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Influence of the Distance of Transportation of Goods on Operating Costs of a Motor Transport Enterprise

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ABSTRACT

The object of research is the transportation process. The subject of research is dependence of influence of the distance of transportation of goods on the cost of transportation of goods. Since no studied literary sources have revealed reliable dependences of influence of the distance of transportation on the cost of transportation of goods in specific conditions for a single enterprise, the research task considered in the article seems to be relevant.

The objective of this article is so to study the impact of distance of transportation of construction goods by dump trucks of Volgograd motor transport enterprise on operating costs. The solution to the problem is considered at the example of transportation of bulk cargo by MAN and Mercedes-Benz dump trucks with equal mileage. Several empirical research methods were used: observation (by means of purposeful perception of an object determined by the task of activity), comparison (by establishing similarity and difference between objects and phenomena of reality), measurement (by means of actions performed using measuring instruments to find the numerical value of the measured quantity in the adopted measurement units). To calculate the cost of transportation, the methodology for determining costs for transporting goods by road transport is used. To obtain experimental data, an analysis of the work of fleet of a motor transport enterprise is carried out using waybills with confirmed data. The process of obtaining actual data is carried out by means of calculations according to the given formulas. The research tool is calculation of the cost of transportation of goods according to the data obtained as a result of activities of the enterprise.

Regression dependences of influence of the distance of transportation of goods on the cost of operation of dump trucks with different carrying capacity were obtained to determine the type of the regression equation, construct estimates of unknown parameters included in the regression equation, and test statistical hypotheses about regression. The verification of the adequacy of obtained models was performed by calculating the correlation coefficient to establish the presence of a connection between random variables.

Keywords: *road transport, operating costs, distance, carrying capacity, regression.*

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Background

Transport provides a link between production, storage, and consumption. It also adds value to the goods. The availability of efficient transportation methods is the backbone of 20th century logistics due to the growing globalisation of trade and logistics. This is likely to continue over the next several centuries. The main requirements of the transport industry to support global logistics are reduced cost and travel time, on-time delivery, less variability in travel time, availability of seamless uninterrupted transport services through a combination of modes, minimal delays, damage and loss, and other logistics options such as storage, export, and delivery, etc. [1]. Transport enterprises and forwarding companies challenge an acute issue of reducing the cost of transportation of goods. Now, the system of existing tariffs for transportation of goods can be conditionally divided into:

a) tariffs depending on time of use of vehicles;

b) tariffs depending on vehicle mileage;

c) combined tariffs.

Practices of urban operating conditions use pricing that depends on time of use of trucks (time rate), or the cost of using vehicles that perform a certain transport work (piece rate). Evaluation of profitability of tariffs established of the use of vehicles, set in a competitive environment, as a rule, is carried out through the calculation of cost of rendering services for transportation of goods.

In most simple didactic variant, the impact on cost of transportation of goods is mainly exerted by indicators of the use of vehicles, such as:

- carrying capacity – q_c, t;
- transportation distance – L_{tr}, km;
- time for loading-unloading operations – t_l, h;
- technical speed – V_t, km/h [2].

Let us select the distance of transportation as a constant value when applying for performance of a service for transportation of goods. A review of the theory of freight road transportation indicates the influence of distance of transportation of goods on the cost in the form of continuous rectilinear and hyperbolic dependencies [3].

The immediate *objective* of this article is to study the impact of distance of transportation of construction goods with dump trucks of Volgograd motor transport enterprise (CJSC ATP) on operating costs. The solution to the problem is considered stydying the example of transportation of bulk cargo by MAN and Mercedes-Benz dump trucks with equal mileage.

Results

In conditions of competition in the motor vehicle market, enterprises use fleet belonging to various series, types, models, using different fuel, etc. The studied enterprise operates fleet consisting of MAN 41.414 (hereinafter – MAN) (Pic. 1) and Mercedes-Benz Actros 4141 K (hereinafter – Mercedes-Benz) (Pic. 2) trucks for transportation of bulk cargo in urban operating conditions.

Values of technical and operational features (hereinafter – TOF), such as:

- working days – D_w, days;
- time of duty – T_d, h;
- fuel consumption – F_{km}, l/100km;
- load capacity utilization factor – $\gamma_{c;}$
- number of tires – $n_{ti,\ units;}$
- transportation tariff – $T_{t,\ roub/h;}$

Pic. 1. Dump truck MAN 41.414.

Pic. 2. Mercedes-Benz Actros 4141 K.

