

Economic efficiency of road transport vehicles of fleet and its impact on commercial indices and production plan of a motor transport enterprise

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Abstract. At the current stage of development of the branch of motor transport in Ukraine, satisfactory equipment of enterprises with the fixed assets, particularly motor transport enterprises, is one of the main problems. Fleet of road transport vehicles of those enterprises needs almost complete renovation, and productive-technical base for maintenance inspection and repair of transport requires complete technical re-equipment. The aim of the work is to develop theoretical approaches and practical recommendations concerning maintenance of road transport vehicles of motor transport enterprises, choice of the type of transportation means and determination of the necessary number of vehicles depending on the production plan of their operation.

1 Introduction

Pollutant emissions from vehicles continue to affect human health and hinder the achievement of the Kyoto targets. Transport is not the only factor in air pollution. However, gas emissions from the streets can have a negative effect on the general health of the community. Moreover, road traffic is a source of fine and overfine emissions in cities. Scientific research shows that these particles have a serious impact on human health. The transport network in Ukraine is quite dense, the number and activity of vehicles in cities is large, and the damage to the environment is very significant. The main reasons for this are outdated engine designs, the fuel used (gasoline, not gas or other less toxic substances) and poor traffic organization, especially in cities, at intersections.

The situation is aggravated by the fact that automobile emissions are concentrated in the surface layer of air - precisely in the zone of our breathing. In addition, domestic cars are much more environmentally "dirtier" than many Western models: they spend more fuel per 100 kilometers, which means they pollute the air more.

Every year the European Union countries, which are the principal partners of Ukraine in foreign-economic field, strengthen the requirements to technical and ecological conditions of motor vehicles. Hence, without urgent actions concerning their renovation, it will be impossible for most Ukrainian motor vehicles to enter most of those countries and the country can lose its positions at the market of international road transportation. Therefore, there is a need to justify the renewal of the rolling stock of modern motor transport enterprises.

Unsatisfactory level of the fleet of motor transport vehicles of domestic transporters is often the reason for restrictions of the quotas of permissions for transportation by different countries. Nowadays, 10.7 thousand motor transport vehicles require urgent substitution. Thus, there is a necessity of renovation of motor transport vehicles that sufficiently increases quality of transportation services, and considerably reduces expenditures for transportation. Moreover, there is a problem of preliminary analytical research concerning argumentation of the necessity of renovation of motor transport vehicles and choice of the type of transport vehicles depending on different factors.

The aim of the work is to develop theoretical approaches and practical recommendations concerning argumentation of renovation of motor transport vehicles of motor transport enterprises, choice of the type of transport vehicles and determination of the required amount of them depending on the production plan of vehicles operation.

Implementation of the set goal determines the necessity to solve the following tasks:

- 1) analysis of the current fleet conditions at motor transport enterprises (on the example of a typical one);
- 2) determination of a production plan for operation of vehicles at the enterprise;
- 3) completing of the plan of maintenance and production plan of maintenance inspection and repair of motor vehicles at the enterprise;
- 4) determination of the necessary number of workers of the motor transport enterprise and total wages fund;
- 5) determination of the calculation of motor transportation costs;
- 6) argumentation of renewed motor transport vehicles of motor transport enterprises and estimating of all

- indices of the enterprise with a new type of motor transport vehicles;
- 7) development of an economic-mathematical model for estimation of transportation costs;
 - 8) choice of an optimal type of motor transport vehicles fleet of motor transport enterprises depending on transportation costs.

2 Literature review

The impact of each of the groups of factors on choice of motor transport vehicles of motor transport enterprises was studied and considered in many works. Such scientists as Volkov V.P., Belousov E.V., Shpakov V.I., Rudometkyn V.P., Savchuk V.P., Marmut I.A., Kryvoshapov S.I. [43] pay much attention and have got important practical results, which substantiate the process of projecting of motor transport enterprises. Hovorushchenko M.Ya., Varfolomeiev V.M., Voloshyna N.A. [24] supply the project support for formation of a productive-technical base of enterprises of motor vehicle transport; Kanarchuk V.Ye., Levkovets P.R., Melnychenko O.I. [25] propose methods, models and algorithms of management of the processes of cargo conveyance in a transportation complex. Despite the existing arsenal of research by scientists on contemporary issues related to the rolling stock of the fleet, the process of transportation management, etc. these issues have not been sufficiently studied from the point of view of calculating economic efficiency, how the structure of the existing fleet can affect economic indicators and the production program. However, while the system of car operation is a dynamic one both from the side of changes of fuel consumption, capacity and regimes of employment, the regularities concerning reduction of the indices of operation properties of vehicles are changed and thus, they require further continuous investigations.

