IMPACT OF SPATIAL LOCATION OF SUPPLY CHAIN ELEMENTS ON SUPPLY CHAIN COST EFFECTIVENESS AND PERFORMANCES

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Abstract

The proposed paper is dedicated to identification and appraisal of factors that should be considered within decision making process about spatial allocation of logistics objects in a supply chain. Such decisions are relevant either in designing of a new supply chains or in redesigning of a current one due to change in market condition or internal aspects such as corporate strategy, product portfolio, customers etc. Moreover, special attention is given to an impacts of these factors on facility location problem. The aforementioned aim of this paper is achieved based on real case study of a Czech middle size distribution company. Spatial location variants of distribution warehouses and of their numbers are created by means of the location problem method. Optimal distribution routes are set by using metaheuristic algorithm. Nonetheless, it is highly important to emphasize that the authors´ intention is not to asses suitability and accuracy of the methods themselves but they are used as the tools for creation of variants. Which are further evaluated regarding their cost-effectiveness and other factors e.g. customer requirements, labour force availability, supply and price of logistics properties for rent and supply of logistics services and their price

Key words: Supply chain, costs, allocation of logistics objects, optimization of a supply chain

JEL Code:M20, M21

Introduction

Effective and efficient management of supply chains enables gaining a significant competitive advantage over competitors not only for a particular company within a SC but especially for all parties being encompassed in that. Today competition is among supply chains unlike to the past when it was among particular companies(Christopher, 2010). Both effectiveness and efficiency are difficult to be achieved due to complexity of supply chain management problems caused by:

- Number of proprietary independent parties with various interests and goals

- Recent Economic changes of booms and recessions
- Variability of demands
- Lack of collaboration among SC parties
- Wide range of factors influencing SC operation and sustainability such as PEST and ecological factors

Decision making process about location of logistics facilities in a supply chain belongs to problems that are complex and high number of factors of different nature have to be involved in order to enhance supply chain performances in terms of time, costs and quality. Thus, decision about number, location and capacities of warehouses and manufacturing plants and flow through them falls into strategic decision management level in which network is designed(Shapiro, 2001).

Location theory was firstly established by Alfred Weber in 1909 who formulated how to position a single warehouse so that in can serve number of customers in minimized distance(Weber, 1929). The criterion of effectiveness was the shortest distances needed for customer satisfaction.

Based on that P-median problem was developed by Hakimi. P-median problem enables finding appropriate location of P facilities that the total weighted travel distance between customers and facilities is minimized. The distances are weighted by customer demand. Hakimi´s method enables identification location of limited number of facilities but not setting their number. (Hakimi, 1964)Since that the study of location theory has flourished and branch out into many subareas. Facility location problem could be currently classified into the following models (Klose & Drexl, 2005):

- Models in the plane, network location, discrete location and mixed-integer programming – models differ based on typography of located objects
- Minsum or minimax models – in minsum average travel distance is minimized; in minimax maximized distance is minimized
- Models with or without capacity constraints of facilities – in constrained models facilities have limited capacities that can impede customers from being served from a particular facility even when the distance would be closer in comparison to other possible solutions.
- Single or multiple stage models – in multiple stage model customers could be satisfied from hierarchical set of facilities

- Single or multiple product models – models are based on either single product, representing the whole product portfolio, or multiple heterogeneous product
- Elasticity of demand regarding spatial decision – in elastic demand distance and demand has to be explicitly involved in the model.
- Static or dynamic model – static model represent situation of one period and dynamic model incorporates changes of factors throughout one planning horizon consisting of several periods.
- Deterministic and probabilistic models –in deterministic models inputs are considered to be certain; probabilistic model works with uncertainty of inputs (demand, transportation time, etc.) and assign probability to their changes
- Isolated or combined location problem – in isolated model pair of supply or demand facilities are always compared and measured; combined model represent situation of milk run in which set of supply or demand points are served together, hence such relationship has to be involved in the model.

Facility location has long been a popular research area of Operation research since 1960s, nonetheless, the practical usefulness in logistics and Supply Chain Management has rarely been in main concern.(Melo, Nickel, & Saldan-Da-Gama, 2009).

