Model for Determining the Optimum Location for Performance Improvement in Supply-Chain Strategies

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Abstract

The economic crisis which started in 2007 has caused damaging effects to most international companies. In several EU countries, foreign investments decreased and international companies closed or relocated production and/or distribution centres, due to cost reduction measures. This paper is aiming to demonstrate that applying a performant solution in defining the supply chain strategy can be a low cost process, which can generate positive effects on the sales and revenues. The research objective is to present a concrete solution for redesigning the supply chain, in order to achieve the optimal delivery strategy. The solution implies the use of mathematic methods, for determining the optimum location for placing a central warehouse, in a geographic region. The use of an optimum delivery strategy leads to lower depositing and transport costs, which generates positive effects on sales, by offering more competitive prices on products. The main contribution of the author is the development of a model, used to identify the optimal location for placing a central warehouse.

Keywords: supply chain strategy; optimum location; informatics solution; mathematical optimization;

JEL Classification: L23; L25; M11;

1. Introduction

The supply chain management is the process of planning, implementing and control of the procurement, warehousing and product delivery activities. A part of the planning phase is represented by the process of defining the supply chain strategy.

Broadly examined in theory and confirmed in nowadays practice, the crisis and post-crisis period led to profound changes at political-national and organizational-corporate levels, claiming for economic and social solutions aimed to mitigate the subsequent negative effects (Iamandi and Munteanu, 2014).

During the last years, it has been noticed a growing interest of organizations in improving their business processes in order to be more competitive in a globalized economy that passed through a severe financial crisis with restrictive market conditions and limited profit margins (Geambaşu, 2012). Most retail stores expect their suppliers to offer competitive prices, because in the post-crisis years, customers are more likely to use the cost criteria when they choose the goods they buy, especially when it comes to household items and groceries.

The information technology available to large parts of the population leads to better informed customers, as they can easily compare prices for similar products. This has led to the need of rethinking the overall management strategies for both multinational companies and small companies, in order to increase efficiency and ensure the survival of the economic entity.

In the process of rethinking a business strategy, an important objective is to increase the supply chain performance. The economic crisis was a low-point from which companies could rise by applying performance management principles in order to make the processes of procurement, storage and delivery run with maximum efficiency. The purpose of this paper is to introduce a new framework that can be used in the process of managing the performances of the supply chain.

2. Literature Review

2.1 Supply chain strategies

The current context, strongly marked by the global crisis, determines the organizations to initiate radical changes in their strategies (Androniceanu and Drăgulănescu, 2012). This section focuses on the synthesis of the most important contributions on the subject of supply chain strategies and management. Two main categories were identified: strategies used for designing the supply chain and strategies proposed for increasing the supply chain performance.

The first category of supply chain strategies on which we focus is the one used for the *supply chain design*. A reference work in this regard is “A hybrid fuzzy-based approach for identifying global logistics strategies” (Sheu, 2004). The author identifies six types of supply chain strategies used for the supply chain design, noted GL-mode A to F (Global Logistics - Strategy A to F):

- GL-mode A, is based on the centralization of production, so the entire process of production, storage and inventory are realized in-house. Raw materials are purchased on the international market, and most customers are also from the international market, but managing the delivery process is conducted by the company.
- GL-mode B is a strategy similar to the first described, but the novelty is that some of the production work is outsourced to markets that offer advantages in terms of lower cost labour. Storage activity, inventory and delivery is coordinated and carried out by the company through its own resources.
- GL-mode C is a strategy also derived from GL-mode A, carrying the same idea of the centralization of production, but with a different distribution system. In this case the distribution is made not only by the company but there are external distribution centres supplying to various customers according to their geographical location so as to reduce transport costs.
- GL-mode D strategy is derived from GL-mode B and C, and proposes the solution of outsourcing for a part of the production activities in order to capitalize on opportunities and to decrease labour costs in other markets; also it suggests contracting external centres of distribution, with the scope of decreasing costs with the international delivery of products. Specific advantages enjoyed by the company that chooses this strategy are harnessing resources to transnational and global logistics network. Of course, by choosing this strategy, the logistics system complexity increases, requiring the use of modern supply chain management-delivery techniques.

- GL-mode E and GL mode-F are two models with complex strategies, used mainly by advanced technology companies. Within these, several activities are outsourced as part of the production and assembly of components. Both strategies aimed at the partial or total outsourcing of distribution to foreign distribution centres.
- GL-mode F strategy has extra features such as: partner companies that take part in the production and distribution centres, thus reducing logistics costs for distribution to foreign consumers. Flows of raw materials and goods in the two cases become extremely complex, logistical system becomes a vital component for the operation of production and distribution.

