INTERNATIONAL JOURNAL OF INTERDISCIPLINARITY IN THEORY AND PRACTICE
ITPB - NR.: 8, YEAR: 2015 – (ISSN 2344 - 2409)

LOCALIZATION OF LOGISTICS OBJECTS

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Abstract: *The main task of the proposal for a logistics system is an achievement of logistics goals that are conformed profit maximizing in most cases. Logistically, it is therefore necessary to continue to increase expenditures on logistics performance until marginal costs are equal to marginal revenue. Immediate profit is maximal at this point. The implementation of this objective is difficult and often impossible. The causes are varied; there are problems with the measurement of marginal costs, difficult logistics costs are separated from other business activities, it is difficult to quantify the relationship between the changes implemented in a logical system and its direct effects, the problem is a formulation of the relationship between logistics performance and corporate earnings and the liabilities arising from functions of logistics system for example rents and so on must not be quickly modified. We come to finding an optimal structure of logistics system with the fact that it is possible to find at least approximate of ideal solution through the above problems. The process is expressed through an example of location decisions in logistics.*

Keywords: Transport economics, logistics system, transportation and storage, cost function

1 INTRODUCTION

The issue of localization of objects was firstly formulated by J. von Thünen in 1921, about the impact of land prices and transport costs on trade. A mathematical formulation of a model of a location of the point in the plane that interacts with the existing points was even formulated even earlier. Currently, a choice of the optimal localization of objects relates substantially to all the places in the logistics chain, which products, raw materials and semi-finished products are produced and stored. Thus, it is localization of manufacturing companies, stocks of raw materials, products, wholesale and retail network in relation to the place of final consumption. It is clear that their location delivers long-term effects of many of them, but for some there is a great mobility of the current period from a view of the possible adjustment positioning. For example rent warehouses can be included.

The long-term strategic decisions include an appropriate location of the production company whose long-term work should be a guarantee of return on capital. Localization of retailers creates in turn a very specific group of decision-making situations given localizations of the market and competition in place. From our point of view there are expected mainly on localization of distribution warehouses, which is the most frequently identified decision-making localization task. Only from time to time strategic positioning decisions are taken regarding the location of production capacity.

Basic patterns of placing distribution warehouses should be formulated in terms of methods and criteria for their placement into three groups:

- Localization on market segment.
- Location on the manufacturing principle.
- Combined localization.

The function of the distribution warehouses located on the segment of the market is mainly restocking customers. Therefore, they are placed as close to the supplying region as possible and should ensure the best economic supply the customer group. Criteria for their placement imply under the desired rate of replenishment of inventory, the average size of customer orders and the cost of delivery, which is furthermore dependent on transport costs. These stocks may be operated by manufacturers and wholesale organizations or groups of retailers. In essence, provide storage services and assembling shipments. Typically, the wholesale grocery stores are located as close to the main concentration of food consumption as possible, mostly in large urban areas. Stocks of spare parts for cars etc. have similar function.

2 TRANSPORT ECONOMICS

To locate a warehouse there in addition to other cost items mainly transport costs. We shall pay attention to the location of one terminal between the manufacturer and the place of consumption for an explanation of the relationship of transport costs and localization. It is appropriate to take into account an assumption that the distance between manufacturers, in stock and customers are direct transport costs, which are a linear function of distance.

Let the average size of delivery is 1,100 kg and shipping rate 7 € / 100 kg in the direct delivery from the manufacturer to the customer in that market segment. If we set up a deployed warehouse and add complement its stock to 44 tonnes, shipping rate would drop for 7 € / 100 kg. Internal average transport rate in the market segment with an average 1,100 kilograms of supplies would be given to smaller distances of about 3,50 € / 100 kg. In this case, an establishment of a warehouse would bring a decrease of the cost of transport, because the costs of direct distribution are:

$$11*7=77\frac{Eur}{l}$$

And of supplies from a distribution warehouse:

$$\frac{440*7}{\frac{44000}{1100}}+11*3{,}5=115{,}50\frac{Eur}{l}$$

The procedures pointed out by the example can be generalized. The costs of operating the store should be subtracted from eventual savings. If this value is greater than or equal to zero, the establishment of warehouse is appropriate.

