An optimization of distribution network in polymers' industry

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Abstract

This Master thesis examines the current distribution network of a European Polymers trading company and provides different optimization possibilities. The thesis problem does not only focus on costs aspect but also on responsiveness to customers' orders, as according Chopra & Meindel (2013) the logistic fit is very important. In order to achieve the most accurate results of the optimization, some econometric models were conducted which reveals information about transport costs and their determinants. One still observes that the most important aspect in road transportation is the distance. Besides the spatial optimization of the distribution network, which according to the thesis should allow to save 6% of the total costs, some additional opportunities were proposed, such as leverage of usage of Light Weight Semi-Trailers.

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Introduction

The polymers trading company analyzed in this thesis reaches globally with its sales. As a consequence, it delivers products to various destinations across the entire World. It has subsidiaries on each continent and each subsidiary runs its business separately. This thesis focuses on challenges that its European subsidiary needs to face, and to which it must respond. Particularly, the European branch supplies customers in the entire Europe with products that it purchases from many refineries located in various countries. The profits are generated due to the achieved difference between the purchase price and the sales price. As a result, the company is involved in the price speculations and it incurs a risk. Besides administrative and labor costs (sales representatives and customer service) which are mostly fixed, the Entity incurs transportation and warehousing costs that might have a significant impact on the bottom line.

As noted during interviews with the Entity's insiders, the returns on deals relating to the same product and the same customer differs because of the transportation and warehousing costs. The reason for the differences comes from the lack of a distribution allocation policy. It means that there is no standard stating, where products should be stored if they come from a certain supplier. As a consequence, an allocation is performed randomly, causing the business less profitable. Usually, when an order from a customer is placed, the product is sent from a location where it is available, not meaning the most favorable from the costs perspective. Thus, in order to make the Entity more cost-effective, the allocation standard should be introduced. Knowing this business case and the necessity of allocation creation, the transportation network creation becomes a main objective of this Thesis.

The scope of the Thesis includes one product for one supplier. I consider the two supplier locations and seven currently used warehouse places. Additionally, two alterative warehouse locations, which have never been used before by the company, are incorporated in the analyses. The main research question is:

'Where should the company store its products in order to make transportation and warehousing the most cost efficient?'

It indicates that one needs to determine from which supplier location and how much of product should be transported to a certain warehouse and then to a customer in the most costs efficient way from a holistic perspective. So the total transportation and warehouse costs needs be as low as possible and not only for a single route, but in total. In order to provide a reliable solution one needs to take a few steps. First, the transport costs between locations needs to be determined. Because there are different aspects of transport costs, I decided to incorporate a transportation price determinants model which results will be used in the optimization process. Thus, the thesis also contributes to existing studies of transport price determinants. When one has the transportation costs for every route an interactive heuristic model is used in order to help to propose the most effective allocation. Moreover, short sea shipping is investigated if it can improve cost efficiency. At last, alternative opportunities for optimization are proposed.

The thesis is structured as follows: first a literature review is presented regarding transportation price determinants as well as warehouse optimization and Short Sea Shipping. Next, a framework and the results of transportation price determinants model are presented and discussed. Then, a similar analyses flow for transportation network optimization is applied. I conclude with the limitations and discussion of the results.

Chapter I Literature Review

Within the last century the transportation costs decreased by 95% (Glaeser & Kohlhase, 2004). There are two reasons for this incredible improvement. First, an enormous improvement in technology. Second, the change in both quality and weight of the goods transported. While the latter decreased, the former increased strongly. That indicates the value to tonnage ratio significantly rose. So one transports fewer tones but higher value of money. As it was revealed by Behrens & Picard (2011) most of the firms does not have in-house transportation and they are strongly dependent on different carriers. The road transportation, being in the scope of the analyses, is an unregulated industry, because usually there are no special protective regulations. Entrepreneurs need to balance their investments and costs and impose appropriate fares in order to make their business profitable. As a consequence, the transport market is highly competitive with large number of independent players and the demand for transport services increases when rates fall (Behrens & Picard, 2011). This section presents literature review of the different types of transport fares determinants. It also reveals how strongly each determinant imposes on the fares based on the historical studies. The considered elements are: distance, infrastructure, cargo weight, origin, destination characteristics and trade imbalances. Additionally, I have reviewed and summarized possible advantages and disadvantages regarding the usage of Short Sea Shipping in the Company's transportation network. Last, I revise Facility Location Problem literature from the perspective of the method chosen to determine the most optimal allocation and general impact of facility location on a company costs.

1.1 Distance as transport costs proxy

Following the study of Martínez-Zarzoso & Nowak-Lehmann (2007), I would like to investigate if the distance is a good proxy for transport costs. The authors admit that distance is better for road transportation than for maritime. There are some inconsistences in the results but it usually shows the positive relation between distance and transport costs. The influence of distance and transport costs on trade volumes between countries is also tested. It shows that the magnitude for transport costs is significantly higher than for the distance. It means that transport costs influence more the volume traded between countries than a real geographical distance between them. This reasoning supports the perspective that the distance is not a good estimator of transport costs in general, when there is a possibility to incorporate some other factors. There is a similar study that provides similar findings (Kleinert & Spies, 2011) but it points out some other aspects: such as technology investment decision and export between the countries. However, MaCann (2001) states that there is economics of distance and the distance has a significant impact on transport fares. The Hummels's (2001) study determines an elasticity of distance at the level of 0.28 for the road transportation. It mean that a 10% increment of distance indicates 2.8% increase of transport costs. However, it is worthwhile to admit that it has changed over time. Based on the aviation transportation the elasticity dropped from 0.43 to 0.16 (Hummels, 2009). Because of dynamic transportation development, it is very interesting to investigate the issue and the changes over time. As it was presented above, some papers doubt in the importance of the distance for transport fares. Overall, the consideration of this determinant seems inevitable in the transport fares model that helps to propose the most optimal transportation network.

1.2 Is time a good determinant of transport costs?

Martínez-Zarzoso & Nowak (2007) considered the travel time as a transport costs determinant. They assumed that time would have similar impact on transport costs as the distance and they partially proved it. As it is very straightforward, an infrastructure level induces the time needed for transport. A deterioration of infrastructure significantly increases the transport costs (Limão & Venables, 2001). The authors use a combination of different measures, such as density of road network paved road network, in order to provide a certain proxy for infrastructure level. According to the authors, the improvement of the quality of infrastructure from median to the top 25th percentiles results in the decrease of transport costs by 23%, while the change opposite results in 10% increment. However, the data consists of both land and sea transportation. This determinant seems to be important for the transportation fares, however because of technical difficulties to obtain proper values for the entire origin and destination matrix, it is omitted in the main research problem solution.

1.3 The cargo weight impact on transport costs

The weight is used in two ways in transport-related literature. The first is the weight to value ratio Clark, Dollar and Micco (2004), Martínez-Zarzoso and Suárez-Burguet (2005) as well as Abe and Wilson (2009). Note that, this measure represents the characteristics of transported good. Nevertheless, I am interested in the influence of weight itself on the transport costs and this is a second aspect of weight considered in the literature. The sign and the significance of this relation is very simple to anticipate - it increases logarithmically along with weight, because transport costs per unit weight is declining with the weight increase. The only issue is to find the magnitude of it or said in more economical terms, I am interested in what is the elasticity of transport costs with respect to the weight. Based on my review there is a little interest of this kind of elasticity for road transportation. Therefore, I would like to focus explicitly on weight coefficient. Only one paper examines the issue, but because of not taking the logarithms in the model, the elasticity varies with respect to the distance weight between 0.1 and 0.4 (Mun, Konishi, Nishiyama , & Sung, 2013). The paper justifies the consideration of Cargo weight as the transport costs determinant, because it presents significant results. However, I believe the usage of the elasticity of weight will be more appropriate in order to provide results that will be easier to apply in other studies. An another reason why the cargo weight should considered is very prosaic, the weight of goods has an impact on Logistics Service Providers costs, e.g. the heavier a good the larger fuel consumption. Based on this little literature support and business understanding it is inevitable to incorporate the weight as the transport costs determinant.

1.4 Domestic vs. International Transport Costs

For years, the General Agreement on Tariffs and Trade (GATT) and the World Trade Organization (WTO) have been working on decreasing the trade tariffs. Their work have strongly contributed to the large increase of global trade (Goldstein, Rivers, & Tomz, 2007). As a consequence of all these efforts, transport costs have become more important for the trade than tariffs. From the European perspective, the integration of Europe and Schengen Agreement helped to increase the speed of transportation, which is also followed by the transport costs decline. There is scarce literature on characteristics differences between domestic and international transportation. Therefore, I try to summarize, where the differences are possible:

- the utilization of resources – a possible utilization of backhaul transport,
- settlement of drivers – traveling allowances for differs that are required by law,
- fuel costs – different countries impose different excise on fuel,

As it seems to be a very important aspect of price determination I need to take it into account while creating the price determinant model and extrapolating it to transport fares between origin and destination cities while creating the distribution optimization model.

1.5 Transport to an neighboring country

The transport literature reveals the importance of the sharing border effect (adjacency) that decreases the transport costs. Particularly, the scientists focus on the reasons for the sharing border effect while the distance is controlled for. First, the trade volume between neighboring countries is higher, there might be a several explanation such as: similar language, culture and even history. All of commonalities raise the chance of sharing costs over two trips, because there is higher likelihood of backhauling. Therefore, using this kind of measure in transport costs models partially explains the trade balance influence on transport costs. Second, countries that share the border exhibit more integrated transport network that reduces the travel time because a number of transshipments is limited and probably border regions cooperates with each other during the infrastructure development. Moreover, the literature explains the phenomenon where such countries usually have customs agreements that decrease the transits time (Limão & Venables, 2001). This argument does not hold in the current European situation as most of the countries belongs to Schengen Agreement. However, the two former justifications are still in power in my opinion. The literature shows that having a common boarder decreases the transport costs from 10 to 30 percent (Limão & Venables, 2001), (Martinez-Zarzoso, Garcia-Menendez, & Suarez-Burguet, 2003). The papers plainly show the relations between transport prices and transportations to neighboring country. Although I admit the importance of this factor, it will not be considered in the transport costs model because its importance seems to be strongly limited is the area which is the scope of the study – Europe.

1.6 Inbound vs. Outbound Transportation

One usually expects that outbound transportation is more expensive than the inbound. The inbound is characterized by larger lots sizes, because of transport consolidation (Chopra & Meindl, 2013) what lowers a unit cost. Especially in the past decades, the inbound transportation was not carefully managed. Shipment details was not perceived as the top priority and therefore there was lower time pressure (Heaney, 2010). There is also a possibility that spatial concentration of industries plays a role. As the destination of inbound transportation are usually industrial areas, which exhibits higher demand for transportation services. For the outbound, this is more difficult because final customer for some enterprises are spread around. Because of characteristics of distribution network that will be proposed, and it will look like Hub-and-Spoke scheme, the difference between inbound and outbound transportation costs is very relevant.

1.7 Regional Characteristics as Transport Costs Determinants

Many studies focused on conditions of landlocked countries regards transport costs. Being landlocked indicates a geographical location where a country does not have any access to a sea, so direct sea shipping is not possible. In 1995, such countries had just a little more than one third of import to GDP ratio[1] in comparison to costal economies (Limão & Venables, 2001). If landlocked countries want to increase their competitiveness, they will need to invest in the transport infrastructure. However, the study shows that being landlocked increases the transport costs between 49% and 75% depending on the model configuration. There are two main reasons for this phenomenon, such as: extra transport charges, border delays (what makes the delivery time uncertain) and the higher insurance costs. The same authors proved that being an island has a negative effect on transport costs. That means that if the country is the island it incurs lower transport costs. As Europe is analyzed area and some special regional characteristics may play a crucial role in transport costs, the regional dummies will be provided in the econometric model of transport fare as the additional value of the thesis.

