

KAUNAS UNIVERSITY OF TECHNOLOGY
FACULTY OF MECHANICAL ENGINEERING AND DESIGN

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**SUPPLY CHAIN OPTIMIZATION IN A SMALL
MARKET: FOOD INDUSTRY'S CASE**

Final project for Master's degree

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KAUNAS, 2016

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Reviewer

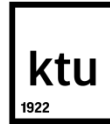
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KAUNAS, 2016



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SUPPLY CHAIN OPTIMIZATION IN A SMALL MARKET: FOOD
INDUSTRY'S CASE

DECLARATION OF ACADEMIC INTEGRITY

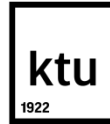
20 MAY 2016

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MASTER STUDIES FINAL PROJECT TASK ASSIGNMENT
Study programme INDUSTRIAL ENGINEERING AND MANAGEMENT

The final project of Master studies to gain the master qualification degree, is research or applied type project, for completion and defence of which 30 credits are assigned. The final project of the student must demonstrate the deepened and enlarged knowledge acquired in the main studies, also gained skills to formulate and solve an actual problem having limited and (or) contradictory information, independently conduct scientific or applied analysis and properly interpret data. By completing and defending the final project Master studies student must demonstrate the creativity, ability to apply fundamental knowledge, understanding of social and commercial environment, Legal Acts and financial possibilities, show the information search skills, ability to carry out the qualified analysis, use numerical methods, applied software, common information technologies and correct language, ability to formulate proper conclusions.

1. Title of the Project

Supply Chain Optimization in a Small Market Food Industry's Case

Approved by the Dean Order No.V25-11-7, 3 May 2016

2. Aim of the project

Evaluate logistic cluster formation possibilities of a small markets food industry's supply chain.

3. Structure of the project

Introduction: problem, aim, novelty and importance.

Literature analysis: literature analysis related to small markets, supply chain, food industry and cluster concept.

Methodology: optimization goal formation, specialist interview methodology, statistical methods overview.

Research part: interview analysis and process, optimization function formulation, logistic network modeling.

Results and recommendations: insights related to a case study of west Europe food industry.

4. Requirements and conditions

5. This task assignment is an integral part of the final project

6. Project submission deadline: 2016 May 20.

Given to the students: Valentas Gružasuskas, Dalia Olencevičiūtė

Task Assignment received: Valentas Gružasuskas

Task Assignment received: Dalia Olencevičiūtė

Supervisor: Assoc. prof. Saulius Baskutis

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1. Literature Review (52 %)	1. Literature Review (48 %)
1.1.. Small markets	1.2. The singularities of small markets food industry
1.4. Logistic clustering process	1.3. Supply chain
2. Methodology (51 %)	2. Methodology (49 %)
2.3. Optimization process	2.1. Logistic network costs 2.2. Expertise assessment
3. Research part (50 %)	3. Research part (50 %)
3.2. Logistic network modelling	3.1. Food supply chain's expertise assessment

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Study area and field: Production and Manufacturing Engineering, Technological Sciences

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SUMMARY

Supply chain complexity due to globalisation has changed dramatically. Today implementation of new distribution strategies and concepts are essential in order to maintain an efficient and visible supply chain. Moreover, the concern for the environment has affected the planning stage of the supply chain. Depending on the distribution strategy financial possibilities and CO₂ emission level must be analysed and the best strategy should be recommended.

This study will be focused on small markets which has a tendency to work with partial freights. One of the key concepts analysed today is logistic cluster development. However, the clustering processes in terms of environmental effect and partial freight distribution practically is not analysed. Therefore, the main aim of the research is to evaluate different distribution strategies based on financial and environment effect by referring to a small market food industry's case.

To achieve this aim several objectives must be accomplished. Firstly, the analysis of literature must be done regarding the food industry, small market concept, supply chain and clustering processes. Later a specialist interview was conducted during which information regarding the west Europe food industry was gathered: warehouse construction costs, warehousing management costs, transportation costs, fuel consumptions rates, demand of manufacturers and other information regarding the order of raw materials. The gathered results were analysed using regression analysis and the data was expressed as fixed costs and variable costs. With this information a case study was modelled using R language. Just in time, consolidation warehouse and partial freight gathering strategies were evaluated in Lithuania, England, Netherlands, Germany and Belgium.

The calculations showed that the best distribution strategy is to gather partial freight in the region (short-freight forwarding), then consolidate them in a regional warehouse and distribute them directly to another region (long-freight forwarding).

By gathering partial freight in the region it is possible to optimize CO₂ emission level and transportation costs.

The main problem of this strategy is that individual companies won't have enough freight to make cost saving routes, therefore only by forming a logistic cluster this strategy is possible to implement. In the scientific literature the possibility for clusters to collaborate together practically is not analysed, therefore this statement – “The collaboration between regional clusters can minimize distribution costs and minimizing the environmental effect for all parties involved in the regional clusters, not only individual players. Without shared knowledge and collaboration between the parties effective partial freight distribution is not possible”, will make a large contribution to further scientific of clustering concepts. These findings can be implemented not only in the food industry, but in other industries which has a tendency to distribute partial freight as well. By implementing automotive vehicles and alternative fuel the CO₂ emission level, transportation costs can be minimized even further.

Valentas Gružasuskas, Dalia Olencevičiūtė. Mažos rinkos tiekimo grandinės optimizavimas: maisto pramonės atvejis. *Magistro* baigiamasis projektas / vadovas doc. dr. Saulius Baskutis, konsultantas prof. Valentinas Navickas; Kauno technologijos universitetas, Mechanikos inžinerijos ir dizaino fakultetas.

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SANTRAUKA

Tiekimo grandinės struktūra šiuo metu yra pasikeitusi dėl globalizacijos. Norint užtikrinti efektyvią ir aiškią tiekimo grandinę, yra būtinas naujų distribucijos sistemų diegimas. Tiekimo grandinės planavimas stipriai pasikeitė dėl naujai besiformuojančio požiūrio į aplinką ir jos taršą.

Išanalizavus krovinių gabenimo tipą, CO₂ išsiskyrimą bei finansines galimybes, galima parinkti geriausią strategiją, kuri tenkintų įmonę. Šis tyrimas skirtas analizuoti mažas rinkas, kuriose dažnai susiduriama su daliniais krovinių ir jų pervežimais. Logistikos klasteriai bei jų formavimasis yra vienas iš pagrindinių šių dienų klausimų. Tačiau dalinių krovinių klasterizacijos procesai dėl aplinkos taršos beveik nėra analizuojami.

Šio darbo tikslas yra išanalizuoti skirtingus krovinių gabenimo atvejus, atsižvelgiant į CO₂ emisijos lygį bei finansines galimybes, kurie gali būti pritaikyti mažoms rinkoms. Siekiant įgyvendinti šį tikslą, pirmiausia buvo analizuojama literatūra, kurioje buvo aprašoma maisto pramonė, mažos rinkos, tiekimo grandinė bei klasterizacijos procesai. Atlikus literatūros analizę, buvo apklausiami įmonių darbuotojai, kurie suteikė informaciją apie maisto pramonę Europoje. Sandėlio statybos kaštai, sandėlio valdymo kaštai, transportavimo kaštai, kuro suvartojimo normos, paklausa, pasiūla ir kita informacija, susijusi su žaliavų pirkimu, buvo surūšiuota. Gauti rezultatai buvo išanalizuoti naudojant regresijos modelį: duomenys buvo išskirstyti į kintančius ir pastovius kaštus. Naudojantis gauta informacija bei R programavimo kalba buvo suprogramuotas algoritmas. Gamyba pačiu laiku, konsolidacijos sandėlių atvejis bei dalinių krovinių surinkimo strategija buvo išanalizuoti Lietuvoje, Anglijoje, Olandijoje, Vokietijoje bei Belgijoje.

Skaičiavimai parodė, kad geriausia distribucijos sistema yra dalinių krovinių surinkimas regione (artimi reisai), jų iškrovimas bendrame sandėlyje ir jų transportavimas į kitą regioną (tolimi reisai).

Taikant dalinių krovinių surinkimą regione įmanoma optimizuoti CO₂ emisijos lygį ir transportavimo kaštus.

Pagrindinė šio būdo problema yra tai, kad atskiros kompanijos neturės pakankamai dalinių krovinių, kuriuos renkant galima būtų sudaryti maršrutus, mažinančius transportavimo kaštus. Todėl,

formuojant logistikos klasterį, šis būdas gali būti įgyvendintas. Mokslinėje literatūroje beveik nėra analizuojama galimybė klasteriams dirbti tarpusavyje, todėl teiginys – „Bendradarbiavimas tarp regioninių klasterių gali minimalizuoti distribucijos kaštus, tuo pačiu sumažinat aplinkos poveikį visiems klasterio dalyviams, ir ne tik individualiems. Be bendros informacijos ir bendradarbiavimo, efektyvus dalinių krovinių optimizavimas nebus įmanomas.“, gali padaryti didelę įtaką klasterizacijos procesų tolimesniems moksliniams tyrimams. Šios išvados gali būti įgyvendintos ne tik maisto pramonėje, bet ir kitose pramonės šakose, kurios turi tendenciją dirbti su daliniais kroviniais.

Papildomai įdiegus autonomines mašinas ir naudojant alternatyvų kurą, CO₂ emisijos lygis bei transportavimo kaštai gali būti sumažinti dar labiau.

Introduction

The world's economy is growing and rapid technology change requires a new perspective to competitive advantage maximization possibilities. This project is orientated to the small markets and particularly to the food industry. Today a new perspective to the small market competitiveness is needed because there are countries that are developing rapidly and some are failing in the market. Regarding the competitive world index Lithuania has dropped from the 41th place to the 48th. Our neighbours: Latvia from the 42th place has dropped to the 52nd, Estonia from the 29th place to the 32nd, however Poland has risen from the 43rd place to the 42nd. Relatively a similar country by size, Netherlands remains in the 8th place. Even the United States lowered its rank from the 3rd place to the 5th. Nevertheless, Belgium has fallen from the 17th to the 18th place [1]. Regarding this information, it is important to determine the competitive advantage maximization strategies of the small markets. The food industry has been chosen because new trends in the industry have required a more complex supply chain management and one of the most complex is the food supply chain. There is a new trend: a consumer's desire for safe, healthy and high quality food products. There are investigations concerning competitive advantage increases for the food industry.

Novelty: only a few analysed the implementation of logistic clusters into a small market. Strategies of industries working in different size markets are different. Larger markets require more complex management of supply chain, naturally the intensity of the flow of cargo is much higher. Smaller markets do not require advanced management systems or tracking systems because their flow of cargo may not need it. Smaller markets need a different approach in order to obtain competitive advantage. Small markets tend to distribute partial freight, which requires a different supply chain management perspective when comparing to larger markets.

This is why the object of the study is to analyse supply chain's competitive advantages maximization strategies and to adapt them to a smaller market. The enterprises consist of various aspects of their activities – manufacturing, distribution, marketing and selling. All these activities are important in order to achieve competitiveness advantage. In order to achieve competitiveness advantage, it is important to conduct a strategic plan and to keep to it. All irrational expenses strongly raise the final cost of a product in small markets as this may lower the company's competitive advantage. Moreover, the environmental effect must be taken into consideration. Partial freight distribution may decrease the transportation costs but due to high number of trucks, or increased distance, the CO₂ emission level might increase. Therefore, it is important to analyse the computability possibilities of environmental effect and profit.

Many companies in a small market cannot compete with the international market and announce bankruptcy every year. It is essential to develop a proper strategy in order to increase competitiveness of small markets. The clusters are identified as a necessary strategy in order to

maintain competitiveness in today's world. However there is a need to conduct deeper model for proper implementation of clusters in a small market. An important factor is logistic computability. Many researches indicate the importance of warehousing, land and sea aspects of proper distribution systems. However, the most effective competitiveness advantages are proper combinations of different logistic types. They are also clearly related to logistic clusters. In order to model a proper clustering model for a small market a wide scope of logistic cluster possibilities needs to be analysed. **Aim:** to evaluate logistic cluster formation possibilities of a small markets food industry's supply chain.

Objectives:

1. analyse the small market's singularities;
2. overview the singularities of food industry's supply chain;
3. overview the logistic type's computability issues and warehousing possibilities for the food industry
4. overview the concept of clusters;
5. conduct a specialist interview to determine the common problems of the supply chain and gather information about the logistic network;
6. modell just in time, consolidation warehouse and partial freight optimization logistic network scenarios and evaluate these strategies based on costs and CO₂ emission.

Contribution of Authors:

Valentas Gružasuskas:	Dalia Olencevičiūtė:
1. Literature Review (52 %)	1. Literature Review (48 %)
1.1. Small markets	1.2. The singularities of small markets food industry
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2. Navickas, Valentinas; Baskutis, Saulius; **Gružasuskas, Valentas**. Logistic cost optimization in the food industry of small countries // Vadyba = Journal of management / Vakarų Lietuvos verslo kolegija. Klaipėda: Klaipėdos universiteto leidykla. ISSN 1648-7974. 2015, vol. 26, no. 1, p. 61-66. [IndexCopernicus; CEEOL; Business Source Complete] [M.kr. 04S].
3. Baskutis, Saulius; Navickas, Valentinas; **Gružasuskas, Valentas; Olencevičiūtė, Dalia**. The temperature control impact to the food supply chain // Mechanika 2015: proceedings of the 20th international scientific conference, 23, 24 April 2015, Kaunas University of Technology, Lithuania / Kaunas University of Technology, Lithuanian Academy of Science, IFTOMM National Committee of Lithuania, Baltic Association of Mechanical Engineering. Kaunas: Kauno technologijos universitetas. ISSN 1822-2951. 2015, p. 42-47. [M.kr. 09T].
4. Navickas, Valentinas; **Gružasuskas, Valentas**. Big data concept in the food supply chain: small markets case // Analele Stiintifice ale Universitatii Al I Cuza din Iasi - Sectiunea Stiinte Economice = Scientific annals of economics and business. Iasi: Alexandru Ioan Cuza - University of Iasi. ISSN 0379-7864. 2016, vol. 63, no. 1, p. 15-28.
5. V. Navickas, S. Baskutis, V. **Gružasuskas**, The food industry's supply chain's effectivity management: small markets' case, Acta Oeconomica Universitatis Selye, vol. 4, no.2, pp.149-161, 2015.
6. S. Baskutis, V. Navickas, V. **Gružasuskas**, A. Kabasinskas; "Warehouses Consolidation in the Logistic Clusters: Food Industry's Case", Polish Journal of Management Studies, ISSN 2081-7452, (Submitted).
7. Participation in international school organized by Bremen University in Germany, "LogDynamics" school, Control Interfaces in Logistics: Data and Algorithms, February 29 to March 4, 2016

1. Literature Review

The literature review is focused on several parts. In the first part a focus on a small market is maintained. As was mentioned in the introduction part, small market's today have difficulties to compete with the international market, therefore, proper competitiveness advantage strategies must be made. One of the possible small markets has been chosen for analysis. Lithuania is a tactical place to develop food-manufacturing companies, because it is in a good geographic position for a distribution centre [7]. In addition, Lithuania has a strong tendency to work in the manufacturing area, because of high specialist workers and cheap labour [8]. Veiderytė identified the importance of sea clusters in Lithuania enterprise [11]. However, this particular work is oriented only to the sea sector and doesn't consider other combinations of distribution systems. Computability of different distribution systems is an important factor to consider while developing competitive strategies.

The other part of literature review is focused on the food industry. The food industry recently started to receive more attention from the government and consumers, therefore, it is chosen as a key representative industry. There is a new trend that consumer desire for safe, healthy and high quality food products [2]. There are studies done about competitive advantage strategies for the food industry. Sam Saguy and Vera Sirotinskaya studied the importance of innovations in the food industry, mainly on medium enterprises [3]. The globalization has effected the perception of wealth creation – today resources and land are not the main factor influencing wealth generation, the main factor is what kind of know how the enterprise has and how efficient it can utilize it [4]. The internet has created new possibilities and today industries that learn how to distribute information and products faster will prevail. There was a study done which analysed the logistic cost singularities and their results indicated the need for caution in interpreting changes in logistics costs, and for simultaneously controlling the effects of numbers of employees, transport costs, warehousing costs and total logistics costs [6].

The last part of the analysis of literature was focused on clustering process. Part of the literature indicates the importance of clusters in a small market and they identify cluster formation as one of the most important strategies for a small market [10]. Bosana and Gebresenbet indicated the importance of food supply chain clustering in order to increase supply chain competitiveness [5]. Rivera analysed the logistic cluster concept and concluded that companies located in logistic clusters do collaborate more and offer more value added services than companies that are not agglomerated [9]. Turkensteen and Klose analysed the demand dispersion on logistics costs and determines that the market segmentation is essential for warehouse management systems and offers a one-to-many distribution system in which central facility serves all demand points [12]. For a proper competitiveness strategies development several key areas will be analysed in the following paragraph.

1.1. Small markets

1.1.1. Peculiarities of small markets

Globalization has made an impact to the world technological and economics growth. More and more companies are striving to achieve maximum results by using advanced technologies and other strategies. The problem is that the world has changed and the main power isn't any more in the land, resources and population. These principals would have been a result in the past, but not today. Today all countries are small relative to the relevant market [13]. This happened, because of rapid technology change and free trade. Also a large impact was made by the internet – it reduced the transaction cost and speed. “As small enterprises are economically viable by being competitive in some fields and being complimentary to large firms in other fields, so are small countries competitive and complementary to large countries in the world market” [14]. In today world this is even more reasonable, because business can do trade with the whole world and the size of the country doesn't matter.

Before analysing the singularities of small markets and determining the main aspects and possibilities of competitive strategies, is important to understand what exactly small markets are and how they can be categorized. The categorization of countries has been developed for quite a while.

First of all it is important to mention the basic categorization of countries – by measuring the size. This particular categorization developed in the beginning of the 19th century researches used geographical measures to categorize the country. But measuring only the area isn't effective in these days. Later researches have started to offer a measurement based on population, but this particular measure wouldn't explain African situation these days. In Africa there are large countries which cannot be called large. Because of these other researches offered to analyse the national income. Gross domestic product (GDP) and this particular method is one of the best ones to categorize countries. Regarding this information Damijan has combined all these criteria and developed an empirical statistical analysis and determined a new approach to countries categorization [15]. Also the researched and imperial weight coefficients need to be changed today, because the world has developed and the criteria's has shifted.

$$ASC_i = \frac{sA_i * w_1 + sP_i * w_2 + sG_i * W_3}{w_1 + w_2 + W_3} \quad (1.1)$$

ASC – index of a country's size

sA_i – ratio of the country's size to the total world size

sP_i – ratio of the country's population size to the world population size

sG_i - ratio of the country's GDP to the total world GDP

w_1, w_2, W_3 – weight coefficients achieved by empirical statistics

Using 1.1 formula the countries by their population, GDP and area can be calculated and categorized. The results were modified and showed that out of 193 countries: 4 large, 26 medium, 97 small and 66 micro states. But these results need to be changed a bit for better accuracy of today's world, because of these the categories were changed by very large, large, medium and small. Also the interval was modified to get better results.

Table 1.1 Classification of countries according to area, GDP and population. [16]

Country	GDP (\$, billion)	Population	Area (km ²)	Type
China	10355,4	1.393.783.836	9.596.947	Very large
United States	17416,3	322.583.006	9.629.056	Very large
Egypt	284,9	83.386.739	1.001.450	large
India	2047,8	1.267.401.849	3.287.265	large
Turkey	813,3	75.837.020	783.562	large
Belgium	527,8	11.144.420	30.528	medium
Czech Republic	200	10.740.468	78.866	medium
Finland	276,3	5.443.497	338.147	medium
Germany	3820,5	82.652.256	357.021	medium
Greece	246,4	11.128.404	131.956	medium
Ireland	245,8	4.677.340	70.273	medium
Italy	2129,3	61.070.224	301.318	medium
Japan	4769,8	126.999.808	377.873	medium
Netherlands	880,4	16.802.463	41.528	medium
Poland	552,2	38.220.543	323.251	medium
Sweden	559,1	9.631.261	449.954	medium
Switzerland	679	8.157.896	41.284	medium
Ukraine	134,9	44.941.303	603.701	medium
United Kingdom	2847,6	63.489.234	2.429	medium
Latvia	32,8	2.041.111	646	small
Lithuania	48,7	3.008.287	653	small
United Arab Emirates	416,4	9.445.624	836	small

Table 1.1 shows the modified results and just a sample of all the countries. These results are also made only by regarding the criteria of area, GDP and size and many of them should be questionable, because they do not exactly represent the situation. Because of this it is important to analyse the singularities of the countries. Every country is really different and may have it owns peculiarities. Lithuania has been chosen as the primary test subject, because by its size, GDP and

population it is a small market, that has a low economics power, small market and population. In summary a small market is a country whose population is lower than 16 million and gross domestic product is less than 100 billion dollars. The markets can't be categorized only by the GDP, population and area. This particular method would be fine for the 19th century, but not for the 21st. This has changed because of the rapid technologies development and the internet has increased the speed of information, technologies and money.

First of all it is important to analyse the free trade concept. Small markets can now participate in international trade freely and their size, pollution of area do not matter. The only thing that matters is how they use the resources and technologies that they control. The free trade concept is closely related to the public sector. The public sector in small markets usually is big and requires more expenses, but they are also interested to develop even more the countries policies to achieve better possibilities to use technologies and international trade. The strategy of developing technologies can be used by large and small markets. Padilla-Perez and Gaudin indicate that “in the last decade, there has been an increasing recognition among central America policy makers of the central importance of science, technology and innovation (STI) for inclusive and sustainable economics growth, based on higher productivity. Officials in each country showed that Central American government have built public organizations and institutions to support STI” [17]. These results show that the government understands the free trade concept and is creating development centres and other ways to help to achieve maximum free trade. Chen and Turnovsky also indicate the importance of free trade. They analyse the impacts of different structural shocks through their effects on agent's relative wealth and their labour supply decisions. Their results indicate that “Both theoretical analysis and numerical simulations demonstrated that openness – access to an international capital market – enriches the growth-inequality relations from those of corresponding closed economy” [18].

Another important aspect of small markets is the cost of labour and size of a company. In high developing countries the cost of land or labour can be high, because of the living expenses and high cost of education. The international comparison of hour labour indicates that in 2010 the hourly labour cost in Denmark was about 33 dollars per hour, in Germany it was about 23 dollars, in China - about 3 dollars [19]. This information is important, because the cost may vary from the country size. Also a similar situation is in Lithuania. In Lithuania there are many high educational workers. 1st in the EU for mathematics, science and technology graduates per capital and 2x EU average of young people studying Engineering, Manufacturing and Construction [20] [8]. Also regarding the educational index Lithuania is in the 35th place, Belgium is the 21st, Netherlands - the 4th. While other developed countries are failing behind the educational level – Russia - the 57th, the United Kingdom – the 14th [21]. Because of this the labour cost is significantly different from different countries. Because Lithuania is a relative small country with a low GDP, the labour cost is also lower, but the

educated work force is much higher than in some countries. The size of a company is also closely related to the size of the country. Yo-yi and Deng-Shing Huang analysed a competition equilibrium model and considered two types of firms: big with a higher fixed cost but lower marginal cost, and small with a lower fixed cost but with high marginal cost. They proved that free trade may not always benefit the big-country and big firms. The smaller country may take more than proportional market share after free trade in the big-firm and small firm market, if the cost advantage dominates the disadvantage in the smaller home market. They also proved that an increase in the global market size may lead to more small-size firms, unless the elasticity of substitutions is large enough [22]. These findings also indicate the impotency of Scale economic.

Economic of scale can give competitive advantage and also they can provide negative effect. The main principles of the scale economy that provide positive effect [23]]:

1. Purchasing - are gained when larger firms buy in large quantities and achieve discounts. For example, a large company can buy its products in much greater quantities than a small company.
2. Financial – large company can usually borrow money cheaper than small firms. This is because they usually have more valuable assets which can be used as a deposit, and are seen to be a lower risk, especially in comparison with new businesses. In fact, many new businesses fail within their first few years because of cash-flow inadequacies.
3. Managerial - administrative savings can arise when large firms spread their administrative and management costs across all their departments.
4. Technical - the cost savings a firm makes as it grows larger, and arise from the increased use of large scale mechanical processes and machinery.
5. Marketing – large companies can do a more aggressive marketing style, because if they fail to sell the product, they won't lose large amounts of profit, this doesn't apply to small countries. They can lose significantly more.

Also there are reasons why economic of scale can be negative [24]:

1. Larger firms often suffer poor communication because they find it difficult to maintain an effective flow of information between departments, divisions or between head office and subsidiaries.
2. Co-ordination problems also affect large firms with many departments and divisions, and may find it much harder to co-ordinate its operations than a smaller firm.
3. Average cost inefficiency is the loss of management efficiency that occurs when firms become large and operate in incompetitive markets. Such loses of efficiency include paying for resources, such as paying managers higher salaries than needed to secure their services, and excessive waste of resources.

4. Low motivation of workers in large firms is a potential diseconomy of scale that results in lower productivity, as measured by output per worker.
5. Large firms may experience inefficiencies related to the principal-agent problem. This problem is caused because the size and complexity of most large firms means that their owners often have to delegate decision making to appointed managers, which can lead to inefficiencies.

Understanding the concept of small markets is essential for a proper competitive maximization strategy. It is not possible to use clustering process without understanding the main economic principles or profit maximization.

1.1.2. Why analyse small markets?

This part will indicate the possibilities of small versus large markets by comparing world global competitive index (GCI). Competitive advantage is essential for every country in order to maximize its profit and power. The report groups the main competitive indexes and summarizes them by [1]:

1. Institutions - the institutional environment is determined by the legal and administrative framework within which individuals, firms, and governments interact to generate wealth.
2. Infrastructure - extensive and efficient infrastructure is critical for ensuring the effective functioning of the economy, as it is an important factor in determining the location of economic activity and the kinds of activities or sectors that can develop within a country.
3. Macroeconomic environment - the stability of the macroeconomic environment is important for business and, therefore, is significant for the overall competitiveness of a country.
4. Health and primary education - a healthy workforce is vital to a country's competitiveness and productivity. Workers who are ill cannot function to their potential and will be less productive. Poor health leads to significant costs to business, as sick workers are often absent or operate at lower levels of efficiency.
5. Higher education and training - quality higher education and training is crucial for economies that want to move up the value chain beyond simple production processes and products.
6. Goods market - efficiency countries with efficient goods markets are well positioned to produce the right mix of products and services given their particular supply-and-demand conditions, as well as to ensure that these goods can be most effectively traded in the economy.
7. Labour market efficiency - the efficiency and flexibility of the labour market are critical for ensuring that workers are allocated to their most effective use in the economy and provided with incentives to give their best effort in their jobs.
8. Financial market development - the financial and economic crisis has highlighted the central role of a sound and well-functioning financial sector for economic activities. An efficient

financial sector allocates the resources saved by a nation's citizens, as well as those entering the economy from abroad, to their most productive uses.

9. Technological readiness - in today's globalized world, technology is increasingly essential for firms to compete and prosper. The technological readiness measures the agility with which an economy adopts existing technologies to enhance the productivity of its industries, with specific emphasis on its capacity to fully leverage information and communication technologies (ICTs) in daily activities and production processes for increased efficiency and enabling innovation for competitiveness.
10. Market size - the size of the market affects productivity since large markets allow firms to exploit economies of scale. Traditionally, the markets available to firms have been constrained by national borders. In the era of globalization, international markets have become a substitute for domestic markets, especially for small countries.
11. Business sophistication - there is no doubt that sophisticated business practices are conducive to higher efficiency in the production of goods and services. Business sophistication concerns two elements that are intricately linked: the quality of a country's overall business networks and the quality of individual firms' operations and strategies.
12. Innovation - innovation can emerge from new technological and non- technological knowledge. Non-technological innovations are closely related to the know-how, skills, and working conditions that are embedded in organizations

The global competitiveness report assesses the competitiveness landscape of 144 economies, providing insight into the drivers of their productivity and prosperity. The report remains the most comprehensive assessment of national competitiveness worldwide.

Table 1.2 The Global competitiveness index 2014–2015 rankings and 2013–2014 comparisons [1].

Country/Economy	Score (1–7)	GCI 2013-2014	GCI 2014-2015
United States	5.54	3	5
Finland	5.50	4	3
Germany	5.49	5	4
Netherlands	5.45	8	8
United Kingdom	5.41	9	10
Sweden	5.41	10	6
Norway	5.35	11	11
Belgium	5.18	18	17
Luxembourg	5.17	19	22
France	5.08	23	23
Ireland	4.98	25	28
Estonia	4.71	29	32
Lithuania	4.51	41	48
Latvia	4.50	42	52
Poland	4.48	43	42

Table 1.2 indicates the situation of the countries in the global competitive index ranking. The United States has lowered its rank by two positions, while Germany has increased from the 5th to the 4th. Some of the smaller countries have also increased their competitiveness, Belgium from the 18th went to the 17th, while the Netherlands has remained in the 8th place. Also a relatively small but powerful country Sweden has risen from the 10th place to the 6th place. This information shows that utilization of technology and resources can maximize competitive advantage and not only the size of the countries.

The next index that needs to be reviewed is logistics. Supply chain in today's economy is essential, because the main idea is to distribute information about your product and the quality of the product doesn't necessarily need to be the highest. Because of this it is essential to overview the logistics index of countries. The logistics performance (LPI) is the weighted average of the country scores on the six key dimensions [25]:

1. customs - efficiency of the clearance process (i.e., speed, simplicity and predictability of formalities) by border control agencies, including customs;

2. infrastructure - quality of trade and transport related infrastructure (e.g., ports, railroads, roads, information technology);
3. international shipment - ease of arranging competitively priced shipments;
4. logistics competence - competence and quality of logistics services (e.g., transport operators, customs brokers);
5. tracking & tracing - ability to track and trace consignments;
6. timeliness - timeliness of shipments in reaching destination within the scheduled or expected delivery time.

Table 1.3 Global logistics performance index (LPI) 2014 [25]

Country	LPI Rank	LPI Score	1	2	3	4	5	6
Germany	1	4.12	4.10	4.32	3.74	4.12	4.17	4.36
Netherlands	2	4.05	3.96	4.23	3.64	4.13	4.07	4.34
Belgium	3	4.04	3.80	4.10	3.80	4.11	4.11	4.39
United Kingdom	4	4.01	3.94	4.16	3.63	4.03	4.08	4.33
Sweden	6	3.96	3.75	4.09	3.76	3.98	3.97	4.26
Norway	7	3.96	4.21	4.19	3.42	4.19	3.50	4.36
Luxembourg	8	3.95	3.82	3.91	3.82	3.78	3.68	4.71
United States	9	3.92	3.73	4.18	3.45	3.97	4.14	4.14
Japan	10	3.91	3.78	4.16	3.52	3.93	3.95	4.24
Ireland	11	3.87	3.80	3.84	3.44	3.94	4.13	4.13
France	13	3.85	3.65	3.98	3.68	3.75	3.89	4.17
Switzerland	14	3.84	3.92	4.04	3.58	3.75	3.79	4.06
Denmark	17	3.78	3.79	3.82	3.65	3.74	3.36	4.39
China	28	3.53	3.21	3.67	3.50	3.46	3.50	3.87
Latvia	36	3.40	3.22	3.03	3.38	3.21	3.50	4.06
Estonia	39	3.35	3.40	3.34	3.34	3.27	3.20	3.55
Lithuania	46	3.18	3.04	3.18	3.10	2.99	3.17	3.60

The index of competitiveness is a global factor relating not only to the industry, because of these the Logistic performance index is essential for a proper analysis of small markets. One of the best small markets examples is the Netherlands and Belgium. These are significant small countries, but their overall logistics performance is one of the best. On the other hand, Lithuania is only in the 46th place of the LPI. First of all it is important for Lithuania to prepare efficiency the ordering process and the declarations, because this is lowered by a point from the first places. The infrastructure of

Lithuania needs to be reorganized, because even if it is in a good geographic position, it is still lacking efficiency. Regarding the size of the country the international shipment isn't so low, because Lithuania is positioned next to the Baltic Sea and the shipping possibilities are quite good. Other aspects of Lithuania also need to be optimized. The problem is that the logistic sector is lacking technological innovation, but on the other hand a small market doesn't necessary need these technologies at the start, because they don't have large flows of orders. The first thing should be to optimize the infrastructure and customs.

The last important index is the global manufacturing competitiveness index. This is another area important to analyse, because the small markets have cheap and professional labor that can increase their manufacturing level. On the other hand small markets may have less advanced technologies, so the manufacturing index may be lower in some countries. The competitive index also depends on the countries strategies some of them may choose distribution, other services and part of them manufacturing.

In order to quantify country competitiveness more precisely, manufacturing executives were asked to rate the overall manufacturing competitiveness of 38 countries, currently and in five years. The selection of the countries was based on the conclusions of a sampling of executives as well as subject matter experts from the Council, Deloitte, and Clemson University. Also, executives who participated in the survey could add and rate any other country not included on the list. The global manufacturing competitiveness index (GMCI) was developed directly from their responses, assigning a single number for each country reflecting its relative attractiveness in terms of manufacturing.

