Master Thesis
Project Report

Silva Sweden AB
Kungliga Tekniska Högskolan

Pre-study for
a central warehouse

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Preface

With this master thesis we complete the last step of our Master of Science degree from the school of industrial engineering and management of KTH. This thesis was carried out both at Silva Sweden AB in Sollentuna and the department of Industrial Production at KTH. This thesis was a good opportunity to improve our experience in the field of logistic and supply chain as well as to acquire valuable knowledge.

We are grateful to Silva Sweden for giving us the opportunity to work on this project. We would like to thank you Göran Sjöquist our supervisor at Silva for his help during our work, also Göran Andersson, Scott Beveridge, Stefan Dahl, Philippe Lemarchand and Silva France employees, Dirk Lösel, Gunilla Pedersen, Bengt Porseby, Christer Tillander for providing us valuable information and helping us along our thesis.

We would like to thank our supervisor Jerzy Mikler at KTH for support and guidance throughout the project.
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INTRODUCTION

Project overview

Project definition

The Silva Group is evaluating the strategic possibility to step up to a centralized supply chain with a European 3PL solution through a central warehouse. The continuous request for improved service levels toward the customers worldwide is currently held up by the existing network structure of transports and the lead times involved. The situation motivates an analysis of the situation and an evaluation of a number of identified alternatives.

Project objective

Silva acquisition by Fiskars and the consequent introduction of new Gerber products in the logistics system claimed a reorganisation of warehousing and distribution network. The central warehouse project to which this master thesis is dedicated, is taking part in this global supply chain reorganisation. Initially planned to start in early 2008, the central warehouse project aims at a more relevant, more efficient and above all more customer-oriented organisation of the logistic system.

The thesis is in itself a preliminary part of the global project as it consists of a feasibility study as well as an analysis of benefits, drawbacks and risks linked to the settlement of a central-warehouse logistic system. Results and first conclusions will be used as grounding to launch the effective project in the beginning of 2008.

For many reasons and from the beginning of the master thesis, it is highly likely that the execution of the project will be committed to an external company, a third party logistics which will be more able to respond optimally to the customers requirements. Therefore, the thesis will focus more on the feasibility, pros and cons to a central warehouse in Silva's supply chain rather than on the execution itself.

In order to assess in the best way all the benefits and inconveniences, the thesis will be divided in 4 main chapters dealing with the different parts related to the project: location, stocks transportation and warehousing. Each of these areas will be examined so as to determine the current state, to estimate the potential advantages as well as expected drawbacks, and to evaluate the risk of the project regarding the field concerned. Last, the various alternatives will be confronted through a decisional model, conclusions and proposals will be presented.

Project boundaries

In this project only the supply chain related to European operations are taken into consideration. The project scope is restricted to the finished product flows linked to the sales, services and distribution activities of the European offices.
A. Diagram In/Out

The following diagram is a tool used for a first approach of the project. It shows the boundaries of the project with the main features related to the project surroundings. It helps to define the scope of the project so as to highlight the key elements to get onto and those to disregard.

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The Silva Group

Company presentation

Silva is a Swedish manufacturer of compasses created in 1933. The company is held by the Finnish group Fiskars within the Outdoor Recreation division. The Silva group has approximately 250 employees split up into 6 main structures. The parent company Silva Sweden AB, also Head Office of the company, is located in the north of Stockholm. The group has 5 subsidiaries: Silva Limited in United Kingdom, Silva France, Silva Germany, Brunton in the United States and Silva Far East in Hong Kong.
In 2006, the former marine division of Silva now renamed Nexus got separated from the Silva Group and is now an independent entity. All marine products except compasses are product references excluded from this project. Gerber is a subsidiary of the Fiskars Group which products are sold in Europe through Silva’s distribution network.

Silva Far East is a subsidiary of the Silva Group located in Hong Kong and acts as the interface with Silva’s Chinese factory and takes care of the shipments from the factory to Europe. Silva Germany, Silva France and Silva Limited are three subsidiaries that only deal with their respective local market. Besides selling Silva’s products, Silva France and Silva Limited have also a distribution activity of products manufactured by other companies. This distribution activity accounts for more than half of Silva France total turnover. Accounting for a fifth of Silva limited total turnover, this distribution activity is bound to disappear during the following year. As the name Silva was already used on the US market, Silva bought the Brunton company and turned it into its American subsidiary. Like the other subsidiaries, Brunton only deals with its local market. Moreover it has its own production facility and a different range of products, adapted to the American market. Thus Brunton will be referred as a different entity and all the activities of Brunton will not be considered in this project.
Products review

A. Products

Silva produces and distributes products for Outdoor uses. Silva’s products are organized into 7 categories:

- Compasses
- Mobile Lightning (Flash lights, headlamps…)
- Exercise-4-life, exercise tool (pedometers, stopwatch…)
- Binoculars
- Outdoor instruments (GPS, Map measurers, Solar cells panel, Atmospheric probes)
- Professional instruments (professional compasses, clinometers…)
- Accessories (lighter, map case…)

Here is a set of different Silva products sorted by category:

1) Compasses

The compasses are set into 8 different series. Some batches based on the regular series are also customized on customer requests.

Field Series

Ranger Series

Expedition Series

Voyager Series
2) **Mobile lightning**

- High Power
- L - Series
- Batteries and chargers

**Excercise-4-life**

- Pedometers
- Stop Watches
- Walking Poles
3) **Binoculars**

4) **Outdoor Instruments**

Atmospheric Data Center  GPS  Portable Power  Map Measurer

5) **Professional instruments**

Compass  Clinometers / Height meter

6) **Accessories**

Multi purpose compass  Storm Lighter  Map Case

**B. Internal classification**

To keep the product catalog organized with regards to all the different references, Silva has a specific internal classification. The products are organized into a classification tree with the following categories: Product Group, Item Group and an identification number. The identification number composed of 4 digits is attributed by reference. The first digit represents the Product Group, the highest level of the classification. The second digit represents the Item Group, the next level of classification. As a product can often have different attributes such as different colors, the 2 last digits identifies to the final product reference.
Fig. 4 - Partial Product Group tree

The partial tree above is a part of the product classification acquired through the ERP system.

<table>
<thead>
<tr>
<th>Main product category</th>
<th>N. of subcategories</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>COMPASSES/PROFESSIONAL</td>
<td>53</td>
<td></td>
</tr>
<tr>
<td>MOBILE LIGHT</td>
<td>20</td>
<td>Flash lights, Headlamps</td>
</tr>
<tr>
<td>WELLNESS</td>
<td>22</td>
<td>Pedometers...</td>
</tr>
<tr>
<td>OUTDOOR INSTRUMENTS</td>
<td>27</td>
<td>GPS, Portable power...</td>
</tr>
<tr>
<td>OPTICS</td>
<td>13</td>
<td>Binoculars...</td>
</tr>
<tr>
<td>OUTDOOR OTHER</td>
<td>64</td>
<td>Orienteering Accessories, knives, lighters...</td>
</tr>
<tr>
<td>MARINE COMPASSES</td>
<td>15</td>
<td>Nexus products (Not considered in this project)</td>
</tr>
<tr>
<td>MARINE ELECTRONICS</td>
<td>18</td>
<td></td>
</tr>
</tbody>
</table>
Customers

Overview of Silva’s customers

Silva is composed of Silva Sweden AB and 4 subsidiaries: Silva Far East, Silva Germany, Silva France and Silva limited in UK. As it has been introduced previously, Brunton and North American operations are excluded of the organization. Therefore the main part of the Silva’s supply chain organization is focused in Europe. Each of the 3 subsidiaries (Silva Germany, Silva France and Silva Limited) focuses on their own local market while Silva Sweden AB takes care of the Scandinavian market and the rest of the customers worldwide.

Fig. 5 - Sales split up by region (2006)

Considering the sales by region, Sweden and Scandinavia (Denmark, Finland and Norway) represents almost 40% of the total sales. It is worth noting that the part labelled USA corresponds to products sold to the USA by Silva Sweden (mostly to Brunton) and is not directly linked to Brunton activities. Thus it can be observed that around 78% of the sales are in Europe.
Subsidiaries main customers

The following maps show the main customers for each Silva’s subsidiary and their locations.

Fig. 6a - 10 main customers in Germany and Austria (2007)

Fig. 6b - 10 best customers in France (2007)

Fig. 6c - 10 best customers in UK and best customer in Ireland (2007)

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**IT and databases**

Silva AB Sweden uses an Enterprise Resource Planning system (ERP) to integrate all data and processes of its organization into a single database. This database contains all information concerning the supply chain of the company such as Inventory, Order Entry, Purchasing, Supply Chain Planning, Inspection of goods, Claim processing...

The current ERP system implemented at Silva AB Sweden is Jeeves. Jeeves, produced by the company of the same name, is built on several modules providing information on all steps of the Supply Chain Management. Access to the database is made through an integrated query system. The data collected from Jeeves can be then exported to a spreadsheet program such as Excel for data processing and analysis.

For the moment, the ERP system is not completely centralized. Only Silva Sweden AB and Silva limited are equipped with this system. The subsidiaries in Germany and France are using other systems.

A project is underway to implement Jeeves ERP system in all the subsidiaries. According to the project schedule it should be up and running at the beginning of 2008. Using the same ERP system for the whole Silva Group will considerably help for the global Supply Chain Management and ease the integration of a central warehouse in the logistic organization. Data updating between Silva Sweden and the subsidiaries will be in real time and the activity report will be performed faster. Moreover the integration of this ERP system will also be easier in case Silva calls upon the services of a third party logistic provider.
CENTRAL WAREHOUSE
PROJECT

Introduction

Nowadays with the market globalization and the European common market, the competition between companies tends to rise as well as the need for a high level of efficiency and reliability. This trend forces companies to reconsider their strategy by focusing on their core business competences and calling upon a provider for the other activities (for example: transportation, warehousing...).

In industry, companies aim to have a strong and structured Supply Chain to fulfill these efficiency and reliability requirements. By changing into a polar logistic organization i.e. a structure organized on a very few major distribution poles, the flows are concentrated and the number of warehouse reduced. The objectives of such strategies are to optimize the Supply Chain in terms of quantity, quality, cost and lead time.

For warehousing activities, companies have the choice either to have their own central warehouse or use the services of a third party logistic (3PL) provider.

Supply chain – Overview & current status

Currently, Silva’s organization is mainly centered on Silva Sweden.

Considering only Silva’s products (Brunton excluded), the two main manufacturing facilities are in Sweden and in China. Products manufactured in China are transferred directly to Silva Far East. Products manufactured in China are shipped to Silva Sweden from Silva Far East based in Hong Kong. All Silva’s products are gathered in Sweden then shipped to the Silva’s subsidiaries (France, Germany, UK) or directly to customers in Sweden, Europe and in the rest of the world. Each subsidiary takes care of its local market. Besides selling Silva’s product, Silva France and Silva Limited have a distribution activity. The products of the distribution activity are directly ordered to the suppliers and delivered by them without passing through Silva Sweden AB, except for most of the products coming from Gerber.

Below comes a set of maps representing product flows for the 4 entities of Silva: Silva Sweden, Silva France, Silva Germany and Silva Limited. On these maps, internal product flows are shown by red arrows and external product flows by green arrows. Internal product flows refer to flows of products manufactured by Silva and external product flows to flows coming from suppliers or subcontractors. With each arrow comes the total product value related to this specific product flow.
Silva France is located in Mantes la Ville, west of Paris. Approximately a third of Silva France’s turnover is related to sales of Silva’s products. The distribution activity which represents most of the product flow to Silva France comes from the need of central purchasing agency or large Sport Distribution Company to use a commercial representative. Indeed those ones could not always order products directly from the manufacturer. Thus Silva France is acting both as a Silva’s products wholesaler and as a commercial representative of third party companies.
Silva Germany

Silva Germany is located in Frankfurt. It is the smallest subsidiary of Silva and has no distribution activity like Silva France and Silva Limited. The sales concern Silva products for a market area that includes both Germany and Austria. There is one flow of products usually coming from Sweden. Occasionally a shipment comes from Asia when the amount of products needed is large. In this case, products are shipped from China to Hamburg and then transferred to Frankfurt.

From time to time, some product references are missing in one of the subsidiary or some slow seller products are required by customers of another subsidiary. When this happens the subsidiaries organize the products transfer between them without passing through Silva Sweden. This kind of event can occur in any of the 3 subsidiaries but remains very seldom. For this reason this type of product flow has been neglected in this study.
Silva Limited is located in United Kingdom near Edinburgh. It also has a distribution activity but unlike Silva France it is bound to disappear in the following years. For now the products come from two main flows, one coming from Sweden (Silva Sweden AB) and the second one from the USA (Brunton and Gerber).
Silva Sweden AB

Silva Sweden AB, located in Sollentuna near Stockholm, is the headquarters of the Silva group. As Silva Sweden AB acts as a central warehouse for the whole Silva Group, there are several flows coming from and going out to different locations.

The main incoming flow is composed of the products manufactured in Asia from both Silva’s factory and subcontractors or suppliers. Silva’s Asian factory is located in China and its main subcontractors are both in China and Taiwan. Silva Far East managed the production activity of Silva’s products and takes care of products’ shipments. The second incoming flow represents products from Brunton and Gerber. Since Silva Sweden also distributes the Gerber products to the subsidiaries, the amount of products from the USA is rather big.