[1] Landlocked countries - 11% and costal economies – 28%

1.8 Trade imbalances from the logistics perspective

Besides more tangible and predictable determinants like distance and infrastructure, one distinguishes trade imbalances as the factor that has a significant impact on freight rates. One explains this relation as the backhaul problem that was not intensively investigated in the literature (Behrens & Picard, 2011). As Behrens & Picard remind Wickell's words from 1918 paper: imbalanced cargo loads for a route increases the charges for one way while offering more competitive pricing for the route back. Such phenomena makes trade costs essentially endogenous with respect to export and import difference for a certain region. The economic activity expansion leads to higher transport charges for exporting goods and the opposite for importing one. The size of a destination region has a positive effect on the rates, meaning that the higher the density of the region the larger the freight prices because there is a demand surge. One proves that the one standard deviation increment of trade imbalances raises the transport costs by 7% (Jonkeren, Demirel, van Ommeren, & Rietveld, 2011). The imbalances are easily noticeable in the container transportation example. In 2005, there were around 70% of empty slots that were leaving the U.S. (Theofanis & Boile, 2009). For instance, one needs nineteen vessels of 8,000 TEU capacity per week in order to move empty container form the U.S. to a demand region. The imbalances cause very serious issues for the transportation management, because *"excess capacity, an intrinsic characteristic of the liner shipping industry, has a destabilizing effect on rate stability"* (Haralambide, 2004). The back haul fare is likely to be 40-50% lower than the head one. In 2007, the average transportation cost of one TEU form Asia to the U.S. cost $1,707, while the back haul of the same route was only $794, what makes it less than half of the head haul. McKinnon (1999) states that regional imbalances force carriers to "triangulate" in order to improve vehicles utilization. It indicates that one needs to compose a route with more stops in order to minimize the "empty" kilometers driven. Therefore, not only the exchange between a pair of countries is important but also more general trading flows. The latest evidence that trade imbalances positively influence the head haul rates is provided by Márquez-Ramos et al. in their 2011 paper. They also showed the negative effect of export volume on the rates, as there is the economics of scale. The same as the previous determinant the trade imbalances will not be considered in the provision of the most optimal distribution network. However, this is a very important aspect of transport fares and its importance will be revealed in the econometric model in the further sections.

1.9 Short Sea Shipping

A definition of Short Sea Shipping (SSS) varies across studies. In general, this is "*a complex maritime transport service"* performed by different types of ships, carrying different types of goods within one unified region of the World (Paixão & Marlow, 2002). Around twenty percent of intra-European trade is performed in the form of SSS (Mulligan & Lombardo, 2006). The number is even more spectacular when one shows a data for bulk goods, because this is 42% and the authors presents Europe as a showcase for the U.S. how SSS should be introduced. Short Sea Shipping brings the welfare improvement due to two main aspects:

- The reduction of environmental pollution, if and only if ships keep moderate speed. The improvement is connected with the following pollutants: carbon dioxide (CO_2), carbon monoxide (CO) and hydrocarbon (HC). However there is still a room for further development that can reduce the nitrogen oxide (NOx) and sulphur dioxide (SO2) (Paixão & Marlow, 2002).
- The overland traffic congestion mitigation while there is constant increase of freight movement that highly exceeds a pace of a new infrastructure development. Besides the fact that SSS is a competitor of overland transportation it brings a positive value for it, because it can increase its profitability just thanks to alleviation of overland congestion – less delays, higher resources utilization.

Some strengths and weaknesses should be taken into account during the evaluation of Short Sea Shipping. Paixão & Marlow (2002) have conducted the comprehensive description of both. The first advantage of SSS is a low level of infrastructural investments that is necessary to start operations, especially in comparison with rail or road transportation. One only needs terminals where a throughput might be performed, and some additional layouts are required for optimization of process to release some bottlenecks and navigation infrastructure. Deriving from low investment is theoretically unlimited capacity of seas - no congestion in the open space. The only congestion that is possible may appear close to terminals. Finally, a ship can operate all the time, 365 days per year without night hours and weekends restrictions.

However, there is always a tradeoff in the economy and the same applies to the SSS. First, one points out that SSS cannot offer door-to-door service and it needs to be leveraged by the intermodal logistics, what requires some investments and cooperation between different parties in the supply chain. As the consequence of the necessary linkages, there is an increased possibility of delays of one supply chain node, demands having some warehouses what increases the total logistical costs. Additionally the intermodal transport raises handling costs due to more throughput points on the way. Moreover, one needs to reach a critical mass that will enable to run its business profitably. Reaching it is more difficult in SSS in comparison with rail or road transportation, because of intrinsic SSS characteristics such as vessel size.

The speed condition that was mentioned in the first bullet point holds also for competitive pricing of SSS, because speed is highly correlated with fuel consumption and this is perfectly related with pollution. Mulligan and Lombard (2006) provide many determinants that influence SSS, but I choose to distinguish a few of them, because of their usefulness to the thesis.

I start with the ones that positively influence the competitiveness. First, the prices of overland (truck/rail) transportation has significant impact of demand on SSS. Second, the SSS awareness, because one assumes that some entrepreneurs does not even know that they can use ships to deliver their product. This way of transportation might be very attractive for business that are not very time sensitive. Third, port and terminal infrastructure and intermodality of load unit (containerization for example) improve the transit time. Additionally, vessels require large volumes in order to benefit from the economics of scale, therefore I claim that the SSS sector needs a certain "critical mass". Last, the low traffic congestion, which significantly decreases the travel time in comparison to the overland transportation. The main negative factors, which can influence the SSS competitiveness, are all port and terminal fees and some additional taxes that might be imposed on undertakings connected with SSS.

As the result of many positive sides of SSS according to the provided literature, it is considered in the facility location solution.

1.10 Facility location problem

There are three types of supply chain decisions: strategic, tactical and operational one. Designing a facility network is a strategic undertaking that has a long-term effect on the business operations (Melo, Nickel, & Saldanha-da-Gama, 2009). One needs to determine the location, number and capacities of warehouses that can serve a certain service level for customers in order to meet the logistic fit (Chopra & Meindl, 2013). In order to make the optimize a distribution network, one needs to have a holistic view and consider all possible interactions between different costs layers and trade-offs among customer responsiveness, warehouse costs, transport costs, inventory and holding costs (Nozick & Turnquist, 2001). As soon as the Just-in-Time (JIT) scheme is introduced there is a significant decrease of inventory costs while the transportation costs stay the same in relation to GDP. When one wants to save costs, the minimization of the number of facility location is necessary. However, it negatively influences the customer responsiveness. Such trade-off impacts also the transportation costs, because the lower the number of facilities, the longer the distance traveled by goods and outbound transportation might be more fragmentized. Thanks to advanced computing skills one is able to compute the precise solution that solves the inventory costs and transportation costs trade-off in the most optimal way. However, the responsiveness is not measured in monetary values therefore incorporation of time into the optimization process is always a challenge. Nozick and Turnquist (2001) used optimization process - besides having inventory and transportation costs in the objective function, they also try to minimize the weighted uncovered demand within a time limit. The higher the weight of the demand, the higher the total costs because the number of facilities and responsiveness increase.

The facility location models have a lot of classifications that are based on different aspects of a problem. Relying on the literature (Klose & Drexl, 2005) one can distinguish the models depending on:

- The distribution of demand, which may be presented in three ways. First, one has planar location model, for which the demand exists in any place on the plane and one can create a facility anywhere. Second is network location model, where demand and facilities might be located on the links or nodes of the network. The final model is a discrete location model that uses a distance matrix between candidate facility and demand locations and it is regularly described by mix-integer programing problem (Daskin, 2011).
- The aim of the optimization. First is the minsum, where a focus is on the minimization of average, e.g. minimization of average distance because it indicates minimum total number of kilometer, thus the lowest costs. The second is minmax for which the objective is to minimize the maximum of a certain measure, for example distance. One points out that the former is used by the private sector and the latter by the public one.
- A capacity constrain. One can either have or not have the capacity constrain imposed on different facilities in the supply chain. Regardless, of the capacity constraints single-sourcing or multiple-sourcing might be in favor because of different business decisions. Single – sourcing indicates that a certain product is supplied just from one location.
- The numbers of layers involved in the optimization process. Either one looks at one stage of chain or it has a more holistic view and includes the possible trade-offs in the analyses.
- The number of products incorporated in the analyses. It might be either a single-product optimization or multi-product one, where inhomogeneity of products needs to be investigated carefully as it may cause serious operational issues.
- Elasticity of the demand in the respect to the distance. When the demand is inelastic the location and the distance between facility and demand region does not play a role. However, when it does the cost minimization should be rather replaced by the revenue maximization, for the latter one needs to know the relationship between demand and facility time sensitiveness of customers).
- A time horizon that is taken into account. One has either static models when only single period is analyzed or dynamic one when all the model inputs, such as costs, demand, vary over time.

- Uncertainty incorporation. When one assumes that its forecast is the only one scenario it is a deterministic model. In contrary to it we have probabilistic models when the inputs are uncertain.
- The type of route that is performed by a mode of transport. First is a replenishment when one just connects two nodes and the second is a tour type when serval demand location are supplied during one route (Ambrosino & Scutella, 2005).

The provided literature review enables to identify what kind of logistic problem I need to tackle and what types of methods are the most appropriate for main research question.

Depending on the approach chosen, one distinguishes two main solution methods: exact or heuristic (Nagy & Salhi, 2007). There are different problems that might be tackled by the exact methods that are listed by Nagy and Sahli (2007). The general conclusion is that these methods enable to have a deep insight into business issues and thanks to this solution, one is able to answer business questions in details. But they are rather limited to a small scope (40 candidate warehouse or 80 demand locations). The heuristic methods allow to solve more complex problems. There are three main types of heuristic methods: clustering, interactive and hierarchical. All of them were broadly used in the literature and have positive and negative attributes. I would like to focus on the second type, because this the one, which is used in the further analyses of the thesis. Perl and Daskin (1985) introduced the method, which deals with depos locations and route transportations simultaneously. It uses saving type procedure and when there is no gain (e.g. costs reduction) the procedure is stopped. According to Hansen el at. (1994) it enables to eliminate the risk of finding a local minimums and it is appropriate method for large data sets.

1.11 Literature Review Summary

Although, the main research problem is the product allocation, different aspects are studied in this section, such as: determinants of transport fares, usage of Short Sea Shipping and the ways, in which facility location problem should be tackled. I want to summarize the main points and determine the research problem from a literature perspective. All mentioned determinants of transport fares are important, however because of technical capabilities I am not able to insert all of them in the facility location solution and I need to divide them into two groups:

- Determinants considered in Facility Location Problem and in the econometric model of transport fares: distance, inbound or outbound transport, cargo weight and domestic or international transport.

- Determinants only applied in the econometric model of transport fares: level of infrastructure, regional characteristics, trade imbalances and traveling to neighboring country.

Deriving from the Owen & Daskin (1998) paper the facility location problem that the thesis needs to tackle should be described as a static uncapacitated variable charge facility location problem with different scenarios. The aim is to minimize the combination of:

- Transport costs, mostly described by the median problem, where the location is chosen by minimization of distanced travel to a large extent.
- Variable warehouse costs based on the number of pallets stored.

The "uncapacitated" term means that one assumes that each facility is able to store all possible goods. The scenario planning models was chosen because of advantages of its strategic nature. I used this paper as the overview one, because it summarizes different approaches of facility location problem based on large number of papers. Additionally, the number of citations is very large and Daskin is one of the most cited authors in this topic. The method chosen to solve the problem is based on Melkote and Daskin (2001), because according to the authors, who approached the most classical UFLNDP (Uncapacitated Facility Location/Network Design Problem), this is an effective way. They also have used a standard Mix Integer Programing solver that is easy to apply and very effective thanks to computational developments.

Chapter II Data, Methodology and Results

As it was said in the Literature Review section the inventory distribution is a strategic decision and it has a long term effect on business operations. For this reason, I want to provide a reliable standard for the company in question, which suffers from the lack of this. Definitely, creating such standard requires as accurate as possible estimation of transportation prices. The company which business case I try to solve has shared with me the data set consisting of three areas:

- Sales
- Transportation costs
- Warehouse pricing

First, the data provided is described. Later, the transport costs determinants, which have been investigated in the literature, are tested for their significance and magnitude. The results of these tests are incorporated in further analyses in order to answer for the main thesis problem. It will be followed by some sensitivity analyses and profitability of short sea shipping usage. Finally, I will conclude the research results and provide some limitations and directions for further analyses.

2.1 Sales

Among large amount of sales data, one have chosen one product for one supplier and all the costs calculations are based on this example. The company representatives think that this is a representative product therefore optimization can be extrapolated to the distribution for a certain supplier or even to entire European distribution network for all the goods. The product that was chosen is Low Density Polyethylene (LDPE).

In the Sales date, there were almost six hundred transactions since the beginning of 2010 until March 2014 for LDPE for the certain supplier. The spatial distribution of customers and some trends will be described in Seasonality of the Sales Data section. The LDPE has a solid state of matter in the form of granules. It is widely used in the packaging industry (wrapping materials) and many others, because there is very large number of products, which people use every day, consisting of LDPE (Arvanitoyannis, Biliaderis",, Ogawa, & Kawasaki, 1998). The company uses 25 kilograms bags as a minimal unit of transportation. Nevertheless, the company sells larger amounts and therefore usually pallets are used and one pallet consists of 55 bags. In the majority of cases, the Pallet Return System is utilized and sizing of one pallet is 1100mmx1300mmx136mm. However, 75% of all transports are Full Track Load, and the rest is Less than Track Load. The most popular truck type is van curtain side trailer, because many customers does not have special facilities for container unloading, what strongly limits the intermodal transportation.

