# THE EVALUATION TECHNIQUE OF LOGISTICS' SYSTEM CARGO TRANSPORTATION EFFICIENCY DEVELOPMENT

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**Summary.**The paper presents model to optimize the number of different types of transport used in different stations of transport-storehouse's complex and also to determine the optimal traffic volume, storage and handling of materials, which provide minimum costs on them at which the efficiency of transport and storehouse complex is estimated

Key words. Transport, storehouse, logistics, shipping organizing, industrial transport, material flow, dataflow, dataware.

#### INTRODUCTION

As known, the main aim of transport and storehouse logistics system building is finding the optimal variant of freighting from suppliers to customers, or choosing the most suitable one, satisfying specific customer requirements. The customer may be supplier, consumer or shipper, depending on who will use the system. The profitability of any enterprise considerably depends on the logistics system ware flow efficiency. We know that the cost of transportation and storehouse's freight handling is from 7% to 30% of finished goods' prime cost, depending on the kind of goods and source materials [1] and in the metallurgical and mining, forestry and woodworking industry it's up to 50%.

# RESEARCHES

Improving the productivity of enterprise and reducing the prime cost on goods is a very topical problem. The solution can be achieved by implementing various measures, including such as reducing material and energy intensity, labor inputs and others. However, the most promising and effective are the technological measures, which reduce costs on transport and storehouse processing of ware flows, data ware, and do not require additional capital costs. Implementation of this direction can be achieved on the basis of logistics.

When planning and shipping organizing of bulk cargo through railway stations' storehouses, storehouse terminals, large material and technical bases, the macro logistic system is designed for parameter optimization that determines its efficiency, and as a rule consists of logistics systems of middle and micro-levels [2], Fig. 1.



Fig. 1. The scheme of ware flow's logistic system IndT - industrial transport, MF -Material flow, MT – main (magisterial) transport

The logistic system of middle level includes: terminal of sale (storehouse, base etc.), main or industrial transport (depending on the technology and transportation distance), distributing centre and the consumer's storehouse. One of the important and integral parts of any logistic system is also information system, the operation costs of

which are comparable with the costs of transport and storehouse processing of ware flows.

These are the main parts of the system from the efficiency of which mainly depends the effectiveness of the whole system. The real logistic system can be expanded by adding additional parts. The most complete criteria of logistics' system functioning efficiency are the costs  $C_{JC}$  Evaluation and minimization of the costs can

be achieved only through simulation and optimization of the key parameters of each part of the system, so the general criterion using dynamic programming method [2,3] is the sum of individual criteria on the stages. As follows:

$$C_{LS} = U_{1} + U_{2} + U_{3} + U_{4} + U_{5},$$
(1)

where  $U_1, U_2, U_3$  - the minimum cost of the forwarder's storehouse terminal to the customer's transport and warehouse,

 $U_4$  - costs on freight handling in distributing centre (logistic depot),

 $U_5$  - costs on information system.

Let's consider the forwarder's storehouse terminal, going into detail on modeling only material flow as the most expendable.

The usage of factor of area, material handling equipment and demurrage during the loading operations should be considered as the basic parameters that characterize the use of storehouse terminals of freight yards and side tracks' storehouses.

Since there are well developed technologies the evaluation of the first parameter does not cause any problems.

The evaluation of the other two parameters requires taking into account the circumstances arising from the laws of market economy.

The characteristic feature of bulk cargo storehouses and container depots is the opportunity to use similar or interchangeable handling equipment. Therefore, if there is a possibility of such use, the problem can be formulated as the optimization of separation of interchangeable cargo-handling machines by the cost criterion:

$$U_{1} = \min\left\{\sum_{j} \frac{1}{x_{j}} \left[ \frac{\sum_{fi} \left( y_{fij} + y_{fij}^{0} \right) C_{1}}{\sum_{jk} Z_{jk} g_{jk}} + \frac{\sum_{fi} \left( y_{fij} + y_{fij}^{0} \right) C_{1}}{\sum_{jk} Z_{jk} g_{jk}} \sum_{i} C_{j} P_{fij} \right] + \sum_{jk} a_{k} Z_{jk} \right\}$$
(2)

under the conditions:

$$Z_{jk} \ge 0 \tag{3}$$

where:  $x_i$  - the number of material deliveries *a* to the storehouse,

 $Z_{jk}$  - the number of cargo-handling machines of k type in storehouse j,

 $g_{ik}$  - the productivity of cargo-handling machines,

 $y_{fij}$ ,  $y_{fij}^{0}$  - the number of loaded and empty cars of *i* type given from the loading depot *f* to the storehouse *j*,

