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Selection of a Transportation Option for the Procurement of Goods for Own Needs, in Order to Increase the Efficiency of Operational Planning

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Abstract **- The competitiveness of each product mostly depends on its price, which includes transport costs from the place of its production to the place of its consumption. Sometimes these costs can be comparable the cost of production. Due to the high transport costs, the competitiveness of the manufactured products decreases, not only on the domestic but also on the foreign market. Substantial part of the freight transport nationwide is carried out by trucks owned by the manufacturing companies. They transport goods needed for their production needs with their own transport and at their own expense. At the same time, the operational planning of such shipments has been insufficiently studied, in which a large number of factors of technological and organizational nature must be taken into account. Operational planning has a significant potential for reducing transportation costs. The article considers the possibility to increase the efficiency of own-account transport at the stage of operational planning.**

Keywords - road transport, efficiency criterion, operational planning, cargo for own needs, pendulum route.

I. INTRODUCTION

Research by scientists [1, 2 ,3, 4 and other] proves that modern practice of operation of motor vehicles on routes in urban conditions has many features, which determines the need to apply a systematic approach in their study. The presence of system properties in the operation of vehicles on urban routes requires a systematic solution to the problem and separately for each level of complexity, starting with the simplest system. Professor Nikolin's scientific concept for the development of the theory of road freight transport was adopted as a basis. The concept envisages the application of a systematic approach, according to which the vehicle can't work in isolation and the result of its work is influenced by many factors: other vehicles, the method of preforming loading and unloading operations and others.

The practice and theory of road freight transport over the last 30 years shows that the existing methods for increasing the efficiency of freight transport are in most cases applied to public transport. The transport of goods for own needs of enterprises, which are characterized by certain features are not well reflected in modern scientific approaches. In addition, an analysis of research shows that the operational planning of such shipments, which must take into account a large number of factors of a technological and organizational nature, has not been well studied.

The purpose of the study in this article is to analyze the possibilities for increasing the efficiency of freight transport for own needs of enterprises with one vehicle by improving operational planning.

II. MATERIALS AND METHODS

In practice, when transporting goods for the company's own needs with one vehicle, the following types of routes are performed: pendulum without the use of reverse mileage; pendulum with full use of reverse mileage; pendulum with incomplete use of reverse mileage; pendulum with full use of the reverse mileage, but with a different load utilization factor; circular;

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delivery; collection and collection-delivery routes. The article discusses the different types of pendulum routes.

The minimum level of complexity of the organization of road freight transport corresponds to the operation of one vehicle in operational mode, then the planned volume of transport over a specific distance doesn't exceed the possible transport work per unit of rolling stock for one workday.

Since one vehicle is used for the transport of goods on each of the listed routes, the compatibility of the goods during transport (transport uniformity of the cargo) is taken into account when compiling more complex routes.

The study considers a topographic method for routing, which consists in the development and application of more complex routes than the pendulum with no use of reverse mileage [2]. When applying a route for a vehicle with a certain load capacity, the following factors are taken into account: transport characteristics of the load, the method of loading and unloading activities, allowable axle load, size restrictions and the need to meet the planned volume of transport per working day. Alternatives for solving the task of choosing a vehicle are considered its ownership (own or rented at an hourly rate) and its load capacity. The minimum cost of transporting goods for a workday is accepted as a criterion for choosing a vehicle. [5] Based on the characteristics of the load and the type of loading platform of the vehicle, the manner and duration of the loading and unloading activities is determined. [6] The duration of operation of the vehicle is limited to one shift, which corresponds to modern practice.

As a criterion for the efficiency of the transport of goods for own needs of the manufacturing companies is accepted the difference in the costs of transport of goods with its own vehicle and for the transport of same volume of goods with rented one.

The method of chain substitutions has been adopted as a method of analysis, as it has become the most widespread in road transport. In this method, all factors, except one, are provisionally considered constant, and one is variable.

