EFFICIENCY EVALUATION OF TRANSPORT INCLUDING SELECTION OF ROLLING STOCK TO TASKS IN SUPPLY CHAINS

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Abstract

To evaluate the efficiency of transport subsystem in complex logistics structures it should be assessed in terms of quantitative and valuable assessment. The quantitative assessment of its efficiency testify such indicators as performed tonne-kilometers, the number of items handled, the actual working time of transport, the quantity of goods carried, transport costs per tonne-kilometer and per consignment, utilization of working time and transport capacities owned means of transport. The article indicated, that the systemic approach to the assessment, large role play the technical aspects. They take into account the issues, among others: rational use of means of transport, effective operation and their renewal, maximizing the utilization of means of transport, minimizing empty runs.

Keywords: Transport efficiency, efficiency indicators, effective operation

1. INTRODUCTION

In the era of market economy, enterprises devote a lot of space efficiency of performed tasks. Efficiency is treated as feature of the system, which takes into account the impact of the most significant features of the system and the environment on the results of its operation. Thus, the overall efficiency reflects the corresponding relationship between the effects, objectives, expenditures and costs in terms of structural and dynamic [1][3][7][13][14].

To evaluate the functioning of the different classes, including eg. enterprise, supply chains, supply chains is determined certain indicators through which expresses the degree of adaptation of the system to perform a function referred to it. The efficiency of the system is the assessment of its operation and is a measure of the efficiency of its action.

Measuring the efficiency of transport in supply chains is a key factor in the success of the company and gain a competitive advantage [4][5][8][13]. The authors of the studies [34][35] point to two main difficulties in measuring performance, eg. supply chains: firstly the existence of a very extensive and diverse measures of efficiency and efficiency of the elements of supply chains require a variety of data, secondly potential conflicts between participants in supply chains associated with the values of individual measures [9][12].

In the study, the efficiency of transport, special attention is put on the analysis of the technical - technological organization of transportation services and logistics businesses [1][6][7][8]. While creating, shaping, designing and reorganization of the supply chain should be aware that their high efficiency also depends to adapt their equipment to the performed tasks [4]. The efficiency of the transport is one of the basic objectives of supply chain management. Both in terms of supply chain management and analysis of technical - technological organization of transport service enterprises an important issue is the efficiency of choice of means of transport or handling equipment for tasks [5][9][11].

The article analyzes the specific problems of assessing the efficiency of the selection camp for the tasks in supply chains, taking into account of technical and organizational.

2. ALGORITHM FOR CONSTRUCTION EFFICIENCY INDICATORS

To evaluate the quality and efficiency of the system are used in a variety of efficiency indicators for determining the extent to adapt its equipment to perform the tasks. As noted by M. Brzezinski indicators of the logistics system may be either [5][9][11]:

- structural, when they are referred to the structure of the flows of material goods,
- productivity, they are referred to the implemented system tasks,
- economy, they are referred to the cost,
- qualitative, they are referred to the level of customer service.

To formulated efficiency indicators allowed for a proper assessment processes carried out in the test system, recognized the problem in a comprehensive manner. For example, to evaluate the effective organization of supply chains, transport services and the configuration of the supply chain should beehive consider both elements of point and linear.

Many authors believe that the basis for the formulation of a variety of indicators of the effectiveness of the system, eg. Transport or supply network, it is given a set of objectives and targets which is to execute the system. The basic condition for the assessment of any element is to determine the indicators or a set of indicators showing the consistency that will ensure the elimination of conflicts of objectives while determining the boundaries of the areas studied. The algorithm formulation of indicators to assess the efficiency of the selection of the tasks can be represented as in **Figure 1**.