Development of any enterprise is based on its capability of dynamic response to transformations in the market conjuncture. In its turn, it requires application of flexible business-models, skills to adapt the existing strategic plans to the requirements of market participants. However, in spite of the enterprise' attempts to dynamic development, the main task of management is to secure stability of its development under market conditions. The issue of sustainable development of enterprises is studied in the scientific works by Garetti, M. and Taisch, M. [20] and Gunasekaran, A. and Spalanzani, A. [23], which consider the main factors, preventing such development under conditions of innovative market transformation. Martínez-Costa, C., Mas-Machuca M., Benedito E. and Corominas A. [27] stresses the necessity of strategic planning of production capacities by application of mathematical models of programming. A Peymankar, M., Dehghanian, F., Ghiami, Y. and Abolbashari, M.H. [31] describe the problem of formation of reserve stocks of accessories for maintenance of internal production capacities.

Permanent development of motor transport enterprises largely depends on the ability of appropriate

and qualitative maintenance inspection of motor transport vehicles, securing operating reliability and permanent financial income. In the works by Zhang, Y., Andrews, J., Reed, S., Karlberg, M. [47], Gary, L., Amos, Ng H.C., Tehseen, A [21], main stress is made on the problems of modeling and optimization of the processes of maintenance of production capacities of enterprises. Considering the dominating problem of ecology and environmental protection, the works by Ajukumar V.N., Gandhi O.P. [2] and Ba, K., Dellagi, S., Rezg, N., and Erray, W. [4] are of a considerable scientific interest. The mentioned works study the problems of obligatory consideration of ecological standards and requirements while performing maintenance inspection in order to reduce the negative impact on the environment.

The scientific work by Diaz, N., Pascual. R., Ruggeri. F., Lopez Droguett, E. [11] proposes an original methodology for determination of a multidimensional policy of maintenance inspection for machines, which require use of several time scales for their depreciation processes. Such idea of the author can be considered as modification of the traditional approach, which usually applies a unique time scale and a uniform age limit for performance of the maintenance inspection.

3 Methodology

To argue economic efficiency of motor transport vehicles of a fleet and its impact on commercial indices and production plan of a motor transport enterprise, the researchers used the following methods of investigation, particularly economic analysis and comparison (applied for systematization of restrictions of authorized load on the axle and authorized weight for transportation; graphical (for visual depiction of the argued models); mathematical modeling (for argumentation of a dependence of the annual amount of work of MI and OR at the enterprise depending on the weight of cargo, transported by a single road train); abstract-logical – for theoretical generalization and formation of conclusions; inductive and deductive – for gathering and systematization of characteristics of motor transport vehicles of the motor transport enterprise concerning commercial indices and production plan; scientific generalization and systematization.

To consider the impact of different factors on transportation costs, the research has developed an economic and mathematic model of operation of a motor transport enterprise in Microsoft Office Excel. It supplies gradual determination of the following data for the four grade composition of the enterprise fleet, particularly:

- 1) production plan of vehicles operation at the enterprise;
- 2) amount of depreciation payments for motor vehicles renovation;
- 3) calculation of motor transportation costs;
- 4) gross income, accounting and estimated profit;
- 5) level of economic efficiency of motor transport vehicles of a fleet;
- 6) mileage emissions of pollutants for all automobiles.

Introducing initial data into the program for calculation of a production plan forces the necessity of restriction of full weights and authorized load of transport vehicles.

It is expected to get harmonization of a maximum weight and overall dimensions of motor transport vehicles and trailers for their registration in the member-countries according to the Directive 96/53/EU (1996), which sets maximum authorized dimensions for national and international transportation for some kinds of vehicles, circulating within the Community. It also determines maximum authorized weight for international transportation, because the above-mentioned Directive deals only with transport conveyances on the territory of member-countries, but it does not concern the technical requirements, set in the Directive 70/156/EUC (1970). Thus, to estimate the impact of characteristics of motor transport vehicles of the fleet of a MTE on commercial indices and production plan, it is necessary to limit the cargo weight within the range from 16 to 28 tons.

To determine the dependence of the studied indicators, it is necessary to make correlation-regression analysis and develop economic-mathematic models. Correlation-regression analysis uses regression equation to determine the analytical form of the relation between variation of the characteristics x_i and y_i , to assess significance of the relation (F-criterion) and compactness of the relation (determination coefficient R^2) between the resultant and factorial features on the basis of regression analysis (Formula 1, 2); to interpret results of calculations and apply them for the following improvement of the activity [26].

$$F = \frac{\sum (\hat{y}_i - \bar{y})^2 / k_1}{\sum (y_i - \hat{y}_i)^2 / k_2}, \quad (1)$$

$$k_1 = m,$$

$$k_2 = n - m - 1,$$

where k_1, k_2 - are degrees of freedom;
 m — is a number of independent variables;
 n — is a number of observations.

$$R^2 = \frac{\sum (\hat{y}_i - \bar{y})^2}{\sum (y_i - \bar{y})^2}, \quad (2)$$

The work supplies qualitative assessment of a total impact of the studied factors on the resultant index by means of MS Office Excel. A complex interaction of all factors with the resultant index can be described by a polynomial regression of n-order [5, 16, 22]:

$$y = a_0 + a_1 x + a_2 x^2 + a_3 x^3 \dots + a_n x^n + \varepsilon. \quad (3)$$

A theoretical base for the study of cargo conveyance rules, moving of transport vehicles according to the set principles of control for keeping to the laws in the field of transport and conveyance of cargo in the countries of the EU is made by the following sources, in particular (Regulation (EC) No 1071/2009 [34]; Regulation (EC) No 561/2006 [33]; Regulation (EU) No 165/2014 [36]; Regulation (EU) No 182/2011 [35]). Concerning Ukraine, the field is regulated by such regulatory acts, as the Law of Ukraine About transport [40], the Law of Ukraine About conveyance of dangerous cargo [41], the

Law of Ukraine About technical guidelines and compliance assessment [39], the Resolution of the Cabinet of Ministers of Ukraine About transit of large and heavy motor vehicles by motor ways, streets and railway crossings [37], etc.

