

Influence of Technical and Operational Indicators on the Results of Planning Motor Transport Operation

Varakin V.V.

Procurement Department,
FSBI Roslesinforg
Moscow, Russia
vlad_varakin@mail.ru

Chebakova E.O.

Logistics Dept.
Siberian Automobile and Highway University (SibADI)
Omsk, Russia
elena_chebakova@mail.ru

Abstract—Mathematical apparatus for calculating the road transport operation volume, existing in the modern theory, corresponds to the only technology of the transport process – functioning of the pendulum route with reverse unloaded mileage. However, modern specifics of freight motor transport enterprises functioning today is, as a rule, a frequent change of the clientele, types of freights and their volumes, distances of transportations, quantity and type of the rolling stock, average sizes of the technical and operational indicators, road congestion, number of drivers, condition of technological infrastructure and material and technical service opportunities. In this regard, studies have been carried out and the results aimed at making informed management decisions and accurate calculation of the planned need for vehicles have been presented. In the course of the research the methods of linear programming; professional-logical approach using the apparatus of mathematical modeling, including algorithm and software implementation of models were used. The analysis of the results of the previously developed methods and models application in the practice of planning the freight motor transport enterprises operation is carried out. It is revealed that the previously developed mathematical models are not implemented as there are significant discrepancy between the planned values and the results of motor transport enterprises work.

Keywords—rolling stock; motor transport enterprises; management; planning; technical and operational indicators

I. INTRODUCTION

In the Russian Federation, transport is one of the largest basic sectors of the national economy, an important part of the production and social infrastructure. The changed social and economic conditions force to radically reconsider ideas about the foundations of the operation organization of any enterprises [2, 12].

Unlike other industries, resource savings in the production of transport products can be obtained if measures are developed to save them at the planning stage of the transport process, because if the transportation is provided, it is simultaneously consumed, so it is too late to consider savings. It is revealed that the mathematical apparatus for calculating the volume of work in tons and ton-kilometers, existing in the

modern theory, to some extent correspondences to the only technology of the transport process – the functioning of the pendulum route with reverse unloaded mileage. However, modern specifics of functioning of freight motor transport enterprises today usually presupposes frequent change of the clientele, types of freights and their volumes, distances of transportations, quantity and type of the rolling stock, average sizes of technical and operational indicators, road congestion, availability of drivers, a condition of the technological infrastructure, material and technical supply, etc. [3,8].

In addition, the use of the previously developed models and methods in preventing or eliminating any consequences of a man-made or natural character, in terms of operational planning of vehicles at these facilities, due to the inadequacy of models to real processes, can lead to negative consequences – damage to personal and state property, environmental disasters, human victims, etc. [15].

The absence of a negative feedback between the intensity of operation, resulting from the improvement of technical and operational indicators, and the degradation of the vehicles technical condition, the increase in resource requirements, indicates the inadequacy of the description models and questions the appropriateness of their use in the planning and management of the enterprise [11, 13].

The mentioned shortcomings indicate the need for the research aimed at improving existing approaches and methods of analysis of transport activities of enterprises.

II. THEORY

The methodological basis of the work was the tenets of the theory of freight motor transport. The research was conducted from the position of system approach and system analysis, using the general theory of systems, operations research and the theory of mathematical statistics. The calculations are based on theoretical positions and models of motor transport systems functioning.

The current state of the theory and practice on the planning and analysis of production activities of road transport enterprises is considered. It is confirmed that the existing planning methodology is based on the idea of a continuous

and monotonically changing transport process, resulting in significant differences in practice between the planned and actual results of the work. The results of the theoretical and practical studies make us turn to the issue of improving the planning and management of the rolling stock of freight transport enterprises and supply chains in general [1, 4, 5, 14].

The disadvantages of the applied factors and mathematical apparatus during the planning of the cargo motor transport enterprises operation were considered by many Russian and foreign scientists [6, 7, 9, 10]. The discrepancy between the planned and actual performance of rolling stock in practice can reach 50%. This discrepancy was previously considered as an imperfection of the system of technical and operational indicators and planning of road transport in general. At the same time, the basis of the planned calculations used the average values of technical and operational indicators, which does not allow to obtain reliable results on the operation of vehicles and to identify the reasons for the discrepancy between the planned and actual indicators.