There are three outgoing flows for Silva’s subsidiaries, each going to one of Silva’s subsidiaries. These flows are internal flows and so are not related to customers. Thus flows of products to Scandinavian countries and other countries (i.e. market not covered by the subsidiaries: rest of Europe, Asia, Africa…) are not represented on the above map.

Fig. 10 - Incoming Product Flow for Silva Sweden AB by month

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Central warehouse objectives & stakes

Reducing operational costs is the leading objective in a strategy of moving logistic organization into a central warehouse structure.

Four main factors prevail in this strategy:

**Market globalization**

For the last few years, consumption habits have evolved with the market globalization and the abiding changes in the consumer needs force the manufacturers to always develop new products.

**Product market evolution**

The structure of the logistic system is usually highly related to the type of product sold. With needs continuously evolving and a demand that remains uncertain in some ways, a central warehouse allows a better management of slow-seller products and an increased stock turnover.

**Seeking for economy of scale**

Seeking for cost reduction by concentrating the flows, optimizing distance and location… etc

**Communication infrastructure development**

The development of the transportation infrastructure allows reaching a wider geographical area in shorter time. Moreover the rapid development of communication allows having simultaneous and synchronized data from the different part of complex and spread logistic structure.

With this strategy and according to these factors, it is expected to gain on the following items:
- inventory and stock cost reduction,
- decrease of warehouse staff,
- an improved communication,
- a faster transportation process.

In this project, the purpose of changing for a central warehouse is mainly driven by the need of reducing the inventory, optimizing the Lead-time and making it uniform.

As previously presented, two prevailing options could be considered: a warehouse ran by Silva itself or the use of a Third Party Logistic. For the 3PL solution, the activity can be delegated to the service provider in its whole or just part of it.

In the evaluation of these two main options, an important point will be difficult to grasp: Silva’s warehouse management knowledge. Is it valuable for Silva to keep its warehousing activities or should Silva focus on its core competences and delegate warehouse operations?
Key Performance metrics and indexes

In order to objectively compare the changes between the current situation and the future scenarios, it is fundamental to establish quantitative and reliable performance indexes. These indexes should outline the situation by providing key figures in various relevant areas. The calculation method and data selection and gathering procedure have to be clearly defined to enable reproducibility and thus pertinent comparison.

Several fields can be assessed, such as cost management, customer service, quality, productivity and asset management.

A. Cost management

Cost has a direct impact on profit and consequently is a major indicator of performance. Several sources of cost will be considered and related to sales and produced quantity.

Total cost

The total cost is including all the existing costs: inventory, order processing, production, quality, administrative, etc. Its calculation requires a broad knowledge of the work procedures and process to extensively list the cost origins.

Cost per unit and cost as a percentage of sales

The total cost is a good starting point but it is well appropriate to weigh its value against the quantity of manufactured goods. It will especially bring to light the respective effects of fixed and variable costs.

Inventory levels

Assessment of the current inventory is a critical step in the total cost valuation. Overstock testifies of a loose inventory management policy and has a weighty consequence on costs (extra space consumption, tied capital, products obsolescence…). Under-stock means probably shortage at a certain point of the supply chain, and therefore sale losses and indirect costs (shortfalls, unsatisfied customers…)

Administrative, order processing cost, direct labour…

Many other costs are to be taken into account, such as wages, administrative procedures, buildings or warehouse rents, etc.

B. Customer Service

A good supply chain is often presented as the ability to deliver the right product at the right place at the right time. This definition emphasizes on the customer service focus of supply chain. The aptitude of a company to fulfil at best the customer’s needs can be monitored in several ways:

Fill rate

The fill rate is the proportion of orders that are fulfilled, or the number of satisfied customers, out of the total number of orders or customers. From one company to
another the definition of a fulfilled order can slightly change whether each line is considered separately or the order is seen as a whole and indivisible.

**Back orders**

Back orders are orders which should have been delivered but which are still pending.

**Shortage**

Shortage occurs when an order cannot be delivered because of a too low inventory level. Shortage can occur either in production (regarding raw material) or in warehouses/shops (with finished goods).

**Shipping errors**

Incorrect shipment means delivery of the wrong product and/or at the wrong place. This induces customer dissatisfaction, costs for reverse logistics and costs for an extra delivery of the right product, at the right place.

**On-time delivery**

The on-time delivery indicator can be related to the fill rate. It evaluates the company performance when it comes to delivering in the previously agreed period of time.

At the moment, Silva is not monitoring any of these indicators. This lack of information regarding customer service has to be fixed in the future situation. The central-warehouse organisation will facilitate assessment and control of these indexes. Furthermore, this new system will most likely increase the service level by enabling global visibility and comprehensive inventory management.

**C. Quality**

Measuring accuracy in the completion of specific tasks (picking/shipping, document/invoicing) or the failure frequency in some processes gives quantitative information on the warehouse performances. Quality in information management has to be taken into consideration too: information availability and accuracy must be among the top priorities.

**D. Productivity**

Just as for a production site, productivity can be calculated in a warehouse. Simple indicators as the number of units shipped per employee or per labour euro/SEK will make the efficiency improvements observation possible.

**E. Asset Management**

To ensure viability of the company, capital turn has to be maximal to optimize profit. On the one hand, this means that customer needs must be fulfilled to develop sales and increase turnover. On the other hand, it implies as well that investment has to be as low as possible.

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The main source of tied capitals is inventory. Therefore, it is imperative to monitor key values regarding stocks:

1) **Inventory turns**

   Inventory turns are calculated using the following formula:

   \[
   \text{Inventory Turns} = \frac{\text{Cost of products sold (Over Period } P\text{)}}{\text{Average Inventory (for Period } P\text{)}}
   \]

   Inventory turns describes the occurrence of stock turnover during a certain period of time (the number of times the stock is completely renewed during this period). Usually, the higher it is the better. Indeed, high inventory turns corresponds to lower stocks and therefore reduced holding costs and obsolescence.

   However, an extremely high inventory turns can be the evidence of under-stocks and shortage risk.

2) **Inventory levels, numbers of days supply, coverage**

   High inventory level leads to extra holding costs and important obsolescence. In addition to these cost-related issues, it has the negative effect to hide any problem in the supply chain by acting as a buffer and absorbing any un-forecasted demand change. The company remains then with this illusory safety cushion and does not fully realise the situation, which tend to slow down optimisation oriented processes and efficiency research.

   Low inventory level is the main obvious cause for shortage and thus has to be avoided at all costs.

3) **Obsolete inventory**

   Even though Silva’s products are not perishable, holding them for too long can decrease their value for several reasons. First, any design change for a particular product makes the older version almost impossible to sale as customers don’t want to pay for older versions. Then, products using a battery (wireless anemometers, pedometers, etc.) cannot be hold for a long time without losing power and repacking and battery change/reload is rather costly.

4) **Inventory classification (ABC)**

   ABC method, also known as 80-20 or Pareto optimum, is a method to classify the products in three distinct classes according to their turnover. Usually, it appears that the 80% of inventory value is due to only 20% of the SKUs. The resulting sorted list helps to focus on differences between slow and best sellers. If no specific stock policy is applied yet, ABC classification can be a good start for creation of inventory management policies adapted to each product category.

   Silva Sweden classifies its products according to the ABC method every year to get an organised vision of the current state and to take appropriate measures for the future. However the results are not used yet to determine respective inventory policy for each of the ABC categories.

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STUDIES & ASSESSMENTS

Warehouse localization

A. Theory

In this problem, the main objective is to locate the central warehouse in such a way that relevant requirements are satisfied and relevant costs minimized.

It is assumed that the problem is planar and the coordinates used are Euclidean. Three models have been used to assess the best location for the central warehouse.

1) Gravity Model

The gravity model is the simplest and a widely used interaction model in location analysis. The Gravity Model is based on the Newtonian gravity formula with customer locations and a weight defined by the customer demands, turnover or number of customers. The result gives an optimized and economical new facility location.

![Scheme of gravity center](image)

Calculation formulas for the coordinates of the new facility:

- \( n \) is the number of customer.
- \( (x_{c_i}, y_{c_i}) \) is the given location coordinates of the i-th customer.
- \( (x, y) \) is the unknown location coordinates of the new warehouse facility.
- \( w_i \) is the weight associated to the i-th customer.
2) Model based on the Weiszfeld procedure

This model is very similar to the gravity center but the method is based on an iterative procedure developed by Weiszfeld using Euclidean distances but then extended to $L_p$ distances (see formula).

The problem working out uses weights that are assumed to be proportional to the demand of the customer, related to the cost of service for a specific location and a specific customer.

With the $L_p$ norm, the problem can be formulated through the following formula:

$$Min(W(S)) = \sum_{i=1}^{n} w_i \cdot 1_p$$  \hspace{0.5cm} (2)

- $P_i = (x_{c_i}, y_{c_i})$ is the given location coordinates of the i-th customer.
- $S = (x, y)$ is the unknown location coordinates of the new warehouse facility.
- The distance between the new warehouse facility and the i-th customer is given by the following formulas of the Lp norm:
  
  $$L_p(S, P_i) = \left( (x - x_{c_i})^p + (y - y_{c_i})^p \right)^{\frac{1}{p}}$$, with $p \geq 1$  \hspace{0.5cm} (3)

  For $p=1$, the formula represents the rectilinear distance.

  For $p=2$, the formula represents the Euclidean distance.

- $w_i$ is the weight given to the i-th customer.

Iterative calculation formulas for the coordinates of the new facility:

$$x = \frac{\sum_{i=1}^{n} w_i \cdot x_{c_i}}{\sum_{i=1}^{n} w_i}$$  \hspace{0.5cm} (1a)

$$y = \frac{\sum_{i=1}^{n} w_i \cdot y_{c_i}}{\sum_{i=1}^{n} w_i}$$  \hspace{0.5cm} (1b)
As any iterative procedure, the procedure has to converge to give relevant result. The convergence of the method has been proven to work with value of \( p \in [1; 2] \).

Here the interest is not to optimize the formulas. Therefore Euclidean distance will be used in the following parts, which means using a value \( p=2 \).

3) **MapNod software**

MapNod is a transportation modeling software that allows performing location analysis, minimum run finding with specific criteria. The software is using a map made of a set of nodes linked to each other by a set of arcs. Each node represents a city and each arc represents a mean of transportation (road, train, speedway).

In the current study, a map of Europe with 426 nodes and approximately 1500 arcs has been chosen.
Minimum runs calculation is performed according to one of these two criteria: time or distance. Here, time is the most relevant factor to consider in calculation. The minimum runs are calculated as follow.

For each arcs, the transit time is the division of the arc’s length by the average speed on the arc. All the transit times on the run between two nodes are summed and the minimum run between two nodes is obtained.

The calculation also takes into consideration specific requirements of the means of transportation. In the present case, transportation is made by trucks and thus...
calculations are performed in compliance with road transportation regulations. The calculation algorithm conforms to the European road transport regulation (C.E.E. n° 3820/85). The rules are the following:

- 45 minutes of rest every 4 hours 30 minutes of driving,
- If the run is 1 hour or less, there are 45 minutes of rest,
- A minimum rest of 9 hours per day for long run.

As there are also ferry’s runs in the model, the time spent on a ferry can be considered as rest time. Thus the software finds the best solution when road compete with a ferry trip. For a long distance ferry trip, the calculation algorithm adds 1 hour for the loading operations and 30 minutes for the unloading operations. For a short distance ferry, the calculation algorithm adds 15 minutes for the loading operations and 10 minutes for the unloading operations. Considering the Eurotunnel shuttle between France and England, the total transit time is 45 minutes (loading and unloading included).

The transit time on the minimum run given by the software includes these rules or calculations features so that the result is as close as possible to reality.

Location analysis

With the minimum runs calculated, weights can be applied to nodes. Then a location problem calculation can be performed to find the best time-distance solution.

4) Remarks on the models

On the one hand, the two first models have simple formulas to apply and calculations are performed fairly fast. But the calculation does not take into consideration transportation infrastructures. These two models are using directly weighted location coordinates to calculate distances. Thus the distances used could be very different from reality depending on geography.

On the other hand, the third model is much more complex. Based upon a mesh of nodes and arcs, the model is built of geographical data and data from transportation infrastructures. The calculations also consider other parameters such as transportation regulations to catch up with reality but at the expense of calculation time.

Even if the third model seems to be more relevant, the first two models are more likely to give a fast assess of the area in which the central warehouse should be located. It can also be observed that the models disregard parameters such as potential development or social and political environment which could have contributed to come closer to reality.

B. Data for optimization problem

Customers’ location

The most important customers in terms of turnover are organized by country. A simple gravity center is applied for each country and the resulting data is a list of countries with the turnover and geographical coordinates. Each center of gravity is plotted on a map that will be used later for placing the new warehouse.
In Europe there are two main customer areas in terms of turnover. The first one, Scandinavia (with Sweden, Finland and Norway) counts for 6 705 000 € (55% of the European turnover) and the second one, formed by the triangle UK-France-Germany, counts for 3 535 000 € (29% of the European turnover) for a total turnover of 12 135 000 € in Europe.

**Harbour**

Most of the products coming from the factories arrive in a European harbour before being shipped to Sweden. The warehouse location has to be chosen in order to optimize both outgoing product flow and incoming product flow. So it would also be relevant to take into consideration the incoming and outgoing product flow related to the harbour activity by applying a weight based on merchandise values and use coordinates of the harbour.