Empiric researches are grounded on the Directive of the European Parliament (Directive (EU) 2015/719 [13] concerning determination of maximum authorized dimensions and maximum authorized load for transport vehicles while performing national and international transportation. The statistical data about the volume of cargo conveyance in the EU countries and Ukraine are supplied by the State Statistics Committee of Ukraine [38] and Eurostat [15]. Review of the market of motor transport vehicles in Ukraine for examination of conditions and average age of motor vehicles is made on the basis of the investigations by Movcharenko V. and Hlyvenko, V. [30]. The applied algorithms for analyzing of statistical data, their aggregation were based on the approaches and principles proposed by Wasserman, L. [45] and Mogull, Robert G. [29].

Correlation-regression analysis was made on the ground of theoretical approaches of such scientists, as [3, 9, 16-18, 42, 44, 46].

The issues of optimization and modeling of the structure of motor vehicles fleet of an enterprise from the position of not only economic benefit, but also impact on the environment are considered by Abdi A. and Taghipour S. [1] and Micheli, G. J. L. and Mantella, F. [28].

The price approach and minimization of time for maintenance of motor transport vehicles according to the approaches, proposed by Erbe H., Lung B., and Morel G. [14] and impact of heterogenic structure of the fleet, which is described in the work by Guerrero de la Peña, A., Davendralingam, N., Raz, Ali K., DeLaurentis, D., Shaver, G., Sujan, V., Jain, N. [23], are considered while developing the economic-mathematical model of costs calculation for transportation services supplied by the enterprise.

4 Empirical analysis and discussions

A transporter is interested to increase maximum capacity of a transport vehicle. Moreover, to secure long life of road cover it is necessary for all transporters to keep to the maximum authorized figures of total weight and load on the axle of a vehicle, set by auto-producers. In Ukraine, such weight constitutes 44 tons, load on the axle – 10 tons. Transit of transport vehicles with large load on the axle on the motor ways causes considerable shortening of the period of road cover exploitation and its early destruction. Continuous growth of traffic intensity and increase of the weight motor vehicles cause of physical deteriorations of the constructions of bridges.

Similar restrictions are set in all neighboring countries. For instance, Table 1 presents figures of authorized loads on the axle in such countries as Belgium, Italy, England, Germany, France, Poland, Netherland, Luxemburg, Denmark, Greece, Spain (Council Directive 2007/46/EC of 5 September [8]).

Table 1. Maximum authorized axle load and maximum authorized weight for transportation in the countries of the EUC

Dimensions	Country										
	Belgium	Italy	England	Germany	France	Poland	Netherlands	Luxemburg	Denmark	Greece	Spain
Load on road cover, ton/sec											
- drive axle	12	12	10.5**	11	13	12	11	12	10	10	13
- single axle	10	12	10.2	10	13	10	10	10	10	10	13
- double-axle cart with the base from 1.3 to 1.8 m	20	19	18.5	18	21***	19	18	20	16	19	21
- three-axle cart with the base of 2.6 m	24-27*	26	22.9	24	24	24	-	27	24	26	-
Total weight, tons:											
- a single vehicle:											
2 axles	19	18	16.3	17	19	19	-	19	18	19	20
3 axles	28	24	24.5	24	26	26	-	26	24	26	26
4 axles	32	24	30.5	32	26	30	-	32	32	33	26
- trailer:											
2 axles	20	-	18	18	19	18	-	-	20	19	20
3 axles	30	-	22.4	24	24	24	-	-	24	24	26
- trailer road train:											
4 axles	38	40	32.2	35	38	37	-	38	38	38	38
5 and 6 axles	44	44	32.5	40	40	40	50	44	48	38	38
- articulated road train:											
3 axles	29	30	24.4	27	-	29	-	-	-	29	-
4 axles	39	40	32.5	35	38	38	-	-	-	38	38
5 and 6 axles ****	44	44	38	40	40	40	50	44	48	38	38

* 27 tons in case of pneumatic suspension and coupled wheels

** 10.5 tons for articulated road trains with the total weight above 32.5 tons

*** In case of the base of 1.35 m and more, but less than 1.8 m

**** 40 tons for container vehicles ISO

Source: Adapted by authors based on Council Directive 2007/46/EC of 5 September [8]. Retrieved from: <http://data.europa.eu/eli/dir/2007/46/oj>

Exceeding of the weight brings responsibility in the form of penalties or fines. Control for weight parameters of vehicle should be performed by state organizations, i.e. services of motor ways, customs service, and traffic inspection.

