot' and relevant industrial design, low-cost innovations, competitive quality and of good value. The other are pragmatic professionals, within small companies (< 5 employees) who use a wide range of power tools occasionally for a variety of specific jobs in which the tools have to be dedicated and have a relevant industrial design, need relevant innovations, have competitive quality, are of good value and are robustness. Looking at the reversed procurement matrix the tools of Skil are commodity products situated in the upper regions of this square because they have an innovative character with a good quality.
This means that the product that Skil has don't have a huge strategic value for the home improvements centres and that Skil needs to be innovative at their way to keep the market share at all tie. The positioning of Skil in the market isn’t so strong that they can’t have specific demands to their customers. The demands of the customer are very important for Skil and Skil tries to meet their demand in order to keep their connections with the costumers as good as possible. Therefore the KPI of service level is very important for Skil.

4.2.3 Product characteristics

The product characteristic can be given in broad term and in narrow term like Figure 27 displays. These characteristics determine if the structure of the logistic network chosen by the company fits the efficient distribution of the products. For this research the characteristics are given but a benchmark with other companies to look if they use the same kind of logistic structure hasn’t been performed.

![Diagram of product characteristics and related processes]

Figure 27 Relation marketing, logistics and product characteristics (Van Goor et al., 1999)

The product characteristics in broad term are discussed in paragraph 4.1. the product characteristics in narrow terms will be discussed in this sub paragraph and at the end the conclusions for the distribution system of these characteristics will be discussed.

The product characteristics in narrow terms are distinguished in 5 characteristics, the value density, preservability, packaging, appearance and volume weight ratio. These product characteristics are given in appendix K.
4.3 Sub-Conclusions

First it will be important that it is clear what the corporate strategy is of the company because this will be the starting point in structure the logistic basic form. As earlier mentioned the competitive strategy matrix of Porter's (Figure 16) could be used to get the strategy clear. Skil uses a strategy which lies in between the focus and differentiation. This is remarkable because the theory gives that the best way of getting a good market positioning for their products a clear corporate strategy must be chosen. In this case Skil doesn't make a clear choice regarding the integrated costs. They don't want to be the lowest because that will mean less service or lower marketing budgets. But it can't get higher costs because than they will enter the Bosch tool markets. The logistic target Skil has is to eventually get a service level of 98 % with the supply chain costs [% of Total Net Sales] below 13 % in 2011.

The next step will be to get a clear overview of the as-is organization. Skil uses different warehouses in Europe to distribute their products from the main warehouse in Breda / Meer to the customers in the 37 countries. These warehouses are affiliated to the customers in the countries. Skil keeps inventory in these warehouse at a level that the service level will be met. Therefore the CODP are lying at these warehouses. The products between the warehouses are transported by a carrier which uses mainly truck loads. The transport of products is divided in rough distribution (warehouse to warehouse) and fine distribution (warehouse to customer) and done in all cases by a 3PL. Due to the fact that the lead times are rather long (65 - 75 days), the CODP lies that far in the logistic chain the costs and the service level target is 98 % it means that probably a lot of costs are at transport and inventory. The strategic value of the product of Skil and their complexity aren't that high, which means that Skil is keen on meeting the customers demand.

With use of the costs analysis made in the next chapter a scope will be formed which will present the requirements. These requirements presents the objectives and boundaries for a alternative design.

This alternative design will be made using a location-allocation model. This model is constructed to optimize the logistic structure of Skil in terms of costs. For the situation of Skil a model is constructed which uses the ADD heuristic. The ADD heuristic is one of the most widely known heuristic and is still strong foundation for much of the location theory research done. Although in case of heuristic no guarantee exists that it would find an optimal solution, using exact methods is not a feasible option either. First, exact solution methods require more knowledge of linear programming and more sophisticated programs to solve those problems. Secondly when the problem becomes too large exact methods may not be computationally feasible.
For the situation of Skil the ADD heuristic will be a strong and usable tool to solve easily location problems if there are relatively few possible locations.

4.3.1 Progression in the generic framework

To gain more sight of the progression in this research the generic framework is used to guide the reader better and to give a quick and clear overview of what has been done.

This chapter provided the overview of the generic framework and it also started to analyse the as-is situation of Skil (see Figure 28). The only aspect that hasn’t been done yet in the analysis of the organisation is the cost analysis. This will be done in the next chapter.

Figure 28 progression in the generic framework
5 Logistic costs in a distribution network
For this research the supply chain costs are very important. But where do these supply chain costs occur and how can these be assigned to the right activities so that there will become a clear overview of the supply chain costs of the physical distribution network?

This chapter provides the theory of the supply chain costs in a network in general, explained in paragraph 5.1. In paragraph 5.2 the structure and the calculated costs for Skil are described. These calculated costs will be used in this research to analyze the cost situation within Skil. Also the structure of calculating the costs will be used in the location-allocation model to calculate the costs.

The physical distribution network consists of three main processes; these are inventory control, warehouse & material handling and external transport. These three processes determine also the main costs within physical distribution (Van Goor et al., 1999; Chopra, 2003). These processes determine how the costs are divided in the logistic network and are further explained in the next paragraph.

5.1 Logistic Cost drivers

To get a clear overview of the costs made in the physical distribution it is important that the costs are allocated to the right activities, also called activity based costing (Van Goor et al., 1999; Huizinga et al., 2000). First there is a need to distinguish activities. The activities within physical distribution are mainly transport, inventory and warehouse & handling. For these activities cost drivers need to be distinguished. The cost drivers that can be distinguished are transport, handling in, handling out, storage and interest. The idea is to account these cost drivers to the activities. For these cost drivers parameters need to be given. For this research the following diversion is made, seen in Figure 29. This diversion is made to keep the structure of costs consistent with the way the financial department of Skil analysis their costs (see appendix F). Finally tariffs are assigned to the parameters. The parameters differ in the case of transport and goods out / packaging. This depends on the position of the goods in the logistic chain. By structuring the costs this way an aggregated overview can be made of the physical distribution costs. With the cost drivers eventually the logistic costs performance indicator can be filled in.
Within the Skil logistic organization the following costs can be determined like Figure 30 will show. For this research there are transport cost, inventory costs and warehouse & handling cost on the outbound side.

Now there will be an explanation of which components the different costs consists of. First the total physical distribution costs is explained, further on the transportation costs, the inventory costs and finally the warehouse & handling costs are explained. In this paragraph only the main equations for the calculation are given. Further explanation and specification of the method of calculating different costs are given in the mentioned appendices.
The physical distribution costs consists of the three activities given in Equation 2.

**Equation 2 Physical distribution costs**

<table>
<thead>
<tr>
<th>Physical distribution Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>$TC = T + I + W$</td>
</tr>
<tr>
<td>$TC = \text{Total costs in physical distribution (euro/year)}$</td>
</tr>
<tr>
<td>$T = \text{Transport (euro/year)}$</td>
</tr>
<tr>
<td>$I = \text{Inventory cost (euro/year)}$</td>
</tr>
<tr>
<td>$W = \text{Warehouse &amp; handling cost (euro/year)}$</td>
</tr>
</tbody>
</table>

5.1.1 Transport

For transport costs there is one cost drivers, namely transport. For the transport from the main warehouse to the IDC or LDC’s the parameters are ‘pallets’. For the transport from IDC or LDC to customers in the affiliated countries the parameter is ‘gross weight of the delivery’. The transport to the IDC or LDC is also called rough distribution and the transport from the IDC or LDC to the costumers in the affiliated countries is called fine distribution. The totals transport cost is the sum of the total costs of the rough and fine distribution. The time period is for a year (Equation 3). For specifications of the transport cost rough distribution see appendix L and for fine distribution see appendix M

**Equation 3 Transport cost**

| $T = T_{\text{rough}} + T_{\text{fine}}$ |
| $T_{\text{rough}} = \text{total transport costs for rough distribution (euro / year)}$ |
| $T_{\text{fine}} = \text{total transport costs for fine distribution (euro / year)}$ |

5.1.1.1 Transport costs rough distribution

The transport of the goods from the main warehouse to the IDC or LDC’s is outsources to 3PL and fix contracts are made with these 3PL for transporting to the different LDC in the different countries. The contracts make a diversion in transport with a full truck load (FTL) rate or a less truck load (LTL) rate. A FTL is an amount of pallets, depending on the turn-over-point calculated with the prices for a pallet or a full truck load (see appendix L). All shipments below the turn-over-point, in terms of pallets, is a LTL. For a FTL there is a fixed price and for LTL there is a price per pallet. An overview of these prices and 3PL’s to which countries can be seen in appendix N.
5.1.1.2 Transport costs fine distribution

For the calculation of the transport from IDC or LDC to the customers in the affiliated countries a different parameter is used due to the fact that there are many customers in a country which have to be delivered with the tools that are ordered. The costs made by these distribution centres are normally calculated by the Bosch organisation and they charge Skil for the incurred costs they made to deliver the tools to the customers. The Bosch organisation calculated these transport costs based on delivery type and gross weight. To be able to calculated this costs in this research only the gross weight of general cargo is used, which mean that depending on the weight of a delivery a transport price is charged.

5.1.2 Inventory costs

The inventory costs consist of costs for keeping inventory in the warehouse. Inventory in transit is not taken into account because the time in transit at the outbound side is often too low which infects the inventory cost with a minimum. The inventory in warehouses is stock that lies as safety stock and replenishment stock to cope with the fluctuations in the demand of customers and consists of capital charges. In appendix 0 the specifications of this calculations are given. The parameters used for this calculation is the capital charge on the value of a part number in the logistic chain.

\[
I = S_{\text{tot}}
\]

\[
I = \text{Inventory costs (euro/year)}
\]

\[
S_{\text{tot}} = \text{Total stock costs (euro/year)}
\]

5.1.3 Warehouse & handling costs

The warehouse & handling cost consists of handling cost and storage costs (Equation 5) The handling costs consist of the following parameters; the number of pallets, delivery lines or pieces handled in the warehouses (Equation 15). Which parameter is used depends on the location of the goods in the logistic chain. The storage costs are the costs for keeping the pallets in the warehouse for a certain amount of time (Equation 16)(see appendix P). The fixed warehouse costs are not taken into account in this research because Skil only bears variable costs for the warehouses.
Equation 5 Warehouse & handling costs

\[ W = H_{\text{total}} + S_{\text{total}} \]

\( W \) = Warehouse & handling costs (euro/year)

\( H_{\text{total}} \) = Handling costs (euro/year)

\( S_{\text{total}} \) = Storage costs (euro/year)

5.2 Logistics Costs for SKIL Europe B.V.

As earlier mentioned the costs for warehousing, inventory and transportation determine a great deal of the supply chain costs. In Table 7 an overview of these costs is given divided into three main elements of the logistic process, the source side, the make side and the deliver side. Within these elements a separation is made based on activity based costing which lead to a maximum of 7 activities and only three are given; transport & packaging, warehouse & handling and inventory. The complete overview of all cost is given in Appendix F.

Table 7 Costs for warehousing, inventory and transportation Skil Europe B.V. (Skil, 2008B)

<table>
<thead>
<tr>
<th></th>
<th>2008</th>
<th></th>
<th>Share costs NGU</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cost [TUR]</td>
<td>Share</td>
<td></td>
</tr>
<tr>
<td>Source</td>
<td></td>
<td>costs</td>
<td></td>
</tr>
<tr>
<td></td>
<td>total</td>
<td>3.238</td>
<td>3,9%</td>
</tr>
<tr>
<td>Transport &amp;</td>
<td>Var</td>
<td>3.238</td>
<td>3,9%</td>
</tr>
<tr>
<td>packaging</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Make</td>
<td>total</td>
<td>1.468</td>
<td>1,8%</td>
</tr>
<tr>
<td>Transport &amp;</td>
<td>Var</td>
<td>1.468</td>
<td>1,8%</td>
</tr>
<tr>
<td>packaging</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Warehouse &amp;</td>
<td>Fix</td>
<td>225</td>
<td>0,3%</td>
</tr>
<tr>
<td>handling</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Var</td>
<td>596</td>
<td>0,7%</td>
</tr>
<tr>
<td>Inventory</td>
<td>Var</td>
<td>647</td>
<td>0,8%</td>
</tr>
<tr>
<td>Deliver</td>
<td>total</td>
<td>9.728</td>
<td>11,7%</td>
</tr>
<tr>
<td>Transport &amp;</td>
<td>Var</td>
<td>9.728</td>
<td>11,7%</td>
</tr>
<tr>
<td>packaging</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Warehouse &amp;</td>
<td>Fix</td>
<td>2.712</td>
<td>3,3%</td>
</tr>
<tr>
<td>handling</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Var</td>
<td>1.523</td>
<td>1,8%</td>
</tr>
<tr>
<td>Inventory</td>
<td>Var</td>
<td>1.529</td>
<td>1,8%</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>14.434</td>
<td>17,4%</td>
</tr>
<tr>
<td>NGU</td>
<td>[Mio. EUR]</td>
<td>83</td>
<td></td>
</tr>
</tbody>
</table>

The main costs on the source side are at the transport & packaging activities and on the deliver side also with transport & packaging. This activity is variable because Skil has no fixed assets
for transportation and it depends on the demand of the customer which goods eventually have to be transported from supplier to customer. Also on the deliver side the warehouse & handling represents an amount of 5.1% of the supply chain costs. Overall on the costs on the deliver side are 11.7% of the supply chain costs from a total of 17.4% overall. These 17.4% are of the total net sales (NGU).

These are the actual costs and are calculated by the financial department of Skil. These figures can be used to make a comparison with the costs calculated by the reference model that will be used in this research.

All tables, figure and diagrams shown further on in this report or appendices are the result of own calculations and analysis of the costs calculated with the use of the equations of paragraph 5.1 and related appendices

5.2.1.1 Use of data set

When starting to make the cost analysis with the reference model the main question arise which data is needed to calculate the cost of Skil using the equation from paragraph 5.1. Skil uses a SAP system and three other systems in which the data needed are stored. These different systems are needed because not all sale countries are adapted to one single information system. For example, the warehouses rent by Bosch are connected to the SAP system, but the warehouses rented by the CSO's are not connected to SAP. So for this example the sales data has to be generated from two different systems. Also the question arise which data set in which form can be used to calculate the current costs with the reference model.

The data set is needed to calculate the costs of the current organisation and to calculate the costs of the alternative network designs further on in this research. These alternative designs might be for the future so a forecast has to be made of the data that will be used. In order to be able to make a good forecast at least figure of one year are necessary and when possible two year. With the use of the information systems that Skil uses figures over the last two year were available. So the choice is to take the data set over the last two years, from Jan 2007 till Dec 2008, to make a reliable forecast.

Due to the great number of different part number Skil uses a search for the most important part number is made. For this comparison the Pareto rule is used. First an analysis of the sales figures of product groups was made. Product group are a number of tools together with more or less the same users function. From analysis it appears that the Pareto rules did not matched. There is no clear distinguishing of 20% of the tools that make 80% of the sales. So using the product groups wasn't useful. The reason for this is that within the product groups there are
tools that don’t sell a lot over the year. From this analysis it became clear that the research had to be based on the individual part numbers to make a good analysis of the costs. Over the last two year Skil used more than 1200 different part numbers.

As a start the demand of all part numbers over the last two years is taken. Due to the different information systems it takes too much time to get the demand of all countries on daily or weekly basis, so the demand pro month is taken. This is means that some adjustments had to be made for the calculations. Although transportation to the different distribution centre is done every week this will be no restricting for calculating the costs in a proper way that will reflect the actual costs.

For this research a start was made with sales data of the part numbers that were transferred to the different distribution centres. When calculating the different costs and understanding the distribution network the conclusion was made that these data wasn’t sufficient enough for the development of a redesign of the distribution network. For the redesign also the demand of the customers in the different countries most become clear to be able to forecast the demand and design the distribution network as whole. Therefore the demarcation of this research was adjusted as described in paragraph 2.4. After this conclusion a new set of data was generated from Skil’s information system and turned into the right format for the use of calculation the costs. This data set is used with the equations of paragraph 5.1 for calculation the costs of the current organisation. In the next sub-paragraphs these costs are discussed.

For the calculation of the safety and replenishment stock needed in each of the warehouses the starting point is the demand of each country with a constraint of at least a service level of 98%. For the calculation of service level 1: availability the number of fully order lines delivered divided by the number of order lines required is calculated. For this research the data set that is used is the demand each month for the individual part numbers in each country. For the calculation of this KPI a translation has to be made with the average number of part numbers pro order lines and the average order line pro month. When this ratio is clear the inventory can be calculated the right way with the use of the service level percentage to reach. In this research the service level is not an output of the logistic structure but it is an input and a constraint set be the management so that is becomes clear what the logistic costs are holding on to this constraint of service level: availability of 98%.