III. METHODS

The study of the influence of technical and operational indicators on efficiency of functioning of the rolling stock of the freight motor transport enterprise were based on the following mathematical dependences:

– traditional approach:

$$Q = AD_{inv} \cdot \alpha_{and} \cdot T_n \cdot W_Q, \quad (1)$$

$$P = AD_{inv} \cdot \alpha_{and} \cdot T_n \cdot W_P, \quad (2)$$

where Q is the volume of traffic, t; P is the transport work of the car part, t·km; AD_{inv} is the number of automobile-days inventory; α_{and} is the utilization rate of the park; T_n is the duration of the rolling stock utilization on the line per day (shift), h;

$$W_Q = \frac{q \cdot \gamma_s \cdot \beta \cdot V_t}{l_{ge} + V_t \cdot \beta \cdot t_{l/u}} \text{ is the performance}$$

of an automobile, t; $W_P = \frac{q \cdot \gamma_d \cdot \beta \cdot V_t \cdot l_{ge}}{l_{ge} + V_t \cdot \beta \cdot t_{l/u}}$ is the performance

of an automobile, t·km; q is the weight capacity of the vehicle, t; γ_s is the coefficient of static usage of weight capacity; γ_d is the coefficient of dynamic usage of weight capacity; β is the coefficient of using mileage; V_t is the secondary technical speed, km/h; l_{ge} is the average length of a haul with freight on the route, km; $t_{l/u}$ is the idle time for loading / unloading per haul, h

$$Q_a = \sum_1^m \left(\frac{T_n \cdot V_T \cdot \beta \cdot q \cdot \gamma_C \cdot D_C \cdot \alpha_r}{l_f + V_t \cdot \beta \cdot t_{l/u}} \right) \cdot A_{list}, \quad (3)$$

$$T_a = Q_a \cdot l_f, \quad (4)$$

where Q_a is the analytical volume of traffic, t; m is the number of models of the vehicles; D_c is the number of calendar days; α_r is the coefficient of vehicles release on the road; l_f is the average distance of the haul; A_{list} is the list number of vehicles; T_a is the analytical freight turnover, t·km; l_f is the average distance of transportation of 1 ton of freight, km.

– the proposed improved models that provide the

ability to analyze the impact of TOC (technological and operational characteristics) on the efficiency of the car park for any period of time, taking into account their negative impact on the utilization rate of the park:

$$Q = AD_{inv} \cdot \frac{1}{1 + \frac{T_n \cdot l_{ge} \cdot V_t \cdot d_y}{l_{ge} + t_{l/u} \cdot \beta \cdot V_t}} \cdot K_\alpha \cdot \frac{D_{rg}}{D_{inv}} \cdot \frac{T_n \cdot \beta \cdot q \cdot \gamma \cdot V_t}{l_{ge} + V_t \cdot \beta \cdot t_{l/u}}, \quad (5)$$

$$P = AD_{inv} \cdot \frac{1}{1 + \frac{T_n \cdot l_{ge} \cdot V_t \cdot d_y}{l_{ge} + t_{l/u} \cdot \beta \cdot V_t}} \cdot K_\alpha \cdot \frac{D_{rg}}{D_{inv}} \cdot \frac{T_n \cdot l_{ge} \cdot \beta \cdot q \cdot \gamma \cdot V_t}{l_{ge} + V_t \cdot \beta \cdot t_{l/u}}, \quad (6)$$

and also in which there is no β and all errors associated with the use of this coefficient, and takes into account the change in the idle time of the vehicle under loading and unloading, depending on the change in load capacity and the value of the loaded mileage:

$$Q = AD_{inv} \cdot \frac{1}{1 + \frac{T_n \cdot l_R \cdot V_t \cdot d_y}{l_R + V_t \cdot q \cdot \sum_1^n (\tau_{l/u} \cdot \gamma_i)}} \cdot K_\alpha \cdot \frac{D_{rg}}{D_{and}} \cdot \frac{T_n \cdot V_t \cdot q \cdot \sum_1^n \gamma_i}{l_R + V_t \cdot q \cdot \sum_1^n (\tau_{l/u} \cdot \gamma_i)}, \quad (7)$$

$$P = AD_{inv} \cdot \frac{1}{1 + \frac{T_n \cdot l_R \cdot V_t \cdot d_y}{l_R + V_t \cdot q \cdot \sum_1^n (\tau_{l/u} \cdot \gamma_i)}} \cdot K_\alpha \cdot \frac{D_{rg}}{D_{and}} \cdot \frac{T_n \cdot V_t \cdot q \cdot \sum_1^n (\gamma_i \cdot l_{rei})}{l_R + V_t \cdot q \cdot \sum_1^n (\tau_{l/u} \cdot \gamma_i)}, \quad (8)$$

where D_{rg} is the number of working days in a calendar year; D_{and} is the number of days of operation technically drivable vehicles on the line; K_α is the utilization ratio of vehicles, suitable for exploitation; d_y is the ratio of vehicle downtime for maintenance and repair for 1000 kilometers, days; l_R is the length of the route, km; n is the number of loads, $\tau_{l/u}$ is the time for loading and unloading of one ton of freight, h; γ_i is the utilization of capacity in the forward or reverse direction.

The initial data taken for the calculations: transportation of goods is carried out by the rolling stock of the TMC (trucking motor company), consisting of 3 motor columns: motor column № 1 – KamAZ-5410, $A_{list} = 15$ units, $\bar{q} = 8$ t, $\gamma = 1$, $T_n = 9$ h, $\beta = 0.5$, $V_t = 26$ km/h; motor column № 2 – ZiL-MMZ-4502 $A_{list} = 9$ units, $\bar{q} = 6$ t, $\gamma = 1$, $T_n = 9$ h, $\beta = 0.5$, $V_t = 26$ km/h; motor column; № 3 – KamAZ-55111 $A_{list} = 16$ units, $\bar{q} = 13$ t, $\gamma = 1$, $T_n = 9$ h, $\beta = 0.5$, $V_t = 26$ km/h; Time for loading and unloading is taken in accordance with the norms of time spent on loading and unloading operations, depending on the load capacity of the automobile, the method of performing the work and the type of freight.

IV. RESULTS AND DISCUSSION

As an example, the graphic dependences for column № 1 are given. The graphical dependences constructed using mathematical expressions 5, 6, 7 and 8 are located below the graphs built on the basis of the existing theory using mathematical expressions 1, 2, 3 and 4 (fig. 1, table 1). From that follows the conclusion: the value of of transport

production in tons and ton-kilometers, obtained using mathematical expressions 5, 6, 7 and 8, is less than the value obtained using classical approaches, which is more consistent with the real performance of the rolling stock in practice.

TABLE I. REGRESSION EQUATIONS AT CHANGING Tn

Math. dependence	Regression equation P = f(x)	Math. dependence	Regression equation Q = f(x)
2	$y = 176874.7x + 1876621.3$	1	$y = 34778.4x + 392651.2$
4	$y = 192652.6x + 2128189.1$	3	$y = 37675.3x + 415625.3$
6	$y = 1.2x^3 - 433.5x^2 + 162278.3x + 1838098.8$	5	$y = 0.2x^3 - 85.0x^2 + 31819.3x + 359607.7$
8	$y = 0.4x^3 - 212.0x^2 + 113019.1x + 1280370.6$	7	$y = 0.1x^3 - 41.6x^2 + 21456.1x + 252953.1$

such an indicator as the idle time of the automobile under loading and unloading ($t_{L/U}$) changes. At that, graphical dependencies, built using mathematical expressions 5, 6, 7 and 8 show that similarly to the previous case, the value of transport production is less than the value obtained using the traditional approaches (fig. 2, table 2).