It is worth noting that Ukrainian industry does not produce motor transport vehicles, which meet the mentioned requirements and there is no hope the one will be initiated in the nearest future [32].

In Ukraine, there are above 2 thousand enterprises and organizations of different forms of ownership, which make international conveyance of cargo by motor transport vehicles and work according to different transport tariff. Transport tariff is the price for conveyance of a material object in space and it includes tariffs for cargo conveyance. Cargo transport, while transporting products from producers to consumers, increases their value. Cargo transportation is based on socially required labor expenditures for conveyance of cargo. It determines the price of transportation, which is monetary revealed in the form of transport tariff.

The price of transportation, which is set in the agreement between the parties, has got the form of advanced fixed payment in the process of transport development. Tariffs set the price for transportation in advance. They are announced for information and applied to all senders and obtainers of a cargo. The level of tariffs for transportation is determined according to

standard expenditures per a unit of transport work, level of profitability and tax payment.

Determination of transport tariffs is based on the costs of cargo conveyance, including the value of production assets, which are used in the process of transportation, salary of workers and other expenditures. Costs of transportation depend on the size of cargo flow, its content, direction, distance of conveyance, kind of vehicles and others.

The work determines a production plan of the enterprise for the mentioned restriction of capacity and for setting of an annual amount of cargo transportation under the set amount according to the data of the operating enterprise.

A production plan is the amount of work, which is performed by a MTE for a definite period. Figures of the plan depend on the number, capacity of the fleet, as well as on the organization of transportation and character of the cargo, influencing employment of the capacity of transport vehicles and others.

Making calculation of the production plan, one sets automobile-days of stay at the enterprise, automobile-days of work, automobile-hours of work, total operational kilometers of the vehicles, operational kilometers with cargo.

At the current stage the calculation determines the total annual number of transportation with cargo, annual amount of cargo conveyance and transportation, annual

production capacity per one automobile-ton in tons and ton-kilometers.

Projecting of new STM and MTE, reconstruction of the operating ones and technical re-equipment of the operating production-technical basis requires application of a set of regulatory documents, which are based on the recent findings of science and technics, new international and national standards in the field of requirements to exploitation of technological properties of constructions. The principal document is the operating guide of the plant. Standards of maintenance inspection (MI) and repair of motor vehicles are set by the production plant and cannot be corrected by the enterprise.

The plan of maintenance determines the number of MI and MR (hereafter actions) and their labor intensity in a year including OR per one vehicle, and production

plan – annual and variable number of impacts and annual amount of work in the whole fleet of motor vehicles. To complete the plan of maintenance it is necessary to know the average daily operational kilometers of a vehicle, repetition and labor intensity of impacts, annual duration of operating period and annual operational kilometers of the vehicle.

Amount of production of MI and OR sets the total annual labor intensity of work of each kind and is a basis for estimations of the enterprise need for labor force, workshop bays and equipment. The authors of the research have made calculations of the dependence of the annual amount of work of MI and OR at the enterprise depending on the weight of cargo of a single road train, transporting from 16 to 28 tons (Fig. 1).

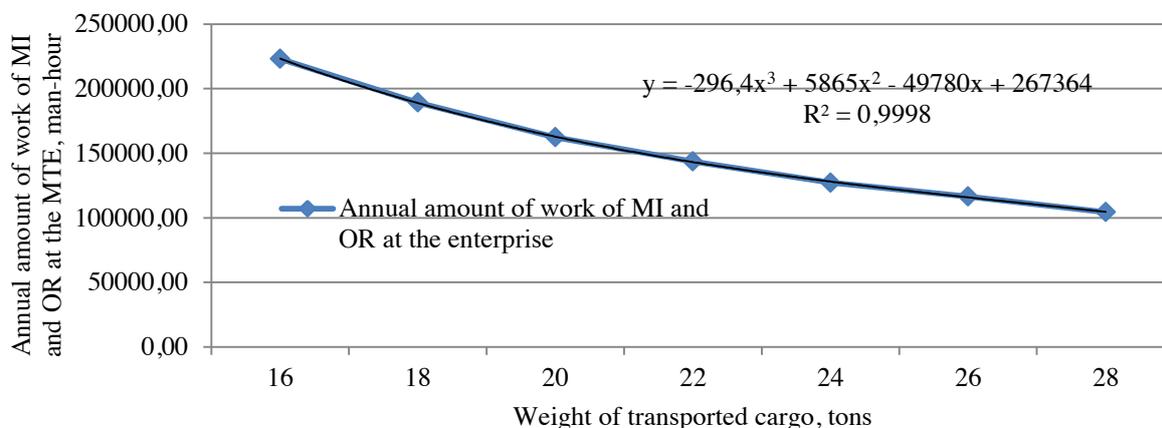


Fig. 1. Relation of the annual amount of work of MI and OR at the enterprise depending on the weight of cargo, transported by a single road train

Note. Estimation of essentiality of the relation according to F-criterion: $4,68970782 > 4,400918685$ under the level of significance $\alpha = 0,09$ and the figure of the degrees of freedom $k_1 = 1$ and $k_2 = 5$. The developed polynomial model of the third order is adequate to the reality and connection between the studied features, included in the regression model, are essential and not random.

