THE CENTRE OF GRAVITY METHOD IN NETWORK MODELING OF MILITARY TRANSPORTS

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Abstract

Location theories contribute significantly to modeling in the transport and distribution of material resources in the supply of military contingents and their application results in a reduction of total logistic costs. The paper uses the gravity point method (CoG) formulated and developed in order to explain the nature of forecasting in the area of spatial organization on an international basis.

Keywords: Logistics nets, location teory, military contingents, center of gravity

1. INTRODUCTION

Logistic chains are the result of applying a flow principle in the economic practice. The most close to the essence of logistic chains is the functional approach. Logistic chain as a logistics base is such a warehouse and transport chain, which is a technological combination of storage and trans-shipment points along freight routes, as well as organizational and financial coordination of operations, procurement processes and inventory policy of all links in the chain. The logistics chain should achieve the following goals [1]:

- ensuring fast and efficient flow of goods,
- reducing the cost of this flow.

The concept of the supply chain is dominated by a different philosophy than the concept of the logistics chain. In the concept of the logistics chain, the companies included in it concentrated their efforts mainly on the efficiency and effectiveness of the flow of goods. Based on research conducted by Christopher M., Ciesielski M., Fey P., Gudehus T., and Witkowski J., the author puts forward a thesis about the possibility of reducing logistics costs through the indirect base model using the center of gravity method.

2. STRUCTURAL TRANSFORMATION - FROM CHAINS TO NETWORKS

The philosophy of close integration of the producer with suppliers prevails in the concept of the supply chain and recipients to achieve market success. In theory, P. B. Schary and T. Skjott-Larsen, supply chains began to arise because entrepreneurs discovered the possibility of solving the problems of duplication of activities and reacting to market changes. The supply chain assumes that it is customers who initiate decisions taken in the supply chain. Hence, the supply chain begins at the customer's, and decisions flow in the opposite direction than the supply of products [2]. According to the theory of A. Kuhn and B. Hellingrath, all processes should be seen in a specific relationship - from the final customer back to raw materials, in one steady stream without roundabouts, which will ensure shorter flow times, higher quality and lower costs [3].M. Christopher describes "The supply chain as a network of organized organizations through links with suppliers and recipients in various processes and activities that create value in the form of products and services provided to final customers [4].

3. EVOLUTION OF LOGISTIC NETWORKS

The term "network" is increasingly used in logistics and related economy areas with logistics. An attempt to define supply networks means to define that it is a connected number of supply chains (both simple and network), within which comprehensive material flow optimization is performed in all supply chains entering it

composition. The evolution of the supply network is connected with the fact of growing participation of subsequent entities in more than one supply chain. The essence of modern networks are its integrators - ie links (specific network interfaces) that are the point of contact of more than one supply chain in which optimization of the entire network is implemented, eg coordination of activities and combining the resources of individual participants to perform a specific task. There are strategic networks, economic networks, dependence networks, supply networks and logistics networks. Therefore, the concept of the network should be taken as a starting point for reflection on supply networks. A special example in this matter appears to be the Second World War and the analysis of intended German submarine operations in the Atlantic and the North Sea.

The development of effective methods of fighting German submarines was preceded by a deep analysis of the network of "wolf hordes", as they were known in the U - bots (Unterseeboot) groups. The network of vessels was characterized by strong communication links, a decision-making process developed on the basis of a series of information from reconnaissance and surveillance units. As a consequence, the decision made of an imperial nature led to the destruction of the unit detected (which was the goal of the whole process).

4. NETWORK METHOD IN BALANCING THE TRANSPORTATION AND SUPPLY MODEL

The essence of the network approach is determined by many factors. The network approach is characterized by: shared goals, shared competencies, common work, a high level of trust and reciprocity, a lack of clear relations of formal subordination, the ability to innovate and be flexible and information links based on modern communication technologies. Different configurations of entities (enterprises), between which there is no clear relationship of subordination, operate on the principles of exchange and mutual trust according to a specific strategy for the implementation of common goals.

One of the types of networks are supply networks. These networks are usually considered from the point of view of material flows and related information. However, as he rightly notes J. Witkowski, material flows between enterprises are usually not linear, but they happen between many different producers and distributors who can be links of many supply chains [5]. These relationships form a large system that includes the lead entity and the network of suppliers and customers around it. It is a supply chain defined by M. Christopher as "a network of interrelated and interdependent organizations that, acting on the basis of mutual cooperation, control, direct and streamline material flows and information from suppliers to end-users" [6]. There is a definite relationship between networks and supply chains. Supply chains overlap with supply networks. In the simplest solution, one delivery network can be "unbuttoned", as M. Ciesielski writes, only one supply chain [7]. In practice, flows belonging to many supply chains can take place in a defined supply network.

