BUSINESS, MANAGEMENT AND EDUCATION
ISSN 2029-7491 / eISSN 2029-6169
2014, 12(1): 109–126
doi:10.3846/bme.2014.08

THE IMPACT OF SUPPLY CHAIN COST ON THE PRICE OF THE FINAL PRODUCT

Indrė Lapinskaitė[1], Justina Kuckailytė[2]

Vilnius Gediminas Technical University, Saulėtekio al. 11, LT-10223 Vilnius, Lithuania
E-mails: [1]indre.lapinskaite@vgtu.lt (corresponding author); [2]j.kuckailyte@gmail.com

Received 19 May 2014; accepted 4 June 2014

Abstract. Nowadays, as consumption and production are growing enormously fast, companies are seeking for costs reduction aimed at ensuring competitiveness. In manufacturing companies, supply chain expenses play a colossal role in the cost of the final product. This paper focuses on the main processes in the logistics chain and their components. The authors analyse the relationship between the supply chain expenses and the price of the final product, the classification of logistics chain costs and their minimization as an assumption for the competitiveness of the final price.

Keywords: pricing, supply chain cost, linear programming, optimisation.

Reference to this paper should be made as follows: Lapinskaitė, I.; Kuckailytė, J. 2014. The impact of supply chain cost on the price of the final product, *Business, Management and Education* 12(1): 109–126. http://dx.doi.org/10.3846/bme.2014.08

JEL Classification: C61, D4, D23, L91.

1. Introduction

Due to the increasing globalization, companies need to become more and more competitive in order to sustain in the market. The only way to stay competitive and to keep customers is to provide a reasonable price of the product. Supply chain costs compose around 55% of the total product cost. Since the supply chain has a big influence on the cost of the final product, it is necessary to continually improve the processes within the supply chain and thereby reduce the overall cost. The need to keep the price competitive on the market empowers the company to be flexible and adaptable, offering different prices to different customers (Shaffer, Zhang 1995, 2002; Feinberg *et al.* 2002; Liu, Zhang 2006). The supply chain can be described as a tool for cargo movement, in our case – industrial tools. The chain is considered as the total sum of supply, material management and distribution actions.

The topic was chosen to determine the impact of the supply chain cost on the cost of the final product in a small-sized German tools manufacturing company Holger Clasen

GmbH & Co. KG (hereinafter – Holger Clasen). The supply chain costs will be analysed regarding costs related to four components: transportation, inventory, warehousing and packaging (Rushton *et al.* 2010). Considering the total supply chain costs, the real impact on the cost of the final product will be presented as well as and opportunities for its reduction.

The goal of this paper is to discuss the nature of the supply chain, the key processes and their accompanying component costs; to practically analyse activities of Holger Clasen and explore transportation, warehousing, inventory and packaging costs aiming to develop and optimise opportunities for the cost of the final product.

The work is dedicated to finding a solution to the main problem, namely, the enormous role of supply chain costs in the price of the final product. In order to stay competitive in the market, it is necessary to find a way to reduce supply chain costs. The paper suggests the optimisation task as means of solving the problem related to the reduction of supply chain costs.

2. Supply chain concept

In the 21st century, more and more companies understand and evaluate the importance of the supply chain concept. In a company, the supply chain is strategically relevant for internal and external areas of activity. Also, it is considered as one of the best ways to control distribution processes of the company. Generally, the supply chain is not focusing on financial improvements; nevertheless, it has a big influence on the profit of the company by optimizing processes and reducing final product cost (Morana 2013).

There are many different definitions of the term “supply chain”. Results of the in-depth analysis of definitions present in the literature are given in the Table 1 below.

To sum up the table, the supply chain is the overall processes of the product movement starting from the supplier to the end customer.

The goal of a supply chain is to control all planning functions. This includes the planning of supply, demand, inventory, logistics capacity and sourcing. The core task of the supply chain is to connect customers with suppliers; in order to accomplish the task; the supply chain is responsible for all execution functions: purchasing, warehousing and transportation (Sehgal 2011). Aiming at the best result, a supply chain should balance all functions, which are mentioned above. Moreover, by providing a developed and functional supply chain strategy, the supply chain management can support the business strategy. It can be implemented in the overall enterprise process by acceding the meaningful asset at the end.