Sheu (2004) presents graphical illustrations of each supply chain design strategy and propose a decision making model for choosing the right logistics strategies, depending on the objectives of the company.

Another major category of logistics strategies are the ones used for *supply chain performance improvement*. Bowersox and Daugherty (1987) divided supply chain strategies in three categories: process-oriented strategies, market-oriented strategies and information-oriented strategies.

- In companies which apply the first strategic orientation (process-oriented), supply chain management is considered an internal activity that creates added value to products. This should be carried out with maximum efficiency, focusing on continuous improvement process management.
- The second strategic direction (market-oriented) is based on the market so the company can reduce operations complexity by outsourcing the supply chain management process (or part of it) to a supplier that provides a package of integrated logistics services. The company is able to focus on core business in order to offer customers the best possible products and services. This strategy is based on creating a synergy with a 3PL [1] company, ensuring performance management of the supply chain.
- The third strategic orientation (information-oriented) involves creating a supply chain network in which several companies, which collaborate for the delivery, carry out joint logistic activities. To achieve such coordination of inter-company logistics processes, it is necessary to create a communication system consisting of channels for transmitting information between participants in the logistics network.

In 1989, Bowersox and Daugherty collaborated with Droge, Rogers and Warlow to verify and improve the three categories previously defined by the first two authors. The market research was conducted by email and had 375 respondents. The analysis retained the three categories defined above, but changed the name for the last category from information strategy to channel strategy (Bowersox *et al.*, 1989).

McGinnis and Kohn (1990) also made a market research conducted by email, with 222 respondents to verify the hypothesis: the categories of logistics strategies can be determined empirically. They used methods like: factor analysis, clustering and ANOVA, and the results were the identification of four categories of supply chain strategies: i) intensive; ii) integrated; iii) poor integrated; iv) low efficiency.

[1] 3PL is ‘a firm that provides multiple logistics services, such as: transportation, warehousing, cross-docking, inventory management, packaging, and freight forwarding.’ (Council of Supply Chain Management Professionals)

McGinnis and Kohn (1993) conducted a parallel investigation for empirical verification of the three categories of logistics strategies defined by Bowersox and Daugherty (1987). They conducted a market research by email, with 59 respondents and the data processing was done by using factor analysis methods, clustering and ANOVA. The study confirmed the first two categories of logistics strategies: processes orientation and market orientation and identified three sub-categories, depending on the competitiveness of the economic environment: intense, balanced and unfocused.

Starting from the same study published by Bowersox and Daugherty (1987), Clinton and Closs (1997) conducted an empirical research of the three categories of supply chain strategies through market research conducted also by email, with 103 respondents. The methods of data analysis consisted of factor analysis and MANOVA. The results confirmed the three categories of logistics strategies (process, market and channel), and also the possibility of combining them, identifying the contributing factors.

In 1997, Kohn and McGinnis continued their research and published two more studies. The first one aimed to examine supply chain strategies through market research conducted by email, with 94 respondents whose data were processed by factor analysis and ANOVA methods. Thus, they identified two supply chain strategies used by companies: market and channel oriented strategy (the two combined) and processes-oriented strategy. It was concluded that the competitive environment had a decisive influence on the choice of supply chain strategy. The second study aimed to determine the correlation between categories of strategies and verify the hypothesis that logistic priorities affect the orientation of supply chain strategy. The market research was conducted by email, with 94 respondents and data processing methods were used: factor analysis, clustering and ANOVA. Two categories of supply chain strategies were identified: orientation towards integrated logistics (managing complex logistics flows through coordination) and orientation to processes (efficiency, control and cost reduction). It identified four logistical strategies: intense, intense integration, process intense and extensive.

Another study conducted in 2002 by McGinnis and Kohn aimed at determining the relationship between the categories of supply chain strategies defined by Bowersox and Daugherty (1987) and their efficiency. The market research was conducted by email, with 172 respondents. Data processing was done by using factor analysis and multifactorial regression methods. As a result, two types of strategies were identified: process-oriented and market-oriented strategies; the information strategy overlapped the first two, facilitating their implementation. The conclusion was that they are all interdependent and dynamic.