The supply networks understood in this way should be considered in the product and spatial approach. Logistic networks are another type of strategic networks. According to P. Fey, the logistic network should be understood as nodes and paths that make up the system through which streams of materials, cooperative elements, finished products, energy and information flow. [8].

According to T. Gudehus, a logistics network is a defined number of sources and places of flow that are interrelated by the transport system. The logistic network flows streams of products and people that are stimulated, controlled and controlled by information streams [9].

The structure of the logistic network is therefore defined by two components: nodes and paths.Nodes symbolize the function of overcoming time and / or physical transformation of materials and semi-finished products (places of obtaining raw materials, production places, assembly places, storage places, distribution centers). Paths symbolize the tasks of overcoming space and include active elements (means of transport, means of handling) and passive elements (roads, railway tracks).

5. METHODOLOGY OF RESEARCH & THESE

In the research methodology with reference to research on material orientation in the logistics network of the supply of a wide spectrum of property for the needs of tasks at a distant theater of operations, the author has implemented the method of weighted gravity. In the course of several years of research, it was found that the processes of supplying recipients on the theater of activities are carried out on the "extended arm" of logistics, i.e. there are no intermediate points of "wrist" character. They leave from the Newtonian assumptions regarding the relationship between mass and force to be used to move this mass, it is necessary to make changes in the constituent parts of vector relations in order to bring about a balance.

On the basis of the research preceded by the analysis of statistical data, the thesis was formulated that: *Lack of an intermediate logistic base in the quota supply model results in a significant increase in total logistic costs*. Knowing the mass of cargo in particular periods of shipment and cargo mass sent in "reverse" processes it is possible to use the method of searching for such a gravity point, so that the values on both sides of the said support point strive for balance .

For this purpose, it is possible to use the location theory using a grid in the Cartesian system. Covering the research area with a map with scaled distance values, it is possible to read the values of the places of *sending (N1 , N2, N3, .. Nn)* on individual axes and in a similar way, reception points *(O1, O2, O3, ..., On).*

The assumption of the model was defined:

ΣM Cargo comes from N suppliers *(N1, N2, N3)* distributed in cartesian system on the *X, Y* plane, thus: *N1 (x1;y1), N2 (2;y2), N3 (x3;y3).* Similarly for recipients: *O1(x1;y1), O2(x2;y2), O3(x3;y3)* distributed in two-dimensional space: *O1(x1;y1), O2(x2;y2) and O3(x3;y3).* It was also assumed that the supply is sustainable, therefore using mathematical tools, it is possible to carry out analysis and determine a place (point) with *XM*, *YM* coordinates.

$$X_M = \frac{x_s \times k_s \times S + \sum_{i=1}^{n} x_i \times k_i \times D_i}{k_s \times S + \sum_{i=1}^{n} k_i \times D_i} \quad \text{and} \quad Y_M = \frac{y_s \times k_s \times S + \sum_{i=1}^{n} y_i \times k_i \times D_i}{k_s \times S + \sum_{i=1}^{n} k_i \times D_i} \tag{1}$$

where:

XM - means the value of the parameter sought on the X axis;

YM - value of the parameter sought on the Y axis;

x (s), y (s) - location parameters of cargo mass senders;

S - expected cargo mass (transmitted to a potential base);

x (i,) y (i) - location parameters of recipients (at the theater);

k (s) - unit cost of transport from the sender of the mass to the intermediate base (bp);

k (i) - unit cost of transport from the intermediate base (bp) to mass recipients at the theater.

Knowing the unit cost of transport (here in t / h) it is possible to use the above-mentioned models (in a modified form). In the formulas of the book, because in many contracts the transport costs are the same regardless of the location of points a and b (the month of dispatch and receipt of cargo mass). The essence of this type of calculation is the conversion of the volume of transport expressed in terms of quantity into economic values. To sum up the assumptions, the meaning of the research itself should be emphasized. In addition to information on the cost of transport and searching for the right (economically justified location), i.e. a point (intermediate base, central warehouse) that would introduce an indirect link to the supply chain (logistic joint), the intention of scientific inquiry is also to consider the idea of circular motion.