Table 1.4 2013 Country manufacturing competitiveness index rankings [26]

Current competitiveness			Competitiveness in five years		
Rank	Country	Index score 10 = High 1 = Low	Rank	Country	Index score 10 = High 1 = Low
1	China	10.00	1	China	10.00
2	Germany	7.98	2	India	8.49
4	India	7.65	4	Germany	7.82
14	Poland	5.87	18	Poland	5.69
15	United Kingdom	5.81	19	United Kingdom	5.59
21	Sweden	5.50	20	Switzerland	5.42
22	Switzerland	5.28	21	Sweden	5.39
23	Netherlands	5.27	24	Netherlands	4.83
27	Belgium	4.50	30	Belgium	3.63

The statistics of the manufacturing index is in the last area, because they are more based on a survey type, then structural analysis. Nevertheless this information can help to understand the positioning of countries. China is long known for the “China effect”, if you are starting to manufacture a new product, it is likely that China will start manufacturing the same product, but a cheaper one. Other industries such as Germany and India are forecasted to grow the manufacturing index, because these countries have positioned themselves a more manufacturing type. This can also be seen by the Logistic performance index, because China is only in the 28th place, nevertheless it is still a powerful country. A different version can be seen with the Netherlands and Belgium. These two countries are not so competitive in the manufacturing area, but the logistic index shows a high competence. This is essential to understand, that small countries also have potential to become powerful countries, but they need to conduct a strategy for competitive advantage maximization.

1.1.3. The basic structure of small markets

The second part of the small market concept that is necessary to overview in order to achieve maximum competitive advantage is a market structure. This is necessary because depending on the industry the strategies of profit maximization can differ. Firstly, it is essential to distinguish the industry types. This can be done by overviewing the global industry classification standard (GICS). GICS was created for investors to efficiency identify the companies working area, this can be achieved by separate the sectors and industry’s. The GICS has been accepted for investors as a research and portfolio management helper. The GICS system consists of 10 sectors, 24 industry groups, 68 industries and 154 sub-industries.

Table 1.5 Global industry classification standard [27]

Sector	Industry group	Industry	
Energy	Energy	Energy Equipment and Services	
		Oil, Gas & Consumable fuels	
Materials	Materials	Chemicals	
		Construction Materials	
		Containers & Packaging	
		Metals & Mining	
		Paper & Forest Products	
Industrials	Capital Goods	Aerospace & Defence	
		Building Products	
		Construction & Engineering	
		Electrical Equipment	
		Industrial Conglomerates	
		Machinery	
		Trading Companies & Distributors	
	Commercial Services & Supplies	Commercial Services & Supplies	
	Transportation	Transportation	Air Freight & Logistics
			Airlines
			Marine
			Road & Rail
			Transportation Infrastructure
	Consumer Discretionary	Automobiles & Components	Auto Components
Automobiles			
Consumer Durables & Apparel		Household Durables	
		Leisure Equipment & Products	
		Textiles, Apparel & Luxury Goods	
Consumer Services		Consumer Services	Hotels, Restaurants & Leisure
			Diversified Consumer Services

	Media	Media
	Retailing	Distributors
		Internet & Catalog Retail
		Multiline Retail
		Specialty Retail
Consumer Staples	Food & Staples Retailing	Food & Staples Retailing
	Food, Beverage & Tobacco	Beverages
		Food Products
		Tobacco
	Household & Personal Products	Household Products
Personal Products		
Health Care	Health Care Equipment & Services	Health Care Equipment & Supplies
		Health Care Providers & Services
		Health Care Technology
	Pharmaceuticals, Biotechnology & Life Sciences	Biotechnology
		Pharmaceuticals
		Life Sciences Tools & Services
Financials	Banks	Commercial Banks
		Thrifts & Mortgage Finance
	Diversified Financials	Diversified Financial Services
		Consumer Finance
		Capital Markets
	Insurance	Insurance
	Real Estate	Real Estate -- Discontinued effective
		Real Estate Investment Trusts (REITs)
		Real Estate Management & Development
Information Technology	Software & Services	Internet Software & Services

		IT Services
		Software
	Technology Hardware & Equipment	Communications Equipment
		Computers & Peripherals
		Electronic Equipment & Instruments
		Office Electronics
		Semiconductor Equipment & Products
		Semiconductors & Semiconductor Equipment
Telecommunication Services	Telecommunication Services	Diversified Telecommunication Services
		Wireless Telecommunication Services
Utilities	Utilities	Electric Utilities
		Gas Utilities
		Multi-Utilities
		Independent Power Producers & Energy Traders

Table 1.5 indicates the main classification of industries: energy, materials, industry consumer discretionary, consumer staples, health care, finances, Information technology, telecommunication services and utilities. This information is important, because every industry in different market may have different market structure and may require different strategies for competitive advantage maximization. Mura and Buleca analysed the trends in the Slovak Food industry. In today's world small and medium food companies are working domestically and also internationally, because the international market creates new opportunities - faster growth and better market position. "According to their findings in business practice the Slovak food small and medium enterprises are economically active predominantly in Central European economic area and there are only simpler forms of expansion into foreign markets" [28]. These findings show how competitive advantage strategy can differ for a company's size and industry. Other researches also analysed the small and medium food industry in the Greek market. They evaluated their firms based on sustainable performance measurements – consumption, flexibility, responsiveness, product quality and total supply chain

performance. The findings identified the food supply chain members who perform or underperform in relation to size. Specific reasons are provided for these sustainability performance differentials including the role of locality as well as the asset and resources intensity of some operations. Also they indicated that small firms are the top performers in terms of sustainability performance especially in the area of flexibility and responsiveness. Another key finding is that members of this chain underperformed in the product conversation time measure, irrespective of size [29]. This is another issue related to food industry – the flow of orders intense and the quantity often is quite low. Because of this many firms find difficulty with the supply chain. This may result in weaker competitive advantage for the food industry. On the other hand an industry with a lower order and product quantity also can use supply chain optimization as a competitive advantage strategy, but the strategy could differ from speed and precision to lower price or differential logistics. Wagner, Riedel and Kimme analysed the Large Scale Manufacturing (LSC) in the metal-plastic-hybrid industry. They designed a logistic concept and a logistic planning procedure that was oriented to multifunctional lightweight structures. This strategy made a different in the common manufacturing process, usually they ordered and started production, but the new plan designed a cycle between the numbers of transportation cycle and warehouse space. Also the plan offered to order constant quantities and not deepened on the required amount, this helped to achieve better prices from the suppliers [30]. Competitive strategies differs from the market size and the industry, the same strategy as works in the metal industry could be devastating to a food company, because of this it is important to understand the analysed countries industry's and markets structures. Lithuania is a small country that is a good example of the variety of companies and industries.

Table 1.6 Lithuania active enterprise in the beginning of the year [31]

Yr	All types of industries		Food product manufacturing		Warehousing and transportation	
	Companies	Variation	Companies	Variation	Companies	Variation
2006	56792	-	1030	-	801	-
2007	60094	5,81	897	-12,91	890	11,11
2008	63562	5,77	823	-8,25	948	6,52
2009	65629	3,25	788	-4,25	1057	11,50
2010	63840	-2,73	761	-3,43	1133	7,19
2011	66840	4,70	801	5,26	1256	10,86
2012	62889	-5,91	757	-5,49	1313	4,54
2013	65779	4,60	797	5,28	1458	11,04
2014	68279	3,80	816	2,38	1592	9,19
2015	76428	11,93	880	7,84	1857	16,65
Yr	Furniture Manufacturing		Constructions		Tobacco manufacturing	
	Companies	Variation	Companies	Variation	Companies	Variation
2006	608	-	1605	-	1	-
2007	650	6,91	2437	51,84	1	0,00
2008	721	10,92	3004	23,27	1	0,00
2009	798	10,68	3620	20,51	2	100,00
2010	791	-0,88	3417	-5,61	1	-50,00
2011	781	-1,26	3265	-4,45	1	0,00
2012	722	-7,55	2934	-10,14	1	0,00
2013	741	2,63	3017	2,83	1	0,00
2014	755	1,89	3070	1,76	1	0,00
2015	850	12,58	3619	17,88	1	0,00

Table 1.6 indicates the active enterprises of Lithuania by their industry. In the last 10 year Lithuania has increased her overall active company quantity by 19636, also regarding the Lithuania's DGP growth the country is prospering. It is also important to indicate that the food industry's amount of companies has decreased in the last 10 years by 14.56%. Nether less the food export has increased averagely by 12.74% from 2009 till 2014 [32]. Similar tendencies can be seen in other industries. Furniture manufacturing company's amount has increased by 39.8%, construction companies by 125.48%. Also there is an increased demand in warehousing and transportation companies – growth

of 131.8% since 2006. This information is essential in order to understand competitive advantage. The economy is growing, there are more and more companies in the industry, nether less many of them bankrupt in the first years of business. The technologies have changed and it is needed to conduct new competitive strategies in order to maximize competitive advantage.

The next concept that needs to be overviewed for a proper clustering model is market structure. Different industries has different market structures and it can be that the same industry in different countries will work in different markets. On the other hand a large company that is working world wide may work in different markets, regarding the country's economic structure. There are many researches done that identify the priority of understanding the market structure. Hsu, Lo and Wu analysed the nexus of privatization policy and market concentration ratio in a mixed oligopoly "where one enterprise competes against n private firms with asymmetric cost. It showed that the nexus of privatization policy and market concentration ratio is highly sensitive to the curvature of the market demand. When the market demand is concave (convex to the origin, a higher concentration ratio leads to a higher (smaller) degree of privatization" [33]. This research identifies that in an oligopoly market when another party enters the market, or the government policy changes, the demand is related. Regarding this fact the company's strategy may change. Other researchers analysed the R&D and innovation in the oligopoly market. "Their model described the optimal R&D choice of firms operating in an oligopoly market for several substitute good, they predicted a convex relationship between competition and innovation; that is, innovation declines as a function of product market competitiveness up to a certain level, and rises thereafter, when competition becomes intense. I other words, firms in an oligopoly market may engage in an "R&D war" and spend excessively on R&D when product market competition is tense" [34]. These research also indicates the competitive strategies of oligopoly market, but they research a different area – technology development. R&D centres and innovation may help companies to increase competitive advantage, but the strategy and the investment size may differ depending on the market structure. These researches showed only one type of market peculiarities, but there are other types of markets that is essential to analyse. In order to understand correctly the market structure, there are free main important questions:

1. What is the concentration of buyers and sellers?
2. What kind of product differentiation there is in a market?
3. Are there barriers to enter the market?

By answering to these questions, there can be main 4 types of market structure.

Table 1.7 Market structure types and characteristics [35]

Market structure	Number of Buyers & sellers	Type of product	Barriers to entry industry	Firm's influence over price	Industry's Example
Perfect competition	Many	Identical	None	None	Agriculture - crops, cereal
Monopolistic competition	Many	Differentiated	None	Moderate	Chicken, beef, pork
Oligopoly	Few	Identical or differentiated	High	Moderate to substantial	Dairy
Monopoly	One	Unique	Impossible	Substantial	Electricity

There are a few researches done about the market structure in small countries. Eifert analysed infrastructure and market structure in least developed countries. His research logic is based on the scale economies (1.1 chapter). The concept is demonstrated in a simple homogenous-products oligopoly framework with heterogeneous technologies, an explicit model of electricity service and a fixed set of large incumbent firms facing potential entry. The results of this research were: „the most interesting possibility is that incumbent firms may bargain with providers of public services for (inefficient) preferential treatment that keeps the playing field asymmetric. This story is consistent with the well-known “missing middle” phenomenon in least-developed countries, and may contribute to weak product market competition and high prices“ [36]. These results indicated the importance of market structure in different countries. In Lithuania the electricity industry can be called monopolistic, because for Lithuania’s enterprises the entry to the market is impossible. Different situation may be in other countries. On the other hand, the situation in Lithuania may also change if more neighbourhood companies would start providing electricity services. Another research indicates the importance of small markets communication with large multinational firms. The research results show that „corporate reputation has a negative effect on a firm’s foreign direct investment involvement in the least developed countries, supporting the view that reputation could constrain firm action in uncertain environments“ [37]. Small countries can only achieve competitive advantage by working internationally. This is also closely related to foreign investments and allowing firms to join the market. Clustering process may not be so effective in a local market, but it can show a significant decrease in cost, when small countries are working in a large market. It is also important to understand the relationship between large and small countries. Jaaskela and Kulish identified the butterfly effect of small economies. “Their main finding is that “smallness” is a property of the unique rational expectations equilibrium of the large economy, and not a general property of small open economy

model. If the large economy fails to anchor expectations, shocks to the small economy can affect the large one. This form of indeterminacy gives rise to a butterfly effect” [38].

To sum up, small markets are similar to small and medium enterprises by their behavior. It is hard for them to influence the world economy. Nevertheless there are examples of countries that have developed a decent competitive strategy, that helps them to compete with large nations. The basic overview of the singularities of small markets is necessary for the next phase of the research. A more depth analysis of a small market food industry is necessary for a proper clustering model. Also the supply chain concept and logistic compatibility for the food industry needs to be reviewed. This information is essential in order to model a proper clustering process for the small markets food industry.

1.2. The singularities of small markets food industry

As it is known, a human cannot survive without the necessary process in life. The most important source of life is water, because the human body is made up of more than 70 percent of water. But do not forget, from where all living organisms get energy. A person could survive about 3-5 weeks, when he is drinking enough water without food. On the other hand, a normal person could survive only 4-6 days completely without food and drink.

Food is a necessary condition of human existence – the body’s building blocks. It is an inherent part of human life, as well as sleep, rest, water.

Because of the importance of food for human body, it must be always easily accessible. Food market needs to be constantly filled with fresh food products. Therefore, enterprises need to have reliable suppliers, optimal logistics and coordinated warehouse work plan.

1.2.1. The History of Food Processing

The first steps in food processing starts in ancient Egypt and it symbolizes the history of the culture of mankind. At present, bread, which is characterized by using fermentation action of yeast and which uses flour as its raw material, is baked all over the world. The beginning of beer also starts in Babylon and Egypt in the period from 3000 to 5000 BC. In the beginning of humanity, humans hunted wild animals, first with their hands, later they constructed tools from stone, wood. They also collected wild plants and made food. In every age, humans became smarter and more creative. They started to keep some products for example, for winter. From 11,000 BC, humans began to change lifestyle from a hunter-gatherer towards cultivating crops and animals and use it for food [39].

Nowadays, the processed foods that are prospering in shops are foods which are modern processed or left from the ancestry. Their manufacturing technology, process control, manufacturing, packaging environmental facilities have been advanced and rationalized to an incomparable extent in the last 30 years [40]. Seeing that food science is progressing, due to the general introduction of hygienic, applied microbiology, mechanical engineering, chemical engineering, electronic

engineering and high-polymer technology, products with uniformity and high quality are being manufactured. The most monumental developments until now have been pre-cooked frozen foods, resort pouch foods and dried foods. The mass production of food without using unnecessary food additives has been made possible in the last 30 years, when companies started to grade and inspect the process material, carry out proper inspections of processed foods.

The history related to processed food is the history of the systematization of advanced technology. It includes all operations related to raw material: treatment operations, processing operations, storage operations, also other processing equipment, cleaning of facilities, sterilizing and conservation treatment operations and effluent and waste treatment operations [40].

As mentioned earlier, one of the most important developments was frozen food. Frozen products need proper maintenance. If the company produces frozen products, it has to have good refrigeration equipment. Not all products need the same temperature in order to keep it good for use. But not all products have the same requirements for transportation or storage. It depends on a lot of requirements.

1.2.2. Classification of food products

In the beginning of food storage requirements, all the differences among products should be known. Food products are classified according to their specific characteristics – the origin, chemical composition, usage.

According to natural origin, they are divided into animal origin (meat, milk, fish, eggs and their products) and plant origin (fruits, vegetables, mushrooms, corns and their products). Classification of goods, food products are classified according to the main material of which they are made into bread and bakery products, fruits and vegetables, milk and products of milk, fish, meat, eggs, fat, drinks, tobacco, confectionery and others. Each group of goods is divided into sub-groups, types, also what form are they, what name they bear and what brand.

Table 1.8 Food classification [41]

Class	Type	Group	Food
Plant origin	Cereal grains and legumes/pulses	Cereal grains	Rice (brown rice), wheat, barley, rye, corn (maize, including pop corn and sweet corn), buckwheat, other cereal grains
		Legumes/pulses	Soybeans, dry, beans, dry (including butter beans, cowbeans (red beans), lentil, lima beans, pegia, sultani, sultapya and white beans), peas, broad beans, peanuts, dry, other legumes/pulses
	Vegetables	Potatoes	Potato, taro, sweet potato, yam, konjac, other potatoes
		Sugar sources	Sugar beet, sugarcane
		Cruciferous vegetables	Japanese radish, roots, leaves (including radish), turnip, roots (including rutabaga), leaves (including rutabaga), horseradish, watercress, Chinese cabbage, cabbage, brussels sprouts, kale, <i>Komatsuna</i> (Japanese mustard spinach), <i>Kyona</i> , Qing-geng-cai, cauliflower, broccoli, other cruciferous vegetables
		Composite vegetables	Burdock, salsify, artichoke, chicory, endive
		Composite vegetables	<i>Shungiku</i> , lettuce (including cos lettuce and leaf lettuce), other composite vegetables
		Liliaceous vegetables	Onion, welsh (including leek), <i>nira</i> , garlic, asparagus, multiplying onion (including shallot), other liliaceous vegetables
		Umbelliferous vegetables	Carrot, parsnip, parsley, celery, <i>mitsuba</i> , other umbelliferous vegetables
		Solanceous vegetables	Tomato, pimiento (sweet pepper), eggplant, other solanceous vegetables
		Cucurbitaceous vegetables	Cucumber (including gherkin), pumpkin (including squash), oriental pickling melon (vegetable), water melon, melons, <i>makuwauri</i> melon, other cucurbitaceous vegetables
		Legumes vegetables	Peas, immature (with pods), kidney beans, green soybeans
		Mushrooms	Button, <i>shiitake</i> , other mushrooms
		Miscellaneous vegetables	Spinach, okra, ginger, bamboo shoots
		Vegetables not categorized in the above-listed vegetable groups.	Other vegetables
		Fruits	Citrus fruits
Pome fruits	Apple, Japanese pear, pear, quince, loquat		

		Stone fruits	Peach, nectarine, apricot, Japanese plum (including prune), mume plum, cherry
		Berries	Strawberry, raspberry, blackberry, blueberry, cranberry, huckleberry, other berries
		Grape	Grape
		Assorted tropical and sub-tropical fruits	Japanese persimmon, banana, kiwifruit, papaya, avocado, pineapple, guava, mango, passion fruit, date
		Fruits not categorized in the above-listed fruit groups.	Other fruits
	Nuts and seeds	Oil seeds	Sunflower seeds, sesam seeds, safflower seeds, cotton seeds, rapeseeds, other oil seeds, ginkgo nut, chestnut, pecan, almond, walnut, other nuts
Class	Type	Group	Food
Plant origin	Nuts and seeds	Seed for beverages	Coffee beans, cacao beans
	Spices and herbs	Spices	<i>Sansho</i> (Japanese pepper), other spices (refer to all spices, except horseradish, <i>wasabi</i> (Japanese horseradish) rhizomes, garlic, peppers chili, paprika, ginger, lemon peels, orange peels (including navel orange), <i>yuzu</i> (Chinese citron) peels and sesame seeds)
		Herbs	Spearmint, peppermint, other herbs (refer to all herbs, except watercress, nira, parsley stems and leaves, celery stems and leaves)
	Tea		Tea (green, black, oolong and wulong tea), tea (black, oolong and wulong tea)(except unfermented tea)
	Hop		Hop
Animal origin	Terrestrial mammals	Terrestrial mammals, muscle	Cattle, pig, other terrestrial mammals, muscle (all terrestrial mammals, except cattle and pig) Sheep, horse, deer, goat, muscle
		Terrestrial mammals, fat	Cattle, pig, other terrestrial mammals, fat Sheep, horse, deer, goat fat
		Terrestrial mammals, liver	Cattle, pig, other terrestrial mammals, sheep, horse, deer, goat, liver
		Terrestrial mammals, kidney	Cattle, pig, other terrestrial mammals, sheep, horse, deer, goat kidney
Animal origin	Terrestrial mammals	Terrestrial mammals, edible offals	Cattle, edible offal refers to all body parts, except muscle, fat, liver and kidney, pig, other terrestrial mammals, sheep, horse, deer, goat, edible offal
		Terrestrial mammals, milk	Milk

Poultry	Poultry, muscle	Chicken, other poultry animals, muscle all poultry animals, except chicken, duck, turkey muscle
	Poultry, fat	Chicken, other poultry animals, duck, turkey fat
	Poultry, liver	Chicken, other poultry animals, duck, turkey liver
	Poultry, kidney	Chicken, other poultry animals, duck, turkey kidney
	Poultry, edible offals	Chicken, other poultry animals, duck, turkey, edible offal
	Poultry, eggs	Chicken, other poultry, eggs
Aquatic animals	Fish	Salmoniformes, anguilliformes, perciformes, tetraodontiformes, other fish
	Shellfish	Crustaceans, shelled molluscs
	Other aquatic animals	Other aquatic animals all aquatic animal, except fish, crustaceans and shelled molluscs
Bee products		Honey (including royal-jelly)
Mineral waters		Mineral waters (natural mineral waters and bottled/ packaged drinking waters)

As it is seen in table, food products are divided in to more than 40 groups. It can be assumed, that all of these groups have requirements for storage and transportation. The main aim of food industry is to deliver food products without aberrations. It means, that structure of products could not be changed.

1.2.3. Temperature and time

The most important factor in food industry is to keep good quality of products. For supporting this factor, food must be stocked in right temperature, when it is transported and stored in warehouses.

Nevertheless, that food products are divided in to 40 groups according to natural origin, also food could be dry, powdery, having a solid form, liquid and etc. Different consistency products have to be transported and stored differently. For example, dry products have to be stored at the temperature up to 23°C, while the ice cream must be stored at the temperature from -12° C to -18° C. All required temperature is reported in the table 1.9., below:

Table 1.9 Required temperature for food products [42]

Group of product	Required temperature	Indoor relative humidity
Dry products	Up to +23 ° C	Up to 60 %
Bread, cake and pastries	From +6 ° C till +23 ° C	Up to 60 %
Dairy products	From 0 ° C till +6 ° C	
Milk(raw or heat-treated) in tanks	Up to +4 ° C	
Confectionery (floury, confectionery)	+6 °C – +20 °C	
Confectionery (pastry with cream)	0 °C – +6 °C	
Semi-finished products from vegetables	0 °C – +6 °C	
Fresh chilled meat, except rabbit meat, small meat of wild animals, poultry	Up to +7 ° C	
Products from eggs	+4 ° C	
Chilled poultry, rabbit meat, meat of wild animals and their semi-finished products	Up to +4 ° C	
Cold-smoked sausages	0 °C – +15 °C	70 – 85 %
Products from hot smoked meat	0 °C – +6 °C	70 – 85 %
Frozen melt lard and tallow	- 18 °C	
Frozen meat, minced meat, fish and their semi-finished products, molluscs, crustaceans	- 18 °C	
Ice cream	-12 °C till -18 °C	

As it is shown in table, all food products are divided in to 15 groups, which have different requirements for temperature. Temperature is a relevant factor, when company works on food transportation, storage and reputation pursuit. For this factor, companies ought to have perfect refrigeration system, which is very expensive for partial loads, when logistics is not developed and it could decrease competitiveness because of cost.

Food industry has two factors, which exclude it from other industries. It is time and temperature requirements. As it is known, all food products have expiration date, which means that each minute of delay could mean a huge loss. Labels always show the date with the text: „best before“, which means that these products could be used longer, but the quality will be lower. When the product does not have a label, it is useful to know its time of storage. Tightly packed products such as salt, sugar, flour, rice, starch, oatmeal, pasta, dry pastries, dried fruits, nuts, coffee, tea, honey in dry place (when temperature is 15-20° C) could be stored for more than 6 months. Longer than one month (when temperature is 9-15° C) could be kept the following products:

- Pear, celery, citrus fruits, cheese - from 1 to 2 months period;
- Carrots, turnips, flitch – from 2 to 3 months period;
- Potatoes, cabbage, apples, garlic and salami – from 3 to 4 months period.

All spices must be stored in dry and dark places in tightly closed boxes. They must be revised once a year. They should be stored in tightly closed boxes too, because of other products' smell penetration.

- Fresh fish and minced meat – for 6 - 8 hours;
- Sausage, smoked fish, green spicy – for 1 - 2 days;
- Fresh meat, cooked bacon – for 3 – 4 days;
- Milk and sour cream – for 5 – 6 days;
- Eggs and butter – for 20 – 30 days.

These periods of products storage time show, that some group of products should have extremely fast transportation. Customers always choose those, who could deliver „fresh“ and quality product. Supply chain management is the key for good transportation, storage and delivery. It could ensure required temperature in all steps from production to consumption. It would be discussed in next chapter.

1.3. Supply chain

1.3.1. Supply chain management

Planning of product path is an important and responsible activity, when a company tries to reach profitability and recognition. When customers imagine how a product came to their hands, they do not realize all complex operations. Manufacturing, delivery and purchase sounds very easy, but companies have to discuss more than few aspects: where it is possible to get cheaper but qualitative raw materials, how to transport it into a factory with the lowest costs and etc. Nowadays there is a way to answer all questions and get results faster – Supply Chain Management. Shapiro (2001) says that a supply chain comprises geographically dispersed facilities where raw material and intermediate

or finished products are acquired, transformed, stored or sold, and the transportation links that connect the facilities along which products flow [43].

Supply chain management (SCM) includes main activities which create companies added-value: from designing, planning and buying to manufacturing and product delivery. SCM is a conception, which describes movement of raw materials, services, information, finances from suppliers to final customers. SCM also includes processes, which create and deliver product or service to final customer.

Supply chain could be divided into 3 parts [44]:

- Upstream part – it describes activities with first level suppliers (it could be extended to primary raw materials level).
- Internal part – it is related to all activities, which are performed inside the company:
 - ✓ Production planning and control;
 - ✓ Write off raw materials, products accounting, labour power, technological materials, equipment load;
 - ✓ Planning needs of raw materials, internal logistics.
- Downstream part – it describes product delivery to final customer:
 - ✓ Warehousing
 - ✓ Distribution
 - ✓ Transport and logistics
 - ✓ Wholesale and retail trade
 - ✓ Support

All these parts are necessary in order to have good profitability and customers' acceptance. If a company has good SCM, it could save a lot of money for logistics, warehousing, raw materials ordering. No company is able to control all recourses, which are required to run their business. There appears an important term „Supply Chain Management“ and it includes purchase of goods and services [45]. A key to success is to ensure an uninterrupted flow of information and materials.

As it is known, in this century nobody imagine their life without internet. Internet technology systems could help in all industries, in every step from raw materials to customers. In supply chain internal part company could use transaction processing system (TPS) which includes all functional areas. Customer relationship management (CRM) is a system for managing a company's communications with current and future clients. CRM include using technology for sales, marketing, customer service, technical support organization, automation and synchronization and it could be used in upstream part in supply chain.

As it is discussed, the companies which are using supply chain are getting better results [46]:

- Booking procedure value and time decrease from 20 to 40 %;

- Access to the market shorten from 15 to 30 %;
- The time of purchase reduce from 5 to 15 %;
- Warehousing cost decrease from 20 to 40 %;
- Production cost decrease from 5 to 15%
- Profit increase from 5 to 15 %.

The main aim of every supply chain is to maximize overall value. The value a supply chain generates difference between value of the final product to the customer and the costs the supply chain runs up in filling the customer's request [47]. The value of supply chain is strongly connected with supply chain profitability, the difference between the revenue generated from the customers and whole outgoings across the supply chain.

To understand the supply chain, variety of stages should be discussed. The basic stages include:

- Customers
- Retailers
- Wholesalers/distributors
- Manufacturers
- Component/raw material suppliers

All stages in supply chain are related to the flow of products, information, funds. It could be seen in the table below. Suppliers are always related to manufacturers, and they are connected with distributors. Distributors joined with retailers and they are linked with customers.

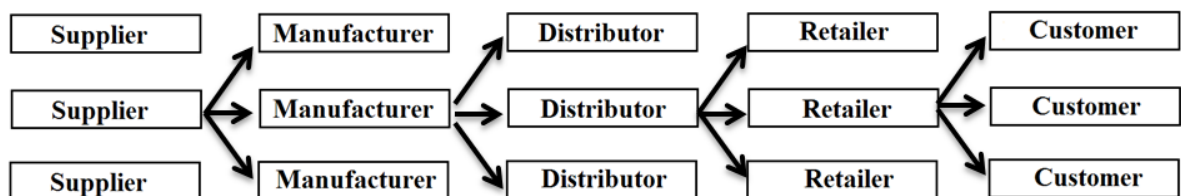


Figure 1.1 Supply chain stages [47]

All supply chains could be named as continuance of flows and connections. As it is known, supply chain has five main stages and it could be retailed with four cycles:

- Customer order cycle
- Replenishment cycle
- Manufacturing cycle
- Procurement cycle

A cycle view is useful when considering choices of activity. First, let's discuss about customer order cycle. It includes customer arrival into a supermarket or other place where he/she could buy necessary products, express their needs, order the right product from inventory, and receive the

product. Replenishment cycle shows all processes replenishing retailer inventory: trigger and entry ordering, fulfilment and receiving orders. Manufacturing cycle includes product arrival from a retailer, production scheduling, manufacturing and transportation and receiving at distributor. The procurement cycle involves information about the materials and their adequacy for manufacturing. All cycles are shown in 1.2 and 1.3. figures below.

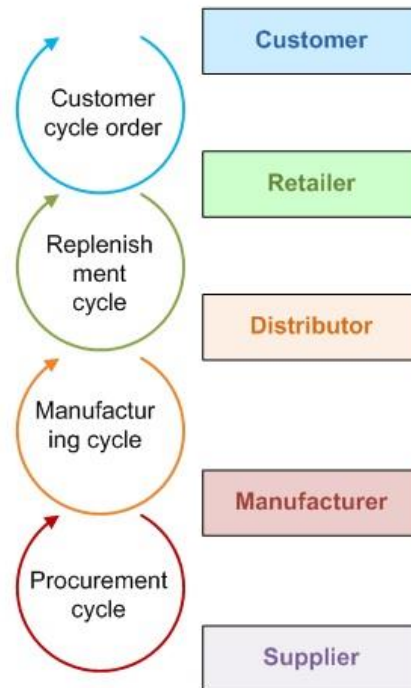


Figure 1.2 Supply Chain process cycle

As it is known, supply chain incorporates raw material ordering, manufacturing, warehousing, but all these activities are dependent on transportation. Without transportation, manufacturing process could not be implemented. If company does not have a vision and schedule for transportation, raw material arrival could be delayed, what affects manufacturing process and transportation into warehouses. The activity which affects supply chain is logistics.

1.3.2. Logistics solutions

„Logistics“ is a relatively new and complex word which is used in many contexts. But the meaning of it is very simple – transportation from one location to another.

The basic definition of logistics is: „Logistics in and among companies is the organization, planning, and realization of the total flow of goods, data, and control along the entire product life cycle [48]“. Logistics includes all product travelling paths over its entire life cycle. Logistics network is composed of the suppliers, manufacturers, distributors, retailers and users.

Logistics is the key for success in supply chain. When a company starts its activity, transportation causes the biggest discussion because it takes the highest cost. It could increase product

cost but also decreasing is thinkable and desired. The world biggest companies get the biggest profit because of their thoughtful logistics path.

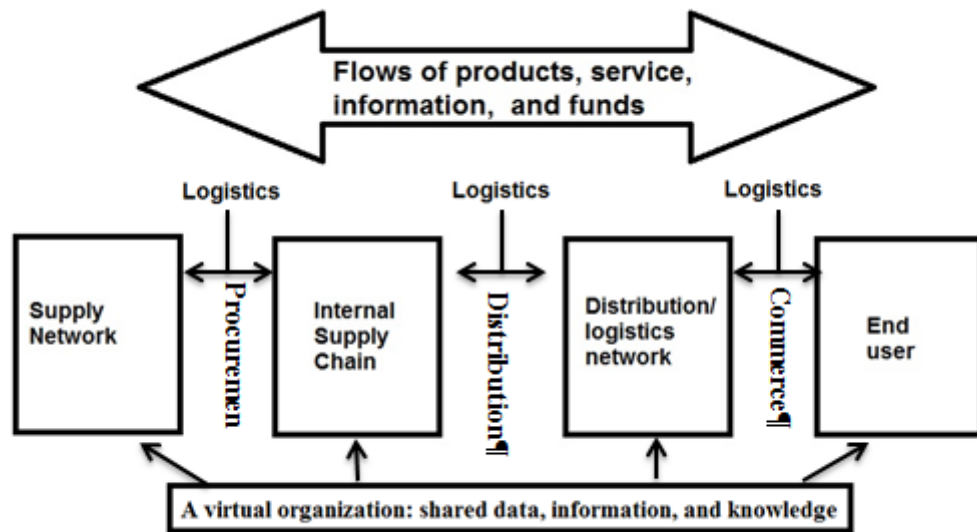


Figure 1.3 Logistics network [49]

As it is seen logistics exists in every step; raw material must be transported into manufactures, after manufacturing process a product is transported into warehouses, products are transported by retailers and then customers could get it. If one part of a chain stops, then all logistics stops.