TABLE II. REGRESSION EQUATIONS AT CHANGING Qγ

Math. dependence	Regression equation P = f(x)	Math. dependence	Regression equation Q = f(x)
2	$y = 56819.9x + 1935276.3$	1	$y = 11260.8x + 379565.9$
4	$y = 61549.1x + 2096070.8$	3	$y = 12098.1x + 410984.3$
6	$y = 52796.0x + 1785062.3$	5	$y = 10352.1x + 351873.0$
8	$y = -0.1x^4 + 5.0x^3 - 337.0x^2 + 23671.7x + 1568921.4$	7	$y = x^3 - 66.1x^2 + 4455.4x + 305770.9$

The hyperbolic change in vehicles output with an increase in the average technical speed according to the current theory is explained by the fact that the increase in V_t reduces the time for driving or turnover, and it is possible to perform a greater number of hauls in the same period. At the same time, the vehicle is more often at the points of loading and unloading, in connection with which the time spent on loading and unloading operations increases. This, in turn, adversely affects the volume of the output.

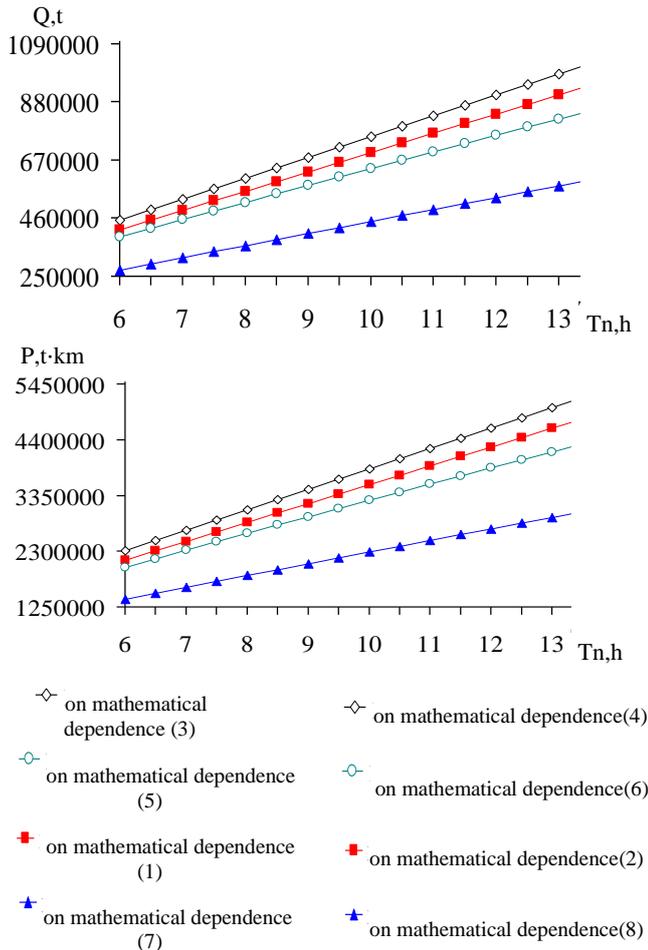


Fig. 1. Change in Q and P as a result of Tn growth

As follows from mathematical expressions 1, 2, 3 and 4 with increasing q and γ, automobiles output always increases in direct proportion. In fact, with an increase in load capacity,

