Predicting the economic efficiency of the business model of an industrial enterprise using machine learning methods

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Abstract. The paper considers the problem of studying the impact of key determinants on the industrial enterprise business model economic efficiency and aims to build an optimal model for predicting the industrial enterprise business model effectiveness using neural boundaries. A system of key determinants key factors has been developed. Significant factors were later used to build neural networks that characterize the studied resultant trait development vector. The procedure for constructing neural networks was performed in the STATISTICA Neural Networks environment. As input parameters, according to the previous analysis, 6 key factor indicators were selected. The initial parameter is determined by economic efficiency. According to the results of the neural network analysis, 100 neural networks were tested and the top 5 were saved. The following types of neural network architectures, multilayer perceptron, generalized regression network and linear network were used. Based on the results of the neural network modeling, 5 multilayer perceptrons of neural network architectures were proposed. According to descriptive statistics, the best model was a multilayer perceptron, with the MLP 6-10-1 architecture, which identifies a model with 6 input variables, one output variable and one hidden layer containing 10 hidden neurons. According to the analysis of the sensitivity of the network to input variables, it was determined that the network is the most sensitive to the variable the share of electricity costs in total costs. According to the results of selected neural networks standard prediction, the hypothesis of the best neural network was confirmed as Absolute res., Squared res, Std. Res for the neural network MLP 6-10-1 reached the optimal value and indicate that the selected model really has small residues, which indicates a fairly high accuracy of the forecast when using it.

Keywords: neural networks, forecasting, business model, economic efficiency, digitalization, oil transportation company.

1 Introduction

The intensification of the digital transformation of industrial enterprises in general and oil transportation in particular necessitates the urgent introduction of digitalization tools and means, which should ultimately lead to an increase in the efficiency of economic entities. Given these circumstances, the issue of assessing the economic efficiency of the enterprise business model from the introduction of modern IT is relevant. Digitalization is one of the industrial enterprises' development key determinants, it is a field for the formation of economic efficiency of the enterprise business model. Therefore, the success of companies, including their performance indicators, depends on the effective use of modern IT in the activities of business entities. In such conditions, it is important to model the enterprise business model effectiveness in the digital transformation of economic systems.

2 Background

Examining the topic of modeling the effectiveness of economic entities, we can conclude that there are many methods, techniques, tools, methods of economic and mathematical modeling of the phenomenon. The difficulty of studying this phenomenon is that for different companies, the efficiency of activities can be affected by various factors. In addition, the concept of efficiency is not unambiguous, so it can be considered through the prism of various result indicators, influencing factors and their combinations. There is a huge variety of built efficiency models for different enterprises. Therefore, consider some of the proposed models of efficiency.

In particular, we can highlight economic production quantity model with learning in production, quality, reliability and energy efficiency. The article [9] of B. Marchi, S. Zanoni and M. Y. Jaber proposes a lot sizing model for a manufacturing company that includes the relevant learning outcomes, directly and indirectly, affecting its energy efficiency. The main result of the study is to show how learning in production and energy efficiency affects each other and the optimal lot size quantity [9]. In this paper, the model of the company's success is considered through optimization derived an economic order quantity model with controllable production rate.

A. Zakharov and S.-L. Jämsä-Jounela in [16] are suggested an iterative method for optimization of the plant profit rate is proposed avoiding the control saturation and is applied to the Pulp Mill benchmark model optimization. Three different static models describing the steady state values of the manipulated variables are constructed and used in the optimization. The results of the optimization are presented and compared against the straightforward single-step optimization of the plant economic efficiency [16].

In addition Agnieszka Bezat-Jarzębowska and Włodzimierz Rembisz proposed efficiency-focused economic modeling of competitiveness in the agri-food sector [2]. Authors believe that the main source of producers' competitiveness and growth is not the increase of input factors but the efficiency of their use. The efficiency-focused modeling presented in the paper bases on the production function, more precisely on the SFA method (the Stochastic Frontier Approach), which is appropriate primarily for samples with high randomness. In the analysis Cobb-Douglas and translogarithmic models are applied [2].

Katarína Teplická in the article [15] discussed methods of pricing for the selected product and examined the impact on economic efficiency of the enterprise. Through comparing of various methods could find out reserves in area of costs decreasing by the way it could satisfy demands of client at the level of target price. She compared calculating methods at the pricing of product. In present time customers influence considerably product's price by their demands and therefore producers, businessmen must nowadays adapt prices of their products to demands of customers [15].

Mykola Havrylenko, Vira Shiyko, Liliana Horal, Inesa Khvostina, and Natalia Yashcheritsyna [4] are propose two methods for evaluating the financial efficiency of a business model of industrial enterprises. In order to evaluate the financial efficiency of the business model of an industrial enterprise, a system of single indicators for assessing the financial condition of the enterprise by such components as financial stability, liquidity and solvency, business activity and profitability was formed. Fishburne's rule weights the major components of an integral measure of an enterprise's business model financial performance. In addition, an integral measure of the financial performance of the business model is modeled using the fuzzy set method and taxonomic analysis, which will help to evaluate the financial performance level of the business model more objectively. The comparative analysis of the obtained results by different methods of calculation of integral indicators is carried out [4].