The main object in logistics is a material flow. All logistics is about this flow movement. Material flow includes raw material, incomplete product and final product movement. Some physical movements are granted for those material flows:

- Loading;
- Unloading;
- Purchase;
- Transporting;
- Sorting;
- Consolidation;
- Dissolution, etc.

If a product does not move in logistics system, it is named as reserves. All reserves and their warehousing would be discussed in chapter about warehousing.

The main product properties which generate logistics cost are:

- Cost
- Products assortment
- Package size
- Weight

- Vulnerability
- Risk (when transporting, warehousing)

Logistics cost is analysed by a density index.

$$\text{Density ratio} = \frac{\text{product weight}}{\text{density}} \quad (1.2.)$$

This ratio is related to transporting and warehousing costs. Products with high density ratio take low cost for transporting and warehousing. The place for those products is used optimal. Next important ratios are cost and weight ratio. Production with a low ratio has low cost for warehousing but high cost for transportation. The biggest influence for warehousing is a load value and for transportation – a load weight.

Time and cost are most important criteria for companies and for customers. A company is trying to reach the lowest cost for manufacturing and transportation and get the shortest path for transporting products. The cost includes both job processing costs and delivery costs, and time refers to the time interval between the time when a customer places an order and the time when the customer receives the ordered product [50]. Customers are trying to reach the same purpose: the lowest cost and the fastest delivery. Ordinary customers do not realize how hard it is to choose the fastest and cheapest transportation structure.

The first step for lower expenses is to combine a good path for production. The company has to choose which type of transport should be used. Transport has three basic forms: land, water and air. Transportation is separated into seven types:

- Air
- Package carriers
- Trucks
- Rail
- Water
- Pipeline
- Intermodal

First of all let's consider air transport. Air transportation could offer fast transportation, but for an airport is necessary. Airplane could reach 1000 km/h speed and they can travel to different countries. Airplanes could save time because there is no traffic on their way. But air transport has some limitations as well: feeder and distribution centers are needed, weight and volume are limited, they are dependent on weather and cost is very high. Nowadays airlines are more for passengers not for cargo. This type of transportation is useful when product delivery is more important than the cost of the load. This type of transportation has very high cost and it is not useful for food industry.

Package carriers are companies which deal with transportation like FedEx, UPS and also postal system. But it is clear that no frozen food is sent using postal services. This type is useful when a load is small and time-sensitive. Package carriers have trucks and could pick up loads and make deliveries.

Truck transport type is also named road transport. This transport mode is dominating in, for example, United States and in most countries. Also it is dominating in Lithuania. Road transport is very manoeuvrable and flexible. It could offer point - to - point service between almost any origin and destination [51]. The road network consists of 21 121 km in Lithuania and this type is preferential. Road transportation has no limitation to fixed terminals or fixed route. With this type of transportation, a load could be delivered to any country. Time of transportation could be easily calculated because of road length and speed limitations. Also this type is right for food industry because of refrigerated trucks. Time is not the most dangerous factor, but temperature is. For this type load dimensions and weight are limited. Trucks also produce high air pollution, they perform traffic jams. Road transport, especially trucks, consume a lot of fuel for movement and cooling. A load could be stolen if it is left without care. Nevertheless road transportation is very popular and beneficial in intermodal operation.

Next type is rail transport. In some countries rail transport is a dominating type of transportation (Eastern Europe). This type of transportation is useful in intermodal operations. One of the most advantages is low cost. This type could offer a terminal – to – terminal service. Any type of production could be transported by rail, and food is not an exception. Load dimension and weight are not limited like in other types. As it was mentioned, low cost is very attractive and there are no limitations for weather or traffics.

Nevertheless rail transport has some limitation: distribution services and feeder are needed, load has to be packed safer than in road transportation. Delivering time is very slow and could not deliver express. For a large number of companies transportation cost is more important than transportation time.



Figure 1.4 Rail Baltic [52]

Water transport is an important type when a country has a port. Lithuania is one of those countries which has developed water transportation. This type is a cost-effective way of transporting for long distances and it is widely used for international transportation. Advantages of water transport are: low cost, no limitation for load, no traffic in open sea, it also offers very safe and secure services.

But as all types it has some limitations. This type is useful between countries with ports. It is also terminal – to – terminal service. Water transport is dependent on bad weather and it could make cargo delay. Also sea transport offers slow transportation. Despite this, water transport is very useful in intermodal transportation.

Pipelines are primarily used to send petroleum, natural gas, and chemicals. They offer a closed system with little risk of loss or damage to the products sent, and extremely low costs because minimal labour is involved in their operations [53]. This type of transportation is useful for chemicals industry not for food industry, so it will not be important for food transportation.

As it was mentioned before, the biggest logistics problem is how to decrease cost for transportation? For this intermodal transportation is useful. Intermodal transportation consists of more than one transportation type. The most popular model is a rail – truck model. As it was mentioned, rail transportation is very cheap but it could not be door – to – door service. Trucks could deliver loads to rail terminal in country A and then it could be taken from another terminal to warehouses. It could save money for long road transportation. It is mentioned because Rail Baltic is one of the most expected projects in Lithuania rail history. This project will open a railway from Finland to Germany. It will help to save money on transportation and would be useful for food industry. Water – truck

model is also acceptable. It would save money, because of water transportation cost. Trucks could deliver loads to terminal A, from where it could be transported by ships and in terminal B another truck could deliver load to final destination.

Supply chain always chooses which type is the best for a company. Facts of transportation in Lithuania are shown in 1.10 table:

Table 1.10 Lithuanian load transportation and turnover [54]

Types of carriage		Years				
		2008	2009	2010	2011	2012
Freight and mail transport and turnover with Lithuania airline aircraft.						
Load and mail turnover, million tonne-kilometers		4465	1902	2605	2862	652
Load and mail transportation, thous. tons		4199,2	3657,3	2910,8	3476,3	1087,3
Freight transport by road and turnover (food products, beverages and tobacco)						
Inland transport	Load turnover, million tonne-kilometres	336	507	422	461	437
	Load transportation, thous. tons	4000,1	4512,6	3607,8	3727,2	3413,8
International transport and cargo loaded in Lithuania	Load turnover, million tonne-kilometres	680	582	729	832	878
	Load transportation, thous. tons	561,7	557,6	646,5	725,8	826,3
International transport and cargo unloaded in Lithuania	Load turnover, million tonne-kilometres	577	454	583	591	999
	Load transportation, thous. Tons	419,7	366,8	448,7	482,2	692,7
International transport, among other countries	Load turnover, million tonne-kilometres	1531	1548	1616	1769	2081
	Load transportation, thous. tons	838	931,1	1015,9	1168,2	1493,3

Freight transport by Lithuania rail and turnover (food products, beverages and tobacco)						
Inland transport	Load transportation, thous. tons	198,6	159,7	129	148	113,7
	Load turnover, million tonne-kilometres	49702	41562	39860	44680	32538
Imported in to the country	Load transportation, thous. tons	157,2	302,1	282,7	317,9	462,6
	Load turnover, million tonne-kilometres	42328	97968	95137	105825	166921
Exported from the country	Load transportation, thous. tons	540	607	818,4	746,6	719,6
	Load turnover, million tonne-kilometres	203876	224832	311995	293403	286580
Cargo handling in Klaipėda State Seaport and the Butinge terminal (food products, beverages and tobacco)						
Load unloading, thous. tons		875,2	661,1	914,5	851,8	599,7
Load loading, thous. Tons		107,4	213	211,2	222,7	285

Good transportation model could save money but it is not enough for best supply chain. The other problem in supply chain is warehousing and location of a warehouse. As it was mentioned, the purpose of this article is to find best model of transportation and the best location for warehouse.

1.3.3. Warehousing and distribution

A warehouse is not only the place for inventory storage, but it also has some functions which are important for logistics effort. In fact, warehousing is integrally involved in four distinct supply chain processes: sourcing logistics, processing/manufacturing, outbound distribution, and reverse logistics (returns, recycling, etc.)[53].

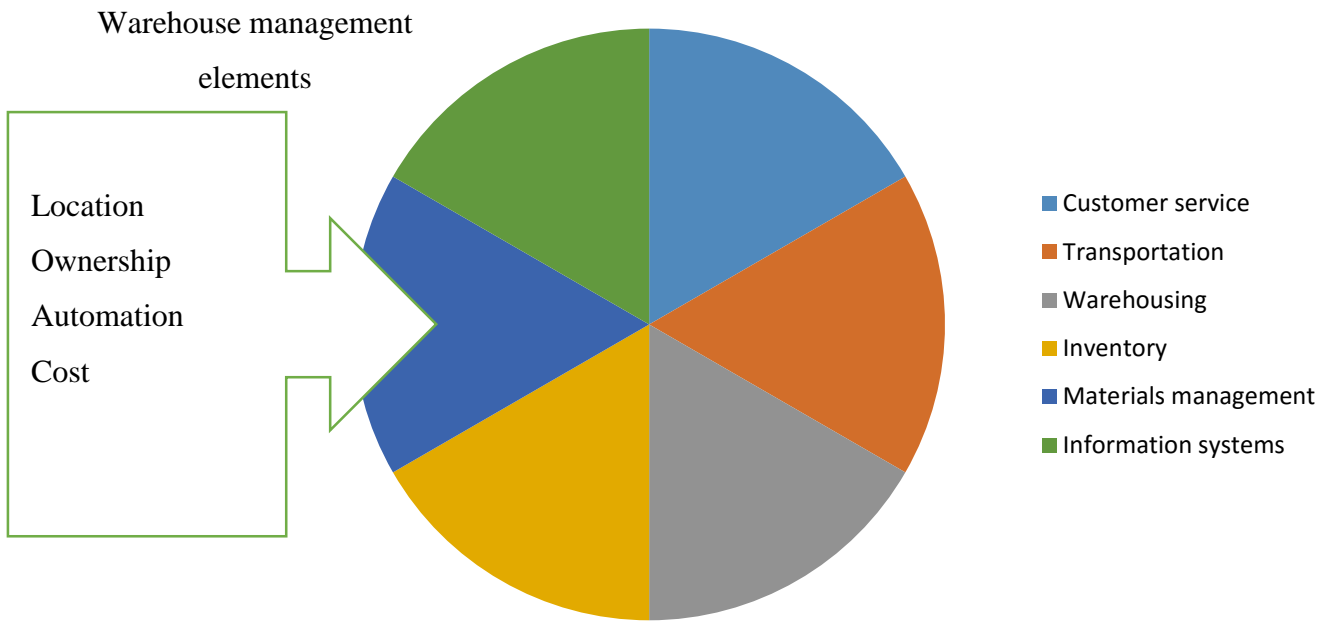


Figure 1.5 The role of warehousing within the logistics system [53]

The basic definition of the term warehouse is „Building for goods receiving and storing, prepare and send“. Warehouse is one of the most important elements in logistics, because requirement of the warehouse is felt in every step of material flow movement. Some of warehouse roles are in the following list [55]:

- Inventory holding point;
- Consolidation centre;
- Cross – dock centre;
- Sortation centre;
- Assembly facility;
- Trans – shipment point;
- Returned goods centre.

One of the key to decrease warehousing cost is to pick the best size of warehouse. The size must be adapted to load flow. Characteristics, which influence warehousing systems are type of transportation, handling unit and intensity of flow [56]. Also a warehouse design is very important because warehouses have requirements which should be performed. The typical design of a warehouse is shown in 1.11 table.

Table 1.11 Typical design of warehouse [56]

Name of room group	Name of room
Warehousing room	General warehouses
	Freezer
	Expedition room
	Conflicted cargo storage room
Auxiliary room	Inventory warehouse
	Tare warehouse
	Closed auto platforms
	Waste warehouse
	Repair room
	Handling equipment garage
	Accumulator room
	Ventilation chamber
	Thermal unit
	Baffle arrangement
	Security room
Administrative, domestic rooms	Office
	Domestic rooms
	Entrance
	Medical room
	Samples of goods room

Next step is to choose the location of warehouse and quantity; is one warehouse enough or more is needed. Good solution of location could save money because a warehouse is related to logistics. Each company has to answer these questions:

- How many warehouses should be there?
- Where should they be located?

When a company calculates flows then solution could be adopted: is one warehouse enough or a company need one consolidating warehouse to get all products from different locations. Also the company has to discuss if a warehouse will be near public transport or near the shops or other locations. The best way to find location is to calculate all flows and then check the required quantity of warehouses and the best location for it.

“Logistics cost is normally referred to as cost components related to distribution or transportation cost, and costs for warehouses as reflected by the definition of logistics according to Lambert et al. (1998)” [43]. The main aim of this final project is to get minimum cost for logistics and warehousing. The objective is to find connections between transportation and warehouse location and choose the best solution.

Location could be dependent on many aspects as cost, environment, transportation time and etc. Ozcan used only main criteria that consist of unit price, stock holding capacity, average distance to the shops, average distance to main suppliers, and movement flexibility[57]. This paper will try to find algorithm to calculate the best choice for warehouse location and quantity of it.

1.4. Logistic clustering process

1.4.1. Concept of clusters

The last chapters indicated the singularities of the food industry. The most common aspect of the food industry that needs to be understood in performing a cluster is the different temperature requirements for different products. This is essential to take into consideration, because there is a new trend that a consumer desires safe, healthy and high quality food products [58]. The technology for temperature controlled transportation and warehousing were also reviewed. The usage of these technologies is also important to understand for the creation of a proper clustering process. Without the combination of different transportation types achieving competitive advantage could be difficult. The usage of all these methods can be combined in a clustering process. Before combining a clustering process it is important to overview what are clusters and what benefits can they provide.

A cluster is simply a group of industries or organization that has similarities and are aiming to achieve a common goal. There are many types of clusters and figure 1.6 was made after a deep analysis of literature.

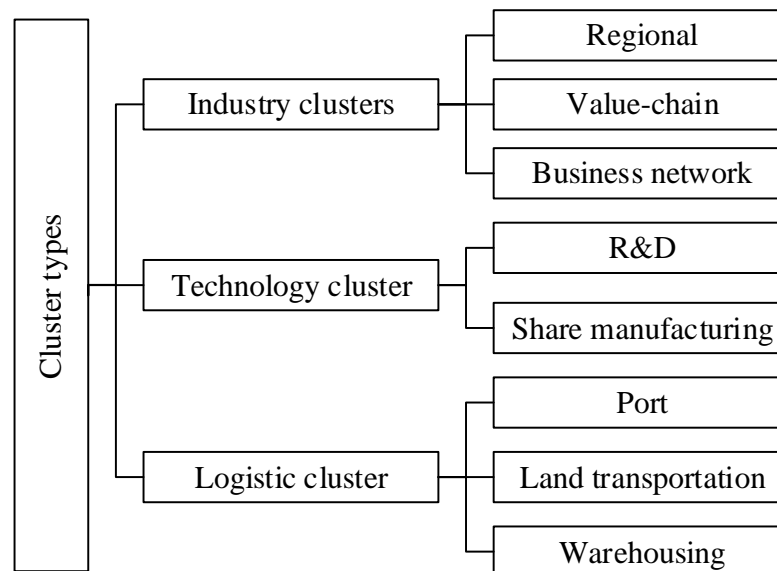


Figure 1.6 Cluster types [59]

The first groups of the clusters can be divided into industrial, technological and logistic clusters. The process of clustering is similar in a simplistic way to say companies that have similarities. They can combine their information, technology, money and increase their competitive advantage. This particular method is popular around the world, because only working together it is possible to stay competitive and ahead of the growing technology.

Industrial clusters are clusters that work together and share their information. These kinds of clusters usually are located regionally and have similar suppliers and working area. After all to get a better price it is wise to buy raw material together and by doing this the cost for raw material would be lower. Additionally there are companies that work as groups and are trying to monopolize a specific market. There are many examples like this: particularly in Lithuania there are companies such as “Arvi kalakutai”, “Viči group“, „Kauno grūdai“ and etc. These companies have their own and primary working area, but as time goes by they start working with different companies and buy their stocks. This is just one example of a possible industrial cluster. Another aspect of the industrial clusters are promoted by the government. “Most successful clusters are created spontaneously as a result of natural competitive advantage. However, owing to dedicated clusters policies in Member states, notably since the end of the 1990s, there are an increasing number of cases where forward-looking public policies, business initiatives or top-class universities and research institutes have been instrumental in the emergence of strong clusters by acting as a catalyst and helping to unleash the economic and scientific potential of particular regions” [60]. The government interference is a huge help to combine clusters. Many companies are competing with each other and a 3rd party member can help to show the common goals. From this point of view another type of clusters can be created.

The other type of cluster is called technological. To put it simple, these companies combine their knowledge and technology to increase capacity, R&D centres and etc. One of the best examples

is Food Valley, which is a region in the Netherlands. The Food Valley area is the home of a large number of food multinationals and within the Food Valley about 15,000 professionals are active in food related sciences and technological development. Within this region, the Food Valley Organization is intended to create conditions so that food manufacturers and knowledge institutes can work together in developing new and innovating food concepts.

And the last type of clusters is logistic clusters. These clusters are orientated totally to logistic services. This clustering process is the best method for small markets, because of the food industry singularities the partial cargos can be combined and it will help to optimize cost. One of the best food logistical clusters in the world is “World food programme”. This cluster helps to solve the hunger problem in the world and they combine thousands of companies together and organize distribution through the whole world. The logistic systems used in this cluster are incredible, because they have achieved high level of logistic compatibility. They control over 100 planes, 3000 railways, trucks, 30 ships and they distribute the food from Amazon jungles to Iraq etc.

In general it is hard to determine just one type of clusters. Usually they are combined clusters and are working in several areas. For example industrial and logistic clusters can often be used together. Also there are researches done about the patterns of clusters growth. “Analysis results suggested that the real-world clusters rarely future any single type of topology; a mixed type of topology is much more prevalent in reality. Different industries tend to support different types of clusters typologies. In other words, an individual cluster’s topology is to some extent shaped by the industry group it belongs to [61]. These findings indicate the importance of cluster concept understanding, because it can help identify the goals of different cluster members.

1.4.2. Benefits of clusters

This chapter will indicate the impact of clusters to the transportation area. In order to understand the impact to the logistics sector the cost of transportation needs to be reviewed. Information was gathered from a Lithuania’s company that indicate the common cost of transportation from a 3PL service provider.

Table 1.12 Transportation costs specification of 3PL Company's [62]

Distance , km	Trip time, hours	Quantity of pallets, pieces	Required temperature	Fuel for temperature maintenance , l	Fuel for truck, l	Weight of cargo, t	Price, Euro
832	22.4	32	chilled	44.8	257.9	18.7	1300
1138	26.5	5	frozen	79.5	352.8	3.5	1550
999	24.7	25	chilled	49.3	309.7	17.0	
788	21.8	9	chilled	43.7	244.3	4.3	390
1093	25.9	12	none	0.0	338.8	8.6	1550
1100	26.0	9	none	0.0	341.0	11.0	
1072	25.6	5	none	0.0	332.3	1.0	
1070	25.6	12	none	0.0	331.7	13.0	
1007	24.8	33	frozen	74.3	312.2	22.0	1400
1000	24.7	30	chilled	49.4	310.0	17.5	1300

Table 1.12 is a summary of data from Lithuanian logistics companies transiting frozen and chilled food production. Generally, the transportation costs are dependent on quantity, distance and product transported. One of the purposes of data analyses was to determine fuel consumption rates depending on different requirements of temperature values inside typical refrigerated semi-trailers. The results indicated that frozen temperature maintenance inside semi-trailers requires approximately 45-55 % more diesel fuel than for maintenance of chilled temperature. This fuel consumption includes only the energy consumed by the refrigeration equipment. Fuel consumption for trucks varies more with load factor and distance travelled than with capacity. Another interesting aspect of the study was the comparison of the weight and volume of the cargo and influence on the costs of transportation per pallet. It was determined that the weight of the cargo has relatively little impact on total costs, while the volume of the cargo has a larger influence. For instance, when transporting with fully loaded semi-trailer (32 euro pallets) the pallet price is approximately 40-48 euro per piece. While partial cargo is transported, the price per pallet may vary from 80 up to 120 euro and total costs can rise dramatically. Therefore, given small consignments of goods, in order to reduce the price per pallet, consolidated cargo delivery service is one of the best solutions for small markets. The essence of the method is that several small consignments of goods are consolidated and carried with one transportation facility in one direction. Transportation of consolidated cargoes is most effective when distribution network from suppliers to customers has sufficient chain of warehouses. Unfortunately,

for small and medium enterprises which make majority in the small market, it is difficult to implement practically. To correct this issue, the promotion of logistics clusters is the most attractive decision.

Because of this the clustering process can be used to achieve a competitive advantage. Clusters can help to combine industry and increase their information flow, R&D and optimize transportation and ordering cost. Why should a company give away its orders to an outsourcing logistic company, if they can create clusters and share cargo together? This way the margin of the cargo can be shared between the cluster for developing centres and development possibilities. This is a strategy that small markets are already using, but not all understand this kind of competitive strategy. To understand the importance of clustering to optimize cost it is essential to overview different types of clusters.

Cluster can help combine distributors and increase their information flow, optimize transportation and ordering cost. Why should a company give away their orders to an outsourcing logistic company, if they can create clusters and share cargo together? This is a strategy that small markets are already using. One of the best food cluster example is Food Valley, which is a region in the Netherlands [63]. Within this region, the Food Valley Organization is intended to create conditions so that food manufacturers, distributors and knowledge institutes can work together in developing new innovating food concepts. Also Bigliardi and Galati indicate the importance of innovation within the food industry. “Due to the wide number of players involved in the development of innovative products, innovation activities must be carefully coordinated. As such, the sector should exhibit a significant number of open innovation strategies, whose purpose may range from merely access to external source of knowledge to actively taking part in the creation of inter-organizational knowledge and skills” [64]. Therefore, the authors offer to use clustering processes for competitive advantage maximization. These clusters could be linked to food suppliers, food manufacturers, food distributors and customers/retailers (Fig. 1.7).

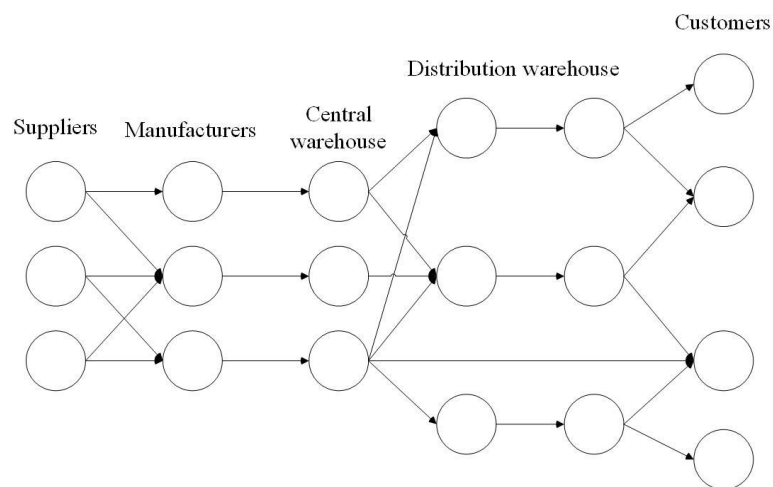


Figure 1.7 Distribution network of flow from food suppliers to customers [62]

The structure indicates that there may be several suppliers and distribution centres that are working with manufactures. Additionally, the producers could have the same customers. The authors

offer clustering methods for the manufacturers and wholesalers to combine their transportation quantity and ordering size to optimize logistic cost. After all if the quantity is larger, the price become lower and this method can be regarded as a competitive advantage maximization factor. Furthermore, integration of distribution network by using clusters could ensure positive improvements towards potential markets, logistics efficiency, environmental issues and traceability of food quality. Industries located in a strong cluster register higher employment and patenting growth. Regional industry growth also increases with the strength of related clusters in the region and with the strength of similar clusters in adjacent regions [65].

Transporting combined cargo and organizing clusters could dramatically increase competitive advantage. Pu-yan Nie and Peng Sun analysed the formation of industrial clusters based on spatial competition and search costs in a game theoretic model. By establishing a spatial competition model, this paper compared firm profits under clustering to those without clustering. They found that search costs are an extremely important factor in the formation of industrial clusters that can give rise to industrial clusters in certain industries [63]. Therefore, clusters can be used as a cost optimization strategy for complete advantage increases that would provide economic benefits that are similar to large countries. For example a small market enterprise can cluster with similar companies and they can use then the concept of economical scale that was reviewed in the 1.1.1 chapter.

1.4.3. Logistic clustering process algorithm

The previous chapters indicated the concept of clusters and the possible benefits of clustering process. In this chapter the method of clustering needs to be reviewed and how it can be applied to a logistic cluster. Logistic clusters have their own singularities, especially in the food industry. Quantity of cargo, variety of products needs to be largely spread between the members of cluster. Only then it is efficient to combine and work together to minimize cost. Magdalena described this concept as a clustering the clusters process [66]. In today's world this is important to produce large networks for better and cheaper distribution of products. Innovation in the food industry is very important, but only a few researches were done in this area. A network of individuals and organizations assembled around the frozen food institute, backed by the government and worked on creating and getting information across to everyone in the supply chain. A cluster of food producers and supporting industries were formed spontaneously in the south of Sweden and existed until the technology become a commodity [67]. This natural cluster was formed because of the benefits that logistic clusters can provide, in general they can help increaser geographical concentration, better resistance to macro environmental factors and innovation possibilities. The impact of these factors was discussed in chapter 1.4.2.. The main question is how to create these kinds of clusters on purpose and without the government interference. It is a strategy that needs to be review and modelled. Regarding the previous analysed information the authors conducted a logistic clustering process.

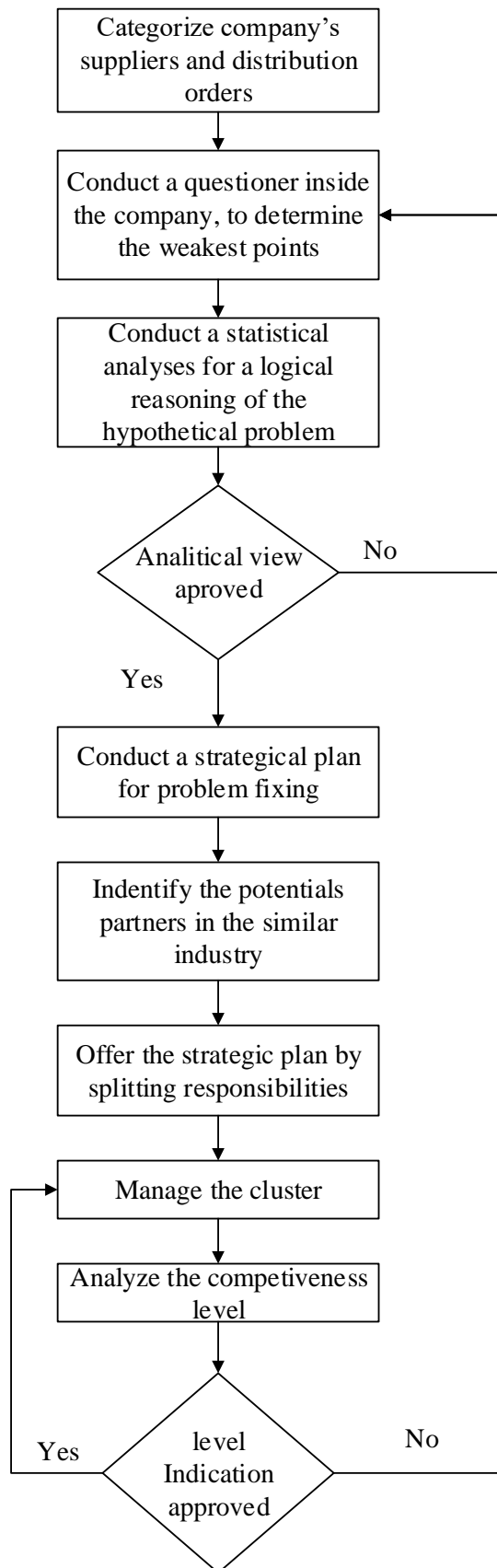


Figure 1.8 Logistic clustering process algorithm

A universal clustering process algorithm is described in figure 1.8 This particular method is modelled for small and large markets, but it also helps indicated the necessary optimization strategy in the small markets. First of all it is important to categorize all the suppliers and distribution orders. This is important for two reasons. All the suppliers need to identify about their reputation quality and price. If the suppliers are satisfying the company's needs, then they may be used as a potential bargain object. No supplier could refuse being recommended to potential partners. In addition, buying the same supplies within the cluster could reduce raw material cost. On the other hand, if there is a problem with the suppliers, new recommendations can be achieved within the cluster partners. The other aspect is about the potential customers. This can be sad the same way, similar companies may have the same customers, but they may be not competitors together. By combining distribution together the customer could get additional value with the same products. This could be an example about the wellness business in the direct selling industry. These kinds of clusters usually consist of a few manufacturers. For example, cosmetics, supplements and vitamins, coffee, pasta etc. Then these products can be distributed to the same customers and it would dramatically reduce lead-time and cost. This is also important to do not just by wishful thinking, but by doing a questionnaire inside the company, that would help identify the problem faster. It is important to understand that there may be misunderstandings within the working staff and in order to identify the real problem a statistical analysis needs to be done about the orders. Only then a plan can be developed. In addition, when you are searching for potential partners the statistical results can be as an indicator to identify the correct partners. On the other hand, a forecast of potential benefits of clustering process can be made. This would benefit all members of the cluster, because they would have a vision about the upcoming future. It is also important to share responsibilities within the cluster, this is essential in order for all members to stay active inside the clusters. If one of the members will be only a taker, the cluster may fail in the long run. In addition it is important for every member of the cluster to understand the situation and management systems needs to be implemented. If the members were small before the cluster, now there orders would increase and an enterprise data base would be essential for proper management. The last important factor is that the algorithm needs to be remade regularly, because the technology and products changes and there may be new opportunities for the cluster members. To prove this theory a specialist interview needs to be conducted in a small market. The goal of the interview is to obtain information and apply the clustering algorithm to indicate the economic benefits of using clusters.

2. Methodology

2.1. Logistic network costs

The total freight costs are full cost of these operations:

- transportation inside the company and warehousing;
- transportation from company to warehouse;
- warehouse operations;
- accounting in warehouse.

2.1.1. Warehouse construction costs

To build a warehouse is very expensive because a price of building is formed by the price of land, price of materials for building works, the size of warehouse. About 80 % of warehouse cost consists of concrete, steel, earthwork, site utilities, roofing, general conditions, fire protection, and design fees. The simple rule is valid for warehouse; small size building is expensive and big buildings are more economical. Also the proposition is to build a warehouse footprint square. It would minimize the cost for tilt-wall panel.

The price of warehouse depends on a storage area, production area and expedition area. Climate control also increases the price, because temperature requirement must be exact as product needs it. If the biggest place of warehouse needs frozen temperature price would increase. Only after a detailed plan of warehouse with all sizes, temperature requirements the cost would be fully clear [68].

2.1.2. Warehousing costs

Warehousing cost is composed of the fixed part and variable costs.

Warehousing cost includes:

- warehousing percentage of cost (inwards and outwards);
- auxiliary measure cost;
- management and usage cost;
- invested capital cost;
- damage cost.

Warehousing cost is related to material cost and staff:

- staff cost;
- buildings cost;
- amortization;
- percent;
- repair and supervision cost;
- heating and lighting cost;

- energy cost;
- insurance cost;
- loss cost;
- various taxes.

The fixed costs in warehousing take more than half of the overall cost.

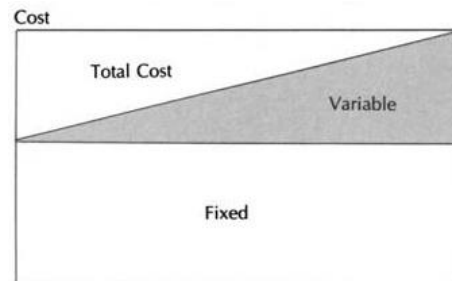


Figure 2.1 Part of fixed and variable cost [69]

The cost of warehouse also is connected with employees, management cost and quantity of palletes. Warehouse management cost would be decreased when quantity of palletes would be exact as it is needed, but not too big or too small. It depends on orders; when warehouse is always full of palletes than cost of warehousing increases but when it is empty – cost decreases. In manufacturing companies it is like: produced as much as ordered. The same could be in logistics work, do not have a lot of inventory which is increasing warehouse cost. But in this article the quantity of palletes will be maximum and the cost of warehousing also will be maximum.

2.1.3. Transportation costs

Transportation is one of the factors which take a lot of cost. Road transportation cost depends on distance of transportation, weight of cargo and type of cargo. In this article the most important factor is type of cargo; the requirements for temperature are increasing the price for transportation. Fixed cost of transportation is arising regardless of the size of cargo. When truck is sending to deliver each order, it cost the same to send full truck or half-empty truck. Less than truckload pricing also includes a fixed components that is independent of the quantity shipped and variable components that increases with the quantity shipped [49].

Nevertheless, CO_2 emission is most important in this century. All cars are emitting CO_2 and trucks have very big emission. It depends not only from type of car but also from type of temperature. Temperature also increased this level and only when distance would be optimized, CO_2 emission level would decrease.

2.2. Expertise assessment

2.2.1. Process of the assessment

One of important research was to collect data from different companies which are transporting food products. As it was described food products need more care than simple goods. The priority is to choose the right temperature for food products to keep it in safe.