Facility location problem is commonly solved within supply chain management when a company penetrates into a new market, significantly expands, changes substantially logistics and customer service strategy, restructures its supply chains, organizes a tender to change logistics provider or a developer renting logistic or production facility or establishes off-shoring strategy etc. Aforementioned situations embraces various factors that have to be reflected during decision making process about facility location. This paper is dedicated to logistic facility location, thus hereinafter list of factors are narrowed down regarding this focal area. The main factors are:

Facility type

Facility types could be classified regarding there size of gravity: international, regional and local. Moreover, they can be distinguished based on their function:assembly plant, warehouse, distribution centre, cross-docking centre, logistics centre, terminal of multimodal and combined transportation.

Density of demand

When customer demand is more scattered then more of logistics facilities are needed to provide the same level of service as under condition of high density of demand. Moreover, larger distances between customers cause rise of transportation cost which could trade off savings of centralized storing and manipulation.Less scattered demand requires higher number of smaller vehicles as drivers spent more time on road and thus they cannot serve the same number of customers within allowed working hours. However, this is relevant under condition of the same level provided logistics service.

Scope and volume of provided logistics services

Besides logistics costs customer service shapes the boundaries of gravity field as the rest of the time left of subtracting order processing lead time, order completion lead time, packaging and expedition lead time from customer delivery time provides maximum time left for transportation. Moreover, customer order value or profit and a delivery distance are used for calculation of Minimum Order Quantity that directly influences the frequency of delivery. Hence, number of facilities and their location is effected by that.

Transport infrastructure

Type of logistics facility predetermines accessibility to a particular transport infrastructure. Logistics centres and terminals of multimodal and combined transport have to be connected with more modes of transportation, commonly road and rail at least, sometimes even air freight or inland water transport is appreciated.In addition to that, low density of highways, lack of city rings, insufficient number of rail/road terminals increase number of logistics facilities operating in a particular gravity field as otherwise required service level wouldn´t be able to be provided.

Available structure and amount of workforce

Availability of workforce can become a constrain especially when a facility is planned by a model to be allocated by into a place which is highly exposed by other companies. Thus, those companies that establishes their facilities in such area earlier can employ all relevant workforce. Furthermore, an allocation model can pick up right place concerning gravity and infrastructure but the place could be totally remote from suitable workforce. It could be solved by employing part time employees by using external HR company that would organize commuting of hired employees. However, it increases cost of operation.

Available storing and manipulation

Companies that prefer allocation their processers into available space and don´t want to have built a new facility because of time or cost can be highly dependent on this criterion. They can pick up only from limited number of suitable properties.

Available service of logistics provider

This criterion is similar to the previous one, nonetheless, it is relevant for companies searching for outsourcing of logistics.

Ecological aspect

Ecology can play important role when the preferred location in which logistics park or industry zone is not approved in urban plan. Furthermore, when a company store and distribute chemical substances close proximity to ecologically valuable and protected area can induce significant cost of measures or even make it impossible to go life.

Local authority support

Local authority support/opposition is usually dependant of total effect of proposed location project on local environment and economy. A project bringing new job opportunity of tens or hundreds in case of small city and hundreds or thousands in case of big city, some investments into new city infrastructure could be easily promoted. Therefore, some marginal negative effects in terms of insular increase of noise could be overweighed.

Local authority factor could have devastating consequences and thwart initial investments due because of local people and authorities' opposition to proposed project. However, local authority can also provide financial support to attract investments to a particular region, hence the positive attitude of local authorities could become significant factor due to it beneficial financial impact on facility location project. Investment incentives could be provided not only on local level e.g. city but also on region or state level.

Competitors

Presence of a competitors´ facility in a particular place could have contradictory effects and make the particular place either more attractive or less attractive for placing s facility. Presence of new location next to competitors could enable utilization of established local demand e.g. allocation of retail stores or can benefit from asset sharing within transportation and warehousing provided by one logistics provider. However, this factor could significantly influence preferred location.

Economic cycles

Economic cycles predetermines evolution of demand throughout a time and so capacity requirements and economy impact of that.

Above mentioned factors could be classified into hard and soft factors. Hard factors are involved in quantitative analyses and soft in qualitative.