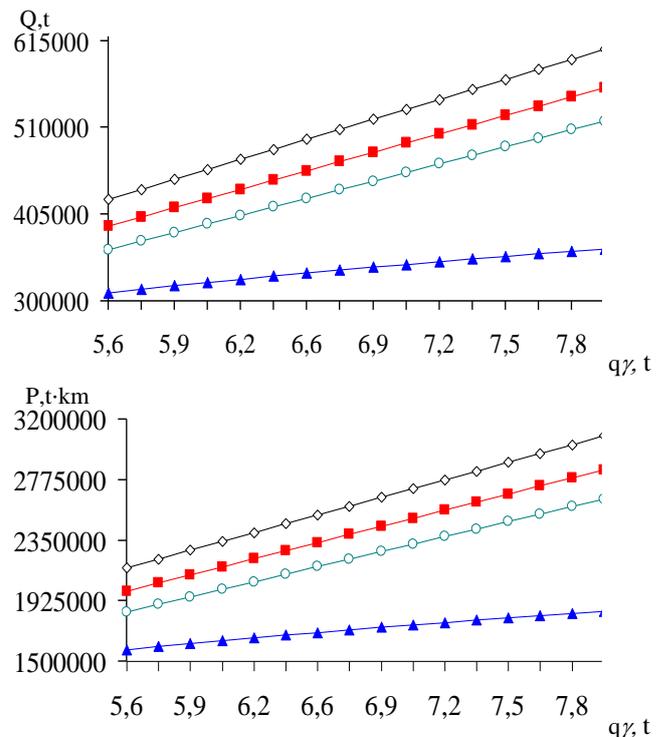


Fig. 2. Change in Q and P as a result of qγ growth

The hyperbolic nature of the dependence of the transport output in tons and ton-kilometers with an increase in the average technical speed in the results of calculations using mathematical expressions 5, 6, 7 and 8 remains. But just as in the previous sections, the graphical dependencies are located below the graphs built on the basis of the existing theoretical bases (fig. 3, table 3).

TABLE III. REGRESSION EQUATIONS AT CHANGING Vt

Math. dependence	Regression equation P = f(x)	Math. dependence	Regression equation
2	$y = -0.7x^4 + 35.4x^3 - 1686.1x^2 + 83003.7x + 2246220.4$	1	$y = -0.1x^4 + 7.8x^3 - 330.6x^2 + 15079.2x + 358651.1$
4	$y = -0.7x^4 + 37.3x^3 - 1826.2x^2 + 89817.1x + 2538992.4$	3	$y = -0.1x^4 + 7.3x^3 - 358.1x^2 + 17415.1x + 497841.7$
6	$y = -0.7x^4 + 35.8x^3 - 1610.7x^2 + 83949.6x + 2190667.7$	5	$y = -0.1x^4 + 6.8x^3 - 315.8x^2 + 14598.9x + 327542.7$
8	$y = -x^4 + 46.8x^3 - 1228.2x^2 + 32132.4x + 1623916.8$	7	$y = -0.2x^4 + 8.2x^3 - 430.8x^2 + 7669.1x + 426454.3$

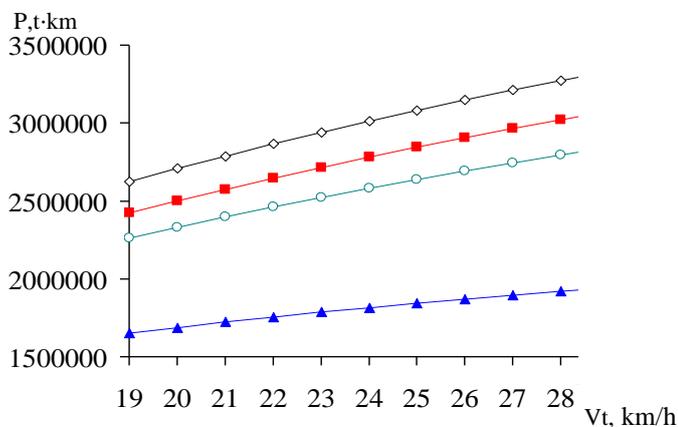
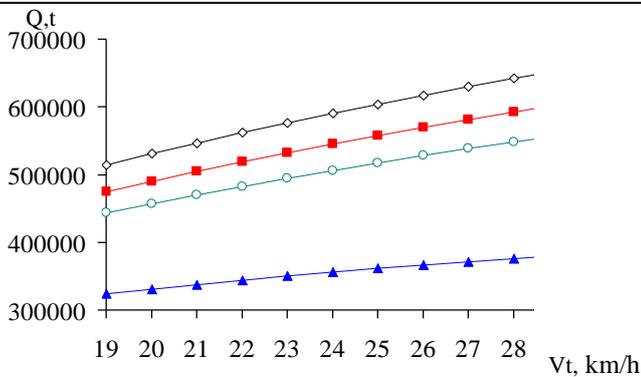


Fig. 3. Change in Q and P values as a result of Vt growth

According to the current theoretical bases, it is argued that with the increase in the distance of carriage of goods, the function measured by the quantity of goods delivered decreases, and the function measured in ton-kilometers increases.