Therefore, the main aim of this survey was:

- to identify the most common loading addresses;
- to analyse cargo which needs different temperature;
- to define frequency of partial load;
- to delineate warehousing cost.

All the information was collecting by phone calls. The part of surveyed companies were working with the food industry. The other part of companies were engaged in logistics. Various correspondents of the companies (head of production, directors, CEO, logistic expeditors, head of warehouse) were asked questions related to the loading addresses, different temperature conditions, warehousing costs, export/import problems, possession of transport and warehouse. 50 companies were selected for the interview, however the data was provided only from 9 companies selected.

After survey all warehousing and logistics fees were analysed and structured. Part of companies presented the detailed workflow and the main problems.

Based on enterprises which are specialized in warehouse installation, construction costs were evaluating abroad. All the data which are related to cost of land, rental price for the palette, palette service price was collected according to real estate sites.

Rates that prevail in Lithuania were received from the survey and rates that dominate in Europe were collect from sites [70].

2.2.2. Interpretation of the results

For all calculations one type of analysis is needed to find the correct answer. Multiple regression analysis is the key for answer when a lot of data is known.

When one unknown value of variables must be found from the known value of two or more variables – it is called multiple regression analysis. This model is whit just one dependent and two or more independent variables. Variable with predicted value is called dependent variable and variables with value which are used for prediction are known as independent variable.

Multiple regression analysis attempts to sort out the individual effect of each explanatory variable. An explanatory variable's coefficient estimate allows us to estimate the change in the dependent variable resulting from a change in that particular explanatory variable while all other explanatory variables remain constant [71].

Multiple regression analysis refers to a set of techniques for studying the straight-line relationships among two or more variables. Multiple regression estimates the β 's in the equation

$$y_j = \beta_0 + \beta_1 x_{1j} + \beta_2 x_{2j} + \cdots + \beta_p x_{pj} + \varepsilon_j \quad (2.1)$$

The X's are the independent variables (IV's). Y is the dependent variable. The subscript j represents the observation (row) number. The β 's are the unknown regression coefficients. Their estimates are represented by $\hat{\beta}$'s. Each β represents the original unknown (population) parameter, while b is an estimate of this β . The ε_j is the error (residual) of observation j [72].

Although the regression problem may be solved by a number of techniques, the most-used method is least squares. In least squares regression analysis, the b's are selected so as to minimize the sum of the squared residuals. This set of $\hat{\beta}$'s is not necessarily the set you want, since they may be distorted by outliers--points that are not representative of the data. Robust regression, an alternative to least squares, seeks to reduce the influence of outliers.

Multiple regression analysis studies the relationship between a dependent (response) variable and p independent variables (predictors, regressors, IV's). The sample multiple regression equation is

$$\hat{y}_j = b_0 + b_1 x_{1j} + b_2 x_{2j} + \cdots + b_p x_{pj} \quad (2.2)$$

If p = 1, the model is called simple linear regression.

The intercept, b_0 , is the point at which the regression plane intersects the Y axis. The b_i are the slopes of the regression plane in the direction of x_i . These coefficients are called the partial-regression coefficients. Each partial regression coefficient represents the net effect the i^{th} variable has on the dependent variable, holding the remaining X's in the equation constant.

A large part of a regression analysis consists of analysing the sample residuals, e_j , defined as

$$e_j = y_j - \hat{y}_j \quad (2.3)$$

Once the $\hat{\beta}$'s have been estimated, various indices are studied to determine the reliability of these estimates. One of the most popular of these reliability indices is the correlation coefficient. The correlation coefficient, or simply the correlation, is an index that ranges from -1 to 1. When the value is near zero, there is no linear relationship. As the correlation gets closer to plus or minus one, the relationship is stronger. A value of one (or negative one) indicates a perfect linear relationship between two variables.

The regression equation is only capable of measuring linear, or straight-line, relationships. If the data form a circle, for example, regression analysis would not detect a relationship. For this reason, it is always advisable to plot each independent variable with the dependent variable, watching for curves, outlying points, changes in the amount of variability, and various other anomalies that may occur.

If the data are a random sample from a larger population and the ε_j are independent and normally distributed, a set of statistical tests may be applied to the b 's and the correlation coefficient. These t-tests and F-tests are valid only if the above assumptions are met [73].

2.3. Optimization process

Optimization is a process, which allows finding the most cost effective or highest performance solution, under certain constraints. This can be achieved by minimizing and maximizing certain factors. To optimize a particular situation a target function needs to be developed. A target function can be the result of an attempt to express a business goal in mathematical terms for use in decision analysis, operations research or optimization studies. In computer science, business processes or logistics the optimized solution is usually achieved by linear or non-linear programming.

Linear programming is the process of taking various linear inequalities relating to some situation, and finding the "best" value obtainable under those conditions. A typical example would be taking the limitations of materials and labour, and then determining the "best" production levels for maximal profits under those conditions. An example is given below. Find the sales functions $z = 3x + y$ optimal value, with certain constraints (formula 2.4).

$$\begin{cases} x + 2y \leq 14 \\ 3x - y \geq 0 \\ x - y \leq 2 \end{cases} \quad (2.4)$$

The solution is displayed in figure 2.2

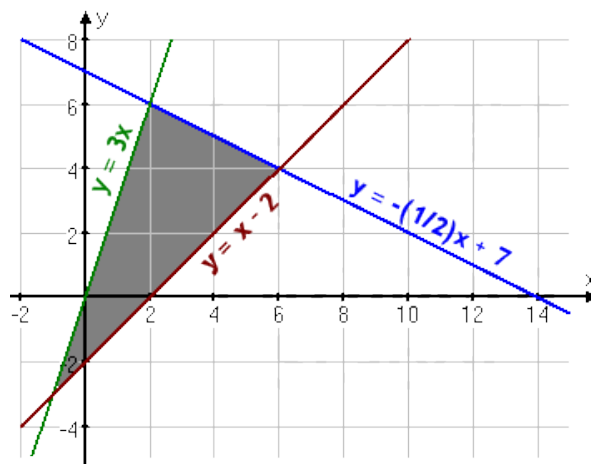


Figure 2.2 Linear problem solution [74]

During a logistic network solution, non-linear problems are solved. These functions are more advanced ones and consist of various variables, not only linear. This is, because when evaluating the transportation routes GPS coordinates are used. In this research an R code package will be used together with OpenStreetMaps (OSM) software [75]. OSM provides freely accessible and editable geographic data, while the "osmar" package integrates the OSM project into the R ecosystem. The aim of the OSM project is to create a free editable map of the world. The project maintains a database

of geographic elements and features: streets, buildings and landmarks. These criteria are represented by different attributes:

Node: The basic element. It consists of the attributes latitude and longitude.

Way: An ordered interconnection of nodes to describe a linear feature (e.g., a street). Areas (e.g., buildings) are represented as closed ways.

Relation: A grouping of elements (nodes, ways, and relations), which are somehow geographically related (e.g., bus and cycle routes).

Moreover, the optimization algorithm requires to work with large amounts of data, therefore, an offline routing application is used. OSM provides planet.osm that is the world's map, by using this source calculations on the local computer can be done [76].

Because of the large amount of data heuristic methods will be used to optimize not only the function, but also the calculation speed [77]. In computer science, artificial intelligence, and mathematical optimization, a heuristic is a technique designed for solving a problem more quickly when classic methods are too slow, or for finding an approximate solution when classic methods fail to find any exact solution. This is achieved by trading optimality, completeness, accuracy, or precision for speed. In a way, it can be considered a shortcut. A heuristic function, also called simply a heuristic, is a function that ranks alternatives in search algorithms at each branching step based on available information to decide which branch to follow. Referring to figure 2.1, the optimal solution can be found the calculating the function with particular variables. These variables can be selected by different criteria:

1. Calculates all possible solutions;
2. Selects random variables in different sections of the function;
3. Selects variables based on certain criteria: cost based, distance based and so on.

The classic problem that can be used to illustrate the preliminary solution of the logistic network can be described by referring to the traveling salesman problem. Traveling sales problem is well known in graph theory. When speaking directly, the problem is between salesman and set of cities. The salesman has to visit each one of the cities starting from a certain one (e.g. the hometown) and returning to the same city [78]. The main objective is to find the minimum distance, minimize the total length of trip.

The traveling salesman problem can be described as follows:

TSP = $\{(G, f, t): G = (V, E)$ a complete graph, f is a function $V \times V \rightarrow Z$, $t \in Z$, G is a graph that contains a traveling salesman tour with cost that does not exceed $t\}$.

For example, consider the following set of cities:

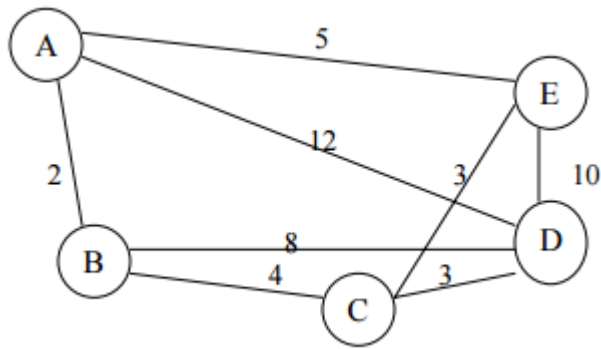


Figure 2.3 A graph with weights on its edges [78]

Problem is to find the shortest path. For example, the path Path1 {A, B, C, D, E, A} and the path Path2 {A, B, C, E, D, A} pass all the vertices but one of path length is 24 and others is 31. From these two examples Path1 is shorter. This traveling salesman case could help to find the shortest path in logistics.

When problem is to find the near optimal solution, nonlinear and linear programming for Traveling Salesman Problem is the best selection. Simulated annealing is based on heuristic methods not classical methods i.e. the solution is obtained by trial and error way. This may not be the most optimal solution, but a quick and less demanding solution.

Heuristic optimization method is one of the artificial intelligence search method. This method could be used to find the most favorable decision for designing, managing thousands of complex systems. Heuristics search methods could be like tabu search, simulated annealing, genetic algorithms, genetic programming, multiobjective methods and dynamically dimensioned search. All these algorithms are using to find the optimal values or variables which could optimize all the system or improve system dependability.

Heuristic algorithms are classified in to improvement heuristics and construction heuristics. Construction heuristics algorithm could use start without schedule and add one job at a time. Improvement heuristics are using start with a schedule and trying to find a better similar schedule. Local search methods as simulated annealing, tabu search are examples of the improvement heuristics [80].

The method which is used in all calculation is simulated annealing. When the number of objects becomes too large than simulated annealing could help to find the right answers. Traveling salesman problem belongs to the Non-deterministic Polynomial time class of problems. For these problems, there is a very effective practical algorithm called simulated. While this technique is unlikely to find the optimum solution, it can often find a very good solution, even in the presence of noisy data [81].

The basic iteration in simulated annealing program is to move from one direction to other and it is repeating until the direction is good enough to satisfy the conditions.

For explanation, the traveling salesman problem could be used as an example for simulated annealing. The main problem is that salesman must visit all the cities and find the best route. If a salesman starts with a random city it does not ensure that the route will be minimized.

The difficulty with this approach is that while it rapidly finds a local minimum, it can not get from there to the global minimum. Difference between global and local minimum is that global minimum is the smallest value in all the graph and local minimum is not the lowest value in all graph.

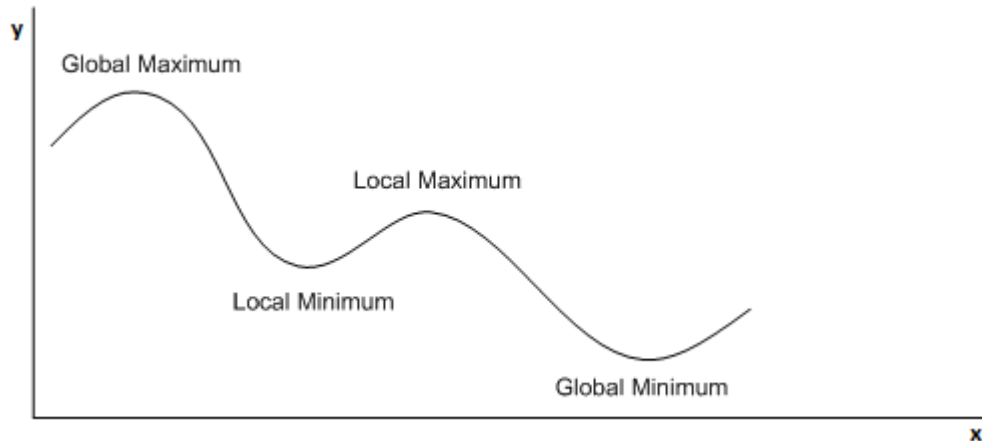


Figure 2.4 Visualization of global and local minimum, [79]

Simulated annealing could give the best result with two tricks. The first is called “Metropolis” in which some trades that do not lower the mileage are accepted when they serve to allow the solver to "explore" more of the possible space of solutions [81]. Criteria,

$$e^{-\Delta D/T} > R(0,1)$$

where, ΔD is the change of distance implied by the trade (for a „good trade it is negative and for a „bad“ trade it is positive) is using to allow „bad“ trades. T is for sintetic temperature and $R(0,1)$ is accidental number from interval $[0,1]$. Cost function indicated by the letter D and match to the free energy in the case of annealing a metal (“in which case the temperature parameter would actually be the kT , where k is Boltzmann's Constant and T is the physical temperature, in the Kelvin absolute temperature scale”). When temperature T is large than a lot of „bad“ trades are accepted and a large part of solution could be reached. Objects which would be traded are chosen indiscriminately [81].

The next trick which is used for simulated annealing is used to reduce the temperature. When many trades are made and the cost function is decreasing slowly, one lowers the temperature, and thus limits the size of allowed "bad" trades. When the temperature is launching to a low point value, one may then put down the process by accepting only "good" trades so the local minimum of the cost function could be found.

All the methods for optimization could take more time than expected. And the most important thing is to choose the right method. What is the relationship between number of cities and time in traveling salesman problem could be seen in table 2.1.

Table 2.1. Time relation with numbers of cities

Number of cities		Number of tours	Time
5	$(5-1)! / 2$	12	
6	$(6-1)! / 2$	60	
7	$(7-1)! / 2$	360	
8	$(8-1)! / 2$	2520	
9	$(9-1)! / 2$	20160	
10	$(10-1)! / 2$	181440	< 1 s
11	$(11-1)! / 2$	1814400	~ 1.8 s
12	$(12-1)! / 2$	19958400	~ 20 s
15	$(15-1)! / 2$	43589145600	12 hours
20	$(20-1)! / 2$	$6,08225502 \cdot 10^{16}$	1928 years
25	$(25-1)! / 2$	$3,102242009 \cdot 10^{23}$	~9837144877 years

When a number of cities is less than 12 than the tour is not very big and the calculation result is not so frightening. But but when the number of cities reached 15, the time is growing fast, i.e. 15 cities took 12 hours and 20 cities took 1928 years.

3. Research part

3.1. Food supply chain's expertise assessment

3.1.1. Demand and supply information

After the survey analysis, all data about loading addresses, type of products, delivery addresses, and temperature requirements was systemized in the 3.1 table.

Table 3.1 Detailed information about cargo

No.	Sales Country	Sales City	Delivery Country	Delivery City	Product name	Required temperature	Quantity of cargo, European standard pallets
1	Belgium	Antwerp	Lithuania	Šiauliai	Diary products	Chilled	16
2	Belgium	Alken	Lithuania	Vilnius	Cereal, Flakes	None	32
3	Belgium	Geel	Lithuania	Šiauliai	Vegetables	Chilled	5
4	Belgium	Aalst	Lithuania	Vilnius	Tea, Coffee	None	10
5	Belgium	Alken	Lithuania	Vilnius	Spices and herbs	None	7
6	Belgium	Kortrik	Lithuania	Kaunas	Vegetables	Chilled	12
7	Germany	Kiel	Lithuania	Šiauliai	Spices and herbs	None	16
8	Germany	Löhne	Lithuania	Šiauliai	Cereal, Flakes	None	16
9	Germany	Extertal	Lithuania	Šiauliai	Diary products	Chilled	16
10	Germany	Lügde	Lithuania	Šiauliai	Nuts and seeds	None	16
11	Germany	Bielefeld	Lithuania	Šiauliai	Bread	Chilled	16
12	Germany	Melle	Lithuania	Šiauliai	Spices and herbs	None	16
13	Netherlands	De Kwakel	Lithuania	Šiauliai	Fruits	Chilled	16
14	Netherlands	Purmerend	Lithuania	Šiauliai	Fats	Frozen	16
15	Netherlands	IJssel	Lithuania	Šiauliai	Spices and herbs	None	16
16	Netherlands	Veenendaal	Lithuania	Šiauliai	Fish	Frozen	16
17	Netherlands	Veldhoven	Lithuania	Šiauliai	Fats	Frozen	16
18	Netherlands	Helmond	Lithuania	Šiauliai	Spices and herbs	None	16
19	United Kingdom	London	Lithuania	Vilnius	Meat	Chilled	32
20	United Kingdom	Bristol	Lithuania	Vilnius	Bread	Chilled	12
21	United Kingdom	London	Lithuania	Kaunas	Fats	Frozen	5

22	United Kingdom	Aylesford	Lithuania	Kaunas	Meat	Chilled	12
23	United Kingdom	Curbridge	Lithuania	Kaunas	Cereal, Flakes	None	12
24	United Kingdom	London	Lithuania	Kaunas	Tea, Coffee	None	5

Table 3.1 shows a part of all the information which is collected [62]. Four countries are selected after all interviews because of quantity of loading addresses. Those countries are Germany, Belgium, The Netherlands and The United Kingdom. Because of confidentiality, exact coordinates are not shown in this table, but cities could be seen. Delivery country always is Lithuania, only cities are different. Companies gave information about the products which are transported, all those products could be seen in column named “Product name”. It is easier to group those products because of temperature requirements. Some of those products need freezing temperature, some of those need neutral temperature (0 °C). All temperature requirements are divided in to three types: frozen, chilled and none. Furthermore, quantity of palettes is described and it could help for counting partial freight distribution and see, which addresses could be connected in one shipment.

Full table with all loading addresses could be found in Appendix No. 1.

3.1.2. Warehouse construction cost information

In all industries of products it is very important to know how much investment is necessary to have the own warehouse. After data analysis warehouse construction costs are known in all five countries. Detailed information is shown in 3.2 table.

Table 3.2 Detailed warehouse construction cost

Country	Size sqr meters	Type	Rent price per sqr meters	Service price per sqr meters	Total rent price per month	Land price per sqr meters	Construction cost, sqr meter	Construction cost
Germany	1440	None	4,83 €	0,97 €	8 346 €	160,00 €	670,83 €	966 000 €
Germany	1440	Chilled	6,76 €	1,35 €	11 685 €	160,00 €	687,50 €	990 000 €
Germany	1440	Frozen	13,93 €	2,79 €	24 071 €	160,00 €	698,61 €	1 006 000 €
Belgium	1440	None	6,25 €	1,25 €	10 800 €	300,00 €	828,47 €	1 193 000 €
Belgium	1440	Chilled	8,75 €	1,75 €	15 120 €	300,00 €	845,14 €	1 217 000 €
Belgium	1440	Frozen	18,03 €	3,61 €	31 147 €	300,00 €	856,25 €	1 233 000 €
Netherlands	1440	None	6,30 €	1,26 €	10 886 €	360,00 €	895,83 €	1 290 000 €

Netherlands	1440	Chilled	8,82 €	1,76 €	15 241 €	360,00 €	912,50 €	1 314 000 €
Netherlands	1440	Frozen	18,17 €	3,63 €	31 396 €	360,00 €	923,61 €	1 330 000 €
United Kingdom	1440	None	7,30 €	1,46 €	12 614 €	550,00 €	1 168,75 €	1 683 000 €
United Kingdom	1440	Chilled	10,22 €	2,04 €	17 660 €	550,00 €	1 187,50 €	1 710 000 €
United Kingdom	1440	Frozen	21,05 €	4,21 €	36 380 €	550,00 €	1 200,00 €	1 728 000 €
Lithuania	1440	None	3,00 €	0,60 €	5 184 €	50,00 €	388,89 €	560 000 €
Lithuania	1440	Chilled	4,20 €	0,84 €	7 258 €	50,00 €	400,69 €	577 000 €
Lithuania	1440	Frozen	7,30 €	1,46 €	12 614 €	50,00 €	408,33 €	588 000 €

For understanding, five countries are shown with the biggest warehouse size – 1440 square meters. For each country, three types of temperature requirements are chosen: chilled, frozen and none.

It is very important to analyse all three types, because the price of warehouse depends on temperature. The lowest prices for square meter are in Lithuania: for frozen type it is 7,30 €, for chilled type – 4,20 € and for none type – 3,00 €. As it is seen, the most expensive warehouse could be construct in United Kingdom, where one square meter for chilled type is 10,22 €, one meter for frozen type is 21,05 € and for none type – 7,30 €. For comparison, one square meter for frozen type in Lithuania costs as much as in United Kingdom, but type is different - none.

The lowest service price could be found also in Lithuania: for frozen type it is 1,46 €/square meter, for chilled type it is 0,84 € / square meters, for none type it is 0,60 € / square meters. The biggest prices are, again, in United Kingdom: for square meter of frozen type price is 4,21 €, for chilled type - 2,04 € and for none type - 1,46 €. The Netherlands and Belgium maintain the similar prices.

As showed the calculations, frozen type warehouse could be cheapest for rent in Lithuania, the price is 12 614 €. United Kingdom holds the biggest price, which is equal to 36 380 €.

When talking about construction cost, the cheapest warehouse could appear in Lithuania. The price of new warehouse would be approximately 588 000 €. After comparison with the other countries, to build a new warehouse in Lithuania is cheaper more than two times than in Germany, Belgium or Netherlands. Moreover, for United Kingdom the price is three times more.

Full table could be found in Appendix No. 2

Table 3.3. Warehouse construction cost in different countries

Country	Type	Fixed cost (FCWC)	Variable cost (VCWC)
Belgium	Chilled	305 927,26 €	607,40 €
	Frozen		618,17 €
	None		591,42 €
Germany	Chilled	379 651,76 €	399,94 €
	Frozen		410,72 €
	None		383,96 €
Lithuania	Chilled	208 941,14 €	245,57 €
	Frozen		252,69 €
	None		233,84 €
Netherlands	Chilled	306 921,46 €	671,15 €
	Frozen		682,65 €
	None		655,89 €
United Kingdom	Chilled	339 580,04 €	913,79 €
	Frozen		925,53 €
	None		895,89 €

Table 3.3 shows simple details for construction cost. Fixed cost does not depend on temperature type. These costs are always the same and fixed. However, variable cost depends on temperature type and quantity of palletes.

In conclusion, warehouse construction cost is equivalent to the sum of fixed cost and variable cost multiplied by quantity of pallets (PQ).

3.1.3. Warehousing cost information

When a warehouse is build, the cost of warehousing is very important and it depends on quantity of palletes, temperature type, and quantity of employees. Take a look at table 3.4 where quantity of palletes is the same for each choice – 1500 palletes and for each variant quantity of employees is equal to 6.

Table 3.4 Detailed warehousing cost

Country	Type	Management cost per month	Energy	Average wage	Depreciation	Other expenses
Belgium	Chilled	20 968 €	1 890,0 €	2 742,50 €	1 963 €	660 €
Belgium	Frozen	23 193 €	3 893,4 €	2 742,50 €	1 982 €	862 €
Belgium	None	20 343 €	1 350,0 €	2 742,50 €	1 935 €	603 €
Germany	Chilled	18 199 €	1 460,6 €	2 457,89 €	1 453 €	538 €
Germany	Frozen	19 923 €	3 008,8 €	2 457,89 €	1 472 €	694 €
Germany	None	17 708 €	1 043,3 €	2 457,89 €	1 424 €	493 €
Lithuania	Chilled	7 961 €	907,2 €	1 002,10 €	773 €	269 €
Lithuania	Frozen	8 712 €	1 576,8 €	1 002,10 €	786 €	337 €

Lithuania	None	7 654 €	648,0 €	1 002,10 €	752 €	241 €
Netherlands	Chilled	19 895 €	1 905,1 €	2 524,50 €	2 181 €	662 €
Netherlands	Frozen	22 138 €	3 924,5 €	2 524,50 €	2 200 €	866 €
Netherlands	None	19 265 €	1 360,8 €	2 524,50 €	2 153 €	604 €
United Kingdom	Chilled	22 600 €	2 207,5 €	2 769,60 €	2 979 €	796 €
United Kingdom	Frozen	25 197 €	4 547,5 €	2 769,60 €	3 000 €	1 032 €
United Kingdom	None	21 871 €	1 576,8 €	2 769,60 €	2 946 €	730 €

Management cost per month consists of energy, wages for employees, depreciation and other expenses. Let's discuss about The United Kingdom chilled type of temperature. Management cost for this type is 22 600 €. As it is seen, this price depends on temperature type. Energy cost also depends on type of temperature and equal 2207,5 €. As it was mentioned, 6 employees are working in warehouse and average wage is 2769,60 €. Depreciation is 2979 € and it belong on temperature. Other expenses could reach 796 €. For other countries the structure is the same.

Full table, where different quantity of employees and palettes are shown, could be seen in Appendix No. 3.

Table 3.5 Warehouse management cost

Country	Type	Fixed Costs (FCWMC)	Variable costs (VCWMC)
Belgium	Chilled	10265,72 €	7,26 €
Belgium	Frozen	10356,82 €	8,68 €
Belgium	None	10240,83 €	6,86 €
Germany	Chilled	9336,04 €	6,02 €
Germany	Frozen	9415,00 €	7,12 €
Germany	None	9314,42 €	5,70 €
Lithuania	Chilled	3907,94 €	2,75 €
Lithuania	Frozen	4074,79 €	3,14 €
Lithuania	None	3889,21 €	2,56 €
Netherlands	Chilled	9517,39 €	7,04 €
Netherlands	Frozen	9633,40 €	8,45 €
Netherlands	None	9482,51 €	6,64 €
United Kingdom	Chilled	10543,33 €	8,17 €
United Kingdom	Frozen	10780,44 €	9,76 €
United Kingdom	None	10479,30 €	7,73 €

Table 3.5 shows warehouse management cost. As it is seen, cost consist of variable cost and fixed cost. For comparison, Belgium and United Kingdom have biggest fixed cost, it is more than 10000 € for all temperature types. The lowest price, again, could be find in Lithuania; it is about 4000 € for all types of warehouse.

3.1.4. Transportation cost evaluation

When all loading addresses and distances are known, transport cost could be calculated. All the prices for fixed and variable cost are shown in table 3.6.

Table 3.6 Transportation cost

Type	Cargo	Fixed cost (FC)	Variable cost from pallet quantity (VCPQ)	Fuel cost per kilometre (FCPK)
	Temperature			
International	Chilled	336,63 €	37,03 €	0,45 €
International	Frozen	374,03 €	41,15 €	0,45 €
International	None	299,23 €	32,92 €	0,45 €
Local	Chilled	185,78 €	12,6 €	0,45 €
Local	Frozen	206,43 €	14 €	0,45 €
Local	None	165,14 €	11,2 €	0,45 €

Fixed cost consists of wage, insurance, amortization and it is depend on temperature, because of insurance. Variable cost is made of quantity of pallets and type of temperature. For example, international transportation with frozen type of temperature could cost 41,15 €. The fixed cost would be 374,03 €. And fuel cost could be calculated after knowing distance. The local transportation is cheaper. Fixed cost for frozen temperature cargo is 206,43 €. Price for one pallet is 14 € and the fuel cost is the same – 0,45 €. Fox example, if company transports 10 palettes with chilled type of temperature and distance is 1200 km, the cost would be

$$336,63 + 37,03 * 10 + 0,45 * 1200 = 1246,93 \text{ €}$$

All cost could be calculated when quantity of palettes and distance are known. Tables 3.6. were made from Appendix No. 3 where all information could be seen.

Nowadays, environment is very important and trucks emit lots of CO_2 . Quantity of CO_2 depends on temperature type and it could be seen in table 3.7

Table 3.7 Fuel consumption rates

Name	Rate	Index
Average truck's consumption rate	0,3	Per kilometre
Frozen transportation	3	l per hour
Chilled transportation	2	l per hour
None transportation	0	l per hour
Average CO_2 emission	2,9	kg per 1 litre
Average truck's speed	80	km per hour

Average of CO_2 emission is 2,9 kg/liter [82], also it depends on which type of temperature is in the truck. If it is frozen than every hour CO_2 emission increase by 3 kg / hour, when average of

truck's speed is about 80 km/h. After analysis of warehouse location and distances CO_2 emission could be decreased by the shortest path.

3.2. Logistic network modelling

3.2.1. Description of scenarios

The developed logistic network will be evaluated different scenarios based on total logistic cost and CO_2 emission level. Raw material from Western Europe is important for the small market's food industry, therefore, different distribution possibilities will be evaluated. It is recommended for the market to share information and conduct a cluster, but to evaluate the benefit a more detail calculations must be done. In this case two scenarios by using 3 different criterions were analysed.

Logistic network scenarios:

Just in time (JIT) distribution

An inventory strategy companies seek to increase efficiency and decrease waste by receiving goods only as they are needed in the production process, thereby reducing inventory costs. This method requires that producers are able to accurately forecast demand. In this scenario it will be distributed from all suppliers directly to delivery place (Lithuania).

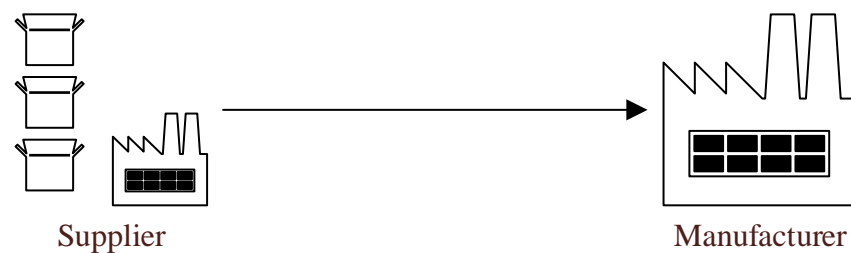


Figure 3.1 Just in time scenario visualization

Consolidation warehouse

Is a form of warehousing that pulls together small cargo from a number of suppliers in the same geographical area and combines them into larger, more economical, shipping loads intended for the same area. In this case the consolidation warehouses will be positioned in The United Kingdom, Germany and The Netherlands. The positions were chosen theoretically, based on logistic infrastructure. In The UK, Maidstone was chosen because of its position next to the boarder. Moreover, primary the freight in The United Kingdom is positioned in London region. In The Netherlands Antwerpen was chosen, because in the future the sea transportation should be also implemented in the logistic network. However, in this scenario, the sea transport won't be evaluated. Lastly, Bylefeld in Germany was chosen, because it is positioned directly in the route and Rail Baltic is planned to open nearby that also can be implemented inside the logistic network.

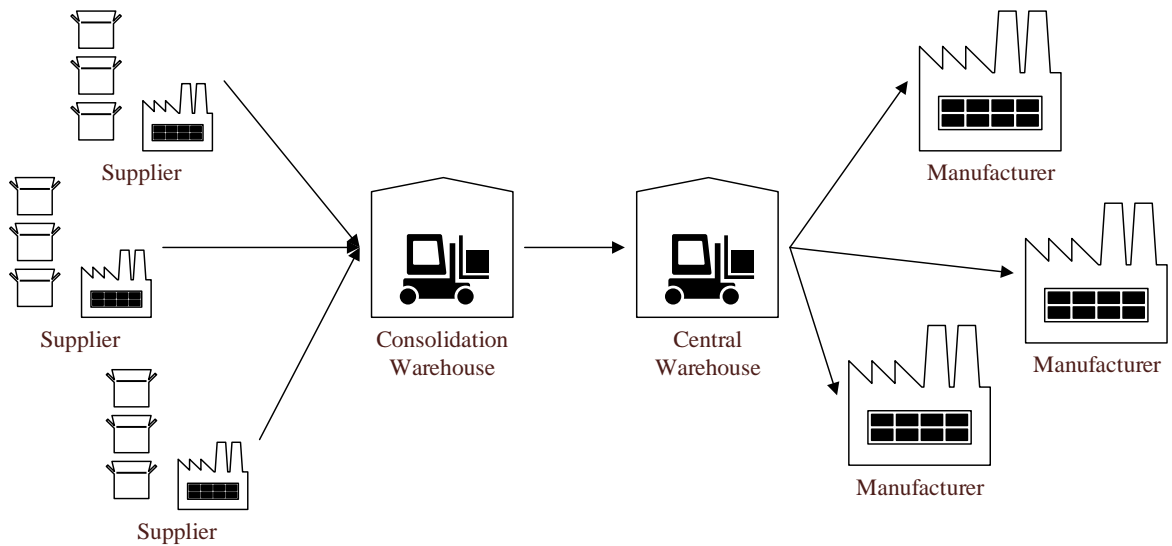


Figure 3.2 Consolidation warehouse scenario visualization

Partial freight distribution

Partial freight forwarding is a distribution method, when transporting small amounts of cargo. Usually companies manufacture large quantities of products or buy raw material in larger quantities, however this might be difficult to accomplish for the food industry. Therefore, partial freight forwarding can be done by evaluating the best possible route to gather the cargo. This process is quite complicated especially when trying to maintain a transparency in the supply chain. In this model we will gather partial freight up to two loading places due to computational limitation.

