Logistics Solution for Choosing Location of Production of Road Construction Enterprise

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Abstract. The current state of construction of highways indicates that not all the resources of the construction organization are implemented and supported by the modern approaches in logistics problems solving. This article deals with the solution of these problems and considers the features of basic road linear works organization, their large extent and different locations of enterprises. Analyzing these data, it is proposed to simulate the logistics processes and substantiate the methods of transport operations organizing by linking the technology and the organization road construction materials delivery which allows one to optimize the construction processes, to choose the most economically advantageous options, and also to monitor the quality of work.

1. Introduction
One of the directions of construction is the construction of highways, which has its own peculiarities, namely the large volume of transport works.

All works on the construction of roads are divided into procurement, transportation and construction [1].

Transportation works are the link between procuring and construction and installation. So 80% of the estimated cost of building a road is in the construction of pavement, the construction of which is provided by transport, manufacturing enterprises by types of semi-finished products (ACP, CCP), stone crushing plants, quarries of non-metallic materials, bitumen bases, etc. [2]

To optimize the estimated cost of construction, we turn to the term "logistics", which originated from the Greek λογιστική (Logistika) - the art of calculation.

Currently, there are several dozen definitions of the term "logistics", including logistics - a process of planning, implementing and monitoring the efficiency of flow and storage of material and technical resources and production stocks.

2. Formatting the title, authors and affiliations
To solve the logistics tasks for organizing and optimizing the transport-production flow, we will consider the components of transportation operations. It is necessary to use the initial data, such as the construction area; general construction plan; choice of transportation mode; data on the road section length; need for road construction materials in accordance with the terms of technical reference [3].

Analyzing the initial data it is necessary to model the logistical processes and substantiate the methods of organization of work. As an example, Figure 1.
When transporting road-building materials, it becomes necessary to determine the rational range of the car. Since the cost of local materials is the same for a given construction area, the cost of materials in the workplace depends only on transportation costs. Therefore, in the case of the presence of several quarries with the same natural material in the construction zone, it is necessary to calculate by a graphical-analytical method to determine the boundary of the service area of a particular quarry, where the cost of transportation works will be determined on the basis of the Territorial Estimate Norms of TEN 81-01-06-2001 "Automobile and rail transportation" [4].

Determination of the average range of material and average distance of the haul from all deposits is carried out according to the formulas [5]:

\[
l_{\text{aver}} = \frac{l_0 + \frac{l_1}{2} \cdot l_1 + \left( l_0 + \frac{l_2}{2} \right) \cdot l_2}{l_1 + l_2}
\]

(1)

where:

- \( l_0 \) – distance from quarry to track, km;
- \( l_1 \) – distance from the zero km to the exit of the quarry into the route, km;
- \( l_0 \) – distance from the exit of the quarry into the route to the accepted kilometer of service, km.

\[
l_{\text{aver}}^b = \frac{l_{\text{aver}}^1 \left( l_{\text{aver}}^1 + l_{\text{aver}}^2 \right) + l_{\text{aver}}^2 \left( l_{\text{aver}}^1 + l_{\text{aver}}^2 \right)}{L}
\]

(2)

where:

- \( l_{\text{aver}}^1 \) – average distance of carrying the first quarry materials, km;
- \( l_{\text{aver}}^2 \) – average distance of carrying the second quarry materials, km;
- \( l_{\text{aver}}^l \) – length of the first section from the received kilometer to the exit of the quarry into the route, km;
- \( l_{\text{aver}}^r \) – length of the first section from the exit of the quarry into the route to the next kilometer taken, km;
- \( l_{\text{aver}}^i \) – length of the second section from the received kilometer to the exit of the quarry into the route, km;
- \( l_{\text{aver}}^j \) – length of the second section from the exit of the quarry into the route to the next kilometer taken, km;
- \( L \) – length of the whole route, km.

As an example, Figure 2.
Figure 2. Scheme of service areas for sand quarries.

Having determined the type of the manufacturing enterprise by the nature of the technological process (ACP-asphalt-concrete plant, CCP-cement-concrete plant), we will consider the variants of their placement according to the accepted rules [6]:

- in the immediate vicinity of the main sources of supply of road-building materials, i.e. in quarries or, when using imported materials, at railway stations, etc.;
- as close as possible to the road under construction (it is necessary to provide convenient entrances to it);
- in places where there are sufficient areas for the placement of equipment, storage facilities and auxiliary structures;
- taking into account the possibility of supplying the construction site with electricity, water, steam, etc..