Nevertheless, the harbour weight only includes products sent to customers outside of Europe. The reason is that most of the products are manufactured outside of Europe.
so the weight to be applied for incoming products would be too high and any harbour chosen would place the warehouse at its location. It is decided to mainly focus on flows of products to the customers and therefore on accessibility to the customers.

Thus the central warehouse should be located between these two areas (See the red area on the map below) as four of the first main harbours in Europe are located within this area.

![Map showing suggested area for the central warehouse location](image)

*Fig. 14 – Suggested area for the central warehouse location*

<table>
<thead>
<tr>
<th>Rank</th>
<th>Harbour</th>
<th>Country</th>
<th>2004 000s TEU</th>
<th>2005 000s TEU</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Rotterdam</td>
<td>Netherlands</td>
<td>8,281</td>
<td>9,287</td>
</tr>
<tr>
<td>2</td>
<td>Hamburg</td>
<td>Germany</td>
<td>7,003</td>
<td>8,088</td>
</tr>
<tr>
<td>3</td>
<td>Antwerp</td>
<td>Belgium</td>
<td>6,064</td>
<td>6,482</td>
</tr>
<tr>
<td>4</td>
<td>Le Havre</td>
<td>France</td>
<td>2,132</td>
<td>2,119</td>
</tr>
</tbody>
</table>

"TEU" stands for "Twenty-foot Equivalent Unit,"

Calculations are performed using the center of gravity and turnover of each European country concerned for each main harbour of the area (using weight for incoming products and products send to long distance customers).

The following map shows all the geographical positions considered in the calculations.
C. Application

Using the previous methods with up-to-date data will result in the selection of a certain geographical area, suitable for the warehouse implantation.

Calculations are mainly performed with the Scilab software (see the appendix).

Scilab is a free platform for numerical computation with a graphic library used to plot the results.

A matrix of dimensions \((n,3)\) is filled in with the coordinates and weight of the \(n\) customers.
1) Gravity model

The coordinates of the new facility are given using directly the formulas into Scilab with the matrix or with a spreadsheet application (such as MS Excel). The result of the gravity center model comes with the results of the Weiszfeld procedure and is plotted on the same chart.

2) Model based on the Weiszfeld procedure

The procedure is written in a file apart and executed into Scilab. The procedure code is available in Appendix 1. Four calculations are performed, one for each harbour: Le Havre, Antwerp, Rotterdam and Hamburg. Plotting from Scilab is then combined with a map of Europe. Results are shown on the following maps. Each map represents the results for a chosen harbour (surrounded by a red circle).

![Plotting from Scilab is combined with a map of Europe. Results are shown on the following maps. Each map represents the results for a chosen harbour (surrounded by a red circle).](image)

Fig. 16 – Results from the Weiszfeld procedure
3) **MapNod location analysis**

With MapNod, using a matrix of minimum runs (calculated for road transport) and a set of weight applied to the countries gravity center, the location result for the central warehouse is in Flensburg (Germany) close to the border with Denmark.

![MapNod location analysis](image)

**Fig. 17 - Location of Flensburg**

### D. Results analysis

1) **Gravity model**

The spread of the four results (for each harbour) with this model is quite narrow and for each case the warehouse is located west of the extreme northern part of Germany, within the same area.

Despite the fact that three of the results are located in the sea, these results have to be compared to the results from the other models.

2) **Model based on the Weiszfeld procedure**

Here as well, the four results are not very spread. The warehouse location for this model is located close to Århus (Denmark). The results are nearby those of the gravity center model.

3) **MapNod location analysis**

The result of this model gives a warehouse location between the results of the previous models. The warehouse is located in Flensburg at the border between Germany and Denmark.

It can be noticed that the location of the warehouse with the simple gravity center model is within a range of 100 kms around the location of a warehouse obtained with the MapNod location analysis. It could have been expected that the warehouse would be located closer to Sweden since the weight applied to Sweden and Norway is high. In fact the fastest run doesn’t pass by Denmark but goes directly from Germany to Sweden by ferryboat. From a global point of view, the run catch up with the flight run used in the gravity center model.

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The set of location results are all within a range of approximately 250 kms in an area located between Denmark and Germany. The nearest harbour to this area is Hamburg. Currently, most of Silva’s products coming from Asia and the USA arrive in Hamburg and so it would be relevant to consider setting up the central warehouse in an area around Hamburg. Therefore it is assumed that the central warehouse is located around Hamburg and the geographical location of the warehouse used will be Hamburg.

Stock and order policies

Working capital requirements can be cut down by reducing safety stocks as well as lead time. Indeed diminishing lead time allows savings at various places: on safety stock, by lowering uncertainty, and also on in-transit stocks through shorter shipment duration. Global lead time can be divided into several intermediary lead times from order placement to final delivery to customer. This chapter will deal with safety stock and therefore focuses exclusively on the upstream lead time, which is the lead time from the supplier to the warehouse.

A. Safety stock at Silva

For managers, decreasing safety stock is one of the most expected consequences of the creation of a central warehouse. Bringing down the number of stocking places from 4 to 1, indeed, should significantly cut the minimum inventory level to ensure avoiding shortages. However, relying on the data provided by the survey sent to Silva Sweden and the subsidiaries, this effect does not seem to be obvious if the current safety stock policy is still applied with the central warehouse.

As dimensioning safety stock for Silva could be a master’s thesis subject on its own, it will only be introduced briefly in this paper. The purpose here is to study the impact of a central warehouse and assess potential savings.

1) Current state

Description of the various categories of shipments to warehouses

First type: from the USA to Europe (SW/UK/FR/GER)

In this case, products manufactured in the USA are shipped to Europe. Gerber products come from Portland, Oregon, with an approximate lead time of 2 months (by train and boat) and Brunton products are sent from Riverton, Wyoming, and arrive in Europe either within 2 weeks (by air freight) or within 1 month (by sea).

Second type: from China to Europe (SW/UK/FR/GER)

Products from China (either produced by suppliers or by Silva Far East) are delivered within 5 weeks from Hong-Kong or 6 weeks from Shanghai. Almost all of the products are shipped by sea (except solar chargers, sent by air).
Third type: from Sweden to the other subsidiaries (UK/FR/GER)

Current lead time changes according to destination country: Germany receives its products within 3 to 4 days whereas France and UK are delivered within 1 week. This lead time applies to all product categories, and all the goods are shipped by truck.

**Current safety stock policy and calculation**

The current state is evaluated through information gathered with the survey (see appendix). So far the policy is almost the same in all the subsidiaries, and no distinction is made according to product category: safety stock should be dimensioned to ensure a 5-day supply. Calculation is done manually in most of the cases safety stock can therefore vary from this basic assessment a little.

The 5-day supply policy is rather simple and the safety stock is calculated with the following formula:

For a given product $i$ and a given warehouse $j$:

$$SafetyStock_{i,j} = 5 \times DailyDemand_{i,j}$$

which means a total safety stock for the whole system of:

$$TotalSafetyStock_{current state} = \sum_{i,j} SafetyStock_{i,j} = 5 \times \sum_{i,j} DailyDemand_{i,j}$$

**Consequences of a central warehouse if the same safety stock policy is conserved**

With the safety stock policy and calculation as defined above, it is possible to make a brief assessment of the central warehouse impact on safety stock. Basically, for a given product $i$ shipped from the USA, the central warehouse will have to cope with a global demand that equals to the sum of the regional demands of the previously concerned warehouses.

$$DailyDemand_{i,central} = \sum_j DailyDemand_{i,j}$$

Using the same 5-day supply policy gives a safety stock of:

$$SafetyStock_{i,central} = 5 \times DailyDemand_{i,central}$$

i.e.

$$SafetyStock_{i,central} = 5 \times \sum_j DailyDemand_{i,j}$$

As a result
And finally

\[ TotalSafetyStock_{central} = TotalSafetyStock_{current state} \]

According to the calculations above, implementing a central warehouse will not have any effect on the safety stock in case the safety stock policy is not changed. Although this conclusion is justified with the actual policy, it has to be qualified and readjusted to become completely relevant.

In the case of a central warehouse indeed, the 5-day supply target can be re-evaluated. In order to better take into account the lead time variations due to system physical modification and increased shipment frequency, the required 5 days could probably be lowered to 4 or even 3 days. Yet, this decision seems arbitrary and does not rely on quantitative facts.

The 5-day safety stock policy in reality

By surveying the subsidiaries stock managers it appeared clearly that the 5-day policy was not followed at all. 5 days being far too optimistic and leading to too many shortages and sales losses, the recommendation was not taken seriously and most of the time safety stocks of 2 or 3 weeks of sales are held by the subsidiaries so as to ensure an acceptable service level.

However, in order to be able to compare the theoretical results for the future state with a single figure in the current state, the 5-day cover target will be used as a touchstone. The immediate consequence is that really low savings are expecting when it comes to safety stock only: considering the service level objective and the current constraints due to the lead time and lead time variations, it is not possible to run safely an inventory on with less than 5 days of stock cover.

Following is a more legitimate approach based on statistical tools such as demand standard deviation or absolute average deviation. This method provides details about this 5-day coverage and enables a more rational calculation of safety stock in the central warehouse.

2) Statistical approach

In order to simplify as much as possible, most of the formulas are given for one product in one warehouse. However, the reasoning is the same whatever product or warehouse is concerned, and more aggregated results can be easily obtained through adding the safety stocks.

**Theory and statistical tools**

First of all, the demand is assumed to be normally distributed, with an average \( \mu_d \) and a standard deviation \( \sigma_d \). Gaussian distribution is the most popular distribution model for determining probability and is known for working well in predicting demand variability based on historical data.
Second, the lead time from suppliers is assumed to be normally distributed too, with an average $\mu_l$ and a standard deviation $\sigma_l$.

The safety stock is always given by the formula:

$$SS = Z \sqrt{\frac{\sigma_d^2 \cdot m + \bar{d}^2 \cdot \sigma_l^2}{m}}$$

where:
- $Z$ = security factor (number of standard deviations covered by the stock)
- $\sigma_d$ = demand standard variation
- $m$ = lead time duration / demand calculation period duration
- $\bar{d}^2$ = average demand per time unit
- $\sigma_l$ = lead time standard variation

$\bar{d}^2$ and $\sigma_l$ have to be expressed in the same time unit (unit per day; day), (unit per week; week), etc.

**Assumptions and simplifications**

In the current system (see flow map), products are manufactured either in Sweden, in China or in the USA.

Products made in Sweden and China are then directly shipped to the Swedish warehouse. The lead time between production and receipt in the Swedish warehouse are very various: from less than one week (from the Swedish factory) to 6-7 weeks (from China). Then, products are delivered to the subsidiaries and other customers from the Swedish warehouse.

Products made in USA are shipped directly from there to the European warehouses. Lead time is 2 months by sea, one week by air. Air shipment should be avoided for regular use due to its high cost. Except for emergency orders, sea shipment should be considered.

There are therefore different types of delivery with significantly different lead times.

**Deliveries to Silva Sweden warehouse**

Silva Sweden is either supplied by its own factory, by Chinese manufacturing sites (Silva Far East, or other suppliers) or by Gerber.

**From Silva Sweden AB**

In this case, the lead time is rather short, most often less than a week. Besides, lead time standard deviation can be neglected for this type of deliveries. The safety stock formula then becomes:

$$SS_{SwedenToSweden} = Z \sqrt{\sigma_d^2 \cdot m} = Z \sigma_d \sqrt{m}$$
From China or the USA

Shipments from China or the USA do not follow the same rules. Lead time is much longer and cannot be considered as constant either, $\sigma_d$ cannot be neglected. Thus the safety stock formula remains:

$$SS_{\text{China/USAToSweden}} = Z \sqrt{\sigma_d^2 m + \bar{d}^2 \sigma_{lt}^2}$$

Deliveries to Silva Ltd, Silva France and Silva Germany warehouses

From Silva Sweden AB

Silva’s subsidiaries receive their Silva products “made in Sweden” or “made in China” directly from the warehouse in Sweden. Consequently, the lead time is quite short and relatively stable. For this study, we will consider that the lead time duration standard deviation is negligible. As a result, the safety stock formula is again:

$$SS_{\text{SwedenToUK/FR/GER}} = Z \sqrt{\sigma_d^2 m} = Z \sigma_d \sqrt{m}$$

From the USA

Shipments from the USA, again, do not follow the same rules. Lead time is much longer and cannot be considered as constant either, $\sigma_d$ cannot be neglected. Thus the safety stock formula remains:

$$SS_{\text{USAToUK/FR/GER}} = Z \sqrt{\sigma_d^2 m + \bar{d}^2 \sigma_{lt}^2}$$

3) Central warehouse benefits on stocks with the new policy

First, the new organisation of the global system will come to a shorter lead time by avoiding intermediary steps. As seen in the formulas above, shorter lead time means directly lower safety stock.

However, the greatest benefit regards safety stock. Due to the suppression of intermediary inventories hold in the regional warehouses, intermediary safety stocks are suppressed too. In addition, frozen capitals can be further decreased as well as service level enhanced through demand consolidation. By aggregating the demand the safety stock will actually diminish. This effect is due to the natural compensation of the standard deviations when data are observed globally. For a given service level, the safety stock will be much lower in a central warehouse organisation.

This noticeable fact can be showed mathematically using the previous set of formulas. Again, in order to simplify the demonstration, the calculations are done for only one particular product, made in Sweden. The same results are also valid for all the other products, separately and/or as a whole (simple sum).

