ALGORITHM FOR MILITARY AUTOMOBILE CARGO TRANSPORTATION PLANNING AND ITS MATHEMATICAL MODEL

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In the article, with the aim of technical supply of military facilities, the algorithm and the mathematical model of automobile cargo transportation planning and the method for the evaluation of effectiveness are introduced.

Key words: *military automobile cargo transportations, method of effectiveness, effectiveness indicators, method of evaluation, planning algorithm, mathematical model.*

1. INTRODUCTION

The management of shipping is not possible without designing high quality planning on effective utilization of transport means. The key issue in transportation management is defining of itineraries providing with optimisation factors and the identifying the transport means for those itineraries. Reports on trips, technical-exploitation parameters of transport means (carrying capacity, coefficient of being in good condition, the number of trips, the cost of one trip for either model of an automobile, etc.) should be taken into consideration.

In accordance with market terms and conditions, minimum transportation expenses are taken as a major optimization criterion. However, the effects on transportation process have multiple factors, therefore, approaches to the solution and the selection of the optimization criterion become pretty much different.

The transportation plans developed in the concerning departments of Military Forces should provide the supply system with minimum expenses, and the optimal indicators. It creates some difficulties to define optimization measures of shipments as the effectiveness of automobile cargo transportation depends on many factors in the Armed Forces of Azerbaijan Republic [1].

2. BUILD UP THE ALGORITHM AND MATHEMATICAL MODEL OF PLANNING OF AUTOMOBILE CARGO TRANSPORTATIONS.

By using the theory of Graphs, the process of automobile cargo transportation could be considered as a stream in the network. Let us fix a pick point of graph on either store, may the length of the arcs be the distance among the points.

Optimal organizing algorithm of shipments could be described as following by considering the possible itineraries, restrictions on carrying capacity of the transport means, their number, types and assumption on theirconditions, the number of stores and consumers, etc:

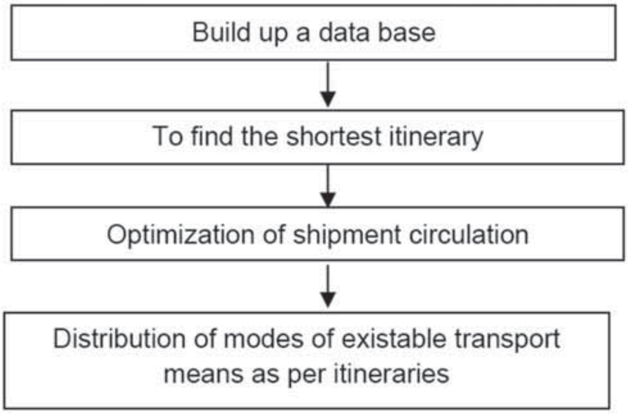

Fig. no. 1. optimal organizing algorithm

Let us take the following marking in order to build up a data base:

- l_{ij} – distance between i and j numbered points;
- m – quantity of stores;
- n – quantity of consumers;
- a_i – volume of product in i numbered store;
- b_j – order by j numbered consumer as per plan;
- K – the quantity of modes of transport means;
- c_{ij} – expense per kilometer of the route from i point j point;
- g_k – capacity of transport mean of k numbered model;
- N_k – the number of transport mean belonging to k numbered model;
- s – the quantity of all summits in the network.

In the second phase, the shortest distance between the points is found by applying l^*_{ij} Bellman-Shimbel algorithm [2]:

$$l_{ij}^{2k} = \min_{1\le\lambda\le s} \left(l_{i\lambda}^k + l_{\lambda j}^k\right), \quad k = 1,2,\ldots$$

In the third phase, transport issue with the classic linear programming is solved:

$$\sum_{i=1}^{m}\sum_{j=1}^{n} l_{ij}^{*} x_{ij} \quad \rightarrow min;$$

$$\sum_{j=1}^{n} x_{ij} \leq a_i , \qquad i = \overline{1,m}$$

$$\sum_{i=1}^{m} x_{ij} = b_j , \qquad j = \overline{1,n}$$

$$x_{ij} = [x_{ij}] \geq 0 , \ i = \overline{1,m} , \qquad j = \overline{1,n}$$

$$\sum_{i=1}^{m} a_i \geq \sum_{j=1}^{n} b_j .$$

By solving the given transport issue, one gets the matrix of shipment stream (xij)m,n (shipment turnover) and, the mass of the shortest itineraries are formulated among repositories and consumers. Let us assume their number as *L*.