Table 1. Comparison of supply chain definitions (created by the authors)

Definition	Authors
"A set of approaches utilized to efficiently integrate suppliers, manufacturers, warehouses and stores, so that merchandise is produced and distributed at the right quantities, to the right locations, and the right time, in order to minimize system wide costs while satisfying service level requirements."	Simchi-Levi *et al.* 2008; Kumar, Nambirajan 2013
"Logistics is essentially a planning orientation and framework that seeks to create a single plan for the flow of products and information through a business. Supply chain management builds upon this framework and seeks to achieve linkage and co-ordination between the processes of other entities in the pipeline, i.e. suppliers and customers, and organization itself."	Christopher 2011
"<…> the supply chain should be understood as a network 1 of entities delivering the product (or service) to the market, end-customer or consumer."	Szymczak 2013
"A supply chain is a network of facilities and distributions that performs the functions of procurement of materials, transformation of these materials into intermediate and finished products, and the distribution of these finished products to customers. Supply chain exists in both service and manufacturing organizations, although the complexity of the chain may vary greatly from industry to industry and firm to firm."	Bhatnagar 2009
"SCM is the management of a network of interconnected businesses involved in the provision of product and service packages required by the end customers in a supply chain. Supply chain management spans all movement and storage of raw materials, work-in-process inventory, and finished goods from point of origin to point of consumption."	Dhakry, Bangar 2013

Product costing is a powerful tool. Determining the costs of products can enable management to discern, which of its products are viable, which cost more, and which contribute most to the bottom line. In fact, understanding the savings of product costs can be a key to improving the viability (Hirschland 2005). Logistics is a diverse and dynamic function that has to be flexible and has to change according to the various constrains and demands imposed upon it and respect to the environment, in which it works (Rushton *et al.* 2010). Below is the formula of logistics described theoretically:

$$\text{Logistics} = \text{Materials Management} + \text{Distribution}.$$

Nevertheless, logistics is a part of a supply chain, which describes the overall process and takes into account suppliers and customers. The theoretically described formula of a supply chain (Rushton *et al.* 2010):

$$\text{Supply chain} = \text{Suppliers} + \text{Logistics} + \text{Customers}.$$

All in all, importance of the problem (how much do logistics costs impact on the cost of the final product) in the following papers will be analysed. Naturally, the optimisation goal is to optimise the overall process including suppliers and customers.

3. Comparison of supply chain components

Reduction of the cost of a final product is based on analysing different logistics supply chain components. Different authors have different opinions on the components. The most essential activities of the logistics supply chain in industrial tools manufacturer industry will be analysed more in detail.

Table 2. Comparison of supply chain components (created by the authors)

	Rushton *et al.* 2010	Vierasu, Balasescu 2011	Chopra, Meindl 2007	Sadler 2007	Bhatnagar 2009	Vogt *et al.* 2007
Transportation	X	X	X	X	X	X
Inventory	X	X	X	X	X	X
Procurement				X		X
Materials Handling			X	X		X
Reverse Logistics						X
Warehousing	X	X	X	X		
Information	X	X	X	X	X	X
Order processing				X		X
Customer Service						X
Location		X			X	
Production					X	
Price		X	X			
Packaging	X					X

Some comments regarding the Table 2 should be provided. Vogt *et al.* divide inventories in to two parts: manufacturing inventory and finished goods inventory. Sadler defines procurement as provision. Both terms are used synonymously. Chopra and Meindl (2007) define material handling as sourcing. In this book, both terms are used synonymously. Vierasu and Blasescu define warehouse as facilities. In this article, both terms are used synonymously. Chopra and Meindl (2007) define warehouse as facilities. In this book, both terms are used synonymously. Vogt *et al.* connect information and communication activities. Sadler defines material handling as order-picking and forecasting demand.

Based on analysis provided in the Table 2, there are five tools more commonly used in the sources: transportation, inventory, information flow, warehousing and packaging. The fifth component, packaging, was chosen because it is important for the analysed

company. To clarify each of the components, there short definitions are provided. Also, information flow will not be analysed as the influencer factor to the final product cost, because it does not have direct connection with the product cost. Each of the relevant components is described below.