 $P_{fij}$  - the rate of vehicle loading given from the depot f to the depot j,

 $a_k$  - cost ratio of depreciation charges,

 $C_1$  - cost of vehicle demurrage per hour,

 $C_i$  - hourly fuel consumption, according to the cargo-handling mechanism.

The first term of the function is the cost on loading or unloading, the second one - the cost on energy resource for the cargo-handling mechanism, the third one - the cost on depreciation and maintenance of the cargo-handling mechanism.

The second part of the logistic system is main or industrial transport depending on the consumer's location relative to the supplier's storehouse terminal.

For the shipping of a certain type of bulk cargo (for which the logistic system is being developed) is used both general and special rolling warehouses (hopper - batcher, grain carrier, hopper wagon, container car) and others. When organizing the transportation by vehicles the effectiveness of use of such rolling warehouse is incontestable. However, the costs on transport optimization is a real need, especially when using a limited number of special rolling warehouses for satisfying the claims of a wide range of clients.

Evaluation of a limited number of special-purpose cars or general service cars' efficiency and their optimization is the criteria of minimum cost.

When the route is well-known the usage of the special train is determined by the minimum-cost criterion of locomotive and wagon-hours in loaded and unloaded condition.

Costs of wagon-hours by the route trains transportation can be determined by the formula:

$$C_{cp} = T_p + T_g + T_g \tag{4}$$

where:  $T_n$ ,  $T_e$  - costs of wagon-hours according to the point of loading and unloading;  $T_g$  - costs of wagon-hours on movement in loaded and unloaded condition.

$$T_n = A \left( t_1^n + t_n^{(1)} m + t_2^n \right) k \tag{5}$$

where: *A* - daily maintenance of materials expressed in cars,

- $t_1^n$  the average time for storehouse's handling after arrival, feeding, cleaning, waiting and detention between operations,
- $t_2^n$  the average time for storehouse's handling at train departure;

 $t_n^{(1)}$  - time for wagon loading,

*m* - the number of wagons during the route,

*k* - the coefficient of unevenness of operations,

$$T_{e} = A \left( t_{1}^{e} + t_{e}^{(1)} m + t_{2}^{e} \right) k \tag{6}$$

where:  $t_1^{\ell}$ ,  $t_2^{\ell}$  - the average detention of one car before and after unloading;  $t_{\ell}^{(1)}$  - unloading time of a car.

$$T_g = A \left( t'_g + t''_{gg} \right) k \tag{7}$$

where:  $t'_g$ ,  $t''_g$  - time for movement of loaded and empty wagons.

Thus, costs of wagon-hours:

$$T_{cn} = A \Big[ t'_g + t''_g + m \Big( t_n^{(1)} + t_e^{(1)} \Big) + t_1^n + t_2^n + t_1^e + t_2^e \Big] k .$$
(8)

Costs of locomotive - hours can be determined by the formula:

$$B_{cn} = B_n + B_g + B_\theta \tag{9}$$

where:  $B_n$ ,  $B_e$  - costs of locomotive-hours on train service

 $B_g$  – costs of locomotive-hours on movement between points of loading and unloading, back and forth:

$$B_g = \frac{\left(t'_g + t''_g\right)Ak}{m} \tag{10}$$

$$B_{s} = \frac{\left(t_{p}^{s} + t_{y}^{s}\right)Ak}{m_{c}^{s}}$$
(11)

where:  $m_f^{\theta}$  - cargo capacity in loading depot,

 $t_n^{\theta}$ ,  $t_v^{\theta}$  - time costs on wagon feeding and moving to side track or station.

$$B_p = n_{pv}^p \left( t_p^p + t_v^p \right) k_c k \tag{12}$$

where:  $n_{py}^{p}$  - the number of wagon feeding and removing to the freight track;

 $t_{\nu}^{p} t_{\nu}^{p}$  the number of wagon feeding and removing from the freight track;

 $k_c$  - the number of special-purpose trains formations.