And at the final stage, the issue of distribution of transport means defined at the third stage is solved:

$$\sum_{k=1}^{K}\sum_{l=1}^{L} c_{kl} y_{kl} \rightarrow min$$

$$\sum_{l=1}^{L} y_{kl} \leq N_k , \ k = \overline{1,K}$$

$$\sum_{k=1}^{K} g_k y_{kl} \geq G_l , \qquad l = \overline{1,L}$$

$$y_{kl} = [y_{kl}] \geq 0 , \ k = \overline{1,K} \ , l = \overline{1,L}$$

In here G_l is the amount of the shipment, defined at the third stage for l itinerary, and y_{kl} is the number of the transport means from k model, which is supposed to move through l.

Automobile cargo transportation plays a crucial role in preparing the troops for combat as well as in providing the combat ability. Therefore, the purpose to work out the method of evaluation of military automobile cargo transportation is to define operability of these transportations, their implementation in accordance with plans, eceonomic efficiency and to evaluate necessary proposals for increasing its effectiveness [3].

As a result of conducted researches very interesting parameters and criterions, which affect the effectiveness of cargo transportations have been defined. They are the following:

- the length of the overcome route during the transportation S_d;
- overall time T_d, spent for transportation;
- transportation speed v_d ;
- effective utilization of nominal capacity of automobiles;
- minimization of overcome distance of an automobile without cargo (Syz), or percentage ratio of overcome distance without cargo to the total travelled distance ($\frac{S_{yz}}{S}$x 100%);
- reducing the cost of transport service ($\frac{x_d}{M} \to min$) in shipments;
- increasing the transportation effectiveness ($\frac{M}{T_d} \to \max$) in;
- increasing of advantageous expences F_x in transportations.

$$\sum_i \sum_j l_{ij} \to min$$

In the course of the transportation, the length of total route Sd–is the sum of distances overcome by vehicles involved in transportation during the calculation period. The most appropriate itinerary for the delivery of the cargo from point i to point j is found by calculation of the shortest route by employing network model or by applying the criterion of seeking the most secure route ($\min_i p_i^k \xrightarrow{k} max$).

$$\sum_i \sum_j l_{ij} \to min$$

Here, in p^k_i is the probability of the cargo delivery to *i* numbered consumer in *k* numbered version. For the period of calculation, $\mathbf{S_d}$ could be used as a constant in the evaluation of effectiveness indicators by calculating once (if the distance between the points does not change).

The total time spent on transportations T_d is the sum of transportation time spent by the vehicles involved in the transportations during the calculation period. When we talk about the shipment time for per vehicle *(unlike the transportation implemented in civil organizations),* we imply the time spent by a vehicle for travelling from the parking lot of the military unit till the determined point (where it receives cargo), loading duration as well as its delivery to the destination and unloading process.

The minimum value of this criterion, on its turn stimulates some effectiveness indicators to become closer to the optimal rates. But, the abnormal activity (that is to say, a system which doesn't provide effectiveness factors close to optimal values) of the real transportation could disturb this kind of dependence. If a vehicle spent more than a day on transportation, while calculating T_d – for that vehicle, resting time for the personnel and time for other things are to be taken into consideration.

Increasing of T_d for each vehicle could led to the decrease of the technical readiness co-efficiency of the military unit to which it appertains ($n_{a.faktiki}/n_{a.siyahı}$, in here $n_{a.faktiki}$ actual number of the vehicles in good condition, $n_{a.siyahı}$ is the number of the vehicles on the records) and combat readiness of the military unit.

Despite the application of modern information technologies on transportations, documentation process requires plenty of time. For instance, preparation of orders and substantive documents, submission of documents to the Transport Service of the Ministry of Defence, obtaining documents for distribution etc. could result in increasing of T_d [4].