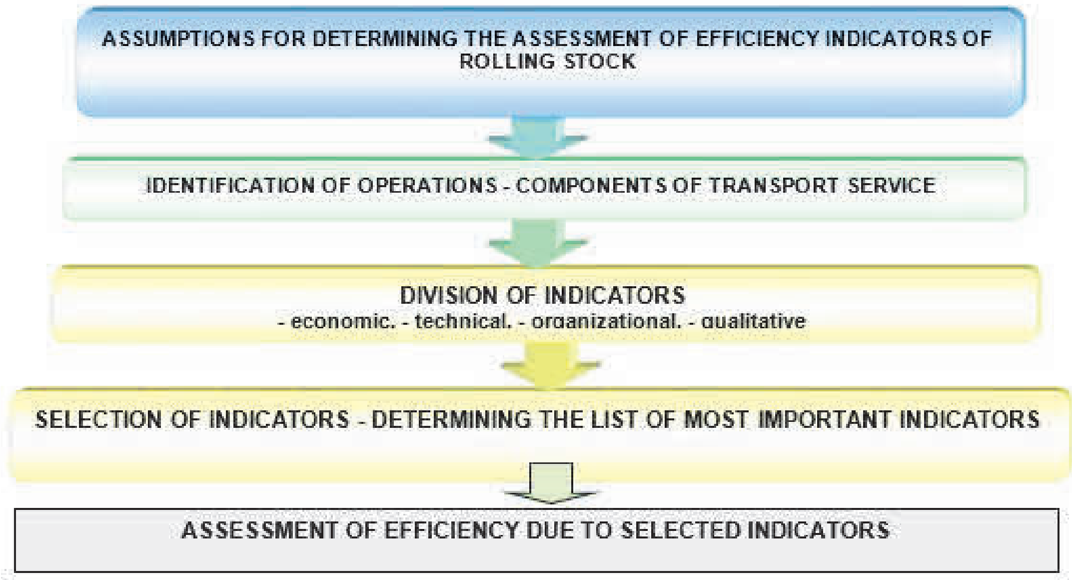

Figure 1 Algorithm for construction assessment indicators of the selection means of transport to the tasks

As indicated in the algorithm of the first stage of the construction of indicators to develop guidelines in terms of data availability and ease of calculation and the links to the practice of taking into account the standards and regulatory requirements. The definition of a number of indicators to assess include logistic logistics infrastructure and ongoing processes in the literature is presented in the works of, among others. For example, the author of the work indicates that in order to assess the efficiency of the logistics subsystem "subsystem of transport" should be the quantitative assessment and evaluation valuable. The quantitative assessment of efficiency is determined by such indicators as kilometers, number of means of transport, number of employees of transport department, or the number of failure modes. In the opinion of value as indicators of partial author assumes, among others, transport costs, the value of their means of transport and depreciation costs attributable to transport.

The second phase of construction of performance indicators is the identification of activities that make up the process of transport service. As indicated by the authors [2][13][14] the transport service is the implementation of various types of freight transport, that the required level of service and at an acceptable cost of meeting the needs of customers (traders) located in a given area. At the same time it is determined by the structure of transport tasks, which are determined by both the type and amount of cargo and the relationship movement of cargo and the date of delivery.

The third step is to identify indicators divided into four groups, ie.: economic indicators, technical indicators, indicators of organizational, qualitative indicators. Assessing the efficiency of the transport subsystem to be made not only by the use of quantitative and qualitative indicators in each group, but also using indicators of productivity. Indicators of productivity, enable the assessment of the reliability and flexibility of transport and the number of damaged goods during transport. Among the indicators to assess the transport lists to e.g .: tonne-kilometers performed, the number of completed shipments, the actual working time of transport, utilization of means of transport and economic indicators such as. Transport costs per tonne-kilometer or shipment.

The last step is the selection of the most important indicators of each group. Among the most important indicators are mentioned, such as: tonne kilometers, the number of items, the actual working time of transport, the quantity of goods carried, transport costs per tonne-kilometer or per consignment, utilization of working time and the ability to transport their means of transport.