When feeding wagons right from the connecting station to the loading station  $k_c=0$ 

$$B_{p} = \frac{A(t_{p}^{p} + t_{y}^{p})k}{m_{f}^{e}}$$
(13)

Having substituted expressions (10, 11, 12) in (9) and done some transformations we get:

$$B_{cp} = A \left[ \frac{t_{p}^{p} + t_{y}^{p}}{m_{f}^{s}} + \frac{t_{p}^{s} + t_{y}^{s}}{m_{f}^{s}} + \frac{t_{g}^{\prime} + t_{g}^{\prime\prime}}{m} \right] k$$
(14)

General costs on the transit organization:

$$U_2 = T_{cp} a_{sp} + B_{cp} a_{lq} \tag{15}$$

where:  $a_{eq}, a_{lq}$  - the indicated cost of wagon- and locomotive-hours.

Having substituted the values  $T_{\varphi}$  and  $B_{\varphi}$  in expression (15), differentiated it with respect to m, entered some transformations, we would get the optimal number of wagons in the route train, that provides the minimum of costs:

$$m = \sqrt{\frac{a_{l_q}(t_g' + t_g'')}{a_{eq}(t_p'' + t_e^{(1)})}}$$
(16)

Costs of consumer storehouse  $U_3$  can be determined by the method as for the sender's terminal (i.e.  $U_1$ ) or optimized by the methods developed in the [4] depending on the structure and technical equipment. The distributing centre (logistic depot) can be considered as the multiproduct storehouse, which combines storehouses for different purposes and handles different cargos. This structure can be produced as the directed graph A. The nodes of graph are the track sections  $i \in k_s$  that handle the cargo in the way of their transit from the transfer reloading point C of the main transport to the receipt by the consumer or another type of transport.  $i \in k_0$  – dispatching and receiving sections. The objective function that provides minimum costs on transportation and storehouse handling of cargos  $U_4$  can be expressed as follows:

$$U_{4} = \sum_{M} \sum_{i} \left\{ \sum_{i \in K_{o}} C_{i\pm}^{nt} X_{i\pm}^{Mnt} + \sum_{i \in K_{s}} \left[ \sum_{i \in K_{o}} d_{iL}^{Mnt} y_{iL}^{Nnt} + d_{Li}^{Mnt} y_{Li}^{Nnt} \right] + e_{i}^{nt} r_{i}^{nt} + g_{i}^{nt} \left( v_{i+}^{nt} - v_{i-}^{nt} \right) \right] + \sum_{m \in G_{M}} \left[ \sum_{(i,j) \in L} C_{ij}^{mn} \omega_{ij}^{mn} + \sum_{(i,j) \in L} d_{i\pm}^{mnt} \alpha_{i\pm}^{mnt} + \sum_{i \in K_{s}} \left( e_{i}^{mt} S_{i}^{mt} + g_{i}^{mt} \left( \delta_{i-}^{mt} - \delta_{i+}^{mt} \right) \right) \right] \right\} + \sum_{i} \sum_{i \in K_{s}} C_{i}^{i} \Delta_{i}^{i}$$

$$- \sum_{G} \sum_{i \in K_{s}} C_{e} \Delta_{e} \rightarrow \min$$

$$(17)$$

Under the condition of appropriate constraints imposed on independent variable. where:  $C_i^{nt}$  - traffic handling cost of a cargo unit;

- $d_{iL}^{Mnt}$ ,  $d_{Li}^{Mnt}$ ,  $d_{i}^{mnt}$ ,  $g_{i}^{nt}$  considerable costs on handling, loading, unloading and storing materials,
- $e_i^{nt}$  considerable costs on transportation of excessive cargo,
- $C_i^t$  considerable costs on storehouse's extension,
- $C_i^{mt}$ ,  $e_i^{mt}$  considerable costs on queuing and renting additional transport and handling machinery; considerable costs on car detention,
- $C_{ii}^{mt}$  considerable costs on constant queuing,
- $\Delta_i^t$  additional storehouse's extension for the receiving capacity of lot acceptance,

(1 =)