In transportation, the key activity is the movement of goods from one place to the other. The transport system is indispensable in determining whether customers receive goods as and when required (Vogt *et al.* 2007). According to Tseng *et al.* (2005), transportation plays one of the biggest roles in the logistics chain and it is considered as the most important component because it takes the biggest part in the life cycle of a product. Transport system makes goods and products movable and provides timely and regional efficacy to promote value-added under the least cost principle. During transportation activity, time and quality aspects are considered as the most important.

Inventory encompasses all raw materials, work in process, and finished goods within a supply chain (Chopra, Meindl 2007). Inventory is expressed though the carrying costs. Inventory carrying costs are all costs required to keep the stock, which includes all operating costs, such as utilities, rent and salaries. It is counted over the period of time, usually one year. Several ways how to improve inventory and to reduce costs are considered: reduce the inventory capacity, handing-over some operations to third party companies and improving the stocks in timely manner (Lee 2013).

Warehousing entails the activities related to managing the space needed to hold or maintain inventories. Goods must be stored for later sale and consumption unless customers need them immediately after production (Vogt *et al.* 2007). Olayinka (2010) pointed out three types of costs: picking/retrieval costs, packing costs and loading costs, as important factors to minimize the cost and enhance effective warehousing services in manufacturing companies.

Packaging basically performs two roles: marketing and logistics. From the logistics point or view, packaging also has a dual role. Firstly, the package protects the product from damage and sometimes prevents potentially hazardous products from damaging other goods. Secondly, packaging can make it easier to store and move products, thereby lowering materials handling and distribution costs (Vogt *et al.* 2007).

4. Understanding the supply chain material flow

Supply chain system consists of three processes: sourcing, production and distribution. Each of them is special in terms of supply chain functioning. A supply chain is a dynamic process and includes information flows, production, warehousing services, packaging services and transportation components. A business is considered as a node where all activities are confronted (Xin *et al.* 2011).

In Figure 1, the supply chain processes are presented graphically. Supply chain system would not exist without two core components: a customer (demand) and a supplier

(supply). This is why the processes of supply chain starts with management of the customer and supplier relationship and service level management. In this case, supply chain is a stepping stone, which makes it easier to understand and complete the demand and supply needs. In order to satisfy customers, the remaining processes have to be ensured; and in this case, order fulfilment and product development are the most important. The importance of these two processes lets business maintain its customers and run operations appropriately.

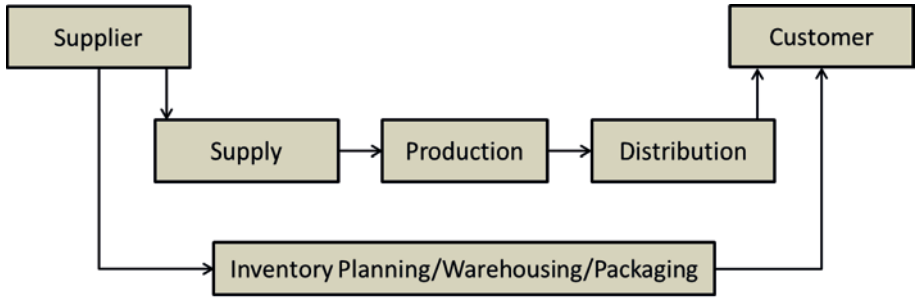

Fig. 1. Supply chain processes (adopted from Braškienė 2009)

According to Braškienė (2009), supply chain processes can be classified into three sections: sourcing, production and distribution. Sourcing function is required to ensure supply of material resources for the company, often identified as a purchase management system. Production is a function ensuring the production preparation and continuity of the production process. Distribution covers all activities related to the flow of trade (tangible) and services (intangible) or finished goods from the warehouse to outlets.

5. Research methodology

Holger Clasen Data Analysis. Data analysis (Table 3) is one of the most popular ways for formatting and modelling loads of information. Statistical data helps different business, organisations or research groups to forecast the up-coming situation, to make decisions and find out the trend.

Table 3. Strengths and weaknesses of statistical data analysis
(adopted from Statistical data analysis 2014)

Strengths	Weaknesses
− Objective information − The possibility to see the trend	− Difficult to observe loads of data

A four-year period is analysed in the paper from 2010 to 2013 with over 60.000 of data units. Several sources were used to get the data such as internal company's ERP system proAlpha and historical Excel tables made by HC controller. Statistical data

summarizes the overall period information about suppliers, customers, internal company's operations and financial data.