The graphs presented in fig. 4 and table 4 based on the data obtained using mathematical dependencies 1, 3 and 2, 4 (according to the current theory, respectively, for Q and P), as well as 5, 7, and 6, 8, confirm the direct dependence for transportation output in ton-kilometers and the inverse dependence for the transportation output in tons. At the same time, the graphical dependences constructed using mathematical expressions 5, 6, 7 and 8 are located below the graphs constructed on the basis of the current theory, which also indicates the possible cause of the discrepancies between the planned and actual performance of the rolling stock.

The idle time of vehicles in freight areas ($t_{i/u}$) is determined primarily by the performance of loading and unloading mechanisms. According to the existing theoretical basis, it is believed that as a result of the reduction of t_{LU} , the output of the rolling stock increases.

TABLE IV. REGRESSION EQUATIONS AT CHANGING LGE

Math. dependence	Regression equation P = f(x)	Math. dependence	Regression equation Q = f(x)
2	$y = 0.1x^5 - 2.7x^4 + 93.0x^3 - 2829.0x^2 + 93108.5x + 2781209.6$	1	$y = 0.6x^4 - 22.1x^3 + 670.0x^2 - 19752.5x + 580199.7$
4	$y = 0.1x^5 - 3.0x^4 + 103.7x^3 - 4053.3x^2 + 90013.6x + 3012289.3$	3	$y = 0.7x^4 - 23.9x^3 + 725.7x^2 - 21393.6x + 628406.2$
6	$y = 0.1x^5 - 2.7x^4 + 86.6x^3 - 2600.1x^2 + 75036.6x + 3593242.2$	5	$y = 0.7x^4 - 23.6x^3 + 667.4x^2 - 18903.8x + 608900.2$
8	$y = -0.9x^4 + 41.3x^3 - 1615.5x^2 + 69602.4x + 2183574.5$	7	$y = 0.1x^4 - 5.3x^3 + 220.4x^2 - 9061.3x + 392084.2$

It was previously found out that this dependence can be described by the equation of the isosceles hyperbola. Hyperbolic character of dependence of transport products in tons and ton-kilometers at change of idle time of the rolling stock while performing loading and unloading operations remains unchanged in the calculations results with the use of mathematical expressions 5, 6, 7 and 8.

But just as before, the graphic dependences are located below the graphs, built on the basis of the current theoretical provisions (fig. 5, table 5), which also indicates a possible cause of discrepancies between the planned and actual performance of the rolling stock.