The factors that influence the increase of the efficiency of the transportations are the distance over which the goods are transported on the listed routes in urban conditions. The distance at which transport can be performed in urban conditions for our country is 80 km, and the step of changing the distance is assumed to be 1 km. It is known from the theory of road freight transport that the distance at which the goods are transported depends on the productivity of the vehicle, expressed in tons (t) and ton-kilometers (tkm), which was reported in the study.

When performing the calculations for determining the indicators of the transport activity, the widely known and tested mathematical models for determining the technical-operational indicators for the operation of the rolling stock on the respective routes were used.

III. Result and Discussion

A. Pendulum route without reverse mileage (mileage utilization factor $\beta = 0,5$)

The task is to transport goods on pendulum route without the use of reverse mileage (reverse mileage without load), where the vehicle must perform one course for one cycle, i.e. $Z_o = 1$. In this case, the own rolling stock performs first zero mileage $L_{н1}$, loading T, mileage with cargo $L_{т1}$, unloading P, second zero mileage $L_{н2}$ (Fig.1).

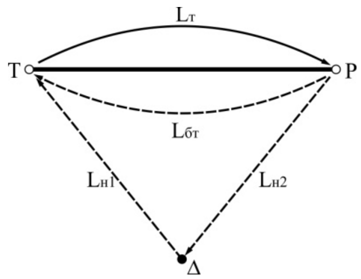

Fig. 1. Pendulum route scheme with no reverse mileage.

The solution of the problem is made with the following initial data: vehicle with load capacity $q_н$=3 t, one-way cargo flow, first class loads $\gamma_c = 1$, one-shift operation, urban operating conditions, the quantity and parameters of the load are known in advance and don't change, mechanized loading and unloading. The numerical values of the output data at a distance equal to the mileage with load $L_т = 1$ km are presented in Table 1.

Table 1
Output data at Lт = 1 km

Indicator	Value
Number of requests	1
Load class	1
Load capacity of the vehicle, q, t	3
Volume of cargo, Q, t	3
Coefficient of static load capacity utilization, γ_c	1
First zero mileage, $L_{н1}$, km	1
Second zero mileage, $L_{н2}$, km	1
Mileage utilization factor, $\beta_к$	0,5
Average technical speed, $V_т$, km/h	25
Loading and unloading time, $t_{т-р}$, h	0,425

The determination of the technical-operational indicators during operation of own rolling stock is made according to the following formulas:

- Time to complete a course:

$$t_k = \frac{L_т}{V_т} + t_{т-р}\text{, h;} \tag{1}$$

- Performed transport work:

$$P = Q\ .\ L_т\text{, tkm;} \tag{2}$$

- Total mileage of the vehicle for one course:

…………….. $L_{общ} = L_{н1} + L_т + L_{н2}$, km; (3)

- Actual operating time:

$$T_{нф} = \frac{L_{общ}}{V_т} + t_{т-р}\text{, h.} \quad (4)$$

The results of the calculations are presented in Table 2.

TABLE 2
TECHNICAL AND OPERATIONAL INDICATORS FOR OPERATION OF A VEHICLE AT $L_т$ = 1 KM, β = 0,5

Indicator	Value
Own transport	
Time for one course, $t_к$, h	0,5
Transport work, P, tkm	3,0
Total mileage, $L_{общ}$, km	3,0
Actual operating time, $T_{нф}$,h	0,55
Rented transport	
Time for one course, $t_к$, h	0,5
Transport work, P, tkm	3,0
Total mileage, $L_{общ}$, km	1,0
Actual operating time, $T_{нф}$,h	0,5

The total cost (P, BGN) for transportation of goods for own needs on a pendulum route without using the return mileage for one course at $L_т$ = 1 km is ≈ 10,00 BGN. A company that provides car rental offers the following tariffs: for vehicle with a load capacity q = 3 t - 40 BGN per course within 2 hours. Every next hour is paid 20 BGN, and every 15 minutes – 5 BGN.