Source: author's calculation based on The State Statistics Committee of Ukraine [38], Retrieved from: <http://www.ukrstat.gov.ua/>

Extra work includes the work for maintenance of the vehicle service station (repair and maintenance of technological equipment, instruments, repair and servicing of engineering equipment, networks and communications, maintenance of compressor equipment), transportation work (conveyance of units, aggregates, materials and others on the territory of the vehicle service station), acceptance, storage and issuance of material items, driving of motor transport vehicles for inspection and repair), cleaning of production premises and territory of the enterprise.

The availability factors of motor vehicle fleet can be improved by increase of the amount of control and diagnostic work while performing MI and repair. For the mentioned type of new automobiles, the factor increases 25-30 % of the total amount of the work of MI and repair. Normally, the time, which is spent for measuring of the parameters determining technical conditions, on average equals 5-10 % of the total time for diagnostics, other 90-95 % are spent for installation and disassembling of sensors, for setting of an appropriate mode of the automobile operation and processing of the results of diagnostics).

Making renovation of the motor transport vehicle it is necessary to consider increase of the amount of diagnostic works for new automobiles by 15-20 % depending on the automobile model. It is connected with the necessity to use specific diagnostic equipment and apply the function of self-diagnostics.

Generally, for the set task, under a shift of cargo weight of a single road train, which transports from 16 to 28 tons, and applying the developed program in calculations, it is determined that there is an impact of capacity on the shift of an annual amount of work of MI and OR at the enterprise (Fig. 1). However, the dependence confirms reduction of the amount of work of MI and OR at the enterprise due to increase of the weight of conveyed cargo by a single road train, connected with a change of the needed number of vehicles, regardless of increase of the amount of diagnostic work.

The goal of the obtained polynomial regression is to simulate the nonlinear dependence of the annual amount of work of MI and OR of the enterprise depending on the weight of cargo of a single road train. This polynomial function is used as an empirical method for

approximating a curve. 3rd degree polynomial regression $y = -296,4 \cdot x^3 + 5865 \cdot x^2 - 49780 \cdot x + 267364$ describes a trend with variable acceleration of change. Coefficient a_3 characterizes the nature of the acceleration change. With $a_3 = -296,4$ the acceleration decreases.

The value of the determination coefficient characterizes the quality of the polynomial model and indicates the presence of a high correlation in the model, which indicates a close relationship between the resultant and factorial features: the weight of cargo of a single road train and the annual amount of work of MI and OR for the enterprise. The value of the R-square, the multiple coefficient of determination, indicates the correspondence of the initial data and the regression

model, since its value is close to 1 and amounts to $R^2 = 0,9998$. Grade 3 polynomial regression explains 99,98% of the variation, which means that the model factors studied are correctly selected. The 99,98% variation in the annual volume of maintenance and repair work in the enterprise is explained by such a factor as the mass of a single freight train load, which was introduced into the correlation-regression model. The calculation indicates a high accuracy of approximation.

Applying the methods of use of the adopted program, the research also determines a dependence of the needed area of operating zones at the enterprise depending on the weight of cargo, transported by a single road train (Fig. 2).

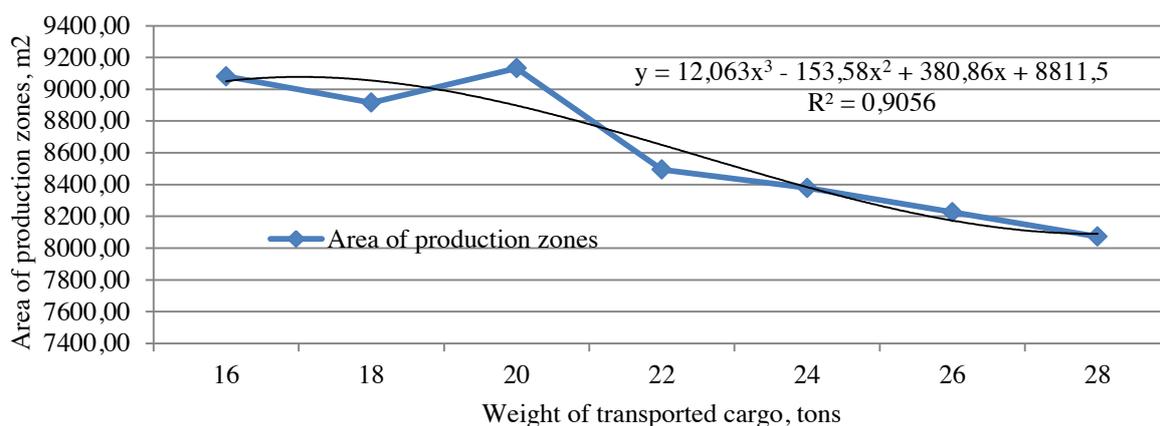


Fig. 2. Dependence of the required area of production zones at the enterprise referring to the weight of cargo, transported by a single road train

Note. Estimation of essentiality of the relation according to F-criterion: $4,977161032 > 4,400918685$ under the level of significance $\alpha = 0,09$ and the figure of the degrees of freedom $k_1 = 1$ and $k_2 = 5$. The developed polynomial model of the third order is adequate to the reality and connection between the studied features, included in the regression model, are essential and not random.