In-Depth Interviews. A personal interview (Table 4) is a lengthy personal conversation with a group of people or an individual. The goal of personal interviews is to get valuable information and experience-based knowledge from each respondent.

Table 4. Analysis of strengths and weaknesses of in-depth interviews (adopted from Social research methods 2014a)

Strengths	Weaknesses
− Detail answers − Arguments are stated more clearly compared to written answers	− Summarise difficult answers − Possibility of interpretation − Data can be inaccurate − Subjective opinion

Interviews were made during a three months internship at the company. Information was collected through short interviews based on daily communication or special meetings in the particular case; the meeting were made with sales managers, supply chain manager, controller and internship supervisor.

Observation. The observation method (Table 5) is used to study dynamic situations and to preserve the interrelationships of the person and situation. The observation methodology is observing the person or group of persons based on their professional field. Observation method was used on the same bases as in-depth interviews.

Table 5. Analysis of strengths and weaknesses of observation (adopted form Social research methods 2014b)

Strengths	Weaknesses
− Flexibility (approach can be changed as needed) − Learning from professionals	− Language barrier − Cultural barrier − Risks ofmisunderstanding

Linear Programming. Linear programming (Table 6) is a mathematical method, which achieves the best outcome (minimized or maximized value). Usually, it is used as a technique of the optimisation model, as well can be called a multi-criteria decision analysis. In this paper, lp_solve 5.5.2.0 linear programming tool is used. Programming solver is based on the revised simplex method and the branch-and-bound method for the integers (lp_solve 5.5.2.0 2014). Optimisation problems are mostly closely related with the limited number of costs or distribution of raw materials. Usually, resources have more than one way of distribution. It is rational to formulate the cost or product distribution, which would bring the biggest profitable effect to the company (Kalanta 2007).

Table 6. Strengths and weaknesses of the linear programming method (adopted from Kalanta 2007)

Strengths	Weaknesses
− Basically no limit on model size − Supports Integer variables, Semi-continuous variables and Special Ordered Sets − Easy callable from other programming languages	− It is difficult to determine constrains and bounds

The linear programming problem is mathematically formulated as follows. The main function of linear programming tool is to minimize or maximize the value, which can follow as an example (1):

$$\max f(x) \text{ or } \min f(x). \quad (1)$$

After, settling the main function, problem constraints should be determined.

For example (2):

$$g_i(x) = b_i,\ i = 1,2, \ldots, m_1;\ g_i(x) \leq b_i,\ i = m_1 + 1, \ldots, m; \quad (2)$$

$g_i(x)$ is a function, which described the costs of production or transportation; x is variables (unknowns); b_i is bounds for a particular problem, for example it can be expressed as quantity of raw materials (Kalanta 2007). It is very important to mention, that both objective function and constraints must be linear equations. This means that no variables can be multiplied with each other. Such formulation is called a standard form and will be used in the practical part to optimise supply chain cost (lp_solve 5.5.2.0 2014).

In our case, the following expressions for task minimisation were used:

$$\min: c_1/t_1{*}x_1+c_2/t_2{*}x_2+\ldots+c_n/t_n{*}x_n; \quad (3)$$

$$\sum x_n = A, \quad (4)$$

where:

x_n – amount of goods transferred in a specific way;
c_n – transportation costs of goods transferred in a specific way;
t_n – transportation time of goods transferred in a specific way;
A – the amount of goods needed for the process.

6. Introduction of Holger Clasen GmbH & Co. KG

Holger Clasen GmbH & Co. KG was founded in 1932 in Hamburg. It is a family owned business that has been known for its high-quality tools and excellent service for three generations. Company is guided by philosophy, which states that industrial tools both reflect and drive human progress because they make work easier. Holger Clasen GmbH & Co. KG manufactures and procures high-quality pneumatic, electronic and hydraulic tools and tool components all over the world. The company has over 100 suppliers and

around 2000 customers. Also, it provides customised and innovative tools solutions for the automotive sector, the power industry and the maritime industry. From the year 2000, the company runs Technical Service Centre which maintains and repairs Holger Clasen tools, as well as tools made by other manufacturers. In addition, it provides extra activities such as picks up and returns customer-owned tools, provides maintenance service in 24 hours and offers an extra reminder for the tool current status.

In April 2009, the company successfully introduced the quality management system DIN EN ISO 9001, which assures high quality of the products. Moreover, the quality management system concerns the quality of work of all departments and efficiency descriptions, which are adopted in daily company's work.