Table 3 presents some of the results obtained. They show that when transporting goods at a distance L = 1, 2, …, 23 km the criterio for efficiency C_e for the use of rented rolling stock doesn't increase,which is indicative of the fact that in this range it is more profitable to use own rolling stock.

TABLE 3
Expenses for transportation of goods with own and rented rolling stock with equal load capacity. (q = 3 t) при Z_o = 1

L, km	Q, t	Freight transpotation costs		C_e, BGN.
		Own transport	*Rented transport*	
1	3	12,5	40	-
2	3	13,75	40	-
3	3	15	40	-
…	…	…	…	…
22	3	38,75	40	-
23	3	40	40	-
24	3	41,25	40	1,25
25	3	42,5	40	2,5
…	…	…	…	
78	3	108,75	75	33,75
79	3	110	75	35
80	3	111,25	75	36,25

On the basis of regression analysis with the help of MS EXCEL a functional dependence of the criterion for efficiency C_e in transportation of goods for own needs from distance $L_т$ is obtained (Fig.2). This dependence is a third degree polynomial, which is:

$$C_e = 0{,}0003L^3 – 0{,}0533L^2 + 3{,}0302L – 56{,}432. \quad (5)$$

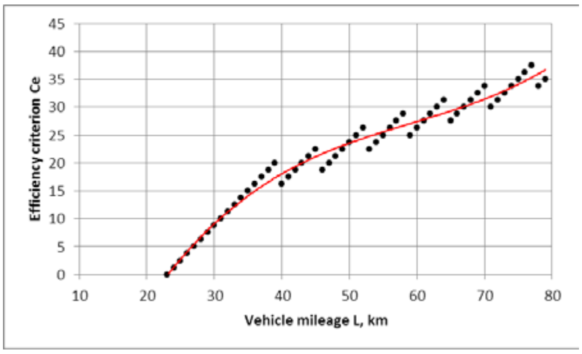

Fig. 2. Dependence of C_e = f(L) at $L_т$ = 24, 25, …, 80 km

The coefficient of determination of equation (5) is R^2 = 0,9801,which shows that it well describes the studied process. The standart error of the approximation is 2,51%, which allows us to claim that the regression dependence for the influence of the distance L = 24, 25, 26 …, 80 km on the efficiency criterion C_e on a pendulum route without using the reverse mileage Z_o = 1 adequatly describes the studied process.

B. Pendulum route with full use of reverse mileage (mileage utilization factor β = 1)

The task is to transport goods on pendulum route with full use of reverse mileage, where it can be performed one cycle Z_o = 1. In this case the own rolling stock performs first zero mileage $L_{н1}$, first loading T_1, first mileage with cargo $L_{т1}$, first unloading P_1, second loading T_2, second mileage with cargo $L_{т2}$, second unloading P_2, first zero mileage $L_{н1}$ (Fig.3). The output is similar, i.e. L = $L_т$ = 1.

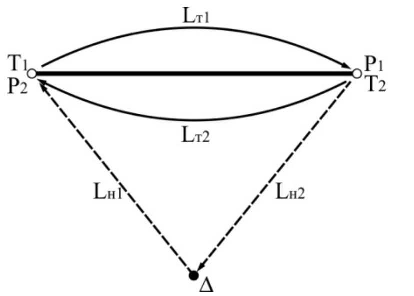

Fig. 3. Pendulum route scheme with full use of reverse mileage.

Determining the technical-operational indicators on a pendulum route using the reverse mileage is made according the following formulas:

$L_м = L_{т1} + L_{т2}$, km; (6)

- Time to make one cycle:

$$t_o = \frac{L_м}{V_т} + t_{т-р1} + t_{т-р2}\text{, h;} \qquad (7)$$

- Total mileage of the vehicle:

$$L_{общ} = L_{н1} + L_м + L_{н1}\text{, km;} \qquad (8)$$

- Actual operating time:

$$T_{нф} = \frac{L_{общ}}{V_т} + t_{т-р1} + t_{т-р2}\text{, h.} \qquad (9)$$

The results of the calculations are presented in Table 3.