Let’s consider a given product $P$, previously stocked in $n$ warehouses. Let $d_j$ denote the local demand for the area $j$, $\sigma_j$ the related standard deviation. Lead time to each warehouse is assumed to be the same (the warehouses are all in Western Europe and so is the production site).

According to the previous formulas, the total safety stock for $P$ in the multi-warehouse system is:
\[ SS_{\text{multiWH}} = \sum_{j=1}^{n} SS_j = \sum_{j=1}^{n} Z \cdot \sigma_j \cdot \sqrt{m_j} \]

Now all the lead times are equal, so \( \forall j \), \( m_j = m \) and

\[ SS_{\text{multiWH}} = Z \cdot \sqrt{m} \cdot \sum_{j=1}^{n} \sigma_j \]

From now, \( P \) will be stocked in a single warehouse which has to supply the same demand as previously. The demand is therefore \( d_{\text{central}} = \sum_j d_j \) and let \( \sigma_{\text{central}} \) denote its standard deviation.

So, the safety stock for the central warehouse is:

\[ SS_{\text{centralWH}} = Z \cdot \sqrt{m \cdot \sigma_{\text{central}}} \]

In order to be able to compare the two safety stock values, it is necessary to compare \( \sigma_{\text{total}} \) to \( \sum_{j=1}^{n} \sigma_j \). As \( d_{\text{central}} = \sum_j d_j \), then \( \text{var}(d_{\text{central}}) = \text{var}(\sum_j d_j) \). The demands \( d_j \) are assumed to be uncorrelated, which means that

\[ \text{var}(d_{\text{central}}) = \text{var}(\sum_j d_j) = \sum_j \text{var}(d_j) \]

Furthermore, by definition

\[ \sum_{j=1}^{n} \sigma_j = \sum_j \sqrt{\text{var}(d_j)} \quad \text{and} \quad \sigma_{\text{central}} = \sqrt{\sum_j \text{var}(d_j)} \]

Square root function is concave, thus

\[ \sum_j \sqrt{\text{var}(d_j)} \geq \sqrt{\sum_j \text{var}(d_j)} \]

i.e.

\[ \sum_{j=1}^{n} \sigma_j \geq \sigma_{\text{central}} \]

and

\[ SS_{\text{multiWH}} \geq SS_{\text{centralWH}} \]

**Graphic illustration**

The following graphic shows the case of a single product managed in two different warehouses 1 & 2 in comparison to a central management system. Safety stocks are considered to be proportional to the standard deviation (i.e. the square root of variance).
In the separate stocks case, safety stocks $S_1$ and $S_2$ are managed independently and are summed separately. The resulting safety stock value is read through the blue curve, at the abscissa (var1 + var 2).

When stocks are grouped, as the variance of the sum is equal to the sum of the variances, the safety stock value is read at the same abscissa (var 1 + var 2). However the value is given by the red curve as the group is managed as a single stock. The graphic clearly shows that common management lead to lower safety stocks.

**B. Economical Order Quantity**

Besides safety stock savings, grouping stocks enables to lower the economical order quantity and therefore to lower the average stock quantity.

1) **Current state**

**Order policy**

At the moment, all the orders placed by Silva Sweden AB are dimensioned according to the EOQ policy. This method takes several parameters such as cost per order, demand rate, holding cost into account, in order to determine the economical order quantity. The formula is:

$$Q^* = \sqrt{\frac{2 \cdot C \cdot R}{H}} \quad (1)$$

where:

$Q^*$ = optimal order quantity  
$C$ = cost per order event
\( R = \) monthly (annual) demand of the product
\( H = \) holding cost per unit per month (per year) \((H = \) purchase cost per unit * holding cost factor\)

**Average stock level**

In a model using EOQ method for ordering and a safety stock \( SS \) to cover unexpected variations and prevent shortages, the average inventory level is:

\[
\bar{Inv} = \frac{1}{\text{CycleDuration}} \int_{\text{cycle}} \text{InventoryLevel} = \frac{Q^*}{2} + SS
\]

where:
\( Q^* \) is the economical order quantity
\( SS \) is the safety stock

The following diagram illustrates the order and inventory cycles in a perfect theoretical model.

![Inventory cycles](image)

*Fig. 19 – Inventory cycles*

It is obvious that decreasing safety stock leads to lower inventory and thus lower costs. It is also clear that reducing the economical order quantity can contribute to cut down the frozen capital.

**C. Extra advantages of a central warehouse system**

1) **Decrease of obsolescence losses**

Obsolete stock is finished products that are unlikely to be used in the future. These products have been manufactured and stored, but will most probably never be sold. Obsolescence should be paid a great attention. It is a pure loss of raw material, machine and personnel time, inventory space and any other resource consumed along the value chain to deliver the final product. Several phenomena can generate obsolete stocks: overestimation of future sales, cannibalisation by a new product, outdated products, etc.
More accurate sales forecasts

As seen previously, grouping stocks leads to more precise sales forecasts as variations in each zone tend to statistically balance themselves. Consequently, the sales potential of each product is less likely to be significantly overestimated and overproduction and overstock will become more seldom.

Improved communication

To deal with only one warehouse makes communication easier within the company. Information transfer between the product development team, the production site and the central warehouse will be improved. As a result, product cannibalisation can be easily foreseen and its consequences taken into consideration in advance. Particular efforts should be put on selling off the pieces due to be short term cannibalized, before the introduction of the new product.

Higher stock turnover rate

In a system relying on several warehouses, the demand is parcelled out. Under some circumstances, the demand for a product in a given storehouse can be rather low. If the daily demand is not big enough then shipment cannot be done every day. In order to break even, truck frequency has to be lowered and shipment processed weekly, for instance. For really slow sellers (GPS in Silva Germany for instance or Open Up in France), a stock level of a single box can be equivalent to several years of cover. Due to their nature, Silva’s products are not likely to be outdated but many events can still make products unfit for sale:

- batteries can discharge
- law regulations can change (for ex. Tolerance for wave emission of wireless devices, …)
- competitors can release new products making Silva’s ones outdated and no longer attractive (external cannibalisation)
- etc.

When one of these problems happens with large quantities of products idle on the shelves accounting for years of stock cover, it results in considerable losses for the company.

By increasing quantities involved, demand rate and shipment frequency also increase too and thus speed up warehouse turnover. The previous issues are thus less likely to occur during shorter lifecycles. Furthermore if they do occur, their effect will be significantly cut down in proportion and duration.

2) Better service to customers

In addition to its effect on inventory turnover, an increase of shipment frequency results in a better service to customers through simultaneously shorter lead times and improved service level.
**Shorter lead times**

Slow sellers and slow movers have a rather low demand which, in a multiple warehouses system, is again split between the regional areas. For evident economical motives, the company cannot afford to have only three-quarters full trucks and consequently shipments are processed when quantities are enough to fill a truckload. For that reason, shipments are only weekly, monthly or even less frequent when demand is really low. It is then easy to apprehend the repercussions on service to customers in terms of lead time.

Higher shipment frequency lowers lead time and enables customers to get their products earlier and surely increase their satisfaction level.

**Higher service level**

Another advantage of more frequent shipments is the improvement of reaction time towards any type of demand changes. Especially when combined with a close monitoring, higher delivery rate enhances reactivity and limits the negative consequences of unexpected demand peaks.

**D. Application**

1) **Introduction, ground data and general assumptions**

Calculating safety stocks and evaluating inventory could be a thesis subject on its own. Therefore the previously exposed theory will be applied on only three product categories in order to observe its consequences. The three product categories are yet the three major product groups and can be considered as representative of Silva’s activity: compasses, headlamps and pedometers. Furthermore the safety stock as well as the inventory level will be assessed roughly, in the aim to get an evaluation precise enough and estimate the consequences from an economic point of view.

**Current safety stock policy**

The current global safety stock policy is to hold enough products to cope with a 5-days demand. This is the same throughout the year for any product category or product family. Studying inventory levels and surveying the warehouse managers in the subsidiaries shows that this safety cover instruction is not fully observed and that an overstock tendency is widely spread.

**Service level**

In the whole application part, a 90% service level related to lead time is aimed at and an associated security factor Z is used. From statistical tables, the safety factor Z corresponding to a 90% service level is 1.2815. These values will be used in every calculation henceforth.
**Lead time**

In the current situation most of the products are manufactured in China and some compasses are still made in Sweden. However, production will be moved totally to China in the coming years and indeed the only lead time considered in these examples is the lead time from China to a warehouse in northern Europe.

No long history of deliveries is available but as the lead time duration is too important to result in a relevant statistical study under a period of only 20 weeks, the few existing data were used for a first rough lead time evaluation. From the existing records, the calculation returned a lead time of 50 days and a standard deviation of 12 days. In parallel, the warehouse manager was asked to make an estimation of this lead time and its standard deviation. Based on his experience, the lead time was around 43 days and a standard deviation of 4 days approximately. The shipping company confirmed the lead time, but was not able to provide any information about standard deviation. In order to avoid over-optimistic results, a lead time of 43 days with a standard deviation of 8 days will be used a ground data in the following.

**Sales data**

There is no record of actual or potential sales. Instead of sold quantities, invoiced quantities will be used as ground data. To reflect as precisely as possible the reality, potential sales should be considered. Indeed, potential sales do not take into account all the internal problems that cause sales losses: efficiency drops, holidays, etc. These types of events lower the amount of items shipped in respect to potential sales, which on the contrary do not depend on company efficiency. Potential sales are the most reliable estimator of actual demand. This is not the case for Silva.

Relying on sales records and sales forecasts, a sales trend is identified. The ground data used in the safety stock calculation will depend on this trend. For instance a simple monthly average is used for flat-profile products with a rather stable demand through the years whereas higher estimations are used for growing products. The purpose of this chapter is not to assess precisely stocks but to enable a rough evaluation of savings and benefits for the company.

2) **Application**

**Compasses**

Compasses - varugrupp 1 - are Silva’s traditional core activity and stands nowadays for more than 30% of turnover. Currently manufactured in both China and Sweden, the trend is to move progressively production to factories in China for financial reasons. In the coming few years the whole production will take place in the Chinese factories. Therefore all calculations carried out with a lead time default value of 43 days even though some products are, at the moment, still manufactured in Sweden.

**Sales data**

The following table summarizes the data available at Silva Sweden AB about compasses sold in the past.

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For each month, the average demand is calculated through the past complete 3 years. Then a global monthly average is computed, as well as the standard deviation of demand.

<table>
<thead>
<tr>
<th>Month</th>
<th>1</th>
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<th>5</th>
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<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td>64 630</td>
<td>61 481</td>
<td>73 664</td>
<td>71 233</td>
<td>59 484</td>
<td>56 128</td>
<td>41 267</td>
<td>59 531</td>
<td>67 126</td>
<td>69 952</td>
<td>65 314</td>
<td>52 040</td>
</tr>
<tr>
<td>Std Dev</td>
<td>8 682</td>
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According to the formulas, safety stock needed to ensure a 90% service level during the lead time is 24 975 units. From the average monthly demand, an average daily demand is computed and safety stock is converted to a day-supply cover of more than 8 days. In comparison to the current 5-day objective, then it seems that no direct savings can occur. The main explanation to this higher stock level is the targeted service level. Indeed, in a central warehouse system and with the sales data, a 5-day safety stock cover would correspond to a hypothetical service level of 53% under the lead time. Bearing in mind that today’s situation is not centralized and therefore that lead times are higher, the current service level during the lead time should be even lower than 50%. The goal is then to higher up service level at least till 90% as stated in the beginning, and simultaneously to reduce safety stock.

Safety stock increases with lead time and lead time deviation and also with demand and demand deviation, which unfortunately cannot be totally controlled or driven by the company. On one hand lead time depends on transportation mode, and lead time deviation is rather random, on the other hand demand can be estimated by forecasts and demand patterns can be identified along the year.

**Seasonality**

Observing the sales profile along the year, it appears that compasses sales are characterized by a strong seasonality. By comparing monthly sales to the average
monthly sales, a natural distinction can be established between two periods: the high season (January to April, September to November) and the low season (mainly summer –May, June, July and August). December will be classified as a low season month too. The relatively low average invoiced quantity can be imputed to a lower activity around Christmas time. Customers are

<table>
<thead>
<tr>
<th>calendar month</th>
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<td>65 314</td>
<td>52 040</td>
</tr>
</tbody>
</table>

High season (orange) and low season (blue) are determined by a simple comparison with the global average.

The main advantage offered by the definition of this pattern is that a specific safety stock can be calculated for each season. Indeed, one average demand and one demand standard deviation is assessed for each period and the resulting safety stocks are more accurate, more adapted and therefore more efficient.

First step in the new calculation is to study separately each of the two sorted samples in order to evaluate their own average and standard deviation. These raw data allow then to evaluate safety stock target in units and cover.

| SS high season (unit) | 23878 |
| cover high season     | 10,6  |
| SS low season (unit)  | 21101 |
| cover low season      | 11,8  |

In term of stock cover, two different calculations were performed: the first one with the global monthly demand average (calculated through the whole year) while the second one used a local monthly demand average (evaluated from the sales during the observed high or low period). The total cover necessary for comparison was then recomputed with a weighted average according to the relative durations of high and low periods. Both ways gave a rather similar result: with the seasonality pattern the cover can be lowered to approximately 11,1 days, which means a saving of 1 day in comparison with the value without taking seasonality into account.

However, even with a seasonality-handling model safety stock cannot be as low as 5 days as long as the company is aiming at a 90% service level during lead time. If the 5-day target was to be maintained, it would correspond to a service level of only 53% during lead time.