Table 1

Initial TOF for calculation

Indicator	Measurement unit	Mercedes-Benz	MAN
q_c	t	28,6	25
V_t	km/h	30	28
F_{km}	l/100 km	52	52,3
t_l	h	0,25	
T_t	roub./h	220	
L_{tr}	km	8... 40	
P_f	roub./l	45,99	
D_w	days	256	
T_d	h	7	
n_{ti}	units	12	
P_{ti}	roub.	5000	
F_{t*km}	l/(t • km)	1,5	
N_{nr}	roub./year	500	
N_n	roub./1000 km	0,27	
C_{mr}	roub./100 km	374	
N_t	%/100 km	2	
γ_c	–	0,9	
β_{mil}	–	0,5	
α_u	–	0,8	
b_f	–	1,04	

• price of one tire – $P_{ti, roub.;}$
• mileage utilization factor – $\beta_{mil;}$
• fleet utilization factor – $\alpha_{u;}$
• coefficient of preparatory and final operations – 1,06;
• correction factor to T_t α_{wages} – 1,3
were obtained based on the results of practical research and taken from the reference literature [4].

Also, the following input data were used:
• normal rate of depreciated deductions for one car per year (average for the surveyed fleet) – N_{nr}, roub./year;
• depreciated deductions for renewal – N_n, roub./1000 km;
• normal rate for tire restoration – N_t, %/100 km;
• costs for maintenance, repair – C_{mr}, roub./100 km;
• additional fuel consumption rate – $F_{t\cdot km}$, l/(t • km);
• coefficient considering additional fuel consumption – b_f;
• fuel price – P_f, roub./l, data provided by CJSC ATP.

Operations are assumed to be conducted in urban conditions, calculation of operating costs is performed using formulas 2–13 below.

When carrying out research, data presented in Table 1 were used. For calculation, technical characteristics of vehicles provided by CJSC ATP were used.

In addition, statistical studies of indicators γ_c, t_l, V_t, α_u were carried out. The research was carried out according to the waybills provided by the enterprise. The mathematical expectation of the above values is presented in Table 1.

The dependence of performance of MAN and Mercedes-Benz cars on distance of transportation (L_{tr}) is determined by the formula (1) the obtained calculations are summarized in Table 2 and Pic. 3.

$$W_Q = \frac{q_c \cdot \gamma_{mil} \cdot \beta_t \cdot V}{l_{tr} + \beta_{mil} \cdot V_t \cdot t_l} \qquad (1)$$

To calculate the constituent parts of the cost of transported cargo, in most cases, the methodology for determining the logistics costs for transportation of goods by road transport based on the methodology for determining operating costs is used [5; 8]. The formulas used in calculating logistics costs are shown in Table 3. The obtained values are reduced to theoretical and experimental data and then analysed.

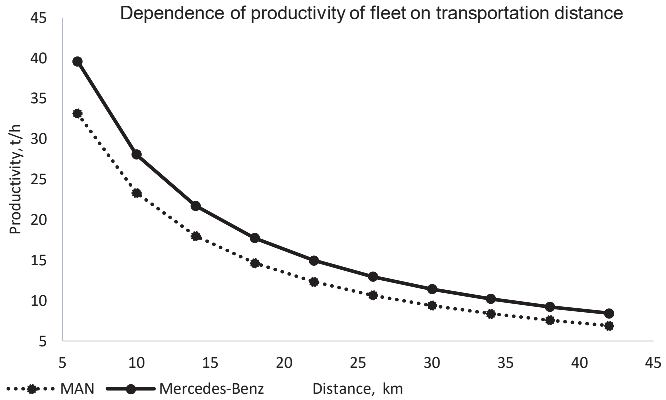
To obtain experimental data, an analysis of the work of the fleet of a motor transport enterprise was carried out using waybills with actual confirmed data. The process of obtaining actual (experimental) data is carried out by calculations using similar formulas, using data on operation of vehicles on routes of delivery of goods to consumers. The calculated prime cost of cargo transportation, using experimental data, is summarized in Table 4 (summary) and Table 5 (calculated).

The analysis of change in theoretical and actual data after the calculations made is shown in Pic. 4 and 5.

Table 2

Dependence of components of productivity of vehicles on the value of L_{tr}, t/h

Vehicle brand	Transportation distance, km									
	6	10	14	18	22	26	30	34	38	42
MAN	33,16	23,33	18,00	14,65	12,35	10,68	9,40	8,40	7,59	6,92
Mercedes-Benz	39,60	28,08	21,75	17,75	14,99	12,99	11,44	10,23	9,25	8,44



Pic. 3. Dependence of productivity of the fleet on L_{tr} for two vehicles.