The decision of establishing a warehouse therefore can be formulated so that there must be a disparity:

$$A+B+C\leq D$$

where:
A- average costs for replenishing stock attributable to one delivery to the customer.
B- average storage costs of a delivery to the customer.
C- average transport costs in the locality.
D- the average costs of procurement and transport of one direct delivery.

Extension to more stores will not cause major methodological problems. Transport costs will initially decline with the increasing number of stores until the moment when the continuously decreasing supply replenishment, thus increasing shipping rates induce a rise in transport costs of replenishing such an increasing amount of storage that continuously increasing cost savings in areas that are no longer sufficient to cover growth, including growth in the cost to maintain storage.

3 ECONOMY OF STORAGE

Deployed stores are an important tool for market expansion and increase the volume of sales (Fig. 1).

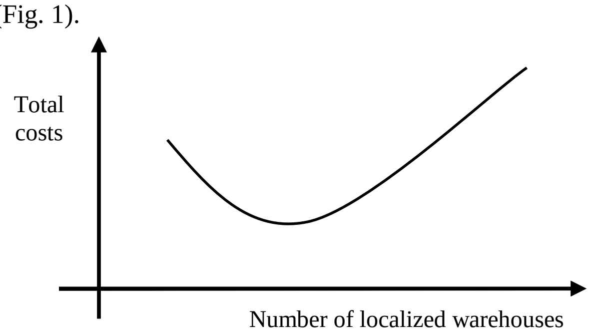

Fig. 1 The cost of transportation and storage

Especially nowadays there is an effort of major manufacturers still to expand primary markets. This is possible only through network of distribution warehouses. The growth of the number of warehouses, however, affects the structure of stocks. Not only that, the total amount of common stocks increases, but the stock size products in transit, and buffer stocks is changing with the growth cycles restocking plurality of storage. This change may be important factors in the decision making to a greater extent than normal inventory change, which size is more dependent on other factors, especially the size of the order. Attention should be paid primarily supplies products in transit, which means tying capital funds. A reduction in stocks of the road occurs mostly by including additional delivery cycles.

Assuming that an alternative supply of two market segments from one store should be replaced by an alternative supplying each of them by an individual stock, it is necessary to establish an additional stock to supply the other segment of the market. Let the demand on the market K is 12 tons / day, delivery time 5 days, on the market L 20 tons / day with the delivery cycle of 10 days from one distribution warehouse.

If instead of one two distribution warehouses A and B are set up, where the stock will supply market K with the delivery cycle again 5 days and stock B will supply market L with the delivery cycle 4 days, average stock products will decrease in transit,

From:

$$\frac{5*12+10*20}{2}=130 \text{ tons a day}$$

To:

$$\frac{5*12+4*20}{2}=70 \text{ tons a day}$$

However, the analysis is not complete. Increasing the number of stores will increase the number of cycles of replenishment of stocks. If goods to the warehouse are supplied by, for example, three suppliers, they will supply instead of one to two distribution warehouses, after the establishment of further distribution warehouse. As again delivery cycles are lost, supply products in transit will fall again. A highly simplified example that was used, it sufficiently illustrates the effect of changes in the structure of the distribution of the stock of goods in transit.

The opposite situation is with buffer stocks. Regarding the result of the outlined changes there will be a need to increase the average size of buffer stock for two reasons:

1. The buffer stocks should be created in several places.
2. Due to an increase of the number of delivery and additional cycles the number of possible risk periods increases depletion of stocks before the arrival of the next supply.

Characteristic of random fluctuations in demand will not be changed by a change of the structure of the distribution.