TABLE 3
TECHNICAL AND OPERATIONAL INDICATORS FOR OPERATION OF A VEHICLE AT $L_т$ = 2 KM, β = 1,0

Indicator	Value
Own transport	
Time for one cycle t_o, h	0,93
Quantity of transported goods Q, t	6
Transport work, P, tkm	6
Total mileage $L_{общ}$, km	4
Actual operating time $T_н$, h	1,01
Rented transport	
Time for one cycle t_o, h	0,93
Quantity of transported goods Q, t	6
Transport work, P, tkm	6
Total mileage $L_{общ}$, km	2
Actual operating time $T_н$, h	0,93

The influence of the distance on the efficiency criterion C_e for a pendulum route with full use of the mileage at one cycle was studied in an analogous was. When transporting goods at a distance L = 1, 2, …, 11 km the criterio for efficiency C_e for the use of rented rolling stock doesn't increase, which is indicative of the fact that in this range it is more profitable to use own rolling stock.

According to the results of the research the functional dependence of the criterion for efficiency C_e on the distance L at L = $L_{т1}$ has been established, the equation is:

$$C_e = 0{,}8972L - 7{,}9888. \qquad (10)$$

Figure 4 shows graphically the regression dependence of C_e in the range from 12 to 80 km.

The coefficient of determination of equation (10) is R^2 = 0,9933, which shows that it well describes the studied process. The standard error of the approximation is 1,49%, which allows to claim that the regression dependence for the influence of the distance L = 12 – 80 km on the efficiency criterion C_e when transporting goods on a pendulum route with full use of the mileage at Z_o = 1 adequately describes the researched process.

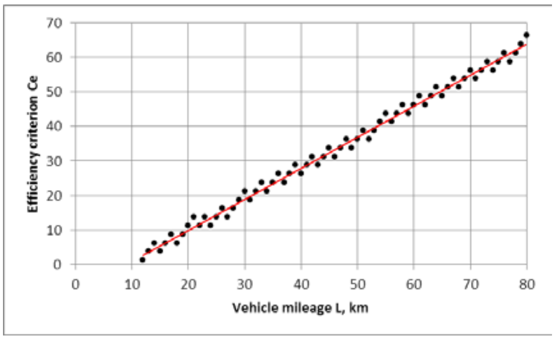

Fig. 4. Dependence of C_e = f(L) at $L_т$ = 12, 17, …, 80 km

C. Pendulum route with incomplete use of reverse mileage (mileage utilization factor β = 0,75)

The task is to transport goods on pendulum route with incomplete use of reverse mileage, where it can be performed one cycle Z_o = 1. In this case the own rolling stock performs zero mileage $L_{н1}$, first loading T_1, first mileage with cargo $L_{т1}$, first unloading P_1, second loading T_2, second mileage with cargo $L_{т2}$, second unloading P_2, zero mileage $L_{н3}$ (Fig.5).

The initial data (except $L_{т2}$ = 0,5, $L_{н1}$ = 1 km) and the calculation of the technical performance indicators are the same as the pendulum route with full use of the reverse mileage. The results of the calculations are presented in Table 4.

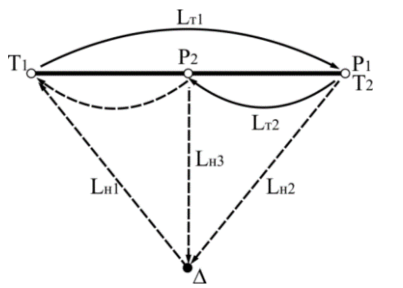

Fig. 5. Pendulum route scheme with incomplete use of reverse mileage.