Although no financial savings will be done on the compasses safety stock, service level will be significantly increased providing high added-value to the company through increased reliability and consequently higher customer satisfaction.

**Results**

In the central warehouse configuration, the pooling of finished goods in a unique stocking place makes possible the implementation of a proper ordering policy. With this
fixed order quantity policy, the average stock along the year is given by the formula \( \bar{S}_{\text{inv}} = \frac{Q^*}{2} + SS \) (see B.1). \( Q^* \) is the economical order quantity, or any fixed order quantity that has been determined as the optimal order quantity. For compasses, the balanced average order size is 1000 pieces.

The following table sums up results for compasses. The global conclusion regarding a central-warehouse based system is positive, both from an economic and a service level point of view. Estimated gains are savings of about 350 000 SEK (equivalent to an 8% cost reduction) combined to an almost doubled service level (90 % during the lead time in comparison with a former 53%).

<table>
<thead>
<tr>
<th></th>
<th>units</th>
<th>cover (days)</th>
<th>value (in SEK)</th>
<th>value (in €)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current stock level</td>
<td>133 000</td>
<td>63,57</td>
<td>4 417 545</td>
<td>472 971</td>
</tr>
<tr>
<td>incl. Safety stock</td>
<td>10 303</td>
<td>5,00</td>
<td>342 226</td>
<td>36 641</td>
</tr>
<tr>
<td>Future stock level</td>
<td>122 856</td>
<td>59,62</td>
<td>4 080 620</td>
<td>436 897</td>
</tr>
<tr>
<td>incl. Safety stock</td>
<td>22 856</td>
<td>11,09</td>
<td>759 158</td>
<td>81 280</td>
</tr>
<tr>
<td>Savings</td>
<td>10 144</td>
<td>3,95</td>
<td>336 925</td>
<td>36 073</td>
</tr>
<tr>
<td>incl. Savings on SS</td>
<td>-12 553</td>
<td>-6,09</td>
<td>-416 932</td>
<td>-44 639</td>
</tr>
</tbody>
</table>

See appendix 2 for detailed calculations.

**Headlamps**

Headlamps - varugrupp 2 - are a growing activity for Silva. The activity started a few years ago, offering high-class performance headlamps. The range was then extended with entry level products at lower price, in order to reach other customer categories. Now, the focus is back on advanced top-of-the-line headlamps with the new L series. All the mobile lighting equipments including headlamps are manufactured in China. As previously in the compasses study, all calculations carried out with a lead time default value of 43 days, with a standard deviation of 8 days.

**Sales data**

The following table summarizes the data available at Silva Sweden AB about headlamps sales during the past three years.

<table>
<thead>
<tr>
<th>year</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004</td>
<td>14511</td>
<td>7417</td>
<td>7496</td>
<td>6838</td>
<td>4193</td>
<td>7530</td>
<td>5211</td>
<td>8486</td>
<td>7008</td>
<td>13811</td>
<td>15500</td>
<td>14215</td>
</tr>
<tr>
<td>2005</td>
<td>8305</td>
<td>6958</td>
<td>7796</td>
<td>13252</td>
<td>8228</td>
<td>6133</td>
<td>9322</td>
<td>15890</td>
<td>40219</td>
<td>38451</td>
<td>56554</td>
<td>35258</td>
</tr>
<tr>
<td>2006</td>
<td>41207</td>
<td>35551</td>
<td>36853</td>
<td>23561</td>
<td>30718</td>
<td>24382</td>
<td>15938</td>
<td>24102</td>
<td>28097</td>
<td>42718</td>
<td>50214</td>
<td>42871</td>
</tr>
</tbody>
</table>

*Fig. 22 – Headlamps sales' figures from 2004 to 2006*

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Contrary to the compasses data, sales are not stable but significantly increasing. The following graph illustrates sales evolutions better.

Sales data profile is rather different from compasses. Headlamps are still a young product for Silva and consequently data should not be used in the same way as for the compasses. The profiles for 2004, 2005 and 2006 clearly show an evolution in sales. 2004 is characterised by a flat profile and low sales, corresponding to the beginning of product group life. 2005 was a year of high growth which can be explained efficient commercial actions and introductions of new products thanks to a better knowledge of customers needs.

Fig. 23 – Invoice evolution for headlamps from 2004 to 2006

2006 is the first year of relative stability with apparition of a seasonal pattern: customers demand is lower during summer and December. Relying on assumptions made with the Sales Department, the 2006 demand profile is likely to become the usual sales profile for headlamps. Consequently, all data required for assessing safety stocks will be calculated from the 2006 data table:

<table>
<thead>
<tr>
<th>Month</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sales</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2006</td>
<td>41 207</td>
<td>35 551</td>
<td>36 853</td>
<td>23 561</td>
<td>30 718</td>
<td>24 382</td>
<td>15 938</td>
<td>24 102</td>
<td>28 097</td>
<td>42 718</td>
<td>50 214</td>
<td>42 871</td>
</tr>
<tr>
<td>Average</td>
<td>33 018</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Std Dev</td>
<td>9 746</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Fig. 24 – Headlamps sales’ figures for 2006

Headlamps are manufactured in China; therefore lead time is the same as for compasses. Using this ground data with formulas from previous chapter give:

- Lead Time: 43 days
- Lead Time standard deviation: 8 days
- Safety Stock needed (quantity): 15 000 units
- Safety Stock needed (cover): 13,6 days
Without considering any seasonality pattern, the theoretical safety stock is 15000 units. This quantity is equivalent to a stock cover of 13.6 days. This value is almost three times bigger than the current objective of 5 days. However, if applied, the previous 5-day target would have lead to a service level of only 47% during lead time compared to the theoretical 90% that would be obtained with 13.6 days of stock cover.

Seasonality

As seen in 2006 sales and in accordance with Product Managers assumptions, demand is following a seasonal pattern. One-year records being too short to determine precisely the seasonality of the product, two different scenarios will be studied.

**Case 1: with a simple seasonality**

<table>
<thead>
<tr>
<th>month</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006 sales</td>
<td>41 207</td>
<td>35 551</td>
<td>36 853</td>
<td>23 561</td>
<td>30 718</td>
<td>24 382</td>
<td>15 938</td>
<td>24 102</td>
<td>28 097</td>
<td>42 718</td>
<td>50 214</td>
<td>42 871</td>
</tr>
</tbody>
</table>

SS high season (unit) | 7030 | SS low season (unit) | 7314 |
cover high season | 8.6 | cover low season | 5.1 |

**Case 2: with a 3-period seasonality model**

<table>
<thead>
<tr>
<th>month</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006 sales</td>
<td>41 207</td>
<td>35 551</td>
<td>36 853</td>
<td>23 561</td>
<td>30 718</td>
<td>24 382</td>
<td>15 938</td>
<td>24 102</td>
<td>28 097</td>
<td>42 718</td>
<td>50 214</td>
<td>42 871</td>
</tr>
</tbody>
</table>

SS high season (unit) | 3713 | SS low season (unit) | 7030 | SS Peak season (unit) | 5369 |
cover high season | 2.94 | cover low season | 8.62 | cover peak season | 3.56 |

Comparison, cost and savings

Market knowledge and demand study on other outdoor equipments are reliable data that would justify taking seasonality into consideration. Therefore only the two seasonality scenarios will be financially evaluated. Besides, experience and knowledge about customers’ needs and behaviors gives qualitative information about the seasonality pattern that could be drawn. Determining seasonality requires more than a global idea of the sales graph. To optimize its efficiency, reliable ground data are needed for the trends and variations model to be applied. Due to the trend during the three past years, only data from 2006 can be used as ground data and consequently it is probably too optimistic to establish a detailed three-period seasonality model. For that reason, the 2-period model will be selected as the most appropriate seasonality pattern. Following table sums up the impact of a central warehouse system on safety and overall stocks:
As for compasses, no savings are made on safety stock. This can be imputed to the objective of a 90% service level under lead time which increases significantly the safety stock level to cover mainly the lead time uncertainty.

The global balance is yet positive and almost 250 000 SEK (26 800 €) could be saved on headlamps stocks thanks to centralized management.

**Pedometers**

Last, varugrupp 3 – Pedometers – was observed in order to assess potential savings. The method used is the same as previous: sales data from the past years are collected and analyzed, seasonality is taken into account to size safety stock and total inventory level is estimated.

**Sales data**

Pedometers are a rather new activity for Silva. The most noticeable specificity of this market is that more of 40% of pedometers sold are to be offered as gifts. This means that direct customers are companies intending to offer these pedometers, either as an internal gift to their employees or as an external gift to their own customers as a promotional action. This means also that products need to be customized according to customer requests, which require post-manufacturing operations before final delivery.
The sales evolution seems quite close to headlamps sales records seen in previous chapter. However, the conclusion that market is growing and will probably stabilize in the next few years as for headlamps should not be drawn too fast. Indeed, even though data are quite similar, market knowledge and experience emphasize some particular features of pedometers. The gift market is highly variable and uncertain and regular customers are more seldom. As agreed with the product manager at Silva, 2006 will be used as ground data for calculations. As far as seasonality is concerned, records of the past years will be observed in order to establish a relevant sales pattern.

Seasonality

Sales data shows a common point: the end of the year is a favourable period. Figures show as well that sales increase around spring; however, according to the product manager recommendations, this should not be taken into account when drawing the seasonality pattern. Variations are high for the pedometers market and only Christmas peak can be considered as a proper characteristic for the sales.

Results

Following table sums up the results and consequences of the new stock policy on the inventory levels:

<table>
<thead>
<tr>
<th></th>
<th>units</th>
<th>cover (days)</th>
<th>value (in SEK)</th>
<th>value (in €)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current stock level</td>
<td>59 519</td>
<td>29,78</td>
<td>2 255 451</td>
<td>241 483</td>
</tr>
<tr>
<td>incl. Safety stock</td>
<td>9 992</td>
<td>5,00</td>
<td>378 641</td>
<td>40 540</td>
</tr>
<tr>
<td>Future stock level</td>
<td>52 045</td>
<td>26,04</td>
<td>1 972 228</td>
<td>211 159</td>
</tr>
<tr>
<td>incl. Safety stock</td>
<td>13 605</td>
<td>6,81</td>
<td>515 574</td>
<td>55 201</td>
</tr>
<tr>
<td>Savings</td>
<td>7 474</td>
<td>3,74</td>
<td>283 223</td>
<td>30 324</td>
</tr>
<tr>
<td>incl. Savings on SS</td>
<td>-3 614</td>
<td>-1,81</td>
<td>-136 933</td>
<td>-14 661</td>
</tr>
</tbody>
</table>

Savings of around 12,5% could be expected according to theoretical calculations. However, these results should be seen as quite optimistic and actual benefits could happen to be lower for several reasons: first, due to the market specificity variations in sales can be higher than what has been observed so far which would require extra safety stock to ensure a good service level; second, as a gift, most of the products need to be customized before final delivery, and consequently extra safety stock can be possibly required to cover the additional lead time caused by post-manufacturing operations.
Transportation & Warehousing - Running costs

**E. Two solutions**

For the future organization of the supply chain, two solutions can be considered.

**Solution 1 - Central warehouse**

In this solution, all the regional warehouses are removed and the supply chain is organized around a single warehouse. This warehouse will be in charge of processing all the finished goods delivered from the factories, stocking those products, preparing orders and shipping these orders directly to the customers. With such a structure, all internal flows are avoided.

**Solution 2 - Central warehouse with regional warehouses**

With this solution, the regional warehouses remain related to the subsidiaries but a central warehouse is set up. With this configuration, customers in Sweden, France, Germany and United Kingdom are delivered by the subsidiaries. For the rest of the customers, products are sent from the central warehouse. Thus the central warehouse delivers both customers and subsidiaries.

**F. Transport**

**Current state**

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All the data about transportation costs for the current state have been gathered from Jeeves and also from information given by all the subsidiaries. Those data cover both internal product flows and product shipments to customers. Eventually the central warehouse is supposed to remove all internal flows and thus lead to savings on transportation costs.

All internal product flows are made through truck transportation. For customers located outside Europe, shipments are sent by air. For the rest, big shipments to customers are dispatched by trucks and small consignments through parcels forwarders. For a certain time, the current policy has been to reduce as much as possible the number of forwarders. Thereby it is eased to control shipments, costs and have more impact on decisions with the forwarder.

<table>
<thead>
<tr>
<th></th>
<th>Freight cost / year (€)</th>
<th>Lead time</th>
<th>Shipment / year</th>
</tr>
</thead>
<tbody>
<tr>
<td>France</td>
<td>from Silva SWE to customers</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>18 000</td>
<td>1 week</td>
<td>67</td>
</tr>
<tr>
<td></td>
<td>116 000</td>
<td>1 day</td>
<td>5520</td>
</tr>
<tr>
<td>UK</td>
<td>from Silva SWE to customers</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>35 000</td>
<td>1 week</td>
<td>161</td>
</tr>
<tr>
<td></td>
<td>113 000</td>
<td>1 day</td>
<td>17160</td>
</tr>
<tr>
<td>Germany</td>
<td>from Silva SWE to customers</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>19 000</td>
<td>4 days</td>
<td>149</td>
</tr>
<tr>
<td></td>
<td>14 000</td>
<td>1 day</td>
<td>3120</td>
</tr>
<tr>
<td>European Countries</td>
<td>to customers</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>57 000</td>
<td></td>
<td>543</td>
</tr>
<tr>
<td>Outside Europe</td>
<td>to customers</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>27 000</td>
<td></td>
<td>126</td>
</tr>
<tr>
<td>Sweden</td>
<td>to customers</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>88 000</td>
<td>1 day</td>
<td>7692</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>486 000 €</td>
</tr>
</tbody>
</table>

Fig. 26 – Current state transportation costs

In average, one shipment is sent to each of the three subsidiaries every week. These shipments are usually regularly scheduled with some changes from time to time according to the local demand variations. Locally, each subsidiary manages its own shipments to the customers with a specific forwarder and contract depending on order size. For customers outside Europe, Silva Sweden has a deal with the forwarder that delivers products from the Chinese factory. Those shipments are freighted forward by air.