5.2.1.2 Transport costs

For the calculation of the total transport cost a distinction is made between rough distribution and fine distribution. The rough distribution is from the main warehouse in The Netherlands to
the different warehouses in the other European countries. The fine distribution is from these warehouses to the affiliated countries. For the calculation of the transport costs the data from appendix Q is used. This data is available in part numbers sold to customers pro month pro country.

'Rough Distribution'

For the rough distribution Skill normally delivers on a weekly base. So a remark is on its place that these costs calculated don’t reflex the actual situation completely. For the calculation of the transport costs rough distribution the total numbers of part numbers are converted to number of pallets. This is done by every part number individually because the packages of most part numbers have different dimensions and therefore the total numbers of part numbers on one pallet differs. With the calculation it becomes clear how many pallets pro month there need to be transported to the IDC or LDC’s to cope with the demand of the costumers. The number of items and pallets used for the calculation of rough distribution are given in appendix R. A complete overview of the transport costs for rough distribution for 2007 and 2008 from the warehouse Breda / Meer to the LD’s are given in appendix R. The total costs for the rough distribution in 2008 was an amount of almost 1.526.950,- Euro (see Table 8).

<table>
<thead>
<tr>
<th>Warehouse</th>
<th>Year 2007</th>
<th>Year 2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>IDC Germany</td>
<td>€ 429,177.67</td>
<td>€ 260,253.93</td>
</tr>
<tr>
<td>211G Great Britain</td>
<td>€ 80,302.08</td>
<td>€ 40,067.08</td>
</tr>
<tr>
<td>211N Denmark</td>
<td>€ 103,472.20</td>
<td>€ 77,997.20</td>
</tr>
<tr>
<td>211P Spain</td>
<td>€ 211,500.47</td>
<td>€ 150,646.60</td>
</tr>
<tr>
<td>211T Italy</td>
<td>€ 148,765.07</td>
<td>€ 82,597.23</td>
</tr>
<tr>
<td>211L Poland</td>
<td>€ 133,901.30</td>
<td>€ 131,720.33</td>
</tr>
<tr>
<td>LDC Romania</td>
<td>€ 169,715.00</td>
<td>€ 134,244.50</td>
</tr>
<tr>
<td>211H Hungary</td>
<td>€ 111,399.60</td>
<td>€ 104,622.27</td>
</tr>
<tr>
<td>LDC Greece</td>
<td>€ 233,220.00</td>
<td>€ 166,902.67</td>
</tr>
<tr>
<td>211F Finland</td>
<td>€ 85,458.75</td>
<td>€ 64,086.75</td>
</tr>
<tr>
<td>LDC Bulgaria</td>
<td>€ 104,570.70</td>
<td>€ 72,791.77</td>
</tr>
<tr>
<td>LDC Latvia</td>
<td>€ 344,205.33</td>
<td>€ 241,037.33</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>€ 2,155,688.17</strong></td>
<td><strong>€ 1,526,949.67</strong></td>
</tr>
</tbody>
</table>

Table 8 Transport Cost Rough Distribution

'Fine distribution'

For the fine distribution Skill uses different carrier in Europe for direct shipments to deliver the next day from the LDC’s to the end-customer. The main carrier Skil is using in Europe is DHL. DHL distributes the packages from the warehouses to the end-customers. But for the input of the model the transportation costs of UPS are used. For DHL only a few cost figures from the warehouse of Germany to six countries are known. The others numbers couldn’t be retrieved due to confidentiality. Also a search on the internet didn’t give these prices. After contact with
DHL about their prices from the different warehouse countries to all other European countries these still weren't available. From UPS the transport costs needed were available. So the cost of transport from UPS are used to calculate the transport costs fine distribution. These prices are of the service that UPS will deliver within 24 hours at required destination. These 24 hours are set by the management of Skil.

First the standard price from and to the different countries will be determined before a standard discount for national and international shipments because of the good price agreement between Skil respectively Bosch, will be applied. This discount is not known or is so confidential that for this research the discount of the agreement could not be used. So the calculations made are with the full prices of UPS. Eventually a discount percentage is calculated at the end when comparing the calculated figures with the figures from the financial department. These prices depend on the total weight per packages. These packages consist in most cases of shipments from different business units from Robert Bosch GmbH, like the Skil tools, the Dremel tools, Bosch Green tools and Lawn and Garden. The Bosch organisation will pay for the shipment and Skil is charged by Bosch for the % of weight that was in the total packages was Skil Tools. For the research this way of calculation is not possible because a clear trend or rule of thumb couldn't be formed as said by the financial department of Skil. This couldn't be verified by data because data from shipments from LDC to customers of other business units are confidential and weren't available.

For this research the way of calculating the fine distribution costs are based on the prices per weight of shipment. These prices differ from 0,5 to one kg's. For this research a diversion is made between bigger brackets of kg so it will fit the model of calculation, otherwise it would become too complex. The average price of these brackets is calculated (see appendix S). For every shipment with a weight higher than 70 kg's an additional charge is made for every kg. This is also done in the calculation of the transport costs fine distribution.

The prices charged by UPS are taken from the official web sites of UPS in the different countries in which a warehouse is situated (UPS, 2009). For every different country with a warehouse different prices are charged to the different European countries. These European countries are put in so called zones (UPS, 2009)(see appendix T). The costs are given in Table 9. For a complete overview of the calculated cost fine distribution see appendix U.
Table 9 Transport Cost Fine distribution

<table>
<thead>
<tr>
<th>Warehouse</th>
<th>Year 2007</th>
<th>Warehouse</th>
<th>Year 2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>Germany</td>
<td>€ 16,378,179,23</td>
<td>Germany</td>
<td>€ 13,671,530,30</td>
</tr>
<tr>
<td>Great Britain</td>
<td>€ 552,680,96</td>
<td>Great Britain</td>
<td>€ 233,287,13</td>
</tr>
<tr>
<td>Denmark</td>
<td>€ 2,166,682,60</td>
<td>Denmark</td>
<td>€ 1,585,946,63</td>
</tr>
<tr>
<td>Spain</td>
<td>€ 1,267,616,49</td>
<td>Spain</td>
<td>€ 904,787,09</td>
</tr>
<tr>
<td>Italy</td>
<td>€ 740,174,06</td>
<td>Italy</td>
<td>€ 532,715,83</td>
</tr>
<tr>
<td>Poland</td>
<td>€ 826,017,16</td>
<td>Poland</td>
<td>€ 875,511,81</td>
</tr>
<tr>
<td>Romania</td>
<td>€ 162,600,41</td>
<td>Romania</td>
<td>€ 150,871,21</td>
</tr>
<tr>
<td>Hungary</td>
<td>€ 841,030,68</td>
<td>Hungary</td>
<td>€ 857,201,29</td>
</tr>
<tr>
<td>Greece</td>
<td>€ 559,621,13</td>
<td>Greece</td>
<td>€ 492,658,35</td>
</tr>
<tr>
<td>Finland</td>
<td>€ 193,635,06</td>
<td>Finland</td>
<td>€ 163,186,80</td>
</tr>
<tr>
<td>Bulgaria</td>
<td>€ 897,015,82</td>
<td>Bulgaria</td>
<td>€ 699,447,50</td>
</tr>
<tr>
<td>Latvia</td>
<td>€ 3,538,472,50</td>
<td>Latvia</td>
<td>€ 2,580,392,64</td>
</tr>
<tr>
<td>Total</td>
<td>€ 28,123,726,11</td>
<td>Total</td>
<td>€ 22,747,536,53</td>
</tr>
</tbody>
</table>

‘Total Transport Cost’

The total transport cost is the sum of the fine distribution costs and the rough distribution costs. This will give the following result seen in Table 10. In appendix V the results for 2007 and 2008 with the fine distribution costs and rough distribution costs are given.

Table 10 Total Transport Cost

<table>
<thead>
<tr>
<th>Warehouse</th>
<th>Year 2007</th>
<th>Warehouse</th>
<th>Year 2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>IDC Germany</td>
<td>€ 16,807,357</td>
<td>IDC Germany</td>
<td>€ 11,931,784</td>
</tr>
<tr>
<td>211G Great Britain</td>
<td>€ 632,983</td>
<td>211G Great Britain</td>
<td>€ 273,354</td>
</tr>
<tr>
<td>211N Denmark</td>
<td>€ 2,270,155</td>
<td>211N Denmark</td>
<td>€ 1,663,926</td>
</tr>
<tr>
<td>211P Spain</td>
<td>€ 1,479,117</td>
<td>211P Spain</td>
<td>€ 1,055,434</td>
</tr>
<tr>
<td>211T Italy</td>
<td>€ 888,939</td>
<td>211T Italy</td>
<td>€ 615,313</td>
</tr>
<tr>
<td>211L Poland</td>
<td>€ 959,918</td>
<td>211L Poland</td>
<td>€ 1,007,232</td>
</tr>
<tr>
<td>LDC Romania</td>
<td>€ 332,315</td>
<td>LDC Romania</td>
<td>€ 285,116</td>
</tr>
<tr>
<td>211H Hungary</td>
<td>€ 952,430</td>
<td>211H Hungary</td>
<td>€ 961,824</td>
</tr>
<tr>
<td>LDC Greece</td>
<td>€ 792,841</td>
<td>LDC Greece</td>
<td>€ 659,561</td>
</tr>
<tr>
<td>211F Finland</td>
<td>€ 279,094</td>
<td>211F Finland</td>
<td>€ 227,274</td>
</tr>
<tr>
<td>LDC Bulgaria</td>
<td>€ 1,001,587</td>
<td>LDC Bulgaria</td>
<td>€ 772,239</td>
</tr>
<tr>
<td>LDC Latvia</td>
<td>€ 3,882,678</td>
<td>LDC Latvia</td>
<td>€ 2,821,430</td>
</tr>
<tr>
<td>Total</td>
<td>€ 30,279,414</td>
<td>Total</td>
<td>€ 24,274,485</td>
</tr>
</tbody>
</table>

From the table above can be concluded then in the current organization the biggest share of part numbers are distributed via the warehouse in Germany and that the biggest costs are from the fine distribution.
5.2.1.3 Warehouse & Handling Costs

The warehouse & handling costs consist of two components, costs for handling the pallets and goods and costs for storage in the warehouses.

Handling Costs

The parameters for handling the pallets differ at each distribution centre. The prices are set by the 3PL from which Skil rents these services. For the main warehouse in Breda /Meer the prices of the warehouse Meer are used because most pallets and goods go from Meer to the other distribution centres. The parameters for the different distribution centres are given in appendix W (Ouweland, 2008; Skil, 2008c). The costs calculated for the handling costs can be found in appendix X and appendix Y. The parameters for the warehouses of the CSO warehouses (Romania, Greece, Bulgaria, Latvia and Hungary) are calculated as an average of the other warehouses because these parameters weren’t available. In Table 11 the cost for the handling are given.

Table 11 Handling costs

<table>
<thead>
<tr>
<th>Handling costs</th>
<th>2007</th>
<th>2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>Goods in</td>
<td>€167,816,00</td>
<td>€105,931,00</td>
</tr>
<tr>
<td>Goods out</td>
<td>€2,183,237,00</td>
<td>€1,577,261,00</td>
</tr>
<tr>
<td>Total</td>
<td>€2,351,053,00</td>
<td>€1,683,192,00</td>
</tr>
</tbody>
</table>

Storage Costs

For the storage costs the average number of pallets a month that are stored in the warehouses is the parameter with the exception of the warehouse in Meer, this is the average by the week. The parameters can be found in appendix Z. To calculated these averages the number of items of the total stock are used. The items are divided by the number of items on a pallet and round up to a integer number because normally there are no mixed pallets stored in a warehouse because this will cause pollution in the inventory registration. The number of pallets of all items are summed up and multiplied by the parameters. In appendix AA the total costs a month and over the year are given. In Table 12 the total cost can be seen.

Table 12 Storage costs

<table>
<thead>
<tr>
<th>Warehouse</th>
<th>total pallets stock</th>
<th>Storage costs pro month</th>
<th>Storage cost pro year</th>
</tr>
</thead>
<tbody>
<tr>
<td>totals 2007</td>
<td>31867</td>
<td>€101,540</td>
<td>€1,218,483</td>
</tr>
<tr>
<td>totals 2008</td>
<td>26147</td>
<td>€82,572</td>
<td>€990,864</td>
</tr>
</tbody>
</table>
5.2.1.4 Inventory costs

For the inventory cost the interest rate of the total stock is calculated. The total stock is the surplus of the safety stock and the replenishment stock which are kept in the warehouses. This inventory is kept in the different warehouses to deal with the fluctuation in demand in the different affiliated countries. In Breda / Meer also a safety stock and replenishment stock is kept to cope with the fluctuation and to be able to distribute on time to the different warehouses in Europe. First the costs for keeping total stock is calculated with the use of the demand pattern for each part number as an aggregated demand for the warehouse dedicated to these countries. To calculate these costs an interest percentage of 8% is taken.

Within this interest percentage the opportunity cost of capital are taken into account for Skil. For the calculation of the safety stock and replenishment stock the lead time is important. This lead time is the time from entering an order in the SAP system till the moment that the order is administrative handled at the destination. The lead time differs from LDC to LDC. An overview of these lead times is given in appendix J. The costs for the total stock for the different warehouses can be seen in appendix BB and in Table 13 the total costs are given.

Table 13 Inventory in warehouse costs

<table>
<thead>
<tr>
<th></th>
<th>2007</th>
<th>2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>€</td>
<td>2.303.760</td>
<td>€ 1.911.407</td>
</tr>
</tbody>
</table>

A remark has to be made with the calculation of the inventory costs. For the calculation all the part numbers that were sold in the period from 2007 till 2008 are taken into account for keeping inventory in the warehouses. It is not said that all these part numbers are still in the portfolio of the sales organisation. So there is a great possibility that a certain amount of part number are not sold anymore in a certain period because their life cycle has come to an end. In depth research has to be done to mark the part numbers that are not in the portfolio anymore. Beside this effect it can also be that new part numbers are introcuded to replace old part number during this time. So simply deleting part numbers in the compleet period is not an options because the aggregated demand pattern will not reflect the actual situation anymore in that case. For the benefit of the calculation time and effort that has to be made to look at each partnumber individual the data set used is kept and the remark has to be kept in mind when looking at the costs for the inventory.
5.2.2 Conclusive overview costs calculated

In this paragraph a short overview of the costs calculated and represented in previous paragraphs is given in Table 14.

Table 14 overview calculated costs 2007 and 2008

<table>
<thead>
<tr>
<th></th>
<th>own calculation</th>
<th>own calculation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2007</td>
<td>2008</td>
</tr>
<tr>
<td>Transport costs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transport costs rough distribution</td>
<td>€2,155,688</td>
<td>€1,526,950</td>
</tr>
<tr>
<td>Transport costs fine distribution</td>
<td>€28,123,716</td>
<td>€22,747,537</td>
</tr>
<tr>
<td>total</td>
<td>€30,279,414</td>
<td>€24,274,486</td>
</tr>
<tr>
<td>Warehouse &amp; Handling costs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Handling costs Goods In</td>
<td>€167,816</td>
<td>€105,931</td>
</tr>
<tr>
<td>Handling Costs Goods Out</td>
<td>€2,183,237</td>
<td>€1,577,264</td>
</tr>
<tr>
<td>storage costs</td>
<td>€1,218,483</td>
<td>€990,864</td>
</tr>
<tr>
<td>total</td>
<td>€3,569,537</td>
<td>€2,674,095</td>
</tr>
<tr>
<td>Inventory costs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inventory costs</td>
<td>€2,303,760</td>
<td>€1,911,407</td>
</tr>
<tr>
<td>total</td>
<td>€2,303,760</td>
<td>€1,911,407</td>
</tr>
<tr>
<td>Overall Total Costs</td>
<td>€36,152,711</td>
<td>€28,859,948</td>
</tr>
</tbody>
</table>

From this table can be concluded that the biggest share of costs is in the fine distribution of the part numbers from the local warehouses to the customers in the countries.

5.2.3 Comparison of calculated costs with cost of financial department Skil.

In this paragraph the costs calculated in previous paragraphs and the costs calculated by the financial department are compared. This comparison is made to look for differences and similarities between the two calculated costs of the supply chain.

