



## THE MODELLING OF FACTORS DETERMINING THE GOODS AND TRAFFIC FLOWS MOVEMENT IN A LOGISTICAL SYSTEM

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**Abstract.** The purpose of this article is to model the factors determining the goods traffic along the logistical channels located in various geopolitical regions on the basis of the transport network. The attention is focused on theoretical presumption of logistical channels formation in a logistical system. In this modeling the factors which determine the formation of the goods flow along the subsystems of the entire logistical system from the geopolitical point of view are defined. In this model the competitiveness of a logistical channel is determined by its technological, economical, legal characteristics as well as the length of the entire channel. The states, having the model provided, can evaluate the characteristics of the elements of the logistical channel and seek for the optimum ways to improve them. While planning the allocation of investments to improve the characteristics of separate elements of a logistical channel, it is a matter of utmost importance to consider the characteristics and their prospects of the entire logistical channel, a part of which stretches along the other states. It is very important for the Baltic States which are situated at the intersection of transit goods flows and logistical channels.

**Keywords:** logistical system; goods flows; tops and borders of transport network; indicator of competitiveness of logistics channel.

### 1. Introduction

Goods traffic is one of the most important factors ensuring the growth of the world economy. Owing to the rapid growth of the processes of globalization more and more expanding scale of the international trade determines the steadily growing volume of goods carriage among the world's regions. The states that serve as channels for transit goods flow bring economic benefit and seek to attract bigger and bigger goods flows. Since the flow of goods is limited, an issue of competitiveness among logistical channels has arisen. The logistical subsystems of separate states compete in order to gain the bigger amount of transit goods flows.

The purpose of this article is to model the factors determining the goods traffic along the logistical channels located in various geopolitical regions on the basis of the transport network. Theory as well as the applied methods of the selection of the shortest way and those of the multicriteria analysis [1 – 4] are presented.

For the purpose of modeling chains [5] as well as the theoretical principles of the global logistical network according to which the flow of goods will pass along that channel within the global pipework [6], symbolizing the transport network, the cross section of which is said to be the largest. The article aims at providing a mathematical

description of the factors which determine the breadth of that cross section.

While modeling the factors which are influential on the formation of goods flows, the theory of supply and demand laws [7] is used as well as the theory of the common logistical system [8, 9]. Moreover, the assessment carried out by forwarding agents – transport architect outlook to the premises for the formation of goods flows [10] is also applied.

### 2. The Elements of the Logistical System

Goods traffic in time and space is ensured by the interaction of a great number of physical, information as well as organizational elements, which can be regarded as constituent parts of organizations involved in organizing goods traffic or influencing it in any other way from consignors to consignees as well as the infrastructure ensuring that goods traffic is considered to be the main subject of the logistical system.

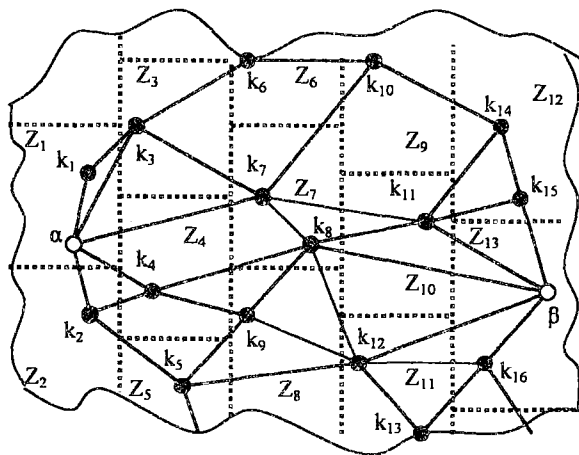
Consignors and consignees are essentially concerned about solving issues related to marketing, organization, production and trade policy. They are also responsible for stock management, warehouses, acquisition of transport means and renting, and hiring labour force. Logistics organizations are usually preoccupied with such tasks

as the optimization of routes, the strategic allocation of terminals and warehouses. They are also concerned about solving the economic tasks related to providing logistical services, selecting kinds of transport, its alternatives and means of transport.

The indispensable element of the logistical system is the existing transport network composed of the tops (terminals), the main features of which are warehouse types, capacities and border (roads of various transport kinds) connecting the former two. The characteristic features of borders are length, carriage speed and output.

### 3. The Model of Goods Flows Distribution in a Logistical System

In Fig a fragment of the transport network is depicted, where  $Z_i$  – is a geopolitical region. In terms of application it could be a separate state, a union of states, an economic community or any other territorial unit.  $\alpha$  stands for a consignor, whereas  $\beta$  symbolizes a consignee. Terminals or the tops of the transport network are marked as  $k_i$ . The borders connecting the tops are transport roads.