Considerable research has been carried out in the field of supply chain performance management since 1990. Different perspectives of supply chain performance measures are cost and non-cost perspective; strategic, tactical or operational focus; business process perspective and financial perspective. Successful supply chains use integrated measurement systems as a vehicle to achieve their organizational goals (Kurien and Qureshi, 2011). The earlier focus of performance measurement was on financial perspective which is gradually changing to non-financial perspectives. Most of the models have gone through some empirical testing and some have only theoretical developments (Taticchi *et al.*, 2010).

2.2 Factors that Influence the Change in Supply Chain Strategies Taxonomy

Today's marketplace is shifting from individual company performance to supply chain performance: the entire chain's ability to meet end-customer needs through product availability and responsive, on-time delivery. Supply chain performance crosses both functional lines and company boundaries (Supply Chain Online, 2014). The latest development in this field is supply chain performance management software, offered by companies like SAP, the world leader in enterprise software and software-related services in terms of revenue (SAP Supply Chain Performance Management, 2014).
The international economic environment is constantly changing as the customers became more exigent with their demands, the sources of supply are global, workforce is migrating, the manufacturing process can be relocated based on cost restrains and the product cycles are shorter, as the advance in technology permits new improvements faster than ever before.

In order to be able to adapt the supply chain of a company to the economic environment, we must identify the factors that should be taken into consideration when the supply chain strategy is being defined.

La Londe and Masters (1994) identified a series of factors that determine the need to adjust supply chain strategies to the global business environment changes, synthesized in **Figure 1**. Through a personal interpretation, the factors identified by La Londe and Masters (1995), were adapted to the current economic period so the following market variables resulted:

(1) The process of globalization. Trade liberalization has led to an increase in trade and many companies have expanded their operations in the international market. Raising living standards in most countries resulted in an increase of consumer exigency both in terms of product quality and related delivery services. Thus, the competition has become increasingly fierce and the complexity of logistic processes increased.

(2) Mergers and acquisitions. In the ‘80 mergers and acquisitions have become a widely used method of expansion in the capitalist countries to increase turnover and profit. The newly created companies often had an oversized and redundant logistic function in terms of capacity, due to the merge of several logistics departments from those firms.

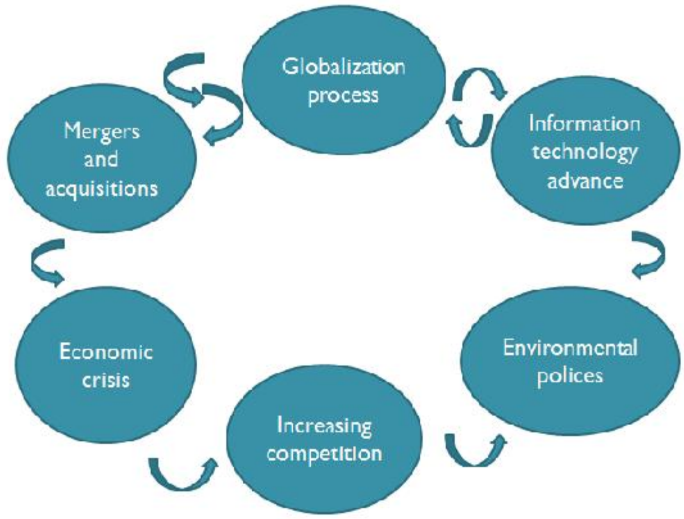
(3) The economic crisis. There were several economic crises over the time, but we’re going to focus on the latest one. In the last 3-4 years, the financial crisis effects were felt through the need to reduce costs, reflected in particular by reducing the production capacity and staff. Some companies have seen an opportunity in the economic downturn to rethink the medium and long term strategy, using cost-cutting plans to increase long-term competitiveness of the company.

(4) Intense competition and increasing market uncertainty. If we look at the three factors mentioned above, we find that they have led to fierce market competition: over the past three decades, multinationals have entered national markets (1) and the demand had decreased (3), so uncertainty in the market increased. Considering all factors stated before it can be concluded that the complexity of decision making process in business has increased.

(5) Legal regulations regarding the environment and product traceability. The trend in environmental regulation and consumer protection, determined additional costs for businesses and increased the complexity of logistics processes.

(6) *Advances in Information Technology*. This is one of the factors that have helped to a more efficient management of supply chain activities and faster delivery. In the last decade, the cost of purchasing hardware products decreased and software capabilities have improved in a fast pace. Each project has specific characteristics that should be taken into consideration when choosing the methodology that will be used for software development. (Geambaşu *et al.*, 2011)

Figure 1: Factors that determine the necessity of adapting logistic strategies to the changing economic environment



Source: by the author based on the information from La Londe and Masters (1994)

The next section of the paper is conducting an analysis on the supply chain strategies implementation, as case studies on successful companies present it.