**Future state**

In this part, an assessment is performed for each of the two solutions previously proposed. The first assumption for cost of transportation is that calculations are based on cost table for DHL Europremium Service and DHL 24 hours’ delivery given through software provided by DHL Sweden. Since it was rather difficult to obtain a price table for shipment from Hamburg, it has been decided to use the price table of DHL Sweden. The price table is based on calculations from Sweden to different zones in Europe but nevertheless a second assumption had to be set up to assess the cost for shipment sent from Hamburg. With advices from the Europe Sales & Purchasing manager and by comparing different destination for the same freight type with the cost to Hamburg, an average value of 12% of the freight cost was assigned to the transportation between Sweden and Hamburg area. Moreover to check this method, a comparison has been performed between real costs of shipments sent from Sweden and costs estimated with the table. The difference between the two costs is rather small (less than 5% with an average difference of 3%). The third assumption is to apply a 30% discount allowed by
the forwarder for long period partnership contracts. This sort of discount is a common practice.

For the first solution, all the products are delivered directly from the warehouse to the customers. There are two options in this case. Either the 24-hours delivery service is considered or it is assumed that the customer accept to be delivered within a period of 72 hours. For the first option, the costs are quite high due to this policy of 24 hours delivery. Especially for products sent to France and United Kingdom. With the second option, justified by the fact that the customers accept longer delivery time but reliable, the costs are much less than the first option.

<table>
<thead>
<tr>
<th></th>
<th>Solution 1-1</th>
<th>Solution 1-2</th>
<th>Solution 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Freight cost / year (€)</td>
<td>Lead time</td>
<td>Freight cost / year (€)</td>
</tr>
<tr>
<td>France</td>
<td>from Hamburg to customers</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>256 000</td>
<td>2-3 days</td>
<td>78 000</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>116 000</td>
</tr>
<tr>
<td>UK</td>
<td>from Hamburg to customers</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>121 000</td>
<td>2-3 days</td>
<td>57 000</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>113 000</td>
</tr>
<tr>
<td>Germany</td>
<td>from Hamburg to customers</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>14 000</td>
<td>2 days</td>
<td>14 000</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>14 000</td>
</tr>
<tr>
<td>European Countries</td>
<td>to customers</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>50 000</td>
<td></td>
<td>50 000</td>
</tr>
<tr>
<td>Outside Europe</td>
<td>to customers</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>27 000</td>
<td></td>
<td>27 000</td>
</tr>
<tr>
<td>Sweden</td>
<td>from Hamburg to customers</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>238 000</td>
<td>2-4 days</td>
<td>351 000</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>88 000</td>
</tr>
<tr>
<td>Total</td>
<td>706 000 €</td>
<td></td>
<td>577 000 €</td>
</tr>
</tbody>
</table>

Fig. 27 – Future state transportation costs

**G. Warehousing**

1) **Facilities**

**Warehouse surfaces and space cost**

Each subsidiary has its own warehouse dedicated to the local market. Currently most of these warehouses are fully replete. A Warehouse denotes a rather good usage of the warehouse surface which is relevant in terms of cost saving and storage “efficiency”.

The surface required in a warehouse is related to the stock level. And the more stable the stock level is, the better the usage of the warehouse surface can be achieved. Nevertheless even if it is made good use of the warehouse surface, it does not imply that the stock level is optimized. To reach the best cost saving, both stock level and surface optimizations have to be considered. The stock level has to be as low
as possible but must fulfil the requirements in terms of product availability or any other service level objectives.

Fig. 28 - Warehouse rental cost per square meter per year in Western Europe

The map on previous page shows the main logistics area with the surface costs for warehousing. The information provided by the map is non-exhaustive but provides a rather good insight of the warehouse surface costs in Western Europe.

Space cost is a very important parameter in the warehouse cost. The surface for the warehouse is assessed using information on the upstream and downstream logistic flows, order policy and calculation of safety stock. With the surface value known, the location of the warehouse will be determined by the best compromise between the geographical location (ease of transportation) and the local space cost, regarding also transportation process.
**Current state**

In the current state, most of the warehouses have their surfaces fully occupied.

<table>
<thead>
<tr>
<th></th>
<th>Surface m²</th>
<th>Cost (€) / Year / m²</th>
<th>Total Cost (€)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silva Sweden AB</td>
<td>1630</td>
<td>94</td>
<td>153 220</td>
</tr>
<tr>
<td>Silva France</td>
<td>408</td>
<td>60</td>
<td>24 500</td>
</tr>
<tr>
<td>Silva Germany</td>
<td>80</td>
<td>74</td>
<td>5 920</td>
</tr>
<tr>
<td>Silva Limited</td>
<td>607</td>
<td>59</td>
<td>35 800</td>
</tr>
</tbody>
</table>

Fig. 29 - Warehouse surface cost review for the current situation

After having compared prices of the warehouse surfaces, the highest cost among all Silva’s facilities in Europe is situated in Sweden. By removing the Swedish warehouse which is the largest warehouse, there is rather important savings to benefit. It is then expected to find the most suitable area for implementing the new warehouse in order to gain on surface cost and thus on global cost.

**Future state - solution 1**

According to stock calculations, the total stock amount can be decreased of 10%. It is assumed that it can be applied directly on the warehouse surface used. In this model, there is one central warehouse and no more local warehouses. Silva Limited has 49% of its turnover made with the distribution activity and Silva France has 64%.

![Diagram showing the distribution of warehouse surfaces and the central warehouse](image)

Using the same assumption with the turnover, only the percentage allocated to distributed products in the subsidiaries is added to the surface of the central warehouse.

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As all Silva’s products come from Silva Sweden, the surface allocated to Silva’s products is the same as Silva Sweden warehouse.

The following table summarizes the warehouse costs in the solution 1 of the future state with a surface cost chosen in Hamburg area.

<table>
<thead>
<tr>
<th>Surface (m²)</th>
<th>Cost (€) / Year / m²</th>
<th>Total Cost (€)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central warehouse</td>
<td>1 970</td>
<td>66</td>
</tr>
</tbody>
</table>

*Fig. 30 - Warehouse surface cost review for solution 1*

**Future state - solution 2**

With this solution, all the regional warehouses are maintained. The objective is to reduce the Swedish warehouse and move a large part of its logistics operations to the central warehouse. Based on the turnover figures, 47% of the products in the Swedish warehouse are bound to the Swedish market. It is assumed that the same percentage represents the allocated surface in the warehouse for those products. The rest is dedicated to products for the non Swedish customers. In opposition to the solution 1, the German warehouse is kept apart from the central warehouse in order to avoid a certain amount of small orders for the German market in the central warehouse.
The following table summarizes the warehouse costs in the solution 2 of the future state with the corresponding surface costs linked to the area.

<table>
<thead>
<tr>
<th></th>
<th>Surface m²</th>
<th>Cost (€) / Year / m²</th>
<th>Total Cost (€)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silva Sweden AB</td>
<td>603</td>
<td>94</td>
<td>51 691</td>
</tr>
<tr>
<td>Silva France</td>
<td>408</td>
<td>60</td>
<td>24 500</td>
</tr>
<tr>
<td>Silva Germany</td>
<td>80</td>
<td>74</td>
<td>5 920</td>
</tr>
<tr>
<td>Central warehouse</td>
<td>864</td>
<td>74</td>
<td>63 929</td>
</tr>
<tr>
<td>Silva Limited</td>
<td>607</td>
<td>59</td>
<td>35 800</td>
</tr>
</tbody>
</table>

*Fig. 31 – Warehouse surface cost review for solution 2*

**Summary**

**Warehouse surface (m²) & cost per year (€)**

The diagram above summarizes the warehouse costs for the two solutions and compares it with the current state. It can be noticed that the gain expected on costs with the solution 1 is at least 40% lower than the current situation. Hence with such a figure and at this step of the assessment great savings can be expected from the solution 1.

**Warehouse flow**

The warehouse has a complex organization connecting upstream and downstream according to a shipment planning and an order policy. Those rule the regular stock that
fluctuates over the time and define the safety stock which avoids risks of depletion and meets service level or customer requirements.

2) Human Resources (Warehouse & Service)

Warehouse employees

The warehouse employees have four main tasks to perform in the warehouse: incoming delivery process, inventory management, order preparation and shipment.

Current state

Figures on current human resources dedicated to Silva’s warehouse are summarized in the following table:

<table>
<thead>
<tr>
<th></th>
<th>Silva France</th>
<th>Silva Germany</th>
<th>Silva Limited</th>
<th>Silva Sweden AB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of employees</td>
<td>1 ½</td>
<td>½</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Average salary / month</td>
<td>2 750 €</td>
<td>433 €</td>
<td>1 912 €</td>
<td>2 350 €</td>
</tr>
<tr>
<td>Working time (/week)</td>
<td>39</td>
<td>10</td>
<td>39</td>
<td>40</td>
</tr>
<tr>
<td>Total cost</td>
<td>49 500 €</td>
<td>5 200 €</td>
<td>68 800 €</td>
<td>141 000 €</td>
</tr>
</tbody>
</table>

All the information presented in the previous table has been gathered from data provided by managers of the subsidiaries and persons in charge at Silva Sweden.

Future state - solution 1

There are no specific rules to evaluate the number of employees necessary in the warehouse as several parameters step in the assessment. Indeed depending on the size of the warehouse, the number and the size of orders to process as well as the incoming product flow, the number of employees is prone to variations. Hence this is more likely determined by experience of warehouse clerks and managers.

In this project, it has been assumed that the number of employees required is related to the number of shipments sent and the turnover achieved by the warehouse. By comparison of figures from each of Silva’s warehouse and with advices of warehouse clerks, the number of employees that would be adapted for the central warehouse is 6. From information obtained on salaries in Hamburg area, the salary of a warehouse clerk is 15€ per hour. It is assumes then that there is 22 days of work per month and 8 hours of work a day. As a result the average salary per month totals 2640€.

<table>
<thead>
<tr>
<th></th>
<th>Central warehouse</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of employees</td>
<td>6</td>
</tr>
<tr>
<td>Average salary / month</td>
<td>2640</td>
</tr>
<tr>
<td>Total cost</td>
<td>190 000 €</td>
</tr>
</tbody>
</table>
Future state - solution 2

With the same assumptions seen previously and the same methodology, the number of employees required in the solution 2 is summarized in the following table:

<table>
<thead>
<tr>
<th></th>
<th>Silva France</th>
<th>Silva Germany</th>
<th>Silva Limited</th>
<th>Silva Sweden AB</th>
<th>Central warehouse</th>
</tr>
</thead>
<tbody>
<tr>
<td>N. of employees</td>
<td>1</td>
<td>½</td>
<td>2</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Total cost</td>
<td>33 000 €</td>
<td>5 200 €</td>
<td>45 900 €</td>
<td>56 400 €</td>
<td>95 000 €</td>
</tr>
</tbody>
</table>

The number of warehouse clerks in the subsidiaries’ warehouse has not really changed. With the objective to move part of the warehouse activities of Silva Sweden, most of the changes appear in Sweden and of course the new central warehouse. As a matter of fact Silva Sweden had a warehouse acting as some sort of central warehouse. With this solution, all the products coming from China go directly to the central warehouse in Germany and only the products for the Swedish market are stored in Silva Sweden warehouse.

Summary

The diagram above summarizes the human resources costs of the two solutions and compares it with the current state. As expected, the solution 1 offers the best costs savings.
H. Global savings

Savings on warehouse cost & transportation

The diagram above sums up the three main costs for each solution and the current state. The total is given with a saving ratio for each solution. The saving ratio shows the percentage of gain to expect by a solution from the current situation. It is calculated as followed:

\[
\text{Saving ratio} = \frac{\text{Solution } i \text{ total cost} - \text{Current state total cost}}{\text{Current state total cost}}
\]

With the first solution, a completely centralized warehouse, the expected gain goes up to 7,5% of the current costs every year which represents 73 000 € every year. With the second solution, a structure with a central warehouse and still the local warehouses, the expected gains are a bit lower with 5,9% which represents 57 500 € every year. In spite of these low figures compared to the annual turnover of the company, these savings are the result of calculations performed with several assumptions and the calculations concern direct costs. For this reason, other cost savings could be expected from a change in the supply chain organization but could hardly be assessed with ease. For instance, no negotiations or discussions were possible with Third party logistics providers considering the early state of the project at Silva.
DECISIONS & CONCLUSIONS

Interview of subsidiaries’ manager

As part of the project, a visit of the subsidiaries has been planned in agreement with the supervisor at Silva, Göran Sjöquist. The main objectives were to assess the local supply chain structure and discuss with the local managers their opinion on the project. Thereby one trip to the French subsidiary was organized as well as a meeting with the manager of Silva Limited in the Swedish premises. It has been impossible to have a meeting with the German subsidiary manager owing to scheduling difficulties.