Table 3

Costs items for calculation of the prime cost of cargo transportation

Item	Formula	№
Basic and additional drivers wages with deductions and contributions, roubles/t [1]	$C^{\text{wages}}_{\text{term}} = \frac{T_{\text{т}} \cdot t_1 \cdot \alpha_{\text{wages}}}{q_{\text{c}} \cdot \gamma_c}$	(2)
Fuel costs, roubles/t • km	$C^{transp}_{\text{transportation}} = \frac{\text{F}_{t \cdot km} \cdot \text{b}_f \cdot P_{\text{f}}}{100} + \frac{b_f \cdot P_f \cdot F_{km}}{q_{\text{c}} \cdot 100 \cdot \gamma_c \cdot \beta_{\text{mil}}}$	(3)
Costs of transportation operations, roubles/t • km	$C^{\text{wages}}_{\text{transportation}} = \frac{1{,}06 \cdot \alpha_{\text{wages}} \cdot T_{\text{t}}}{\gamma_c \cdot V_t \cdot q_{\text{c}} \cdot \beta_{\text{mil}}}$	(4)
Costs of consumable items 11 %	$C^{c}_{\text{transportation}} = 0{,}11 \cdot C^{t}_{\text{transportation}}$	(5)
Costs for maintenance and repair, roubles/t • km	$C^{mr}_{transportation} = \frac{C_{\text{mr}}}{\beta_{\text{mil}} \cdot q_{\text{c}} \cdot 1000 \cdot \gamma_c}$	(6)
Costs associated with reimbursement of wear and repair of tires, roubles/t • km	$C^{ti}_{\text{trnasportation}} = \frac{P_{\text{ti}} \cdot N_{ti} \cdot n_{ti}}{1000 \cdot \beta_{\text{mil}} \cdot \text{q}_{\text{c}} \cdot \gamma_c \cdot 100}$	(7)
Vehicle depreciation, roubles/t • km, where R_d – is set at 1,07	$C^{v}_{\text{transportation}} = \frac{R_{\text{d}} \cdot N_n}{10 \cdot \beta_{\text{mil}} \cdot \text{q}_{\text{c}} \cdot \gamma_c}$	(8)
Costs implied between terminal operations, roubles/t	$C^{\text{nr}}_{\text{term}} = \frac{N_{\text{nr}} \cdot \text{t}_1}{D_w \cdot \alpha_{\text{u}} \cdot \text{T}_{\text{d}} \cdot \text{q}_c \cdot \gamma_c}$	(9)
Costs implied between transportation operations, roubles/t • km	$C^{\text{nr}}_{transportation} = \frac{N_{\text{nr}}}{D_w \cdot \alpha_{\text{u}} \cdot T_{\text{d}} \cdot \text{q}_c \cdot \gamma_c \cdot \beta_{mil}}$	(10)
Cost of transportation of a ton of cargo	$C_{\text{term}} = C^{\text{wages}}_{term} + C^{\text{nr}}_{term}$	(11)
Variable costs	$C_{\text{transportation}} = C^{\text{wages}}_{transportation} + C^{t}_{\text{transportation}} + T^{t}_{\text{transportation}} + C^{\text{mr}}_{transportation} + C^{ti}_{\text{transportation}} + C^{n}_{\text{transportation}} + C^{\text{nr}}_{transportation}$	(12)
Prime cost of transportation	$\text{C}_{\text{e}} = \text{C}_{\text{term}} + \text{L}_{\text{tr}} \cdot \text{C}_{\text{transportation}}$	(13)

[1] *Term* is for terminal (initial and final) operations; *transportation* is for transportation operations.

Table 4

Summary table of operating costs

costs indicators	MAN		Mercedes-Benz	
	Theoretical	Actual	Theoretical	Actual
Costs implied between terminal operations				
C_{term}^{wages}, roubles/t	3,177	2,387	2,777	2,087
C_{term}^{nr}, roubles /t • km	0,004	0,004	0,003	0,003
ΣC_{term}, roubles /t	3,181	2,391	2,780	2,090
Costs implied between transportation operations				
C_{transp}^{wages}, roubles /t • km	0,962	0,548	0,785	0,446
C_{transp}^{nr}, roubles /t • km	0,031	0,024	0,027	0,021
C_{transp}^{c}, roubles /t • km	0,324	0,270	0,292	0,246
C_{transp}^{v}, roubles /t • km	0,002	0,002	0,002	0,001
C_{transp}^{mr} roubles /t • km	0,033	0,026	0,029	0,023
C_{transp}^{transp}, roubles /t • km	0,106	0,083	0,093	0,073
C_{transp}^{ti}, roubles /t • km	2,941	2,458	2,650	2,239
ΣC_{transp}, roubles /t • km	4,399	3,411	3,878	3,049