TABLE 4
TECHNICAL AND OPERATIONAL INDICATORS FOR OPERATION OF A VEHICLE AT $L_т$ = 1,5 KM, β = 0,75

Indicator	Value
Own transport	
Time for one cycle t_o, h	0,91
Quantity of transported goods Q, t	6
Transport work, P, tkm	4,5
Total mileage $L_{общ}$, km	4
Actual operating time $T_н$, h	1,01
Rented transport	
Time for one cycle t_o, h	0,91
Quantity of transported goods Q, t	6
Transport work, P, tkm	4,5
Total mileage $L_{общ}$, km	1,5
Actual operating time $T_н$, h	0,91

The study of the influence of the distance on the criterion for efficiency on a pendulum route with incomplete use of the reverse mileage at $Z_o = 1$ was done in the same way as in previous pendulum routes. When transporting goods at a distance L = 1, 2, …, 12 km the efficiency criterion C_e from the use of hired rolling stock doesn't increase, which is indicative of the fact that in this range it is more profitable to use own rolling stock.

According to the results of the research the functional dependence of the criterion for efficiency C_e on the distance L at $L = L_{T1}$ has been established, the equation is:

$$C_e = 1{,}3275L – 8{,}3498. \qquad (11)$$

Figure 6 shows graphically the regression dependence of the efficiency criterion C_e on the distance at $L = L_{T1}$ in the range from 13 to 80 km.

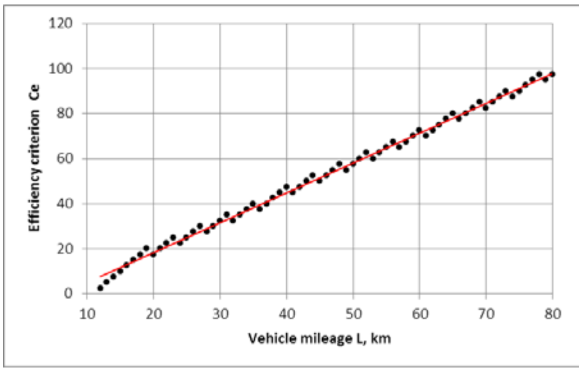

Fig. 5. Dependence of $C_e = f(L)$ at L_T = 13, 14, …, 80 km

The coefficient of determination of equation (11) is R^2 = 0,9959, which shows that it well describes the studied process. The standard error of the approximation is 1,72%, which allows to claim that the regression dependence for the influence of the distance L = 13 – 80 km on the efficiency criterion C_e when transporting goods on a pendulum route with incomplete use of the mileage at Z_o = 1 adequately describes the researched process.

D. Pendulum route with full use of reverse mileage, but with a different load utilization factor (mileage utilization factor $\beta = 1{,}00$, $\gamma_1 \neq \gamma_2$)

The task is to transport goods on pendulum route with full use of reverse mileage, but with a different load utilization factor $\gamma_1 \neq \gamma_2$, where it can be performed one cycle $Z_o = 1$. In this case the own rolling stock performs zero mileage $L_{н1}$, first loading T_1, first mileage with cargo L_{T1}, first unloading P_1, second loading T_2, second mileage with cargo L_{T2}, second unloading P_2, zero mileage $L_{н1}$ (Fig.3).

The output data are the same as for the previous routes, except for Q_2 = 2 t. In this route $\gamma_1 \neq \gamma_2$, from which follows $t_{T\text{-}p1} \neq t_{T\text{-}p2}$. The results of the calculations are presented in Table 5.