In 2011, manually operated crimping tool RC 14-A was noticed having exceptionally high performance characteristics. "At only six kilograms of weight, it has a crimping force of 14 tonnes equalling the weight force of 14 VW Golfs. As the only battery-powered tool in the world, it makes K38 crimps, which corresponds to a cable cross-section of 400 mm². New lithium-ion batteries provide the power machine with a battery capacity that is 65% higher than that of other tools" (Holger Clasen 2014).

The mission of Holger Clasen GmbH & Co. KG: helping the customers to solve the challenges they have to meet in daily life.

The vision of Holger Clasen GmbH & Co. KG: to become the biggest industrial tools supplier in Europe.

Every day, Holger Clasen strongly follows their principals and the mission. The Company is up to date and the main source for innovations and trends are customers, which as Holger Clasen states are the core for innovative developments and realization of efficient ideas. To protect the market position and secure corporate loyalty helps the understanding of tradition and innovation as a commitment and a unique feature of corporate culture. The company for internal operations is using internal ERP system proAlpha. ProAlpha is used for internal management of company's documents. All documents are kept for a 10-year period. The system is one of the oldest and the most popular system used in Germany. Holger Clasen GmbH & Co. KG has been using the program for 12 years already. Every year, the system undergoes external improvements. The improvements depends on the increasing demand and the upcoming work-related trends.

7. Supply chain cost analysis in Holger Clasen

Cost analysis is relevant in order to find out the impact of supply chain processes costs on the overall financial operations of the company. Three columns are presented in the table below: the cost component of the cost of goods sold, supply chain process managing the cost component and the financial metrics affected by these costs and processes presented in the first two columns (Table 7).

Table 7. Cost components of sales and supply chain processes that help manage them (adopted from Sehgal 2011)

Cost component of COGS	Supply Chain Process Managing the Cost Component	Financial Metrics Affected
Direct Materials and Supplies, Cost of Raw Materials and Inputs (for manufacturers) or Merchandise (for retails), etc.	Forecasting, Replenishment, Inventory Management (raw materials), Sourcing, Purchasing	Gross Margin, EBITDA, Inventory, Inventory Turnover, Current Assets, Working Capital, Return on Assets
Direct Labour, Cost of transportation (production, manufacturing, processing etc.), Depreciation, Direct Manufacturing, Overheads etc.	Production Planning, Factory Planning, Resource Planning, Inventory (work in progress), Management	Gross Margin, EBITDA, Working Capital, Return on Capital Employed
Cost of Freight (all inbound, outbound, and intra-facility transfers of material)	Transportation Management	Gross Margin, EBITDA, Working Capital
Cost of Warehousing, Inventory Shrink, Obsolescence, Mark-downs, Handling, Inventory Carrying	Warehouse Management, Labour Management, Inventory Management (finished goods or merchandise)	Gross Margin, EBITDA, Working Capital

COGS – Cost of Goods Sold.

EBITDA – Earnings Before Interest, Taxes, Depreciation and Amortization.

Summarizing the table and the overall processes in the company's supply chain department, we can state that there are four main cost groups, which are needed for the deeper analysis: *transportation cost, inventory cost and warehousing and packaging cost*. All groups will be analysed in more detail in order to make the assumptions of financial company's activities.

DISCLAIMER: all the data provided in the analysis are based on presumptions and cannot be treated as 100% official assumptions provided by Holger Clasen GmbH & Co. KG.

Transportation costs can be divided in to two parts: transportation costs from supplier to the company and transportation costs from the company to the customer. Both delivery stages are relevant for the company; however, the first stage is more important for transportation costs analysis while the main suppliers are located outside Europe. The company has contracted the third part company UPS for logistics services. UPS provides three different transportation modes: air freight, see freight and carrier services as well providing express carrier services. Holger Clasen has been using UPS services for 15 years. The outgoing products are collected at the end of each working day, the incoming products are delivered during a day without a fixed time. The company has

installed UPS delivery program, which saves customer names and addresses. In addition, each package gets a barcode, which contains all related transportation information, e.g. the weight and type of a cargo and data about the company.

The transportation cost depends on several factors:

− The size and weight of a cargo;

− The internal company's agreements regarding transportation customs;

− The country of origin of the supplier or the customer.