2.3 Best Practices in Implementing Supply Chain Strategies

A case study on the implementation of logistics strategies was conducted in 2006 by AberdeenGroup. The study entitled "Best Practices in International Logistics Report" presented strategies for increasing the supply chain performance implemented by eight companies selected as "best practice winners" in logistics. The report identified different segments of the supply chain on which companies can concentrate in order to achieve an improvement in the logistic management process.

Valuation of companies was based on the following criteria:

- The impact of supply chain strategy on company competitiveness
- The degree of improvement in the logistics system flexibility, cycle time and total cost
- Impact of the supply chain strategy implementation on other departments (sales, purchasing, production, finance)
- Efficiency of strategies in internal management upgrade
- The degree of collaboration with suppliers and logistics service providers

Although the analysed companies have focused efforts on improving performance in various areas of international logistics, some basic strategies were identified:

(1) Automation strategy
(2) The strategy of using ultra-performance computing technology
(3) The strategy of creating an integrated network with suppliers and customers

(4) The effective inventory strategy
(5) The strategy of maximizing the benefits derived from trade agreements
(6) The strategy of outsourcing logistics activities

Combining logistics strategies can lead to new strategies by achieving a synergistic effect. An example of this is the logistics strategy "just-in-time", which was successfully applied by Toyota in the 20^{th} century. The "Just in time" strategy is based on a set of principles, tools and techniques that allow a company to manufacture and deliver products in small quantities at short notice to meet specific customer needs. This strategy is aimed at delivering the right products, in the required quantity and at the right time. The objectives are defined in terms of:

- Reducing the production cycle;
- Reduce stocks and quantity of products under manufacture;
- Reducing of staff performing unproductive duties;
- Reduction of the “non-quality" indicator;
- Provide a high level of customer service;
- Increased capacity to adapt to environmental changes.

To achieve these objectives, different strategies can be combined, for example:

- Automation to reduce labour costs;
- Computerization, for an advanced information management.

Other measures to support the implementation of the strategy "just-in-time" are:

- Fast reception of product;
- Modifying the organizational structure;
- Streamlining the production process;
- Continuous training of employees and a good motivational system.

The two main objectives of the company that applies this strategy are apparently contradictory:

- The company must provide quality products at low prices as soon as possible;
- The production system must be characterized by reliability and flexibility.

The utility value of quantitative objectives is determined by the costs which would be involved in the use of alternative marketing instruments (Cărăgin and Drăgoi, 2008).
Mathematical optimization and modelling can be applied in the area of improving the supply chain performance by obtaining specific solutions for decisions regarding the supply chain strategy. Further, our research is focused on applying supply chain strategies in the European Economic Area, with the determination of optimum strategies for European companies, with international operations.

3. Research Methodology

The research question is whether mathematical optimization can be used to develop a performant supply chain strategy aiming to decrease depositing and transport costs. This should generate positive effects on sales, by offering more competitive prices on products. The research methodology is based on statistical data collection for European countries, their analysis and presentation of findings on recommended solutions to increase the supply chain performance.