2.2 Transport Costs

The company does not own any trucks and any other modes of transport. Therefore, it needs to outsource these services. Transportation orders history of the company starts in 2006 and ends in 2015. It is held by the company employees in an Excel file, therefore it was very easy accessible. Based on such long data set one can strongly rely on the data. It consists of truck transportation. Each observation provides information about:

- Transport Origin
- Transport Destination
- Final transport price for the company
- Year of Transportation
- The size of a load transported. It is specified in the number of pallets. The company leverages the FHG PRS Return System[2], which is characterized by different pallets' sizing than Euro-pallets, thus the company pallets' dimensions are 1300mmx1100mm. The database does not contain information if it was a Full Track Load (FTL) or Less than Track Load (LTL), however all transports with seventeen or eighteen pallets are assumed as FTL and every transport between one and fourteen pallets is taken as LTL – own assumption for the research purposes. Theoretically, a common truck used for long-haul transport, a curtain side trailer, can carry 22 this kind of pallets, but because of weight restriction the maximum payload is eighteen pallets – details presented in the next subsection.

Having final/pure transportation prices for many routes enables to avoid tolls searching and others fees that could apply to the transportation, therefore the costs function will consists of all costs that the company needs to incur. Moreover, carriers' profits are included in the pure fares. Deriving from these facts one might easily admit that the model should help companies, which outsource the transport services. On the other hand, companies that have the in-house transportation might compare their costs with outsourcing scenario.

2.3 Transport Costs Determinants

2.3.1 Variables

There are almost ten thousand observations for FTL. Based on these observations I would like to provide reliable information about transportation costs within Europe and its determinants.

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[2] http://www.palletreturnsystem.com/en/producers/pallettypes.html

Ordinary Least Squares method was used to investigate the sign, significance and magnitude of different variables that can have impact on the transportation rates.

The dependent variable is transportation price (in Euro). The entire set of data comes from the company's transportation history and all of the prices are in Euro. The first explanatory variable is:

- Distance in kilometers between origin and destination

The explanatory variable was obtained thanks to the usage of the Google spreadsheet provided by Winfred van Kuijk[3]. It relays its values either on Google maps or on Mapquest. Because of usage of this tool, that provides highly reliable values, one needs to introduce some assumptions that were hold during model creation. A trip distance between origin and destination assumes car usage. Moreover, there are only names of the cities available, therefore the obtained values assume that transportation is between two city centers.

The average trip distance in the data set equals to 895 kilometers and the standard deviation is 680. Transport price per kilometer against distance is plotted in Figure II.2 and total transport fare and distance is shown by Figure II.1. As explicitly presented, there is an inverse relation between these two variables (Figure II.2). Figure II.1 releases fixed transport costs, which are visible in the transport pricing. According to the estimation, the transport costs starts from 888 Euro and each additional kilometer increases the fare by 0.28 cents. This is very logical because there are some pseudo fix costs that a carrier needs to incur in order to provide the service. One is a time that a driver cannot utilize because (s)he waits for a (un)loading. The shorter the distance the more time these processes stands for, proportionally. Also, I assume that in majority of cases, a truck needs to travel empty in order to pick up goods. Theoretically, I would prefer to leverage the price per kilometer estimation, because there is a very small number of trips below one hundred kilometers and coefficient of determination (R^2) is much larger for this scenario (0.47 vs. 0.056). However, this estimation is rather useful for distances below 1700 kilometer. When a trip is longer, it definitely underestimates the costs – reaching even below zero results for two thousands kilometers trips and longer ones. As both linear models fail for provided data I would recommend to leverage a polynomial estimation presented in Figure II.3:

$$\text{Price per Kilometer} = 0.0000015 * \text{Distance}^2 - 0.0046 * \text{Distance} + 4.3$$

[3] http://winfred.vankuijk.net/

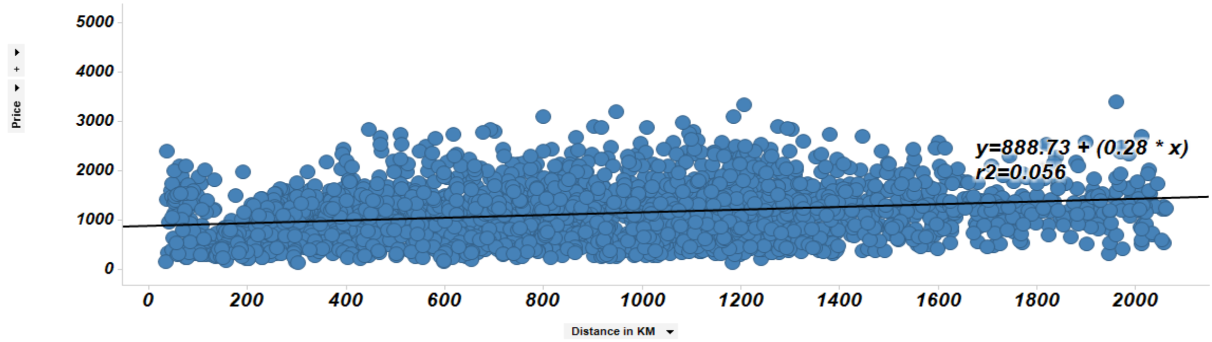


Figure II.1 Price in Euro and Distance Relation

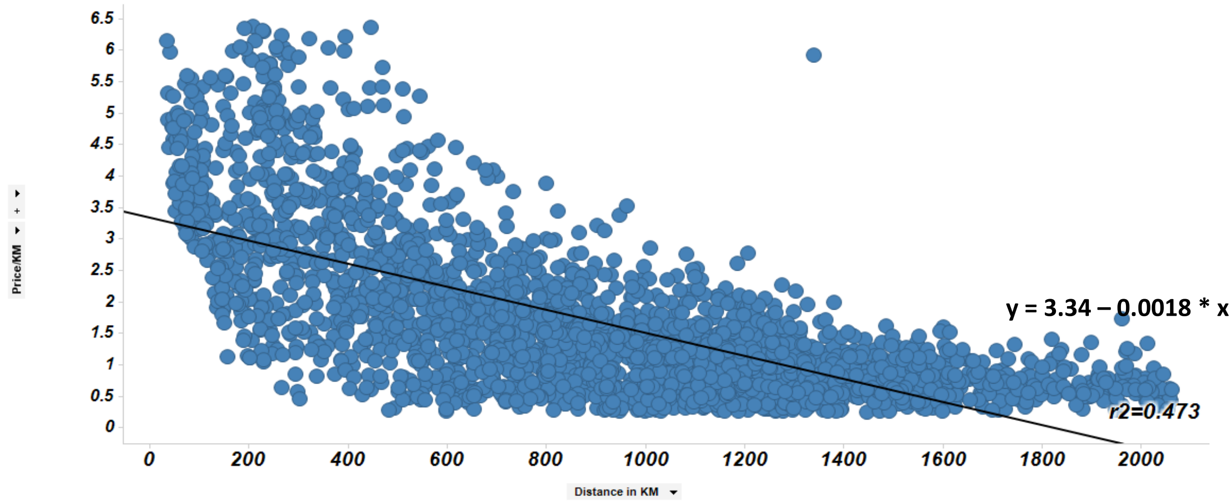


Figure II.2 Price per Kilometer in Euro and Distance Relation

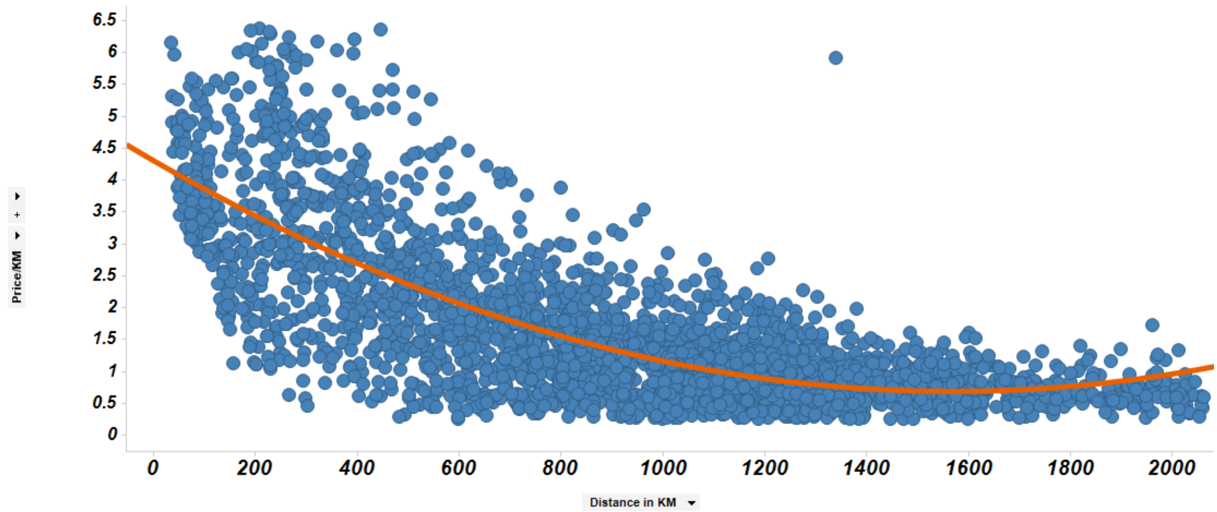


Figure II.3 Price per Kilometer in Euro and Distance Relation - Polynomial Estimation

The next continues variable used in the different model configuration (Table II.1) is weight capacity ratio and it is calculated as follows:

$$\frac{Number\ of\ Pallets * 1375\ kilograms}{24750\ kilograms}$$

The 1375 kilos is the weight of one pallet and round 247500 kilos is the maximum weight capacity of the truck with regular semi-trailer.

One expects that this variable has diminishing returns to scale and has significant impact on Less than Truck Loads transportation rates. The same kind of variable should be used for dimensions limitations. However, there is no chance to use it since the parcels are homogeneous (each pallet has exactly the same measurements) and the weight ratio and dimensions ratio would bring the same results, because they are perfectly correlated. Based on the calculation below, weight capacity ratio is a stronger determinant:

$$Number\ of\ Pallets = 18$$

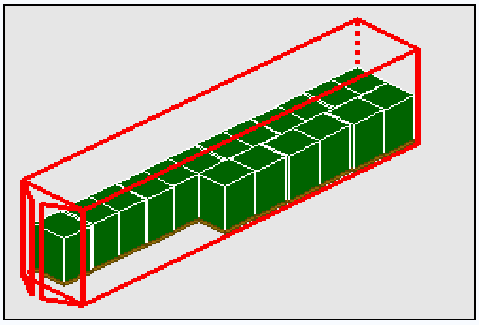
Transports	Cargo packing
All transports: Truck 1: 1 units	Total: 30 packages. Packed: 18 packages. (60%)
	**Truck №1** (Truck 1 1 units) Packed: 18 packages: (60%). Including: **Cargo1** - 18packages(60%) **Cargo volume:** 47.62 m³ (35% of volume) **Cargo weight:** 24750 kg. (99% of max payload) Cargo quantity is limited by max payload.

Figure II.4 Semi-Trailer Space Optimization by Dimensions

Source: searates.com

Dimensions of one pallet are 1850mmx1300mmx1100mm and the dimension of a loading truck area are 2500mmx2815mmx13600[4]. Thanks to the usage of searates.com one maximizes the number of pallets. The result for this optimization is 22 pallets. This results in choosing the weight capacity as a stronger determinant of capacity usage.

[4] http://ec.europa.eu/transport/modes/road/events/doc/2009_06_24/2009_gigaliners_workshop_acea.pdf

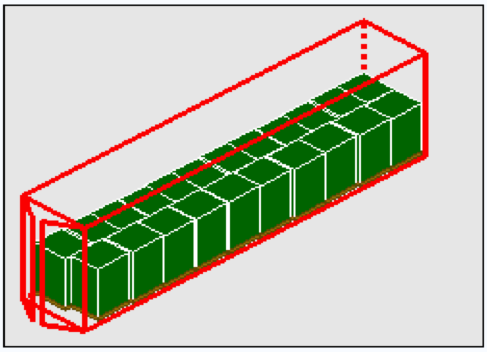
Transports	Cargo packing
All transports: Truck 1: 1 units	Total: 30 packages. Packed: 22 packages. (73%)
	**Truck №1** (Truck 1 1 units) Packed: 22 packages: (73%). Including: **Cargo1** - 22packages(73%) **Cargo volume:** 58.2 m^3 (43% of volume) **Cargo weight:** 22 kg. (0% of max payload) Cargo quantity is limited by volume

Figure II.5 Semi-Trailer Space Optimization by Dimensions and Weight

Source: searates.com

The following aspect of transport rates are trade imbalances. It is represented by three measures:

- Export Value of origin country to destination country – millions of Euro (A).
- Import Value of origin country from destination country – millions of Euro (B).
- Export Value of destination country to entire Europe – millions of Euro (C).