Holger Clasen GmbH & Co. KG has two warehouses. The main warehouse is in the main company building, which is around 100 m2 size. The warehouse stores approx. 100 000 parts throughout a year. The warehouse is divided into two main parts: storage place and packaging area. It has two employees: the warehouse manager and the packer. In theory, both supply chain components are described separately; nevertheless, in the practical part, by observing the work, it is difficult to exclude warehousing costs from packaging costs as the packaging area is the part of the warehouse even if it is an essentially different function.

8. Optimisation of the sourcing process cost

The following chapters, aiming to ensure the relevance of optimisation for the company, will present Holger Clasen activities, which influence material flow processes. In order to achieve the best result, each of the process were evaluated in respect of different factors and boundaries, which will be presented in each section separately. The goal of using linear programming tool is to optimise the process which is directly affecting the final product cost. It means to find optimal proportion between delivered product amount and the right transportation mode; including the delivery time restriction. Holger Clasen uses four modes of transportation: air freight, sea freight, road freight and rail freight. All transportation is ensured through third-parties. Transportation mode or services was chosen depending on availability and price.

For these analyses we will take into account product delivery cost measured by product weight, average amount ordered per product, delivery time and transportation mode. Rail freight is used in calculations in order to find out its value for the company. The other transportation modes are used in daily company's activities. Short interviews with Holger Clasen employees demonstrated that the most costly is the product delivery from supplier to the company. Nevertheless, it will be analysed. Finally, solutions and suggestions for the company will be presented on how the product supply and distribution can be divided.

Product cost depends on several factors. Holger Clasen product cost is divided into two parts: direct product cost and indirect product cost. Direct product cost is defined as costs that are completely contributed to the production. Indirect cost is all costs that are more difficult to evaluate and estimate; for example, administration costs. To gain more

understanding, the most sold tool of 2013 will be analysed; it will be referred to as Tool 1. Costs of the presented tool will be analysed starting from the supplier to the end customer. Tool 1 is supplied by two suppliers. The tool is used as a base of the five different types of tools, which means that tools are modified in the company or have extra parts in the selling package. During 2013, 647 tools were sold out of 900 of total tools sales. The table below (Table 8) presents the list of costs that impact on the final product cost.

Table 8. Tool 1 costs in EUR (created by the authors)

Direct costs		Indirect costs	
Materials Costs	331.00	Administrative Costs	60.00
Transportation Costs	45.00	Depreciation Costs	21.00
Packaging Costs	22.20	Other Costs	23.00
Warehousing Costs	17.80		
Total:	416.00		104.00
			520.00

Holger Clasen material flow starts in sourcing process. Sourcing process is based on relationships among the company and its suppliers. The company has over 100 suppliers all over world. The chapter on supplier analysis describes the main information about suppliers, including the country of origin and the product group, which they supply to Holger Clasen. Further analysis will be based on this prepared information about each company.

Supply chain costs amount to 85 euros per one tool (Fig. 2). Taking into account that the company sells 450 tools per year, it amounts to approx. 38.000 euros per year for the supply chain. Nevertheless, it is just one half of all expenses related to tools logistics. Transportation costs are the most costly part in the product cost. Therefore, the following chapter will present optimisation model, analysing the possibilities to minimize product cost through supply chain cost minimisation.

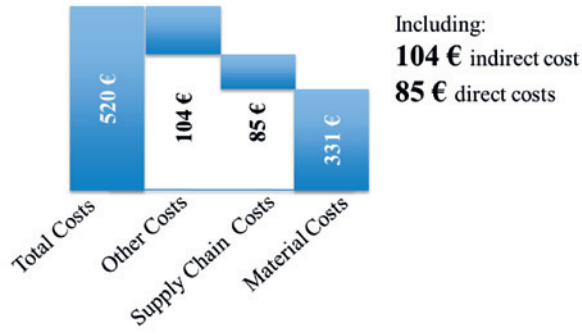

Fig. 2. Impact on final product cost of direct and indirect supply chain costs (made by the authors)

Sourcing includes such processes as inventory planning, scheduling deliveries and choosing transportation mode. The goal of this section is to find the dependence of final product cost on the right transportation freight (air, sea, road or rail freight). The theoretical part discusses the reasons for and appropriateness of different transportation freights or different types of services of the same freight. In the practical part, three main factors are chosen to evaluate the transportation mode, which is the best for a particular supply logistics. The Table 9 below presents the relevant data.