The comparison can be made for the year 2008 because the actual figures for 2008 are known. When looking at the own calculated and the figures calculated by the financial department (appendix F) of Skill, see Table 15, it is obvious that at the own calculation the transport costs are much higher, the warehouse & handling costs are slightly higher and the inventory costs are slightly lower. The costs calculated by the financial department are the variable costs of the make and delivery side because in our own calculation the warehouse of Breda / Meer is taken into account. Normally this is the make side in the cost table.
<table>
<thead>
<tr>
<th></th>
<th>own calculation 2008</th>
<th>financial department 2008</th>
<th>absolute differences 2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transport costs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transport costs rough distribution</td>
<td>€1,526,950</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transport costs fine distribution</td>
<td>€22,747,537</td>
<td></td>
<td></td>
</tr>
<tr>
<td>total</td>
<td>€24,274,486</td>
<td>€3,964,000</td>
<td>€20,310,486</td>
</tr>
<tr>
<td>Warehouse &amp; Handling costs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Handling costs Goods In</td>
<td>€105,931</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Handling Costs Goods Out</td>
<td>€1,577,261</td>
<td></td>
<td></td>
</tr>
<tr>
<td>storage costs</td>
<td>€990,864</td>
<td></td>
<td></td>
</tr>
<tr>
<td>total</td>
<td>€2,674,055</td>
<td>€2,128,000</td>
<td>€546,055</td>
</tr>
<tr>
<td>Inventory costs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inventory costs</td>
<td>€1,911,407</td>
<td>€1,911,407</td>
<td></td>
</tr>
<tr>
<td>total</td>
<td>€1,911,407</td>
<td>€1,911,407</td>
<td></td>
</tr>
<tr>
<td>Overall Total Costs</td>
<td>€28,859,948</td>
<td>€8,268,000</td>
<td>€20,591,948</td>
</tr>
</tbody>
</table>

For the transport cost the explanation is that normally Skill gets a discount percentage of the transport rates for transporting the packages to the different countries. Also in this research the prices used by UPS are taken. The prices of other carrier to transport from one country to another country could differ. The prices of UPS are for the delivery of the packages the next day. The height of this discount, Skil gets, is not known, therefore with the use of this table a certain price discount can be calculated for the fine distribution. Due to fact that the prices for the rough distribution are the actual rates gathered from Skill the difference is made in the fine distribution. To get to the actual figure of the transportation cost a discount rate is calculated of 90% of the prices of UPS. In Table 16 the overview is given with this discount percentage.

The 90% discount percentage is a figure that is only based on the comparison made by the calculated figures and the own made calculation. There is no indication that the carrier will accept this amount of discount percentage for Skil. In this new situation Skil should make own price agreements with this carrier. Only now the amount of packages transported only by Skil will be lower than the amount of packages transported by all divisions of Bosch.

If no price discount is taken the costs for fine distribution will be by no doubt the biggest share of costs. In the sensitive analysis this will be taken into account for the further calculations.
Table 16 Comparison cost with 90 % discount fine distribution

<table>
<thead>
<tr>
<th>Category</th>
<th>Own calculation 2008</th>
<th>Financial department 2008</th>
<th>Own calculation (90% discount)</th>
<th>Absolute differences (90% discount) 2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transport costs</td>
<td>€ 1.526.950</td>
<td>€ 2.747.537</td>
<td>€ 1.326.950</td>
<td>-€ 161,297</td>
</tr>
<tr>
<td>Transport costs fine distribution</td>
<td>€ 24.274.486</td>
<td>€ 3.964.000</td>
<td>€ 3.801.703</td>
<td>€ 162,297</td>
</tr>
<tr>
<td>Total</td>
<td>€ 2.674.055</td>
<td>€ 2.128.000</td>
<td>€ 2.674.055</td>
<td>€ 546,055</td>
</tr>
<tr>
<td>Warehouse &amp; Handling costs</td>
<td>€ 1.911.407</td>
<td>€ 1.911.407</td>
<td>€ 1.911.407</td>
<td>€ 0</td>
</tr>
<tr>
<td>Total</td>
<td>€ 28.859.948</td>
<td>€ 8,268.000</td>
<td>€ 28.859.948</td>
<td>€ 546,055</td>
</tr>
</tbody>
</table>

An explanation for the inventory cost can be that other prices for the tools are used to calculated these costs or that there are in the calculation less inventory in the warehouses due to the fact that with the calculation of the stock the safety stock and the replenishment stock are calculated with the use of the standard deviation. Nevertheless if this would be the case you should think that the handling costs should also be lower than calculated. But hereby a remark should be made that for 5 warehouses an average price for the parameters are used. This is about the warehouses that are not rent by the Bosch company but by the CSO’s. So it could be possible that these prices are lower than suggested.

In Figure 31 the share of the cost with use of data from the financial department can be seen and in Figure 32 can be seen that the 45% of the costs are generated by transport in which the fine distribution takes 60% of those costs.

Figure 31 Share of cost by Financial department
5.2.4 Performance metrics

Skil identifies four main logistic key performance indicators (KPI) as mentioned in paragraph 4.1. These four KPI's are the figures on which the management of Skil evaluates frequently the performance of their logistic structure. These four KPI's with their definitions are seen in Table 17.

Table 17 Key Performance indicators

<table>
<thead>
<tr>
<th>Metric</th>
<th>Definition</th>
<th>displayed as</th>
</tr>
</thead>
<tbody>
<tr>
<td>Service level 1: availability</td>
<td>Share of physically fully available order lines among all order lines at required delivery creation date (time of transmission of orders from ERP to WMS)</td>
<td>Percentage reached ordeline deliveries (%)</td>
</tr>
<tr>
<td>Value of stock (Euro)</td>
<td>The value in euro of the total stock finished goods in inventory</td>
<td>Total value in Euro (Euro)</td>
</tr>
<tr>
<td>Total Coverage (GEZ)(days)</td>
<td>The quotient of average month-end inventories and average total net sales (NGU) for the reporting period, multiplied by 30 days</td>
<td>Number of days (days)</td>
</tr>
<tr>
<td>Supply chain costs</td>
<td>The costs for all logistic activities divided by the total nett sales</td>
<td>Percentage of total nett sales (%)</td>
</tr>
</tbody>
</table>

Skil uses their logistical information system to calculate these KPI each month. In this research the KPI's are calculated with the use of the equations from paragraph 5.1 and the data used as discussed in paragraph 5.2.1.1.
5.2.4.1 Service level 1

For the calculation of service level 1: availability the number of fully order lines delivered divided by the number of order lines required is calculated. For this research the data set that is used is the demand each month for the individual part numbers in each country. For the calculation of this KPI a translation has to be made with the average number of part numbers pro order lines and the average order line pro month. When this ratio is clear the inventory can be calculated the right why with the use of the service level percentage to reach.

In this research the service level is not an output of the logistic structure but it is an input and a constraint set be the management so that is becomes clear what the logistic costs are holding on to this constraint of service level: availability. So the ‘output’ of the calculation of this KPI is always 98% in this research. In appendix A an overview is given pro LDC for the average number of tools pro order line. This data is used to calculate the 98% service level for the demand of individual part numbers.

5.2.4.2 Value of stock

The KPI ‘Value of Stock’ can be calculated with the use of the value of the total stock, as calculated in paragraph 5.2.1.4. This value can also be found in appendix BB. The total value of the stock over 2008 is 23,896,338.- euro.

5.2.4.3 Total coverage

For this research this figure is can’t be calculated because it is to complex to gather this information from the calculation model.

5.2.4.4 Supply chain costs

The value of the supply chain costs is the sum of the transport & packaging costs, inventory costs and warehouse & handling costs. The supply chain costs is put as a percentage of the total Nett sales. For 2008 with the fine distribution discount of 90% the supply chain costs are 10%.

5.3 Sub-Conclusions

This chapter provided an overview of cost in general within a physical distribution network. It gives the basis of making costs more transparent within a network. An overview of the cost drivers derived from theory research and applied on the situation of Skil has been generated. (see Figure 33)
Figure 33 Cost drivers overview for Skil (derived after field and desk research at Skil)

With use of this costs diversion within Skil equations to calculated the costs have been formed based on the main Equation 6. These equations make it possible to calculated the different costs within the physical distribution network. These equations are also used further in the research for calculating the costs when applying the ADD Heuristic.

**Equation 6 Physical distribution costs**

\[
TC = T + I + W
\]

- **\( TC \)** = Total costs in physical distribution (euro/year)
- **\( T \)** = Transport (euro/year)
- **\( I \)** = Inventory cost (euro/year)
- **\( W \)** = Warehouse & handling cost (euro/year)

The demand of each part number per month per country for the years 2007 and 2008 is used to calculate the different costs in the physical distribution network. In Table 18 an overview is given of these calculated costs for the year 2007 and 2008.
Table 18 Physical distribution costs calculated with use of the equations

<table>
<thead>
<tr>
<th></th>
<th>own calculation 2007</th>
<th>own calculation 2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transport costs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transport costs rough distribution</td>
<td>€2,155,688</td>
<td>€1,526,950</td>
</tr>
<tr>
<td>Transport costs fine distribution</td>
<td>€28,123,726</td>
<td>€22,747,537</td>
</tr>
<tr>
<td>total</td>
<td>€30,279,414</td>
<td>€24,274,486</td>
</tr>
<tr>
<td>Warehouse &amp; Handling costs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Handling costs Goods In</td>
<td>€157,816</td>
<td>€105,931</td>
</tr>
<tr>
<td>Handling Costs Goods Out</td>
<td>€2,183,227</td>
<td>€1,577,261</td>
</tr>
<tr>
<td>storage costs</td>
<td>€1,218,483</td>
<td>€990,864</td>
</tr>
<tr>
<td>total</td>
<td>€3,569,537</td>
<td>€2,674,055</td>
</tr>
<tr>
<td>Inventory costs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inventory costs</td>
<td>€2,303,760</td>
<td>€1,911,407</td>
</tr>
<tr>
<td>total</td>
<td>€2,303,760</td>
<td>€1,911,407</td>
</tr>
<tr>
<td>Overall Total Costs</td>
<td>€36,152,711</td>
<td>€28,859,948</td>
</tr>
</tbody>
</table>

From this table can be concluded that the biggest share of costs is in the fine distribution of the part numbers from the local warehouses to the customers in the countries.

To validate the calculation model a comparison is made with the costs calculated by the financial department of Skil (see Table 19).

Table 19 Comparison own calculation with Skil's calculation

<table>
<thead>
<tr>
<th></th>
<th>own calculation 2008</th>
<th>financial department 2008</th>
<th>absolute differences 2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transport costs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transport costs rough distribution</td>
<td>€1,526,950</td>
<td>€3,964,000</td>
<td>€20,310,486</td>
</tr>
<tr>
<td>Transport costs fine distribution</td>
<td>€22,747,537</td>
<td></td>
<td></td>
</tr>
<tr>
<td>total</td>
<td>€24,274,486</td>
<td>€3,964,000</td>
<td>€20,310,486</td>
</tr>
<tr>
<td>Warehouse &amp; Handling costs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Handling costs Goods In</td>
<td>€105,931</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Handling Costs Goods Out</td>
<td>€1,577,261</td>
<td></td>
<td></td>
</tr>
<tr>
<td>storage costs</td>
<td>€990,864</td>
<td></td>
<td></td>
</tr>
<tr>
<td>total</td>
<td>€2,674,055</td>
<td>€2,128,000</td>
<td>€546,055</td>
</tr>
<tr>
<td>Inventory costs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inventory costs</td>
<td>€1,911,407</td>
<td>€2,176,000</td>
<td>€264,993</td>
</tr>
<tr>
<td>total</td>
<td>€1,911,407</td>
<td>€2,176,000</td>
<td>€264,993</td>
</tr>
<tr>
<td>Overall Total Costs</td>
<td>€28,859,948</td>
<td>€8,268,000</td>
<td>€20,591,948</td>
</tr>
</tbody>
</table>

From this comparison can be concluded that mainly the fine distribution costs are showing a big difference. This can be explained due to the fact that normally Skil gets a discount for the fine distribution rates or the prices used in this research from UPS vary much from the real prices that are charged at Skil. When taken a fine distribution discount of 90% on the current rates of UPS the prices are more in line with the data calculated by the financial department. The diversion of the costs with this discount rate can be seen in Figure 34.
own calculation (90% discount)

Figure 34 Diversion logistic costs

In the next chapter these costs will be analyzed more in depth. This analysis of the costs will give more insight in possible ways to lower these costs and what will be the subjects for further research.

5.3.1 The progression in the Generic framework

Looking at the generic framework this is the last phase of describing the as-is organisation (see Figure 35). The next chapter will fill the as-is analysis for the future situation and the design of the scope which set the requirements for the alternative designs.

Figure 35 progression in the generic framework
Bottleneck analysis of logistic costs and the requirements for the alternative design
This research is looking for possibilities to lower the supply chain costs by (re-) designing the physical distribution network. In the previous chapters a generic framework and the logistic structure of Skil is described. The logistic costs that comes with a physical distribution network are explained and worked out for the situation of Skil. This chapter uses the costs calculated for Skil as a starting point to look more into depth at these costs. It identifies cost bottlenecks for Skil's situation. These bottlenecks are the focus further in the research in a search for a physical distribution network with lower logistic costs.

6.1 Analysis of supply chain cost of Skil

Because this research is looking for a physical distribution network in which the costs are lower than before a good look at the cost to identify the bottlenecks is needed. In paragraph 5.2.3 already some analysis about the costs is made. The own calculated costs will be further analyzed to search for possible differences when changing some parameters in the network.. The previous paragraph 5.2.3 showed us that the calculated costs reflect in more or less the actual situation looking at the costs calculated by the financial department of Skill with the exception of the fine distribution costs. In this costs analysis the situation with a price discount of 90% will be taken. This is done to get the comparison of the costs into the right proportions. As Figure 36 shows the main costs are still the transport costs.

Figure 36 Distribution of costs

In the next paragraphs a further analysis with the causes of these costs and possibilities to lower these costs will be described.
6.1.1 Inventory costs

The inventory costs are caused by the value of the part number and the interest rate on the part numbers. The interest rate is suggested by the management of Bosch and therefore an exogenous parameter. Just like the value of the part numbers, these can’t be changes also. Due to the starting point of a service level of 98% the demand of the customers have to be met. So the number of inventory in the warehouses will be determined by this safety factor. What could be changed is the height of the total inventory in the LDC’s. By using less warehouses the height of the total stock will decrease. So that fact have to be kept in mind. Also the lead time is an important factor in determining the total stock. By reducing the lead time the total stock will decrease and therefore the costs for the inventory is less. This is especially the cause for the total stock in Breda / Meer for which the lead time is the longest and therefore is the biggest carrier of the costs for the inventory.

![Inventory Cost 2008](image)

The costs for inventory at Skil Netherlands are 1.422.035,- Euro (appendix O) with a lead time of 60 days. When the lead time decreases with 10 days, so it will be 50 days, the costs become 1.272.126,- Euro. This is an decrease of 10,5% of the costs.

6.1.2 Warehouse and handling cost

The warehouse and handling costs have also some exogenous parameters which are fixed. These are the costs for the handling of the order lines, pallets and goods. These prices are set by the different warehouses and can’t be charged by the Skill management. But with working with less warehouses the number of items in an order line could increase in which the total order lines will decrease. So these cost could be lower then. But this can’t be calculated further on in the model. The number of handlings in the warehouse depends on the demand of
the customers. The costs of these handling have to be made to meet the 98% service level. But hereby a remark should be made that for 5 warehouses an average price for the parameters are used. This is about the warehouses that are not rent by the Bosch company but by the CSO's. So these warehouse are in Hungary, Romania, Greece, Latvia and Bulgaria. But when looking at Figure 37 and Figure 38 can be seen that these warehouse are together good for 21% of the warehouse costs (storage, good in and goods out) while the calculations of the percentages of pallets, pieces, orderliness and pallets in stock also represents 20% of the totals handled or stored. So these averages calculated for these warehouses don't makes a significant difference on the costs.

Also a look at the effect of putting more part numbers on a pallet can be useful. This will affect the goods in and the storage costs. The effect it has on the costs is of an amount of 40.757,– Euro which is 3.7% of the original costs for Goods in and Storage (see appendix CC).

Figure 37 Warehouse cost pro warehouse (2008)
6.1.3 Transport costs

For the transport costs the cause of the costs has also some exogenous parameters which are the transport rates for the rough and the fine distribution. The transport costs depends on the number of pallets for the rough distribution and the total weight per shipment for the fine distribution. A way of lowering these costs is by maximizing the pallets loads for a part number. So when more part numbers can be stacked on a pallets the less pallets it generates the less costs have to be made for the transport costs.

For example an increase of 2 extra part number per pallets for all part numbers will decrease the costs for the rough distribution for an amount of 64.552,- euro's, which is an decrease of 4,2 % on the original costs (see appendix CC).

On other discussion is how the transport cost will develop when the number of warehouses is changed and affiliated countries to the warehouses changes. This effect will be calculated further on in chapter 7.
6.1.4 Conclusion cost analysis

In the previous paragraph the costs are analyzed. Hereby can be concluded that the main costs driver is the transport costs. Approximately 45% of the costs are determined by the transport costs. The goal for this research in lowering the total logistic costs for the logistic network. Probably the biggest result can be achieved within the transport costs. Also some other factor can result in a decrease of the costs, like increasing the number of items on a pallet. Also by price negotiation results can be achieved. But for the further research we keep the number of items per pallet the same. Also in reducing the number of warehouses can result in a decrease of costs, as well in the inventory in warehouse cost, stock costs and handling in costs because more items are handled in the warehouse. The question arise what will be the result for the all the costs and how big will this result will be.