From one hand side, (A) represents the economics of scale for transportation from a country of origin to the destination one. Knowing the Law of Demand one would expect the larger the export the lower the rates (Márquez-Ramos, Martínez-Zarzoso, Pérez-García, & Wilmsmeier, 2011). On the other side if export is an exogenous for the demand function, the increase of export increases the rates. The changes for (B) represents the simple case for backhaul problem, where the larger the import the higher the utilization of resources. The same explanation would hold for (C), because while there is a broad economic integration within Europe an entrepreneur can easily "triangulate". The trade balance data comes from Eurostat database.

The last continues variable included in the model is Logistics Performance Index (Quality of trade and transportation) proposed by World Bank. It ranges from 1 (the worst quality) to 5 (highest quality) continuously. The evaluations come from a survey's answers of nearly one thousand international freight forwarders. Unfortunately, the data is available for four years (2007, 2010, 2012, 2014) and I have made an linear extrapolation for the rest of the years. The index represents the level of infrastructure of origin and destination country as I have taken an average of indexes for the two.

Additionally, I test if there is any difference between domestic and international rates and if there is any difference between prices for transportation to neighboring countries and the ones that are farther. Moreover, I want to test if there is a difference for inbound and outbound transportation rates. All the following variables were obtained automatically in different ways:

- Domestic transportation – origin and destination are located in the same country.
- Neighboring countries - origin and destination regions shares a border
- Outbound transportation – if the origin city was the city of warehouse (Table II.2)
- Inbound transportation – if the destination city was the city of warehouse (Table II.2)

As the result of large differentiation of infrastructure, economic situation geographical conditions, country dummy variables is introduced. I assume that most of drivers that connects a pair of countries come from one of them so the salaries differentiation allows carriers for having different operational costs and fares consequently. Moreover, tolls and taxes differ across countries that directly influence the costs. I decided to include dummy variables for the following regions: Western Europe, Eastern Europe, Balkans, Southern Europe, British Isles and Scandinavia – for the precise split see Destination Countries. There are different combinations of variables presented as separate models in the Table II.1.

2.3.2 Transport Costs Determinants- Model

As it was mentioned before, the transport costs model would be obtained. The reason for that is the provision of the most reliable transport costs estimation to the distribution network design. As one knows more exact transport pricing between locations, it can assume that model designed is more adequate. Therefore, this is unavoidable to create such model. Additionally, it provides new evidences to the existing literature on transport prices determinants.

Let Y be the dependent variable and X_1 and X_2 the explanatory variables. The model is presented as follows:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \epsilon \qquad (1)$$

where, ϵ is an error term and β, β_1, β_2, β_3, β_4 , β_5 are coefficients of constant, distance, (A), (B), (C) and a proxy for infrastructure level (Infra), respectively. One wants to get a prediction based on the equation (1) estimates the following formula:

$$(\widehat{Transport\ Price}) = \widehat{\beta_0} + \widehat{\beta_1} * (Distance) + \widehat{\beta_2} * (A) + \widehat{\beta_3} * (B) + \widehat{\beta_4} * (C) + \widehat{\beta_5} * (Infra) \qquad (2)$$

However, the formula in equation (2) is a linear and one does not expect it to be so, because of diminishing returns to scale, a natural logarithm of both sides will be taken.

$$\log(\widehat{Transport\ Price}) = \widehat{\beta_0} + \widehat{\beta_1} * \log(Distance) + \widehat{\beta_2} * \log(A) + \widehat{\beta_3} * \log(B) + \widehat{\beta_4} * \log(C) + \widehat{\beta_5} * \log(Infra) \quad (3)$$

The logarithm transformation will apply to all continues variables. Some model combinations are also using categorical variables, as domestic transportation (*Dom*), transporting to neighboring country (*Neigh*) and the outbound transportation (*Out*).

$$\log(\widehat{Transport\ Price}) = \widehat{\beta_0} + \widehat{\beta_1} * \log(Distance) + \widehat{\beta_2} * \log(A) + \widehat{\beta_3} * \log(B) + \widehat{\beta_4} * \log(C) + \widehat{\beta_5} * \log(Infra) + \widehat{\beta_6} * \log(DOM) + \widehat{\beta_7} * \log(Neigh) + \widehat{\beta_8} * \log(C) + \widehat{\beta_9} * \log(Out) \quad (4)$$

These categorical variables were introduced in the Transport Costs Determinants subsection. Moreover, the dummy variables for the regions (See the Destination Countries split) will be included in the model. Let X_{10} to X_{14} to be dummy variables:

$$\log(\widehat{Transport\ Price}) = \widehat{\beta_0} + \widehat{\beta_1} * \log(Distance) + \widehat{\beta_2} * \log(A) + \widehat{\beta_3} * \log(B) + \widehat{\beta_4} * \log(C) + \widehat{\beta_5} * \log(Infra) + \widehat{\beta_6} * \log(DOM) + \widehat{\beta_7} * \log(Neigh) + \widehat{\beta_8} * \log(C) + \widehat{\beta_9} * \log(Out) + \widehat{\beta_{10}} * (X_4) \ldots + \widehat{\beta_{14}} * (X_7) \quad (5)$$

As the reference for the dummy variables is the Balkan region, as this is not important from the study insight perspective, because one still can interpret the results for each of the regions and comparisons by different regions are possible.

2.3.3 Transport Costs Determinants- Results

A couple of regressions were carried out in order to determine what the most important factors of transport costs are. The results are presented in Table II.1.

Table II.1 Determinants of Transport Costs

Variable Type	Variable	Model 1	Model 2	Model 3	Model 4	Model 5 (LTL)	Model 6	Model 7	Model 8
	Constant	2.83*** (0.02)	3.05*** (0.05)	2.98*** (0.06)	2.67*** (0.06)	3.66*** (0.08)	3.43*** (0.11)	3.10*** (0.11)	3.63*** (0.15)
Continuous	Distance	0.61*** (0.003)	0.58*** (0.007)	0.57*** (0.008)	0.61*** (0.008)	0.49*** (0.013)	0.56*** (0.008)	0.64*** (0.008)	0.64*** (0.01)
	Weight Capacity Usage					0.48*** (0.011)			
	Infrastructure						-0.29*** (0.056)		-0.51*** (0.12)
	Export Value							0.14*** (0.008)	0.18*** (0.01
	Import Value							-0.13*** (0.009)	-0.19*** (0.012)
	Export Value from Destination to Entire EU							-0.034*** (0.005)	-0.02*** (0.007)
Categorical	Domestic Transport		-0.12*** (0.015)				-0.13*** (0.016)		
	Transport to Neighboring Country			-0.10*** (0.01)	-0.05*** (0.013)				
	Outbound Transportation			0.24*** (0.012)	0.22*** (0.013)		0.25*** (0.015)		0.11*** (0.013)
Dummy Variables	British Isles				0.29*** (0.02)				0.48*** (0.032)
	Eastern Europe				-0.16*** (0.017)				-0.03 (0.023)
	Scandinavia				0.06** (0.025)				0.27*** (0.029)
	Southern Europe				-0.07*** (0.016)				0.11*** (0.023)
	Western Europe				-0.05** (0.019)				0.17*** (0.023)
	Number of Observations	10650	10650	8544	8544	790	10298	7899	7722
	R^2	0.73	0.73	0.66	0.70	0.82	0.74	0.71	0.73

NOTE: ***, **, * REPRESENTS SIGNIFICANCE AT 1%, 5% AND 10% LEVEL. THE VALUES FOR T-STATISTIC ARE INCORPORATED IN PARENTHESIS. THE DEPENDENT VARIABLES IS NATURAL LOGARITHM OF PURE TRANSPORT PRICES. FOR ALL CONTINUOUS VARIABLES THE NATURAL LOGARITHM WAS USED THEREFORE ONE CAN EASILY DETERMINE THE ELASTICITIES. THE COEFFICIENTS FOR THE DUMMY VARIABLES ARE IN COMPARISON TO BALKANS REGION.

2.3.4 Distance and Duration of the Route

One can plainly see that the most important variable for the overland transportation costs is the distance. However, its significance has diminishing returns to scale therefore the natural logarithm was used. According to all of the models, an increase of the distance by 10% results in the increment of the transportation costs by 5 to 6 percent. The results are aligned with different papers that state that distance is still an important factor of transportation costs. However, my analyses indicate that the economics of distance is not that strong as according to the existing literature.

2.3.5 The Impact of Infrastructure on Transport Fares

In Model 6 and Model 8 the coefficient for Infrastructure proxy differs moderately (-0.29 and -0.51 respectively), but as you see the sign is consistent in both models. The improvement of transport infrastructure quality in origin and destination countries by 10% results in 3% to 5% reduction of transport fares. These elasticities are very realistic taking into account Limão & Venables (2001) paper. The higher the quality the faster the trips, therefore some fixed costs is spread over a larger number of trips. Additionally, some track maintenance costs might be limited.

2.3.6 Weight Capacity Restriction

Based on the Model 5, the weight of the parcel has a significant impact on the transport price. A 10% increment of weight results in a 4.8% increase of the transport price. The trucks loads are restricted by the law to a certain amount of kilos that a lorry can transport depending on its type. As it was mentioned before, during the price estimation a carrier uses also dimensional restriction. However, having data just for one product does not allow testing for both variables because weight capacity ratio and dimension usage ration would be perfectly correlated. Therefore, a stronger determinant in this case was chosen – weight capacity ratio, as proved in Variables section.

2.3.7 Trade Balance Differences

As it was broadly explained in the Literature Review section, the trade imbalances cause significant differences in transportations fares. According to Márquez-Ramos et al. (2011) the increment of goods transported from origin to destination decreases the transportation costs, because of economics of scale. My results are opposite to the authors findings. I show that 10% rise of export value results in 1.4% to 1.8% fares' increment. I believe that besides the economics of scale the Low of Demand plays a crucial role. The export works exogenously, it increases the competitiveness of carriers, thus they can charge higher fares. Other trade balance indicators perform in line with the literature. The 10% increment in the import value from the destination country to the origin one depreciate the fares by 1.3% to 1.9%. Assuming that export stays constant, the import addition makes the track utilization more possible during the backhaul. Deriving from this explanation, the export of a destination country negatively affects the fares, however its magnitude is much lower (0.2%-0.3%). When the destination country export rises, carriers are more likely to find another order to a third destination what is called in the literature as "triangulation" (McCann, 2001). Its magnitude needs to be lower, because such undertaking usually requires higher costs – new customers' penetration.

2.3.8 Destination and Type of the Transport

The domestic transportation seems to be 13% cheaper than the international one. The elimination to large extent of empty back-hauling is a very likely reason of this phenomena. There is a larger likelihood for a carrier to find another order from the point B to point A or even to point C which is not far away and is placed within the same country. The root cause of it is mainly the larger scale of trading within the country than internationally. A similar explanation applies to the transportation between neighboring countries (Martinez-Zarzoso, Garcia-Menendez, & Suarez-Burguet, 2003). According to the Model 3 such transportation decreases the prices by 10% in comparison to international transportation between countries that are not neighbors, the sign of the relation is also confirmed by Model 4, however the magnitude is twice lower.

For producers and trading companies, a very important issue is the difference between inbound and outbound transportation costs. My study presents robust evidence that the outbound transportation is 10% to 25% more expensive than the inbound one. The transport consolidation (Chopra & Meindl, 2013) for inbound transportation makes larger lot sizes. However, this do not apply to analyzed data set, because it has homogenous transportation unit, which is the whole truck. I would rather understand these results as the demand characteristics of each of the transport types. As the demand side of the inbound transportation is the analyzed Entity that is not very time sensitive to a lead time. However, the outbound transportation is more under time pressure from the side-customer. Therefore, the transports are less time sensitive and it probably requires higher price. Such explanation is aligned with the study conducted in UK where one of demand characteristics that is important for trailer operators is a "*Quick Response*" (Fowkes, Firmin, Tweddle, & Whiteing, 2004). Such conditions are connected to short time windows that means that the trucks needs to be on time, because otherwise it needs to wait for the free slot. Moreover, in such scenario the operator is endangered by some money penalties. Therefore, the outbound transportation is a higher risk for the carrier and it needs to cost more.