Table 9. Distribution information of main suppliers (created by the authors)

X1								
Suppliers	Product Group	Product weight (kg)	Distance (km)		Costs (euros/unit)		Time (days)	
			Air	Sea	Air	Sea	Air	Sea
Supplier 1	Tools	1.8	9245	21795	16.4	6.2	14	60
			Road	Rail	Road	Rail	Road	Rail
Supplier 2	Tools	1.6	978	1002	6.2	5	23	31

The table divides suppliers into two groups. The first group includes suppliers, for whom air and sea freight is relevant. Supplier 1 supplied around 427 tools in 2013. The second group is suppliers from Europe, for whom road and rail freight is relevant. Rail freight is not used in daily activities of the company activities; nevertheless, it is presented as an option for improvement. Road and rail freight is considered, because the distance between supplier and Holger Clasen is too small to use sea or air freight. The second supplier supplied around 220 tools in 2013. In total, the analysis covers 647 delivered tools. The data is presented for 2013, because only the most recent information is relevant for analysis of the impact on final product cost as well as tendencies of supplier order quantities, transportation costs and delivery time.

To sum up the table, firstly it evaluated the distance between the supplier and Holger Clasen. Secondly, it determined the costs of each transportation mode considering the weight of the product. Thirdly, it considered the delivery time.

From the data presented in Table 9, a linear programming problem was formulated. First of all, a function is settled. In this case, the goal is to minimise the cost of delivery by optimising the quantity of product delivered by a particular freight (air, sea, road or rail). The function is provided below:

$$\min: 1.17x1 + 0.10x2 + 0.27x3 + 0.31x4; \quad (5)$$

In this case, independent variables are x1 (air), x2 (sea), x3 (road) and x4 (rail); it is named the transportation mode, which is used in the process. Constant matrixes are all real and continuous values. In case of the optimisation task, it expresses the cost of delivery evaluated by days. The results are for air freight delivery per day cost EUR 1.17; for sea freight delivery per day cost EUR 0.10; for road freight delivery per day cost EUR 0.27 and for rail freight delivery per day cost EUR 0.31.

Secondly, problem constrains are settled, which are:

$$x1 + x2 + x3 + x4 = 647; \quad (6)$$

It means the total of delivered 647 tools per year. Table 9 presents variable constrains, which in case of x1 delivered product amount are less or equal to EUR 49 euros; in x2, x3 and x4 delivered product amount are less or equal to EUR 1612 euros per delivery. As it was mentioned before, the theory bounds can be expressed by positive and negative values and there is no restriction for the amount.

Table 9. Supply chain constrains (created by authors)

Variable	Cost/product (euros)	Constrains
x1	16.40	16.4x1 >= 49
x2	6.20	6.2x2 >= 1612
x3	6.20	6.2x3 >= 1612
x4	5.00	5x4 >= 1612

Then, the main problem steps are determined and the problem is solved by linear programming tool lp_solve. Several constrain combinations have been considered in order to ensure the best result. For the final results are presented in Table 10. This table demonstrates the distribution of products by transportation mode. In order to achieve the best result, several options have been considered comparing different variables. In the first row of the table, the minimum amount of products to be delivered by air freight is suggested as it is the most costly delivery. The other options mostly offer dividing the product quantities into half and deliver cargos by either sea, road or rail.

As it was already discussed, supply chain costs per one product amount to approx. EUR 85. Table 8 presents prices of transportation.

Table 10. Results of product distribution by freight (in units) (created by the authors)

	Comparing x1 and x2	Comparing x1 and x3	Comparing x1 and x4
Air	3	3	3
Sea	644	384	322
Road	0	260	0
Rail	0	0	322
	Comparing x2 and x3	Comparing x3 and x4	Comparing x2 and x4
Air	0	0	0
Sea	387	65	325
Road	260	260	0
Rail	0	322	322

It is assumed that each calculation applies different constrains. Table 11 presents the comparison of several constrains of distribution. In the first and second cases, comparing distributions between x1 and x2, x1 and x3, it is assumed that the total transportation costs amount EUR 4,042.00; they are the most expensive options for the company. In the third case, comparing x1 and x4, the assumed costs amount to EUR 386.40 less than the first two options. The fourth option is taking in to account x2 and x3, and increases by EUR 355.80 compared with the previous value. The last two options are the cheapest ways to deliver products of the company. Comparing with the first values, they amount to EUR 417.00 less of final transportations costs.