Source: author's calculation based on The State Statistics Committee of Ukraine [38], Retrieved from: <http://www.ukrstat.gov.ua/>

Number of the workshop bays of the enterprise for repair-servicing actions under equal distribution of work between shifts is determined according to the average labor intensity. Under unequal distribution of work between the shifts, calculation of the number of workshop bays is made according to labor intensity of the work in the most intensive shift. The coefficient of working time managing at a workshop bay depends on the time, spent for performance of a definite action, for setting and driving of an automobile out of the workshop bay, dock or hoist, for moving of the automobile from one workshop bay to another at transition workshop bays, or flow lines, on fault time of the automobile for liquidation of unexpected failure occurrence, etc.

The goal of the obtained polynomial regression is to simulate the nonlinear dependence of the needed area of operating zones at the enterprise depending on the weight of cargo, transported by a single road train. This polynomial function is used as an empirical method for approximating a curve. 3rd degree polynomial regression $y = 12,063 \cdot x^3 - 153,58 \cdot x^2 + 380,86 \cdot x + 8811,5$

describes a trend with variable acceleration of change. Coefficient a_3 characterizes the nature of the acceleration change. With $a_3 = 12,063$ acceleration increases.

The value of the R-square, the multiple coefficient of determination, indicates the correspondence of the initial data and the regression model, since its value is close to 1 and amounts to $R^2 = 0,9056$. Grade 3 polynomial regression explains 90,56% of the variation, which means the selection of the model factors studied is correct. A 90,56% variation in the size of the needed area of operating zones at the enterprise is explained by such a factor as the weight of cargo, transported by a single road train, which was introduced into the correlation-regression model. The calculation indicates a high accuracy of approximation.

The work presents calculation of the required number of workshop bays for MI and OR at the enterprise depending on the weight of cargo, transported by a single road train (Fig. 3).

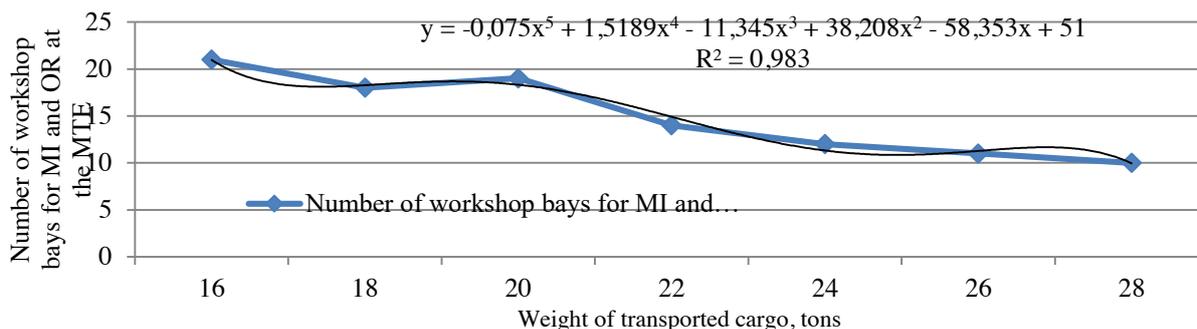


Fig. 3. Relation of the required number of workshop bays for MI and OR at the enterprise depending on the weight, transported by a single road train

Note. Estimation of essentiality of the relation according to F-criterion: $5,00008534 > 4,400918685$ under the level of significance $\alpha = 0,09$ and the figure of the degrees of freedom $k_1 = 1$ and $k_2 = 5$. The developed polynomial model of the fifth order is adequate to the reality and connection between the studied features, included in the regression model, are essential and not random.

Source: author's calculation based on The State Statistics Committee of Ukraine [38], Retrieved from: <http://www.ukrstat.gov.ua/>

This polynomial function is used as an empirical method for approximating a curve. Grade 5 polynomial regression $y = -0,075 \cdot x^5 + 1,5189 \cdot x^4 - 11,345 \cdot x^3 + 32,208 \cdot x^2 - 58,353 \cdot x + 51$ describes a trend with variable acceleration of change. Coefficient a_5 characterizes the nature of the acceleration change. When $a_5 = -0,075$ acceleration decreases.

The value of the R-square indicates the correspondence of the initial data and the regression model, since its value is close to 1 and amounts to $R^2 = 0,983$. Grade 5 polynomial regression explains 98,3% of the variation, which means the selection of the model factors studied is correct. The variation in the required number of workshop bays for MI and OR for the enterprise by 98,3% is due to such a factor as the weight of cargo, transported by a single road train, which was introduced into the correlation-regression model. The calculation indicates a high accuracy of approximation.