A fragment of the transport network

Speaking generally these can be roads for various kinds of transport. We are going to model the shipping of a particular goods set  $\Omega$  during period  $T$  from consignor  $\alpha$  located in geopolitical region  $Z_1$  to consignee  $\beta$  established in geopolitical region  $Z_{13}$ . The borders of the geopolitical zones have only conditionally been shaped as rectangles, just for the sake of simplification.

However, in fact they can assume any other shape. Goods traffic will take place through the intermediate tops and borders located in  $Z_i$ . As the purpose of this modeling is to define the factors which determine the formation of the goods flow along the subsystems of the entire logistical system from the geopolitical point of view, we have confined ourselves to the modeling of the case between one consignor and one consignee. This limitation

has been grounded on the conviction that “goods carriage process takes place under the condition distinguished by quite high uncertainty and it is an accidental process” [4] and each consignor dispatches his goods regardless of others. Therefore, having modeled a single case between one consignor and one consignee, it is possible to use this model as a general case after the theory of entropies maximizing probabilities has been applied to it.

In order to model the factors determining the goods flow passage along a particular part of a logistical system or its subsystem, first there should be considered and analyzed the theory of the formation of goods flows within networks [4]. Let us mark the given fragment of the network as  $G$ , which is composed of borders  $N$  and  $M$  tops.

$$G = [M; N]. \tag{1}$$

For each border of the network fragment  $(k_p, k_{i+x}) \in N$ , where  $x$  is a free operator of the top number, we ascribe a certain positive number  $\lambda(k_p, k_{i+x})$ , which is the competitiveness indicator of that border. This indicator of competitiveness can be expressed by means of a function:

$$\lambda(k_i, k_{i+x}) = f(c(k_i, k_{i+x}), d(k_i, k_{i+x}), e(k_i, k_{i+x})), \tag{2}$$

$c(k_p, k_{i+x})$  – physical capacity indicator showing the maximum amount of goods that can be carried between tops  $k_i$  and  $k_{i+x}$  during a given time period;

$d(k_p, k_{i+x})$  – the indicator of price desirability showing the level of price competitiveness of goods carriage along border  $(k_p, k_{i+x})$ ;

$e(k_p, k_{i+x})$  – the indicator of legal restrictions demonstrating the rate of restrictions imposed on the transportation within border  $(k_p, k_{i+x})$ . The larger the amount of restrictive measures,  $e(k_p, k_{i+x}) \rightarrow 0$ .

The legal coefficient of border restrictions  $e(k_p, k_{i+x})$  depends on the tax system as well as on the transport policy exercised in a given country. Separate states introduce restrictions on goods carriage by various kinds of roads, which in turn diminish this coefficient.

For each network top  $(k_i) \in M$  a certain positive amount  $\delta(k_i)$  standing for the competitiveness level of the top has been ascribed. This competitiveness indicator can be expressed by a function:

$$\delta(k_i) = f(c(k_i), d(k_i), e(k_i)), \tag{3}$$

$c(k_i)$  – the physical capacity indicator showing the maximum goods amount which can be physically managed at top  $k_i$  during a given time period;

$d(k_i)$  – the price desirability indicator showing the level of price competitiveness of goods handling at top  $k_i$ ;

$e(k_i)$  – the legal restriction indicator demonstrating the rate of restriction imposed on goods handling at top  $k_i$ . The bigger the amount of restrictions,  $e(k_i) \rightarrow 0$ .

The legal coefficient of legal restrictions imposed on the tops (terminals) is essentially dependent on the economic policy of the state where the terminal is located. For instance, granting the free economic zone status to

the territories which are places of goods terminals the concentration increases coefficient  $e(k_p)$  significantly. This coefficient also depends on the customs procedure regulations in the given state.

Having defined the factors determining goods traffic through a separate top and border, it is worth considering now the peculiarities of goods traffic from consignor  $\alpha$  to consignee  $\beta$  through a certain set of stated tops and borders. Consignor  $\alpha$  and consignee  $\beta$  will also be considered to be stops. All possible sequences of tops and borders from  $\alpha$  to  $\beta$  can be signified as logistical channels.

Goods flows moving along these logistical channels can be stationary and dynamic. Here we are going to consider the case of stationary goods flow  $v(\alpha, \beta)$  having size  $\Omega$  along logistical channels.

Logistical channels in the transport network are alternatives of goods flows traffic. These channels can be evaluated in accordance with the same characteristics as their elements – borders and tops. This is a set of goods traffic channels  $K$ , between consignors  $\alpha$  and consignee  $\beta$ . The amount of channels is determined not only by the number of tops and borders existing in the transit region, but also by their configuration. While modeling the alternatives of the traffic of the same goods flow along different logistical channels, the objective concerning the competitiveness of the logistical channel is solved. In addition the factors determining the formation of goods flows are also defined within the subregions marked as  $Z_p$ .