TABLE 5
TECHNICAL AND OPERATIONAL INDICATORS FOR OPERATION OF A VEHICLE AT L_T = 2 KM, $\beta = 1$, $\gamma_1 \neq \gamma_2$

Indicator	Value
Own transport	
Time for one cycle t_o, h	0,80
Quantity of transported goods Q, t	5
Transport work, P, tkm	5
Total mileage $L_{общ}$, km	4
Actual operating time $T_н$, h	0,88
Rented transport	
Time for one cycle t_o, h	0,80
Quantity of transported goods Q, t	5
Transport work, P, tkm	5
Total mileage $L_{общ}$, km	2
Actual operating time $T_н$, h	0,80

The study of the influence of the distance on the criterion for efficiency on a pendulum route with full use of the reverse mileage, but with a different load utilization factor at $Z_o = 1$ was done in the same way as in previous pendulum routes. When transporting goods at a distance L = 1, 2, …, 11 km the efficiency criterion C_e from the use of hired rolling stock doesn't increase, which is indicative of the fact that in this range it is more profitable to use own rolling stock.

According to the results of the research the functional linear dependence of the criterion for efficiency C_e on the distance L has been established, the equation is:

$$C_e = 0{,}903L - 4{,}4001. \qquad (12)$$

Figure 7 shows graphically the regression dependence of the efficiency criterion C_e on the distance L in the range from 12 to 80 km.

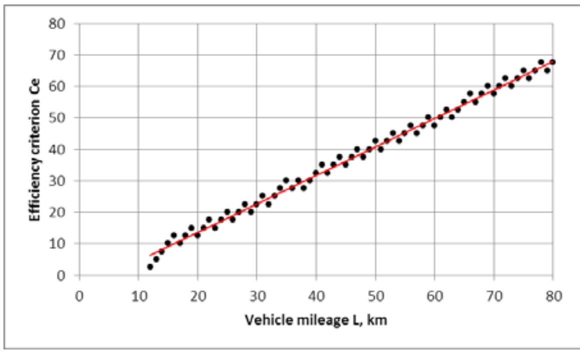

Fig. 5. Dependence of $C_e = f(L)$ at L_T = 12, 13, …, 80 km

The coefficient of determination of equation (12) is R^2 = 0,9928, which shows that it well describes the studied process. The standard error of the approximation is 1,71%, which allows to claim that the regression dependence for the influence of the distance L = 12 – 80 km on the efficiency criterion C_e when transporting goods on a pendulum route with full use of the reverse mileage, but with a different load utilization factor at Z_o = 1 adequately describes the researched process.

IV. Conclusions

The influence of the distance on the criterion for efficiency in the transport of goods for own needs on pendulum routes of any kind – with no use of reverse mileage, with full use of reverse mileage, with incomplete use of reverse mileage and full use of reverse mileage, but with a different load utilization factor is revealed. Upcoming studies are expected to reveal the influence of distance and volume of transportation on the criterion of efficiency, both for the routes discussed in the article and for circular, delivery, collection and collection-delivery routes.

The dependence of the efficiency criterion on the distance of the transportation is described by linear equations and polynomials of different degree. Checking the quality of the equations shows that with 95% confidence they adequately describe the studied process.

The proposed dependencies for the transport of goods for own needs in urban conditions can help to correctly determine the costs that correspond to the interests of the main production.

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References

[1] V. Nikolin, Transport process and optimizatipon of its elements, Publisher “Transport”, Moscow, 1990, pp. 90-91.
[2] V. Nikolin, “Freight road transport”, monograph, Publisher „Variant-Siberia“, Omsk, 2004, pp. 480-485.
[3] V. Nikolin, “Scientific bases for improving the theory of road freight transport”, dissertation, Moscow, 2000.
[4] A. Gorev, Freight road transport, Publishing Center „Academy “,Moscow, 2008, pp. 288-290.
[5] M. Mirgorodsky, “Selection of rolling stock for transport of goods in small batches in urban conditions”, monograph, KAN Polygraphic Center, Omsk, 2012, pp. 139-141.
[6] S. Sapundjiev and P. Stefanova, Road transports of goods (530 questions), Investpress Printing House, Sofia, 2017, pp. 22-25.