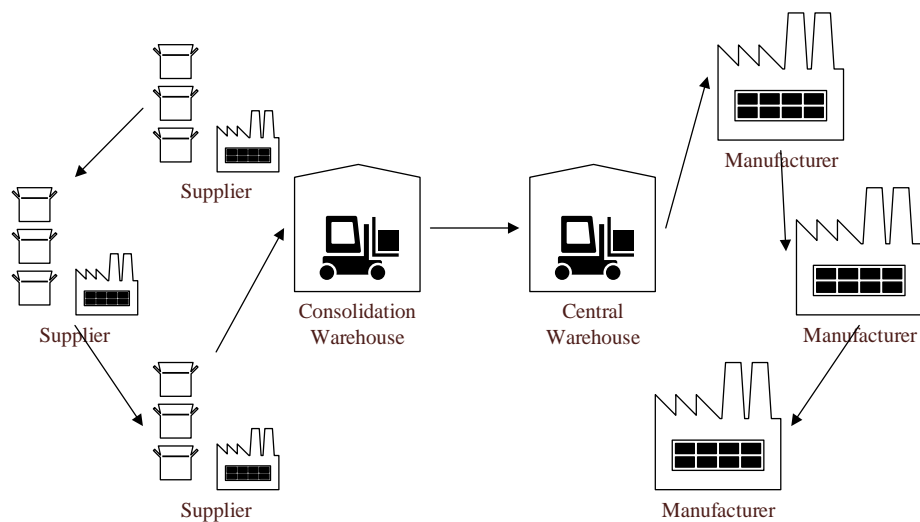


Figure 3.3 Partial freight distribution scenario visualization

Figure 3.4 illustrates the optimal solution of the Western Europe logistic infrastructure. It involves rail Baltic, sea and land transportation. In this project only the land transportation possibilities are analysed. Land transportation possibilities will be evaluated depending on different criterion. The freight distribution process will be modelled based on three criterions. These criterions will simulate different methods of logistics.

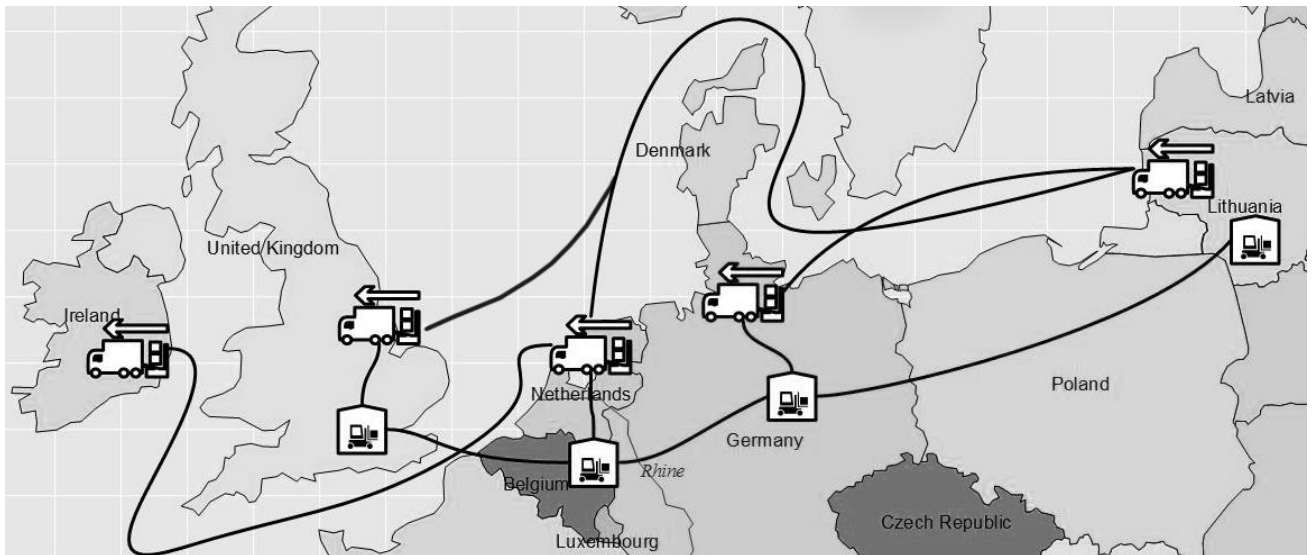


Figure 3.4 Logistic network visualization, [83]

Third-party logistics (3PL) provider

In this case, the enterprise is buying the services from a 3PL provider, therefore, he is not so interested in minimizing the costs for the customer. He is interested in his own profit, therefore, the cargo will be distributed to the nearest warehouse.

Private logistic department

In this case, the enterprise decision is to have his own employees for the transport and not buy services from a 3PL provider. There is the reason why just in time distribution can be implemented, because the employee will look for the solutions by his own. Moreover, he should decide, if it is profitable to distribute directly to Lithuania or to a consolidation warehouse.

Logistic cluster

This criterion will analyse the possibility to distribute partial freight. Partial freight distribution can also be done by a 3PL provider, however in this case the cost effective solution will benefit only the service provider, but not the customer. However, if a logistic cluster would be implemented, the cluster members would have a possibility to distribute the freight together.

3.2.2. Optimization goal

Firstly, it is important to have a concrete goal, which can be measured. The first optimization criterion is based on costs. The first part of costs is transportation cost (see formula 3.1).

$$TC = FC + PQ(T) * VCPQ + D * FCPK \quad (3.1)$$

TC – transportation cost

FC– fixed cost

PQ(T) – pallet quantity, depended on temperature type

VCPQ – variable cost for pallet quantity

FCPK – variable cost per kilometre

The second part of the target function is related with warehouse construction costs (see formula 3.2).

$$WCC = FCWC + PQ(T) * VCWC \quad (3.2)$$

WCC – warehouse construction cost

FCWC – fixed cost for warehouse construction

PQ(T) – pallet quantity, depended on temperature type

VCWC – variable cost for warehouse construction cost

The last part of the logistic cost is related with warehouse management costs (see formula 3.3).

$$WMC = FCWMC + PQ(T) * VCWMC \quad (3.3)$$

WMC – warehouse management cost

FCWMC – fixed cost for warehouse management cost

PQ(T) – pallet quantity, depended on temperature type

VCWMC – variable cost for warehouse management cost

Then all the costs will be summed and the total logistic network costs will be evaluated (see formula 3.4).

$$TNC = WCC + WMC + TC \quad (3.4)$$

TNC – total network cost

The target optimization formula is expressed in formula 3.5

$$\min(TNC) = \sum_S \left(\sum_K WCC(PQ, T) + \sum_i WHC(D, PQ, T) + \sum_i TC(D, PQ, T) \right) \quad (3.5)$$

S- number of scenarios, 0,1,2,3,4,5 – number of warehouses.

K- warehouse index, $K = 1,2,3$

PQ – pallet quantity

D – distance

T- temperature type

Alternatively, the optimization level will be based on CO₂ emission level (see formula 3.6).

$$EL = AE * (D * EFRC + T * TFCR) \quad (3.6)$$

EL – emission level

AE – CO₂ average emission

D – distance

EFRC – engines fuel consumption rate

TFCR – temperature fuel consumption rate

TT – transportation Time

$$TT = \frac{D}{AS} + 11 * \text{DIV}\left(\frac{D}{AS}, 0\right) \quad (3.7)$$

AS – average speed

DIV – is an operator that leaves only the whole number

The transportation time multiplies by 11, because of the legislation issues. Every 10 hours the drivers needs to rest up to 11 hours (see formula 3.7).

3.2.3. Calculation steps

All scenarios and optimization goals are known. Next step after the theoretical hypothesis is to make an algorithm, which could show the best scenario for small market. The algorithm will try to calculate, which scenario should be used: just in time (JIT) distribution, consolidation warehouse or partial freight distribution would be the best choice for some company. Because of time limit, the algorithm was made just for two loading addresses, i.e. programm took two addresses and checked the conditions. In the second chapter (table 2.1) “Time relation with numbers of cities” was talking about time limits, when programm took more than 5, 10 or 20 loading addresses.

The main values are quantity of palettes, distance from one address to another, type of temperature and CO₂ level. When all these values will be pieced together, the program will give the answer too all questions, which were raised in the article. Let’s start from the beginning of calculation. First and one of the most important is transport and warehouse cost.

Transport and warehouse costs

First condition for transport and warehouse calculation is to pick the nearest warehouse. When distance is picked up then the programme calculates the quantity of palettes. It is very important to know the quantity, because cargo might have three types of temperature: none, chilled and frozen. When quantity is captured, total quantity of palettes is known and it also will help to count the CO₂ emission. Furthermore, it is important to know quantity of palettes, because of partial freight (figure 3.4).

```
if (WH_B$Distance < WH_UK$Distance & WH_B$Distance < WH_G$Distance
  Nearest_WH_Edge <- WH_B
  Nearest_WH_Vertex <- WH_B_Vertex
  WH_B_Size_None <- WH_B_Size_None + Vertex$None[i]
  WH_B_size_Chilled <- WH_B_size_Chilled + Vertex$Chilled[i]
  WH_B_size_Frozen <- WH_B_size_Frozen + Vertex$Frozen[i]
```

Figure 3.4 Selection of nearest warehouse

When the distance is known, then transportation costs are split up into local and international costs. Do not forget that transportation cost for three temperature types are different, so programm has to check how much patelles of none/chilled/frozen type are in cargo. Table 3.6 “Transportation

cost” shows the difference between cost. The Fuel cost per kilometre is the same for local and international transportation, but fixed cost and variable cost is different. Local transportation is cheaper than international, therefore, programm has to check, which type would be for selected address (figure 3.5).

```
transportation_costs_S_NWH_Calculated = (Nearest_WH$Distance*Transportation_Costs_Local$VCPK/1000
+Nearest_WH_Vertex$None*Transportation_Costs_Local_None$VCFPQ
+Nearest_WH_Vertex$Chilled*Transportation_Costs_Local_Chilled$VCFPQ
+Nearest_WH_Vertex$Frozen*Transportation_Costs_Local_Frozen$VCFPQ
+Transportation_Costs_Local$FC
```

Figure 3.5 Evaluation of transportation costs

CO₂ emmission level

One of the important calculations is CO₂ emission level. Because of keeping nature safe, this level must be as low as possible. It is known from table 3.7. “Fuel consumption rates” that average truck’s consumption rate is 0,3 kg per 1 kilometer when it drives with the speed of 80 km/h. When truck has long distance, fuel consumption is calculated not only for driving hours, but also for rest time. When cargo must have exact temperature, fridge should work at all travel time (figure 3.6). Hence, CO₂ calculation depends on fuel, distance, rest hours and type of temperature.

```
Rest_Time=((WH_UK_WH_LT$Driving_Time%/%39600)*10)+((WH_UK_WH_LT$Driving_Time-(39600*WH_UK_WH_LT$Driving_Time%/%39600))%/%18000)*1
Total_Time=Rest_Time+WH_UK_WH_LT$Driving_Time/60/60
#Evaluate CO2 level for distance
CO2_Distance=WH_UK_WH_LT$Distance/1000*Emission_Calculation_Data$Truck_Fuel_Rate
```

Figure 3.6 Driving time evaluation

As it was mentioned, average truck consumption rate is 0,3 kg for hour. Also it is calculated for different temperature. None temperature type does not add additional amount. Temperature of frozen type adds additional 3 kg per one hour, while chilled type adds 2 kg per one hour. The algorithm calculates all the fuel consumption for all cargo which has different type of temperature (figure 3.7).

```
if (WH_UK_Size_None != 0 & WH_UK_size_Chilled == 0 & WH_UK_size_Frozen == 0) {
  CO2_Refrigerator = Total_Time*Emission_Calculation_Data$None_Fuel
} else if (WH_UK_Size_None == 0 & WH_UK_size_Chilled != 0 & WH_UK_size_Frozen == 0) {
  CO2_Refrigerator = Total_Time*Emission_Calculation_Data$None_Chilled
} else if (WH_UK_Size_None == 0 & WH_UK_size_Chilled == 0 & WH_UK_size_Frozen != 0) {
  CO2_Refrigerator = Total_Time*Emission_Calculation_Data$Frozen_Fuel
} else if (WH_UK_Size_None != 0 & WH_UK_size_Chilled != 0 & WH_UK_size_Frozen == 0) {
  CO2_Refrigerator = Total_Time*Emission_Calculation_Data$None_Chilled
} else if (WH_UK_Size_None != 0 & WH_UK_size_Chilled == 0 & WH_UK_size_Frozen != 0) {
  CO2_Refrigerator = Total_Time*Emission_Calculation_Data$Frozen_None_Fuel
} else if (WH_UK_Size_None == 0 & WH_UK_size_Chilled != 0 & WH_UK_size_Frozen != 0) {
  CO2_Refrigerator = Total_Time*Emission_Calculation_Data$Frozen_Chilled
} else {
  CO2_Refrigerator = Total_Time*Emission_Calculation_Data$Frozen_Chilled_None
}
```

Figure 3.7 Selection of temperature type

When distance and temperature type are known, all fuel consumption is calculated on the basis of transportation as well as rest time and refrigerator expenses (figure 3.8).

```
#Evaluate CO2 Level for one route
CO2_Level_WH_UK_WH_LT = (CO2_Distance+CO2_Refrigerator)*Emission_Calculation_Data$CO2_Emission*WH_UK_Truck_Quantity
#Time
Traveling_Time_WH_UK_WH_LT_Total = Traveling_Time_WH_UK_WH_LT_Total+Total_Time*WH_B_Truck_Quantity
```

Figure 3.8 Evaluation of CO₂ emission level

After that CO₂ level for one route is known it might be compared with other routes.

3.2.4. Results

Based on the gathered data a logistic network was modeled by using Rstudio. The optimization process was completed by using simulated annealing method. This method is designed for optimizing complex functions by using probabilities and random sampling.

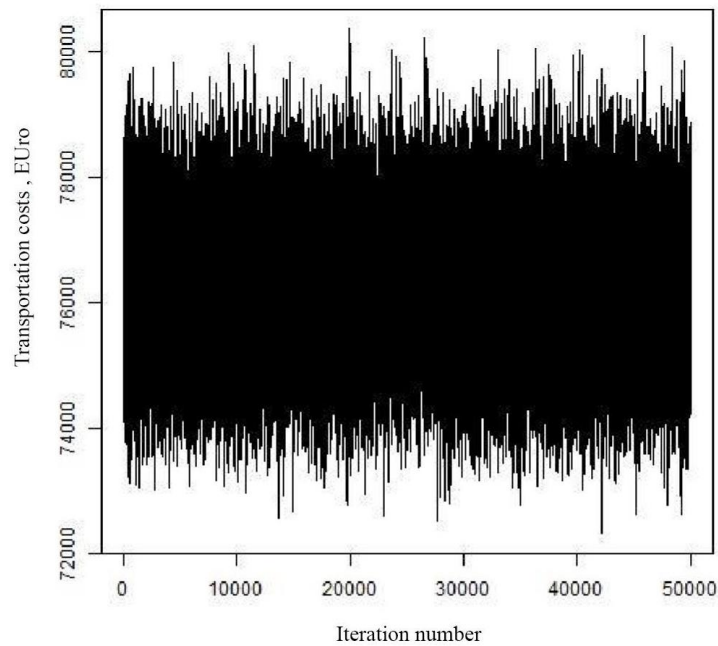


Figure 3.9 Transportation cost alteration by monitoring iteration number

Simulated annealing method calculates multiple times transportation costs by selecting randomly different suppliers and evaluating the possibility to gather the cargo together. The optimization process was evaluated 50 thousand times and the graph above displays different transportation costs. Based on these calculations the algorithm finds the best costs and minimizes the optimization function. The optimization function consists of several parts.

Table 3.8 Evaluation of distribution strategies

Type	Just In Time	Consolidation	Partial Freight
Transportation Costs (Eur)	151047.859	126756.229	107119.975
Warehouse Construction Costs (Eur)	0	339580.040	208941.140

Warehouse Management Costs (Eur)	0	10266.720	3907.940
CO ₂ Level (kg)	180930.694	116766.194	270963.622
Travel Time (min)	3280.374	1667.509	5064.386

Table 3.8 reflects the results of comparison. As it is seen, JIT type has the biggest transportation cost and medium CO₂ level but also it has no warehouse construction and management cost. Travel time is 3280.374 hours. Consolidation type has lowest CO₂ level, the highest warehouse management and construction costs and transportation costs is medium. But the travel time is only 1667.509 hours. The biggest travel time is for partial freight type, but transportation costs is only 107119.975 euro. Also the warehouse cost is lower than consolidation type but CO₂ level is the highest (table 3.8).

From the evaluated data several insights can be seen. Just in time distribution requires lower capital investments and has a less complex management system. However, after 2.5 years consolidation warehouse becomes more profitable and only after 3 months partial freight distribution method becomes more profitable.

However, due to the optimization, the travel distance becomes higher. Therefore, the CO₂ emission level increased approximately 2 times. The evaluation of the partial freight strategy was conducted by evaluating the distribution process from Germany, United Kingdom, Belgium and Netherlands to Lithuania central warehouse. Therefore, the optimization process might be evaluated inaccurate, and a more detailed evaluation must be conducted.

Table 3.9 Supplier – Warehouse in Lithuania optimized route's results

Type	Just in Time	Partial Freight	Change
Transportation Costs (Eur)	113692.300	72320.785	-57.21 %
Travel Time (min)	2705.617	1502.869	-80.03 %
CO ₂ (kg)	139914.947	85723.935	-63.22 %
Distance (km)	45434.700	27148.783	-67.35 %
Route Quantity	95	47	-102.13 %

The CO₂ emission level is related to travel time and distance, therefore, the effect decreased. The comparison of the whole system and the optimized route differs because of the travel time (table 3.9). Mainly it is related to employee rest time that they require taking during their trip. During this time the refrigerator must run, while additional benefits are not generated.

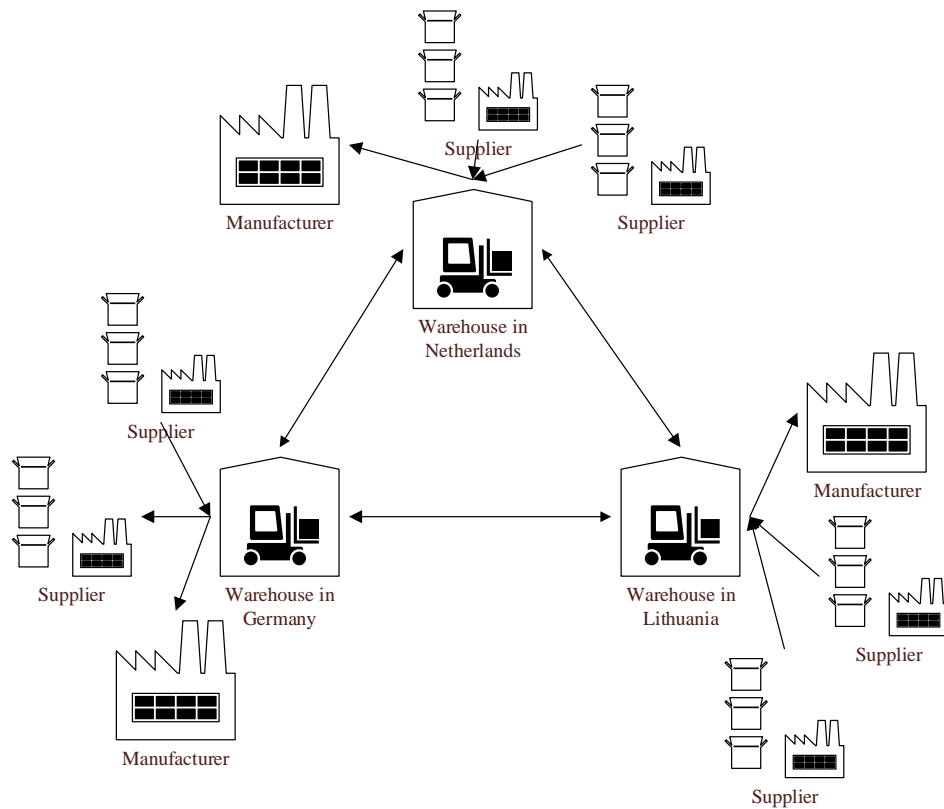


Figure 3.10 Vizualization of regional logistic cluster collaboration

Therefore, the development of big data, route scheduling, fleet management systems, alternative energy and automatous vehicles can be combined to optimize the partial freight distribution strategy [84, 85]. SMEs can create a logistic cluster (figure 3.10), implement these innovative technologies, share information between the cluster members and achieve low costs and environmental safety.

Conclusions and recommendations

Conclusions

1. The small markets have a tendency to work in the distribution industry of products, information and services. This is because most countries lack experience in manufacturing industry.
2. The food industry analysis showed that the most important factors that complicated supply chain management were time and temperature requirements for products.
3. Logistics has seven types of transportation but not all are useful for food transportation. But the most popular transportation is intermodal – use of more than one transportation type. Warehouses for food have a lot of rooms with different levels of temperature but the most important question is where and how many warehouses a company needs.
4. After the clustering analysis and process modeling it can be concluded that the logistic cluster will provide economic benefits, however, a deeper analysis needs to be done for proper argumentation of the developed methodology.
5. After the specialist interview it can be stated that:
 - frozen temperature maintenance inside semi-trailer requires approximately 45-55 % more diesel fuel than maintenance of chilled temperature;
 - the weight of the cargo has relatively little impact on total costs;
 - when transporting a fully loaded semi- trailer (32 euro pallets), the price per pallet is from 40 up to 48 euro per piece. While transporting partial cargo the price per pallet can vary from 80 up to 120 euro.
6. After the modelling of logistic network it can be concluded that:
 - just in time production is designed more for low quantity orders and individual enterprises rather than for large multi-national companies or clusters;
 - consolidation warehouses are a great tool to control the supply chain and optimize costs, however, there is a problem for management the supply chain, buying land and finding capital investments;
 - partial freight gathering optimizing costs might increase during long distance forwarding due to the increased traveled distance and driver's rest time as well as the CO₂ emission level. However, all criteria can be minimized by gathering partial freight in short-distance distribution.

Recommendations

1. One of the main problems of the food industry's supply chain is driver's rest time, because of the work regulations drivers must rest 10 hours after 11 hours of driving. During this time the refrigerator must work, which increases CO₂ emission level and does not provide any financial benefits. New technology development, like alternative fuel, fleet management systems, and autonomous vehicles can avoid this problem.
2. The main limitation of the work is a stationary model and not a stochastic one. However, the analysis of the case study still indicates common tendencies. In the future we recommend to analyse the logistic networks by using stochastic modeling principles, in particular Markov chain theory.
3. From the obtained results it can be concluded, that the best distribution strategy is to gather partial freight in the region (short-freight forwarding), then consolidate them in a regional warehouse. By gathering partial freight in the region it is possible to optimize CO₂ emission level and transportation costs. The main problem of this strategy is that individual companies won't have enough freight to make cost saving routes, therefore, only by forming a logistic cluster this strategy is possible to implement. Moreover, by implementing this strategy in the food industry, it is possible to collaborate with small and medium farmers. The farmers would receive a possibility to decrease their transportation costs and offer their products to the international market in small quantities. This possibility would create a competitive advantage for SMEs and provide them a competitive advantage. In scientific literature the possibility for clusters to collaborate together practically is not analyzed, therefore, this statement – "The collaboration between regional clusters can maximize distribution costs and minimizing the environmental effect for all parties involved in the regional clusters, not only individual players. Without shared knowledge and collaboration between the parties effective partial freight distribution is not possible", will make a large contribution to further scientific reaserch of clustering concepts.

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Appendix

Appendix No. 1

Cargo information

No.	Supplier Country	Supplier City	Delivery Country	Delivery City	Required temperature	Quantity of palletes
1	Germany	Kiel	Lithuania	Šiauliai	None	16
2	Germany	Löhne	Lithuania	Šiauliai	None	16
3	Germany	Extertal	Lithuania	Šiauliai	Chilled	16
4	Germany	Lügde	Lithuania	Šiauliai	None	16
5	Germany	Bielefeld	Lithuania	Šiauliai	Chilled	16
6	Germany	Melle	Lithuania	Šiauliai	None	16
7	Germany	Overath	Lithuania	Šiauliai	None	16
8	Germany	Reichshof	Lithuania	Šiauliai	None	16
9	Germany	Karlstein am Main	Lithuania	Šiauliai	Chilled	16
10	Germany	Verl	Lithuania	Šiauliai	None	16
11	Germany	Bielefeld	Lithuania	Šiauliai	Frozen	16
12	Belgium	Antwerp	Lithuania	Šiauliai	Chilled	16
13	Netherlands	De Kwakel	Lithuania	Šiauliai	Chilled	16
14	Netherlands	Purmerend	Lithuania	Šiauliai	Frozen	16
15	Netherlands	IJssel	Lithuania	Šiauliai	None	16
16	Netherlands	Veenendaal	Lithuania	Šiauliai	Frozen	16
17	Netherlands	Veldhoven	Lithuania	Šiauliai	Frozen	16
18	Netherlands	Helmond	Lithuania	Šiauliai	None	16
19	Netherlands	Dieren	Lithuania	Šiauliai	Chilled	16
20	Netherlands	Ulft	Lithuania	Šiauliai	None	16
21	Germany	Austria	Lithuania	Vilnius	Frozen	32
22	Germany	Ürzig	Lithuania	Vilnius	None	32
23	Germany	Landkern	Lithuania	Vilnius	Chilled	32
24	Germany	Rüdesheim am Rhein	Lithuania	Vilnius	None	32
25	Germany	Langenlonsheim	Lithuania	Vilnius	Chilled	32
26	Germany	Neuburg an der Kammel	Lithuania	Vilnius	None	32
27	Germany	Fischach	Lithuania	Vilnius	None	32
28	Belgium	Alken	Lithuania	Vilnius	None	32
29	Netherlands	KC Vuren	Lithuania	Vilnius	Chilled	32
30	Netherlands	Zoeterwoude	Lithuania	Vilnius	None	32
31	Netherlands	Hertogenbosch	Lithuania	Vilnius	Chilled	32
32	United Kingdom	LONDON	Lithuania	Vilnius	Chilled	32
33	Netherlands	Schijndel	Lithuania	Šiauliai	None	5
34	Belgium	Geel	Lithuania	Šiauliai	Chilled	5
35	Germany	Menzendorf	Lithuania	Šiauliai	Frozen	5
36	Netherlands	Maastricht	Lithuania	Vilnius	None	32

37	Belgium	Aalst	Lithuania	Vilnius	None	10
38	Germany	Lengefeld	Lithuania	Vilnius	Chilled	10
39	Germany	Brandenburg	Lithuania	Vilnius	Chilled	10
40	Germany	Berlyn	Lithuania	Vilnius	Chilled	4
41	Germany	Dortmund	Lithuania	Vilnius	Chilled	32
42	Netherlands	Vuren	Lithuania	Vilnius	Chilled	12
43	Netherlands	Zoeterwoude	Lithuania	Vilnius	Frozen	12
44	Netherlands	Hertogenbosch	Lithuania	Vilnius	None	12
45	Belgium	Alken	Lithuania	Vilnius	None	7
46	United Kingdom	Bristol	Lithuania	Vilnius	Chilled	12
47	United Kingdom	London	Lithuania	Kaunas	Frozen	5
48	United Kingdom	Aylesford	Lithuania	Kaunas	Chilled	12
49	United Kingdom	Curbridge	Lithuania	Kaunas	None	12
50	Germany	Brandenburg	Lithuania	Kaunas	None	12
51	Belgium	Kortrik	Lithuania	Kaunas	Chilled	12
52	Belgium	Lichtervelde	Lithuania	Kaunas	Frozen	12
53	Germany	Aldenhoven	Lithuania	Kaunas	Frozen	12
54	Germany	Ortrand	Lithuania	Kaunas	Chilled	12
55	Germany	Wilthen	Lithuania	Kaunas	Chilled	12
56	Germany	Auerbach	Lithuania	Kaunas	None	12
57	Germany	Ascheberg	Lithuania	Kaunas	Frozen	12
58	Germany	Radolfzell	Lithuania	Kaunas	None	12
59	Germany	Grünsfeld	Lithuania	Kaunas	None	12
60	Germany	Adelsdorf	Lithuania	Kaunas	None	12
61	Germany	Rosa	Lithuania	Kaunas	None	22
62	Belgium	Olen	Lithuania	Kaunas	Chilled	22
63	United Kingdom	London	Lithuania	Kaunas	None	5
64	United Kingdom	Bristol	Lithuania	Vilnius	Chilled	22
65	Germany	Zeitz	Lithuania	Vilnius	Chilled	12
66	Germany	Gotha	Lithuania	Kaunas	Chilled	5
67	United Kingdom	Southall	Lithuania	Kaunas	Chilled	16
68	United Kingdom	Hull	Lithuania	Kaunas	Chilled	32
69	Netherlands	Kampen	Lithuania	Vilnius	Chilled	15
70	Germany	Ludwigsburg	Lithuania	Vilnius	Chilled	15
71	Germany	Reichenbach	Lithuania	Vilnius	None	15
72	Germany	Pausa	Lithuania	Vilnius	Chilled	15
73	Netherlands	Middelharnis	Lithuania	Vilnius	Chilled	15
74	Germany	Hamburg	Lithuania	Marijampolė	Frozen	8
75	Germany	Hamburg	Lithuania	Marijampolė	None	5
76	Germany	Miunhen	Lithuania	Marijampolė	Chilled	5
77	Germany	Essen	Lithuania	Joniškis	Chilled	32
78	United Kingdom	London	Lithuania	kaunas	None	7
79	United Kingdom	Peterborough	Lithuania	kaunas	Frozen	7
80	Belgium	Waregem	Lithuania	Alytus	None	10

81	United Kingdom	Bristol	Lithuania	Vilnius	Chilled	5
82	United Kingdom	Manchester	Lithuania	Vilnius	Frozen	5
83	United Kingdom	rochester	Lithuania	Vilnius	Chilled	5
84	United Kingdom	Wigan	Lithuania	Vilnius	Chilled	5
85	United Kingdom	London	Lithuania	Kaunas	Chilled	6
86	Germany	Garrel	Lithuania	Klaipėda	Chilled	32
87	Germany	Emsdetten	Lithuania	Alytus	Chilled	16
88	Germany	Dahme	Lithuania	Marijampolė	Chilled	2
89	United Kingdom	Manchester	Lithuania	kaunas	Frozen	21
90	United Kingdom	Plymouth	Lithuania	Vilnius	Chilled	5
91	Netherlands	Varsseveld	Lithuania	Alytus	Frozen	5
92	United Kingdom	Harwich	Lithuania	Marijampolė	None	32
93	United Kingdom	Liverpool	Lithuania	Klaipėda	None	32
94	United Kingdom	Birmingham	Lithuania	Klaipėda	Chilled	32
95	United Kingdom	Coalville	Lithuania	Alytus	Chilled	32
96	United Kingdom	Northampton	Lithuania	Alytus	None	32
97	United Kingdom	Bedford	Lithuania	Alytus	Chilled	32
98	Belgium	Geel	Lithuania	Šiauliai	None	6
99	Netherlands	Schijndel	Lithuania	Šiauliai	Chilled	6
100	Germany	Menzendorf	Lithuania	Šiauliai	None	6
101	Netherlands	Moerdijk	Lithuania	kaunas	None	18
102	Netherlands	Venlo	Lithuania	kaunas	None	6
103	Netherlands	Wormer	Lithuania	kaunas	Chilled	11
104	Netherlands	Moerdijk	Lithuania	kaunas	Chilled	18
105	Belgium	Houthulst	Lithuania	kaunas	None	9
106	Belgium	Ledegem	Lithuania	kaunas	Chilled	12
107	Netherlands	Geel	Lithuania	kaunas	Chilled	15
108	Netherlands	Harlingen	Lithuania	kaunas	None	13
109	United Kingdom	Hornchurch	Lithuania	kaunas	Chilled	7
110	Netherlands	Rutten	Lithuania	kaunas	Chilled	6
111	Netherlands	Tilburg	Lithuania	kaunas	None	12
112	Germany	Varsseveld	Lithuania	kaunas	Chilled	12
113	United Kingdom	Brighton	Lithuania	Vilnius	Frozen	10
114	Belgium	Wevelgem	Lithuania	Vilnius	Chilled	12
115	Belgium	Ledegem	Lithuania	Vilnius	Chilled	12
116	Germany	Aldenhoven	Lithuania	Vilnius	None	10
117	Germany	Ascheberg	Lithuania	Vilnius	Chilled	10
118	Germany	Hamburg	Lithuania	Vilnius	Frozen	9