A particular optimal solution of facility location problem is identified based on minimal total costs (Melkote & Daskin, 2001);(Nozick & Turnquist, 2001), delivery distance(Gong, Gen, Yamazaki, & Xu, 1997) or combination of both(Wu, Low, & Bai, 2002); (Doong, Lai, & Wu, 2007).

The main stream of current research is oriented on enhancing an optimization mathematical models by adding additional or replacing some factor(s) considered as hard which can be relevant to facility location problem. Qualitative research targeting at analysing significance of factors in decision making process are in minority. Magnitude of particular factors could be identified by QFD and AHP approach (Kumar & Kumanan, 2011). Hence, authors of this paper have established a fundamental conceptual model proving that soft factors cannot be omitted within decision making process of facility location problem. Conceptual model is depicted in Fig. 1 and expresses not only hard factors that are used commonly in mathematical models in facility location problem but also soft factors that are omitted and undermining efficiency and effectiveness of the solution.

The authors have formulated scientific question: Should soft factors be involved in decision making process about facility location problem as they enable viability and effectiveness of mathematical optimal solution from business perspective?

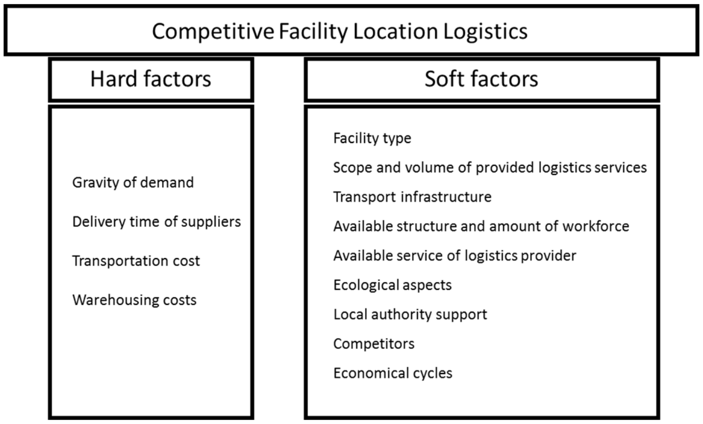
Authors estimates that neglecting these soft factors would lead to identification of facility location that cannot establish competitive advantage of a supply chain. Authors have formulated the hypothesis H1: Soft factors can significantly deviate optimal facility location from the one achieved only on hard factors.

Methodology

Authors have created conceptual model Fig. 1identifying the most critical aspects of logistic facility location problem. Furthermore, it emphasizes that soft factors should have an equal position as hard factors in decision making process about logistic facility location problem. Hence, they formulated the following scientific question: Should soft factors be involved in decision making process about facility location problem as they significantly influence the optimal solution from business perspective?

The conceptual model and its hypotheses are firstly tested on one particular case study hence qualitative descriptive analysis of one case study is used. That should either confirm or not confirm the hypothesis. Moreover, addition aspect could be identified by such qualitative analysis.

Fig. 1: Conceptual model



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Bases on hereinafter information about the ABC Company, authors aim was to find suitable number of distribution warehouses and identify their best location. Hence, such decision making process of the case study should either confirm or not the formulated hypothesis.

The decision making process has the following steps:

- Analysing of logistics processes
- Specification of requirements, constraints and estimations provided by the ABC Company – their cannot be less than four warehouses due to delivery time to customers and company could either outsource or insource warehousing but definitely insource distribution.
- Identification of hard and soft factors based on conceptual model and aforementioned points
- Collection of data
- Programming and testing of tool for FLP
- Searching for optimal facility location under the following conditions:
    - Number of warehouses should remain the same but their location could be changed within their current region – this solution would enable keeping majority of Full Time Employ and also the same customer that would be served by the same sales representatives or Key Account Managers.
    - Number of warehouses should be the same but they could be located across the Czech Republic – number of warehouses is due to keeping the same frequency of delivery for customers as in the past when the distribution is insourced. The condition of insourcing is due to having close relationship with customer but on the other hand cause higher number of warehouses.
    - There could be four warehouses anywhere in the Czech Republic.