A. Current situation

Customers

Silva has built for several years a strong distribution network throughout the world. It has a good brand image and is renowned among the customers for the quality of its products and services. This brand image has to remain as it has been until now and thus improvements have to be focused on the weakness of the lead time.

The subsidiaries are facing two different types of customers: big customers such as central purchasing agencies and small customers. These two types of customers are completely different with specific requirements that are not matching. For example, Silva France has 15 customers counting for 65% of its turnover and 1200 other for the 35% remaining. These bipolar customers raise issues in terms of service level, responsiveness and supply chain structure among others. Silva France ask for a minimum order of 150€ nevertheless small orders remains important and must be processed with the same commitment to avoid backlogs and maintain the brand image.

In terms of lead time, Silva France offers 48 hours delivery (which can be up to 72h in some cases) and Silva limited is committed to deliveries the day following the order. As these different lead times may create difficulties in a centralized organization, a homogenous lead time has to be thought for a future supply chain configuration.

Market & Forecasts

Currently there is no real forecast in the subsidiaries. The central purchasing agencies are the only customers providing forecast information up to a month in advance. Moreover the markets are continuously evolving at high pace as the customers ask for more new products on a shorter period. This gives rise to peaks in the demand and increasing uncertainties. This also leads to more pressure on product development teams in Sweden which may have responsiveness difficulties.

Stocks & Reverse Logistics

Up till now improvements in the internal shipments and the rather good capacity of the Swedish warehouse provide on-time deliveries and avoid products shortage. Nevertheless the lead time remains high and for this reason the safety stock is based
on 3 weeks stock cover (up to a month at Silva Limited). At Silva France, around 40% of the products in the warehouse are Silva’s products. The 60% remaining are products for the distribution activity. Even if no service level is currently monitored at Silva, one central purchasing agency has given the figure of 98%-100% to Silva France. Even if this figure is rather good, it is the normal service level expected by such kind of customer. Therefore a good customer commitment policy would offer this service level to all the customers through a constant monitoring of the overall activity.

There is currently no well defined Reverse logistics structure at Silva on a global point of view. Each subsidiary takes care of the return products according to the defect’s reports. As well as the reverse logistics, there is no specific policy for the slow sellers remaining in stocks. In the case that another subsidiary needs one of these slow seller, the products are shipped directly to this subsidiary. But such a case is rather scarce.

**Jeeves implementation**

As previously presented, Jeeves ERP system is about to be installed in all the subsidiaries. Several improvements are expected such as a decrease in orders processing, a better follow-up of the demand and stock. The overall gains would affect the global organization leading to a better efficiency.

**Key points**

Currently, the key points that have been suggested to focus on are:

- A better follow-up of the market evolution and an improved product development rate
- Delivery issues: avoid any delay that could occur in internal major shipment, avoid non delivery to the customers by the forwarder and get more flexibility from the forwarder to get conformed to customer’s requirements.
- Flexible delivery schedule so any failure occurring could be processed without inducing further problems and delays with other deliveries.
- Flexibility with special customers’ requests and the orders. To settle post-manufacturing operations such as packaging in the warehouse would certainly increase efficiency and reduce material waste.

**B. Central warehouse project**

**Key points**

According to the subsidiary’s managers, the key points to keep in mind when carrying through such a project are:

- Customer commitment: lead time control, fast order processing
- Fast responsiveness towards market evolution

**Benefits**

With a supply chain organized around a central warehouse, the main benefit to expect is a global reduction of costs. Premises expenses and Human resources: A central warehouse implies less stocking facilities with a better use of the surface and
reducing globally the number of employees. Transportation expenses: A unique
distribution platform implies a larger product flow in terms of number of shipments to the
customers. Thus transportation is monitored with ease and it would influence
negotiations (e.g. discounts…) with forwarders.

**Drawbacks and risks**

From the discussions with the subsidiary’s managers, the main drawbacks related
to such a project would be the following:

- A decrease in the service quality: Serving both big customers and small
customers needs two different structures. It doesn't require the same capacity
to prepare 1 order with 40 lines from a big customer and 20 orders with an
average of 2 lines from smaller customers. Besides that each local market has
a specific demand pattern. Customers from one local market won't demand the
same products as those of another local market. Thus a central warehouse has
to take into consideration a wider demand in terms of references. This may
lead to a prioritization for the big customers, implying a growing backlog for the
small customers for instance.

- Loss of responsiveness: Specific demands from the customer for instance
packaging may occur and be related to a local market. A central warehouse
would have to face a wider diversity in the orders than a local warehouse.
Decision Model

Last step in the thesis work is to propose an effective solution. It is therefore capital to choose objectively which of the alternatives is more likely to satisfy customers and generate more profit. In order to take into account the most relevant criteria and to assess simultaneously the alternatives, a matrix decision model will be built as follows:

A. Choice of alternatives

First, it is necessary to determine the set of alternatives that will be compared in the model. The current organization will be the first of them, showing the “as-is” situation. Then, as expected, the central warehouse organization will be one of them as well. Last, drawing on managers’ experiences and proposals gathered during the interviews in Stockholm and Paris, a solution somewhere in-between will be assessed too: a supply chain organization based on the central warehouse but still relying on regional warehouses as secondary inventory locations.

B. Criteria selection

The next step is to define the list of criteria through which the alternatives will be evaluated. This list has been made out of the data gathered during the managers’ interviews and out of articles in specialized literature and websites. The final criteria list used in the model is:

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Customer Service</th>
<th>Financial impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Responsiveness</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Product availability</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lead time to customer when in stock</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lead time to customer when not in local stock</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Handling of small customers/small orders</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Handling of big customers/big orders</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capacity to handle business growth</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adaptability to special customer requests</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inventory rotation speed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subcontracting opportunities</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Human resources costs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transportation costs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inventory costs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Premises costs</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Criteria appear to belong to two main categories: the first part of the list is dedicated to customer service while the last part is related to financial impacts.
C. Weight determination

Although all of the criteria listed during previous step need to be taken into consideration, the influence on the final results might not be as strong from one criterion to the other. To assess as objectively as possible the alternatives, it is necessary to reflect these variations. Consequently, a weight will be assigned to each criterion in accordance with their respective importance. The following table sums up the weight assignment, based on Silva’s strategy and know-how as well as managers’ experience and market knowledge:

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Responsiveness</td>
<td>5</td>
</tr>
<tr>
<td>Product availability</td>
<td>6</td>
</tr>
<tr>
<td>Lead time to customer when in stock</td>
<td>9</td>
</tr>
<tr>
<td>Lead time to customer when not in local stock</td>
<td>3</td>
</tr>
<tr>
<td>Handling of small customers/small orders</td>
<td>10</td>
</tr>
<tr>
<td>Handling of big customers/big orders</td>
<td>10</td>
</tr>
<tr>
<td>Capacity to handle business growth</td>
<td>6</td>
</tr>
<tr>
<td>Adaptability to special customer requests</td>
<td>8</td>
</tr>
<tr>
<td>Inventory rotation speed</td>
<td>5</td>
</tr>
<tr>
<td>Subcontracting opportunities</td>
<td>5</td>
</tr>
<tr>
<td>Human resources costs</td>
<td>6</td>
</tr>
<tr>
<td>Transportation costs</td>
<td>6</td>
</tr>
<tr>
<td>Inventory costs</td>
<td>6</td>
</tr>
<tr>
<td>Premises costs</td>
<td>6</td>
</tr>
</tbody>
</table>

Predominant criteria are linked to customer service. The ability to deliver quickly in-stock product, either to small or big customers by small or big quantities is capital for Silva. Fulfilling customers’ expectations is a *sine qua non* condition to survive in the current competitive environment, which is why financial aspects appear as secondary in the weight assignment. Retaining regular customers and reaching new markets are necessary to preserve the company’s health through viable and sustainable growth. Operation costs should be monitored and minimized but service level is of prime necessity to perpetuate Silva’s image.

D. Alternatives assessment

Once criteria have been assigned a weight, each of the alternatives is assessed depending on how good it responds to the criteria. Table after assessment follows:
### Current Situation

#### Central Warehouse

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Weight</th>
<th>Rating</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Responsiveness</td>
<td>5</td>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td>Product availability</td>
<td>6</td>
<td>4</td>
<td>24</td>
</tr>
<tr>
<td>Lead time to customer when in stock</td>
<td>9</td>
<td>4</td>
<td>36</td>
</tr>
<tr>
<td>Lead time to customer when not in local stock</td>
<td>3</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Handling of small customers/small orders</td>
<td>10</td>
<td>4</td>
<td>40</td>
</tr>
<tr>
<td>Handling of big customers/big orders</td>
<td>10</td>
<td>3</td>
<td>30</td>
</tr>
<tr>
<td>Capacity to handle business growth</td>
<td>6</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>Adaptability to special customer requests</td>
<td>8</td>
<td>4</td>
<td>32</td>
</tr>
<tr>
<td>Inventory rotation speed</td>
<td>5</td>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td>Subcontracting opportunities</td>
<td>5</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Human resources costs</td>
<td>6</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Transportation costs</td>
<td>6</td>
<td>3</td>
<td>18</td>
</tr>
<tr>
<td>Inventory costs</td>
<td>6</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>Premises costs</td>
<td>6</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>91</td>
<td>29</td>
<td>215</td>
</tr>
</tbody>
</table>

#### Cent. WH + Reg. WH

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Weight</th>
<th>Rating</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Responsiveness</td>
<td>5</td>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td>Product availability</td>
<td>6</td>
<td>4</td>
<td>24</td>
</tr>
<tr>
<td>Lead time to customer when in stock</td>
<td>9</td>
<td>4</td>
<td>36</td>
</tr>
<tr>
<td>Lead time to customer when not in local stock</td>
<td>3</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Handling of small customers/small orders</td>
<td>10</td>
<td>4</td>
<td>40</td>
</tr>
<tr>
<td>Handling of big customers/big orders</td>
<td>10</td>
<td>3</td>
<td>30</td>
</tr>
<tr>
<td>Capacity to handle business growth</td>
<td>6</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>Adaptability to special customer requests</td>
<td>8</td>
<td>4</td>
<td>32</td>
</tr>
<tr>
<td>Inventory rotation speed</td>
<td>5</td>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td>Subcontracting opportunities</td>
<td>5</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Human resources costs</td>
<td>6</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>Transportation costs</td>
<td>6</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>Inventory costs</td>
<td>6</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>Premises costs</td>
<td>6</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>91</td>
<td>29</td>
<td>215</td>
</tr>
</tbody>
</table>

Ratings are scaled from 0 to 4. They are assigned according to managers’ experience, comments and ideas shared during interviews.

**E. Scores calculation and comparison**

Last, scores are computed. For each couple {criterion; alternative}, the related score is simply the product of the criterion’s weight by the alternative’s rating. Consequently, global scores for each of the three alternatives are the result of a scalar product between the weight vectors and the respective rating vector. Here follows final table with scores:
The first immediate conclusion is that highest score is obtained by the mixed solution, with implementation of a central warehouse while keeping regional warehouses. Then comes the central warehouse solution, and current situation gets the lowest score. Before concluding that the last alternative with both central and regional is the best one, it is relevant to study more in depth the advantages and the drawbacks of the two highest scores.

1) Central + Regional warehouses solution

The main strength of this model is its capacity to achieve superior service level due to a distribution network close to final customers. With two different levels of stocking places, capacity to handle both small and big orders is allowed as well.

On the other hand, this proximity has an important drawback: premises, human resources and inventory costs. Following table emphasizes the Central + Regional model strengths (in green) and weaknesses (in orange) in comparison with the central model:

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Weight</th>
<th>Current Situation</th>
<th>Central Warehouse</th>
<th>Cent. WH + Reg. WH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Responsiveness</td>
<td>5</td>
<td>2</td>
<td>10</td>
<td>3</td>
</tr>
<tr>
<td>Product availability</td>
<td>6</td>
<td>2</td>
<td>12</td>
<td>3</td>
</tr>
<tr>
<td>Lead time to customer when in stock</td>
<td>9</td>
<td>4</td>
<td>36</td>
<td>2</td>
</tr>
<tr>
<td>Lead time to customer when not in local stock</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td>Handling of small customers/small orders</td>
<td>10</td>
<td>4</td>
<td>40</td>
<td>0</td>
</tr>
<tr>
<td>Handling of big customers/big orders</td>
<td>10</td>
<td>3</td>
<td>30</td>
<td>40</td>
</tr>
<tr>
<td>Capacity to handle business growth</td>
<td>6</td>
<td>1</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>Adaptability to special customer requests</td>
<td>8</td>
<td>4</td>
<td>32</td>
<td>1</td>
</tr>
<tr>
<td>Inventory rotation speed</td>
<td>5</td>
<td>2</td>
<td>10</td>
<td>4</td>
</tr>
<tr>
<td>Subcontracting opportunities</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>Human resources costs</td>
<td>6</td>
<td>1</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>Transportation costs</td>
<td>6</td>
<td>3</td>
<td>18</td>
<td>1</td>
</tr>
<tr>
<td>Inventory costs</td>
<td>6</td>
<td>1</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>Premises costs</td>
<td>6</td>
<td>1</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>91</strong></td>
<td><strong>29</strong></td>
<td><strong>215</strong></td>
<td><strong>38</strong></td>
</tr>
</tbody>
</table>

It appears as explained previously that the composite model is more efficient when it comes to customer service but stays quite behind when costs are concerned.