After this costs analysis it is clear that the biggest costs are at the transportation side. This activity can be influenced by changing the physical distribution network. But by changing this network also the costs for inventory and warehouse & handling will be influenced.

The bottleneck in this research that it is not clear what the results on the supply chain costs will be when changing the lay-out of the physical distribution network. For this question the ADD Heuristic model described in the location-allocation theory, described in paragraph 3.2, will be used.

Before making an alternative design of the physical distribution network is will be good to know what the requirements have to be for this design. These requirements presents the objectives and boundaries for a alternative design. This will be the subject of the next paragraph.
6.2 Requirements for new design models

In the previous paragraphs the bottlenecks within the physical distribution network of Skil are discussed. The next step will be to define a scope of which an alternative design will have to meet. This scope will set certain objectives and boundaries which will be used to guide the arise of an alternative design. This scope is therefore called the requirements for an alternative design of the physical distribution network. These requirements are the subjects of this paragraph.

6.2.1 Defining Scope starting point

For the search of a logistic network in which the logistic costs are lower than before the location-allocation model: ADD heuristic will be used. The issue that will be looked after is how to decrease the total supply chain costs by changing the lay-out of the network. The starting point for the search will be a service level of 98% of the demand of part number in all countries. The problem that occurs is that it is not yet clear how the costs will develop when assigning other countries to warehouses or leave some warehouse out of the network.

It need to become clear what the result will be when assigning other countries to the warehouses and what the result will be when leaving out some of the warehouse in the network.

The search for lowering the logistic cost will be with use of data of the year 2008 to make a comparison to the actual situation and for the future a forecast is made, which will be explained in the next paragraph, in which data is calculated for the next years.

6.2.2 Demand pattern and market development

To calculate the demand pattern of the products for Skil a forecast program, Forecast Pro Unlimited, is used. This forecast program was subject of a study sponsored by the International Journal of Forecasting. The results of this study showed that Forecast Pro "outperformed other software entrants in the competition by attaining the lowest percent error" and "outperformed all but one of the 17 academic entries" (Forecast Pro, 2009; Koning et al., 2005). This forecast program calculates the forecast on monthly base by using different forecast methods and it takes the best suited fit for the calculation of the forecast demand.

In 2008 the total net sales were 83 million euro's. For the year 2010, 2011 and 2012 the expectations made by the management of Skil are respectively 73 million, 82 million and 100 million euro's. For the forecast of the demand of part numbers this means that the demand of each part number pro country is calculated based on the expected values of the Total Net Sales. Two different forecasts are made, an increase and a decrease of the Total Net sales with 20% in relation to the situation of 2008. This means that two new situation arise from this
forecasts, two forecasts of part numbers pro countries when Total Net sales are 100 Million and 66 million euro's.

With Forecast Pro Unlimited it is possible to make forecasts from each individual part number pro country, aggregated forecast for the countries, an aggregated forecast for the LDC affiliated to the countries and a total overview for all LDC's like Figure 40 displays. From these forecasts an output in excel can be made on each of the described levels. So with these forecasts the future demand pattern for Skil can be calculated. In Figure 40 an example of forecast pro is given of the aggregated forecast for all items of Skil when the Total Net sales are 100 Million euro's. The red line reflects this aggregated forecast and the blue line reflects the 5 % boundaries. This aggregated forecast can be set out as a forecast pro part number pro country.

Figure 40 Forecast Total Net sales 100 Million euro's

The forecasts will be used further in the research to see what the outcome of the alternatives design will be when the demand of part number will increase or decrease. Also these forecasts are used for a sensitivity analysis of the changes in demand.
6.2.3 Defining a scope to set the requirements

In order to give a clear overview of the boundaries to make alternative designs a scope can be formulated like Huizinga (2000) explained and the generic framework displayed.

In this scope six subjects have to be formulated.

1. What are the subjects of the decisions that have to be made?
2. What are the evaluation criteria of which these decisions are based on.
3. Which part of the logistic chain will be looked at when making this alternative design?
4. What is the geographical area that will be researched?
5. Which market is subject of the alternative design?
6. What kind of product of the company will be taken into account when researching an alternative design?

Paragraph 6.1 made clear that for the alternative design a search had to be made at the consequences when changing the lay-out of the network. Changing a network in this research means changing: the number of warehouses, locations of warehouses and the allocation of customers to the warehouses. With one restriction as mentioned in chapter 4, the warehouse in the Netherlands will remain open at any time. These changes in the network will be evaluated on the costs they generate with the proposed demand (2008, increase or decrease demand) of all part numbers from the customers in whole Europe.

In Table 20 the overview of the scope is given for the design of our new physical distribution network.
Table 20 Scope new design

<table>
<thead>
<tr>
<th>Scope</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. Decision</strong></td>
</tr>
<tr>
<td>a. Number of warehouses</td>
</tr>
<tr>
<td>b. Location of warehouses</td>
</tr>
<tr>
<td>c. Which countries are delivered by which warehouse</td>
</tr>
<tr>
<td>d. Warehouse in Netherland is always open</td>
</tr>
<tr>
<td><strong>2. Evaluation criteria</strong></td>
</tr>
<tr>
<td>a. Transport cost 'fine distribution'</td>
</tr>
<tr>
<td>b. Transport cost 'rough distribution'</td>
</tr>
<tr>
<td>c. Warehouse costs</td>
</tr>
<tr>
<td><strong>3. Logistic chain</strong></td>
</tr>
<tr>
<td>a. Main warehouse Netherlands -&gt; Local warehouses -&gt; Customers in countries</td>
</tr>
<tr>
<td><strong>4. Geography</strong></td>
</tr>
<tr>
<td><strong>5. Markets</strong></td>
</tr>
<tr>
<td><strong>6. Products</strong></td>
</tr>
</tbody>
</table>

This overview of the scope is tool that helps to guide the development of the alternative designs. The mentioned subjects are used as a guideline to know what to use when making these alternative designs. It is a summary of the facets that are used.

### 6.3 Sub-Conclusion

This chapter handles two topics. The bottlenecks in the current organisation as a start for looking possible ways to lower the supply chain costs and the requirements needed for the alternative designs to handle these bottlenecks.

The first paragraph the costs of the current organisation have been analyzed. From this analyse it became clear that few cost savings can be achieved by using operational decisions, like changing pallet stacks or shortening the lead times. But the transportation cost are the biggest share of the total supply chain costs. This activity can be influenced by changing the physical distribution network. But by changing this network also the costs for inventory and warehouse & handling will be influenced.

The bottleneck in this research that it is not clear what the results on the supply chain costs will be when changing the lay-out of the physical distribution network.

The results in terms of costs and location-allocation of customers when changing a lay-out will be obtained after using the location-allocation model: ADD-Heuristic. Chapter 7 will handle the development and outcome of this ADD-Heuristic for the situation of Skil.
The second paragraph of this chapter explained the forecasts needed for a sensitivity analysis of the Add-Heuristic. It also gives an overview in the form of a scope to provides requirements of which the model must meet in this research to give eventually an outcome that will be within the boundaries of this research.

6.3.1 Progression of generic framework

This chapter provided an analysis of the as-is organisation for the future and a formulation of the scope. The next phase of the generic framework is making a conceptual design (in chapter 7) which will be check of its robustness's by performing a sensitivity analysis (chapter 8)

![Diagram of generic framework progression]

Figure 41 Progression of generic framework
Location-Allocation model for a physical distribution structure for Skil
7.1 Goal of the location-allocation model

From the analysis of the different location-allocation models in paragraph 3.2 and the situation for Skil the conclusion was that the ADD heuristic would be the best suited model. This model will be used to optimize the physical distribution structure for Skil in Europe. The target of the model is:

*Optimization of the transportation and facility costs for a centralized physical distribution structure through migrating local distribution centres to a few distribution centres in Europe.*

7.2 Needed input data for the model

The uncapacitated, single-stage model, described in paragraph appendix M considers the trade-off between operating and variable delivery costs. The formulation of this problem mathematically is

\[
\text{Minimize } \sum_{i \in I} \sum_{j \in J} c_{ij} x_{ij} + \sum_{i \in I} f_i z_i
\]

Here the total demand-weighted distance between customers and facilities is minimized but this is not the driver for Skil. As stated earlier the 3PLs used to transport the tools to the end-customers use the country to deliver and the number of pallets or weight of a package to determine the price of a shipment. Therefore it is not needed, in the research, the exact location of each Skil end-customer to optimize the physical distribution structure and it will be possible to use the aggregation value on country level. The transportation costs will then only depend on the number of parcels and pallets or weight of a shipment between countries or within a country. The warehouse costs also depend on the demand of the part numbers that are shipped through the warehouse to the countries. As a result the total transportation costs and warehouse costs need to be minimized. So instead of minimizing the total distance, the transportation costs together with the warehouse costs have to be optimized.

The bold words in the previous paragraph given the important input parameters needed to minimize the total transportation cost and warehouse costs. For the warehouse costs there are no fixed warehouse costs included because Skil only uses variable warehouse costs which already are integrated in the warehouse costs. Figure 42 below shows the relationship between these parameters.
Figure 42 The relations between the Parameters of the model: ADD heuristic

7.2.1 Input: Demand

For the year 2008 the part numbers sold per country and per month are available. This data is used for the input for the model. Further on two forecasts are made for Skil of the demand of part numbers based on the previous two years. This forecast is made for every individual part number per month per country. Based on these individual part numbers an aggregate forecast of all part numbers can be acquired for these countries. Based on this demand per month per country the number of part numbers that have to be delivered to the countries can be calculated. These numbers are basis input to convert the demand per part number into the different parameters like parcels and pallets to calculate the transport costs. Also this demand is used to calculate the total stock, number of orderliness and pallets and the average value of part numbers in the warehouse which are used to calculate respectively the storage costs, handling costs and inventory in warehouse costs which leads to the final warehouse costs. The transportation costs and warehouse costs are used to for the optimization; minimize the total costs.
7.2.2 Input: Transportation costs

As stated earlier the freight carriers, which will be used to transport the part numbers to the end-customer, also called the fine distribution, are not making any distinction in costs between the distance of the place of collection and the place of delivery but only use the country borders and the weight of the package to determine the price of the shipment.

International freight carriers are offering special express services to shorten the normal transportation time. Most of them are offering next morning or day delivery through almost whole of Europe. For example UPS is offering an ‘Express Saver service’ that guarantees a delivery the next day to whole Europe. The carrier DHL is offering an express service too for delivery the next morning or next afternoon, namely the ‘Express Plus’ and the ‘Express’ respectively.

As stated in paragraph 5.2.1.2 the prices of UPS are taken for the fine distribution. The way of calculating the fine distribution costs are based on the prices per weight of shipment. These prices differ from 0,5 to one kg's. For this research a diversion is made between bigger brackets of kg so it will fit the model of calculation (appendix S), otherwise it would become too complex. The average price of these brackets is calculated and the difference of the minimum and maximum prices on less. For every shipment with a weight higher than 70 kg’s an additional charge is made for every kg. This is also done in the calculation of the transport costs. The relations between the parameters for the transport costs for fine distribution are given in Figure 43

![Figure 43 relation between parameters of the transportation costs fine distribution](image)

For the transportation costs of the rough distribution, which is from the main warehouse in Breda / Meer to a LDC, different freight carriers are used who charge fixed price per FTL or LTL from Breda / Meer to the specific location of the LDC (see appendix N). The way of calculating these costs are explained in paragraph 5.1.1.1. Based on the choice of the
allocating a warehouse X to specific countries these costs can differ. The relation between the parameters of the transportation cost rough distribution is given in Figure 44

![Image of Figure 44: relation parameters of the transportation costs rough distribution]

7.2.3 Input: Warehouse Costs

7.2.3.1 Potential facility Sites

From the 37 countries in which customers are located only 13 countries are chosen as candidates for locations of a warehouse because in the current organisation there are already warehouses situated. Through several selection criterion and research in the potential of a country as a facility site it turned out that not every country that is delivered to be suitable to set up a warehouse. The first selection criterion is that the main warehouse in Breda/Meer and the International distribution Centre in Worms is already an existing warehouse and be open all the time. Therefore another warehouse in Belgium, Germany or Netherlands for example makes little sense, because of the relative low volumes shipped to Belgium. The latter is the second criterion: the number of sold tools shipped to a specific country, and will ensure for example Luxembourg will be excluded as a serious candidate to locate a warehouse.

7.2.3.2 Costs

The costs related to a facility can be represented in terms of

1. Fixed costs

Fixed costs are those that do not change with the level of activities on the facility (for example depreciation, real-estate taxed, rent and supervision). For the warehouse costs there are no fixed warehouse costs included because Skil only uses variable warehouse costs which already are integrated in the warehouse costs.
2. Storage costs

Storage costs are those that vary with the amount of stock stored in the facility. That is, if particular costs will increase or decrease with the level of inventory stored in the facility, then the cost will be classified as storage costs (Figure 45). (For the calculation see Equation 16 in paragraph 5.1.3.)

![Figure 45 Storage costs](image)

3. Handling costs

Handling costs vary with the facility throughput (for example costs retrieve items, to pick and pack orders). These costs depend on the number of part numbers that are distributed via the warehouse. From the number of part numbers the number of pallets and amount of order lines can be calculated and with these figures multiplied with the costs the handling costs for the facility can be calculated (Figure 46). (For the calculation see Equation 15 in paragraph 5.1.3.)

![Figure 46 Handling costs](image)
4. Inventory cost in warehouse

The inventory costs in warehouse are mainly determined by the interest percentage of the stock that is stored in the warehouse (see Figure 47). (For the calculation of this see Equation 14 in paragraph 5.1.2.)

\[
\text{Average value part numbers in warehouse} \times \text{Interest rate} = \text{Inventory in warehouse cost}
\]

Figure 47 Inventory costs in warehouse

7.3 Optimization of the location-allocation model for Skil’s situation

To develop an excel model for determining the best European logistic structure for Skil all the input parameters discussed in the previous chapters has to be converted and linked in coherent information that interacts with each other. Figure 42 shows the schematic diagram and the relation of each of the input data needed to calculate the total transportation costs and the warehouse costs.

The model is created in Excel and it gives an overview which warehouses and countries are linked together. The input of the model is the demand per part number and month for every country. With use of the cockpit of the model a choice can be made which warehouse will be opened or closed and which country will be distributed by this warehouse. The number ‘1’ means that the warehouse is open and will distribute to those countries. Only one warehouse at the time can be open, but all country can be selected. The number ‘0’ means that the warehouse is closed and that there will be no deliveries of part numbers to those countries. In Table 21 this cockpit is shown.
To be sure that only one country will be assigned to one warehouse a control sheet is introduced in which an overview can be generated which countries are assigned to which warehouses. For the year 2008 and in the original situation this sheet can be seen in appendix DD. When these inputs are made the model calculates for the warehouse that is open all the costs as shown in Table 22.

Table 22 Example of cost calculated for open warehouse

| IDC Germany | € 2,734,306 |
| Transport costs fine distribution | € 2,260,254 |
| Transport Costs | € 2,994,360 |
| Inventory in warehouse costs | € 190,372 |
| Storage Cost | € 192,829 |
| Goods in Handling Cost | € 61,339 |
| Good out Handling cost | € 802,064 |
| Warehouse Costs | € 1,759,783 |
| Total Costs | € 4,754,343 |

However to come to an optimal solution every combination has to be filled in manually. Although the thought could be that for this relative small problem it may be solved relatively
easily but even for only 13 potential facility sites 2^n combinations are possible and when only one new potential location will be added the number of combinations will be doubled. However through logically reason several combinations can be omitted beforehand but still the combinations can be large if the problem becomes bigger.

To do this fast the ADD heuristic rules are used to determine the optimal right order (however this is no guarantee) the procedure is to greedily add facilities to the solution until the algorithm fails to find a facility whose addition will result in a decrease of the total costs. To execute the ADD heuristic a comparison is made of the costs made by opening/ closing warehouses and adding or deleting countries to the model. When performing this comparison one important factor must be kept in mind, every part number will pass the main warehouse in the Netherlands. So these warehouse costs must be always be added at the warehouse costs of a potential warehouse.

Firstly, the total cost (transportation costs and warehouse costs + warehouse cost Netherlands) from each potential warehouse site to each of the countries that have to be delivered are calculated.

Secondly the saving in relation to the Netherlands/Belgium are calculated for each site-country combination. If it turns out that the total costs from the Netherlands / Belgium are cheaper than from the potential new sites the savings value is set on 0, otherwise the savings value will be the result of “the total costs from the Netherlands to country X” minus “the total costs Potential site Y to country X”. This step will be executed for each combination and the total savings off adding a warehouse is the summons of all the separate savings values from the potential site to all the different countries.