- Calculation of transportation costs for each of the solution based on root planning software (Road Control)
- Analysing of Logistics Provider Market and supply of warehouse properties available for rent. Warehouse properties or Logistic provider has to be equipped for storing and manipulation with chemical substances.
- Calculation of warehousing costs
- Comparison of solutions
- Identification an impact of the soft factors

Description of company

The real name of the company is changed to ABC a.s. due to confidential nature of the data. The ABC is a distribution company of chemical products of which customers are allocated mainly in the Czech Republic, its annual turnover is 300 mil CZK. Customers could be divided into the following segments: retail chains, small and medium size drugstore and sole traders. Customers can choose from 5 000 SKUs. There are three main ordering channels:

Ordering application – customers can install software that enables them creation of orders and their editing, alert about order submit deadline. At least 70% of orders should be received by this channel, however, in reality hardly 40% of them are transferred by software.

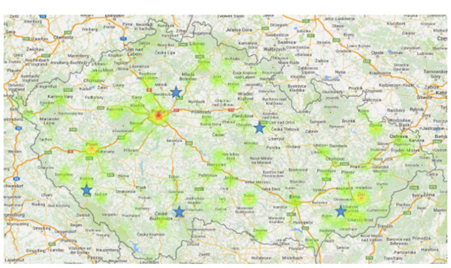
E-mail – 20% of orders are transferred by email.

Telephone – customers call to a local branch and create 20% of orders by phone.

Sales representatives – sales representatives visit their customers during which 20% of customer orders are created. Share of each channel could differ from branch to branch as usually small traders and drugstore shops are reluctant to use this channel and prefer traditional way of ordering.

ABC company uses insourcing for both either warehousing or distribution of goods to customers. There are five regional warehouses (W1-W5) currently allocated in the Czech Republic particularly in district: Pilsen district (W1), South Bohemia (W2), Central Bohemia (W3), Pardubice district (W4), Zlín district (W5). Detail locations are shown in Fig. 2.

Fig. 2: DistributiAvailable storing and manipulationon of sales



Source: own source

Each star in the map represents one distribution warehouse. Moreover, the map contains company sales in kg which are represented by different colours. The higher sales are the darker coloured the place is.Share of each warehouse on sales is in Tab. 1.

Tab. 1: Warehouses´ share of sales

Warehouse	Share on sales	Share of transportation costs on logistics costs costs	Share of each warehouse on total transportation costs	Share on total logistic costs
W1	16%	38%	24%	19%
W2	11%	38%	11%	13%
W3	32%	30%	28%	30%
W4	10%	26%	10%	10%
W5	30%	42%	27%	28%

Source: own source

Company provides quite high level of customer service and so guarantee 24 hour delivery timethat starts at the time of order confirmation and ends when goods is delivered. Costs of transportation from sites to customers are covered by the distribution company ABC when a customer orders more than Minimum Ordering Quantity. It is set based on the minimum value of a purchase order so that a margin would easily cover transportation cost.

Distribution from the warehouses is provided by ABC Company and fixed distribution bone roots are defined for each week day. Each root is carried out at least twice a week which ensures customer satisfactory frequency of delivery. Moreover, the company fleet comprises of 20 vehicles with weight over 3,5t so the regulation 561/2006 ES have to be respected.

Generally, customers´ delivery time window is one day from 9-17:00. However, each customer can have a specific requirements concerning the exact delivery window e.g. when not or 2-3 hour time window which can be desired due to traffic obstacles or operational reasons at the customer facility.

Customers have predetermined deadline for sending their orders which is 2pm so that ABC can managed to process orders, pick and pack appropriate goods and prepare that at an expedition still during the afternoon. Thus, it could be well prepared for the next day loading into a vehicle and for the delivery. However, the fact that customersdon´t respect the deadline for order submission leads to peaks and overloading of staff not only in the afternoon but also even in the morning of the delivery day. Hence, cargo vehicle departure could be delayed.

ABC Company has around 100 suppliers with delivery time one week. Just first three suppliers deliver 90% of all volumes andall suppliers are located in the Czech Republic. Each supplier has fixed delivery day and goods is delivered under DAP term.

Results and discussion

Reallocation of warehouses based on optimization within their initial regions leads to reduction of distribution transportation costs by 25%, see Tab.2. It is obvious from that and Fig.1 that former location of warehouses was inefficient due to quite far distance from main demand gravity centres. There % share of each warehouse on transportation costs in Tab.2 to clarify impact of each on costs changes.