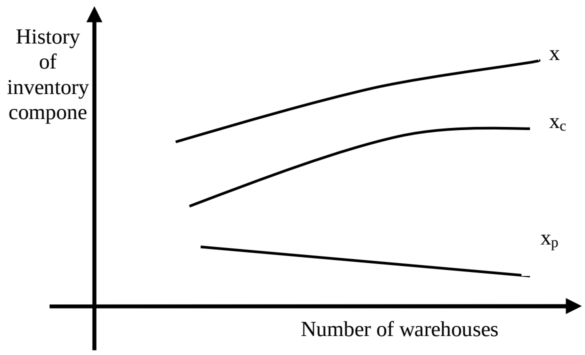

Fig. 2 Size of inventories

Summarizing the above, it is possible to illustrate the overall impact of the number of localized stocks in Fig. 2, where there is a typical history of the size of the average stock x, buffer stock Xp, and the stock of products in transit X_c.

4 ANALYSIS OF TOTAL COSTS

We can come to find the optimal number of distribution warehouses by combining an optimal structure of transportation problems and localization of warehouses. The typical history cost of both main components is shown in Fig. 3, wherein the minimum value of the addition curve determines the optimal number of localized units. This procedure would not only be possible if we admit many simplifications:

- The example, we used assumes a sale in one period. In fact, the logistics decision tied to a longer time horizon, which leads to many changes in sales, prices, etc.
- We assumed one size of delivery. This again is not correspond to practice, where we transport for each customer order in other sizes many times.
- We paid attention to only the relationship between transport costs and the maintaining of inventories. Both components have an impact on the level of availability of supplies and thus services.
- Selection of sites for the location of the warehouse is a separate complex problem on a large scale. It is enough to illustrate a complexity of decision making only to the case where we would like to meet the demand by their products to for the country. It is a huge amount of options, each with a different cost.

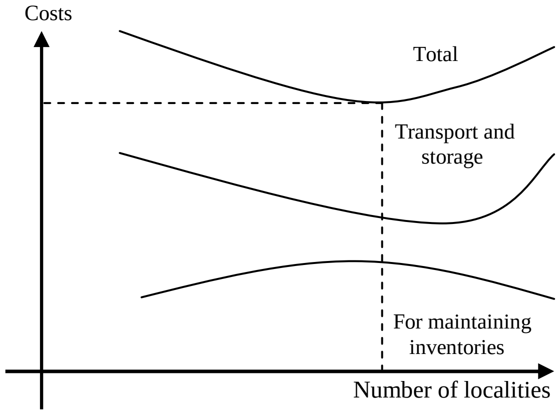

Fig. 3 Cost function

Therefore, it is often necessary to leave a two-dimensional problem of finding relationships between the number of sites and the costs in practice and replace it by a minimum of three-dimensional, where variables would have order size, type of transport, and number of localities. The procedure could be as follows:

Step 1: A relationship between transport costs and modes of transport or combination of them would be formulated for each shipment size and an opportunity would be determined in which the lowest costs are achieved for each of the discrete set size of shipments. The least expensive mode of transportation would be assigned to any size shipment in this way.

Step 2:An optimal number of locations of warehouses would be found for each shipment size. The minimum value of the curve connecting the minimums of functions for each individual alternative of size of shipments would answer to the question, how many warehouses is necessary to establish. A graphic representation of the process is shown in Fig. 4.

We did not change delivery cycles and levels of stock availability in the process. This can be respected e.g. by an additional sensitivity analysis of the obtained a final solution to their changes.

5 LOCALIZATION MODELS

Exact mathematical methods belonging to the so-called localization models can be used for finding the optimal location of the logistics facility. Attention is focused issue to find the location of one or m objects in the plane, which are in relation to n existing facilities from a wide range of models. It is for example placement of several distribution warehouses in relation to the market segments that need to be supplied.