For the assessment of the efficiency of the implementation of tasks in the supply chain using various means of transportation, a measure of efficiency changes sd-this variant of the supply chain will be the difference between the performance indicators obtained for variants using s-the means of transport and the variant (in transport) fixed as the base. The relative change in efficiency can be determined as the quotient of the difference of the performance indicators for the base and variant and the efficiency ratio adopted for the base variant in a fixed time interval. This approach allows the comparison of the implementation of the tasks set transport by various means of transport and selecting more efficient because of the considered indicator. This can save the formula [4][5]:

$$\Delta\Xi(s,sd) = \frac{\Phi(s,sd) - \Phi(s,sd)^*}{\Phi(s,sd)^*} * 100\%$$

where:

- $\Delta\Xi(s,sd)$ - the relative change in the efficiency of the implementation of tasks for *sd*-th variant of the supply chain in relation to the basic,
- $\Phi(s,sd)$ - efficiency indicator of tasks implementation for *sd*- th variant of the supply chain,
- $\Phi(s,sd)^*$ - efficiency indicator of tasks implementation for *sd**- th basic variant.

Calculation of the value of efficiency $\Delta\Xi(s,ld)$ allows answer the question by how many percent in the given period of time the value of the efficiency indicator $\Phi(s,sd)$ of implementation of tasks in *sd*-th variant of the supply chain differs from the efficiency indicator value $\Phi(s,sd)^*$ in the base variant.

3. SPECIFICATIONS OF SELECTED TRANSPORT EFFICIENCY INDICATORS

As the criteria for evaluating the effectiveness and efficiency of logistics processes can be used: the criterion of the time flow of materials and information, the criterion of the level of service quality, cost criterion and the criterion operability action. In assessing the transport efficiency can be distinguished as shown in **Table 1**.

Table 1 Selected indicators of transport efficiency

Technical indicators	Economic indicators	Qualitative and environmental indicators
• the degree of effective operation of the device, means of transport, etc., • the degree of capacity utilization of means of transport in case of realization of transport in transit between cells supply network, • utilization of transport equipment, eg. in warehouse facilities, • number of means of transport, • the number of working hours means of transport, • vehicles mileage , • the average mileage of mean of transport, • the number of failures of mean of transport, • the degree of storage areas filling in warehouses, • daily working time in storage facilities • maximization of capacity utilization, vehicles, etc.	a) absolute measures: • the cost of executed service, • annual operating costs, • transport costs, • the value of means of transport, • depreciation of transportation, • the cost of personal transport department, • the cost of storage, b) relative: • the share of transportation costs in total costs, • transport costs per unit of freight, • maintenance costs of mean of transport for a month, a year, • the cost of the transition units of material through the warehouse facility, • costs per tonne-kilometer,	• loss of time of delivery, • duration of logistics tasks, • the reliability of logistics tasks, • the risk of lack of delivery measured the probability of failure of delivery, • the average number of handling operations allocated to each unit of load, • the ratio of time moving to the waiting time for the storage transhipment, , etc. given with respect to the unit load, • unit time of the service logistics divided into individual cells supply network, • number of failures means of transport, • minimize the emission of harmful exhaust emissions, • minimize congestion in the supply network.

As previously mentioned the measurement efficiency can have many uses, among which: the choice of means of transport to the tasks, the selection of applied technologies, increase the efficiency of logistics processes, reducing time tasks, reducing costs eg. a reduction in fuel consumption.

4. SELECTED EFFICIENCY INDICATORS FOR EVALUATION OF THE ROLLING STOCK

4.1. General Assumptions for the Designation Efficiency Indicators of the Rolling Stock

For the formal record the following assumptions were adopted:

- with variable *s* are numbered types of vehicle classes. $\boldsymbol{S}^{ab}$ is a set of numbers, types of classes of vehicles that carry loads in the relationship (*a,b*), so the s $\in$ $\boldsymbol{S}^{ab}$; wherein payload capacity of the vehicle of *s*-th typy in tonnes was designated as $\mathrm{q}(s)$,
- for each relationship (a,b) $\in E$ is set volume $Q_n^{(a,b)}$ of weight of the *n*-type of load in tonnes, and the number $jq_n^{(a,b)}$ - as number of homogeneous palletized units of n-th type of load in the relationship (a, b) in plu, and $q_p(s)$ - as the cargo capacity of s-type vehicle in jłp,
- for each s-th vehicle is set, that the rate of capacity utilization of the vehicle is $\phi_q(s)$, wherein it is sought that $\phi_q(s) = 0.70 \div 0.8$.
- the number of realized deliveries $\mathrm{LD}(s)$ determines how many courses must complete *s*-th mean of transport to realize transport task in relation supplier recipient. This is the max of two values: number of deliveries resulting from the weight of the load $LD_q(s)$, and the number of deliveries resulting from the cargo capacity expressed in a jłp $LD_p(s)$, which can be written with the formula:

$$LD(s) = \max\{LD_q(s); LD_p(s)\}\ [-]$$

Because the number of realized deliveries affects the duration of the task and the total cost of transport, so the smaller it is the lower the costs of transport and delivery time. In addition, reducing the number of deliveries allows for better utilization of transport means which in the saved-up time can perform other tasks.