Tab. 2: Optimization within initial regions

Warehouse	Share on transportation costs	New location within the same region	Costs changes
W1	24%	Plzeň	-16%
W2	11%	Jindřichův Hradec	-32%
W3	28%	Havlíčkův Brod	-40%
W4	10%	Hradec Králové	-13%
W5	27%	Staré Město	-18%
Total			-25%

Source: own source

Further step in which optimized locations were searched regardless assignment of customers to initial regions enabled more significant transportation cost reductions shown in Tab.3.

Tab. 3: Optimization across the Czech Republic

Warehouse	Share on transportation costs	New regions	Tranpsortation cost changes
W1	19%	Plzeň	
W2	37%	Jihlava	
W3	25%	Praha	
W4	6%	Ostrava	
W5	14%	Staré Město	
Total			-31%

Source: own source

Ability to reduce number of warehouses and optimization of warehouses´ location across the Czech Republic resulted in reduction of transportation costs by 28%, see Tab.4, which is less than in previous step. Reason for that is that less warehouses leads not only to lower warehousing costs but also to higher transportation cost as the vehicles have to serve larger demand regions. Unlike to common situation the warehousing cost grew up as in initial solution ABC Company had unbelievably convenient contracts with developer of warehouses properties. Reallocation would lead to increase of warehousing costs as the rents would be much higher than in the initial solution. Thus, reduction of warehouse number would lead to increase of total logistics costs by 18%, see Tab.4

Tab. 4: Optimization of four warehouses across the Czech Republic

Warehouse	Share on transportation costs	New regions	Transportation costs changes	Warehouse cost changes	Total cost changes
W1	18%	Plzeň			
W2	24%	Jihlava			
W3	24%	Praha			
W4	34%	Staré Město			
Total			-28%	33%	18%

Source: own source

Finally, authors analysed both soft and hard factors concerning their impact on facility location problem in the analysed case study. The factors were classified into hard and soft categories and in each proposed location presented in this paper + or – was assigned regarding if some of the factor disqualify the location from optimal viable solution, see Tab.5. Results presented in Tab.5 confirm the hypothesis H1 and so it has proved that soft factors have to be inevitably involved explicitly in facility location problem and mathematical methods should be used only as a preliminary analysis.

Tab. 5: Warehouses´share of sales

Factor	Hard/Soft	Location					
		Hradec Králové	Jihlava	Jindřichův Hradec	Ostrava	Plzeň	Praha
Facility type	Soft	+	+	+	+	+	+
Demand gravity	Hard	+	+	+	+	+	+
Delivery time of suppliers	Hard	+	+	+	+	+	+
Transportation cost	Hard	+	+	+	+	+	+
Warehousing cost	Hard	+	-	+	+	+	+
Scope and volume of provided logistics services	Soft	-	+	-	-	+	+
Available structure and amount of workforce	Soft	+	+	+	-	-	+
Ecological aspect	Soft	+	+	+	+	+	+
Local authority support	Soft	+	+	+	+	+	+
Competitors	Soft	+	+	+	+	+	+

Economical cycles	Soft	+	+	+	+	+	+
Total		-	-	-	-	-	+

Conclusion

The aim of the proposed paper is to confirm conceptual model emphasizing necessity to involve soft factors into decision making process about logistics facility location problem. Introductory part provides insight into state of the art of this topic and uncover that main stream is focused on improvements of mathematical methods by adding additional hard factors. However, this paper confirmed that the soft factors can significantly influence whether a particular site could or not be a right place for a logistic facility which would establish competitive advantage in terms of time, cost and customer service. It has to be mentioned that the proposed conceptual model has been proved only on one case study. Authors plan to test that on further research of quantitative and qualitative research. Quantitative research should clarify the general magnitude of hard and soft factors of FLP. Qualitative research should uncover specific constraints that a company can solve within conceptual framework.

Acknowledgment

This paper and associated research was carried out as a part of the project financed by Internal Grant Agency of University of Economics, Prague, IG305025 and IP 307055 „National and corporate competitiveness from the perspective of endogenous growth models“.

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