Table 5

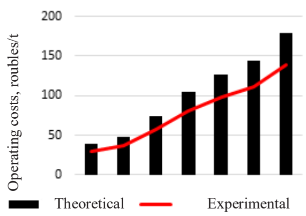
Calculation of logistics costs in case of cargo delivery for two vehicles, roubles/t

	L_{tr}, km	Ze	$C_{e. theor.}$	$C_{e. act.}$		L_{tr}, km	Ze	$C_{e. theor.}$	$C_{e. act.}$
MAN	8	1	38,4	29,7	Mercedes-Benz	8	1	33,8	26,5
	10		47,2	36,5		10		41,6	32,6
	16		73,6	56,9		16		64,8	50,9
	23		104,4	80,8		23		91,9	72,2
	28		126,4	97,9		28		111,4	87,5
	32		143,9	111,5		32		126,9	99,7
	40		179,1	138,8		40		157,9	124,1

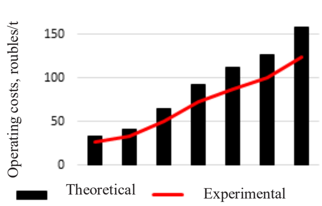
Table 6

Dependence of operating costs on distance of cargo transportation by dump trucks

L_{tr}, km	8	10	16	23	28	32	40
$C_{e,}$ roubles/t	MAN						
	29,7	36,5	56,9	80,8	97,9	111,5	138,8
	Mercedes-Benz						
	26,5	32,6	50,9	72,2	87,5	99,7	124,1



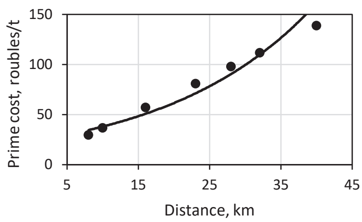
Pic. 4. Change in theoretical and actual operating costs with increase in mileage of a dump truck MAN.



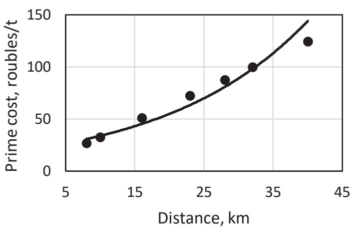
Pic. 5. Change in theoretical and actual operating costs with increase in mileage of a dump truck Mercedes-Benz.

To analyse the influence of L_{tr} on prime cost, a regression analysis is required. Using Table 5, we will compose a related sample of pairs of values (Table 6).

The correlation coefficient for both options was 0,958, which, according to the Chaddock scale, indicates an extremely high dependence.



Pic. 6. Dependence of C_e, roubles/t on L_{tr}, km using the example of MAN.



Pic. 7. Dependence of C_e, roubles/t on L_{tr}, km using the example of Mercedes-Benz.

Regression analysis of the calculation results was carried out in spreadsheets (MS EXCEL) using standard techniques. The functional dependence of C_e, roub./t on L_{tr}, km was obtained using the example of MAN and Mercedes-Benz (Pic. 4). L_{tr} = 8 ... 40 km.

When investigating the dependence of the variable *Y* on the variable *X* in paired exponential regression, its characteristics were estimated using the least squares method. Using the coefficient of determination and Fisher's criterion, the statistical significance of the equation is investigated. It was found, in fact, that in the studied example 91,78 % of the joint variability of *Y* is explained by the change in variable *X*. It was also established, in fact, that the characteristics of the model are statistically insignificant.

The coefficient of determination shows a certain proportion of variance (spread) of the dependent variable explained by the model under consideration. The value of the standard coefficient varies in the range from zero to one. The closer it is to one, the better is the regression model, that is, the constructed model perfectly approximates the initial data [6]. For statistical assessment of accuracy of the constraint equation, the average approximation error is also used [7].

Conclusion. In this work, a new model is proposed that has allowed to achieve a minimum overall logistics costs compared to existing approaches, while sequentially increasing the distance in iterations to obtain the final cost. To support the effectiveness of the proposed approach, it was substantiated using analysis in MS EXCEL and compared with other models in terms of total cost [9].

This dependence is recommended to the commercial units of business enterprises for practical use in assessing and forecasting the cost of transportation provided by motor transport enterprises.

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