4.2. Time and Cost as Significant Efficiency Indicators of the Rolling Stock

Transport time $T_p(s)$ *in* (a,b)-th transport relations is the sum of the components of the times, which can be written with the formula:

$$T_p(s) = t_z(s) + t_j(s) + t_r(s) + t_d(s)\ [h]$$

where:

$t_z^{(a,b)}(s)$ - loading time of *s*-th type of vehicle written by formula: $t_z^{(a,b)}(s) = \frac{\sum_{n\in N} Q_n^{(a,b)} \cdot tz_n(s)}{60}$

$t_j^{(a,b)}(s)$ - driving time of s-th type of vehicle written by formula: $t_j^{(a,b)}(s) = \frac{dp^{(a,b)}}{\beta(s)} \cdot ld^{(a,b)}(s) \cdot \frac{1}{v(s)}\,[h]$

$t_r^{(a,b)}(s)$ - unloading time of s-th type of vehicle written by formula: $t_r^{(a,b)}(s) = \frac{\sum_{n\in N} Q_n^{(a,b)} \cdot tr_n(s)}{60}\ [h]$

$t_d^{(a,b)}(s)$ - additional time in which the vehicle carries out operations resulting from idle and maneuvering time $t_p(s)$ (min / cykl) in handling squares of s-th type of vehicle in relation (a,b), which can be written by formula:.

$$t_d^{(a,b)}(s) = LD^{(a,b)}(s)\ \cdot \frac{t_{pp}(s)}{60}$$

With economic assessment indicators of the selection of vehicles for tasks is the cost of realization of the transport tasks in relation (a, b). It is the sum of the costs of vehicle operation $K_p^{(a,b)}(s)$ and $K_l^{(a,b)}(s)$ cost of the work load, which can be written by formula:

$$K_{ct}^{(a,b)}(s) = K_p^{(a,b)}(s) + K_l^{(a,b)}(s)\ [zł]$$

wherein:

$K_p^{(a,b)}(s)$ - the cost of work of *s*-th type of vehicle in the carriage in relation (a, b) is the sum of the components incurred in realization of this task which can be written by formula:

$$K_p(s) = k_w^{(a,b)}(s) + k_{zp}^{(a,b)}(s) + k_{og}^{(a,b)}(s) + k_e^{(a,b)}(s) + k_{od}^{(a,b)}(s) + k_{uk}^{(a,b)}(s) + k_{pś}^{(a,b)}(s) + k_a^{(a,b)}(s)[zł]$$

where:

$k_w^{(a,b)}(s)$ - compensation expense of drivers in the realization of the task

$k_{zp}^{(a,b)}(s)$ - the cost of fuel consumption in the realization of the task

$k_{og}^{(a,b)}(s)$ - the cost of tire wear in the realization of the task,

$k_e^{(a,b)}(s)$ - the cost of environmental charges in the realization of the task ł,

$k_{od}^{(a,b)}(s)$ - the cost of fees for the use of roads in the realization of the task,

$k_{ub}^{(a,b)}(s)$ - the cost of motor insurance in the realization of the task,

$k_{ps}^{(a,b)}(s)$ - tax cost of means of transport in the realization of the task for s-th type of vehicle,

$k_a^{(a,b)}(s)$ - depreciation cost of means of transport in the realization of the task for s-th type of vehicle.

Formal record of all components of the cost of transport can be found in [5] [12].