If a logistical subsystem of the given subregion does not constitute the entire goods traffic channel from a consignor to a consignee, but it is a constituent part of the entire logistical channel from a consignor to a consignee, then the goods flows traffic through that subregion will be dependent not only on the characteristics of the logistical channel existing in the subregion logistical system, but it will also depend on other regions, the logistical systems of which are involved in the common logistical channel.

Let us say that a number of logistical channels connecting consignor  $\alpha$  and consignee  $\beta$  in the transport network fragment  $G$  is  $H$ . In other words the flow  $v(\alpha, \beta)$  in the fragment  $G$  of the transport network has  $H$  alternative logistical channels. It can be put down as:

$$H = f(M, N, \theta), \quad (4)$$

$\theta$  – the coefficient defining the configuration of the fragment  $G$  of the transport network.

A separate channel will be marked as  $h_j$ . Each  $h_j$  is composed of a certain set  $R_j$  of tops  $k_i$  and a certain set  $Q_j$  of borders  $(k_p, k_{i+x})$  which are arranged in sequence  $s_j$ . Borders  $(k_p, k_{i+x}) \in h_j$  and tops  $k_i \in h_j$  can be called the elements of the logistical channel  $h_j$ . Each element  $k_i$  and  $(k_p, k_{i+x})$  of a logistical channel can belong to set  $D_i$  of the logistical channels passing through that element. If  $h_j \in D_p$  then  $h_j$  characteristics will depend on  $k_i \in h_j$  and  $(k_p, k_{i+x}) \in h_j$  characteristics. In other words, the goods flows passage

along logistical channels is determined by the characteristics of the elements of those channels.

The characteristics of logistical channel  $h_j$  can be expressed employing the coefficient of logistical advantage  $\varphi_{h_j}$ . Each channel has its own coefficient of logistical advantage that is formed by the characteristics of the tops and borders existing in that logistical channel. The advantage coefficient  $\varphi_{h_j}$  of the entire channel  $h_j$  is dependent on the characteristics of the borders  $(k_p, k_{i+x}) \in h_j$  and the tops  $k_i \in h_j$  located in the given channel. Correspondingly it depends on  $\lambda(k_p, k_{i+x})$  and  $\delta(k_i)$ . It can be expressed as follows:

$$\varphi_{h_j} = \prod_{\substack{k_i \in h_j \\ (k_p, k_{i+x}) \in h_j}} \delta_{k_i} \cdot \lambda(k_i, k_{i+x}). \quad (5)$$

If any:

$$\delta_{k_i} \in R_j \rightarrow 0, \quad (6)$$

or

$$\lambda(k_i, k_{i+x}) \in Q_j \rightarrow 0, \quad (7)$$

then

$$\varphi_{h_j} \rightarrow 0. \quad (8)$$

Here we deal with the critical competitiveness condition of a logistical channel. In other words, the minimization of the characteristics of any element can cause the minimization of the characteristics of the entire logistical channel as well as the loss of its competitive abilities.

It is crucial to remember to evaluate another channel  $h_j$  characteristic, i. e. its length  $L_{h_j}$  applied for a certain goods flow  $v(\alpha, \beta)$ :

$$L_{h_j} = \sum_{(k_i, k_{i+x}) \in h_j}^{Q_j} L_{(k_i, k_{i+x})}, \quad (9)$$

$L_{(k_i, k_{i+x})}$  – the length of the border.

A lot of practitioners consider the comparison of the length of a logistical channel with the length of alternative logistical channel to be one of the main tools to measure the competitiveness of logistical channels. Scientists, however, analyzing the advantage of logistical channels often solve the multicriteria task of finding the shortest way, which can be generally described as follows:

$$\text{MINSUM} \sum_{(k_i, k_{i+x}) \in h_j}^{Q_j} L_{(k_i, k_{i+x})} \rightarrow \min. \quad (10)$$

The length  $L_{h_j}$  of channel  $h_j$  is undoubtedly, one of the most important factors determining the passage of the flow  $v(\alpha, \beta)$  through fragment  $G$  of the transport network. However, besides evaluating  $L_{h_j}$  it is crucial to evaluate

$\varphi_{h_j}$ . Here the competitiveness indicator  $\mu_j$  of logistical channel  $h_j$  will be introduced:

$$\mu_j = \varphi_{h_j} \cdot \frac{1}{L_{h_j}} = \frac{\varphi_{h_j}}{L_{h_j}} \quad (11)$$

Each logistical channel  $h_j$  has its fixed distance  $L_{h_j} = \text{const}$ , thus the prerequisite for increasing the competitiveness of a particular logistical channel is:

$$\varphi_{h_j} \rightarrow \max \quad (12)$$

If conditions (6) and (7) are satisfied, then it can be expressed as follows:

$$\mu_{h_j} \rightarrow 0 \quad (13)$$

Now let us consider the competitiveness of a separate geopolitical region  $Z_r$  as a subsystem of the entire logistical system with the logistical subsystems of other regions. A part of the logistical channel form set  $H$  stretches over each region  $Z_r$ . This can be marked as  $h_j(Z_r)$ . Each  $h_j$  in its turn stretches over the set  $E_j$  of the regions  $Z_r$ .