Finally, the warehouse with the maximum savings will be selected. Hereafter the iteration will repeated at step 2 and new savings values will be calculated, not only in relation to the Netherlands / Belgium but also to the new added warehouse, or in other words from the subset of warehouses for which z_j=1 has been decided.

A schematic overview of this calculated is given in appendix FF.

When the steps, described above, are executed, the warehouses are sorted in a decreasing order of total savings which depends on each other. After defining this order of adding warehouses a closer look is taken at the total cost of distributing from a warehouse to a specific country. For every step, when adding a warehouse, a warehouse will be assigned to a country (allocated). This allocation is done based on the lowest total cost of the open warehouses when distributing to that specific country. At the end this will lead to an overview,
see Table 24, of which countries are delivered by which warehouses, based on the lowest total costs.

Plotting the total costs, so transportation costs and the costs of the warehouse, against the total number of warehouses a curve of decreasing costs till the 4th warehouse like Figure 48 will be obtained. The minimum is the point where the total costs are the lowest and doesn't get an lower any more, which represented the optimal solution in this situation.

<table>
<thead>
<tr>
<th>Order of warehouses</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Skil Netherlands</td>
<td>€ 5.511.116</td>
</tr>
<tr>
<td>2 Poland</td>
<td>€ 5.273.291</td>
</tr>
<tr>
<td>3 Hungary</td>
<td>€ 5.267.530</td>
</tr>
<tr>
<td>4 Romania</td>
<td>€ 5.179.786</td>
</tr>
<tr>
<td>5 Germany</td>
<td>€ 5.179.786</td>
</tr>
<tr>
<td>6 Spain</td>
<td>€ 5.179.786</td>
</tr>
<tr>
<td>7 Great Brittain</td>
<td>€ 5.179.786</td>
</tr>
<tr>
<td>8 Italy</td>
<td>€ 5.179.786</td>
</tr>
<tr>
<td>9 Bulgaria</td>
<td>€ 5.179.786</td>
</tr>
<tr>
<td>10 Denmark</td>
<td>€ 5.179.786</td>
</tr>
<tr>
<td>11 Greece</td>
<td>€ 5.179.786</td>
</tr>
<tr>
<td>12 Finland</td>
<td>€ 5.179.786</td>
</tr>
<tr>
<td>13 Latvia</td>
<td>€ 5.179.786</td>
</tr>
</tbody>
</table>

Figure 48 Cost development adding warehouses

In the case of the situation of 2008 and with a transport discount rate for the fine distribution of 90 % the conclusion can be drawn that for serving the European countries in a centralized European logistic structure, four warehouses need to be selected in the order given in Table 23. The red colour means that these warehouses don’t matter in the network. There is no decrease of the total minimum costs. The optimum is reached. In conclusion Table 24 shows which countries are delivered by the warehouses (green combination) and how many countries a specific warehouse has to be distributed to in order to fulfil all the demand with a service level rate of 98 %.

Table 24 Example control table which country is delivered by which warehouse
Previous calculation are made based on the savings of the total costs. Every time new calculated when adding a warehouse that resumed to give the biggest savings. This is done with the warehouse in the Netherlands inserted in the logistic network as a distribution centre that also can fulfil the fine distribution to the different countries. In the current situation this already happens but only on a small scale within Europe. In the calculated situation it means that the warehouse in the Netherlands has to fulfil the demand of fine distribution of 34 countries, which is a the biggest share of the total of 37 countries of demand. The reason that the Netherlands are such a dominant country is that in the costs of this warehouse the goods in and the transport costs rough distribution are zero. The first is because all the goods will have to shipped via Meer / Breda so these costs are made anyway and the second is that there is no
need for the rough distribution, but it can start immediately with the fine distribution. In the calculation also the fixed costs of a warehouse aren’t included because these weren’t available. Looking at the Table 24 can be seen that 3 distribution centres are delivering to only one country, and that is the demand of the country in which the distribution centre is located.

In the current situation the warehouse in the Netherlands don’t distributes goods to the countries, so there is no fine distribution from the Netherlands. The question will arise what if the warehouse in the Netherlands can’t function as a fine distribution centre but only will be a distribution centre to deliver to the other warehouses. The analysis of this situation is shown in the tables and figure below.

![Figure 49 Cost development adding warehouses (without NL)](image)

<table>
<thead>
<tr>
<th>Order of warehouses</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Germany</td>
<td>€ 9,785,774</td>
</tr>
<tr>
<td>2 Poland</td>
<td>€ 8,445,868</td>
</tr>
<tr>
<td>3 Spain</td>
<td>€ 8,313,971</td>
</tr>
<tr>
<td>4 Italy</td>
<td>€ 8,174,901</td>
</tr>
<tr>
<td>5 Hungary</td>
<td>€ 8,082,065</td>
</tr>
<tr>
<td>6 Denmark</td>
<td>€ 8,069,897</td>
</tr>
<tr>
<td>7 Romania</td>
<td>€ 7,941,298</td>
</tr>
<tr>
<td>8 Great Brittain</td>
<td>€ 7,941,298</td>
</tr>
<tr>
<td>9 Bulgaria</td>
<td>€ 7,941,298</td>
</tr>
<tr>
<td>10 Greece</td>
<td>€ 7,941,298</td>
</tr>
<tr>
<td>11 Finland</td>
<td>€ 7,941,298</td>
</tr>
<tr>
<td>12 Latvia</td>
<td>€ 7,941,298</td>
</tr>
</tbody>
</table>

The total minimum costs are 7,941,298,- Euro’s and the number of warehouses used are 7 in total. In appendix EE the allocation of the warehouses to the countries can be seen. In this case the warehouse in Germany is counted for 27 countries. Further on can be seen that the most warehouse only deliver to a maximum of three countries.

7.4 Comparison Optimized model and actual situation

From Table 23, Table 24 and Figure 48 can be concluded that the total minimum cost of the distribution network are lower than in the original situation. In the original situation (see paragraph 5.2.3 and Table 16) the cost are 8,387,165,- Euro an all warehouses are used for the fine distribution. In the optimal situation the costs are 5,179,786,- Euro with the use of only four warehouses instead of 13 warehouses. This is a decrease of costs with 38 %. For transport
cost it means that the costs are 29% lower, for Warehouse and Handling cost the costs are 62% lower and the inventory in warehouse costs are 21% lower.

In Table 26 an overview of specification of the costs can be seen. With use of these data some circle diagram (see appendix A) can be created which can be compared with the original situation to see what makes the biggest differences within the optimum model.

**Table 26 Specification Cost Optimum network Model**

<table>
<thead>
<tr>
<th>Optimal Network</th>
<th>Skil Netherlands</th>
<th>LDC Romania</th>
<th>211L Poland</th>
<th>211H Hungary</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transport costs fine distribution</td>
<td>€ 2,362,704</td>
<td>€ 12,712</td>
<td>€ 19,129</td>
<td>€ 5,257</td>
<td>€ 2,399,797</td>
</tr>
<tr>
<td>Transport costs Rough distribution</td>
<td>€ 0</td>
<td>€ 131,870</td>
<td>€ 85,310</td>
<td>€ 66,080</td>
<td>€ 283,259</td>
</tr>
<tr>
<td>Inventory in warehouse cost</td>
<td>€ 2,101,468</td>
<td>€ 74,376</td>
<td>€ 167,972</td>
<td>€ 42,337</td>
<td>€ 2,195,154</td>
</tr>
<tr>
<td>Storage Cost</td>
<td>€ 389,523</td>
<td>€ 40,249</td>
<td>€ 69,413</td>
<td>€ 30,821</td>
<td>€ 530,006</td>
</tr>
<tr>
<td>Goods in Handling Cost</td>
<td>€ 0</td>
<td>€ 3,683</td>
<td>€ 4,996</td>
<td>€ 2,882</td>
<td>€ 11,568</td>
</tr>
<tr>
<td>Good out Handling cost</td>
<td>€ 312,775</td>
<td>€ 53,420</td>
<td>€ 61,239</td>
<td>€ 32,565</td>
<td>€ 460,008</td>
</tr>
<tr>
<td>Warehouse Costs</td>
<td>€ 1,912,766</td>
<td>€ 171,736</td>
<td>€ 303,621</td>
<td>€ 108,620</td>
<td>€ 2,496,729</td>
</tr>
<tr>
<td>Total Costs</td>
<td>€ 4,275,470</td>
<td>€ 316,318</td>
<td>€ 408,060</td>
<td>€ 179,938</td>
<td>€ 5,179,786</td>
</tr>
</tbody>
</table>

In appendix A a complete overview of the calculation of the cost above and the circle diagrams are given.

**Table 27 Comparison Optimum models with original situation**

<table>
<thead>
<tr>
<th></th>
<th>Optimum Model (with NL)</th>
<th>Original situation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transport Costs</td>
<td>52%</td>
<td>45%</td>
</tr>
<tr>
<td>Warehouse &amp; Handling Cost</td>
<td>19%</td>
<td>32%</td>
</tr>
<tr>
<td>Inventory in warehouse cost</td>
<td>29%</td>
<td>23%</td>
</tr>
<tr>
<td>Transport costs fine distribution</td>
<td>89%</td>
<td>60%</td>
</tr>
<tr>
<td>Transport costs Rough distribution</td>
<td>11%</td>
<td>40%</td>
</tr>
<tr>
<td>Total Cost</td>
<td>€ 5,179,786</td>
<td>€ 8,387,165</td>
</tr>
</tbody>
</table>

From Table 27 can be concluded that the cost for the total network will be lower in the model that is created with the use of the ADD heuristic. An optimum model will be with the main warehouse in the Netherlands which performs also the fine distribution function. In this situation there will be a need of only a few warehouses to cope with the demand of the countries. There for the most costs will be in this situation with the transport cost and in particular the fine distribution side. When leaving the Netherlands out as a fine distribution warehouse, Germany will perform the biggest fine distribution activities with no less than 27 countries to distribute too. In this case no more than 7 warehouses are needed. The total
minimum cost will be quite higher than in the situation with the Netherlands, but still lower than in the original situation.

7.5 Validation

In the previous paragraph the development of the decision support tool to determine the number and locations of the warehouses for the European structure is described. Actual implementation of the decision coming from the tool is only useful if the results provided are valid, i.e. it correctly reflects the reality. The input parameters, demand of part numbers, costs for transportation rough distribution and the costs for storage, handling and inventory are determined by actual data of the Skil organisation. The demand for the future is determined based on figures of the last two years and calculated with the use of Forecast Pro, by literature and experts (Koning, 2005) called the best suited fit for the calculation of the forecast demand. The parameters of the transportation costs rough distribution are actual data from the Skil department or are derived with use of information of Skil. The parameters that determine the warehouse costs are also actual data from the Skil departments are derived with use of data from Skil.

During the development of the Excel model no important assumptions are made that have to be tested and validated. However one substantial issue that has not been discussed so far is the validation of the heuristic on the development model: the ADD heuristic. Those heuristics are used to solve efficiently ‘fixed charge facility location problems’ but unfortunately it will only be optimal in special cases and no guarantee exists that it would find an optimal solution.

A validation of the Add Heuristic in the development model could be performed by evaluating the performance of the ADD heuristic in this context. In order to make this possible the results of the ADD heuristic should be compared to the best solutions of all 8192 \(2^{13}\) combinations. This would be although a very time consuming activity and because of the benefit of time only few possibilities are investigated to validate the heuristic.

Three situation are looked more in detail what the outcome is when these are calculated manually. These manual calculation are made the following way. For all warehouse the costs to distribute to all countries are calculated separately. This gives cost matrix with 13 warehouses and 37 countries. The costs for to deliver to all countries are sommed up for every warehouse. The combination country-warehouse with the lowest total costs is added as warehouse number one. Then a comparison is made between the costs of each warehouse country combination. Because some warehouses can deliver the part numbers against lower costs to the countries. The warehouse that has the biggest savings regarding the first warehouses is added as warehouse number two. The total costs of these two warehouses consists of the total of the
lowest costs of the warehouse-country combination of these two warehouses. This procedure will be repeated until all warehouse-country combinations are selected that will cause the lowest costs.

The outcomes of this manual analysis are compared with the outcomes of the ADD Heuristic. In appendix HH three situations between manual analysis and the ADD heuristic are given in table and figure form. Figure 50 gives one of the compared values of a situation calculated after a manual search with the performed ADD heuristic.

![Figure 50 One comparison of manual search with Add Heuristic](image)

From this outcomes can be concluded that the ADD Heuristic will give the lowest costs for all situations when adding warehouses to the network to obtain the lowest costs. But the sequence of adding warehouses differs between the two methods. The manual model gives a smooth line curve whilst the ADD Heuristics shows a curve that will go down when adding warehouses but with a few sharp turn in the line. Conclusions

7.6 Sub-Conclusion

In this chapter the location-allocation model: ADD Heuristic is explained. This model is used in this research to calculated alternative design for Skil. It is a model that will fits the best for this research to look for alternative design in order to lower the transportation and facility costs. It is a model that also could be used for other companies. The only change that will be needed than is that the input variables have to be adjusted to this other company.
The target for this model is to: Optimize the transportation and facility costs for a centralized physical distribution structure through mitigating local distribution centres to a few distribution centres in Europe.

The important input parameters needed to minimize the transportation costs and warehouse costs are the demand of part numbers and from these derived the number of parcels and pallets or weight of a shipment between or within a country. The relation between the parameter in the model are given in Figure 51

Figure 51 The relation between the parameters of the model

The relation diagram is used to calculate all costs of the physical distribution network. The model is designed in excel in which the demand of the part numbers pro month pro country will be the input. By opening are closing warehouses (one at the time) and allocate countries to these warehouses the costs can be calculated.
For the ADD heuristic the calculation method explained in appendix FF is used.

This is a schematic representation of the order of calculation costs and to greedily add warehouses to the solution until the algorithm fails to find a facility whose addition will result in a decrease of the total costs. When the steps are executed the warehouses are sorted in a decreasing order of total savings. For every step a warehouse will be assigned to a country (allocate). This allocation is done based on the lowest total cost op the open warehouse when distributing to that specific country.

When looking at the original situation of the layout of the network compared to a calculated 'optimized' lay-out of the network, with fine distribution rate discount of 90 %, the following result is obtained (see Figure 52)

<table>
<thead>
<tr>
<th>Description</th>
<th>Optimum Model</th>
<th>Original Situation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transport Costs</td>
<td>52%</td>
<td>45%</td>
</tr>
<tr>
<td>Warehouse &amp; Handling Cost</td>
<td>19%</td>
<td>32%</td>
</tr>
<tr>
<td>Inventory in warehouse cost</td>
<td>29%</td>
<td>23%</td>
</tr>
<tr>
<td>Transport costs fine distribution</td>
<td>89%</td>
<td>60%</td>
</tr>
<tr>
<td>Transport costs Rough distribution</td>
<td>11%</td>
<td>40%</td>
</tr>
<tr>
<td>Total Cost</td>
<td>€ 5,179,786</td>
<td>€ 8,387,165</td>
</tr>
</tbody>
</table>

Figure 52 Comparison optimum model with original situation

The total cost decrease and the share of the fine distribution costs increases a lot. This means less warehouses a more fine distribution from the warehouse in the Netherlands.

To be sure that the ADD heuristic will give a good solution a validation has been done of the heuristic. From this validation can be concluded that the ADD heuristic will give the lowest total costs for all situation when adding warehouses to the network to obtain the lowest costs, but the sequence of adding warehouses differs between the two used methods.
7.6.1 Progression of generic framework

Figure 53 shows in which phase of the generic framework the research is. In this chapter the subject of conceptual design is handled with the use of the location-allocation model: ADD heuristic. In the next chapter a sensitivity analysis will be performed in order to determine the robustness's of the designs.

Figure 53 progression generic framework
Sensitivity analysis of different network designs
Chapter 7 has primarily focused on the development of the model together with defining important variable input parameters. In addition, the infeasibility of manual evaluation of facility locations was emphasized when the problem becomes too large. Through using the ADD heuristic together with macro functions the optimization will be executed semi automatically. As facility locations involves most of the time incredible high costs and are long-lasting decisions, it is important to find robust facility locations solutions and to carry out a sensitive analysis that addresses the problem of input data uncertainty. This chapter deals with some alternative designs and a sensitive analysis to find the robustness of a specific solution.

Although in the previous chapter the possibility that the warehouse in the Netherlands couldn’t deal with that much fine distribution activities the choice is to go on with the warehouse in the Netherlands as a possibility to fine distribute to the countries because the costs with the warehouse in the Netherlands is much lower than without the warehouse and this research is looking for the distribution network with the lowest costs.

8.1 Two categories of control variables

To find out how robust a solution is the model must have some control variables that can be varied to simulate alternative designs. Referring to the input parameters, two different categories of control variables can be identified which are:

1. The demand of part numbers to each country

2. The costs aspect, including the shipment costs of distributing from the main warehouse till the end customer and the costs of running a warehouse.

The next section discusses both categories in more detail.