Warehousing construction cost

Country	City	Size sqr meters	Type	Rent price per sqr meters	Service price per sqr meters	Total rent price per month	Land price per sqr meters	Construction cost, sqr meter	Construction cost
Germany	Beliefeld	368,64	None	5,40 €	1,08 €	2.389 €	160,00 €	1.483,83 €	547.000 €
Germany	Beliefeld	368,64	Chilled	7,56 €	1,51 €	3.344 €	160,00 €	1.500,11 €	553.000 €
Germany	Beliefeld	368,64	Frozen	15,57 €	3,11 €	6.889 €	160,00 €	1.510,96 €	557.000 €
Germany	Beliefeld	737,28	None	5,13 €	1,03 €	4.539 €	160,00 €	873,48 €	644.000 €
Germany	Beliefeld	737,28	Chilled	7,18 €	1,44 €	6.354 €	160,00 €	891,11 €	657.000 €
Germany	Beliefeld	737,28	Frozen	14,79 €	2,96 €	13.090 €	160,00 €	901,96 €	665.000 €
Germany	Beliefeld	1440	None	4,83 €	0,97 €	8.346 €	160,00 €	670,83 €	966.000 €
Germany	Beliefeld	1440	Chilled	6,76 €	1,35 €	11.685 €	160,00 €	687,50 €	990.000 €
Germany	Beliefeld	1440	Frozen	13,93 €	2,79 €	24.071 €	160,00 €	698,61 €	1.006.000 €
Belgium	Anterwepen	368,64	None	7,00 €	1,40 €	2.765 €	300,00 €	1.445,86 €	533.000 €
Belgium	Anterwepen	368,64	Chilled	9,80 €	1,96 €	4.335 €	300,00 €	1.462,13 €	539.000 €
Belgium	Anterwepen	368,64	Frozen	20,19 €	4,04 €	8.931 €	300,00 €	1.472,98 €	543.000 €
Belgium	Anterwepen	737,28	None	6,50 €	1,30 €	5.751 €	300,00 €	1.030,82 €	760.000 €
Belgium	Anterwepen	737,28	Chilled	9,10 €	1,82 €	8.051 €	300,00 €	1.048,45 €	773.000 €
Belgium	Anterwepen	737,28	Frozen	18,75 €	3,75 €	16.585 €	300,00 €	1.059,30 €	781.000 €
Belgium	Anterwepen	1440	None	6,25 €	1,25 €	10.800 €	300,00 €	828,47 €	1.193.000 €
Belgium	Anterwepen	1440	Chilled	8,75 €	1,75 €	15.120 €	300,00 €	845,14 €	1.217.000 €
Belgium	Anterwepen	1440	Frozen	18,03 €	3,61 €	31.147 €	300,00 €	856,25 €	1.233.000 €
Netherlands	Arnhem	368,64	None	7,30 €	1,46 €	3.229 €	360,00 €	1.513,67 €	558.000 €
Netherlands	Arnhem	368,64	Chilled	10,22 €	2,04 €	4.521 €	360,00 €	1.529,95 €	564.000 €
Netherlands	Arnhem	368,64	Frozen	21,05 €	4,21 €	9.313 €	360,00 €	1.540,80 €	568.000 €
Netherlands	Arnhem	737,28	None	6,60 €	1,32 €	5.839 €	360,00 €	1.098,63 €	810.000 €
Netherlands	Arnhem	737,28	Chilled	9,24 €	1,85 €	8.175 €	360,00 €	1.121,69 €	827.000 €
Netherlands	Arnhem	737,28	Frozen	19,03 €	3,81 €	16.840 €	360,00 €	1.127,12 €	831.000 €
Netherlands	Arnhem	1440	None	6,30 €	1,26 €	10.886 €	360,00 €	895,83 €	1.290.000 €
Netherlands	Arnhem	1440	Chilled	8,82 €	1,76 €	15.241 €	360,00 €	912,50 €	1.314.000 €
Netherlands	Arnhem	1440	Frozen	18,17 €	3,63 €	31.396 €	360,00 €	923,61 €	1.330.000 €
United Kingdom	Maidstone	368,64	None	9,00 €	1,80 €	3.981 €	550,00 €	1.852,76 €	683.000 €
United Kingdom	Maidstone	368,64	Chilled	12,60 €	2,52 €	5.574 €	550,00 €	1.871,74 €	690.000 €
United Kingdom	Maidstone	368,64	Frozen	25,96 €	5,19 €	11.482 €	550,00 €	1.885,31 €	695.000 €
United Kingdom	Maidstone	737,28	None	8,20 €	1,64 €	7.255 €	550,00 €	1.394,31 €	1.028.000 €
United Kingdom	Maidstone	737,28	Chilled	11,48 €	2,30 €	10.157 €	550,00 €	1.413,30 €	1.042.000 €
United Kingdom	Maidstone	737,28	Frozen	23,65 €	4,73 €	20.923 €	550,00 €	1.425,51 €	1.051.000 €
United Kingdom	Maidstone	1440	None	7,30 €	1,46 €	12.614 €	550,00 €	1.168,75 €	1.683.000 €
United Kingdom	Maidstone	1440	Chilled	10,22 €	2,04 €	17.660 €	550,00 €	1.187,50 €	1.710.000 €
United Kingdom	Maidstone	1440	Frozen	21,05 €	4,21 €	36.380 €	550,00 €	1.200,00 €	1.728.000 €
Lithuania	Kaunas	368,64	None	3,48 €	0,70 €	1.539 €	50,00 €	811,09 €	299.000 €
Lithuania	Kaunas	368,64	Chilled	4,90 €	0,98 €	2.168 €	50,00 €	821,94 €	303.000 €
Lithuania	Kaunas	368,64	Frozen	10,10 €	2,02 €	4.468 €	50,00 €	830,08 €	306.000 €

Lithuania	Kaunas	737,28	None	3,20 €	0,64 €	2.831 €	50,00 €	527,62 €	389.000 €
Lithuania	Kaunas	737,28	Chilled	4,50 €	0,90 €	3.981 €	50,00 €	538,47 €	397.000 €
Lithuania	Kaunas	737,28	Frozen	8,20 €	1,64 €	7.255 €	50,00 €	546,60 €	403.000 €
Lithuania	Kaunas	1440	None	3,00 €	0,60 €	5.184 €	50,00 €	388,89 €	560.000 €
Lithuania	Kaunas	1440	Chilled	4,20 €	0,84 €	7.258 €	50,00 €	400,69 €	577.000 €
Lithuania	Kaunas	1440	Frozen	7,30 €	1,46 €	12.614 €	50,00 €	408,33 €	588.000 €

Appendix No. 3

Warehousing cost

Country	Type	Management cost per month	Size Euro Palet	Energy	Employee Quantity	Average wage	Depreciation	Other expenses
Belgium	Chilled	12.691 €	384	541,9 €	4	2.742,50 €	773 €	406 €
Belgium	Chilled	16.396 €	768	1.006,4 €	5	2.742,50 €	1.184 €	494 €
Belgium	Chilled	20.968 €	1500	1.890,0 €	6	2.742,50 €	1.963 €	660 €
Belgium	Frozen	13.328 €	384	1.116,3 €	4	2.742,50 €	778 €	464 €
Belgium	Frozen	17.580 €	768	2.073,2 €	5	2.742,50 €	1.193 €	601 €
Belgium	Frozen	23.193 €	1500	3.893,4 €	6	2.742,50 €	1.982 €	862 €
Belgium	None	12.513 €	384	387,1 €	4	2.742,50 €	766 €	390 €
Belgium	None	16.063 €	768	718,8 €	5	2.742,50 €	1.168 €	463 €
Belgium	None	20.343 €	1500	1.350,0 €	6	2.742,50 €	1.935 €	603 €
Germany	Chilled	11.339 €	384	418,0 €	4	2.457,89 €	729 €	361 €
Germany	Chilled	14.424 €	768	794,3 €	5	2.457,89 €	923 €	418 €
Germany	Chilled	18.199 €	1500	1.460,6 €	6	2.457,89 €	1.453 €	538 €
Germany	Frozen	11.832 €	384	861,2 €	4	2.457,89 €	733 €	406 €
Germany	Frozen	15.361 €	768	1.636,2 €	5	2.457,89 €	932 €	503 €
Germany	Frozen	19.923 €	1500	3.008,8 €	6	2.457,89 €	1.472 €	694 €
Germany	None	11.200 €	384	298,6 €	4	2.457,89 €	721 €	348 €
Germany	None	14.158 €	768	567,3 €	5	2.457,89 €	907 €	394 €
Germany	None	17.708 €	1500	1.043,3 €	6	2.457,89 €	1.424 €	493 €
Lithuania	Chilled	4.828 €	384	271,0 €	4	1.002,10 €	383 €	166 €
Lithuania	Chilled	6.227 €	768	497,7 €	5	1.002,10 €	517 €	202 €
Lithuania	Chilled	7.961 €	1500	907,2 €	6	1.002,10 €	773 €	269 €
Lithuania	Frozen	5.148 €	384	558,5 €	4	1.002,10 €	386 €	195 €
Lithuania	Frozen	6.685 €	768	906,9 €	5	1.002,10 €	524 €	244 €
Lithuania	Frozen	8.712 €	1500	1.576,8 €	6	1.002,10 €	786 €	337 €
Lithuania	None	4.736 €	384	192,4 €	4	1.002,10 €	378 €	158 €
Lithuania	None	6.058 €	768	353,9 €	5	1.002,10 €	507 €	187 €
Lithuania	None	7.654 €	1500	648,0 €	6	1.002,10 €	752 €	241 €
Netherlands	Chilled	11.885 €	384	565,1 €	4	2.524,50 €	829 €	392 €
Netherlands	Chilled	15.430 €	768	1.021,9 €	5	2.524,50 €	1.301 €	485 €
Netherlands	Chilled	19.895 €	1500	1.905,1 €	6	2.524,50 €	2.181 €	662 €
Netherlands	Frozen	12.549 €	384	1.164,2 €	4	2.524,50 €	834 €	453 €
Netherlands	Frozen	16.627 €	768	2.105,1 €	5	2.524,50 €	1.305 €	594 €
Netherlands	Frozen	22.138 €	1500	3.924,5 €	6	2.524,50 €	2.200 €	866 €
Netherlands	None	11.699 €	384	403,7 €	4	2.524,50 €	822 €	375 €

Netherlands	None	15.087 €	768	729,9 €	5	2.524,50 €	1.280 €	454 €
Netherlands	None	19.265 €	1500	1.360,8 €	6	2.524,50 €	2.153 €	604 €
United Kingdom	Chilled	13.291 €	384	696,7 €	4	2.769,60 €	1.063 €	453 €
United Kingdom	Chilled	17.418 €	768	1.269,6 €	5	2.769,60 €	1.723 €	577 €
United Kingdom	Chilled	22.600 €	1500	2.207,5 €	6	2.769,60 €	2.979 €	796 €
United Kingdom	Frozen	14.110 €	384	1.435,3 €	4	2.769,60 €	1.069 €	528 €
United Kingdom	Frozen	18.910 €	768	2.615,4 €	5	2.769,60 €	1.734 €	712 €
United Kingdom	Frozen	25.197 €	1500	4.547,5 €	6	2.769,60 €	3.000 €	1.032 €
United Kingdom	None	13.063 €	384	497,7 €	4	2.769,60 €	1.054 €	433 €
United Kingdom	None	17.000 €	768	906,9 €	5	2.769,60 €	1.707 €	539 €
United Kingdom	None	21.871 €	1500	1.576,8 €	6	2.769,60 €	2.946 €	730 €

Transportation orders

N r.	Supplier Country	Supplier City	Delivery Country	Delivery City	Distance	Trip time	Quantity	Required temperature	Temperature fuel	Truck fuel	Worker wage	Weight	Margin	Expenses	Amortization	Price, euro
1	Germany	Bad essen	Lithuania	Kaunas	832	22,4	33	chilled	44,8	257,9	125	18,7	91	66	30	1300
2	Belgium	staden	Lithuania	Vilnius	1138	26,5	5	frozen	79,5	352,8	171	3,5	18	66	30	258
3	Netherlands	Venray	Lithuania	Vilnius	999	24,7	25	chilled	49,3	309,7	150	17	90	66	30	1292
4	Germany	Osterheide	Lithuania	Kaunas	788	21,8	9	chilled	43,7	244,3	118	4,3	27	66	30	390
5	Belgium	Dilbeek	Lithuania	Vilnius	1093	25,9	12	none	0,0	338,8	164	8,6	34	66	30	489
6	Belgium	Brussels	Lithuania	Vilnius	1100	26,0	9	none	0,0	341,0	165	11	26	66	30	367
7	Belgium	Antwerp	Lithuania	Vilnius	1072	25,6	5	none	0,0	332,3	161	1	14	66	30	204
8	Belgium	Kontich	Lithuania	Vilnius	1070	25,6	12	none	0,0	331,7	161	13	34	66	30	489
9	Netherlands	IJmuiden	Lithuania	Kaunas	1007	24,8	33	frozen	74,3	312,2	151	22	98	66	30	1400
10	Netherlands	Venray	Lithuania	Vilnius	1000	24,7	30	chilled	49,4	310,0	150	17,5	91	66	30	1300
11	Belgium	Kontich	Lithuania	Kaunas	1034	25,1	4	frozen	75,4	320,5	155	2,5	25	66	30	350
12	Belgium	Zonnebeker	Lithuania	Kaunas	1106	26,1	8	frozen	78,2	342,9	166	5,1	32	66	30	462
13	Belgium	Warneton	Lithuania	Kaunas	1106	26,1	13	frozen	78,2	342,9	166	9,7	53	66	30	750
14	Netherlands	Veenendaal	Lithuania	Kaunas	963	24,2	1	frozen	72,5	298,5	144	1,2	4	66	30	58
15	Germany	Hamburg	Lithuania	Kaunas	780	21,7	1	frozen	65,2	241,8	117	0,8	4	66	30	58
16	Germany	Bremerhaven	Lithuania	Kaunas	853	22,7	1	frozen	68,1	264,4	128	0,6	4	66	30	58
17	Germany	Hamburg	Lithuania	Kaunas	781	21,7	2	frozen	65,2	242,1	117	1,5	8	66	30	115
18	Belgium	Aalst	Lithuania	Vilnius	1103	26,0	17	none	0,0	341,9	165	10	53	66	30	762
19	Belgium	Dilbeek	Lithuania	Vilnius	1093	25,9	3	none	0,0	338,8	164	1,8	9	66	30	134
20	Belgium	Sint-Agatha-Berchem	Lithuania	Vilnius	1093	25,9	2	none	0,0	338,8	164	0,6	6	66	30	90
21	Belgium	Kontich	Lithuania	Vilnius	1070	25,6	7	none	0,0	331,7	161	5,5	22	66	30	314
22	Belgium	Kiege	Lithuania	Vilnius	1050	25,3	33	frozen	76,0	325,5	158	21	91	66	30	1300
23	Netherlands	Bergen op Zoom	Lithuania	Vilnius	1082	25,8	30	frozen	77,3	335,4	162	20,7	112	66	30	1600
24	Netherlands	Venlo	Lithuania	Kaunas	952	24,0	9	none	0,0	295,1	143	3	42	66	30	600

25	Belgium	Aubange	Lithuania	panevezys	1141	26,5	26	none	0,0	353,7	171	13	91	66	30	1300
26	Netherlands	Rotterdam	Lithuania	Vilnius	1047	25,3	19	chilled	50,6	324,6	157	24	98	66	30	1400
27	Franch	Craywick	Lithuania	Vilnius	1175	27,0	21	chilled	54,0	364,3	176	17	105	66	30	1500
28	Netherlands	De Lier	Lithuania	Vilnius	1057	25,4	32	chilled	50,9	327,7	159	17	119	66	30	1700
29	Netherlands	Venlo	Lithuania	Vilnius	998	24,6	32	chilled	49,3	309,4	150	21	112	66	30	1600
30	Netherlands	De Lier	Lithuania	Vilnius	1057	25,4	32	chilled	50,9	327,7	159	22	119	66	30	1700
31	Netherlands	Zwijndrecht	Lithuania	Kaunas	1049	25,3	26	none	0,0	325,2	157	22	102	66	30	1450
32	Germany	Essen	Lithuania	Vilnius	904	23,4	33	frozen	70,2	280,2	136	33	112	66	30	1600
33	Belgium	Zonnebeker	Lithuania	Kaunas	1106	26,1	33	frozen	78,2	342,9	166	21,3	98	66	30	1400
34	Belgium	Staden	Lithuania	Vilnius	1138	26,5	4	frozen	79,5	352,8	171	2,7	14	66	30	200
35	Netherlands	Bergen op Zoom	Lithuania	Vilnius	1082	25,8	28	frozen	77,3	335,4	162	19	98	66	30	1400
36	Netherlands	De Lier	Lithuania	Vilnius	1057	25,4	33	chilled	50,9	327,7	159	20	109	66	30	1550
37	Franch	Craywick	Lithuania	Vilnius	1175	27,0	22	chilled	54,0	364,3	176	20	98	66	30	1400
38	Netherlands	Lieshout	Lithuania	Kaunas	981	24,4	27	none	0,0	304,1	147	22	91	66	30	1300

Program code

Calculations.R

```

setwd("C:\\Users\\Valentas\\Desktop\\Reaserch project\\R code\\Source_data")
rm(list=ls())
#install.packages("plyr")
library(plyr)
library(ggplot2)

# direct output to a file
sink("Results.txt", append=TRUE, split=TRUE)

#Read Suppliers, delivery from csv file
Vertex <- read.csv("Vertex.csv")
Edge <- read.csv("Edge.csv")
#read transportation cost Variables
Transportation_Costs <- read.csv("Transportation_Costs.csv")
#Read Co2 emission calculation Variables
Emission_Calculation_Data <- read.csv("Emission_Level.csv")
#read warehouse construction and management costs
WH_Construction_Costs <- read.csv("WH_Construction_Costs.csv")
WH_Management_Costs <- read.csv("WH_Management_Costs.csv")

#set the number of iterations for simulated annealing
Iteration_Max_1 <- 50000 #Select the best costs
Iteration_Max_2 <- 1000 # Calculate one time costs

#Input user defined functions
source("Calculate_Costs_JIN.R")
source("Calculate_CO2_JIN.R")
source("Calculate_Costs_CWH.R")
source("Calculate_CO2_CWH.R")
source("Calculate_Optimization_PFG.R")
source("Table_Result.R")
#Eveluation of JIN Costs and Co2 emmision level
JIN_Transportation_Costs <- Calculate_Costs_JIN(Vertex,Edge, Transportation_Costs)
JIN_CO2_Level <- CO2_Level_JIN(Vertex, Edge, Emission_Calculation_Data)
#Eveluation of CWH costs and Co2 emmision level
CWH_Costs <- Calculate_Costs_CWH(Vertex,Edge, Transportation_Costs)
CWH_CO2_Level <- Calculate_CO2_CWH(Vertex, Edge, Emission_Calculation_Data)
Partial_Freight_Optimization <- Partial_Freight_Optimization_ALgorithm(Vertex,Edge, Transportation_Costs, Emission_Calculation_Data,
WH_Construction_Costs, WH_Management_Costs, Iteration_Max_1, Iteration_Max_2)

Results <- Format_Result_table(JIN_Transportation_Costs, JIN_TRC, JIN_CO2_Level, CWH_Costs, Partial_Freight_Optimization)

#Summary table
Summary_Total <- Results[1]
#PFOR
Summary_Route <- Results[2]

#Print Result summary
Summary_Total

Summary_Route
#Print Variables
Variables <- Partial_Freight_Optimization[15]
Variables <- data.frame(Variables)
#Create a Graph of iterations vs transport costs
Min_Location <- subset(Variables, Variables$Min_Transportation_Costs == min(Variables$Min_Transportation_Costs))
Min_Location <- Min_Location[1,]
jpeg(file = "C:\\Users\\Valentas\\Desktop\\Reaserch project\\R code\\Results\\Result graph.jpeg")
plot(Variables$Iteration, Variables$Transportation_Costs, main="Transportation cost eveluation comparison to Iteration number",
      xlab="Iteration number", ylab="Transportation costs", type = "l")
par(new=TRUE)
dev.off()
#display the variation of transportation costs of the optimized route
summary(Variables)
jpeg(file = "C:\\Users\\Valentas\\Desktop\\Reaserch project\\R code\\Results\\Histogram_Transportation_Costs_PFO.jpeg")
hist(Variables$Transportation_Costs
      ,main="Histogram for partial freight distribution system"
      ,xlab="Transportation costs"
      ,prob = TRUE
      )

```

```

par(new=TRUE)
lines(density(Variables$Transportation_Costs))
dev.off()
#return output to the terminal
sink()
Calculate_Costs_JIN.R
Calculate_Costs_JIN <- function(Vertex,Edge, Transportation_Costs){
#distinguish transportation costs by category
#Local and temperature
Transportation_Costs_Local <- subset(Transportation_Costs, Transportation_Costs$Type == "Local")
Transportation_Costs_Local_None <- subset(Transportation_Costs_Local, Transportation_Costs_Local$Cargo_Temperature == "None")
Transportation_Costs_Local_Frozen <- subset(Transportation_Costs_Local, Transportation_Costs_Local$Cargo_Temperature == "Frozen")
Transportation_Costs_Local_Chilled <- subset(Transportation_Costs_Local, Transportation_Costs_Local$Cargo_Temperature == "Chilled")
#International and temperature
Transportation_Costs_International <- subset(Transportation_Costs, Transportation_Costs$Type == "International")
Transportation_Costs_International_None <- subset(Transportation_Costs_Local, Transportation_Costs_Local$Cargo_Temperature == "None")
Transportation_Costs_International_Frozen <- subset(Transportation_Costs_Local, Transportation_Costs_Local$Cargo_Temperature == "Frozen")
Transportation_Costs_International_Chilled <- subset(Transportation_Costs_Local, Transportation_Costs_Local$Cargo_Temperature == "Chilled")

#set Variable to 0
Transportation_Costs_Calculated_Total = 0
#Cycle through all suppliers
for (i in 1:118) {
#Create a subset of the calculated route
Edge_Temp <- subset(Edge, Edge$Source == i & Edge$Target == 118+i)
#Create a subsets of the starting and ending points
Vertex_Source <- subset(Vertex, Vertex$ID == i)
vertex_Target <- subset(Vertex, Vertex$ID == 118+i)
#Select the transportation type based on the country origin
if(Vertex_Source$Country == vertex_Target$Country)
{
#Evaluate Local costs
transportation_costs_Calculated = (Edge_Temp$Distance*Transportation_Costs_Local$VCPK/1000
+Vertex_Source$None*Transportation_Costs_Local_None$VCFPQ
+Vertex_Source$Chilled*Transportation_Costs_Local_Chilled$VCFPQ
+Vertex_Source$Frozen*Transportation_Costs_Local_Frozen$VCFPQ
+Transportation_Costs_Local$FC
)

Transportation_Costs_Calculated_Total = (Transportation_Costs_Calculated_Total + transportation_costs_Calculated)
}
else {
#Evaluate International costs
transportation_costs_Calculated = (Edge_Temp$Distance*Transportation_Costs_International$VCPK/1000
+Vertex_Source$None*Transportation_Costs_International_None$VCFPQ
+Vertex_Source$Chilled*Transportation_Costs_International_Chilled$VCFPQ
+Vertex_Source$Frozen*Transportation_Costs_International_Frozen$VCFPQ
+Transportation_Costs_International$FC
)

Transportation_Costs_Calculated_Total = (Transportation_Costs_Calculated_Total + transportation_costs_Calculated)
}
}
}
Transportation_Costs_Calculated_Total <- Transportation_Costs_Calculated_Total[1]
return(Transportation_Costs_Calculated_Total)
}
Calculate_CO2_JIN.R
CO2_Level_JIN <- function(Vertex,Edge, Emission_Calculation_Data){
#set Variable to 0
CO2_Level__JIN_Total <- 0
Traveling_Time_JIN__Total <- 0
#Cycle through all suppliers
for (i in 1:118) {
#Create a subset of the calculated route
Edge_Temp <- subset(Edge, Edge$Source == i & Edge$Target == 118+i)
#Create a subsets of the starting and ending points
Vertex_Source <- subset(Vertex, Vertex$ID == i)
vertex_Target <- subset(Vertex, Vertex$ID == 118+i)
#Evaluate the Total time
Rest_Time=((Edge_Temp$Driving_Time%%39600)*10)+((Edge_Temp$Driving_Time-
(39600*Edge_Temp$Driving_Time%%39600))%%18000)*1
Total_Time=Rest_Time+Edge_Temp$Driving_Time/60/60
#Evaluate CO2 level for distance
CO2_Distance=Edge_Temp$Distance/1000*Emission_Calculation_Data$Truck_Fuel_Rate
#Evaluate Refrigerator consumption rate based on temperature type
if (Vertex_Source$None != 0 & Vertex_Source$Chilled == 0 & Vertex_Source$Frozen == 0) {

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CO2_Refrigerator = Total_Time*Emission_Calculation_Data$None_Fuel
} else if (Vertex_Source$None == 0 & Vertex_Source$Chilled != 0 & Vertex_Source$Frozen == 0) {
CO2_Refrigerator = Total_Time*Emission_Calculation_Data$None_Chilled
} else if (Vertex_Source$None == 0 & Vertex_Source$Chilled == 0 & Vertex_Source$Frozen != 0){
CO2_Refrigerator = Total_Time*Emission_Calculation_Data$Frozen_Fuel
} else if (Vertex_Source$None != 0 & Vertex_Source$Chilled != 0 & Vertex_Source$Frozen == 0) {
CO2_Refrigerator = Total_Time*Emission_Calculation_Data$None_Chilled
} else if (Vertex_Source$None != 0 & Vertex_Source$Chilled == 0 & Vertex_Source$Frozen != 0) {
CO2_Refrigerator = Total_Time*Emission_Calculation_Data$Frozen_None_Fuel
} else if (Vertex_Source$None == 0 & Vertex_Source$Chilled != 0 & Vertex_Source$Frozen != 0) {
CO2_Refrigerator = Total_Time*Emission_Calculation_Data$Frozen_Chilled
} else {
CO2_Refrigerator = Total_Time*Emission_Calculation_Data$Frozen_Chilled_None
}
}
#Evaluate CO2 Level for one route
CO2_Level = (CO2_Distance+CO2_Refrigerator)*Emission_Calculation_Data$CO2_Emission
#sum all the routs CO2 level
CO2_Level__JIN_Total= CO2_Level__JIN_Total + CO2_Level
#Time
Traveling_Time_JIN_Total = (Traveling_Time_JIN_Total + Total_Time)
}
CO2_Level__JIN_Total <- CO2_Level__JIN_Total[1]
Traveling_Time_JIN_Total <- Traveling_Time_JIN_Total[1]
Result_List <- list(CO2_Level__JIN_Total, Traveling_Time_JIN_Total)
return(Result_List)
}
Calculate_Costs_CWH.R
Calculate_Costs_CWH <- function(Vertex,Edge, Transportation_Costs){
#distinguish transportation costs by category
#Local and temperature
Transportation_Costs_Local <- subset(Transportation_Costs, Transportation_Costs$Type == "Local")
Transportation_Costs_Local_None <- subset(Transportation_Costs_Local, Transportation_Costs_Local$Cargo_Temperature == "None")
Transportation_Costs_Local_Frozen <- subset(Transportation_Costs_Local, Transportation_Costs_Local$Cargo_Temperature == "Frozen")
Transportation_Costs_Local_Chilled <- subset(Transportation_Costs_Local, Transportation_Costs_Local$Cargo_Temperature == "Chilled")
#International and temperature
Transportation_Costs_International <- subset(Transportation_Costs, Transportation_Costs$Type == "International")
Transportation_Costs_International_None <- subset(Transportation_Costs_Local, Transportation_Costs_Local$Cargo_Temperature == "None")
Transportation_Costs_International_Frozen <- subset(Transportation_Costs_Local, Transportation_Costs_Local$Cargo_Temperature == "Frozen")
Transportation_Costs_International_Chilled <- subset(Transportation_Costs_Local, Transportation_Costs_Local$Cargo_Temperature == "Chilled")

#Warehouse construction costs
WH_Construction_Costs_B <- subset(WH_Construction_Costs, WH_Construction_Costs$Country == "Belgium")
WH_Construction_Costs_B_None <- subset(WH_Construction_Costs_B, WH_Construction_Costs_B$Type == "None")
WH_Construction_Costs_B_Chilled <- subset(WH_Construction_Costs_B, WH_Construction_Costs_B$Type == "Chilled")
WH_Construction_Costs_B_Frozen <- subset(WH_Construction_Costs_B, WH_Construction_Costs_B$Type == "Frozen")

WH_Construction_Costs_UK <- subset(WH_Construction_Costs, WH_Construction_Costs$Country == "United Kingdom")
WH_Construction_Costs_UK_None <- subset(WH_Construction_Costs_UK, WH_Construction_Costs_UK$Type == "None")
WH_Construction_Costs_UK_Chilled <- subset(WH_Construction_Costs_UK, WH_Construction_Costs_UK$Type == "Chilled")
WH_Construction_Costs_UK_Frozen <- subset(WH_Construction_Costs_UK, WH_Construction_Costs_UK$Type == "Frozen")

WH_Construction_Costs_G <- subset(WH_Construction_Costs, WH_Construction_Costs$Country == "Belgium")
WH_Construction_Costs_G_None <- subset(WH_Construction_Costs_G, WH_Construction_Costs_G$Type == "None")
WH_Construction_Costs_G_Chilled <- subset(WH_Construction_Costs_G, WH_Construction_Costs_G$Type == "Chilled")
WH_Construction_Costs_G_Frozen <- subset(WH_Construction_Costs_G, WH_Construction_Costs_G$Type == "Frozen")

WH_Construction_Costs_LT <- subset(WH_Construction_Costs, WH_Construction_Costs$Country == "Lithuania")
WH_Construction_Costs_LT_None <- subset(WH_Construction_Costs_LT, WH_Construction_Costs_LT$Type == "None")
WH_Construction_Costs_LT_Chilled <- subset(WH_Construction_Costs_LT, WH_Construction_Costs_LT$Type == "Chilled")
WH_Construction_Costs_LT_Frozen <- subset(WH_Construction_Costs_LT, WH_Construction_Costs_LT$Type == "Frozen")

#Warehouse Management costs
WH_Management_Costs_B <- subset(WH_Management_Costs, WH_Management_Costs$Country == "Belgium")
WH_Management_Costs_B_None <- subset(WH_Management_Costs_B, WH_Management_Costs_B$Type == "None")
WH_Management_Costs_B_Chilled <- subset(WH_Management_Costs_B, WH_Management_Costs_B$Type == "Chilled")
WH_Management_Costs_B_Frozen <- subset(WH_Management_Costs_B, WH_Management_Costs_B$Type == "Frozen")

WH_Management_Costs_UK <- subset(WH_Management_Costs, WH_Management_Costs$Country == "United Kingdom")
WH_Management_Costs_UK_None <- subset(WH_Management_Costs_UK, WH_Management_Costs_UK$Type == "None")
WH_Management_Costs_UK_Chilled <- subset(WH_Management_Costs_UK, WH_Management_Costs_UK$Type == "Chilled")
WH_Management_Costs_UK_Frozen <- subset(WH_Management_Costs_UK, WH_Management_Costs_UK$Type == "Frozen")

WH_Management_Costs_G <- subset(WH_Management_Costs, WH_Management_Costs$Country == "Belgium")
WH_Management_Costs_G_None <- subset(WH_Management_Costs_G, WH_Management_Costs_G$Type == "None")
WH_Management_Costs_G_Chilled <- subset(WH_Management_Costs_G, WH_Management_Costs_G$Type == "Chilled")

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WH_Management_Costs_G_Frozen <- subset(WH_Management_Costs_G, WH_Management_Costs_G$Type == "Frozen")

WH_Management_Costs_LT <- subset(WH_Management_Costs, WH_Management_Costs$Country == "Lithuania")
WH_Management_Costs_LT_None <- subset(WH_Management_Costs_LT, WH_Management_Costs_LT$Type == "None")
WH_Management_Costs_LT_Chilled <- subset(WH_Management_Costs_LT, WH_Management_Costs_LT$Type == "Chilled")
WH_Management_Costs_LT_Frozen <- subset(WH_Management_Costs_LT, WH_Management_Costs_LT$Type == "Frozen")

#set Variable to 0
Transportation_Costs_S_NWH_Calculated_Total <- 0
Transportation_Costs_WH_LT_D_Calculated_Total <- 0
WH_Construction_Costs_Total <- 0
WH_Management_Costs_total <- 0
#Warehouses
WH_B_Vertex <- subset(Vertex, Vertex$ID == 237)
WH_UK_Vertex <- subset(Vertex, Vertex$ID == 238)
WH_G_Vertex <- subset(Vertex, Vertex$ID == 239)

#Setting WH size variables to 0
WH_B_Size_None <- 0
WH_B_size_Chilled <- 0
WH_B_size_Frozen <- 0
WH_UK_Size_None <- 0
WH_UK_size_Chilled <- 0
WH_UK_size_Frozen <- 0
WH_G_Size_None <- 0
WH_G_size_Chilled <- 0
WH_G_size_Frozen <- 0
WH_LT_Size_None <- 0
WH_LT_size_Chilled <- 0
WH_LT_size_Frozen <- 0

#Cycle through all suppliers
for (i in 1:118) {
  #Create a subsets of the starting and ending points
  Vertex_Source <- subset(Vertex, Vertex$ID == i)

  #Evaluating the nearest Warehouse of Belgium, United Kingdom or Germany
  #selecting the main 3 warehouses
  WH_B <- subset(Edge, Edge$Source == i & Edge$Target == 237)
  WH_UK <- subset(Edge, Edge$Source == i & Edge$Target == 238)
  WH_G <- subset(Edge, Edge$Source == i & Edge$Target == 239)

  if (WH_B$Distance < WH_UK$Distance & WH_B$Distance < WH_G$Distance) {
    Nearest_WH_Edge <- WH_B
    Nearest_WH_Vertex <- WH_B_Vertex
    WH_B_Size_None <- WH_B_Size_None + Vertex$None[i]
    WH_B_size_Chilled <- WH_B_size_Chilled + Vertex$Chilled[i]
    WH_B_size_Frozen <- WH_B_size_Frozen + Vertex$Frozen[i]

  } else if (WH_UK$Distance < WH_B$Distance & WH_UK$Distance < WH_G$Distance) {
    Nearest_WH_Edge <- WH_UK
    Nearest_WH_Vertex <- WH_UK_Vertex
    WH_UK_Size_None <- WH_UK_Size_None + Vertex$None[i]
    WH_UK_size_Chilled <- WH_UK_size_Chilled + Vertex$Chilled[i]
    WH_UK_size_Frozen <- WH_UK_size_Frozen + Vertex$Frozen[i]

  } else {
    Nearest_WH <- WH_G
    Nearest_WH_Vertex <- WH_G_Vertex
    WH_G_Size_None <- WH_G_Size_None + Vertex$None[i]
    WH_G_size_Chilled <- WH_G_size_Chilled + Vertex$Chilled[i]
    WH_G_size_Frozen <- WH_G_size_Frozen + Vertex$Frozen[i]

  }

}

##Calculating first position from S to nearest WH
#Select the transportation type based on the country origin
if(Vertex_Source$Country == Nearest_WH_Vertex$Country)
{
  #Evaluate Local costs

  transportation_costs_S_NWH_Calculated = (Nearest_WH$Distance*Transportation_Costs_Local$VCPK/1000
    +Nearest_WH_Vertex$None*Transportation_Costs_Local_None$VCFPQ
    +Nearest_WH_Vertex$Chilled*Transportation_Costs_Local_Chilled$VCFPQ
    +Nearest_WH_Vertex$Frozen*Transportation_Costs_Local_Frozen$VCFPQ