The study of recent years indicates, that the Automobile service superiors of military units are mainly involved in the execution of this work. Since the most of military units are located 300 km far from the center, three days is required for document processing and the delivery of a property by the transport to a military unit. This, in its turn, by increasing Td , could negatively affect not merely the effectiveness of the transportations, at the same time the security of a military unit. Preparation for shipments and its negative impact on security of a military unit is characterized by non-execution of occupation duties of a service commander (inaction in the volume of "special volume" during combat readiness), and also by minimizing of technical readiness co-efficiency. From this perspective, minimization of T_d criterion has a positive effect on the growth of transportation effectiveness.

In cases, where the shipments are executed directly (when the delivery is implemented from unloading point to the loading one by the same vehicle) daily transportation distance is considered 250–300 km with one driver, and 550–600 km with two drivers. In this case, the duration of the driving is considered 12–14 hours per day with one driver, and 17–18 hours with two drivers a day [5].

Considering these, T_d – could be indicated by the following formula:

$$T_d = T_h + T_{y.b} + T_{dinc.} \tag{1}$$

Here T_h is the on moving time, hour, $T_{y.b}$ – time, hour spent for loading and unloading process, and for the wait ,the time, hours spent on t; $T_{dinc.}$ – the time or hours spent of the dirver's resting and stops(brake) while moving.

Transportation rate v_d – is the correlation of algebraic sum of routes, overcome by vehicles, involved in the transportations during the calculation period, to the total time T_d spent on the transportations and is calculated with $v_d = \frac{S_d}{T_d}$ formula. If the period of calculation is $S_d = const$, the realization of $v_d \rightarrow max$ criterion would depend on $T_d \rightarrow min$ terms.

While effectively using the load-carrying norms of vehicles, involved in the transportation the realization of is proposed.

$$\frac{\sum_{i=1}^{n} m_i}{M} \rightarrow 1 \tag{2}$$

Here $\sum_{i=1}^{n} m_i$ is the sum of load-carrying norms of automobiles, mi – is the nominal load-carrying capacity of automobile i, and M – is the amount of the total cargo.

If we call the ratioas $k_m = \frac{\sum_{i=1}^{n} m_i}{M}$ the coefficient of utilization of nominal load-carrying capacity, (2) theoretically the most optimal (ideal) value of criterion would be $km=1$. In addition, by applying $\sum_{i=1}^{n} m_i \geq M$ (the sum of nominal load-carrying capacity of automobiles should not be less than the volume of the shipment), the limitation condition, one can meet the whole transportation reqiremnts. According to this criterion, the formul $(k_m - 1) \cdot 100$ % could be used as deviation percentage from optimal (ideal) value.

Minimization of the overcome distance of a vehicle without load (S_{yz}), or percentage ratio of overcome distance without load to the whole distance ($\frac{S_{yz}}{S}$ x 100%) is possible in the case of sophisticated organization of Automobile Service planning, including transporation.

If we indicate the coefficient of unloaded driving as $k_{yz} = \frac{S_{yz}}{S}$, $k_{yz} = 0$ matches the most optimal level of the planning (loaded round trip of automobiles), and $k_{yz} = 1$ matches the most undesired situation (unloaded round trips of vehicles), that is to say theoretically $0 \leq k_{yz} \leq 1$ could be accepted for automobile transportations.

Coefficient k_{yz} totally characterizes automobile transportation executed during the calculation period. As value $k_{yz} = \frac{1}{2}$ characterizes the case of all automobiles, which travel the same route empty and return with load. In the case of $k_{yz} \in [0; \frac{1}{2}]$, we can consider that the transportations have been well organized. The case $k_{yz} = 1$ is only theoretically possible, and that means the vehicles, involved in transportations during the calculation period travel and return without load.

The case $k_{yz} < \frac{1}{2}$ is possible when at least some of the loaded vehicles travel from military units towards bases, and the case is theoretically possible, it corresponds to the case, where the vehicles deliver some shipment to bases and return to the military units with load.