As the Table II.1 shows depending on the destination of the route different prices applies. The most expensive is transportation to British Isles and Scandinavian countries, the increment amounts 29%-48% and 7%-27% respectively in comparison to Balkans. The geographical location of the regions is the main root cause of these differences. The water separates these two parts of Europe with the rest. There are some additional fees such as ferry costs and channel tunnel. Additionally in Scandinavia case, there are big distance differences between main production regions what makes searching customers for back-hauling more challenging. The cheapest transportation is to the Eastern European countries, probably because of low transport fees and much lower drivers' salaries – 2% to 16% reduction in comparison to Balkans. For the two other regions, Western and Sothern Europe, the results are not robust. My way of thinking would believe more in the Model 8, because the salaries in Western Europe are higher than in the Balkan countries, what raise the costs. The same explanation would apply to the Southern European countries but the magnitude would be lower because of smaller difference. If one controls for the infrastructure level and trade balance the economic situation and burdens imposed on transportation are the main two reasons for regional differences.

2.4 Distribution Network Optimization

Retrieving the information from Literature Review section the shape of distribution network is a strategic decision, especially when large sunk costs are required, such as building a new warehouse. While one just rents out the storing place in the warehouse its flexibility significantly raises. Companies always look for savings in the supply chain in order to become more competitive, i.e. lower costs, higher customer service level. One points out that both vertical and horizontal integrations are necessary in order to improve efficiency of supply chain (Ambrosino & Scutella, 2005). I consider distribution network that consists of three layer (supplier plants, warehouses and customer – demand locations) and the aim is to minimize the total logistics costs by improvement of current network by better allocation and incorporation of some new warehouse candidate locations. This is a discrete location model because the distance matrixes are used. The warehouses are not limited by capacity constraints, multi-sourcing is possible (there are two plants) and the analyses are performed for a given data set that is equivalent to historical data so this is a deterministic model. The uncertainty of inputs will be tested in Sensitivity Analyses section, where included costs vary. The distribution network is characterized by:

- Forecasted Demand
- Transportation Costs
    - Inbound transportation-from supplier to distribution center
    - Outbound transportation- from distribution center to customers

- Inventory Costs
    - Storing Costs
    - Handling costs -(Un)loading costs

There is usually a tradeoff between transportation and inventory costs depending on spatial distribution of warehousing prices, therefore one sets up an appropriate model that allows to reach the most cost effective network. A schematic map of the network looks as follows:

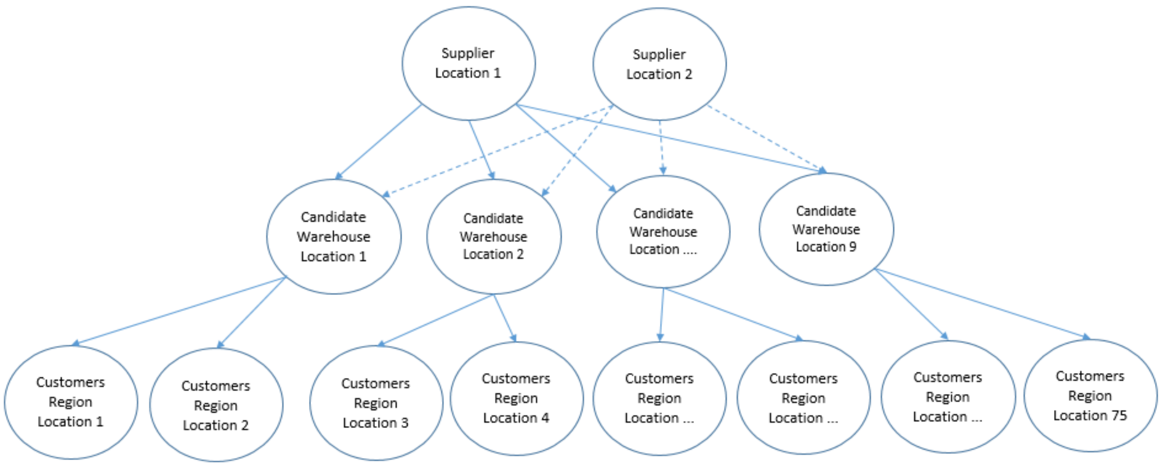


Figure II.6 Schematic Network Map

n = number of potential suppliers

p = number of potential warehouses

m = number of demand regions

D_j = annual demand from market j

t_{zi} = transportation costs from supplier z to warehouse i

c_{ij} = transportation costs from warehouse i to demand region j

x_{zi} = quantity transported from supplier z to warehouse i (pallets)

y_{ij} = quantity transported from warehouse i to demand region j (pallets)

l_i = loading and unloading costs per pallet for warehouse i

g_i = storing costs per month per pallet for warehouse i

u = average time of goods in inventory (months)

The problem is formulated as follows

$$\text{Min} \sum_{z=1}^{n} \sum_{i=1}^{p} x_{zi} t_{zi} + \sum_{j=1}^{m} \sum_{i=1}^{p} y_{ij} c_{ij} + \sum_{j=1}^{m} \sum_{i=1}^{p} y_{ij} l_j + u * \sum_{j=1}^{m} \sum_{i=1}^{p} y_{ij} g_j$$

This objective function represents the total transportation costs from suppliers to the warehouses, the transportation costs from the warehouses to the markets and the unloading and loading costs at the warehouses as well as the warehouse storage costs.

The model is subjected to the following constraints:

- $\sum_{i=1}^{p} y_{ij} = D_{j,}$ for all j=1,…,m: all demand in market j is satisfied from warehouses
- $\sum_{z=1}^{n} \sum_{i=1}^{p} x_{zi} = \sum_{j=1}^{m} \sum_{i=1}^{p} y_{ij},$ the inbound flow to warehouses in pallets equals the outbound flow.
- In the first scenario the average time in inventory is assumed as one month, but different scenarios will be tested in the Sensitivity Analyses section.

One thing that is explicitly different from most of the studies is that there are no fixed costs involved with the usage of a warehouse. This is according to the company executives, who state that the Entity incurs only the variable costs that are dependent on the number of pallets and no minimum throughput is required. Deriving from settlement the analyzed company strategy is based on large flexibility. Theoretically, the likelihood of using all possible sides is higher and it will imply on the results, especially on minor usage of some facilities.

Because of extremely large capacity of warehouses there is no capacity constraint. One assumes that every amount of goods can be stored and the costs are covers both handling and storing.

Nine warehouse cities were included in optimization process:

- Hoogstraten, The Netherlands
- Cremona, Italy
- Sezana, Slovenia
- Helsinki, Finland
- Bucharest, Romania
- Poznan, Poland
- Budapest, Hungary
- Vilnius, Lithuania
- Stenungsund, Sweden

Besides Poznan and Budapest, other warehouse cities were already involved in the company's supply chain. These two were added, because of willingness of optimization of the network based on analysis of spatial customers' distribution.

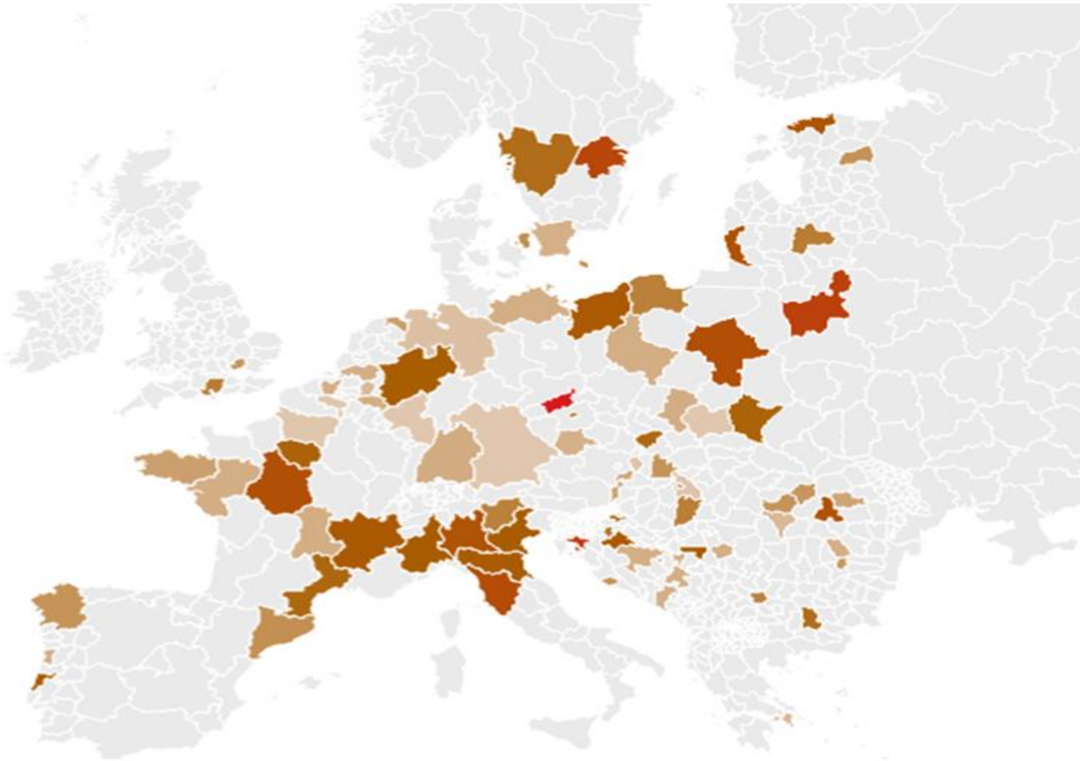
The detailed pricing list (per pallet) of the warehouses is shown in the Table II.2. For the used warehouses the data comes from the company history. For the two additional locations, it is based on personal research.

Table II.2 Warehousing Costs

Warehouse	(Un)Loading Costs	One month storing
Hoogstraten	€ 2.34	€ 3.08
Cremona	€ 2.41	€ 3.92
Sezana	€ 5.00	€ 7.43
Helsinki	€ 5.25	€ 9.49
Bucharest	€ 1.52	€ 4.00
Poznan	€ 1.50	€ 3.96
Budapeszt	€ 2.30	€ 4.00
VILNIUS	€ 1.50	€ 5.00
Stenungsund	€ 3.00	€ -

2.5 Empirical Case Study-Polymers Trading in Europe

The theoretical analyses of transport price determinants are used as inputs in the transportation costs establishment when is necessary to hold a warehouse location optimization. More than hundred customers are distributed all around the Europe. The Figure II.7 presents spatial distribution of the customers in the continent.



The larger the regional demand the stronger the red color is.

Figure II.7 Spatial Distribution of Customers

The demand is concentrated in the entire Europe. However, there is regional concentration that may indicate that there are some industrial clusters, where polymers are necessary as raw materials. The shapes of the provinces represents either NUTS 1 or NUTS 2 or NUTS 3 regions depending on a country. The stronger the red color the higher sales was in the region. Based on the Figure II.7 one plainly observes that this is difficult to state which country is a leader of the demand. However, the highest purchases are exhibited by Czech Republic and Croatia, which are relatively small countries. This confirms the hypothesis regards regional concentration that a couple of customers or even one may determine a large part of the total demand of it. Moreover, two main demand countries in Western Europe were becoming less important since 2013. It indicates that the demand shifted to Eastern part of Europe (See the Figure II.8). The same applies to the group of “Other Countries” what might be a sign for the Entity to focus on countries like Czech Republic, Croatia, Poland and Romania.

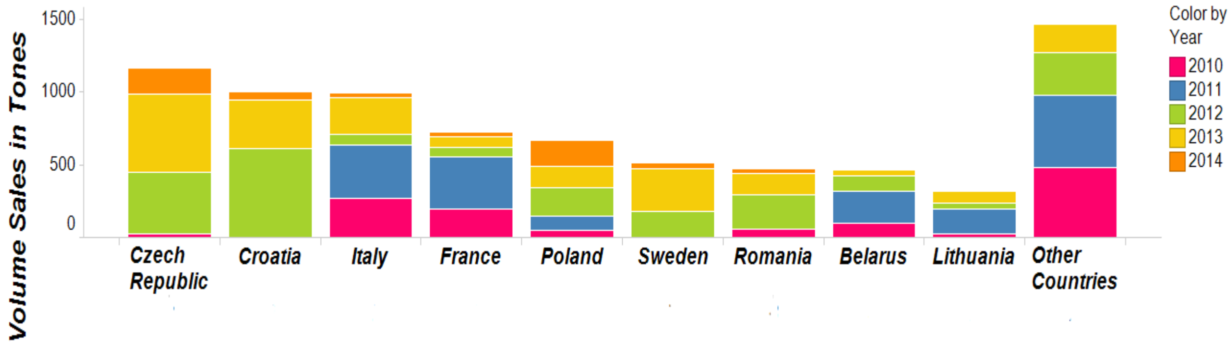


Figure II.8 Volume Sales by Regions

The data for 2014 consists of first three months of sales history.

2.5.1 Suppliers and Warehouses

The supplier has two locations where the goods are produced. These are Porvoo, Finland and Stenungsund, Sweden. The former one has only been supplying the warehouse in Helsinki and the rest of Europe was supplied by Stenungsund. Figure II.9 presents the warehouse allocation that covers entire data set time range. However, one observes that during the last two years the allocation was more concentrated next to supplier location, this is Stenungsund itself and Helsinki for Porvoo.