8.1.1 The demand of part numbers to each country

The facility location solution has to be profitable for the facility lifetime, even as environmental factors change. One of the most important factors for the profitability of a warehouse is the demand or the number of sold units in the served countries now, but also in the future. The number of sold units determines the number of shipments and the number of shipments influences the profitability of the warehouse. If the number of sold part numbers will decrease for example in a specific country or area, the advantages of running an extra warehouse decrease. This emphasises the importance of analyzing a scenario that reflects future trends.
The number of units sold in 2008 are derived from the logistical systems of Skil. To simulate a future scenario two situations are taken, an increase of the demand to a Total Net Sales of 100 Million euro’s and a decrease of the demand to a Total Net Sales of 66 Million euro’s. In paragraph 6.2 the way of the forecast is already discussed. In appendix D the demand pro country pro month for the years 2007 and 2008 is given. This data that will be used for the model and for the forecasts of the increase and decrease of the demand.

8.1.2 The costs aspects
The cost aspect obtains the impact of varying shipment costs of distributing the part numbers to the end-customers and the impact of varying running costs of a warehouse. These parameters are used because they determine the costs per cost driver and eventually per activity of the model. The model consists of transport costs and warehouse costs. A choice is made to vary all prices that are related to the parameters to gain a complete understanding of the sensitivity of all cost drivers and activities. This means also that these prices or percentages need to be decreased and increased for this complete overview. This is to expel the possibility that lower prices will show an illogical result compared to higher prices.

The height of the percentage of changes is taken as 10 % for all parameters with the exception for the interest rate. For the fine distribution rates this is done to be able to compare the changes on the costs stepwise with not too much difference in the prices and over the whole front from 0% discount to 90% discount because they present the most important parameter of which the lay-out will change the most. In line with these changes of fine distribution rate the other parameters are also changed with 10% because this change will generate an almost even absolute change in prices of the rates. For the interest rate this will mean that it will need a change of 2% to get an even absolute change in value.

The variations of costs that will be examined are:

**Transportation cost**

Transportation cost - fine distribution

1. Transportation costs fine distribution with a 75% discount on the standard price of shipments of UPS (only 2008).

2. Transportation cost fine distribution with a 95% discount on the standard price of shipments of UPS (only 2008).
3. Transportation Cost fine distribution with a differences of 10% of discount on the fine distribution rate
Transportation cost - rough distribution

4. Transportation costs rough distribution with a 10% increase of the rates (only 2008).

5. Transportation costs rough distribution with a 10% decrease of the rates (only 2008).

**Warehouse cost**

Warehouse costs - storage costs and handling cost

6. Warehouse costs - storage and handling cost with a 10% lower cost for the prices charged.

7. Warehouse costs - storage and handling cost with a 10% higher cost for the prices charged.

Warehouse costs - Inventory in warehouse cost

8. Warehouse costs - Inventory in warehouse costs with a 6% interest rate

9. Warehouse costs - Inventory in warehouse costs with a 10% interest rate

### 8.2 Scenarios

Regarding the logistical parameters in the model, a difference was made between the demand and the cost variables which are the two main control parameters of the model. To simulate different scenarios and to find out the effect of changing a specific variable, all other variables have to remain unchanged. Furthermore to gain a clear and complete view of the sensitivity of specific variables the next table will be used for the year 2008.
So for the year 2008, 34 different scenarios will be evaluated. For the situation that the Total Net sales increases or decreases with 20% regarding 2008 26 different scenarios each will be evaluated. The following results will be determined:

1. The order of DCs which produce the greatest cost savings for the entire system;
2. the total costs;
3. the relative difference between Highest and Lowest cost.

In appendix II and JJ all the 25 scenarios with the companion graphs for the year 2008 are given with the allocation of countries to the warehouses in appendix KK. In appendix LL the companioned graphs for increased total net sales with 20% are given and the allocation is given in appendix MM. In appendix NN the companioned graphs for decreased total net sales with 20% are given and the allocation is given in appendix OO.
To give an example of the information in the appendix II and JJ Figure 54 shows the different warehouse scenarios with the normal transport rates (90% discount) for year 2008. The table with the cost gives the total cost when adding a warehouse to the network. There are five columns which shows the result with all the transport rates 90% discount but with a variety of warehouse rates. The end of the table gives the indication of the relative differences between the highest cost, with only one warehouse, and the lowest cost of the network. The table on the right corner down give the sequence of the warehouses calculated by the ADD heuristic. When the cell is red coloured is means that the lowest costs are reached and adding a warehouse doesn’t lead to lower costs any more. The graph shows for every scenario the decreasing costs when adding a warehouse. The expectation is that the curve will show a parabolic shape with decreasing cost and eventually increasing cost due to adding warehouses. But this is not the case in this research because the fixed costs of adding a warehouse a left out. So adding a warehouse to the network doesn’t mean increasing costs automatically. The shape of the curve is with decreasing cost till it stays stable due to fact that it isn’t profitable to add a new warehouse.

### Transport Rates Current, Warehouse Rates Variable

<table>
<thead>
<tr>
<th>Normal</th>
<th>Storage and handling cost decrease 10%</th>
<th>Interest rate 10%</th>
<th>Storage and handling cost increase 10%</th>
<th>Interest rate 6%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>€5,511,116</td>
<td>€5,327,792</td>
<td>€5,237,908</td>
<td>€5,088,277</td>
</tr>
<tr>
<td>2</td>
<td>€5,525,201</td>
<td>€5,336,691</td>
<td>€5,245,908</td>
<td>€5,099,124</td>
</tr>
<tr>
<td>3</td>
<td>€5,530,530</td>
<td>€5,340,038</td>
<td>€5,249,908</td>
<td>€5,095,631</td>
</tr>
<tr>
<td>4</td>
<td>€5,536,706</td>
<td>€5,343,555</td>
<td>€5,253,059</td>
<td>€5,091,057</td>
</tr>
<tr>
<td>5</td>
<td>€5,542,908</td>
<td>€5,346,034</td>
<td>€5,256,256</td>
<td>€5,086,529</td>
</tr>
<tr>
<td>6</td>
<td>€5,545,908</td>
<td>€5,346,034</td>
<td>€5,256,256</td>
<td>€5,086,529</td>
</tr>
<tr>
<td>7</td>
<td>€5,548,908</td>
<td>€5,346,034</td>
<td>€5,256,256</td>
<td>€5,086,529</td>
</tr>
<tr>
<td>8</td>
<td>€5,551,908</td>
<td>€5,346,034</td>
<td>€5,256,256</td>
<td>€5,086,529</td>
</tr>
<tr>
<td>9</td>
<td>€5,554,908</td>
<td>€5,346,034</td>
<td>€5,256,256</td>
<td>€5,086,529</td>
</tr>
<tr>
<td>10</td>
<td>€5,557,908</td>
<td>€5,346,034</td>
<td>€5,256,256</td>
<td>€5,086,529</td>
</tr>
<tr>
<td>11</td>
<td>€5,560,908</td>
<td>€5,346,034</td>
<td>€5,256,256</td>
<td>€5,086,529</td>
</tr>
<tr>
<td>12</td>
<td>€5,563,908</td>
<td>€5,346,034</td>
<td>€5,256,256</td>
<td>€5,086,529</td>
</tr>
<tr>
<td>13</td>
<td>€5,566,908</td>
<td>€5,346,034</td>
<td>€5,256,256</td>
<td>€5,086,529</td>
</tr>
<tr>
<td></td>
<td>Relative difference (Highest Cost - Lowest Cost) / (Highest Cost)</td>
<td>6.0%</td>
<td>6.3%</td>
<td>5.7%</td>
</tr>
</tbody>
</table>

Figure 54 Transport rate Current (90% discount), Warehouse rates variable

#### 8.2.1 Performance indicators scenarios

A good way of evaluating the performances of the different physical distribution networks are by comparing the performance indicators of the different designs. This research identified four logistic key performance indicators which are important for Skil. These are:

1. Finished Goods; Average inventory [Mio Euro]
2. Service level 1: Availability [%]
3. Total Coverage [days]
4. Supply chain cost [% NGU]
Service level 1: Availability is a KPI that is taken as an input in all models. With the calculation of the safety stock and replenishment stock of each part number an availability of 98 % of the demand by each country is taken. So in every model this KPI is 98 % availability of the demand.

In appendix OO, QQ and RR all values for the KPI for all scenarios are given.

**KPI Supply Chain Cost (% NGU = % Total Nett Sales)**

For the KPI Supply Chain Cost the values vary from the 25 % a 26 % when the discount rate for fine distribution is 0 % and 5 % a 6 % when the discount rate for fine distribution is 90 %. Changing the rates of the warehouse cost don’t much effect on the Supply Chain Cost, the biggest effect have the discount rate of fine distribution. A 10 % bigger discount means between the 2 % a 3 % lower Supply Chain Cost.

Skil aims at Supply Chain Cost of 13 % in 2011 (see Table 6 pp 73). This means that the fine distribution rate discount need to be about 55 % when the Total Nett sales increases with 20 % and about 60 % when the Total Nett Sales decrease with 20 %.

**KPI Average Inventory (Million Euro’s)**

The Average Inventory is lower when the amount of warehouses needed in the network is also lower. The Average Inventory for the year 2008 is in all cases much higher. This is because there is much more fluctuation is the demand pattern of each power tool which results in higher safety and replenishments stock. The demand pattern of the increased and decreased Total Net Sales are calculated with the use of the forecast program. Hereby the fluctuation is more levelled out to a flat pattern. Therefore less safety and replenishment stock is needed to cope with the service level of 98 %.

8.2.2 Conclusion scenarios

The conclusions of the different scenarios for the year 2008, the increase and decrease of the Total Net sales can be divided into five categories.

**Total minimum costs network**

The total minimum cost of the network decreases when:

1. Increasing the discount of the rates of fine distribution;
2. Decrease the rates of Rough distribution;
3. Decrease the rates of Storage & Handling;
4. Decrease the Interest rate.
The total minimum cost of the network increases when:
1. Decrease the discount of the rates of fine distribution;
2. Increase the rates of Rough distribution;
3. Increase the rates of Storage & Handling;
4. Increase the Interest rate.

From these facts can be concluded that when changing rates so that activities will become cheaper the total minimum cost of the network also will be lower and when changing the rates so that activities will become more expensive the total minimum costs of the network will also be higher.

Warehouses redundant
In all scenarios can be seen that the warehouses in Latvia is redundant. They don't participate in the network. In only a few cases the warehouses in Finland and Greece is needed. In most cases Germany, Denmark, Great Brittan, Italy, Spain and Bulgaria don't lead to lower total costs.

The warehouses that absolutely are needed in the network are in the countries, Netherlands, Poland, Romania and Hungary. The warehouses in these countries casus as significant share to lower the total costs. The fine distribution rates that are valid for these countries are the main cause of this.

The number of warehouses.
This means that we look at the impact on the changes for the number of warehouses that are used for to minimize the total cost of the network. When the total costs are the lowest the number of warehouses used are also the lowest. When the lowest cost increases, like in the fine distribution 75 % discount situation, the number of warehouses used to come to the lowest costs are the most, between the 8 and 11 warehouse used.

The change of any of the warehouses rates doesn't have any great effect on the total number of warehouses that lower the total costs. Which means that at different warehouse rates the number of warehouses that makes the lowest costs will be more or less the same amount of warehouses.

Relative difference \(((\text{Highest cost} - \text{Lowest Cost})/\text{Highest Cost})\)

The change of warehouse rates doesn't affect the relative difference much. This can be seen that in appendix JJ the relative difference are almost the same and in appendix II the relative differences are different.
The change of the rates for the transport have more or less the same impact on the change of the total cost when adding a warehouse till the lowest costs are reached. From Table 29, gathered form appendix II, can be seen that the changes of the rates have the same perceptual effect when taking to relative difference with the original situation into account. With a decrease of the discount with 15 % or and increase with 5 % the change of the total cost when adding warehouses is respectively 4 % and 5 %. For the Rough distribution counts that an increase or a decrease of 10 % of the rates this has an impact on the drop of the total cost of only respectively 6 % and 3 %.

Table 29 relative differences between changes in rates and the decrease of total costs when adding warehouses

<table>
<thead>
<tr>
<th>Relative differences</th>
<th>Normal</th>
<th>Storage &amp; handling Cost decrease 10%</th>
<th>Storage &amp; handling Cost increased 10%</th>
<th>Interest rate 6%</th>
<th>Interest rate 10%</th>
<th>Average Relative difference</th>
<th>Percentual difference Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transport rates Current (FD 90 %)</td>
<td>6,0%</td>
<td>6,3%</td>
<td>5,7%</td>
<td>6,5%</td>
<td>5,5%</td>
<td>6%</td>
<td>90% -90% = 0%</td>
</tr>
<tr>
<td>Fine distribution discount 75 %</td>
<td>21,0%</td>
<td>19,2%</td>
<td>18,4%</td>
<td>19,1%</td>
<td>18,2%</td>
<td>19%</td>
<td>90% -75% = 15%</td>
</tr>
<tr>
<td>Fine distribution discount 95 %</td>
<td>0,2%</td>
<td>0,2%</td>
<td>0,2%</td>
<td>0,2%</td>
<td>0,2%</td>
<td>0%</td>
<td>90% -90% = 0%</td>
</tr>
<tr>
<td>Rough distribution Increase 10%</td>
<td>5,5%</td>
<td>0,0%</td>
<td>5,3%</td>
<td>5,9%</td>
<td>5,1%</td>
<td>5,5%</td>
<td>10% -0% = 10%</td>
</tr>
<tr>
<td>Rough distribution Decrease 10%</td>
<td>6,5%</td>
<td>6,4%</td>
<td>6,2%</td>
<td>7,0%</td>
<td>6,0%</td>
<td>7%</td>
<td>10% -0% = 10%</td>
</tr>
</tbody>
</table>

The assignment of countries to warehouses.

The allocation of the countries to the warehouses can be found in appendix KK, A and OO for every scenario. From this analysis can be concluded that the delivery of the part numbers to the countries (=fine distribution) from the warehouse in the Netherlands is the most cost efficient option. The exceptions on this rule are mostly the delivery to the countries Poland, Hungary and Romania. These countries can be delivered from the warehouse in their own country. When the total cost increases by the increasing rates the delivery with domestic shipments in other countries can be also cost effective. This mean that beside the warehouses in the Netherlands all the other warehouses mainly deliver to costumers in the same country as were the warehouse is situated. This means that the cost of the rough distribution are, in most cases, bigger than the savings that could be achieved with the fine distribution, with the exception of domestic shipments (when total costs are higher).

8.3 Calculations with different discount percentage fine distribution

From the previous analysis it is clear that the biggest results in the cost of the network can be achieved with a change in transport rates. With the current prices (=discount rate 90 % fine distribution) the total cost with the four warehouses is calculated on 5.179.786,- Euro. Within the scenario the current discount that is used for the fine distribution is 90 %. This figure is
derived from the comparison of the calculation of the financial department of Skil and the own calculation. As earlier mentioned the exact prices and discount rates are not known.

After the analysis is appears that these fine distribution discount has a major impact of the cost and the layout of the network.

Normally these price agreements are made by the Robert Bosch organization and made based on the total amount of goods distributed by this organization. This amount contains goods of different business units and not only from Skil. When suggesting a network in which the fine distribution is performed mostly from the Netherlands, as within the optimum network, Skil will have to make own price agreements with a carrier that performs the distribution for only Skil. Could Skil get a discount that is as high as 90%?

Therefore in this paragraph an analysis is made what will be the outcome for the network when the discount rates differ a lot from the earlier suggested 90% discount. In the next paragraphs different discount percentages for fine distribution are taken and the results of these different discount rates on different scenarios.

This calculations are done the situation when the Total Nett sales are: 83 Million (Year 2008), 66 Million (decrease of 20%) and 100 Million (increase 20%).

8.3.1 Total Nett Sales 83 Million (Year 2008)

In the earlier scenario analysis already a discount percentage of 75% is calculated. In this paragraph discount percentages with a change of 10% discount a time is taken. This is done to give Skil a clear overview of what the result will be on the cost and for the network when a lower discount rates are agreed with the carrier. In appendix SS an overview of the development of the costs when adding warehouses is given and in appendix KK the overview of the allocation of countries to warehouses is given.

In Figure 55 the cost development of the total network with different fine distribution discount percentages can be seen.
In the current distribution network the total cost of the network without a discount for any of the rates is 28,859,948,- Euro (see paragraph 5.2.3 and Table 16, pag 99). With the ‘optimal’ network calculated the total costs are 21,484,877,- euro. This is a decrease of costs with 25%.

This means that a change of the allocation of countries to other warehouses can result in a change of costs with 26%.