Table 11. Cost distribution within supply chain (in euros) (created by the authors)

	Comparing x1 and x2	Comparing x1 and x3	Comparing x1 and x4
Air	49.20	49.20	49.20
Sea	3,992.80	2,380.80	1,996.40
Road	–	1,612.00	–
Rail	–	–	1,610.00
Total:	4,042.00	4,042.00	3,655.60
	Comparing x2 and x3	Comparing x3 and x4	Comparing x2 and x4
Air	–	–	–
Sea	2,399.40	403.00	2,015.00
Road	1,612.00	1,612.00	–
Rail	–	1,610.00	1,610.00
Total:	4,011.40	3,625.00	3,625.00

Comparing the result with transportation costs presented in Table 8, the company can save over EUR 5 per unit if they choose to distribute products by one of the last options; it is 65 products delivered by sea, 260 products delivered by road and 322 products delivered by rail; or 325 products delivered by sea and 322 by rail. It should be mentioned, that the use of rail freight can cause delay problems and it would add double handling costs needed for rail freight. The main reason for big savings is the fact that the company mainly uses air freight instead of sea, road or rail freights. The reason is mostly related to time as products are needed quickly and it can be due to ineffective inventory planning. The following supply chain optimisation processes will be analysed next.

All in all, the adopted changes in the company can save around 29% of supply chain costs (Fig. 3) and to reduce around 4.7% of total product cost. It means that the company can save more than 81% of overall spending for the supply chain process by taking overall deliveries of 647 products per year.

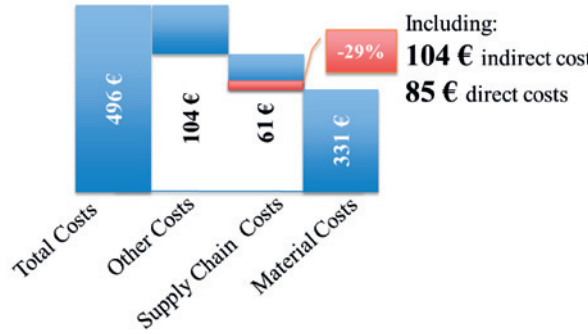

Fig. 3. Product pricing after supply chain optimisation (created by the authors)

The company not only delivers tools, but also more than 100 000 of spare parts and accessories. Considering this number, the company can make enormous savings by reducing air freight deliveries and improving long-term planning and using sea, road or rail freight.

9. Conclusions

The goal of this paper was to discuss the nature of the supply chain, the key processes and their accompanying component costs, analyse the supply chain processes and activities of Holger Clasen, practically including transportation cost, warehousing cost, inventory cost and packaging cost development and to provide optimisation opportunities for the final product cost. All tasks were finalised and the goal was reached.

The importance of the supply chain in the business environment is steadily increasing. The analysis of scientific literature showed that the nature of supply chain has long been separated from its primary functions, where supply chain was identified only as transportation and storage of an operating system. The understanding of supply chains and related education have taken the global scale in business. Supply chain touches many spheres of daily life; therefore, it can be called one of the most critical disciplines in the nowadays global business world.

Analysis of supply chain processes revealed the most costly part, which is transportation, as the company uses air freight for product supply. In order to find out possible savings, a linear programming transportation problem was formulated. The problem was solved using "lp_solve" software, which is perfectly designed to solve transportation problems.

The practical part of this paper presented an example of using the optimisation method in practice. It showed a possibility to optimise the costs of supply chain in one of the three processes of Holger Clasen Company's supply chain. In this practical case,

only the first process sourcing process was taken. The results have shown that optimisation method is an appropriate tool, which could be used in order to reduce costs in a supply chain processes and cut the final costs of the product as well as make it more competitive.

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Indrė LAPINSKAITĖ, PhD, an Associate Professor at Vilnius Gediminas Technical University and Vice-Dean for International Relations, of the Faculty of Business Management. Research interests: sustainable development, pricing, sustainability approach to FMCG.

Justina KUCKAILYTĖ is an ungraduated student of the Business Management Bachelor's Program at Vilnius Gediminas Technical University.