In transportations the cost price of transport service is calculated as the ratio of X_d transportation cost to the amount M of the total transported shipments ($\frac{X_d}{M}$). X_d – is offered to be calculated with the following formula:

$$= S\left(0.01Y_n Q_y(1 + 0.01D) + \frac{Q_{AKB}}{N_{AKB}} + \frac{Q_{şin}}{N_{şin}} + \frac{Q_{AT}}{N_{AT}} + \frac{Y_n(k_1 Q_{my} + k_2 Q_{ty} + k_3 Q_{py} + k_4 Q_{xy})}{100}\right) + E_x G \quad (3)$$

Here X_d – is the shipment expences; S – the total overcome road, Y_n – fuel consumption per 100 km; Q_y - cost of 1 litre fuel, D – addition to fuel consuming norm; Q_{AKB} – the cost of batteries; N_{AKB} – exploitation norms of the batteries; $Q_{şin}$ – the cost of tyres; $N_{şin}$ – exploitation norms of tyres; Q_{AT} – the cost of automobile; N_{AT} –exploitation norms of automobile, Q_{my} – cost of engine oil; Q_{ty} – cost of transmission oil; Q_{py} – cost of plastic oils; Q_{xy} – cost of special oils (liquids); k_1 - k_4 – calculation norms for lubricating materials according to per 100 liter fuel consumtion; E_x – daily trip expenses; G – number of days.

X_d transportation costs depend on exploitation condition - road and climate condition of vehicles, including transport factors as well. Although the road condition, defined with a road construction remains unchanged, visibility, adhesion coefficient of tires, traffic intensity, and weather are included into changeable conditions. Transport factors are characterized by models of utilized vehicles, the weight and sizes of freight, type and lot, as well as by transportation distance.

Since the consideration all influential factors in the calculation of X_d transportation expenses requires long time and a detailed report, some of them are accepted as an average indicator by simplifying and some are not taken into consideration (minor influential factors).

As the transportation itineraries remained same during the calculation period, the norms of fuel and lubricants, as well as and consumptions of automobile properties were applied according to appropriate orders of the Defence Minister, without adding supplementary coefficients.

If during the calculation period the same model of vehicles are utilized in transportation, X_d, will change depended on the indicators of S və E_xG. Although, the transport parking lot comprises, it makes necessary to involve the most useful models in the transportation, and makes necessary to provide the terms of $S, E_xG \rightarrow min$.

This, in its turn, make necessary the involvement in transportation of the most useful model, altough the parking lot comprises various vehicle models, and the realization of terms $S, E_xG \rightarrow min$.

Fertility of transportations is characterized by the correlation of the overall shipment amount M, to overall time T_d spent on transportations during $(\frac{M}{T_d} \rightarrow max)$ (calculation period [6]. The closeness of this criterion to the maximum indicator, first of all depends on appropriate planning of the transportation, the proper choice of vehicles in accordance with norms and standards and the abovementioned parameters.

Advantageous expense (F_x) means the expenses spent on transportation according to nominal load-carrying capacity of an automobile. It is important to provide the advantageous expense indicator $F_x \rightarrow max$ in order to increase the effectiveness of transportations. On this purpose, the amount of the property required during the calculation is to be defined in advance and the transportation si to be planned taking F_x into consideration. The calculation of advantageous expense for the calculation period is offered to be implemented with the following formula.

$$F_x = \frac{X_d \cdot M}{A_{yn} \cdot n_a} \quad (4)$$

Here n_a - is the number of the vehicles engaged in the transportation during the calculation; A_{yn}- is the nominal load-carrying capacity (in kilograms) norm of the vehicles utulized in the transportations.

CONCLUSIONS

In the article optimal organization algorithm of military automobile cargo transportations and its mathematical model have been offered, and based on them evaluation method of transportation effectiveness has been worked out. This method encompasses major criterion for effectiveness evaluation of automobile cargo transportations existing in auto technical maintenance system, and allows to find out their factual and optimal values, calculation of the expenses, and to implement economic evaluation.

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