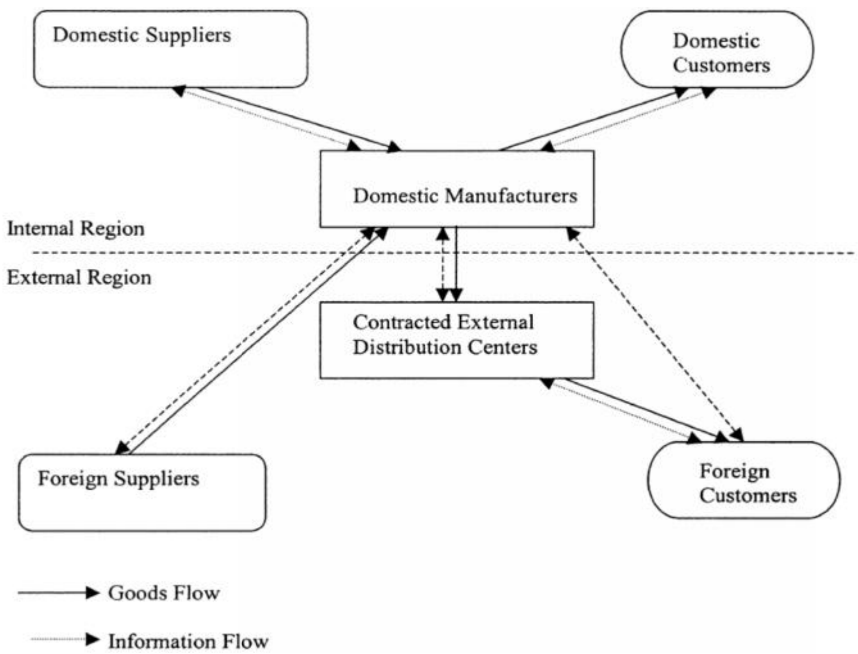
The main methods used in this research are: comparison of the supply chain strategies presented in the literature review section, identification of the main factors that influence the change in logistics strategies taxonomy, analysis of the manner in which different strategies can be combined and statistical data collection on the European economic environment. Specifically, we aim at identifying the main consumer conglomerations, and use mathematical optimization to determine the optimal location for a single distribution centre that can supply the key points identified. This can be achieved by defining and applying a mathematic model, transposed into an informatics solution.

The expected result of the research is the presentation of a solution for an optimal delivery strategy that can lead to increasing the performance of the supply chain for the case of companies with international operations, located in Europe.

4. Supply Chain Strategies and Performance for European Companies

For companies with international operations, located in the European Union, aiming to enhance their competitiveness in order to increase their income from exports, the best choice for the supply chain design would be GL mode-C, a strategy that enables the firm to focus on its core activity (centralization of production). This solution is fit for companies that don’t want to invest very much in large departments for logistics and the latest information technology needed for achieving an efficient communication system that enables the company to coordinate the production process in several locations, from different countries. The fact that the distribution system and the storage are mostly outsourced transforms fixed costs into variable ones, so it gives more flexibility to the supply chain, making it viable for different types of economic cycles.

Figure 2: Global Logistics Strategy-mode C (GL-mode C)



Source: Sheu (2004)

I analysed the theoretical solution presented by Sheu (2004) from the perspective of a company located in the European Union that has international operations or wants to expand their business abroad, taking into consideration the present economic environment. The decision of business internationalization must be taken under the financial constraints of the company and with a clear view on the economic factors. It is imperative that the management team develops a coherent supply chain strategy that can insure an efficient delivery of products to all targeted foreign markets.

As a part of this research, I developed a supply chain model that can be used by companies that carry out international activities in order to deliver products all over Europe. The supply chain model has the scope of identifying the best location for placing a central warehouse, which insures a minimum cost of transportation to all the consumer points, taking into consideration the size of the market by using the population number as a general indicator. For particular situations, a market study on a certain sector could indicate a more accurate approximation of the demand for products of interest in the market. Munteanu *et al.* (2015) considered that: “the simplification of the existent causal structure in the initial space of the variables was needed in order to identify the evolution of the investigated phenomena”. In this case, the simplification was applied on the output variables: the calculation of the estimated distance does not take into account the exact route according to transport infrastructure and the estimated time is determined using an average speed of 90 km/hour (taking into account a SafetyNet report on speeding in Europe stating that for urban roads the average speed is 60 km/h and for rural roads the average speed is between 80-120 km/h). The conceptual framework of the model includes a series of input and output variables, as presented in Table 1.

Table 1: Input and output variables

Main variables	**Secondary variables**	**Technical specification**
Input variables		
A geographic region		
***n* consumer points (c_1, c_2 ...c_n)**	Geographic coordinates	Longitude
		Latitude
	Demand on each point	Approximated by population
Output variables		
A central warehouse DC1	Geographic coordinates	
	Number of served cities	Identical to the number of consumer points
	Served population	Total population estimated see Appendix 1
	The average delivery time	

Source: by the author

The proposed model has a general format and it uses the geographical coordinates of the consumer points and the population for the 100 cities as input data. The model can be categorized as a spatial optimization model that uses the gravity centre method for determining the geometrical place for a central point that insures the minimum path to all the delivery points. For each of the cities the estimated time of delivery was determined, as presented in Appendix 1.

The hypotheses of the model are:

1) Any product can be delivered through a single transport;
2) The model does not take into account the transport infrastructure;
3) The decisional process is considered to be economically rational.

The model is structured in several steps of application.