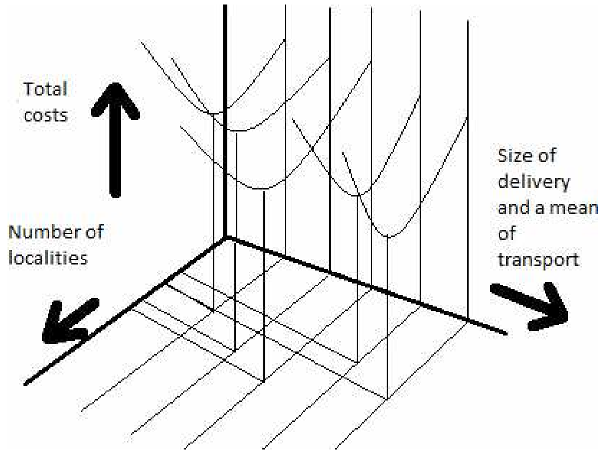

Fig. 4 Trend of total costs

Costs for transporting or storing are selected as a criterion. It is necessary to place m new objects to so far unknown locations Ni with coordinates (x_i, y_i), for i = 1, 2 ... m, which are in connection to the n existing objects located in places M_j with coordinates (x_j, y_j). The cost of connection of individual places, in most cases, the cost of transport of the goods supplied shall be marked:

c_{ij} in cases of connections between new and existing and
c_{ik} when connecting new objects themselves.

For i, k = 1, 2, ... m and j = 1, 2 ... n, communication costs are generally a function of distance. In order not to be necessary to create a matrix of actual distances among locations, a direct distance is usually the coordinate calculated and adjusted by a correction factor greater than 1, according to local conditions. Assuming that shipping rates for the transported unit in km are constant, and if the transported quantity between locations w^{ij} and v_{ik} will be identified, it is possible to formulate costs of the connection of new and existing places, depending on their location in the form:

$$z = \sum_{i=1}^{m}\sum_{j=1}^{n} w_{ij}\sqrt{(x_i - x_j)^2 + (y_i - y_j)^2} + \sum_{i=1}^{m}\sum_{k=2}^{m} v_{ik}\sqrt{(x_i - x_k)^2 + (y_i - y_k)^2}$$

Now we are looking for such x_i and y_i , therefore, such a location of objects that will minimize its costs value in terms of function z. If we use a partial derivative of the function z by x_i and y_i equal to zero and if it will be substituted for:

$$f_j(x_i, y_i) = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2}$$

And for:

$$f_j(x_k, y_k) = \sqrt{(x_i - x_k)^2 + (y_i - y_k)^2}$$

Equations arise for searched coordinates of new objects:

$$x_i = \frac{\sum_{j=1}^{n} \frac{w_{ij} x_j}{f_j(x_i, y_i)} + \sum_{k=2}^{m} \frac{v_{ik} x_k}{f_j(x_k, y_k)}}{\sum_{j=1}^{n} \frac{w_{ij}}{f_j(x_i, y_i)} + \sum_{k=2}^{m} \frac{v_{ik}}{f_j(x_k, y_k)}}$$

$$y_i = \frac{\sum_{j=1}^{n} \frac{w_{ij} y_j}{f_j(x_i, y_i)} + \sum_{k=2}^{m} \frac{v_{ik} y_k}{f_j(x_k, y_k)}}{\sum_{j=1}^{n} \frac{w_{ij}}{f_j(x_i, y_i)} + \sum_{k=2}^{m} \frac{v_{ik}}{f_j(x_k, y_k)}}$$