Figure II.9 Warehouse Distribution and Usage

2.5.2 Seasonality of the Sales Data

Figure II.10 presents the Volume Sales of the product. The time-series of sales volume appears to be stationary. The MacKinnon approximate p-value for the Dickey-Fuller test is 0.009. It means that there is no unit root at 95% significance level. The modified and more robust test (Baum, 2011) DF-GLS, which is the same as Dickey-Fuller but the series is transformed by a generalized least-squares regression, provides the same results. This indicates that data does not follow any trend. Additionally based on the Portmanteau Q-test one states that there is no seasonality because the p-value for it is 0.09 so one cannot reject null hypothesis at 95% significance level that there are no serial correlation. Figure II.10 presents the Volume Sales of the product:

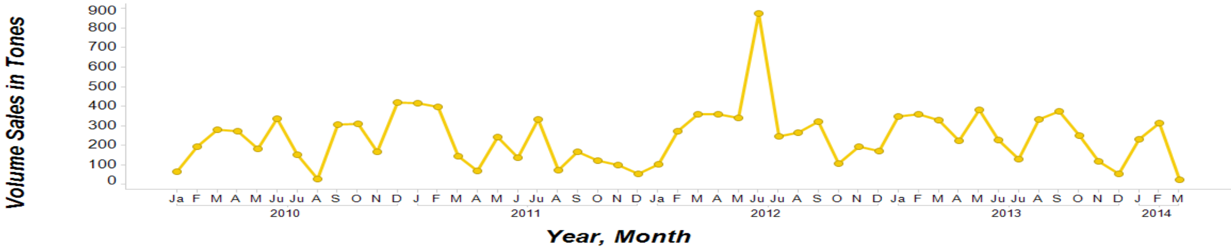


Figure II.10 Monthly Volume Sales

The average monthly demand equals to 249 tones. The Sales coefficient of variance is 0.57 meaning that the demand is highly volatile as is shown in Figure II.10.

2.5.3 Oil Prices and Volume Sold

A correlation between volume sold and oil prices is investigated. The oil price is an average of prices for the following crude types Dated Brent, West Texas Intermediate and the Dubai Fateh. The Index Mundi Portal[5] is the source of the data. Thanks to the Stata usage, I was able to reach the correlations quickly by using one of the basic commands. The lagged values were also obtained thanks to the software capabilities. The volume appears to be most correlated with the oil price that was listed three months before. But still the relation is not strong enough to state that oil price determines the polymers' sales.

Table II.3 Correlation matrix of Oil Prices and Volume Sold

	Pricei~D	Lag1	Lag2	Lag3	SalesV~e
PriceinUSD	1.0000				
Lag1	0.9223	1.0000			
Lag2	0.8146	0.9256	1.0000		
Lag3	0.7438	0.8258	0.9293	1.0000	
SalesVolume	0.1920	0.2418	0.3375	0.3692	1.0000

[5] (2015, June 1). Retrieved from Index Mundi: http://www.indexmundi.com/commodities/?commodity=crude-oil&months=360

2.5.4 Distribution Costs

Based on the Sales data transportation price model and warehouse prices data, I was able to estimate the costs that the company incurred. Moreover, the optimization model is applied in order to reach the optimal distribution network. All the optimization procedures were taken in Microsoft Excel 2013 and Open Solver Add-In. The entire procedure lasts for only a few seconds.

As long as the available data set was limited, I have assumed one month as the average time in inventory at the company side. It means that the product stays one month in one of the nine warehouses, mentioned in Distribution Network Optimization section, on average. The company does not own any report that tracks the average time in the inventory. In the Sensitivity Analyses section, I will deviate from this and I will test the effects on the network allocation. The demand values come from the entire Sales data set, because I base the analyses only on one product and if one takes values just for one year it will be spatially limited. Therefore, all costs calculations refers to entire demand data set (three and half year). The sourcing of a product is indifferent, therefore the company decides from which supplier location it wants to purchase the goods. The warehouse costs consists of handling costs: loading and unloading goods and storing costs.

Table II.4 Distribution Network Costs Structure

	Current Situation		**Optimized Option**		**Difference**
	Absolute Values	Costs Share	Absolute Values	Costs Share	
Transport Costs Inbound	€ 110,631	16.0%	€ 175,731	27.0%	+59%
Transport Costs Outbound	€ 530,590	76.8%	€ 431,032	66.2%	-19%
Warehouse Costs	€ 49,945	7.2%	€ 44,245	6.8%	-11%
Total Costs	€ 691,166		€ 651,008		-6%

Thanks to the network optimization, when both currently used warehouses and some potentially attractive locations were considered, the company will be able to save 6% of its total distribution costs. It will spend 11% less on the warehouses, when the same volume is purchased-mainly because of usage of free supplier warehouse in Stenungsund. This is very unique scenario but it already happens in reality. The company is only charged for loading and unloading. In Delivery Time Restriction section, I will incorporate assumptions that will force the company to use more intensively other warehouse. I will also investigate an effect of introduction some charges for storing in Stenungsund. The leverage of Stenungsund usage also applies to the decrease of outbound and inbound transportation, because one avoids double-traveling to a warehouse as inbound transportation and then going back partially on the same route when delivering to a customer. It also causes the large difference between inbound and outbound transportation. There is an assumption that 25 kilometers is between the supplier production plant and warehouse, but still these costs are very little in comparison to outbound transportation costs. They usually cover hundreds of kilometers. Only 22% of products should be purchased in Porvoo, because the majority of the goods should be supplied from Stenungsund, Sweden. Figure II.11 shows that 60% of good should be distributed from Stenungsund, Sweden. However, the regional warehouse are still important, especially for customers that operate nearby. Since, the transportation model revealed that distance elasticity is significantly below one, one expects very little usage of regional warehouses. However, there is a price differentiation of (according to Models presented in Transport Costs Determinants- Results):

- inbound and outbound transportation
- international and domestic transportation

Because of these two reasons, the regional warehouses supply the surrounding areas. Their competitive advantage decrease while the distance increases. Moreover, such allocation improves the responsiveness to the customers' orders.

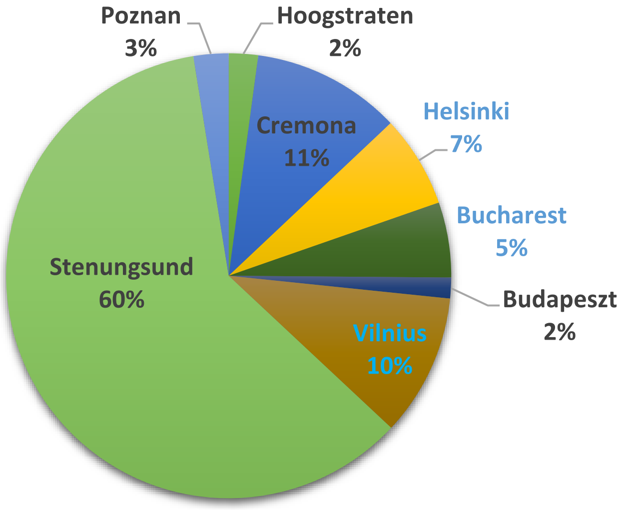


Figure II.11 Warehouse Usage Structure

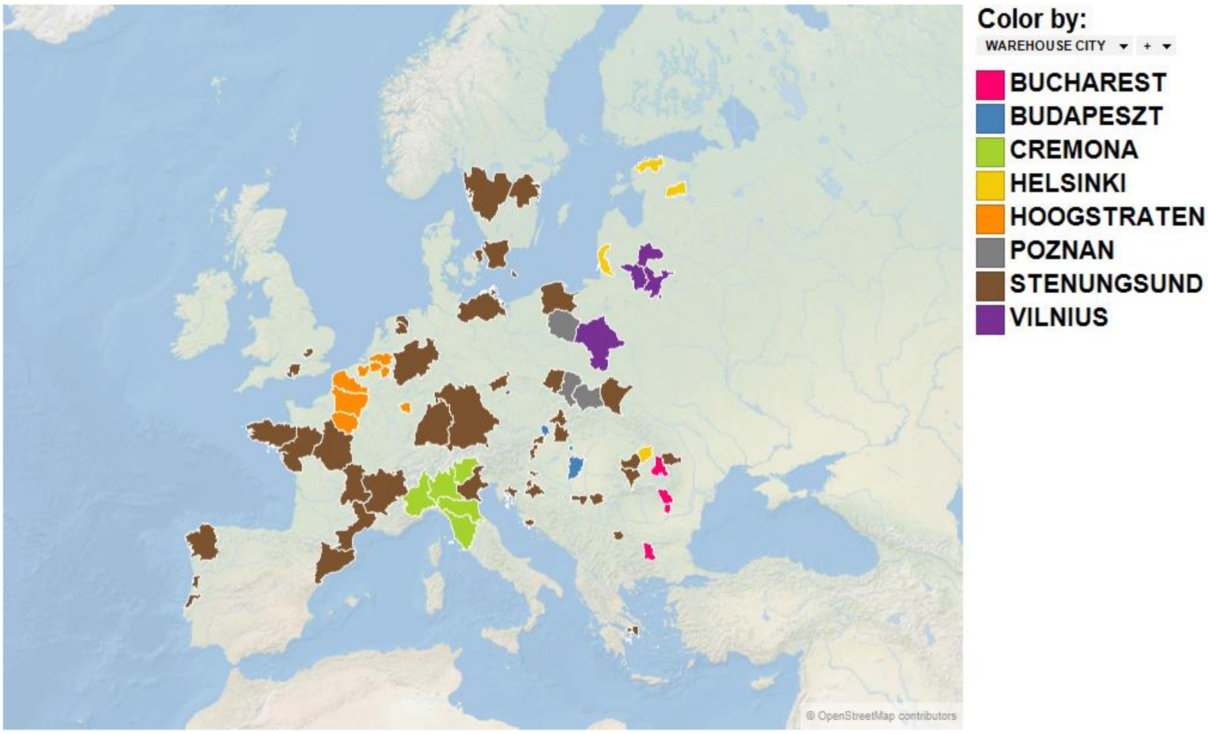


Figure II.12 Optimized Network Distribution

2.5.5 Inclusion of Short Sea Shipping in Network Design

Based on the spatial distribution of suppliers' locations I decided that the most optimal starting ports would be Gothenburg for Stenungsund and Helsinki for Porvoo. Assuming the usage of 40 feet container allows to keep the number of pallets of 18 that is appropriate for road transportation (assuming the regular semi-trailer). Thanks to the searates.com I was able to optimize the container space and it shows that there is no chance to increase the number of pallets inside.

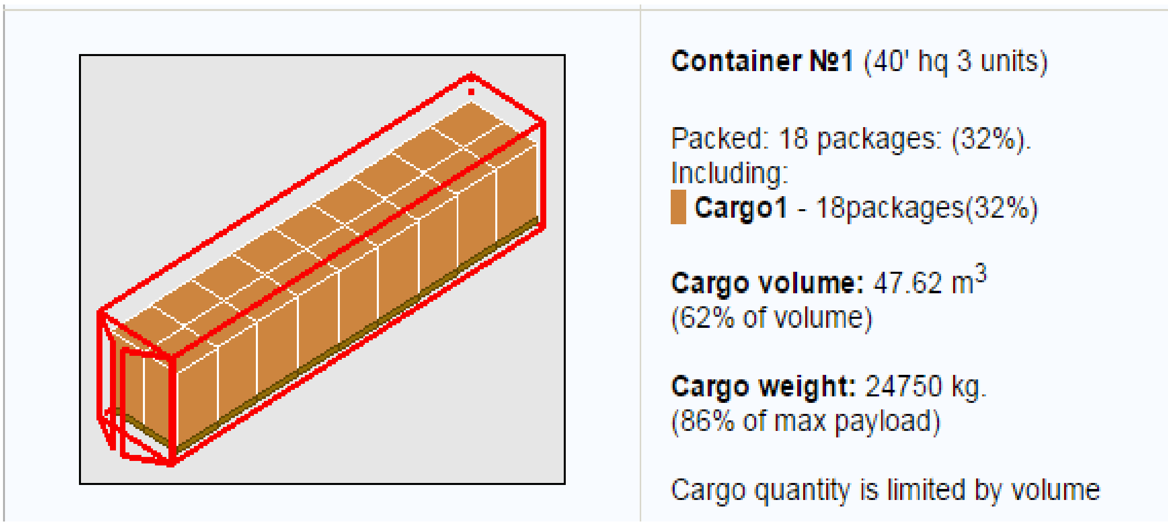


Figure II.13 40ft Container Space Optimization
Source: searates.com

The data for see transportation is derived from the http://worldfreightrates.com. Assuming the sea rates as shown in Table II.5 there is no possibility to decrease the costs by usage of short sea shipping. However, in Sensitivity Analyses section, I want to test what happens if the prices of truck transportation change and the sea rates stay constant. It will enable me to access the possibility and potential profitability of short sea shipping usage. Probably, the usage of SSS would be more appropriate if only sea and rail transportation is leveraged as both are usually cheaper than road transportation, but this is not very likely when the customers are spread around the entire Europe.