- $X_{ij}^{Mnt}$  the number of *n* type of cargo, transported by the *M* mode of transport during the *t* period,
- $\alpha_{ij}^{mnt}$  the number of *M* mode of transport that carries cargo of *n* type in *t*-period,
- $\alpha_{i\pm}^{mnt}$  the number of M mode of transport with the n- type of cargo, loaded and unloaded on *i*-station, in t period,
- $r_i^{Mnt}$  the size of additional cargo delivery over processing capacity of station,
- $v_{i\pm}^{Mnt}$  the volume of *n* –type of cargo imported and exported by the *M* mode of transport in *t* period,

 $S_i^{mt}$  – modes of transport involved in addition,

 $\delta_{i+}^{mt}, \delta_{i-}^{mt}$  – the number of *m* - transport mode in reserve,

- $y_{Li}^{Mnt}$  the number of *n* -type of cargo loaded from *M* to *L* transport mode on *i* - station in *t* - period,
- $y_{iL}^{Mnt}$  the number of *n* -type cargo loaded out of *M* into *L* transport mode on *i*-station in *t* period,
- $g_i^{mt}$  considerable costs on detention of cars,
- $\omega_{ii}^{mt}$  the total number of wagons in moving in *t*-period,
- $G_M$  cargo stream of graph,
- $C_e$  accepted income for rent of free storehouse area to customers,

 $\Delta_e$  - free storehouse area for rent to customers.

It is also important to mention that the task is meaningful when the values of a variable are positive, so:

$$X_{ij}^{Mnt}, v_{i\pm}^{Mnt}, r_i^{Mnt}, y_{Li}^{Mnt}, y_{iL}^{Mnt}, \Delta_i^t, a_{ij}^{mnt}, \alpha_{i\pm}^{mnt}, \delta_{i\pm}^{mt}, S_i^{mt}, C_e, \Delta_e \ge 0.$$

The proposed model of material flow and transport modes of storehouse's type optimization, represented as a network, is a problem of linear programming. For its solution can be used the simplex method taking into account the constraints that are typical for network problems (eg. [3]). Using the model helps to optimize the number of different types of transport used in different stations of transport-storehouse's complex and also to determine the optimal traffic volume, storage and handling of materials, which provide minimum costs on them at which the efficiency of transport and storehouse complex is estimated.

Costs on dataware can be attributed to the link "Marketing", "Management", i.e. links, which mainly use information flow for the logistics system organization.

It should be noted that various companies, including transport, depending on their size and volume of transport work, use various forms of dataware: starting from the traditional (paper documents) and finishing with the interactive Internet technologies of data transmission. Thus, nowadays there isn't reliable enough technique of estimation of costs on information service. It complicates the choice of improvement methods and techniques of dataware. The researches [1] made it possible to develop a methodology of costs estimation for information services and ways of its improvement using the Internet - technologies.

# CONCLUSION

The most complete criteria of logistics' system functioning efficiency are the costs. Evaluation and minimization of the costs can be achieved only through simulation and optimization of the key parameters of each part of the system

The main costs consist of cost of the forwarder's storehouse terminal, to the customer's transport and warehouse; costs on freight handling in distributing centre (logistic depot); costs on information system (dataware). Using the model helps to optimize the number of different types of transport used in different stations of transport-storehouse's complex and also to determine the optimal traffic volume, storage and handling of materials, which provide minimum costs on them at which the efficiency of transport and storehouse complex is estimated.

Costs on dataware can be attributed to the link "Marketing", "Management", i.e. links, which mainly use information flow for the logistics system organization

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#### РАЗРАБОТКА МЕТОДИКИ ОЦЕНКИ ЭФФЕКТИВНОСТИ ФУНКЦИОНИРОВАНИЯ ЛОГИСТИЧЕСКОЙ СИСТЕМЫ ГРУЗОПЕРЕВОЗОК

#### Слободянюк М.Е., Нечаев Г.И.

Аннотация. В работе представлена модель, с помощью которой можно оптимизировать количество транспортных средств разных видов, использующихся на разных участках транспортно – складского комплекса, а также определить оптимальные объемы перевозки, сберегания и перевалки материалов, при которых обеспечивается минимум расходов, по которым оценивается эффективность использования транспортно – складского комплекса с многономенклатурным составом.

**Ключевые слова:** транспорт, склад, логистика, организация, грузоперевозки, промышленный транспорт, материальный поток, информационный поток, информационное обеспечение.