Table 1 Data summary for calculating the center of gravity (x, y) [own study]

SOURCE OF SUPPLY	COST OF TRANSPORT IN USD / HOUR x 10	WEIGHT IN TONS	NETWORK COORDINATES		COORDINATE CALCULATIONS		
			Horizontaly	Verticaly	Horizont. (X)	Vertical. (Y)	Houertons (t/h)
	1	2	3	4	5	6	7
SHIPMENT OF CARGO	**[r]**	**[s]**	**[d]**	**[d]**	**-**	**-**	**-**
A1 Krakow	850000	45.193	91	130	X1 (A1)	Y1 (A1)	**t/h 1**
A2 Hungary PAPA	1900000	200.48	56	190	X2 (A2)	Y2 (A2)	**t/h 2**
A3 Wroclaw	10200000	2320.53	47	103	X3 (A3)	Y3 (A3)	**t/h 3**
Together	**12950000**	**2566,203**			**Σ X(A1-A3)**	**Σ Y(A1-A3)**	**Σ t/h (1-3)**
RETURN	**[R]**	**[M]**	**[D]**	**[D]**	**-**	**-**	**-**
B1 Bagram	40000	19.39	843	440	X1 (B1)	Y1 (B1)	**t/h 4**
B2 Kabul	2200000	99.17	841	450	X2 (B2)	Y2 (B2)	**t/h 5**
B3 Kandahar	3000000	370.40	790	502	X3 (B3)	Y3 (V3)	**t/h 6**
Together	**5240000**	**488.96**			**Σ X**	**Σ Y**	**Σ t/h (4-6)**
Counter	Σ (rxdxs):	-	-	-	Σ X(A1-A3)	Σ Y(A1-A3)	-
	Σ (RxDxM):	-	-	-	Σ X(B1-B3)	Σ Y(B1-B3)	-
	Together	-	-	-	Σ[Σ X(A1-A3) + Σ X(B1-B3)]	Σ[Σ Y(A1-A3) + Σ Y(B1-B3)]	Σ[Σ t/h (1-3) + Σ t/h (4-6)]
Denominator	Σ (rxs):				Σ (rxs)	Σ (rxs)	-
	Σ (RxM):				Σ (RxM)	Σ (RxM)	-
	Together				Σ [Σ (RxM) + Σ (rxs)]	Σ [Σ (RxM) + Σ (rxs)])	-
Center of Gravity:					**220.38**	**199.49**	

Table 1 presents the output parameters and calculations. For the purposes of calculations, maps from the "Google Maps" application were used and they were adapted graphically to the needs of the study. After determining the mass gravity center in points (*220.38 and 199.49),* it was possible to supplement the calculations by determining the material index for the mass of transported cargo in order to make the orientation (for the country or the theater of activities).

In the economic dimension, an important parameter of measuring the transport efficiency of a transport vehicle is the economics of moving cargo from point A to point B expressed by the ratio of transported weight (in tonnes) to the cost of covering a given distance or in the possibility of transporting the maximum amount of mass (in tonnes) at a minimum cost per hour flight. The possibilities of cost estimation and testing of transport efficiency in logistics systems are many.

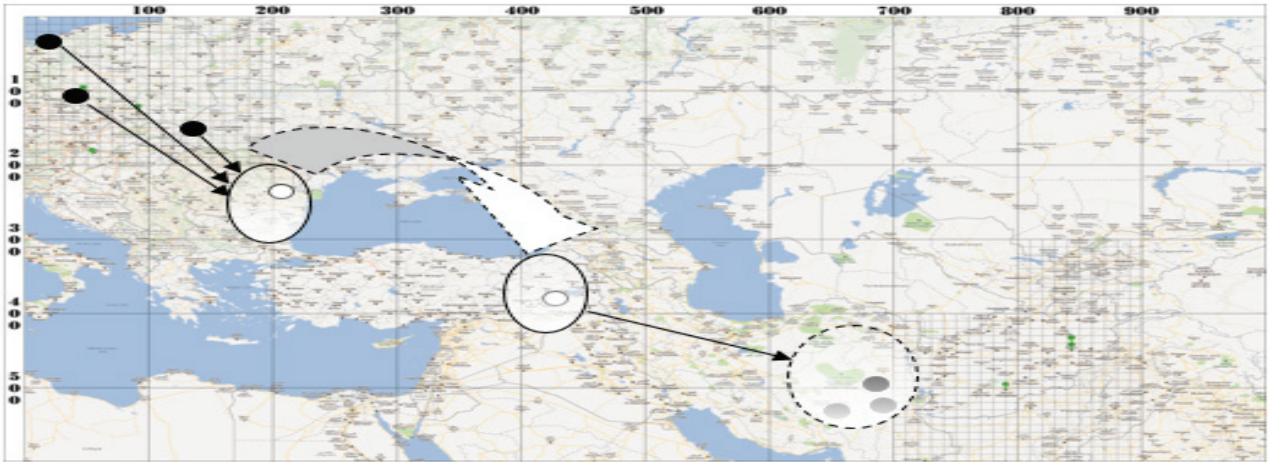

Figure 1 Logistic model with a consolidation center and module compensation after moving the mass gravity point [own study]

6. TOWARDS STABILIZATION OF THE MODEL

Transport in logistics of military contingents should be considered depending on the phase in which it is, because this phase has a direct impact on the possible possibility of dynamic modeling, i.e. one that takes as the basic criterion of the model the time in which the process is realized, the system works, the phenomenon occurs, etc.