While the cost of loading work at transport task realization in relation (a, b) for s-th type of vehicle results from hourly cost of human labor at the loading activities for s-th type of vehicle in zł / h, the hourly cost of operation of the equipment at the loading activities for s-th type of vehicle in zł / h and the time of loading and unloading s-th type of vehicle.

As is clear from the foregoing considerations the cost of implementing one transport is dependent on the amount of load, labor costs of people and equipment and operating costs. Detailed analysis of the cost of implementation of transport tasks can be found in [12]. Reducing the cost of transport increases the efficiency of transport services.

5. CONCLUSION

In the study, the efficiency of transport, special attention is put on the analysis of the technical - technological organization of transportation services and logistics businesses. While creating, shaping, designing and reorganization of the supply chain should be aware that their high efficiency also depends to adapt their equipment to the performed tasks

In the assessment of value for the partial indices can be assumed, among others, transport costs, the value of their means of transport and depreciation costs attributable to transportation.

Greater efficiency means that while incurring lower costs will be carried out tasks at a level not worse than expected. In other words, the higher the efficiency, the higher is the efficiency and efficiency of resource use for the implementation of tasks in the system.

REFERENCES

[1] BECHTEL CH., JAYARAM J.: Sypply Chain Management: A Strategic Perpective, International Journal of Logistics Management, vol. 8, nr 1, 1997.

[2] JACYNA-GOŁDA I., LEWCZUK K., SZCZEPAŃSKI E. MURAWSKI J.: Computer Aided Implementation of Logistics Processes - Selected Aspects, [w]: Tools of Transport Telematics / Mikulski Jerzy (red.), 2015, Springer, ss. 1-14,

[3] JACYNA-GOŁDA I., SANTAREK K., WASIAK M.: Location of warehouse facilities in the logistics network, [in:] Conference Proceedings of Carpathian Logistics Congress / Feliks J. (red.), 2013, Tanger, Kraków 2013,

[4] JACYNA-GOŁDA I.: Decision-making model for supporting supply chain efficiency evaluation, Archives of Transport, Polish Academy of Sciences, Warsaw 2015, vol. 33, is. 1, 2015, p.17 - 31,

[5] JACYNA-GOŁDA I.: Wspomaganie decyzji w łańcuchach dostaw w aspekcie oceny efektywności realizacji zadań. Wydawnictwo Politechniki Poznańskiej, Poznań 2016,

[6] LAMBERT, D. M., COOPER M. C., PAGH J. D., Supply Chain Management: Implementation Issues and Research Opportunities. The International Journal of Logistics Management, Vol. 9, No. 2, 1998.

[7] MICHLOWICZ E.: Improving the efficiency and reliability of material flow in buffered systems. Scientific Journals of the Maritime University of Szczecin 2015, no. 42 (114), pp.26-32, 2015.

[8] NIKFARJAM H., ROSTAMY-MALKHALIFEH M., MAMIZADEH-CHATGHAYEH S., (2015): Measuring supply chain efficiency based on a hybrid approach, Transportation Research Part D-Transport And Environment. Vol. 39 p.: 141-150.

[9] SIENKIEWICZ P. Teoria efektywności systemów. Ossolineum, Warszawa 1987.

[10] SZCZEPAŃSKI E., JACYNA-GOŁDA I., MURAWSKI J.: Genetic algorithms based approach for transhipment HUB location in urban areas. Archives of Transport, ISSN 0866-9546, vol. 31, is. 3, 2014, p. 73-82,.

[11] TWARÓG J.: Mierniki i wskaźniki logistyczne. Biblioteka Logistyka, Poznań 2005.

[12] WASIAK M. Static optimization of potential of logistic systems. Archives of Transport, vol. 20, is. 3, 2008, pp.75-83.

[13] WASIAK M., JACYNA-GOŁDA I.: Transport drogowy w łańcuchach dostaw. Wyznaczanie kosztów. PWN, Warszawa 2016,

[14] ŻAK J., JACYNA-GOŁDA I., WASIAK M.: Effectiveness evaluation criteria of the functioning of the national transport system and its impact on environment, [in:] M. Jacyna, M. Wasiak (red) “Simulation model to support designing a sustainable national transport system”. Index Copernicus International, Warsaw 2014, s. 35-47,