The research supplies calculation of expenditures for fuel, lubricants and other operation materials, and expenditures for maintenance inspection and repair. It specifies the number of drivers and wages fund. Payment for work is done according to the hour-rate and price-rate form. The estimation of wages fund is based on hour rate, acting in the field; regulation about bonuses; payment of extra money for the previous period; annual plan of work. Salary is composed from main and supplementary fund. The principal salary includes payments according to a tariff, i.e. is calculated according to a tariff pay of workers of the motor transport enterprises.

Basing on the made calculations according to the articles of expenditure, the researchers determine the total amount of expenditures for transport conveyance and operation of specific transport, and supply calculation of transportation services costs (Fig. 4).

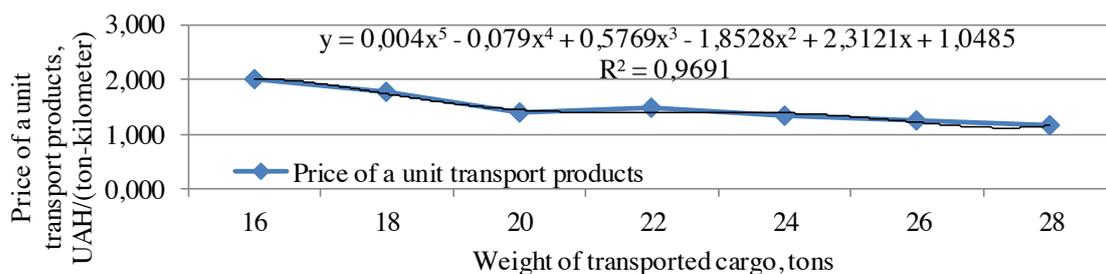


Fig. 4. Dependence of the price of a transportation service at the enterprise referring to the weight of cargo, transported by a single road train

Note. Estimation of essentiality of the relation according to F-criterion: $5,00689407 > 4,400918685$ under the level of significance $\alpha = 0,09$ and the figure of the degrees of freedom $k_1 = 1$ and $k_2 = 5$. The developed polynomial model of the fifth order is adequate to the reality and connection between the studied features, included in the regression model, are essential and not random.

Source: author's calculation based on The State Statistics Committee of Ukraine [38], Retrieved from: <http://www.ukrstat.gov.ua/>

This polynomial function is used as an empirical method to approximate the curve. A 5th degree polynomial regression $y = 0,004 \cdot x^5 - 0,079 \cdot x^4 + 0,5769 \cdot x^3 - 1,8528 \cdot x^2 + 2,3121 \cdot x + 1,0485$ describes the trend with variable acceleration of change. The coefficient a_5 characterizes the nature of the acceleration change. At $a_5 = 0,004$ the acceleration increases.

The value of the determination coefficient $R^2 = 0,9691$ characterizes the quality of the polynomial model

and indicates the presence of a high correlation in the model, which indicates a close relationship between the resultant and factorial features: the price of a transportation service at the enterprise and the weight of cargo, transported by a single road train. The variation in the price of transport products at the enterprise by 96,91% is explained by such a factor as the weight of cargo, transported by a single road train. The calculation indicates a high accuracy of approximation.

Relation of the price of a transportation service at the enterprises (Qprod) to the cargo weight of a single road train is described by the polynomial

$$Q_{prod} = 6 \cdot 10^{-5} \cdot q^5 - 0,007 \cdot q^4 + 0,307 \cdot q^3 - 6,6234 \cdot q^2 + 70,499 \cdot q - 294,9, \text{UAH/ton}$$

where q – is the weight of cargo, transported by a

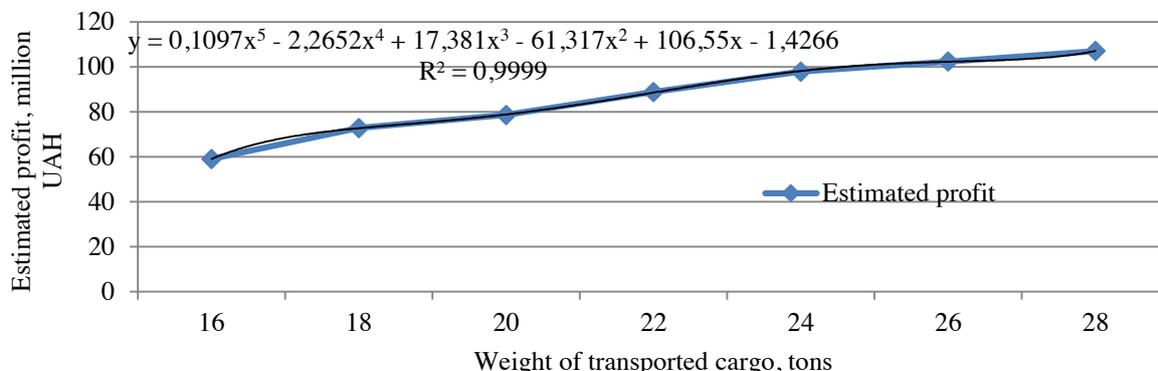


Fig. 5. Dependence of the estimated profit of the enterprises referring to the weight of cargo, transported by a single road train
 Note. Estimation of essentiality of the relation according to F-criterion: $5,000239312 > 4,400918685$ under the level of significance $\alpha = 0,09$ and the figure of the degrees of freedom $k1 = 1$ and $k2 = 5$. The developed polynomial model of the fifth order is adequate to the reality and connection between the studied features, included in the regression model, are essential and not random.
 Source: author's calculation based on The State Statistics Committee of Ukraine [38], Retrieved from: <http://www.ukrstat.gov.ua/>