Q,t

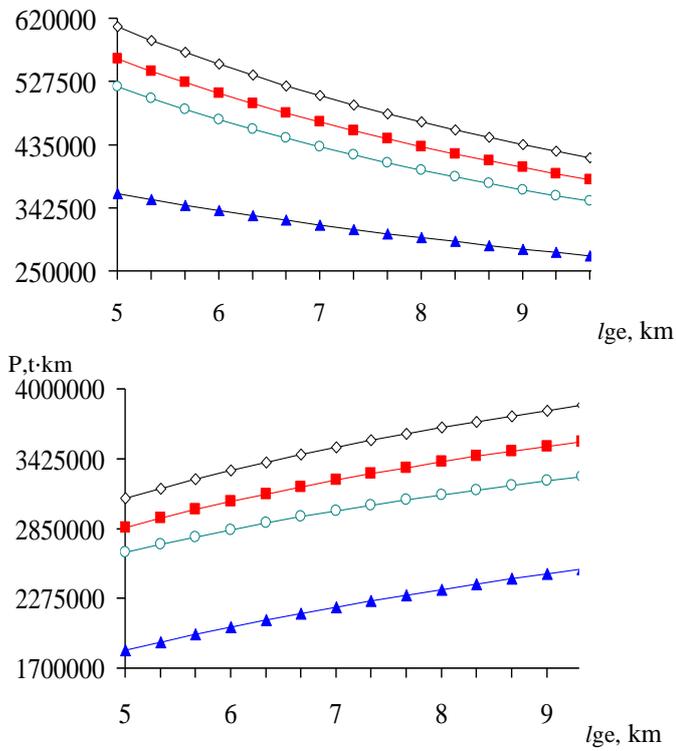


Fig. 4. Changing of values Q and P as a result of lge increase

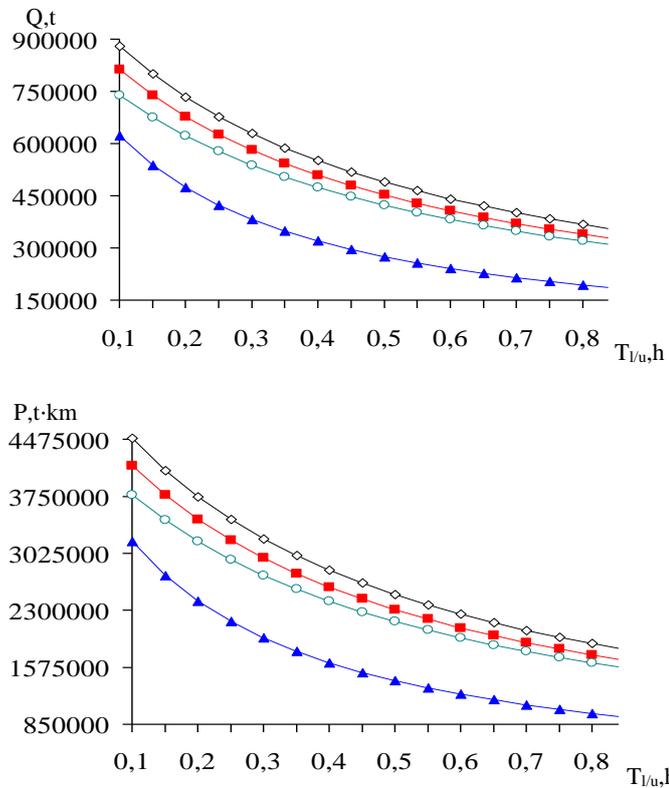


Fig. 5. Change in values Q and P as a result of T_{lu} growth

TABLE 5. REGRESSION EQUATIONS AT CHANGING T_{lu}

Math. dependence	Regression equation P = f(x)	Math. dependence	Regression equation Q = f(x)
2	$y = 0.2x^6 - 6.2x^5 + 28.5x^4 - 3970.7x^3 + 48596.9x^2 - 497449.1x + 4596357.9$	1	$y = -1.3x^5 + 44.2x^4 - 798.6x^3 + 9705.3x^2 - 85539.0x + 901246.6$
4	$y = 0.1x^6 - 7.8x^5 + 238.8x^4 - 4300.6x^3 + 53609.4x^2 - 548780.2x + 4978251.1$	3	$y = -1.4x^5 + 46.8x^4 - 843.2x^3 + 10611.7x^2 - 106643.2x + 976127.7$
6	$y = 0.1x^6 - 5.3x^5 + 165.9x^4 - 3061.7x^3 + 39676.0x^2 - 424290.5x + 4156306.5$	5	$y = -x^5 + 31.5x^4 - 600.3x^3 + 7879.6x^2 - 79606.0x + 815962.0$
8	$y = 0.3x^6 - 21.8x^5 + 613.9x^4 - 9548.9x^3 + 91643.4x^2 - 622542.8x + 3726476.4$	7	$y = 0.1x^6 - 4.5x^5 + 118.4x^4 - 1962.3x^3 + 18361.5x^2 - 136951.5x + 824603.2$

V. CONCLUSION

The results of the research let us conclude that the classical mathematical models used for the planning and analysis of the main production activities of freight transport enterprises cannot give reliable results, because they do not take into account the negative impact of changes in the values of TOC on the vehicles operation. The improved models could be a more accurate tool for planning and analysis, but, like classical models, they do not take into account the discrete nature of the transport process and use the average values of technical and operational indicators in the calculations, which forces them to abandon the use of these models. That is why it is necessary to develop a new scientific approach that would correspond to modern ideas for vehicles operations in the delivery of goods on the routes of freight transport enterprises.