I. Defining the geographic space of interest to the company as a sales market

The first step in optimizing the supply chain strategy is to define the geographic area that includes the targeted sales market. Then the company must try to identify the consumer points that are of interest to the company. Each of the consumer points is to be defined by their geographic position (latitude and longitude) and the demand. Of course, this depends very much on the company's profile, so on a general perspective I selected the largest 100 European cities, considered to be the largest ones by population criterion (the source of data is Eurostat website, the information is gathered at the level of year 2012 official population declared - the data must be from the same year in order to insure data comparability). The data regarding the 100 largest cities of the European Union that is necessary as input variable into our model is presented in Appendix 1.

II. The determination of the location for a central warehouse, which ensures the minimum total delivery cost to all the consumer points.
II.1. The geographic coordinates must be transformed in decimal numbers so that they can be used in calculations. This can be done using Microsoft Excel and the formula:

```
TEXT(ROUND(LEFT(F5,3)+(MID(F5,5,2)+RIGHT(F5,5)/60)/60,6),"00.000000")
```
(1)

II.2. Calculating the geographic coordinates of the gravitational centre of the consumer points we have defined. The mathematical formulas used for determining the optimal location for a central warehouse are:

$$Lat_{cg}= \frac{\sum \boldsymbol{Lat_i * C_i}}{\boldsymbol{Lat_i}} \qquad Long_{cg}= \frac{\sum \boldsymbol{Long_i * C_i}}{\boldsymbol{Long_i}} \tag{2}$$

Lat_{cg} – the latitude of the optimal gravitational point
$Long_{cg}$ – the longitude of the optimal gravitational point
C_i – the demand in the point *i*

As mentioned, these formulas are used in geometry for calculation of a gravitational centre of several points. They are adapted for practical application in supply chain strategy optimization.

The mathematical optimization model was transposed into an informatics solution, implemented in the C++ programming language, in order to obtain the calculation results, which are the exact coordinates for the optimum position of a central warehouse (further referred as CW).

III. Determination of the distances between the CW and each consumer point. The algorithm is based on the Excel function "atan 2" for which we need to have the geographic coordinates of the CW and each city, as well as the earth's radius.

IV. For each consumer centre the time of delivery can estimated using the classic formula:

$$\boldsymbol{T_i = d_i * v} \tag{3}$$

5. Results and Conclusions

After introducing the input data into the model, we obtained the geographic coordinates of the optimal location for placing a central warehouse: the latitude is 47.65552 and the longitude is 12.45081 (decimal format). This result can be graphical represented in the geographic space.

Figure 3. Graphical representation of the optimal location for a central warehouse in the European geographic space

Source: Representation generated by the author, using the web site: http://itouchmap.com/latlong.html

Results showed that the geographic location of the point that insures a minimum transportation cost is placed in Central Europe, more exactly near the border between Germany and Austria. Any location near this point would constitute a good placement for a logistic facility location that can insure the implementation of an efficient supply chain strategy.

The model presented can be adapted to any number of consumer points and the demand can be determined more accurately if a specific type of products are selected.

For small or medium size enterprises from emerging countries we recommend the rental of one central logistic facility which can insure the delivery of products to all the consumer points that are previously identified through a market study. For large companies that want to reduce delivery costs, the recommended supply chain strategy is the construction or acquisition of a large warehouse located near the point indicated by our model that can insure the most efficient supply chain management.

The limitations of this study are represented by the technical difficulties in the area of real-time estimation of transport duration and recognition of current infrastructure. Future research might improve the presented model by coordinating the source code in C++ with an application which determines the estimated time of delivery taking into account the state of infrastructure and GPS real-time positioning.

The main conclusion of this research is that mathematical optimization can be used to develop a supply chain strategy aiming to decrease depositing and transport costs and generate positive effects on sales, by offering more competitive prices on products. The presented solution can contribute to a performant design of the supply chain, because it is widely recognised that transport has the highest impact on logistic operations costs.