Table 30 Comparison network cost current and ‘optimal’

<table>
<thead>
<tr>
<th>Activity</th>
<th>Own Calculation 2008 Current</th>
<th>Own Calculation 2008 ‘Optimal’</th>
<th>Difference (%) 2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transport costs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transport costs rough distribution</td>
<td>€ 1,526,950</td>
<td>€ 1,119,152</td>
<td>27%</td>
</tr>
<tr>
<td>Transport costs fine distribution</td>
<td>€ 22,747,537</td>
<td>€ 16,740,737</td>
<td>26%</td>
</tr>
<tr>
<td>Total</td>
<td>€ 24,274,486</td>
<td>€ 17,859,889</td>
<td>26%</td>
</tr>
<tr>
<td>Warehouse &amp; Handling costs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Handling costs _Goods In</td>
<td>€ 105,931</td>
<td>€ 53,356</td>
<td>50%</td>
</tr>
<tr>
<td>Handling Costs_Goods Out</td>
<td>€ 1,577,261</td>
<td>€ 967,391</td>
<td>39%</td>
</tr>
<tr>
<td>Storage costs</td>
<td>€ 990,864</td>
<td>€ 880,172</td>
<td>11%</td>
</tr>
<tr>
<td>Total</td>
<td>€ 2,674,055</td>
<td>€ 1,900,919</td>
<td>29%</td>
</tr>
<tr>
<td>Inventory costs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inventory costs</td>
<td>€ 1,911,407</td>
<td>€ 1,717,600</td>
<td>10%</td>
</tr>
<tr>
<td>Total</td>
<td>€ 1,911,407</td>
<td>€ 1,717,600</td>
<td>10%</td>
</tr>
<tr>
<td>Overall Total Costs</td>
<td>€ 28,859,948</td>
<td>€ 21,478,407</td>
<td>26%</td>
</tr>
</tbody>
</table>

In Table 30 the difference of every activity can be seen. Although only one warehouse in the optimal network isn’t used for fine distribution and two warehouse take 23 countries to
distribute to, the biggest difference is with handling cost goods in. And the biggest absolute savings are with the fine distribution. This means that the optimal network looked at a solution for the network in which the fine distribution rates are the most important parameter.

The discount percentage that is needed for the fine distribution to make sure that the total cost of the network are the same or below the costs that are calculated by the financial department can be derived from the graph above. The cost calculated by the financial department are 8.387.165,- Euro (see paragraph 5.2.3 and Table 16). Drawing a line at approximately 8.387.165,- horizontal the discount percentage is about 74 % discount (see Figure 56)

Figure 56 Estimate discount percentage needed

With this discount rate agreed with the carrier for their fine distribution of good to countries Skil can manage their own logistic network without the benefits of the scale of economy that they now have contributing to the Bosch logistic network.

8.3.2 Total Net sales Increase 20 % (100 Million)

In appendices TT, VV and QQ the result are shown of the analysis of the network when the total net sales increases with different discount rates for fine distribution. This analysis shows that the total costs always increase which is logical because the number of part numbers distributed
is increased. The warehouse cost although decreases (regarding the year 2008) which can be explained due to the fact that the forecast smoothes the demand pattern pro month which causes eventually lower safety and replenishment stock. The KPI supply chain cost are lower than in the year 2008. This also can be explained due to the fact that the warehouse costs are lower by the smoothing effect of the forecast. But compared this with a decrease of the total net sales the KPI supply chain costs are lower. Which means that a larger amount of part numbers have a positive effect on the KPI supply chain costs. Also the percentage of warehouse costs regarding the total costs are lower in case of an increase of the demand compared with the decrease of the demand.

8.3.3 Total Net Sales Decrease 20 % (66 Million)

In appendices UU, VV and QQ the result are shown of the analysis of the network when the total net sales decreases with different discount rates for fine distribution. This analysis shows that the total costs always decrease which is logical because the number of part numbers distributed is lower. The warehouse cost although decreases which can be explained due to the fact that the forecast smoothes the demand pattern pro month which causes eventually lower safety and replenishment stock. The KPI supply chain cost are higher than in the year 2008. This is remarkable because the warehouse costs are lower by the smoothing effect of the forecast. This means that when a decrease of demand is happening the KPI supply chain costs increases. The costs of the physical distribution network increases in relative sense. This means that a smaller amount of part numbers in the network has a negative effect on the KPI supply chain costs.

8.4 Sub-Conclusion

This chapter looks at the consequences for the network design in terms of costs when parameters are changed. The idea behind this analysis is to look how robust the network is and what has the biggest or least impact on the network when changing the parameters.

The model presented in chapter 6 has two categories of control variables. These are: the demand of part numbers of each country and the costs aspects.

The demand of the part numbers are changed by using a forecast of each individual part numbers based on the demand pattern of the year 2007 and 2008. Two forecasts have been made. The first one is when the demand of part numbers increases with 20 % to a total net sales of 100 million euro’s. The second is when the demand of part numbers decreases with 20 % to a total net sales of 66 million euro’s.
The costs aspects are divided into transportation costs and warehouse costs. Within these costs another diversion is made between the different cost drivers. This is done to gain a complete understanding of the costs developments in the model when changing parameters in the model. To vary the parameters the fine distribution rates were set a starting point. These turned out to produce the biggest impact on the network. So this parameters was changed ten times every time with 10%. This is done to have a full understanding of the effects of this major parameter. Because steps of 10% were taken for this parameters a look has been made to the change of absolute values of this rate. To be sure that the changes of the different parameters were in line with each other these absolute changes must be kept more or less the same. This meant that the other parameters should change also with 10% with the exception for the interest rate. This should change with 2%.

For the year 2008 34 different scenarios have been analyzed and for the situations that the demand increases or decreases with 20% 26 different situation have been analyzed.

From these different analyses the following results from the change of the costs parameters were obtained. When the prices of the parameters increases the total costs of the network increase and vice versa. The warehouse in Latvia will always be redundant and the warehouses in The Netherland, Poland, Romania and Hungary are always needed in the network. The other warehouses are depending on the rate of the fine distribution. The number of warehouses needed highly depend on the fine distribution rate. The rates for the warehouse costs don't have a big effect on the relative differences of the decrease of the total costs in a network. The change of fine distribution rate sorts the biggest effect on the decrease of the total network costs when adding warehouses. It turns out that when adding a warehouse in most cases only the customers in the same country are allocated to this warehouse. An exception in all cases is the warehouse of in The Netherlands. This warehouses is allocates in all cases to the most countries.

From the analysis of the change in demand can be concluded that an decrease of the demand has an negative effect on the KPI supply chain costs. An increase of the demand has a positive effect of this KPI. This means that the network costs benefit when the total demand is increased.
Conclusions, recommendations and limitations
In this last chapter the conclusions, recommendations and limitation of the research are described. The first paragraph gives the main conclusions based on the objective of this research. The next paragraph gives the recommendation. This research describes possible ways of restructuring the physical distribution network. It give a clear direction of possible manner to lower the logistic costs. This research gives no readymade solutions. Therefore the paragraph about recommendation gives subjects for further research which provides a support to come up with solutions to lower the logistic costs. Paragraph 9.3 gives the limitations encountered doing this research within Skil. These limitations have to be kept in mind when discussing the conclusions and recommendations of this research.

9.1 Conclusions
The main objective of this research is to (re)-design the physical distribution network for Skil Europe B.V. for the next 3 to 5 years towards lower the supply chain costs.

To complete this objective a main question is formulated: What is the optimal physical distribution network design for Skil regarding the logistic costs? Within this main question the lower costs will be an important evaluating criteria in the search. Because the main objective is about designing a physical distribution network it will be a search on strategic level.

From this main question 7 sub-questions are derived. When answering these 7 sub-questions the main question is answered and the objective will be reached. The following these questions are displayed again and the answers n the questions are given.

1. What are the criteria for an analysis to design a physical distribution network?

To propose an alternative physical distribution network is it import to gain knowledge about the current logistical structure of a company. With this information a search is made if the current structure needs a change for the future. Chapter 3 provides this necessary information within literature to make an analysis of a design of a physical distribution network. With use of this literature a generic framework to analyze a design of a physical distribution network is generated (see Figure 57). This generic framework is used as a criterion that will be used to analyze the organization of Skil. It can also be used for other companies to better understand the organization in depth in order to gain a clearer overview of their logistical procedures. When looking for a alternative network design this information is needed to be able to change aspects of the organization in order to adept to the future
2. How is the physical distribution network of Skil currently organised?

The answer on this question an analysis is made based of the first three steps of the generic framework. The competitive strategy matrix of Porter’s is used to get the strategy clear. Skil uses a strategy which lies in between the focus and differentiation. This is remarkable because the theory gives that the best way of getting a good market positioning for their products a clear corporate strategy must be chosen. In this case Skil doesn’t make a clear choice regarding the integrated costs. The logistic target Skil has, is to eventually get a service level of 98% with the supply chain costs [% of Total Net Sales] below 13 % in 2011.
The next step is to get a clear overview of the as-is organization. Skil uses different warehouses in Europe to distribute their products from the main warehouse in Breda / Meer to the customers in the 37 countries. These warehouses are affiliated to the customers in the countries. Skil keeps inventory in these warehouse at a level that the service level will be met. Therefore the CODP are lying at these warehouses. The products between the warehouses are transported by a carrier which uses mainly truck loads. The transport of products is divided in rough distribution (warehouse to warehouse) and fine distribution (warehouse to customer) and done in all cases by a 3PL. Due to the fact that the lead times are rather long (65 - 75 days), the CODP lies that far in the logistic chain the costs and the service level target is 98% it means that a lot of costs are at transport and inventory. The strategic value of the product of Skil and their complexity aren’t that high, which means that Skil is keen on meeting the customers demand.

From the calculation of the cost of the current network done in Chapter 5 based on the demand of each part number pro month pro country for the years 2007 and 2008 an overview of costs is generated. In Table 31 an overview is given of these calculated costs for the year 2007 and 2008.

Table 31 Physical distribution costs calculated with use of the equations

<table>
<thead>
<tr>
<th></th>
<th>own calculation 2007</th>
<th>own calculation 2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transport costs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transport costs rough distribution</td>
<td>€2,155,688</td>
<td>€1,526,950</td>
</tr>
<tr>
<td>Transport costs fine distribution</td>
<td>€28,122,726</td>
<td>€22,747,537</td>
</tr>
<tr>
<td>total</td>
<td>€30,278,414</td>
<td>€24,274,486</td>
</tr>
<tr>
<td>Warehouse &amp; Handling costs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Handling costs Goods In</td>
<td>€167,816</td>
<td>€105,931</td>
</tr>
<tr>
<td>Handling Costs Goods Out</td>
<td>€2,183,237</td>
<td>€1,577,261</td>
</tr>
<tr>
<td>storage costs</td>
<td>€1,218,483</td>
<td>€990,864</td>
</tr>
<tr>
<td>total</td>
<td>€3,569,537</td>
<td>€2,674,055</td>
</tr>
<tr>
<td>Inventory costs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inventory costs</td>
<td>€2,303,760</td>
<td>€1,911,407</td>
</tr>
<tr>
<td>total</td>
<td>€2,303,760</td>
<td>€1,911,407</td>
</tr>
<tr>
<td>Overall Total Costs</td>
<td>€36,152,711</td>
<td>€28,859,948</td>
</tr>
</tbody>
</table>

From this table can be concluded that the biggest share of costs is in the fine distribution of the part numbers from the local warehouses to the costumers in the countries.

To validate the calculation model a comparison is made with the costs calculated by the financial department of Skil (see Table 32)
Table 32 Comparison own calculation with Skil's calculation

<table>
<thead>
<tr>
<th></th>
<th>own calculation 2008</th>
<th>financial department 2008</th>
<th>absolute differences 2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transport costs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transport costs rough distribution</td>
<td>€1,526,950</td>
<td>€2,274,537</td>
<td></td>
</tr>
<tr>
<td>Transport costs fine distribution</td>
<td>€24,274,486</td>
<td>€3,964,000</td>
<td>€20,310,486</td>
</tr>
<tr>
<td>total</td>
<td>€26,801,436</td>
<td>€6,938,037</td>
<td></td>
</tr>
<tr>
<td>Warehouse &amp; Handling costs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Handling costs Goods In</td>
<td>€109,050</td>
<td>€157,264</td>
<td></td>
</tr>
<tr>
<td>handling Costs Goods Out</td>
<td>€990,864</td>
<td>€2,128,000</td>
<td></td>
</tr>
<tr>
<td>storage costs</td>
<td>€2,674,055</td>
<td>€2,128,000</td>
<td>€546,055</td>
</tr>
<tr>
<td>total</td>
<td>€4,288,982</td>
<td>€4,226,059</td>
<td></td>
</tr>
<tr>
<td>Inventory costs</td>
<td>€1,911,407</td>
<td>€1,911,407</td>
<td>€0</td>
</tr>
<tr>
<td>total</td>
<td>€1,911,407</td>
<td>€1,911,407</td>
<td>€0</td>
</tr>
<tr>
<td>Overall Total Costs</td>
<td>€28,859,948</td>
<td>€8,268,000</td>
<td>€20,591,948</td>
</tr>
</tbody>
</table>

From this comparison can be concluded that mainly the fine distribution costs are showing a big difference. This can be explained due to the fact that normally Skil gets a discount for the fine distribution rates or the prices used in this research from UPS vary much from the real prices that are charged at Skil. When taken a fine distribution discount of 90% on the current rates of UPS the prices are more in line with the data calculated by the financial department.

3. What are the results of the analysis of Skil's current physical distribution network in terms of bottlenecks?

In Chapter 6 the costs of the current organisation are analyzed more in depth. This analysis of the costs gives more insight in possible ways to lower these costs and what will be the subjects for further research.

The bottlenecks in the current organisation are used as a start for looking for possible ways to lower the supply chain costs and the requirements needed for the alternative designs to handle these bottlenecks.

From the analyse of the costs it became clear that few cost savings can be achieved by using operational decisions, like changing pallet stacks or shortening the lead times. But the transportation cost are the biggest share of the total supply chain costs. This activity can be influenced by changing the physical distribution network. But by changing this network also the costs for inventory and warehouse & handling will be influenced.

The bottleneck in this research that it is not clear what the results on the supply chain costs will be when changing the lay-out of the physical distribution network.
The results in terms of costs and location-allocation of customers when changing a lay-out will be obtained after using the location-allocation model: ADD-Heuristic. Chapter 7 handles the development and outcome of this ADD-Heuristic for the situation of Skil.

4. **What are the requirements for an alternative design of the physical distribution network of Skil?**

It is clear that there will be a search of an alternative network design. In order to give a clear overview of the boundaries to make alternative designs a scope can be formulated like Huizinga (2000) explained and the generic framework displayed.

This overview of the scope is tool that helps to guide the development of the alternative designs. The mentioned subjects are used as a guideline to know what to use when making these alternative designs. It is a summary of the facets that are used.

In Table 33 the overview of the scope is given for the design of our new physical distribution network. This will be used as the requirements to design an alternative lay-out of the network.

**Table 33 Scope new design**

<table>
<thead>
<tr>
<th>Scope</th>
<th>Decisions regarding to:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Decision</td>
<td>a. Number of warehouses</td>
</tr>
<tr>
<td></td>
<td>b. Location of warehouses</td>
</tr>
<tr>
<td></td>
<td>c. Which countries are delivered by which warehouse</td>
</tr>
<tr>
<td></td>
<td>d. Warehouse in Netherland is always open</td>
</tr>
<tr>
<td>2. Evaluation criteria</td>
<td>Logistic costs</td>
</tr>
<tr>
<td></td>
<td>a. Transport cost 'fine distribution'</td>
</tr>
<tr>
<td></td>
<td>b. Transport cost 'rough distribution'</td>
</tr>
<tr>
<td></td>
<td>c. Warehouse costs</td>
</tr>
<tr>
<td>3. Logistic chain</td>
<td>The physical distribution network from main warehouse to the end customers in the various European countries</td>
</tr>
<tr>
<td></td>
<td>a. Main warehouse Netherlands -&gt; Local warehouses -&gt; Customers in countries</td>
</tr>
<tr>
<td>4. Geography</td>
<td>Whole Europe</td>
</tr>
<tr>
<td>5. Markets</td>
<td>Retail and whole salers of power tools in Europe</td>
</tr>
<tr>
<td>6. Products</td>
<td>All products</td>
</tr>
</tbody>
</table>
5. What are the alternative designs for the physical distribution network for Skil regarding the location-allocation policy?

Chapter 6 made clear that for the alternative design a search had to be made at the consequences when changing the lay-out of the network. Changing a network in this research means changing: the number of warehouses, locations of warehouses and the allocation of customers to the warehouses. With one restriction as mentioned in chapter 4, the warehouse in the Netherlands will remain open at any time. These changes in the network will be evaluated on the costs they generate with the proposed demand (2008, increase or decrease demand) of all part numbers from the customers in whole Europe.