Figure 3. Variant of ACP placing in the quarry of crushed stone.
It is necessary to outline two or three options for locating enterprises and to make a technical and economic comparison using the Territorial Estimates of TSS 81-01-06-2001 "Automobile and rail transportation" and the State Elementary Estimate Norms of the GESN 2001-27 "Highways" and Choose the option with the least transportation costs [7]. Variant of ACP shown on figure 3.

Determination of economically advantageous zones for the use of offshore quarries is carried out in cases where the materials of two or more deposits are of a quality suitable for any one constructive layer of pavement. The border between the service areas of two adjacent quarries is a place on the route where the cost of their materials will be the same.

The cost of a unit of material at the workplace (ex-warehouse) is determined by the formula [8]:

$$C = C_m + C_l + C_w$$

where $C_m$ – cost of a unit of material for the franco-quarry (selling prices for local materials); $C_l$ – cost of loading and unloading works per unit of material (conditionally, it can be assumed the same in all quarries and not used in calculations); $C_w$ – cost of transporting a piece of material from the quarry into the route.

In the next stage, we consider the transport-production chain [9]:

Plant $\Rightarrow$ car dump trucks $\Rightarrow$ route

The task is reduced to the determination of the need for vehicles for dumplings for the installation of all layers of pavement and the linkage of the requirements for transportation materials with the plant's productivity [6].

Determine the optimal pace of the device of each layer of the automobile road of a given category with the help of the Optima software package for less reduced costs and a high coefficient of machine interaction in the flow.

When determining the optimal tempo, the values of the minimum and maximum rates of work are used, determined by the formulas [10]:

$$Q_{\text{min}} = \frac{V_i}{T_w \cdot k_{\text{shift}}}$$

where $Q_{\text{min}}$ – minimum amount of replacement work for this unit of vehicles, $m^3(m^2)/\text{shift}$; $V_i$ – total working volume of works of the i-th type along the length of the road under construction, $m^3(m^2)$; $T_w$ – estimated number of working shifts; $k_{\text{shift}}$ – coefficient of shifts.

The value $Q_{\text{max}}$ is taken 2-3 times more than $Q_{\text{min}}$.

$$Q_{\text{max}} = 3 \cdot Q_{\text{min}}$$

The increment in the shift rate of the private flow is determined by the formula:

$$\Delta Q = \frac{Q_{\text{max}} - Q_{\text{min}}}{z}$$

where $z$ – number of steps.

When solving problems on electronic computers, the results are obtained in the form of a printout, which reflects the brands of road construction machines, the number of machines of this brand, the amount of work, the operating time during the shift and the cost of operation. In these results, for each work operation, depending on the change in the amount of construction work, the brands of road-building machines were selected, the number of machines of this brand, the time of their work during the shift and the cost of operation were calculated. For specific shifts of work, the reduced costs per unit of finished goods and the coefficient of machine interaction in the line [11,12].
where $C_{un}$ – resulted expenses for a unit of finished goods, one $m^3$ of the roadbed rub/m$^3$; $C_{qj}$ – costs per one hour of use of machines of the type $q$, brand $j$, rub.; $M_{qj}$ – number of machines of the type $q$, brand $j$; $T$ – duration of shift, h; $Q_{shift}$ – shift volume of excavation works, $m^3$.

Dependence of the resulted expenses and factor of interaction of cars in a flow from replaceable volume of works shown on figure 4.

![Figure 4. Dependence of the resulted expenses and factor of interaction of cars in a flow from replaceable volume of works.](image)

The next stage of the logistics chain is the direct determination of the need for motor transport. To do this, we need to use the calculation of the following indicators [13]:

- boundaries of the service area;
- replacement requirement for the material;
- range of the cargo from the consignor to the consignee;
- performance of the dump truck.

Of these values, it is necessary to determine the performance of a dump truck for each haul [14,15].

$$P = \frac{T \cdot q \cdot K_t \cdot K_i}{\left(\frac{2L}{v} + t\right) \cdot \gamma}$$ (8)

where $T$– number of working hours per shift, h; $q$ – car load capacity, t; $K_t$ – coefficient of machine use by time; $K_i$ – load factor of the machine; $L$ – distance of the road, km; $v$ – dump truck speed, km/h; $t$ – time of loading and unloading, h; $\gamma$ – volume weight.

The number of vehicles (dump trucks) is determined by the formula:

$$N = \frac{Q}{P}$$ (9)

where $Q$ – material requirement, t/km; $P$ – Productivity of motor transport, t/shift.
Installation of GLONASS-dump trucks will allow tracking real-time traffic on the construction site, allowing to optimize the entire logistics scheme. At the same time, transport works must be coordinated with the planning office.

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