Among the phases of the transport process, one should distinguish: preparation, loading (load), transport, handling, unloading, however, there are such phases that are particularly integrative in the area of process interference (they constitute a process binder). Among such processes, one should distinguish: storage, which from the point of view of transport is also the same in itself transport (extremely expensive because of the so-called zero counter) or supply processes, among which it is difficult to exclude in whole or in part components (segments) of the transport process. Relationships between selected logistics subsystems of military contingents can be examined in a subjective way, expressed as opinions of managers, specialists and decision makers. It is a tedious and difficult process and the results should be treated as a more illustrative one, constituting a contribution to further research on logistic systems.

To sum up this research stage, the conclusion is that the transport process has usually a cyclical nature, and the mere use of a means of transport is a closed cycle of the aforementioned phases.

7. CONCLUSIONS

On the basis of the received data, the mass gravity point and the most accessible place to locate the base were determined. Thanks to the calculations, it is possible to make changes to the existing model (**Figure 1**) And to develop a methodology for dealing with future situations.

The methodology of the location of objects (including military facilities) applied in a comprehensive approach, ie at the supranational level for EU and NATO countries, would allow in the future logistic integration (including transport) in the scope of material and equipment shipments and would lead to naturally "enforced optimization" "In the area of inventory management, most of which has similar or the same application (it is assorting in convergence) and correlates with the needs of recipients).

Location of the intermediate supply base in the "articulated" model (**Figure 2**) with an appropriate level of stock of material resources would significantly improve the operation of international service of military contingents,

while reducing the operating costs of contingents and, as a consequence, relieving the budgets of individual countries while maintaining a sufficiently effective level of service.

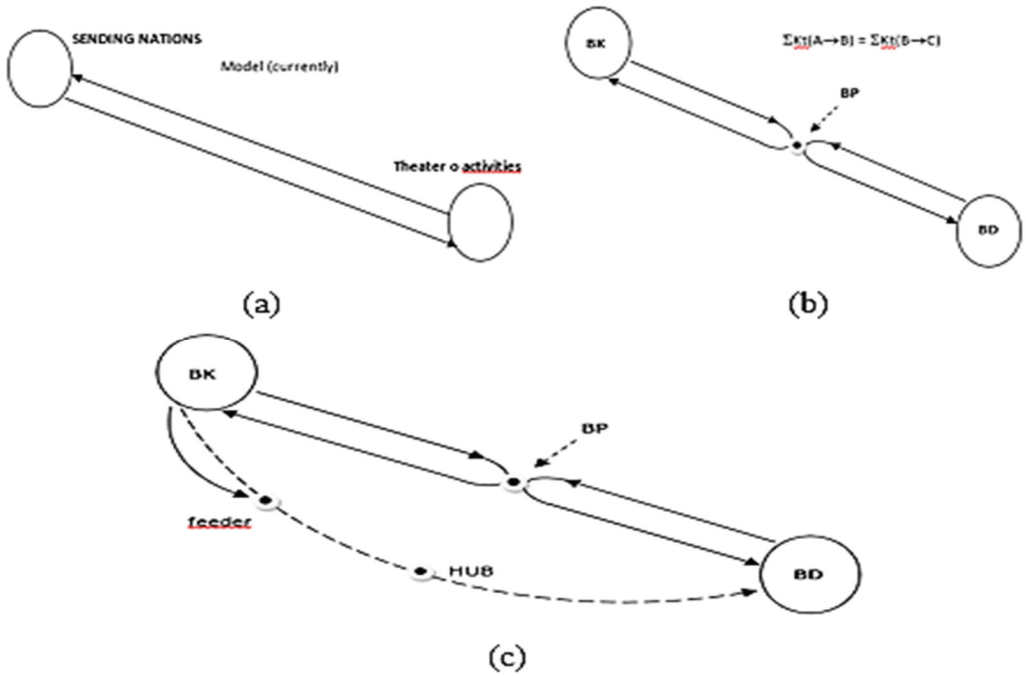

Figure 2 Current displacement model (a), air displacement model (with intermediate point - b), general model of airborne displacement (with intermediate point) and HUB-Feeder system (c) [own study]

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