In Chapter 7 the location-allocation model: ADD Heuristic is explained. This model is used in this research to calculated alternative design for Skil. It is a model that will fits the best for this research to look for alternative designs in order to lower the transportation and facility costs. It is a model that also could be used for other companies. The only change that will be needed is that the input variables have to be adjusted to this other company.

The target for this model is to: Optimize the transportation and facility costs for a centralized physical distribution structure through mitigating local distribution centres to a few distribution centres in Europe.

The important input parameters needed to minimize the transportation costs and warehouse costs are the demand of part numbers and from these derived the number of parcels and pallets or weight of a shipment between or within a country. The relation between the parameter in the model are given in Figure 58.
Figure 58 The relation between the parameters of the model

The relation diagram is used to calculate all costs of the physical distribution network. The model is designed in excel in which the demand of the part numbers per month per country will be the input. By opening and closing warehouses (one at a time) and allocate countries to these warehouses the costs can be calculated. When the steps are executed the warehouses are sorted in a decreasing order of total savings. For every step a warehouse will be assigned to a country (allocate). This allocation is done based on the lowest total cost of the open warehouse when distributing to that specific country.

A result of an alternative network is that, with fine distribution discount of 90%, there are only four warehouses needed to distribute all part numbers to the countries in Europe. The total cost for the network are in this case 5,179,786.- Euro. Table 34 and Figure 59
When looking at the original situation of the layout of the network compared to a calculated 'optimized' lay-out of the network, with fine distribution rate discount of 90%, the following result is obtained (see Figure 60).

<table>
<thead>
<tr>
<th>Order of warehouses</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Skil Netherlands</td>
<td>€5,179,786</td>
</tr>
<tr>
<td>2 Poland</td>
<td>€5,179,786</td>
</tr>
<tr>
<td>3 Hungary</td>
<td>€5,179,786</td>
</tr>
<tr>
<td>4 Romania</td>
<td>€5,179,786</td>
</tr>
<tr>
<td>5 Germany</td>
<td>€5,179,786</td>
</tr>
<tr>
<td>6 Spain</td>
<td>€5,179,786</td>
</tr>
<tr>
<td>7 Great Brittain</td>
<td>€5,179,786</td>
</tr>
<tr>
<td>8 Italy</td>
<td>€5,179,786</td>
</tr>
<tr>
<td>9 Bulgaria</td>
<td>€5,179,786</td>
</tr>
<tr>
<td>10 Denmark</td>
<td>€5,179,786</td>
</tr>
<tr>
<td>11 Greece</td>
<td>€5,179,786</td>
</tr>
<tr>
<td>12 Finland</td>
<td>€5,179,786</td>
</tr>
<tr>
<td>13 Latvia</td>
<td>€5,179,786</td>
</tr>
</tbody>
</table>

The total cost decrease and the share of the fine distribution costs increases a lot. This means less warehouses and more fine distribution from the warehouse in the Netherlands.

To be sure that the ADD heuristic gives a good solution a validation has been done of the heuristic. From this validation can be concluded that the ADD heuristic will give the lowest total costs for all situation when adding warehouses to the network to obtain the lowest costs, but the sequence of adding warehouses differs between the between the two used methods.

With use of this validated method different designs of the network could be made by changing the input parameters of the model.
6. Which parameters can be used to verify the robustness's of the physical distribution network of Skil?

Chapter 8 looks at the consequences for the network design in terms of costs when parameters are changed. The idea behind this analysis is to look how robust the network is and what has the biggest or least impact on the network when changing the parameters.

The model presented in chapter 6 has two categories of control variables. These are: the demand of part numbers of each country and the costs aspects.

The demand of the part numbers are changed by using a forecast of each individual part numbers based on the demand pattern of the year 2007 and 2008. Two forecasts have been made. The first one is when the demand of part numbers increases with 20 % to a total net sales of 100 million euro's. The second is when the demand of part numbers decreases with 20 % to a total net sales of 66 million euro's.

The costs aspects are divided into transportation costs and warehouse costs. Within these costs another diversion is made between the different cost drivers. This is done to gain a complete understanding of the costs developments in the model when changing parameters in the model. To vary the parameters the fine distribution rates were set a starting point. These turned out to produce the biggest impact on the network. So this parameters was changed ten times every time with 10 %. This is done to have a full understanding of the effects of this major parameter. Because steps of 10 % were taken for this parameters a look has been made to the change of absolute values of this rate. To be sure that the changes of the different parameters were in line with each other these absolute changes must be kept more or less the same. This meant that the other parameters should change also with 10 % with the exception for the interest rate. This should change with 2 %.

7. What is the result of the analysis of the robustness's of the different designs of the physical distribution network?

For the year 2008 34 different scenarios have been analyzed and for the situations that the demand increases or decreases with 20 % 26 different situation have been analyzed.

From these different analyses the following results from the change of the costs parameters were obtained. When the prices of the parameters increases the total costs of the network increase and vice versa. The warehouse in Latvia will always be redundant and the warehouses in The Netherland, Poland, Romania and Hungary are always needed in the network. The other warehouses are depending on the rate of the fine distribution. The number of warehouses
needed highly depend on the fine distribution rate. The rates for the warehouse costs don't have a big effect on the relative differences of the decrease of the total costs in a network. The change of fine distribution rate sorts the biggest effect on the decrease of the total network costs when adding warehouses. It turns out that when adding a warehouse in most cases only the customers in the same country are allocated to this warehouse. An exception in all cases is the warehouse of in The Netherlands. This warehouses is allocates in all cases to the most countries.

From the analysis of the change in demand can be concluded that an decrease of the demand has an negative effect on the KPI supply chain costs. An increase of the demand has a positive effect of this KPI. This means that the network costs benefit when the total demand is increased.

Finally an answer is given on the main question:

**What is the optimal physical distribution network design for Skil regarding the logistic costs?**

A clear, one solution answer on this question is not possible with only this research. The optimal physical network design depends highly on the input of the parameters. Especially the height of the fine distribution rate causing changes in the optimal lay-out of the network. Unfortunately this parameter was the only parameter that could not be retrieved from field and desk research within Skil. Therefore an example of another carrier has been taken to be able to calculated the supply chain costs of the alternative designs. But also with prices from this carrier the parameters of fine distribution rates had to be lowered to gain a physical distribution network with lower supply chain costs.

From this research can be concluded that:

- Implementing operational changes, like pallets load, will have a positive effect on the supply chain costs.
- Changing the rates in a way that the activities will become cheaper the total network costs will also be lower.
- The warehouse of Latvia is not necessary in all alternative designs.
- In the physical distribution network the warehouses of The Netherlands, Poland, Romania and Hungary are always needed.
- Changing warehouses rates have less effect on the costs and lay-out of the network than changing transport rates.
• The warehouse in the Netherlands takes the most fine distribution to the country. The other warehouses are used mostly for only domestic shipments
• Increasing the demand will lower the KPI Supply Chain cost.
• It is very important to know exactly the fine distribution rate to decide to change the layout of the network.
• The new introduced generic framework to analyse the design of the physical distribution network is useful tool. This tool provides a clear overview of the procedure to follow from starting to analyse a company in order to suggest a possible (re-) design of physical distribution network with lower supply chain costs.

9.2 Recommendations

This research doesn’t give a best solution for Skil to redesign their physical distribution network. It is a search for possible options to redesign their physical distribution network based on lower logistic costs. It gives a clear insight for Skil how their current network performs and how another network performs. Before Skil can really decide to change network further research will be needed to overlook possible consequences and results.

In this paragraph some recommendations are given that can be subject for a further search to lower the logistic costs.

From this research it becomes clear that the rates of fine distribution determine heavy the layout of the network. A change of the network in terms of using less warehouses and perform more fine distribution from one location also causes the biggest needed changes in the organization.

What is very important to investigate further on is: **What kind of agreements can Skil make with a carrier?**

Based on this outcome a choice can be made if it will be cost effective to change the lay-out of the network. Because of the major impact of the fine distribution rates on the costs for the network a subject for further research can be to look into depth what the exact parameters are for the fine distribution costs and compare them with the calculations made in this research.

In this research a search is done to look for possibilities to lower the total logistic costs for Skil. As mentioned this research aims at a reconfiguration of the physical distribution network, which means that if Skil want to change their physical distribution network strategic decisions have to be made which inflicts the whole organisation. But in this research also some possibilities are given more on operational level that can lower the logistic costs. Think hereby
at the possibility the increase the number of items on a pallet, reducing the lead times, and lower the weights of the packages. These are a few of possibilities can need further research within Skil and there implications for the costs and the organisation.

From the analysis made in chapter 7 of the KPI is becomes clear that the inventory costs of the forecasted demand (increase and decrease of the demand with 20 %) is significant lower than the data of the year 2008. The data of the year 2008 is the real time demand of the countries, which contains big fluctuation of demand pro month pro part number. By smoothening the demand pattern cost savings can be achieved on interest costs. How this can be achieved within the organisation can also be a subject for further research.

To get a 13 % supply chain costs of the Total net sales a certain amount of discount for the fine distribution costs is needed. These calculations are all made based on the service level of 98 %. As earlier mentioned it is important to know what kind of agreements that can be made with carriers. Maybe that the needed amount of discount can’t be reached. Then Skil should have a research if the service level of 98 % can be reached after all with a supply chain costs of 13 % in the future.

When further research within Skil is conducted it is recommended that they divide the different costs activities as a subject. This is to be sure that a thorough research can be done within reasonable time.

For a good and quick overview the recommendations are summarized:

- Further research is absolutely necessary for the subject of the fine distribution costs to be able to make a good decision how to change the layout of the physical distribution network.
- Further research on operational decisions can contribute to lower supply chain costs.
- Further research on how the big fluctuation in the demand pattern can be smoothened is needed to gain extra cost reduction over the complete supply chain.
- Further research is necessary to investigate if the combination of the logistic targets of 98 % service level and the supply chain costs of < 13 % (Total Net Sales) can be reached for the physical distribution network of Skil.
- Divide the different cost activities as a subject each when further research will be performed by others for the benefit of time.
9.3 Limitations

This research has been taken out with as much as carefulness as possible to reflect a truthfully financial situation. This is important because based on some of the conclusions and recommendations Skil can make a more deepened search for possibilities to lower their logistic costs. Certain limitations have to be kept in mind when evaluating the conclusions and recommendations of this research.

The logistic cost is one of the main subjects that comes forward in the search for a possible design of the physical distribution network. The search for the right calculation model for Skil was a harsh task. Due to the incorporation of Bosch for the calculation of many of the logistic costs no complete clear overview could be made of some of the parameters of the different logistic costs. The biggest limitation lies in the parameters of the fine distribution rates. This parameter has a major impact on the costs for the network. When evaluating the costs for the different networks it must be kept in mind that the parameters are from only one carrier and might differ from country to country when using another carrier.

A change of the demand pattern with an increase or a decrease of the demand is a subject of this research. By using a forecast program to generate this demands the demand pattern turned out to be more smoothing than the actual demand of the individual part number per month per countries. This lead to a lower inventory costs because the safety stock and replenishment stock were calculated based on the normal distribution of the demand per month. With a bigger fluctuation of this demand pattern the safety and replenishment stock are also higher. The limitation of the forecast program that smoothes this demand pattern must be kept in mind.
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Abbreviations

CLP = Centre Logistic Planner
DM = Distribution Manager
DIY = Do-It-Yourself
PT = Power Tool
CSO = Country Sales Organization
IDC = International Distribution Centre
LDC = Local Distribution Centre
SC = Supply Chain
KPI = Key Performance Indicator
CODP = Customer Order Decoupling Point
FTL = Full Truck Load
LTL = Less Truck Load
3PL = Third Party Logistic
TOP = Turn Over Point
NGU = Nett Gesamt Umsetz (Net Sales)
Mio = Million
Kg = Kilogramm
UFLP = Uncapacitated Facility Location Model
LP = Linear Programming
SSFL = Single Source Facility Location
CFLP = Capacitated Facility Location Model
IP = Integer Problem
BIP = Binary Integer Problem
SKU = Stock Keeping Unit
Abbreviations from calculations

\[ TC = \text{Total costs in physical distribution (euro/year)} \]
\[ T = \text{Transport (euro/year)} \]
\[ I = \text{Inventory cost (euro/year)} \]
\[ W = \text{Warehouse & handling cost (euro/year)} \]
\[ T_{\text{rough}} = \text{Total transport costs for rough distribution (euro/year)} \]
\[ T_{\text{fine}} = \text{Total transport costs for fine distribution (euro/year)} \]
\[ T_{\text{tot}} = \text{Total transport costs a year for all destinations (euro/year)} \]
\[ T_{\text{dist}} = \text{Total transport cost a year for specific destination (euro/year)} \]
\[ T_{\text{month}} = \text{Total transport cost for specific destination pro month (euro/month)} \]
\[ FTL_{\text{y}} = \# \text{of full truck loads pro month pro destination (# truck / month)} \]
\[ C_{\text{FTL}} = \text{Price for full truck load to specific destination (euro/truck)} \]
\[ LTL_{\text{y}} = \# \text{of pallets that are NOT in a full truck} \]
\[ C_{\text{pl}} = \text{Price pro pallet for specific destination (euro/pallet)} \]
\[ FTL_{\text{max}} = \# \text{of full truck loads pro month with maximum # of pallets} \]
\[ FTL_{\text{top}} = \# \text{of full truck load pro month with # of pallets depending on turn over point} \]
\[ D = \text{Demand in # of pallet pro month (pl/month)} \]
\[ P_{\text{max}} = \# \text{of pallet maximum in truck (=66 pallets)} \]
\[ P_{\text{over}} = \# \text{of pallet over after calculation of max # of pallets in a truck} \]
\[ P_{\text{overmax}} = \# \text{of pallets that are NOT shipped in a full truck} \]
\[ P_{\text{top}} = \# \text{of pallets making a full truck depending on turn over point} \]
\[ LTL_{\text{y}} = \# \text{of specific partnumbers sold a month} \]
\[ P_{\text{pol}} = \# \text{of specific partnumbers on a full pallet} \]
\[ T_{\text{fine}} = \text{Transport cost fine distribution (Euro/year)} \]
\[ W_{d} = \text{Weight of the delivery (Kg)} \]
\[ C_{w} = \text{Cost of transport specific weight of cargo (euro/ # Kg)} \]
\[ I = \text{Inventory costs (euro/year)} \]
\[ S_{\text{tot}} = \text{Total stock costs (euro/year)} \]
\[ T_{I} = \text{Total stock in transit costs (euro/year)} \]
\[ S = \text{Safety stock (partnumber / month)} \]
\[ z = \text{Safety factor} \]
\[ \sigma = \text{Standard deviation of demand} \]
\[ L_{d} = \text{Lead time for specific destination (working days)} \]
\( D_{LT} \) = Demand during lead time (partnumber / month)

\( L_d \) = Lead time for specific destination (fraction of workingdays a month)

\( TS \) = Total stock in warehouse (partnumber / month)

\( SS \) = Safety stock (partnumber / month)

\( RS \) = Replenishment stock (partnumber / month)

\( S_{tot} \) = Total stock costs (eur/month)

\( S_g \) = Stock cost for a certain destination (eur/month)

\( i \) = Interest percentage (%)

\( AV_g \) = Average value monthly turnover pro destination (euro/month)

\( SS_{pd} \) = Total Safety stock pro partnumber and destination (partnumbers/month)

\( RS_{pd} \) = Total replenishment stock pro partnumber and destination (partnumber / month)

\( \bar{V}_p \) = Average value of partnumber (euro)

\( TI \) = Costs total inventory in transit (eur)

\( t_t \) = Total average time in transit (working days)

\( TO_d \) = Daily turnover (# partnr)

\( \bar{V}_p \) = Average value of partnumber (eur)

\( I \) = Interest percentage (%)

\( W \) = Warehouse & handling costs (euro/year)

\( H_{total} \) = Handling costs (euro/year)

\( S_{total} \) = Storage costs (euro/year)

\( H_g \) = Handling costs for a certain destination (eur/month)

\( V_p \) = Number of pallets, order lines or pieces for this destination

\( H_{pg} \) = Costs for handling 1 pallet, order lines or pieces for this destination (eur/#)

\( H_{total} \) = Total handling costs all destinations (euro / year)

\( H_{sd,tot} \) = Total handling costs for this destination (euro / year)

\( S_{total} \) = Total Storage costs all destination (euro/year)

\( S_{sd,tot} \) = Total storage costs one destination (euro/year)

\( S_{g} \) = Storage costs for a certain destination (eur/ month)

\( P_{avg} \) = Average pallets in storage a month

\( C_{st} \) = Costs for storage of one pallet (eur / month)

\( x_{ij} \) = The proportion of customer j's demand satisfied by facility i

\( z_i \) = 1 of facility i is established, 0 otherwise

\( c_{ij} \) = The total production and distribution cost for supplying all of customer j's demand from facility i

\( f_i \) = Fixed costs of establishing facility i

\( I, J \) = The sets of candidate facility sites I and the set of customers J respectively