2) Central warehouse solution

The central warehouse model does not have the same problems. On the contrary, the cost aspect is its major positive point due to minimal premises, human resources and inventory needs. However, due to its size small quantities are difficult to take care of. A direct consequence for customer service is that both small customers and small
orders will not be dealt with efficiently. This is the main fear of managers. For instance in France, around half of the sales are made with small orders and small customers. Minimizing costs is surely a priority but the main concerns are customer service and sustainable growth above all. As for previous alternative, here follows Central warehouse model’s strengths and weaknesses compared to the composite Central + Regional warehouses alternative:

<table>
<thead>
<tr>
<th>Decision Model</th>
<th>Current Situation</th>
<th>Central Warehouse</th>
<th>Cent. WH + Reg. WH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Criterion</td>
<td>Weight</td>
<td>Rating</td>
<td>Score</td>
</tr>
<tr>
<td>Reactivity to demand variation</td>
<td>5</td>
<td>2</td>
<td>10</td>
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<tr>
<td>Product availability</td>
<td>6</td>
<td>2</td>
<td>12</td>
</tr>
<tr>
<td>Lead time to customer when in stock</td>
<td>9</td>
<td>4</td>
<td>36</td>
</tr>
<tr>
<td>Lead time to customer when not in local stock</td>
<td>3</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Handling of small customers/small orders</td>
<td>10</td>
<td>4</td>
<td>40</td>
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<tr>
<td>Handling of big customers/big orders</td>
<td>10</td>
<td>3</td>
<td>30</td>
</tr>
<tr>
<td>Capacity to handle business growth</td>
<td>6</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>Adaptability to special customer requests</td>
<td>8</td>
<td>4</td>
<td>32</td>
</tr>
<tr>
<td>Inventory rotation speed</td>
<td>5</td>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td>Subcontracting opportunities</td>
<td>5</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Human resources costs</td>
<td>6</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>Transportation costs</td>
<td>6</td>
<td>3</td>
<td>18</td>
</tr>
<tr>
<td>Inventory costs</td>
<td>6</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>Premises costs</td>
<td>6</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>Total</td>
<td>91</td>
<td>29</td>
<td>215</td>
</tr>
</tbody>
</table>

This model shows a big savings potential but is not the best-scoring one because of its poor adaptation to Silva’s specific market demands.

Conclusions

A. Decision

The decision model emphasizes on the Central + Regional model superiority, considering the current available data, technical capacities and customer needs. An external parameter can be taken into consideration before making a choice: time. By adding a time dimension to the model, it becomes possible to estimate potential evolutions of the alternatives as well as possible changes in the scores. One of the key advantages of adding time to the model is notably to be able to forecast how the observed weaknesses can be dealt with and eventually strengthened.

As far as Central + Regional model is concerned, its weaknesses are inherent to its structure: multiple stocking points enable certainly better response to customer but it requires premises, human resources and inventories that cannot be reduced under a certain level. For that reason, no significant improvement is to expect and costs will not be reduced considerably in the future.
As for the Central warehouse model, the progress potential is much wider. Thanks to its minimal structure, fixed costs are low from the beginning except for transportation costs. The model is also behind because of its inability to answer optimally to customer demands. However, contrary to the previous case, all these weaknesses can be improved in the future. Turning to a third-party logistics could enable simultaneously better customer service and lower transportation costs. Indeed, 3-PLs companies possess a significant experience in handling small orders as well as very big customers. With a 3-PL solution, size is not a problem anymore and customers can be served in time regardless their size, location and specific demand. In the meantime, 3-PLs balance their activity and optimize shipment by working at the same time for several companies. This leads directly to a noteworthy drop in transportation costs. Subcontracting has an extra positive side-effect regarding firm strategy: Silva would be able to focus all its energy on its core business and entrust the logistic operations to specialized companies. By re-assessing the central warehouse alternative considering the future potential improvements, the decision table becomes:

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Weight</th>
<th>Current Situation</th>
<th>Central Warehouse</th>
<th>Cent. WH + Reg. WH</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reactivity to demand variation</td>
<td>5</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>15</td>
</tr>
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<td>2</td>
<td>4</td>
<td>36</td>
</tr>
<tr>
<td>Lead time to customer when not in local stock</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td>9</td>
<td>6</td>
</tr>
<tr>
<td>Handling of small customers/small orders</td>
<td>10</td>
<td>4</td>
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<td>2</td>
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</tr>
<tr>
<td>Adaptability to special customer requests</td>
<td>8</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>24</td>
</tr>
<tr>
<td>Inventory rotation speed</td>
<td>5</td>
<td>2</td>
<td>4</td>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td>Subcontracting opportunities</td>
<td>5</td>
<td>0</td>
<td>4</td>
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<td>10</td>
</tr>
<tr>
<td>Human resources costs</td>
<td>6</td>
<td>1</td>
<td>6</td>
<td>2</td>
<td>12</td>
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<tr>
<td>Transportation costs</td>
<td>6</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>18</td>
</tr>
<tr>
<td>Inventory costs</td>
<td>6</td>
<td>1</td>
<td>6</td>
<td>2</td>
<td>12</td>
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<tr>
<td>Premises costs</td>
<td>6</td>
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<td>6</td>
<td>2</td>
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</tr>
<tr>
<td>Total</td>
<td>91</td>
<td>215</td>
<td>284</td>
<td>249</td>
<td></td>
</tr>
</tbody>
</table>

By working on its weaknesses and improving its process, the central warehouse becomes the best model in mid- or long-term.

The logical solution is therefore a composite between the two best alternatives in order to run the whole process with the most adapted configuration at all times.

**B. Chronological steps**

The whole transformation can be simply summed up with the following graph:
Current situation is step 0. It is the current stage as described previously: Sweden plays the role of a main warehouse,

Step 1 is the implementation of a central warehouse when still working with the regional warehouses as stocking point and distribution platforms. Information exchanges increase, thanks to IT enhancements. While central warehouse is gradually gaining importance, volumes handled by regional warehouses are decreased little by little. Regional departments can then focus on marketing and product development, which is, according to the managers, one of the current problems at Silva. If needed, regional warehouses are still up for some help and are used as buffer during the whole system transformation.

Second and last step is the use of a unique central warehouse dealing with all the orders. Transition will be done only gradually, it is fundamental not to loose sales or service level points. The change should be imperceptible for final customers, at least in term of service quality. Once final step is reached, the whole logistic system will be clearer and simpler, products and orders will be easier to follow along the supply chain. Customer service will be higher while operational costs will be optimized.
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Appendix 1

Source code of the program used in Scilab to calculate the warehouse location with the Weiszfeld procedure and a simple center of gravity.

```matlab
//matrix with [weight, x position, y position], n contains the number of customers
M=[547037.65,-3.5,-7;171289.125,-3;223491.525,-4.15;174008,-3,-11.5;120718.05,-7,15.5;536379.66,-20.5,-22;148994.35,35.9,-10.87004,3,-6.5;76128.5,-27,-23;29363.85,17,25.5;51114.85,9.5,-2.5;0,22.5,18.5;32626.5,27,5;148994.35,9,-10.5;1120502.765,-10.5,-8.5;1868302.145,-13.5,0;1450247.925,-1.9;271887.5,-1.5,3.5;120718.05,7,5;536379.66,20.5,-22;148994.35,35.9,-10.87004,3,-6.5;76128.5,-27,-23;29363.85,17,25.5;51114.85,9.5,-2.5;0,22.5,18.5;32626.5,27,5;148994.35,9,-10.5;1120502.765,-10.5,-8.5;1868302.145,-13.5,0;1450247.925,-1.9;271887.5,-1.5,3.5;1023928.325,10.5,11.5;4234919.7,2,6;2803703.9,-1.5,-1];
clf();
xtitle('Location of the warehouse', 'X Location', 'Y Location');
a=get("current_axes"); //get the handle of the newly created axes
a.data_bounds=[-30,-30;30,20];
ValueXIt3 = 0;ValueXIt2 = 0;ValueXIt1 = 1;ValueYIt3 = 0;ValueYIt2 = 0;ValueYIt1 = 1;
dconv=5; //Number of figures to consider for convergence criterion
n=size(M,1); //Number of customers
for i=1:n
    plot(M(i,2),M(i,3),"dr"); //Plot center of gravity of all the countries
end
p=2; //Value of the p factor. Value of p should be chosen between 1 and 2
nit=200; //Number of iteration, iteration r
function l = Lp(ai,bi,x,y,pf)
    l=((x-ai)^pf+(y-bi)^pf)^(1/pf); //Define function for distance calculation
endfunction
function result=rond(v,d)
    result = round(10^d*v)*10^(-d);
endfunction
Xw = 0; //initialize the X coordinate for the first iteration
Yw = 0; //initialize the Y coordinate for the first iteration
//Start iterations
for r=1:nit
    //Calculation for x
    //Numerator calculation
    TempSum1 = 0;
    for i=1:n
        TempSum1 = TempSum1 + M(i,1)*M(i,2)/Lp(M(i,2),M(i,3),Xw,Yw,p);
    end
    //Denominator calculation
    TempSum2 = 0;
    for i=1:n
        TempSum2 = TempSum2 + M(i,1)/Lp(M(i,2),M(i,3),Xw,Yw,p);
    end
    //Calculation
    Xw = Xw + (TempSum1/TempSum2 - Xw);
    //Calculation for y
    //Numerator calculation
    TempSum1 = 0;
    for i=1:n
        TempSum1 = TempSum1 + M(i,1)*M(i,3)/Lp(M(i,2),M(i,3),Xw,Yw,p);
    end
    //Denominator calculation
```

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TempSum2 = 0;
for i=1:n
    TempSum2 = TempSum2 + M(i,1)/Lp(M(i,2),M(i,3),Xw,Yw,p);
end

//Calculation
Yw = Yw + (TempSum1/TempSum2 - Yw);

//plot calculated point
plot(Xw,Yw,'bs');
//print of the iteration r and the coordinates calculated in the command line
printf("Iteration %3i X=%f Y=%f\n",r,rnd(Xw,5),rnd(Yw,5));
ValueXIt3 = ValueXIt2;
ValueXIt2 = ValueXIt1;
ValueXIt1 = Xw;
ValueYIt3 = ValueYIt2;
ValueYIt2 = ValueYIt1;
ValueYIt1 = Yw;
//Test for convergence: If three positions in a row are similar, stop calculation
If (((rnd(ValueXIt1,dconv)==rnd(ValueXIt2,dconv))&(rnd(ValueXIt2,dconv)==rnd(ValueXIt3,dconv)))&((rnd(ValueYIt1,dconv)==rnd(ValueYIt2,dconv))&(rnd(ValueYIt2,dconv)==rnd(ValueYIt3,dconv)))) then
    break;
end
end
plot(Xw,Yw,'gd');  //Plot final location
//Simple center of gravity
TempSum = 0;
for i=1:n
    TempSum = TempSum + M(i,1);
end
Xw = 0;
for i=1:n
    Xw = Xw + M(i,1)*M(i,2);
end
Yw = 0;
for i=1:n
    Yw = Yw + M(i,1)*M(i,3);
end
Xw = Xw/TempSum;
Yw = Yw/TempSum;
plot(Xw,Yw,'ys');  //Plot gravity center location
Varugrupp 1: Compasses

### Invoiced Quantities

<table>
<thead>
<tr>
<th>Year</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
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<td>Month</td>
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<td></td>
<td></td>
<td></td>
<td>49,238</td>
</tr>
</tbody>
</table>

#### Without considering seasonality

- **Lead Time**: 43 days
- **LT std dev**: 4 days
- **Safety Stock needed**: 17,000 units
- **Cover**: 8.25 days

Previous 5-day cover was equivalent to a 78% service level during lead time.

#### With Seasonality

- **SS high season (unit)**: 13022
- **SS low season (unit)**: 13884
- **Cover high season**: 6.32 days
- **Cover low season**: 6.74 days
- **Balanced cover**: 6.60 days

Service level during the lead time: 90%

Related coefficient: 1.2815

- **Total evaluated stock**: 117,000 units
- **Quantity saved**: 16,000 units
- **Total compasses savings**: 531,421 kr
  - **12.03%**

<table>
<thead>
<tr>
<th>Year</th>
<th>Current stock</th>
<th>Future stock</th>
<th>Savings</th>
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<td>Savings</td>
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## Decision Matrix

<table>
<thead>
<tr>
<th>Decision Model</th>
<th>Weight</th>
<th>Current Situation</th>
<th>Central Warehouse</th>
<th>Cent. WH + Reg. WH</th>
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<td></td>
<td>Rating</td>
<td>Score</td>
<td>Rating</td>
<td>Score</td>
</tr>
<tr>
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<td>5</td>
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<td>15</td>
</tr>
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<td>24</td>
</tr>
<tr>
<td>Lead time to customer when in stock</td>
<td>9</td>
<td>36</td>
<td>2</td>
<td>18</td>
</tr>
<tr>
<td>Lead time to customer when not in local stock</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td>Handling of small customers/small orders</td>
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<td>3</td>
<td>30</td>
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<tr>
<td>Inventory rotation speed</td>
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<td>Subcontracting opportunities</td>
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</tr>
<tr>
<td>Premises costs</td>
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<td>1</td>
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<td>18</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>91</td>
<td>29</td>
<td>215</td>
<td>44</td>
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Score = Rating * Weight

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