The goal of the obtained polynomial regression is to simulate the nonlinear dependence of estimated profit of the enterprises depending on the weight of cargo, transported by a single road train. This polynomial function is used as an empirical method for approximating a curve. Grade 5 polynomial regression $y = 0,1097 \cdot x^5 - 2,2652 \cdot x^4 + 17,381 \cdot x^3 - 61,317 \cdot x^2 + 106,55 \cdot x - 1,4266$ describes a trend with variable acceleration of change. The coefficient a_5 characterizes the nature of the acceleration change. When $a_5 = 0.1097$, acceleration increases.

The value of the R-square indicates the correspondence of the initial data and the regression model, since its value is close to 1 and amounts to $R^2 = 0,9999$. The 5th degree polynomial regression explains 99,99% of the variation, which means the selection of the model factors studied is correct. The 99,99% variation in the estimated profit of the enterprise is explained by such a factor as the weight of cargo, transported by a single road train, which was introduced into the correlation-regression model. The calculation indicates a high accuracy of approximation.

Results of the calculation of impact of different factors on costs of transportation with application of the economic-mathematical model of the motor transport enterprise performance are presented in the Table 2.

5 Conclusions

Article analyzed the technical condition of the existing fleet of domestic motor transport enterprises and the factors affecting the cost formation of motor transport services. Among these factors, the following are highlighted: annual amount of work of MI and OR,

single road train.

To calculate the balance profit, it is first necessary to calculate the amount of earnings of the MTE from supply of transportation services. Earnings from transportation are calculated as a product of the amount of supplied services and the acting tariff (Fig. 5).

required area of production zones, number of workshop bays for MI and OR, price of a transportation service.

The study of the impact on the motor transport enterprises of each of these factors has previously been given enough attention and important results have been obtained for practice. However, since the automobile operating system is a dynamic system both from the side of changes in fuel consumption, load capacity and usage modes, patterns of decreasing performance indicators of automobiles are changing and, therefore, they need constant further research.

The work determines a production plan for operation of motor vehicles at the enterprise for the set amount of transportation work for the four grade motor transport vehicles of the fleet by application of the developed economic-mathematical model of a motor transport enterprise performance. It contributes to investigation of the impact made by different factors on transportation costs. The researchers have also developed a polynomial for calculation of the costs of motor transportation, depending on the cargo weight of a single road train.

The obtained research results are of practical importance. The proposed approach can be used in the practical activities of domestic and foreign motor transport enterprises.

Studies have shown that the total emissions of pollutants do not grow, but, on the contrary, can decrease even with an increase in the mass of the transported cargo. In general, we believe that there is a need to improve or replace the main components of the characteristics of the rolling stock of MTE's vehicle fleet, since this will increase the carrying capacity of the road train, reduce the level of emissions into the environment, and this, in turn, can lead to an improvement in the level of environmental friendliness.

Table 2. Impact of the characteristics of motor transport vehicles of the MTE fleet on commercial indices and production plan

Index	Figure						
Weight of transported cargo, ton	16	18	20	22	24	26	28
List number of motor vehicles	137	116	100	88	78	71	64
Annual amount of work of MI and OR at the MTE, thousand man-hours	223035.4	189240.1	162389.0	143644.7	127222.6	116466.5	104425.0
Estimation of the number of workshop bays	21	18	19	14	12	11	10
Number of principal producing workers by the kinds of work	123	106	91	80	71	65	58
Number of supplementary producing workers by the kinds of work	41	35	28	26	24	22	20
Number of drivers	241.00	205.00	176.00	155.00	137.00	126.00	113
Estimation of the area of production zones, m ²	9081.60	8915.55	9132.70	8494.05	8379.09	8225.81	8072.536
Wages fund of the MTE, UAH	1855306.69	1593949.05	1386655.60	1240548.89	1114136.47	1029164.95	938051.52
Variable expenditures, UAH	140768737.52	124417106.53	118666329.54	102533437.85	94624514.72	89471394.09	83848527.16
Price of a unit of motor transport products, UAH/(ton-kilometer)	2.005	1.765	1.384	1.486	1.326	1.244	1.161
Estimated profit, UAH	59011503.99	72801756.76	78590376.86	88832284.64	97907120.21	102360065.65	106997093.19
Total emission of pollutants, ton	554081.7713	474927.2325	395772.6938	369387.8475	316618.155	316618.155	263848.4625

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