```



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+Transportation_Costs_Local$FC
)

Transportation_Costs_S_NWH_Calculated_Total <- (Transportation_Costs_S_NWH_Calculated_Total +
transportation_costs_S_NWH_Calculated)
}else {
#Evaluate International costs
transportation_costs_S_NWH_Calculated = (Nearest_WH$Distance*Transportation_Costs_International$VCPK/1000
+Nearest_WH_Vertex$None*Transportation_Costs_International_None$VCFPQ
+Nearest_WH_Vertex$Chilled*Transportation_Costs_International_Chilled$VCFPQ
+Nearest_WH_Vertex$Frozen*Transportation_Costs_International_Frozen$VCFPQ
+Transportation_Costs_International$FC
)

Transportation_Costs_S_NWH_Calculated_Total <- (Transportation_Costs_S_NWH_Calculated_Total +
transportation_costs_S_NWH_Calculated)
}
}

#Evaluating seconded position from Nearest WH to WH in Lithuania
#Evaluating Lithuania warehouse size
WH_LT_Size_None <- WH_B_Size_None + WH_UK_Size_None + WH_G_Size_None + WH_G_Size_None
WH_LT_Size_Chilled <- WH_B_size_Chilled + WH_UK_size_Chilled + WH_G_size_Chilled
WH_LT_Size_Frozen <- WH_B_size_Frozen + WH_UK_size_Frozen + WH_G_size_Frozen

#Evaluating Belgium
WH_B_WH_LT <- subset(Edge, Edge$Source == 237 & Edge$Target == 240)
WH_B_Size = WH_B_Size_None+WH_B_size_Chilled+WH_B_size_Frozen
WH_B_Truck_Quantity <- ceiling(WH_B_Size/32)
Transportation_Costs_WH_B_WH_LT_Calculated =
(WH_B_WH_LT$Distance*Transportation_Costs_International$VCPK/1000*WH_B_Truck_Quantity
+WH_B_Size_None*Transportation_Costs_International_None$VCFPQ
+WH_B_size_Chilled*Transportation_Costs_International_Chilled$VCFPQ
+WH_B_size_Frozen*Transportation_Costs_International_Frozen$VCFPQ
+Transportation_Costs_International$FC*WH_B_Truck_Quantity
)

#Evaluating United Kingdom
WH_UK_WH_LT <- subset(Edge, Edge$Source == 238 & Edge$Target == 240)
WH_UK_Size = WH_UK_Size_None+WH_UK_size_Chilled+WH_UK_size_Frozen
WH_UK_Truck_Quantity <- ceiling(WH_UK_Size/32)
Transportation_Costs_WH_UK_WH_LT_Calculated =
(WH_UK_WH_LT$Distance*Transportation_Costs_International$VCPK/1000*WH_UK_Truck_Quantity
+WH_UK_Size_None*Transportation_Costs_International_None$VCFPQ
+WH_UK_size_Chilled*Transportation_Costs_International_Chilled$VCFPQ
+WH_UK_size_Frozen*Transportation_Costs_International_Frozen$VCFPQ
+Transportation_Costs_International$FC*WH_UK_Truck_Quantity
)

#Evaluating Germany
WH_G_WH_LT <- subset(Edge, Edge$Source == 239 & Edge$Target == 240)
WH_G_Size = WH_G_Size_None+WH_G_size_Chilled+WH_G_size_Frozen
WH_G_Truck_Quantity <- ceiling(WH_G_Size/32)
Transportation_Costs_WH_G_WH_LT_Calculated =
(WH_G_WH_LT$Distance*Transportation_Costs_International$VCPK/1000*WH_G_Truck_Quantity
+WH_G_Size_None*Transportation_Costs_International_None$VCFPQ
+WH_G_size_Chilled*Transportation_Costs_International_Chilled$VCFPQ
+WH_G_size_Frozen*Transportation_Costs_International_Frozen$VCFPQ
+Transportation_Costs_International$FC*WH_G_Truck_Quantity
)

#Evaluating position from WH Lithuania to Final delivery places
for (i in 1:118) {
#Create a subset of the calculated route
Edge_Temp <- subset(Edge, Edge$Source == 240 & Edge$Target == 118+i)
#Create a subsets of the starting and ending points
Vertex_Source <- subset(Vertex, Vertex$ID == i)
vertex_Target <- subset(Vertex, Vertex$ID == 118+i)

Transportation_costs_WH_LT_D_Calculated = (Edge_Temp$Distance*Transportation_Costs_Local$VCPK/1000
+Vertex_Source$None*Transportation_Costs_Local_None$VCFPQ
+Vertex_Source$Chilled*Transportation_Costs_Local_Chilled$VCFPQ
+Vertex_Source$Frozen*Transportation_Costs_Local_Frozen$VCFPQ
+Transportation_Costs_Local$FC
)
}
}

```

```

Transportation_costs_WH_LT_D_Calculated_Total <- (Transportation_Costs_WH_LT_D_Calculated_Total +
Transportation_costs_WH_LT_D_Calculated)

}

#adding all the transportation costs
Transportation_Costs_Calculated_Total <- (Transportation_Costs_S_NWH_Calculated_Total
+ Transportation_Costs_WH_B_WH_LT_Calculated
+ Transportation_Costs_WH_UK_WH_LT_Calculated
+ Transportation_Costs_WH_G_WH_LT_Calculated
+ Transportation_Costs_WH_LT_D_Calculated_Total
)
Transportation_Costs_Calculated_Total <- Transportation_Costs_Calculated_Total[1]

#Evaluating Warehouse construction costs

#Belgium
WH_Construction_Costs_B_Evaluated<- WH_Construction_Costs_B$FCWC
+WH_B_Size_None*WH_Construction_Costs_B_None$VCWC
+WH_B_size_Chilled*WH_Construction_Costs_B_Chilled$VCWC
+WH_B_size_Frozen*WH_Construction_Costs_B_Frozen$VCWC

#United Kingdom
WH_Construction_Costs_B_Evaluated<- WH_Construction_Costs_UK$FCWC
+WH_UK_Size_None*WH_Construction_Costs_UK_None$VCWC
+WH_UK_size_Chilled*WH_Construction_Costs_UK_Chilled$VCWC
+WH_UK_size_Frozen*WH_Construction_Costs_UK_Frozen$VCWC

#Germany
WH_Construction_Costs_G_Evaluated<- WH_Construction_Costs_G$FCWC
+WH_G_Size_None*WH_Construction_Costs_G_None$VCWC
+WH_G_size_Chilled*WH_Construction_Costs_G_Chilled$VCWC
+WH_G_size_Frozen*WH_Construction_Costs_G_Frozen$VCWC

#lithuania
WH_Construction_Costs_LT_Evaluated<- WH_Construction_Costs_LT$FCWC
+WH_LT_Size_None*WH_Construction_Costs_LT_None$VCWC
+WH_LT_Size_Chilled*WH_Construction_Costs_LT_Chilled$VCWC
+WH_LT_Size_Frozen*WH_Construction_Costs_LT_Frozen$VCWC

WH_Construction_Costs_Total = WH_Construction_Costs_B_Evaluated
+WH_Construction_Costs_B_Evaluated
+WH_Construction_Costs_G_Evaluated
+WH_Construction_Costs_LT_Evaluated

#Evaluate warehouse management costs
#Belgium
WH_Management_Costs_B_Evaluated<- WH_Management_Costs_B$FCWMC
+WH_B_Size_None*WH_Management_Costs_B_None$VCWC
+WH_B_size_Chilled*WH_Management_Costs_B_Chilled$VCWC
+WH_B_size_Frozen*WH_Management_Costs_B_Frozen$VCWC

#United Kingdom
WH_Management_Costs_UK_Evaluated <- WH_Management_Costs_UK$FCWMC
+WH_UK_Size_None*WH_Management_Costs_UK_None$VCWC
+WH_UK_size_Chilled*WH_Management_Costs_UK_Chilled$VCWC
+WH_UK_size_Frozen*WH_Management_Costs_UK_Frozen$VCWC

#Germany
WH_Management_Costs_G_Evaluated <- WH_Management_Costs_G$FCWMC
+WH_G_Size_None*WH_Management_Costs_G_None$VCWC
+WH_G_size_Chilled*WH_Management_Costs_G_Chilled$VCWC
+WH_G_size_Frozen*WH_Management_Costs_G_Frozen$VCWC

#lithuania
WH_Management_Costs_LT_Evaluated <- WH_Management_Costs_LT$FCWMC
+WH_LT_Size_None*WH_Management_Costs_LT_None$VCWC
+WH_LT_Size_Chilled*WH_Management_Costs_LT_Chilled$VCWC
+WH_LT_Size_Frozen*WH_Management_Costs_LT_Frozen$VCWC

WH_Management_Costs_total <- WH_Management_Costs_B_Evaluated
+WH_Management_Costs_UK_Evaluated
+WH_Management_Costs_G_Evaluated
+WH_Management_Costs_LT_Evaluated

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#Removing additional values, problem with indexes, Some variables are listed as arrays from 3 elements and not 1.
Transportation_Costs_Calculated_Total <- Transportation_Costs_Calculated_Total[1]
WH_Construction_Costs_Total <- WH_Construction_Costs_Total[1]
WH_Management_Costs_total <- WH_Management_Costs_total[1]
Total_Logistic_Network_Costs <- Transportation_Costs_Calculated_Total+WH_Construction_Costs_Total+WH_Management_Costs_total
#Creating several return Values
Result_List <- list(Transportation_Costs_Calculated_Total, WH_Construction_Costs_Total, WH_Management_Costs_total)
return(Result_List)
}
Calculate_CO2_CWH.R
Calculate_CO2_CWH <- function(Vertex,Edge, Transportation_Costs){
#set Variable to 0
CO2_Level__S_NWH_Total <- 0
CO2_Level_WH_B_WH_LT <- 0
CO2_Level_WH_UK_WH_LT <- 0
CO2_Level_WH_G_WH_LT <- 0
CO2_Level__WH_LT_D_Total <- 0
CO2_Level_Total <- 0
Traveling_Time_S_NWH_Total <- 0
Traveling_Time_WH_B_WH_LT_Total <- 0
Traveling_Time_WH_UK_WH_LT_Total <- 0
Traveling_Time_WH_G_WH_LT_Total <- 0
Traveling_Time_WH_LT_D_Total <- 0

#Warehouses
WH_B_Vertex <- subset(Vertex, Vertex$ID == 237)
WH_UK_Vertex <- subset(Vertex, Vertex$ID == 238)
WH_G_Vertex <- subset(Vertex, Vertex$ID == 239)

#Setting WH size variables to 0
WH_B_Size_None <- 0
WH_B_size_Chilled <- 0
WH_B_size_Frozen <- 0
WH_UK_Size_None <- 0
WH_UK_size_Chilled <- 0
WH_UK_size_Frozen <- 0
WH_G_Size_None <- 0
WH_G_size_Chilled <- 0
WH_G_size_Frozen <- 0
WH_LT_Size_None <- 0
WH_LT_Size_Chilled <- 0
WH_LT_Size_Frozen <- 0

#Cycle through all suppliers
for (i in 1:118) {
#Create a subsets of the starting and ending points
Vertex_Source <- subset(Vertex, Vertex$ID == i)

#Evaluating the nearest Warehouse of Belgium, United Kingdom or Germany
#selecting the main 3 warehouses
WH_B <- subset(Edge, Edge$Source == i & Edge$Target == 237)
WH_UK <- subset(Edge, Edge$Source == i & Edge$Target == 238)
WH_G <- subset(Edge, Edge$Source == i & Edge$Target == 239)

if (WH_B$Distance < WH_UK$Distance & WH_B$Distance < WH_G$Distance) {
Nearest_WH_Edge <- WH_B
Nearest_WH_Vertex <- WH_B_Vertex
WH_B_Size_None <- WH_B_Size_None + Vertex$None[i]
WH_B_size_Chilled <- WH_B_size_Chilled + Vertex$Chilled[i]
WH_B_size_Frozen <- WH_B_size_Frozen + Vertex$Frozen[i]
} else if (WH_UK$Distance < WH_B$Distance & WH_UK$Distance < WH_G$Distance) {
Nearest_WH_Edge <- WH_UK
Nearest_WH_Vertex <- WH_UK_Vertex
WH_UK_Size_None <- WH_UK_Size_None + Vertex$None[i]
WH_UK_size_Chilled <- WH_UK_size_Chilled + Vertex$Chilled[i]
WH_UK_size_Frozen <- WH_UK_size_Frozen + Vertex$Frozen[i]
} else {
Nearest_WH <- WH_G
Nearest_WH_Vertex <- WH_G_Vertex
WH_G_Size_None <- WH_G_Size_None + Vertex$None[i]
WH_G_size_Chilled <- WH_G_size_Chilled + Vertex$Chilled[i]
WH_G_size_Frozen <- WH_G_size_Frozen + Vertex$Frozen[i]
}
}
}

```

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}

##Calculating first position from S to nearest WH
#Evaluate the Total time
Rest_Time=((Nearest_WH$Driving_Time%/%39600)*10)+((Nearest_WH$Driving_Time-
(39600*Nearest_WH$Driving_Time%/%39600))%/%18000)*1
Total_Time=Rest_Time+Nearest_WH$Driving_Time/60/60
#Evaluate CO2 level for distance
CO2_Distance=Nearest_WH$Distance/1000*Emission_Calculation_Data$Truck_Fuel_Rate
#Evaluate Refrigerator consumption rate based on temperature type
if (Vertex_Source$None != 0 & Vertex_Source$Chilled == 0 & Vertex_Source$Frozen == 0) {
  CO2_Refrigerator = Total_Time*Emission_Calculation_Data$None_Fuel
} else if (Vertex_Source$None == 0 & Vertex_Source$Chilled != 0 & Vertex_Source$Frozen == 0) {
  CO2_Refrigerator = Total_Time*Emission_Calculation_Data$None_Chilled
} else if (Vertex_Source$None == 0 & Vertex_Source$Chilled == 0 & Vertex_Source$Frozen != 0){
  CO2_Refrigerator = Total_Time*Emission_Calculation_Data$Frozen_Fuel
} else if (Vertex_Source$None != 0 & Vertex_Source$Chilled != 0 & Vertex_Source$Frozen == 0) {
  CO2_Refrigerator = Total_Time*Emission_Calculation_Data$None_Chilled
} else if (Vertex_Source$None != 0 & Vertex_Source$Chilled == 0 & Vertex_Source$Frozen != 0) {
  CO2_Refrigerator = Total_Time*Emission_Calculation_Data$Frozen_None_Fuel
} else if (Vertex_Source$None == 0 & Vertex_Source$Chilled != 0 & Vertex_Source$Frozen != 0) {
  CO2_Refrigerator = Total_Time*Emission_Calculation_Data$Frozen_Chilled
} else {
  CO2_Refrigerator = Total_Time*Emission_Calculation_Data$Frozen_Chilled_None
}
#Evaluate CO2 Level for one route
CO2_Level_S_NWH = (CO2_Distance+CO2_Refrigerator)*Emission_Calculation_Data$CO2_Emission
#sum all the routs CO2 level
CO2_Level__S_NWH_Total= CO2_Level__S_NWH_Total + CO2_Level_S_NWH
#Time
Traveling_Time_S_NWH_Total = Traveling_Time_S_NWH_Total+Total_Time
}

#Evaluating second position from Nearest WH to WH in Lithuania
#Evaluating Lithuania warehouse size
WH_LT_Size_None <- WH_B_Size_None + WH_UK_Size_None + WH_G_Size_None + WH_G_Size_None
WH_LT_Size_Chilled <- WH_B_size_Chilled + WH_UK_size_Chilled + WH_G_size_Chilled
WH_LT_Size_Frozen <- WH_B_size_Frozen + WH_UK_size_Frozen + WH_G_size_Frozen

#Evaluating Belgium
WH_B_WH_LT <- subset(Edge, Edge$Source == 237 & Edge$Target == 240)
WH_B_Size = WH_B_Size_None+WH_B_size_Chilled+WH_B_size_Frozen
WH_B_Truck_Quantity <- ceiling(WH_B_Size/32)

Rest_Time=((WH_B_WH_LT$Driving_Time%/%39600)*10)+((WH_B_WH_LT$Driving_Time-
(39600*WH_B_WH_LT$Driving_Time%/%39600))%/%18000)*1
Total_Time=Rest_Time+WH_B_WH_LT$Driving_Time/60/60
#Evaluate CO2 level for distance
CO2_Distance=WH_B_WH_LT$Distance/1000*Emission_Calculation_Data$Truck_Fuel_Rate
#Evaluate Refrigerator consumption rate based on temperature type
if (WH_B_Size_None != 0 & WH_B_size_Chilled == 0 & WH_B_size_Frozen == 0) {
  CO2_Refrigerator = Total_Time*Emission_Calculation_Data$None_Fuel
} else if (WH_B_Size_None == 0 & WH_B_size_Chilled != 0 & WH_B_size_Frozen == 0) {
  CO2_Refrigerator = Total_Time*Emission_Calculation_Data$None_Chilled
} else if (WH_B_Size_None == 0 & WH_B_size_Chilled == 0 & WH_B_size_Frozen != 0){
  CO2_Refrigerator = Total_Time*Emission_Calculation_Data$Frozen_Fuel
} else if (WH_B_Size_None != 0 & WH_B_size_Chilled != 0 & WH_B_size_Frozen == 0) {
  CO2_Refrigerator = Total_Time*Emission_Calculation_Data$None_Chilled
} else if (WH_B_Size_None != 0 & WH_B_size_Chilled == 0 & WH_B_size_Frozen != 0) {
  CO2_Refrigerator = Total_Time*Emission_Calculation_Data$Frozen_None_Fuel
} else if (WH_B_Size_None == 0 & WH_B_size_Chilled != 0 & WH_B_size_Frozen != 0) {
  CO2_Refrigerator = Total_Time*Emission_Calculation_Data$Frozen_Chilled
} else {
  CO2_Refrigerator = Total_Time*Emission_Calculation_Data$Frozen_Chilled_None
}
#Evaluate CO2 Level for one route
CO2_Level_WH_B_WH_LT = (CO2_Distance+CO2_Refrigerator)*Emission_Calculation_Data$CO2_Emission*WH_B_Truck_Quantity
#Time
Traveling_Time_WH_B_WH_LT_Total = Traveling_Time_WH_B_WH_LT_Total+Total_Time*WH_B_Truck_Quantity

#Evaluating United Kingdom
WH_UK_WH_LT <- subset(Edge, Edge$Source == 238 & Edge$Target == 240)
WH_UK_Size = WH_UK_Size_None+WH_UK_size_Chilled+WH_UK_size_Frozen
WH_UK_Truck_Quantity <- ceiling(WH_UK_Size/32)

```

```

Rest_Time=((WH_UK_WH_LT$Driving_Time%/%39600)*10)+((WH_UK_WH_LT$Driving_Time-
(39600*WH_UK_WH_LT$Driving_Time%/%39600))%/%18000)*1
Total_Time=Rest_Time+WH_UK_WH_LT$Driving_Time/60/60
#Evaluate CO2 level for distance
CO2_Distance=WH_UK_WH_LT$Distance/1000*Emission_Calculation_Data$Truck_Fuel_Rate
#Evaluate Refrigerator consumption rate based on temperature type
if (WH_UK_Size_None != 0 & WH_UK_size_Chilled == 0 & WH_UK_size_Frozen == 0) {
  CO2_Refrigerator = Total_Time*Emission_Calculation_Data$None_Fuel
} else if (WH_UK_Size_None == 0 & WH_UK_size_Chilled != 0 & WH_UK_size_Frozen == 0) {
  CO2_Refrigerator = Total_Time*Emission_Calculation_Data$None_Chilled
} else if (WH_UK_Size_None == 0 & WH_UK_size_Chilled == 0 & WH_UK_size_Frozen != 0){
  CO2_Refrigerator = Total_Time*Emission_Calculation_Data$Frozen_Fuel
} else if (WH_UK_Size_None != 0 & WH_UK_size_Chilled != 0 & WH_UK_size_Frozen == 0) {
  CO2_Refrigerator = Total_Time*Emission_Calculation_Data$None_Chilled
} else if (WH_UK_Size_None != 0 & WH_UK_size_Chilled == 0 & WH_UK_size_Frozen != 0) {
  CO2_Refrigerator = Total_Time*Emission_Calculation_Data$Frozen_None_Fuel
} else if (WH_UK_Size_None == 0 & WH_UK_size_Chilled != 0 & WH_UK_size_Frozen != 0) {
  CO2_Refrigerator = Total_Time*Emission_Calculation_Data$Frozen_Chilled
} else {
  CO2_Refrigerator = Total_Time*Emission_Calculation_Data$Frozen_Chilled_None
}
}
#Evaluate CO2 Level for one route
CO2_Level_WH_UK_WH_LT = (CO2_Distance+CO2_Refrigerator)*Emission_Calculation_Data$CO2_Emission*WH_UK_Truck_Quantity
#Time
Traveling_Time_WH_UK_WH_LT_Total = Traveling_Time_WH_UK_WH_LT_Total+Total_Time*WH_B_Truck_Quantity

#Evaluating Germany
WH_G_WH_LT <- subset(Edge, Edge$Source == 239 & Edge$Target == 240)
WH_G_Size = WH_G_Size_None+WH_G_size_Chilled+WH_G_size_Frozen
WH_G_Truck_Quantity <- ceiling(WH_G_Size/32)

Rest_Time=((WH_G_WH_LT$Driving_Time%/%39600)*10)+((WH_G_WH_LT$Driving_Time-
(39600*WH_G_WH_LT$Driving_Time%/%39600))%/%18000)*1
Total_Time=Rest_Time+WH_G_WH_LT$Driving_Time/60/60
#Evaluate CO2 level for distance
CO2_Distance=WH_G_WH_LT$Distance/1000*Emission_Calculation_Data$Truck_Fuel_Rate
#Evaluate Refrigerator consumption rate based on temperature type
if (WH_G_Size_None != 0 & WH_B_size_Chilled == 0 & WH_B_size_Frozen == 0) {
  CO2_Refrigerator = Total_Time*Emission_Calculation_Data$None_Fuel
} else if (WH_G_Size_None == 0 & WH_G_size_Chilled != 0 & WH_G_size_Frozen == 0) {
  CO2_Refrigerator = Total_Time*Emission_Calculation_Data$None_Chilled
} else if (WH_G_Size_None == 0 & WH_G_size_Chilled == 0 & WH_G_size_Frozen != 0){
  CO2_Refrigerator = Total_Time*Emission_Calculation_Data$Frozen_Fuel
} else if (WH_G_Size_None != 0 & WH_G_size_Chilled != 0 & WH_G_size_Frozen == 0) {
  CO2_Refrigerator = Total_Time*Emission_Calculation_Data$None_Chilled
} else if (WH_G_Size_None != 0 & WH_G_size_Chilled == 0 & WH_G_size_Frozen != 0) {
  CO2_Refrigerator = Total_Time*Emission_Calculation_Data$Frozen_None_Fuel
} else if (WH_G_Size_None == 0 & WH_G_size_Chilled != 0 & WH_G_size_Frozen != 0) {
  CO2_Refrigerator = Total_Time*Emission_Calculation_Data$Frozen_Chilled
} else {
  CO2_Refrigerator = Total_Time*Emission_Calculation_Data$Frozen_Chilled_None
}
}
#Evaluate CO2 Level for one route
CO2_Level_WH_G_WH_LT = (CO2_Distance+CO2_Refrigerator)*Emission_Calculation_Data$CO2_Emission*WH_B_Truck_Quantity
#Time
Traveling_Time_WH_G_WH_LT_Total = Traveling_Time_WH_G_WH_LT_Total+Total_Time*WH_B_Truck_Quantity

#Evaluating position from WH Lithuania to Final delivery places
for (i in 1:118) {
  #Create a subset of the calculated route
  Edge_Temp <- subset(Edge, Edge$Source == 240 & Edge$Target == 118+i)
  #Create a subsets of the starting and ending points
  Vertex_Source <- subset(Vertex, Vertex$ID == i)
  vertex_Target <- subset(Vertex, Vertex$ID == 118+i)

  Rest_Time=((Edge_Temp$Driving_Time%/%39600)*10)+((Edge_Temp$Driving_Time-
(39600*Edge_Temp$Driving_Time%/%39600))%/%18000)*1
  Total_Time=Rest_Time+Edge_Temp$Driving_Time/60/60
  #Evaluate CO2 level for distance
  CO2_Distance=Edge_Temp$Distance/1000*Emission_Calculation_Data$Truck_Fuel_Rate
  #Evaluate Refrigerator consumption rate based on temperature type
  if (WH_LT_Size_None != 0 & WH_LT_Size_Chilled == 0 & WH_LT_Size_Frozen == 0) {
    CO2_Refrigerator = Total_Time*Emission_Calculation_Data$None_Fuel
  } else if (WH_LT_Size_None == 0 & WH_LT_Size_Chilled != 0 & WH_LT_Size_Frozen == 0) {
    CO2_Refrigerator = Total_Time*Emission_Calculation_Data$None_Chilled
  }
}

```

```

} else if (WH_LT_Size_None == 0 & WH_LT_Size_Chilled == 0 & WH_LT_Size_Frozen != 0){
  CO2_Refrigerator = Total_Time*Emission_Calculation_Data$Frozen_Fuel
} else if (WH_LT_Size_None != 0 & WH_LT_Size_Chilled != 0 & WH_LT_Size_Frozen == 0) {
  CO2_Refrigerator = Total_Time*Emission_Calculation_Data$None_Chilled
} else if (WH_LT_Size_None != 0 & WH_LT_Size_Chilled == 0 & WH_LT_Size_Frozen != 0) {
  CO2_Refrigerator = Total_Time*Emission_Calculation_Data$Frozen_None_Fuel
} else if (WH_LT_Size_None == 0 & WH_LT_Size_Chilled != 0 & WH_LT_Size_Frozen != 0) {
  CO2_Refrigerator = Total_Time*Emission_Calculation_Data$Frozen_Chilled
} else {
  CO2_Refrigerator = Total_Time*Emission_Calculation_Data$Frozen_Chilled_None
}
}
#Evaluate CO2 Level for one route
CO2_Level_WH_LT_D = (CO2_Distance+CO2_Refrigerator)*Emission_Calculation_Data$CO2_Emission
#sum all the routs CO2 level
CO2_Level__WH_LT_D_Total= CO2_Level__WH_LT_D_Total + CO2_Level_WH_LT_D
#time
Traveling_Tlme_WH_LT_D_Total = Traveling_Tlme_WH_LT_D_Total+Total_Time
}

```

```

#adding all the CO2 emmission level
CO2_Level_Total <- (CO2_Level__S_NWH_Total
  + CO2_Level_WH_B_WH_LT
  + CO2_Level_WH_UK_WH_LT
  + CO2_Level_WH_G_WH_LT
  + CO2_Level__WH_LT_D_Total)

```

```

Total_Tlme <- (Traveling_Time_S_NWH_Total
+Traveling_Time_WH_B_WH_LT_Total
+Traveling_Time_WH_UK_WH_LT_Total
+Traveling_Time_WH_G_WH_LT_Total
+Traveling_Tlme_WH_LT_D_Total
)
CO2_Level_Total <- CO2_Level_Total[1]
Total_Tlme <- Total_Tlme[1]
Result_List <- list(CO2_Level_Total, Total_Tlme)
return(Result_List)
}

```

Calculate_Optimization_PFG.R

```

Partial_Freight_Optimization_ALgorithm <- function(Vertex,Edge, Transportation_Costs, Emission_Calculation_Data, WH_Construction_Costs,
WH_Management_Costs, Iteration_Max_1, Iteration_Max_2) {
#Local and temperature
Transportation_Costs_Local <- subset(Transportation_Costs, Transportation_Costs$Type == "Local")
Transportation_Costs_Local_None <- subset(Transportation_Costs_Local, Transportation_Costs_Local$Cargo_Temperature == "None")
Transportation_Costs_Local_Frozen <- subset(Transportation_Costs_Local, Transportation_Costs_Local$Cargo_Temperature == "Frozen")
Transportation_Costs_Local_Chilled <- subset(Transportation_Costs_Local, Transportation_Costs_Local$Cargo_Temperature == "Chilled")
#International and temperature
Transportation_Costs_International <- subset(Transportation_Costs, Transportation_Costs$Type == "International")
Transportation_Costs_International_None <- subset(Transportation_Costs_Local, Transportation_Costs_Local$Cargo_Temperature == "None")
Transportation_Costs_International_Frozen <- subset(Transportation_Costs_Local, Transportation_Costs_Local$Cargo_Temperature == "Frozen")
Transportation_Costs_International_Chilled <- subset(Transportation_Costs_Local, Transportation_Costs_Local$Cargo_Temperature == "Chilled")

#Warehouse construction costs
WH_Construction_Costs_LT <- subset(WH_Construction_Costs, WH_Construction_Costs$Country == "Lithuania")
WH_Construction_Costs_LT_None <- subset(WH_Construction_Costs_LT, WH_Construction_Costs_LT$Type == "None")
WH_Construction_Costs_LT_Chilled <- subset(WH_Construction_Costs_LT, WH_Construction_Costs_LT$Type == "Chilled")
WH_Construction_Costs_LT_Frozen <- subset(WH_Construction_Costs_LT, WH_Construction_Costs_LT$Type == "Frozen")

#Warehouse Management costs
WH_Management_Costs_LT <- subset(WH_Management_Costs, WH_Management_Costs$Country == "Lithuania")
WH_Management_Costs_LT_None <- subset(WH_Management_Costs_LT, WH_Management_Costs_LT$Type == "None")
WH_Management_Costs_LT_Chilled <- subset(WH_Management_Costs_LT, WH_Management_Costs_LT$Type == "Chilled")
WH_Management_Costs_LT_Frozen <- subset(WH_Management_Costs_LT, WH_Management_Costs_LT$Type == "Frozen")

#set Variable to 0
Transportation_Costs_Full_D_Calculated_Total <- 0
transportation_costs_S_WH_LT_Opt_Calculated <- 0
Transportation_Costs_S_WH_LT_Opt_Calculated_Total <- 0
Transportation_Costs_WH_LT_D_Calculated_Total <- 0
transportation_costs_S_WH_LT_Prep_Calculated <- 0
Transportation_Costs_S_WH_LT_Prep_Calculated_Total <- 0
Transportation_Costs_Calculated_Total <- 0
CO2_Level_S_WH_LT_Opt_D <- 0
CO2_Level_S_WH_LT_Opt_D_Total <- 0
CO2_Level__WH_LT_D_Total <- 0
CO2_Level_S_WH_Full_LT_Total <- 0