It can be assumed, then, that owing to the economic reasons each geopolitical region seeks to attract the transit goods flow  $\nu(\alpha, \beta)$  and that the goods flow  $\nu(\alpha, \beta)$  can develop only within the regions  $Z_r$  located along fragment  $G$  of the transport network. So now let us solve the issue concerning the factors determining the formation of the goods flow  $\nu(\alpha, \beta)$  across the region  $Z_r$ . The flow of goods will form in those  $Z_r$  regions through which the logistical channel  $h_j$ , having the highest coefficient of competitiveness  $\mu_j$  stretches. As it has been proved in (5), (6), (7) and (13) the competitiveness of a logistical channel is dependent upon the characteristics of its constituent elements and the minimization of any of them can cause  $\mu_j$  minimization. In other words the minimization of any characteristics attributed to an element of a logistical channel can lead to the loss of the competitiveness of the entire channel.

#### 4. The Area of Application of the Practical Model

This model is universal, however, its application is of crucial importance for the states which are situated at the intersection of transit goods flows and logistical channels.

Goods transit plays a significant role in the economy of the Baltic states. Thus raising of its volume has acquired significant importance. The region of these states is the area of the logistical channels for the prospective goods flows between west Europe and Russia as well as the Far East countries. Having a fixed transit goods flow through the region, this flow will go through those states which will have the logistical channel distinguished by the highest coefficient of competitiveness.

The states, having the model provided, can evaluate

the characteristics of the elements of the logistical channel and seek for the optimum ways to improve them. While planning the allocation of investments to improve the characteristics of separate elements of logistical channel, it is a matter of utmost importance to consider the characteristics and their prospects of the entire logistical channel, part of which stretches along the other states.

Let us consider the goods carriage from the middle Asia using multimodal transportation through the Baltic seaports to West Europe and in the opposite direction. It becomes urgent evaluating the prospects of the increase in containers flow [11]. Some alternatives at logistical channels stretch along the logistical systems of the states situated along the Eastern Baltic seacoast. The goods flows will form along the channel which will have a higher coefficient of competitiveness. It should be noted that the coefficient of logistical channels meant for different types of goods has to be evaluated and compared separately since there will be applied different technological requirements in accordance with the nature of the goods, i.e. one type of requirements is applicable to a container carriage logistical channel whereas other types will be used for oil products, ferrous metals and etc. In this regard significant importance is drawn to the specificity of terminals.

The competitiveness of the logistical channels stretching through the Baltic states is heavily dependent on the interaction of the elements of those logistical channels. For example, the interaction between the Lithuanian important logistic channels: the railway and the seaport, has to express itself in the formation of the general transit policy. Since sea freight and railway tariffs have not been balanced the entire logistical channel loses its competitive ability. The united policy intended to increase the competitiveness of the logistical channel should manifest in:

- 1) optimization of the technological process;
- 2) balancing priorities for investments;
- 3) formation of the pricing system.

The allocation of investments should be even because the complete renovation of the seaport terminal without having allotted investments to improve the state of the railway service will not result in the increase of the competitive ability of the entire logistical channel. Thus, in spite of the increased competitiveness of the seaport terminal, the goods flow will not develop through it.

#### 5. Conclusions

1. If a logistical subsystem of a particular subregion does not constitute the entire goods carriage channel from a consignor to a consignee, but it is just a constituent part of the entire logistical channel from a consignor to a consignee, then the goods flows traffic through that subregion will take place in accordance not only with the characteristics of the logistical channel located in the subregional logistical system, but it will also be dependent upon

other regions, the logistical systems of which are involved in the common logistical channel.

2. Having a few alternative logistical channels meant for the passage of the same goods flow, the flows will pass along the channel having the highest competitive ability.

3. The competitiveness of a logistical channel is determined by its technological, economic, legal characteristics as well as the length of the entire channel. The minimization of any characteristic attributed to an element of a logistical channel will lead to the loss of the competitive ability of the entire channel.

4. This model is universal, however, its application is of crucial importance for the states which are situated at the intersection of transit goods flows and logistical channels.

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