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Appendix 1. The 100 largest cities of the European Union by population within city limits

Rank	City	Country	Latitude	Longitude	Official population 2012	Estimated distance (km)	Estimated delivery time (hours)
1	London	United Kingdom	51.5073	0.1277	8,174,000	1434.9156	15.94
2	Berlin	Germany	52.5192	13.4061	3,501,872	550.8702	6.12
3	Madrid	Spain	40.4167	3.7003	3,284,110	1262.1540	14.02
4	Rome	Italy	41.9015	12.4608	2,799,350	639.4944	7.11
5	Paris	France	48.8566	2.3522	2,234,105	1130.2552	12.56
6	Hamburg	Germany	53.5511	9.9937	1,802,041	709.8549	7.89
7	Budapest	Hungary	47.4984	19.0408	1,740,041	732.6101	8.14
8	Vienna	Austria	48.2082	16.3738	1,730,278	440.3010	4.89
9	Warsaw	Poland	52.2297	21.0122	1,700,612	1078.7915	11.99
10	Bucharest	Romania	44.4377	26.0974	1,677,985	1558.2552	17.31
11	Barcelona	Spain	41.3879	2.1699	1,621,537	1338.1939	14.87
12	Munich	Germany	48.1366	11.5771	1,378,176	110.8496	1.23
13	Milan	Italy	45.4655	9.1865	1,345,890	436.8736	4.85
14	Prague	Czech Republic	50.0755	14.4378	1,290,846	347.9974	3.87
15	Sofia	Bulgaria	42.6965	23.3260	1,204,685	1328.3807	14.76
16	Brussels	Belgium	50.8503	4.3517	1,119,088	967.6218	10.75
17	Birmingham	United Kingdom	33.5207	86.8025	1,016,800	8411.3363	93.46
18	Koln	Germany	50.9375	6.9603	1,000,298	710.9141	7.90
19	Naples	Italy	26.1420	81.7948	957,012	8069.1647	89.66
20	Torino	Italy	45.0629	7.6785	905,554	603.6023	6.71
21	Stockholm	Sweden	59.3289	18.0649	861,010	1439.6017	16.00
22	Marseille	France	43.2965	5.3698	850,602	924.1340	10.27
23	Valencia	Spain	39.4702	0.3768	814,208	1621.1804	18.01
24	Amsterdam	Netherlands	52.3702	4.8952	789,285	989.7913	11.00
25	Kraków	Poland	50.0647	19.9450	756,666	874.8732	9.72
26	Leeds	United Kingdom	53.8013	1.5486	751,500	1390.9149	15.45
27	Łódź	Poland	51.7592	19.4560	750,125	902.2978	10.03
28	Athens	Greece	37.9837	23.7293	3,737,550	1651.2528	18.35
29	Riga	Latvia	56.9462	24.1043	713,000	1656.3768	18.40
30	Sevilla	Spain	37.3826	5.9963	703,206	1348.3703	14.98
31	Frankfurt	Germany	50.1109	8.6821	691,518	499.9020	5.55
32	Zaragoza	Spain	41.6568	0.8799	674,317	1448.5179	16.09
33	Palermo	Italy	38.1157	13.3613	653,522	1065.0597	11.83
34	Wrocław	Poland	51.1079	17.0385	633,950	638.1117	7.09

35	Rotterdam	Netherlands	51.9242	4.4818	615,937	1004.7242	11.16
36	Genova	Italy	44.4056	8.9463	606,206	531.1861	5.90
37	Helsinki	Finland	60.1698	24.9386	600,551	1964.8344	21.83
38	Stuttgart	Germany	48.7754	9.1818	595,452	384.0405	4.27
39	Düsseldorf	Germany	51.2277	6.7735	592,393	745.4765	8.28
40	Glasgow	United Kingdom	55.8642	4.2518	581,900	1289.4285	14.33
41	Dortmund	Germany	51.5136	7.4653	580,444	700.6146	7.78
42	Essen	Germany	51.4556	7.0116	574,635	737.4243	8.19
43	Málaga	Spain	36.7196	4.4200	568,305	1507.9182	16.75
44	Poznań	Poland	52.4064	16.9252	564,035	725.3102	8.06
45	Vilnius	Lithuania	54.6894	25.2800	553,553	1626.0584	18.07
46	Bremen	Germany	53.0793	8.8017	548,477	726.5214	8.07
47	Sheffield	United Kingdom	53.3811	1.4701	534,500	1376.3165	15.29
48	Leipzig	Germany	51.3397	12.3731	533,374	409.5455	4.55
49	Dresden	Germany	51.0504	13.7373	530,548	403.4845	4.48
50	Dublin	Ireland	53.3494	6.2601	525,383	934.7880	10.39
51	Copenhagen	Denmark	55.6761	12.5683	520,659	891.4913	9.91
52	Hannover	Germany	52.3759	9.7320	517,251	605.4136	6.73
53	Gothenburg	Sweden	57.7089	11.9746	507,330	1118.5709	12.43
54	Bradford	United Kingdom	53.7960	1.7594	501,700	1370.2611	15.23
55	Nuremberg	Germany	49.4520	11.0767	500,967	251.3678	2.79
56	Lisbon	Portugal	38.7253	9.1500	499,700	1058.1195	11.76
57	Duisburg	Germany	51.4344	6.7623	496,665	758.9964	8.43
58	Antwerp	Belgium	51.2192	4.4029	493,517	978.2003	10.87
59	Edinburgh	United Kingdom	55.9533	3.1883	477,660	1382.0885	15.36
60	The Hague	Netherlands	52.0705	4.3007	473,941	1030.1551	11.45
61	Lyon	France	45.7640	4.8357	472,304	872.0500	9.69
62	Manchester	United Kingdom	53.4793	2.2479	503,000	1305.6571	14.51
63	Gdańsk	Poland	54.3520	18.6466	456,103	1013.9264	11.27
64	Toulouse	France	43.6047	1.4442	440,204	1303.4738	14.48
65	Murcia	Spain	37.9834	1.1299	436,870	1654.8561	18.39
66	Liverpool	United Kingdom	53.4084	2.9916	434,900	1230.4413	13.67
67	Bratislava	Slovakia	48.1462	17.1073	431,061	520.3809	5.78
68	Bristol	United Kingdom	51.4545	2.5879	421,300	1174.6522	13.05
69	Szczecin	Poland	53.4285	14.5528	408,583	682.8075	7.59
70	Brno	Czech Republic	49.1951	16.6068	403,407	492.5653	5.47
71	Palma	Spain	39.5695	2.6500	401,270	1412.1141	15.69