An iterative method is most suitable for the solution of model. The method is briefly described:
Step 1: The first approximation the coordinates of the new object is selected:

$$N_i^{(0)}(x_i^{(0)}, y_i^0)$$

e.g. coordinates of the center of gravity:

$$x_i^{(0)} = \frac{\sum_{j=1}^{n} x_{ij} w_{ij}}{\sum_{j=1}^{n} w_{ij}}$$

$$y_i^{(0)} = \frac{\sum_{j=1}^{n} y_{ij} w_{ij}}{\sum_{j=1}^{n} w_{ij}}$$

for i = 1, 2, ...m

Step 2: New coordinates of the points (k + 1) are calculated In the k-th iteration:

$$x_i^{(k+1)} = \frac{\sum_{j=1}^{n} \frac{w_{ij} x_j}{f_j^{(k)}(x_i, y_i)} + \sum_{k=2}^{m} \frac{v_{ik} x_k^{(k)}}{f_j^{(k)}(x_k, y_k)}}{\sum_{j=1}^{n} \frac{w_{ij}}{f_j^{(k)}(x_i, y_i)} + \sum_{k=2}^{m} \frac{v_{ik}}{f_j^{(k)}(x_k, y_k)}}$$

$$y_i^{(k+1)} = \frac{\sum_{j=1}^{n} \frac{w_{ij} y_j}{f_j^{(k)}(x_i, y_i)} + \sum_{k=2}^{m} \frac{v_{ik} y_k^{(k)}}{f_j^{(k)}(x_k, y_k)}}{\sum_{j=1}^{n} \frac{w_{ij}}{f_j^{(k)}(x_i, y_i)} + \sum_{k=2}^{m} \frac{v_{ik}}{f_j^{(k)}(x_k, y_k)}}$$

Where value $\varepsilon \to 0$ is added in the function under the square root. This is because it may be that a new object will be located in the locality of an existing object, and thus the value under the square root would be equal to zero.

Step 3:
A decrease is calculated in the objective function:

$$\Delta z = z^{(k+1)} - z^{(k)}$$

And as it will be insignificant, the process of finding an optimal location of points is completed. If not, it is necessary to return to step 2. The suggested approach is out of all used procedures the most effective, but it has not been managed to prove yet that it always leads to a global optimum only in the case that the location of one new object. Therefore, there is an effort to locate multiple objects to replace multiple localization of one object, for example division of the supplied area to area in which then location of a single object is searched for. A procedure of solution is then greatly simplified:
Objective function will then have the form:

$$z = \sum_{j=1}^{n} w_j \sqrt{\left[(x - x_j)^2 + (y - y_j)^2\right]} \quad (12)$$

A searched coordinates x and y of a single object then they arise placing derivations incurred by the x and y equal to zero. If it will be substituted for:

$$f_j(x,y) = \frac{w_j}{\sqrt{((x - x_j)^2 + (y - y_j)^2) + \varepsilon}}$$

and:

$$\varepsilon \rightarrow 0$$

It holds for searched coordinates of relations:

$$x = \frac{\sum_{j=1}^{n} x_j f_j(x,y)}{\sum_{j=1}^{n} f_j(x,y)}$$

$$y = \frac{\sum_{j=1}^{n} y_j f_j(x,y)}{\sum_{j=1}^{n} f_j(x,y)}$$

6 CONCLUSIONS

It is clear from the previous analysis of the effects of the essential elements of the logistics process at the cost and level of service that it is necessary to formulate a relationship the different alternatives of levels of service and corresponding costs.

Comparison of different options is the only way to find at least suboptimal variant of the solved system, because there are problems from quantification of marginal costs and mainly revenues that we already have specified above.

The procedure can be divided into three stages:

1. The structure of the logistics system is determined to ensure a minimum level of service accepted by customers while minimizing the total cost.
2. This variant is subjected to sensitivity analysis to changes in the localization of objects, levels of distribution and storage strategy.
3. Final solutions are formulated.

Achievable level of service at minimum cost is known as a threshold level of service. Their final level is usually determined on the basis of current delivery cycles, standard periods necessary for order processing and transit periods achievable with minimal transportation costs. These provide the current flexibility of services. Under these conditions it can be made using the average order size and the average cost for distribution to quantify the map, where you can mark the curves connecting the points with the same total cost for the distribution of individual warehouses. On this basis it is possible to assign each customer a distribution warehouse that is able to supply them at a minimum cost.

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