Table II.5 Short Sea Shipping Fares in Euro per 40 ft Container

Ports	Gothenburg	Helsinki
Gdansk	654	846
Hamburg	997	1268
Rotterdam	979	1246
Le Havre	979	1264
Bilbao	1121	1388
Sines	1736	2011
Valencia	1313	1558
Marseille	1246	1477
Thessaloniki	1825	1958
Constanta	1896	2118

2.5.6 Sensitivity Analyses

The sensitivity analyses are supposed to help either to access the robustness of previous outcomes or provide some additional solutions if there is a stronger pressure on fast deliveries. Therefore, I will start with a scenario when a customers demand the deliver within a certain time slot. Additionally, I will evaluate the robustness of the basic results and I will conduct two analyses. In the first one, I will investigate what happens when the truck transportation rates changes. In the second one, the assumption that Stenungsund warehouse price increases will be made and I will examine a changes in the distribution network and its influence on the logistics costs.

2.5.6.1 Delivery Time Restriction

The driving law for trailers' drivers (Regulation (EC)561/2006) seems to be very complex and controls driving and resting time not only for the current working week but also for a few previous weeks, for example the maximum driving time within two consecutive weeks is 90 hours. As the driving time restrictions are very relevant for delivery time, it needs to be incorporated in the. As the maximum highway speed for trucks is between 80 to 100 kilometers per hour I assume that truck average speed is 70 km/hour. I made my own assumption because I could not find any study that has been carried out on the topic. Additionally, I assume that there are two drivers in the truck. Being aligned with Regulation (EC)561/2006 regards drivers working time that one driver can drive 9 hours within a day, the effective driving time is 18 hours per day. The graph below explain the basic of the assumptions:

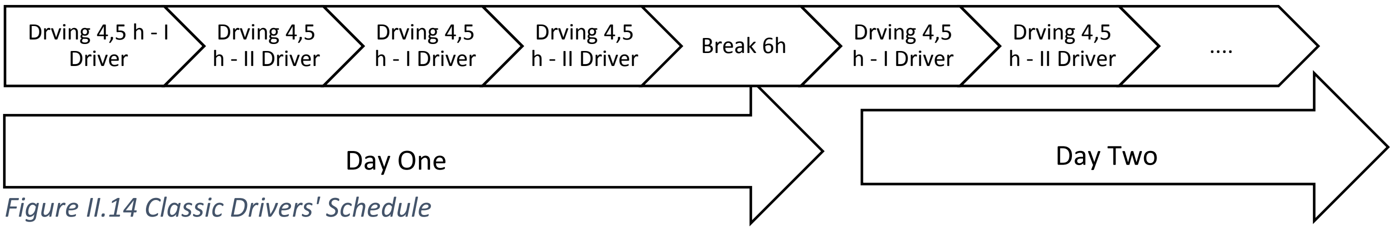


Figure II.14 Classic Drivers' Schedule

All the assumptions leads to:

- 1260 (70 kilometers x 18 hours (4x4.5 hours)) kilometers per day.

Therefore, for the optimization purposes the average speed of:

- 52.5 (1260 kilometers / 24 hours) kilometers per hour will be assumed.

The delivery time restriction indicates that within a given time period, since an order has been made, a delivery needs to be accomplished. When an order is placed before 3 pm. the parcel is sent out the same day. If this is not the case it will be ready for dispatch the next day in the morning. Because of this diversity, I assume 12 hours as the delivery preparation. The necessity of taking ferries is ignored. I am aware that it influences the delivery time but from the other side during the ferry trip drivers rest and therefore they drive longer afterwards. The 72 hours delivery restriction does not change significantly neither the costs structure nor the distribution network. Some changes are happening when a 48 hours restriction is introduced. There is a 53% increase in inbound transportation because there is an increment usage of regional warehouses. One needs to rise the required capacity in Bucharest, Hoogstraten, Helsinki, Budapest, Vilnius and Sezana. They gain in favor of Stenungsund, which cannot offer such good delivery time. None of the analyzed warehouses is able to meet the 48 hours delivery requirement for Portugal customers. However, their demand amounts around 1.6% of the total demand. The distribution network changes more revolutionary when a 24 hours restriction is tested.

Table II.6 Costs Structure Changes when Delivery Time Restriction is introduced

	Most cost efficient network	Delivery Time Restriction (Change in %)		
		72 hours	48 hours	24 hours
Inbound Transportation Costs	€ 175,731	5.2%	53 %	124%
Outbound Transportation Costs	€ 431,032	-1.6%	-18%	-41%
Warehouse Costs	€ 44,245	0.5%	18%	15%
Total Costs	€ 651,008	+0.4%	+3%	+7%

Table II.7 Warehouse usage share when Delivery Policy is introduced

	Most cost efficient network	Delivery TIME Restriction		
		72 hours	48 hours	24 hours
Hoogstraten	4%	4%	9%	11%
Cremona	11%	11%	11%	15%
Helsinki	7%	7%	8%	3%
Bucharest	5%	5%	6%	8%
Budapest	2%	2%	5%	10%
VILNIUS	10%	10%	11%	13%
Stenungsund	60%	58%	40%	13%
Poznan	3%	3%	3%	20%
Sezana	0%	0%	8%	8%

There is a large increase (124%) of inbound transportation costs, because Stenungsund is responsible for only 13% of the distribution in comparison to 60% in the most cost effective solution. There is a trade-off between inbound and outbound transportation so the outbound decreases by 41%.

Additionally, there is 15% increment of warehouse costs. In total, the company needs to spend 7% more on logistics in comparison with the most optimal distribution network when no delivery policy is introduced. Nevertheless, the management of the company needs to determine how time sensitive are its customers. This 7% increment of total supply chain costs should be perceived from a big picture in order to reach a logistic fit (Chopra & Meindl, 2013). This means that one needs to assess the strategic position of the company and examine which distribution network is more appropriate in order to succeed. For the 24 hours scenario around 5.4% of the demand deliveries can not be managed within the time limit. It applies to the customers in the Southern Europe, such as: Portugal, Spain, Greece and Southern France.

The optimization of 24 hours delivery time policy shows what kind of strategic location Poznan has for the company. It is centrally located, with good communication network with the Eastern, Western and Southern part of Europe. The company does not use this location as the warehouse and it is worth to analyze it during a further research. It might be even more interesting for other suppliers for which the inbound transportation would incur less costs.

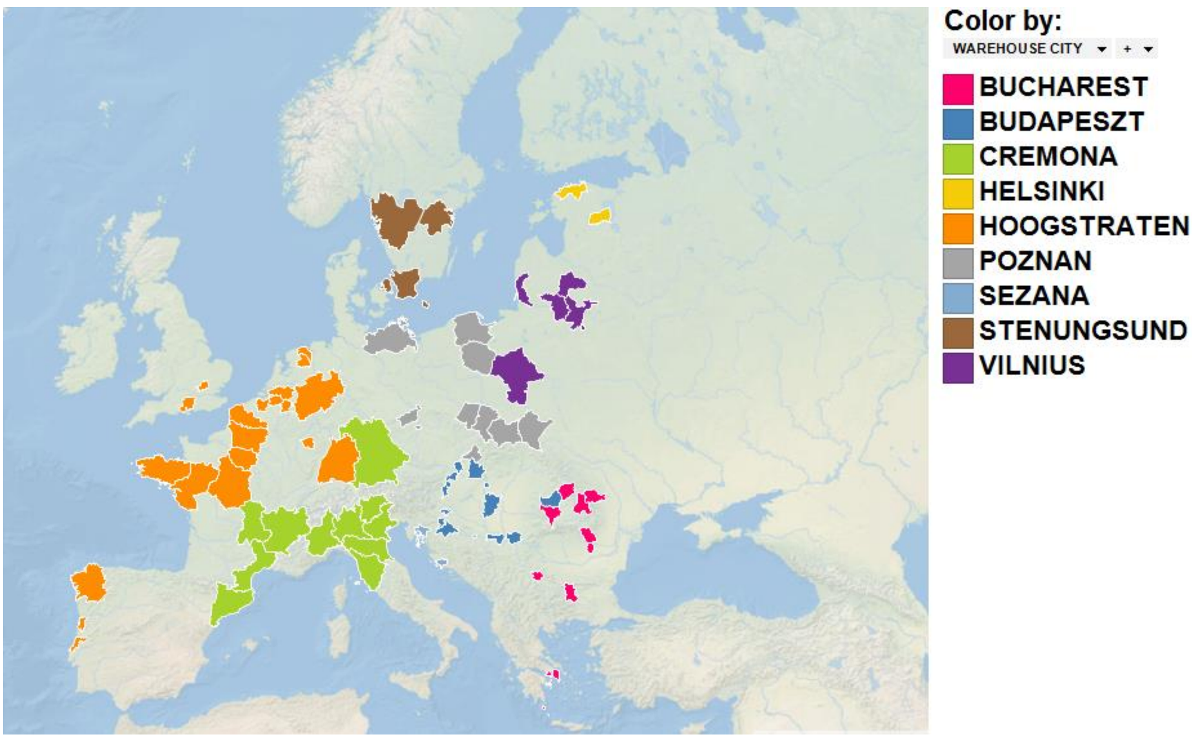


Figure II.15 Distribution allocation when 24 hours delivery policy is applied

2.5.6.2 Transport Rates Variation

Table II.8 presents the changes of both the costs structure and the share of SSS usage while truck transportation costs increases. It is clear that truck transportation is more profitable for the company rather than ship usage.

Table II.8 Truck Transportation Costs Sensitivity Analyses

Truck Transportation Costs Change	-10%	0%	10%	20%	30%	40%	50%
Short Sea Shipping Share	0%	0%	3%	4%	9%	13%	24%
Port Costs	€ 0	€ 0	€ 9,735	€ 11,693	€ 26,535	€ 38,664	€ 87,030
Inbound Transportation Costs	-6%	€ 168,216	12%	23%	40%	52%	75%
Outbound Transportation Costs	-11%	€ 435,701	9%	18%	25%	33%	36%
Warehouse Costs	-5%	€ 44,120	0%	0%	1%	9%	11%
Total	-9%	€ 651,008	9%	18%	27%	36%	45%

However, if one wants to limit the CO_2 emissions, hence the number of truck trips, assuming the current transport rates, it can be achieved by a moderate increase of the total costs. If one wants to keep a 40% share of SSS it needs to incur the increment of the total costs at the level of 7% (Table II.9). Firstly, one opens the connection from Gothenburg to Rotterdam and it supplies Hoogstraten. The next lane to open is Gothenburg-Gdansk and as warehouse is Poznan. At the very end (when road transport costs increases by 50%) the connection to Constanta is made from Gothenburg. Additionally, if the sea transportation costs falls there is a little increment of SSS utilization (See Table II.10), therefore I believe that not the price of SSS is the most important but the location of a port and its connectivity with the market.

The conclusion of the sensitivity analyses is that that usage of SSS does not strongly depend on truck transport prices, because SSS requires bringing the cargo to the port and then transports it from the port of destination to the warehouse. Although, it seems to be not profitable to use the SSS, the increase of total distribution costs is not very high. If the company expects to grow, the volume of transported goods it should be able to reach the economics of scale and have a good negotiation position with ship operators. Additionally, it needs to reach the economics of scale while packaging the containers, because plenty of space is not utilized while using truck in one part of the supply chain.

Table II.9 Increment of SSS usage and the costs structure change

Short Sea Shipping Share	0%	10%	20%	30%	40%
Inbound Trasportation Costs	€ 168,215.71	18%	35%	56%	81%
Outbound Transportation Costs	€ 435,701.33	-5%	-10%	-16%	-22%
Warehouse Costs	€ 44,120.32	1%	2%	3%	4%
Total Costs	€ 648,037.36	1%	2%	4%	7%

Table II.10 Port Costs Sensitivity Analyses

Port Costs Costs Change	0%	-10%	-20%	-30%
Short Sea Shipping Share	0%	3%	4%	13%
Port Costs	€ 0	€ 8,762	€ 10,921	€ 27,065
Inbound Trasportation Costs	€ 175,731	2%	2%	9%
Outbound Transportation Costs	€ 431,032	-1%	-1%	-5%
Warehouse Costs	€ 44,245	0%	0%	1%
Total Costs	€ 651,008	-0.1%	-0.2%	-0.4%

2.5.6.3 Average Time in Inventory Variation

It is plainly seen that the longer the average inventory time the more preferable the option is Stenungsund usage as the warehouse city, because of its competitive pricing. For almost all other cities, there is an opposite trend. There is only one exception for the case of inventory time being maximally one month, then some of inventory that was distributed by Helsinki (one and two weeks inventory time) is taken over by Vilnius and when there is a max two month inventory time, this portion is taken by Stenungsund. As long as the warehouse costs consists of less than 10% of total costs the variation in the average time in inventory does not influence the total costs significantly.