```

```

CO2_Level__S_WH_LT_Prep_Calculated_Total <- 0

WH_Construction_Costs_Total <- 0
WH_Management_Costs_total <- 0
Traveling_Time_S_WH_Full_LT_Total <- 0
Traveling_Time_Prep_total <- 0
Min_Distance <- 0
Distance_Prep_Total <- 0
Total_Distance_Opt <- 0
Route_Quantity <- 0
Not_Optimized_Transportation_Costs <- 0
Optimized_Transportation_Costs <- 0
Transportation_Costs_Prep_Total <- 0
Traveling_Time_WH_LT_D_Total <- 0
Traveling_Time_S1_S2_Opt_Total <- 0
Traveling_Time_S1_S2_LT_Opt_Total <- 0
Min_Co2_level <- 0
Min_Traveling_Time <- 0
Optimized_CO2_Level_Total <- 0
Transportation_Costs_S_WH_LT_Test_Calculated_Total <- 0
Total_Time_Test <- 0

#Warehouses
WH_LT_Vertex <- subset(Vertex, Vertex$ID == 240)

#Setting WH size variables to 0
WH_LT_Size_None <- 0
WH_LT_Size_Chilled <- 0
WH_LT_Size_Frozen <- 0

#Creatint a data frame with suppliers not with 32 pallet size
Vertex_Optimization <- subset(Vertex, Vertex$None != 32 & Vertex$Chilled != 32 & Vertex$Frozen != 32)
Supplier_ID <- data.frame(Vertex_Optimization$ID[c(-96:-nrow(Vertex_Optimization))])
colnames(Supplier_ID) <- paste("ID")

#evaluating S to D if pallet size equal to 32
for (i in 1:118) {
  #Create a subset of the calculated route
  Edge_Temp <- subset(Edge, Edge$Source == i & Edge$Target == 240)
  #Create a subsets of the starting and ending points
  Vertex_Source <- subset(Vertex, Vertex$ID == i)
  vertex_Target <- subset(Vertex, Vertex$ID == 118+i)

  if(Vertex_Source$None == 32 | Vertex_Source$Chilled == 32 | Vertex_Source$Frozen == 32)
  {
    transportation_costs_Full_D_Calculated = (Edge_Temp$Distance*Transportation_Costs_International$VCPK/1000
      +Vertex_Source$None*Transportation_Costs_International_None$VCFPQ
      +Vertex_Source$Chilled*Transportation_Costs_International_Chilled$VCFPQ
      +Vertex_Source$Frozen*Transportation_Costs_International_Frozen$VCFPQ
      +Transportation_Costs_International$FC
    )
    Transportation_Costs_Full_D_Calculated_Total = (Transportation_Costs_Full_D_Calculated_Total + transportation_costs_Full_D_Calculated)
    Transportation_Costs_Full_D_Calculated_Total <- Transportation_Costs_Full_D_Calculated_Total[1]
  }

  Rest_Time=((Edge_Temp$Driving_Time%/%39600)*10)+((Edge_Temp$Driving_Time-
  (39600*Edge_Temp$Driving_Time%/%39600))%/%18000)*1
  Total_Time=Rest_Time+Edge_Temp$Driving_Time/60/60
  #Evaluate CO2 level for distance
  CO2_Distance=Edge_Temp$Distance/1000*Emission_Calculation_Data$Truck_Fuel_Rate
  #Evaluate Refrigerator consumption rate based on temperature type
  if (Vertex_Source$None != 0 & Vertex_Source$Chilled == 0 & Vertex_Source$Frozen == 0) {
    CO2_Refrigerator = Total_Time*Emission_Calculation_Data$None_Fuel
  } else if (Vertex_Source$None == 0 & Vertex_Source$Chilled != 0 & Vertex_Source$Frozen == 0) {
    CO2_Refrigerator = Total_Time*Emission_Calculation_Data$None_Chilled
  } else if (Vertex_Source$None == 0 & Vertex_Source$Chilled == 0 & Vertex_Source$Frozen != 0){
    CO2_Refrigerator = Total_Time*Emission_Calculation_Data$Frozen_Fuel
  }
  #Evaluate CO2 Level for one route
  CO2_Level_S_WH_Full_LT = (CO2_Distance+CO2_Refrigerator)*Emission_Calculation_Data$CO2_Emission
  #sum all the routs CO2 level
  CO2_Level_S_WH_Full_LT_Total= CO2_Level_S_WH_Full_LT_Total + CO2_Level_S_WH_Full_LT
  #Time eveluation
  Traveling_Time_S_WH_Full_LT_Total = Traveling_Time_S_WH_Full_LT_Total+Total_Time
}

```

```

#Evaluate from S to WH LT transportation costs
for (j in 1:nrow(Supplier_ID)) {
  i = Supplier_ID$ID[j]
  #Create a subset of the calculated route
  Edge_Temp <- subset(Edge, Edge$Source == i & Edge$Target == 240)
  #Create a subsets of the starting and ending points
  Vertex_Source <- subset(Vertex_Optimization, Vertex_Optimization$ID == i)
  Vertex_Target <- subset(Vertex, Vertex$ID == 240)
  #Evaluate International costs
  transportation_costs_S_WH_LT_Prep_Calculated = (Edge_Temp$Distance*Transportation_Costs_International$VCPK/1000
    +Vertex_Source$None*Transportation_Costs_International_None$VCFPQ
    +Vertex_Source$Chilled*Transportation_Costs_International_Chilled$VCFPQ
    +Vertex_Source$Frozen*Transportation_Costs_International_Frozen$VCFPQ
    +Transportation_Costs_International$FC
  )
  Transportation_Costs_S_WH_LT_Prep_Calculated_Total = (Transportation_Costs_S_WH_LT_Prep_Calculated_Total +
transportation_costs_S_WH_LT_Prep_Calculated)
  Transportation_Costs_S_WH_LT_Prep_Calculated_Total <- Transportation_Costs_S_WH_LT_Prep_Calculated_Total[1]
  Transportation_Costs_Prep_Total <- Transportation_Costs_S_WH_LT_Prep_Calculated_Total
  Rest_Time=((Edge_Temp$Driving_Time%/39600)*10)+((Edge_Temp$Driving_Time-
(39600*Edge_Temp$Driving_Time%/39600))%/18000)*1
  Total_Time=Rest_Time+Edge_Temp$Driving_Time/60/60
  #Evaluate CO2 level for distance
  CO2_Distance=Edge_Temp$Distance/1000*Emission_Calculation_Data$Truck_Fuel_Rate
  #Evaluate Refrigerator consumption rate based on temperature type
  if (Vertex_Source$None != 0 & Vertex_Source$Chilled == 0 & Vertex_Source$Frozen == 0) {
    CO2_Refrigerator = Total_Time*Emission_Calculation_Data$None_Fuel
  } else if (Vertex_Source$None == 0 & Vertex_Source$Chilled != 0 & Vertex_Source$Frozen == 0) {
    CO2_Refrigerator = Total_Time*Emission_Calculation_Data$None_Chilled
  } else if (Vertex_Source$None == 0 & Vertex_Source$Chilled == 0 & Vertex_Source$Frozen != 0){
    CO2_Refrigerator = Total_Time*Emission_Calculation_Data$Frozen_Fuel
  } else if (Vertex_Source$None != 0 & Vertex_Source$Chilled != 0 & Vertex_Source$Frozen == 0) {
    CO2_Refrigerator = Total_Time*Emission_Calculation_Data$None_Chilled
  } else if (Vertex_Source$None != 0 & Vertex_Source$Chilled == 0 & Vertex_Source$Frozen != 0) {
    CO2_Refrigerator = Total_Time*Emission_Calculation_Data$Frozen_None_Fuel
  } else if (Vertex_Source$None == 0 & Vertex_Source$Chilled != 0 & Vertex_Source$Frozen != 0) {
    CO2_Refrigerator = Total_Time*Emission_Calculation_Data$Frozen_Chilled
  } else {
    CO2_Refrigerator = Total_Time*Emission_Calculation_Data$Frozen_Chilled_None
  }
  #Evaluate CO2 Level for one route
  CO2_Level_S_WH_LT_Prep_Calculated = (CO2_Distance+CO2_Refrigerator)*Emission_Calculation_Data$CO2_Emission
  #sum all the routs CO2 level
  CO2_Level__S_WH_LT_Prep_Calculated_Total= CO2_Level__S_WH_LT_Prep_Calculated_Total + CO2_Level_S_WH_LT_Prep_Calculated
  Co2_Level_Prep_total = CO2_Level__S_WH_LT_Prep_Calculated_Total
  Traveling_Time_Prep_total = Traveling_Time_Prep_total + Total_Time
  Distance_Prep_Total = Distance_Prep_Total+CO2_Distance
}

#simulated annealing
Print_Variables_Array= data.frame(Transportation_Costs_S_WH_LT_Test_Calculated_Total=rep(0, Iteration_Max_1)
,Min_Transportation_costs=rep(0, Iteration_Max_1)
,Iteration_no_1=rep(0, Iteration_Max_1))

Min_Transportation_costs <- Transportation_Costs_S_WH_LT_Prep_Calculated_Total

Iteration_no_1 <- 0
Iteration_no_2 <- 0
#start the simulated annealing process
while (Iteration_no_1 < Iteration_Max_1) {
  print(Iteration_no_1)
  Iteration_no_1 = Iteration_no_1 +1
  # set the variables to 0
  Iteration_no_2 <- 0

  Supplier_ID <- data.frame(Vertex_Optimization$ID[c(-96:-nrow(Vertex_Optimization))])
  colnames(Supplier_ID) <- paste("ID")
  Transport_Costs_Not_Optimized <- 0
  Total_Time_Test <- 0
  Optimized_CO2_Level_Total <0
  Total_Distance_Opt <- 0
  Route_Quantity <- 0
  Not_Optimized_CO2_Level <- 0
  Optimized_CO2_Level_Total <- 0
}

```



```

Transportation_Costs_S_WH_LT_Test_Calculated_Total <- 0
Traveling_Time_S1_S2_Opt_Total <- 0
Traveling_Time_S1_S2_LT_Opt_Total <- 0
S1_WH_LT_Time_Not_Opt <- 0
S2_WH_LT_Time_Not_Opt <- 0
#start the calculation process

while (Iteration_no_2 < Iteration_Max_2) {
  Iteration_no_2 = Iteration_no_2 + 1
  #setting the Supplier ID indexes
  i <- sample(1:nrow(Supplier_ID),1)
  #Choosing randomly the first Supplier
  S1_Index <- Supplier_ID$ID[i]
  #Removing the chosen supplier from the second loading place
  j <- sample(1:nrow(Supplier_ID),1)
  if (i != j) {
    #Selecting randomly the second loading place
    S2_Index <- Supplier_ID$ID[j]
    #adding the pallet sizes of both suppliers
    Vertex_Source_Test_1 <- subset(Vertex_Optimization, Vertex_Optimization$ID == S1_Index)
    Vertex_Source_Test_2 <- subset(Vertex_Optimization, Vertex_Optimization$ID == S2_Index)
    Test_None <- Vertex_Source_Test_1$None + Vertex_Source_Test_2$None
    Test_Chilled <- Vertex_Source_Test_1$Chilled + Vertex_Source_Test_2$Chilled
    Test_Frozen <- Vertex_Source_Test_1$Frozen + Vertex_Source_Test_2$Frozen
    #Testing if the selected suppliers can be distributed together
    if (Test_None < 32 | Test_Chilled < 32 | Test_Frozen < 32){
      #Setting the variables for S1 and S2
      Edge_Temp_1 <- subset(Edge, Edge$Source == S1_Index & Edge$Target == 240)
      Edge_Temp_2 <- subset(Edge, Edge$Source == S2_Index & Edge$Target == 240)
      Vertex_Source_1 <- subset(Vertex_Optimization, Vertex_Optimization$ID == S1_Index)
      Vertex_Source_2 <- subset(Vertex_Optimization, Vertex_Optimization$ID == S2_Index)
      Vertex_Target_Final <- subset(Vertex, Vertex$ID == 240)
      #evaluating the transportation costs from Supplier to WH LT
      S1_LT_Costs = (Edge_Temp_1$Distance*Transportation_Costs_International$VCPK/1000
        +Vertex_Source_1$None*Transportation_Costs_International_None$VCFPQ
        +Vertex_Source_1$Chilled*Transportation_Costs_International_Chilled$VCFPQ
        +Vertex_Source_1$Frozen*Transportation_Costs_International_Frozen$VCFPQ
        +Transportation_Costs_International$FC)

      S2_LT_Costs = (Edge_Temp_2$Distance*Transportation_Costs_International$VCPK/1000
        +Vertex_Source_2$None*Transportation_Costs_International_None$VCFPQ
        +Vertex_Source_2$Chilled*Transportation_Costs_International_Chilled$VCFPQ
        +Vertex_Source_2$Frozen*Transportation_Costs_International_Frozen$VCFPQ
        +Transportation_Costs_International$FC)

      #Evaluate the Total time
      Rest_Time=((Edge_Temp_1$Driving_Time%/%39600)*10)+((Edge_Temp_1$Driving_Time-
(39600*Edge_Temp_1$Driving_Time%/%39600))%/%18000)*1
      Total_Time=Rest_Time+Edge_Temp_1$Driving_Time/60/60
      #Evaluate CO2 level for distance
      CO2_Distance=Edge_Temp_1$Distance/1000*Emission_Calculation_Data$Truck_Fuel_Rate
      #Evaluate Refrigerator consumption rate based on temperature type
      if (Vertex_Source$None != 0 & Vertex_Source$Chilled == 0 & Vertex_Source$Frozen == 0) {
        CO2_Refrigerator = Total_Time*Emission_Calculation_Data$None_Fuel
      } else if (Vertex_Source_1$None == 0 & Vertex_Source_1$Chilled != 0 & Vertex_Source_1$Frozen == 0) {
        CO2_Refrigerator = Total_Time*Emission_Calculation_Data$None_Chilled
      } else if (Vertex_Source_1$None == 0 & Vertex_Source_1$Chilled == 0 & Vertex_Source_1$Frozen != 0){
        CO2_Refrigerator = Total_Time*Emission_Calculation_Data$Frozen_Fuel
      } else if (Vertex_Source_1$None != 0 & Vertex_Source_1$Chilled != 0 & Vertex_Source_1$Frozen == 0) {
        CO2_Refrigerator = Total_Time*Emission_Calculation_Data$None_Chilled
      } else if (Vertex_Source_1$None != 0 & Vertex_Source_1$Chilled == 0 & Vertex_Source_1$Frozen != 0) {
        CO2_Refrigerator = Total_Time*Emission_Calculation_Data$Frozen_None_Fuel
      } else if (Vertex_Source_1$None == 0 & Vertex_Source_1$Chilled != 0 & Vertex_Source_1$Frozen != 0) {
        CO2_Refrigerator = Total_Time*Emission_Calculation_Data$Frozen_Chilled
      } else {
        CO2_Refrigerator = Total_Time*Emission_Calculation_Data$Frozen_Chilled_None
      }
      #Evaluate CO2 Level for one route
      S1_CO2_Level_Not_Opt = (CO2_Distance+CO2_Refrigerator)*Emission_Calculation_Data$CO2_Emission
      #time
      S1_WH_LT_Time_Not_Opt = Total_Time
      #distance
      S1_WH_LT_Distance_Not_Opt = CO2_Distance
      #Evaluate the Total time

```

```

Rest_Time=((Edge_Temp_2$Driving_Time%/%39600)*10)+((Edge_Temp_2$Driving_Time-
(39600*Edge_Temp_2$Driving_Time%/%39600))%/%18000)*1
Total_Time=Rest_Time+Edge_Temp_2$Driving_Time/60/60
#Evaluate CO2 level for distance
CO2_Distance=Edge_Temp_2$Distance/1000*Emission_Calculation_Data$Truck_Fuel_Rate
#Evaluate Refrigerator consumption rate based on temperature type
if (Vertex_Source$None != 0 & Vertex_Source$Chilled == 0 & Vertex_Source$Frozen == 0) {
  CO2_Refrigerator = Total_Time*Emission_Calculation_Data$None_Fuel
} else if (Vertex_Source_2$None == 0 & Vertex_Source_2$Chilled != 0 & Vertex_Source_2$Frozen == 0) {
  CO2_Refrigerator = Total_Time*Emission_Calculation_Data$None_Chilled
} else if (Vertex_Source_2$None == 0 & Vertex_Source_2$Chilled == 0 & Vertex_Source_2$Frozen != 0){
  CO2_Refrigerator = Total_Time*Emission_Calculation_Data$Frozen_Fuel
} else if (Vertex_Source_2$None != 0 & Vertex_Source_2$Chilled != 0 & Vertex_Source_2$Frozen == 0) {
  CO2_Refrigerator = Total_Time*Emission_Calculation_Data$None_Chilled
} else if (Vertex_Source_2$None != 0 & Vertex_Source_2$Chilled == 0 & Vertex_Source_2$Frozen != 0) {
  CO2_Refrigerator = Total_Time*Emission_Calculation_Data$Frozen_None_Fuel
} else if (Vertex_Source_2$None == 0 & Vertex_Source_2$Chilled != 0 & Vertex_Source_2$Frozen != 0) {
  CO2_Refrigerator = Total_Time*Emission_Calculation_Data$Frozen_Chilled
} else {
  CO2_Refrigerator = Total_Time*Emission_Calculation_Data$Frozen_Chilled_None
}
}
#Evaluate CO2 Level for one route
S2_CO2_Level_Not_Opt = (CO2_Distance+CO2_Refrigerator)*Emission_Calculation_Data$CO2_Emission
#time
S2_WH_LT_Time_Not_Opt = Total_Time
#Distance
S2_WH_LT_Distance_Not_Opt = CO2_Distance
#setting new variables for optimized transportation places
Edge_Temp_3 <- subset(Edge, Edge$Source == S1_Index & Edge$Target == S2_Index)
Edge_Temp_4 <- subset(Edge, Edge$Source == S2_Index & Edge$Target == 240)
Vertex_Source_3 <- subset(Vertex_Optimization, Vertex_Optimization$ID == S1_Index)
Vertex_Source_4 <- subset(Vertex_Optimization, Vertex_Optimization$ID == S2_Index)

#evaluating partial freight distribution
S1_S2_Costs = (Edge_Temp_3$Distance*Transportation_Costs_International$VCPK/1000
+Vertex_Source_3$None*Transportation_Costs_International_None$VCFPQ
+Vertex_Source_3$Chilled*Transportation_Costs_International_Chilled$VCFPQ
+Vertex_Source_3$Frozen*Transportation_Costs_International_Frozen$VCFPQ
+Transportation_Costs_International$FC)

S1_S2_LT_Costs = (Edge_Temp_4$Distance*Transportation_Costs_International$VCPK/1000
+Vertex_Source_4$None*Transportation_Costs_International_None$VCFPQ
+Vertex_Source_4$Chilled*Transportation_Costs_International_Chilled$VCFPQ
+Vertex_Source_4$Frozen*Transportation_Costs_International_Frozen$VCFPQ
+50*1)
#Evaluate the Total time
Rest_Time=((Edge_Temp_3$Driving_Time%/%39600)*10)+((Edge_Temp_3$Driving_Time-
(39600*Edge_Temp_3$Driving_Time%/%39600))%/%18000)*1
Total_Time=Rest_Time+Edge_Temp_3$Driving_Time/60/60
#Evaluate CO2 level for distance
CO2_Distance=Edge_Temp_3$Distance/1000*Emission_Calculation_Data$Truck_Fuel_Rate
#Evaluate Refrigerator consumption rate based on temperature type
if (Vertex_Source$None != 0 & Vertex_Source$Chilled == 0 & Vertex_Source$Frozen == 0) {
  CO2_Refrigerator = Total_Time*Emission_Calculation_Data$None_Fuel
} else if (Vertex_Source_3$None == 0 & Vertex_Source_3$Chilled != 0 & Vertex_Source_3$Frozen == 0) {
  CO2_Refrigerator = Total_Time*Emission_Calculation_Data$None_Chilled
} else if (Vertex_Source_3$None == 0 & Vertex_Source_3$Chilled == 0 & Vertex_Source_3$Frozen != 0){
  CO2_Refrigerator = Total_Time*Emission_Calculation_Data$Frozen_Fuel
} else if (Vertex_Source_3$None != 0 & Vertex_Source_3$Chilled != 0 & Vertex_Source_3$Frozen == 0) {
  CO2_Refrigerator = Total_Time*Emission_Calculation_Data$None_Chilled
} else if (Vertex_Source_3$None != 0 & Vertex_Source_3$Chilled == 0 & Vertex_Source_3$Frozen != 0) {
  CO2_Refrigerator = Total_Time*Emission_Calculation_Data$Frozen_None_Fuel
} else if (Vertex_Source_3$None == 0 & Vertex_Source_3$Chilled != 0 & Vertex_Source_3$Frozen != 0) {
  CO2_Refrigerator = Total_Time*Emission_Calculation_Data$Frozen_Chilled
} else {
  CO2_Refrigerator = Total_Time*Emission_Calculation_Data$Frozen_Chilled_None
}
}
#Evaluate CO2 Level for one route
S1_S2_CO2_level_Opt = (CO2_Distance+CO2_Refrigerator)*Emission_Calculation_Data$CO2_Emission
S1_S2_Distance = CO2_Distance
#Time
Traveling_Time_S1_S2_Opt_Total = Total_Time
#Evaluate the Total time
Rest_Time=((Edge_Temp_4$Driving_Time%/%39600)*10)+((Edge_Temp_4$Driving_Time-
(39600*Edge_Temp_4$Driving_Time%/%39600))%/%18000)*1

```

```

Total_Time=Rest_Time+Edge_Temp_4$Driving_Time/60/60
#Evaluate CO2 level for distance
CO2_Distance=Edge_Temp_4$Distance/1000*Emission_Calculation_Data$Truck_Fuel_Rate
#Evaluate Refrigerator consumption rate based on temperature type
if (Vertex_Source$None != 0 & Vertex_Source$Chilled == 0 & Vertex_Source$Frozen == 0) {
  CO2_Refrigerator = Total_Time*Emission_Calculation_Data$None_Fuel
} else if (Vertex_Source_4$None == 0 & Vertex_Source_4$Chilled != 0 & Vertex_Source_4$Frozen == 0) {
  CO2_Refrigerator = Total_Time*Emission_Calculation_Data$None_Chilled
} else if (Vertex_Source_4$None == 0 & Vertex_Source_4$Chilled == 0 & Vertex_Source_4$Frozen != 0){
  CO2_Refrigerator = Total_Time*Emission_Calculation_Data$Frozen_Fuel
} else if (Vertex_Source_4$None != 0 & Vertex_Source_4$Chilled != 0 & Vertex_Source_4$Frozen == 0) {
  CO2_Refrigerator = Total_Time*Emission_Calculation_Data$None_Chilled
} else if (Vertex_Source_4$None != 0 & Vertex_Source_4$Chilled == 0 & Vertex_Source_4$Frozen != 0) {
  CO2_Refrigerator = Total_Time*Emission_Calculation_Data$Frozen_None_Fuel
} else if (Vertex_Source_4$None == 0 & Vertex_Source_4$Chilled != 0 & Vertex_Source_4$Frozen != 0) {
  CO2_Refrigerator = Total_Time*Emission_Calculation_Data$Frozen_Chilled
} else {
  CO2_Refrigerator = Total_Time*Emission_Calculation_Data$Frozen_Chilled_None
}
#Evaluate CO2 Level for one route
S1_S2_LT_Level_Opt = (CO2_Distance+CO2_Refrigerator)*Emission_Calculation_Data$CO2_Emission
S1_S2_LT_Distance = CO2_Distance
#Time
Traveling_Time_S1_S2_LT_Opt_Total = Total_Time

#Setting the cost variables
Not_Optimized_Transportation_Costs = S1_LT_Costs + S2_LT_Costs
Not_Optimized_Transportation_Costs <- Not_Optimized_Transportation_Costs[1]
Optimized_Transportation_Costs = S1_S2_Costs + S1_S2_LT_Costs
Not_Optimized_Transportation_Costs <- Not_Optimized_Transportation_Costs[1]
#choosing the best costs based on separate distribution and partial freight combination
if (Not_Optimized_Transportation_Costs < Optimized_Transportation_Costs) {
  Transportation_Costs_S_WH_LT_Test_Calculated_Total = Transportation_Costs_S_WH_LT_Test_Calculated_Total
+Not_Optimized_Transportation_Costs
  Transportation_Costs_S_WH_LT_Test_Calculated_Total <- Transportation_Costs_S_WH_LT_Test_Calculated_Total[1]
  Total_Distance_Opt = Total_Distance_Opt + S1_WH_LT_Distance_Not_Opt + S2_WH_LT_Distance_Not_Opt
  Route_Quantity = Route_Quantity + 2
  Not_Optimized_CO2_Level = S2_CO2_Level_Not_Opt + S1_CO2_Level_Not_Opt
  Not_Optimized_CO2_Level <- Not_Optimized_CO2_Level[1]
  Optimized_CO2_Level_Total = Optimized_CO2_Level_Total + Not_Optimized_CO2_Level
  Total_Time_Test <- Total_Time_Test + S1_WH_LT_Time_Not_Opt + S2_WH_LT_Time_Not_Opt
  Supplier_ID <- Supplier_ID[ ! Supplier_ID$ID %in% c(S1_Index, S2_Index), ]
  Supplier_ID <- data.frame(Supplier_ID)
  colnames(Supplier_ID) <- paste("ID")
}
else {
  Transportation_Costs_S_WH_LT_Test_Calculated_Total = Transportation_Costs_S_WH_LT_Test_Calculated_Total +
Optimized_Transportation_Costs
  Transportation_Costs_S_WH_LT_Test_Calculated_Total <- Transportation_Costs_S_WH_LT_Test_Calculated_Total[1]
  Total_Distance_Opt = Total_Distance_Opt + S1_S2_LT_Distance + S1_S2_Distance
  Route_Quantity = Route_Quantity + 1
  Optimized_CO2_Level = S1_S2_LT_Level_Opt + S1_S2_CO2_level_Opt
  Optimized_CO2_Level <- Optimized_CO2_Level[1]
  Optimized_CO2_Level_Total = Optimized_CO2_Level_Total + Optimized_CO2_Level
  Total_Time_Test <- Total_Time_Test + Traveling_Time_S1_S2_LT_Opt_Total + Traveling_Time_S1_S2_Opt_Total
  Supplier_ID <- Supplier_ID[ ! Supplier_ID$ID %in% c(S1_Index, S2_Index), ]
  Supplier_ID <- data.frame(Supplier_ID)
  colnames(Supplier_ID) <- paste("ID")
}
}
}
}
#saving the main variables for analysis
Print_Variables_Array[Iteration_no_1, ] = data.frame(Transportation_Costs_S_WH_LT_Test_Calculated_Total
, Min_Transportation_costs
, Iteration_no_1)

#choosing the minimal costs
if (Transportation_Costs_S_WH_LT_Test_Calculated_Total < Min_Transportation_costs) {
  Min_Transportation_costs = Transportation_Costs_S_WH_LT_Test_Calculated_Total
  Min_CO2_level = Optimized_CO2_Level_Total
  Min_Traveling_Time = Total_Time_Test
  Min_Distance = Total_Distance_Opt
  Min_Route_Quantity = Route_Quantity
}
}
}

```

```

#changing the print array names
Print_Variables_Array <- rename(Print_Variables_Array, c("Transportation_Costs_S_WH_LT_Test_Calculated_Total" = "Transportation_Costs"
, "Min_Transportation_costs" = "Min_Transportation_Costs"
, "Iteration_no_1" = "Iteration"))

#evaluating position from WH Lithuania to Final delivery places
for (i in 1:118) {
#Create a subset of the calculated route
Edge_Temp <- subset(Edge, Edge$Source == 240 & Edge$Target == 118+i)
#Create a subsets of the starting and ending points
Vertex_Source <- subset(Vertex, Vertex$ID == i)
vertex_Target <- subset(Vertex, Vertex$ID == 118+i)

Transportation_costs_WH_LT_D_Calculated = (Edge_Temp$Distance*Transportation_Costs_Local$VCPK/1000
+Vertex_Source$None*Transportation_Costs_Local_None$VCFPQ
+Vertex_Source$Chilled*Transportation_Costs_Local_Chilled$VCFPQ
+Vertex_Source$Frozen*Transportation_Costs_Local_Frozen$VCFPQ
+Transportation_Costs_Local$FC
)

Transportation_costs_WH_LT_D_Calculated_Total <- (Transportation_Costs_WH_LT_D_Calculated_Total +
Transportation_costs_WH_LT_D_Calculated)
Transportation_costs_WH_LT_D_Calculated_Total <- Transportation_costs_WH_LT_D_Calculated_Total[1]

Rest_Time=((Edge_Temp$Driving_Time%/%39600)*10)+((Edge_Temp$Driving_Time-
(39600*Edge_Temp$Driving_Time%/%39600))%/%18000)*1
Total_Time=Rest_Time+Edge_Temp$Driving_Time/60/60
#Eveluate CO2 level for distance
CO2_Distance=Edge_Temp$Distance/1000*Emission_Calculation_Data$Truck_Fuel_Rate
#Eveluate Refrigerator consumption rate based on temperature type
if (WH_LT_Size_None != 0 & WH_LT_Size_Chilled == 0 & WH_LT_Size_Frozen == 0) {
CO2_Refrigerator = Total_Time*Emission_Calculation_Data$None_Fuel
} else if (WH_LT_Size_None == 0 & WH_LT_Size_Chilled != 0 & WH_LT_Size_Frozen == 0) {
CO2_Refrigerator = Total_Time*Emission_Calculation_Data$None_Chilled
} else if (WH_LT_Size_None == 0 & WH_LT_Size_Chilled == 0 & WH_LT_Size_Frozen != 0) {
CO2_Refrigerator = Total_Time*Emission_Calculation_Data$Frozen_Fuel
} else if (WH_LT_Size_None != 0 & WH_LT_Size_Chilled != 0 & WH_LT_Size_Frozen == 0) {
CO2_Refrigerator = Total_Time*Emission_Calculation_Data$None_Chilled
} else if (WH_LT_Size_None != 0 & WH_LT_Size_Chilled == 0 & WH_LT_Size_Frozen != 0) {
CO2_Refrigerator = Total_Time*Emission_Calculation_Data$Frozen_None_Fuel
} else if (WH_LT_Size_None == 0 & WH_LT_Size_Chilled != 0 & WH_LT_Size_Frozen != 0) {
CO2_Refrigerator = Total_Time*Emission_Calculation_Data$Frozen_Chilled
} else {
CO2_Refrigerator = Total_Time*Emission_Calculation_Data$Frozen_Chilled_None
}
}
#Eveluate CO2 Level for one route
CO2_Level_WH_LT_D = (CO2_Distance+CO2_Refrigerator)*Emission_Calculation_Data$CO2_Emission
#sum all the routs CO2 level
CO2_Level_WH_LT_D_Total= CO2_Level_WH_LT_D_Total + CO2_Level_WH_LT_D
#Time
Traveling_Tlme_WH_LT_D_Total = Traveling_Tlme_WH_LT_D_Total+Total_Time
}

#adding all the transportation costs
Transportation_Costs_Calculated_Total <- (Transportation_Costs_Full_D_Calculated_Total
+ Min_Transportation_costs
+ Transportation_Costs_WH_LT_D_Calculated_Total
)
Transportation_Costs_Calculated_Total <- Transportation_Costs_Calculated_Total[1]

#adding all the CO2 Emmission levels
CO2_Level_Total <- (CO2_Level_S_WH_Full_LT_Total
+ Min_Co2_level
+ CO2_Level_WH_LT_D_Total)

Total_Traveling_Time <- (Traveling_Time_S_WH_Full_LT_Total
+ Min_Traveling_Time
+Traveling_Tlme_WH_LT_D_Total
)
CO2_Level_Total <- CO2_Level_Total[1]
#evaluating Warehouse construction costs
#evaluating Lithuania warehouse size
WH_LT_Size_None <- sum(Vertex$None)
WH_LT_Size_Chilled <- sum(Vertex$Chilled)
WH_LT_Size_Frozen <- sum(Vertex$Frozen)

```

```

#lithuania
WH_Construction_Costs_LT_Evaluated<- WH_Construction_Costs_LT$FCWC
+WH_LT_Size_None*WH_Construction_Costs_LT_None$VCWC
+WH_LT_Size_Chilled*WH_Construction_Costs_LT_Chilled$VCWC
+WH_LT_Size_Frozen*WH_Construction_Costs_LT_Frozen$VCWC

WH_Construction_Costs_Total = WH_Construction_Costs_LT_Evaluated

#lithuania
WH_Management_Costs_LT_Evaluated <- WH_Management_Costs_LT$FCWMC
+WH_LT_Size_None*WH_Management_Costs_LT_None$VCWC
+WH_LT_Size_Chilled*WH_Management_Costs_LT_Chilled$VCWC
+WH_LT_Size_Frozen*WH_Management_Costs_LT_Frozen$VCWC

WH_Management_Costs_total <- WH_Management_Costs_LT_Evaluated

#Removing additional values, problem with indexes
Transportation_Costs_Calculated_Total <- Transportation_Costs_Calculated_Total[1]
WH_Construction_Costs_Total <- WH_Construction_Costs_Total[1]
WH_Management_Costs_total <- WH_Management_Costs_total[1]
CO2_Level_Total <- CO2_Level_Total[1]
Transport_Costs_Not_Optimized <- Transport_Costs_Not_Optimized[1]
Min_Transportation_costs <- Min_Transportation_costs[1]
Min_Co2_level <- Min_Co2_level[1]
Min_Traveling_Time <- Min_Traveling_Time[1]

#Creating several return Values
Result_List <- list(Transportation_Costs_Calculated_Total
, WH_Construction_Costs_Total
, WH_Management_Costs_total
, CO2_Level_Total
, Transportation_Costs_Prep_Total
, Co2_Level_Prep_total
, Min_Transportation_costs
, Min_Co2_level
, Total_Traveling_Time
, Min_Traveling_Time
, Traveling_Time_Prep_total
, Min_Distance
, Distance_Prep_Total
, Min_Route_Quantity
, Print_Variables_Array)
return(Result_List)

```