72	Tallinn	Estonia	59.4427	24.7532	396,193	1893.5558	21.04
73	Bologna	Italy	44.4949	11.3426	383,418	372.2337	4.14
74	Bochum	Germany	51.4818	7.2162	382,195	720.6164	8.01
75	Las Palmas de Gran Canaria	Spain	28.1248	15.4300	381,847	2195.7238	24.40
76	Florence	Italy	43.7710	11.2480	372,473	451.9425	5.02
77	Thessaloniki	Greece	40.6393	22.9446	363,987	1402.9321	15.59
78	Bydgoszcz	Poland	53.1235	18.0084	362,397	866.4932	9.63
79	Kaunas	Lithuania	54.8969	23.8924	360,630	1504.8816	16.72
80	Wuppertal	Germany	51.2562	7.1508	358,746	712.1112	7.91
81	Bilbao	Spain	43.2570	2.9234	354,860	1166.2588	12.96
82	Lublin	Poland	51.2465	22.5684	352,786	1193.1787	13.26
83	Nice	France	43.6960	7.2656	347,060	725.0818	8.06
84	Plovdiv	Bulgaria	42.1438	24.7496	338,153	1497.8546	16.64
85	Varna	Bulgaria	43.2166	27.9118	334,870	1787.7293	19.86
86	Alicante	Spain	38.3452	0.4810	334,757	1685.3472	18.73
87	Córdoba	Spain	31.3989	64.1821	328,428	6026.5429	66.96
88	Bielefeld	Germany	52.0213	8.5303	326,268	652.1327	7.25
89	Wakefield	United Kingdom	53.6833	1.5059	322,300	1388.6770	15.43
90	Cardiff	United Kingdom	51.4816	3.1791	321,000	1114.7341	12.39
91	Bari	Italy	41.1171	16.8719	319,252	877.1992	9.75
92	Valladolid	Spain	41.6529	4.7284	318,461	1087.0411	12.08
93	Katowice	Poland	50.2649	19.0238	317,864	785.9709	8.73
94	Aarhus	Denmark	56.1629	10.2039	315,193	977.9190	10.87
95	Ostrava	Czech Republic	49.8209	18.2625	310,397	689.2796	7.66
96	Coventry	United Kingdom	52.4068	1.5197	309,800	1324.6663	14.72
97	Wirral	United Kingdom	53.3780	3.1088	309,500	1217.5630	13.53
98	Cluj-Napoca	Romania	46.7772	23.5999	309,136	1242.9329	13.81
99	Timişoara	Romania	45.7555	21.2375	303,708	999.1103	11.10
100	Mannheim	Germany	49.4875	8.4660	300,793	487.4267	5.42

Source: by the author, based on data collected from http://epp.eurostat.ec.europa.eu and http://www.worldatlas.com/aatlas/findlatlong.htm and calculations performed as described in section 6 of this paper