Table II.11 Warehouse Usage while Average Time in Inventory Varies

		Average Time in Inventory				
		One week	Two weeks	1 Month	2 Months	3 Months
Warehouse Costs Share		5.92%	6.09%	6.80%	7.33%	7.89%
Total Costs Increment		-1.37%	-0.89%	€ 651,008	1.44%	2.46%
Supplier City	**Warehouse**	**Inventory Share**				
STENUNGSUND	HOOGSTRATEN	2%	2%	2%	1%	0%
STENUNGSUND	CREMONA	12%	11%	11%	11%	5%
HELSINKI	HELSINKI	12%	8%	7%	3%	3%
HELSINKI	BUCHAREST	5%	5%	5%	2%	2%
STENUNGSUND	POZNAN	3%	3%	3%	0%	0%
STENUNGSUND	BUDAPESZT	2%	2%	2%	2%	2%
HELSINKI	VILNIUS	7%	10%	10%	10%	10%
STENUNGSUND	STENUNGSUND	57%	59%	60%	72%	78%

2.5.6.4 Stenungsund warehouse price increment

As long as Stenungsund has a competitive advantage over other locations, I decided to test what happens if warehouse costs of Stenungsund are equal to Helsinki warehouse (the most expensive in my list). The total costs rise by 7% what I would perceive as a large increment especially that warehouse costs does not weight much (12% in this scenario in comparison to 7.2% for the most optimal one). Once again it shows the very strong position of Stenungsund warehouse when even it is the most expensive it serves 44% of the market. The analyses might be helpful when assessing a business case connected to this supplier.

Table II.12 Costs comparison when Stenungsund costs increases

	The most optimal solution	Stenungsund Warehouse Price Increment
Inbound Trasportation Costs	€ 168,216	45%
Outbound Transportation Costs	€ 435,701	-16%
Warehouse Costs	€ 44,120	87%
Total	€ 651,008	7%

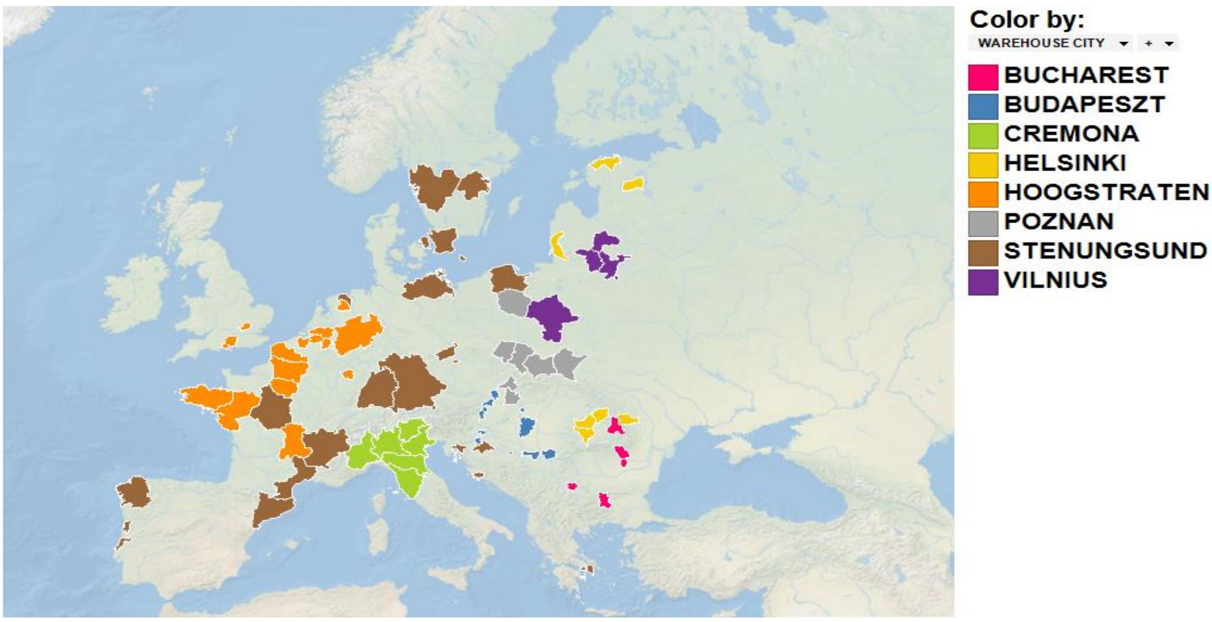


Figure II.16 Warehouse distribution when Stenungsund costs increases

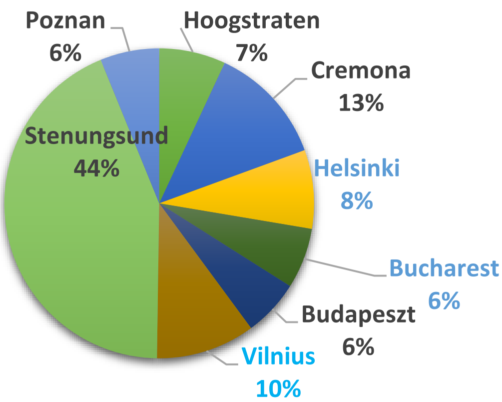


Figure II.17 Warehouse distribution share when Stenungsund costs increases

2.5.7 Discussion and additional optimization opportunities

The main results of the thesis and the sensitivity analyses presents the complexity of the facility location problem. This is clear that Stenungsund has a competitive advantage over other locations, but it is diminishing when delivery policy restrictions are introduced. Additionally, it showes the strategic position of Poznan warehouse. The company does not operate in this location yet, but it should consider to relocate some of their products to that place. It will increase the responsiveness and the customers' satisfaction. However, currently because of the competitive advantage of Stenungsund the company should look for other ways to optimize its distribution network. I have two solutions, which should be considered:

1. Leveraging the usage of a Light Weight Semi-Trailer, because they are characterized by significantly lower tare weight (only 4.7-4.9 tons[6]), hence the payload increases by 20%. Bergerecotrail is producer of such Semi-Trailers and there are no competitors, which can offer substitute with the same parameters. Therefore, the recommendation is to look for carriers that offer this type of truck. It does not necessarily means that it will bring 20% savings in transportation costs but it definitely would help for large volumes orders. Additionally, it reduces the CO_2 emission, hence a lower number of trips and lower fuel consumption. For the company case, an estimated gain would around 16% (21 pallets instead of 18).
    - Semi Track dimension inputs[7]:
        - Length of loading area: 13,620 mm
        - Width of loading area: 2,490 mm
        - Loading height latera: 2,815 mm
        - Maximum Payload: 29,480 kilograms.
    - Pallets Sizing with material:
    - Length: 1300mm
    - Width: 1100 mm
    - Height: 2000mm (1850 mm Material + 150 mm Pallet)

[6] *Bergerecotrail*. (2015, 12 30). Retrieved from Bergerecotrail Models: http://www.berger-ecotrail.com/en/products/models.htm

[7] *Bergerecotrail*. (2015, 01 01). Retrieved from Bergerecotrail Models: http://www.berger-ecotrail.com/uploads/tx_wctypen/LTMn_LTMCn_Produkt_EN_NEU_ANSICHT.pdf

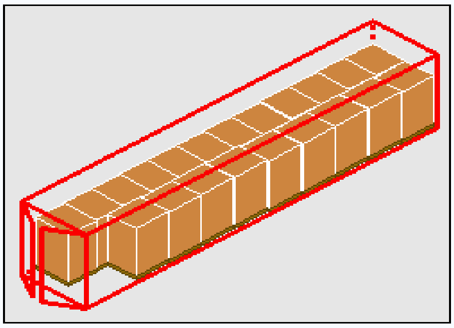
Transports	Cargo packing
All transports: Berger: 1 units	Total: 22 packages. Packed: 21 packages. (95%)
	**Truck №1** (Berger 1 units) Packed: 21 packages: (95%). Including: **Cargo1** - 21packages(95%) **Cargo volume:** 55.56 m^3 (58% of volume) **Cargo weight:** 28875 kg. (98% of max payload) Cargo quantity is limited by max payload. Show packing by blocks Show packing step by step Show pallet loading images

Figure II.18 Light Weight Semi-Trailer Loading Optimization
Source: searates.com

2. Providing a logistics discounts for customers that are accessible easily, I mean in a cheap way. The discount should depend on:
    - An average lot size – the larger the lots the lower the costs per unit.
    - Frequency of transports. The most recommended scenario is to have the minimum number of deliveries with the fixed schedule, because one can agree better deal with Logistics Service Providers.
    - Location of the customer.

Chapter III Conclusions

The historical activity of the analyzed company is a very good base for optimization analyses. It is very important to track the costs side of the company Profit & Loss statement in order to optimize expected profits. The distribution optimization should be a standard procedure and should be performed repeatedly because the environment changes continuously. The spatial distribution of customers, transport fares and warehouse costs vary over time and one needs to adapt to the changes as quickly as possible in order to reach the competitive advantage. The aim of the research was a reaction to the changes and I hope it was a beginning of good practices in the company operations.

The most optimal allocation presented in the thesis should enable to save 6% of the total logistics costs. The network leverages Stenungsund as a warehouse city and trucks as the transport mode. Many different scenarios, which deviates, from the most optimal allocation are presented. They are very interesting to investigate while making strategic decisions.

In my opinion, applying the most optimal distribution is just a one way of bringing potential savings. Definitely, this is the most costs saving scenario, however it trades off other aspects of the business, for example the responsiveness. As a revenue maximization is not the main research problem, I recommend looking for other costs saving solutions. The company should combine one of the most optimal allocation, according to the responsiveness needs, with approaches, which are proposed in the Discussion subsection. Especially, the cooperation with Logistics Providers that offers Light Weight Semi-Trailers enables some savings. It should allow the company to increase the profitability of its undertakings more than just the implementation of the most optimal network. I believe that optimizing the costs side would improve the competitiveness of the Entity. As the calculations show, the most optimal transport mode for the company goods would be trucks with Light Weight Semi-Trailer, because of space utilization and responsiveness to the customers' needs. The thesis highlighted that the currently used Stenungsund warehouse is the most costs effective one, therefore it should be leveraged. While using intra-European warehouse increases total distribution costs slightly, it improves the responsiveness to the customers' orders. The presented trade-off should be evaluated by the company executives. In any case, the first point of their analyses needs to cover an assessment of costs of lost sales.

Additionally, the thesis presents some theoretical aspects of transportation pricing and its determinants. The distance is still the most important aspect of road transportation pricing without any doubts. Moreover, the research points out that infrastructure level, trade imbalances and destinations' location are also relevant while estimating fares.

3.1 Limitations

During the research, I have encountered several limitations and I would like to share the most important ones. First, I was entitled to base my analyses on only one product that is supplied from one supplier. Knowing that the company has plenty of suppliers and it has many products in a portfolio, I am aware that the analyses are not complex enough to be the only source of information for the decision making process.

Second, the investigated business case is very specific, because of avoidance of storage costs in the Stenungsund site. Therefore, the most optimal distribution network is very straightforward. However, my idea to deal with it was the introduction of many sensitivity analyses scenarios.

3.2 Recommendations for the future research

Definitely, the further research should be applied for complex business case with a couple of products and suppliers. Moreover, assuming that a few suppliers deliver the same products with similar quality I would follow the profit maximization optimization rather than cost minimization. Having the business case with combined issues of multiple products and suppliers as well as revenue side introduction, should allow to be more helpful for the decisions making process. However, it might be very difficult because of technical reasons.

From the transport pricing theory perspective, I would recommend to investigate the pricing difference between one and two way trips. This was impossible for the data set provided because the polymers' business is characterized by head-trips, however for example in brewing industry companies struggle with two-way trips while collecting empties.

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7.1 Destination Countries

Destination Country	Regions
Slovenia	Balkans
Croatia	
Serbia	
Bosnia and Herzegovina	
Moldavia	
UK	British Isles
Ireland	
Slovakia	Eastern Europe
Lithuania	
Poland	
Estonia	
Czech Republic	
Hungary	
Romania	
Bulgaria	
Latvia	
Sweden	Scandinavia
Finland	
Denmark	
Norway	
Spain	Southern Europe
Italy	
Portugal	
Benelux	Western Europe
Germany	
France	
Austria	