VI. REFERENCES

- [1] J. Auramo, J. Kauremaa, and K. Tanskanen, "Benefits of IT in supply chain management: an explorative study of progressive companies", *International Journal of Physical Distribution & Logistics Management*, 35 (2), 2005, pp. 82-100.
- [2] J. Matias, A. P.M. Rodrigues, and C. Pimentel, "Third-party logistics continuous improvement through integrated fleet management: the case of a transport company", *International Journal of Logistics Systems and Management*, 31 (1), 2018, pp. 39-68.
- [3] V.V. Varakin and E.O. Chebakova, "Method of the analysis of efficiency of the organizations of freight motor transport. Transport business of Russia" [*Transportnoye delo Rossii*], 6, 2011, 125-127 (in Russian)
- [4] Liu, X., Wang, J., Zhang, H. Research on comprehensive evaluation model of logistics enterprise based on special-line transportation (2010) ICLEM 2010: Logistics for sustainable Economic Development - Infrastructure, Information, Integration - Proceedings of the 2010 International Conference of Logistics Engineering and Management 387, pp. 3265-3271
- [5] Schneider, C. (2013). *Controlling für Logistikdienstleister: Konzepte, Instrumente, Anwendungsbeispiele*, Trends. Deutscher Verkehrsvlg Mai, 2013. 456 p.
- [6] Goods transport in large European cities: Difficult to organize, difficult to modernize. *Transportation Research Part A: Policy and Practice*, 41 (3), 2007, pp. 280-285.

- [7] Borodulina, S. A. (2012). Methodology for Process Management of A Road Transport Enterprise under Conditions of a Non-Stationary Development. Sankt-Petersburg: Publishing house of the St. Petersburg State Engineering and Economic University.
- [8] S. M. Mochalin, Operational management of transport logistics of the company cargo flows, V international. science.-practical. conf. Fundamental science and technology - promising developments, North Charleston, USA, Vol. 2, 2015, pp. 137-139.
- [9] E.S.Iskakova, M.O.Toropova, and N.V Shirochenko, "Automation of transport logistics management", Logistics systems in the global economy. No. 2. 2012. pp. 314-318 (in Russian).
- [10] M. Mochalin et al. "Modeling and optimization of the decision - making process in the transport system", MATEC Web of Conferences: Siberian Transport Forum TransSiberia 2018, Novosibirsk, Russia, 16-19 May 2018. - Les Ulis, 2018. 239. pp. 03015
- [11] S.M. Mochalin, L.V. Tyukina, T.V. Novikova et al. "Problems of inter-organizational interaction of participants in motor transport cargo shipments", Indian Journal of Science and Technology, 9 (21), paper № 95220, 2016, DOI: 10.17485/ijst/2016/v9i21/95220
- [12] Y.A. Shcherbanin, "Transport and transport infrastructure in 2030: some predictive estimates", Studies on Russian economic development. 24. No. 3. 2013, pp. 259-264.
- [13] N. S. Zakharov, R.A. Ziganshin, V. I. Nekrasov, et al. "Method of planning the needs in spare parts when operating special vehicles", International Journal of Pure and Applied Mathematics, 118, 2018, pp. 3735.
- [14] H. Werner, Supply Chain Management: Grundlagen, Strategien, Instrumente und Controlling. Wiesbaden. Springer-Verlag. 2013. 502 p. [In German: Werner, H. 1998. Supply Chain Management: Principles, Strategies, Instruments and Control. Wiesbaden. Springer-Verlag].
- [15] T. Palander, "Environmental benefits from improving transportation efficiency in wood procurement systems", Transportation Research Part D: Transport and Environment, 44, 2016, pp. 211-218.