When forming a business model of an enterprise, it is necessary to take into account risks in order to minimize them. One of the methods for diversifying risks is their insurance [8]. Insurance companies take these risks into account when forming a risk portfolio. The activities of any other enterprise are aimed at increasing the country's oil and gas economy. One of the important indicators of the economic state of the country is the gross domestic product [11], which depends on the successful operation of the enterprise on the basis of a well-built business model.

3 Methodology

Entering the digital space of industrial enterprises, including oil transportation companies, opens up new opportunities for these businesses, which are to use the following technologies and approaches: artificial intelligence and advanced analytics [12]; automation and robotics; digitization of business processes; use of the Internet of Things (IoT) [5], cloud computing [7], sensors, mobile devices [10], flexible development and design thinking.

The process of assessing the impact of these IT on the efficiency of the oil transportation company has remained unexplored [6]. However, to address this issue, industrial enterprises face problems in using such technologies. These include: low level of digital culture of domestic industrial enterprises, lack of leadership, expectation of economic opportunity for change, unclear economic effect of investment in the digitalization process, lack of the digital operations benefits clear vision and better management by senior management through the digitalization process. and non-production processes.

These problems of digitalization of industrial enterprises require the transformation of production and organizational structures of economic entities for the effective implementation of ICT. The new revolution requires the formation of such a system of organization and management of activities, which will ensure, based on the analysis of performance, not only the elimination of the causes of existing discrepancies, but also help to identify and prevent their occurrence.

Thus, there is a need to assess the effectiveness and efficiency of activities "before" and "after" the introduction of ICT and to monitor them constantly. Evaluating the effectiveness of enterprises business processes digitalization will allow on the basis of the digitalized business model of the enterprise to monitor the activities in general, identify problem areas of the entity, make optimal management decisions and experiment by using a digitalized business model (digital twin of the enterprise) without intervention into the actual production process.

It should be noted that the indicators for assessing the effectiveness of digitization may be different for different processes and can be both generalized and detailed for each business process or function.

Due to the large number of the digitalization process influence area on the efficiency of the industrial enterprise digitalization effectiveness determining model will be:

$$E_d = \sum_{i=1}^{n} \sum_{j=1}^{m} e_{ij} \tag{1}$$

where E_d – the overall efficiency of the enterprise digitalization; e_{ij} – unit efficiency of the *i*-th business process (function) from the *j*-th IT.

The tasks performed by the procedure of evaluating of an industrial enterprise business processes digitalization effectiveness is that:

- There is a search for problem areas during the interaction of employees of different departments in the process of information support and business processes;
- The main, additional and auxiliary directions of economic entities activity for the purpose of decomposition on digital business processes are defined;
- Prerequisites are formed for the construction of an orderly electronic document management system;
- The regulation of enterprise activity is established;

- The process of conducting experiments in the activities of the enterprise is possible in order to determine the strategies of enterprise development in the current conditions of enterprises operation.

To form a system for evaluating the effectiveness of digitalization of business processes of JSC "Ukrtransnafta" define its main stages, taking into account the peculiarities of the research enterprise. Figure 1 shows the stages of evaluating the JSC "Ukrtransnafta" business processes digitalization effectiveness.

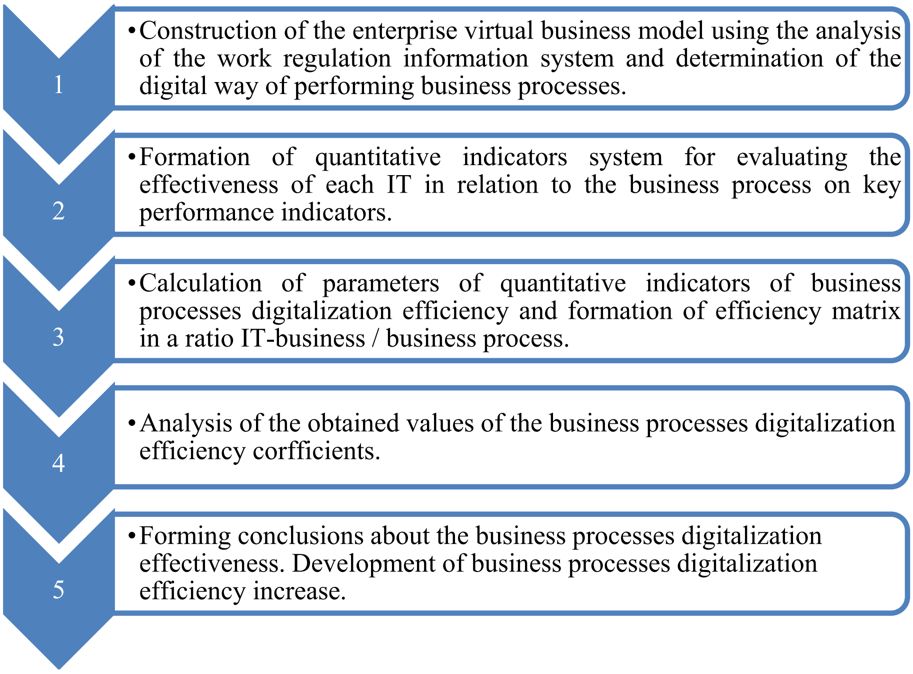

Fig. 1. Stages of evaluating the JSC "Ukrtransnafta" business processes digitalization effectiveness.

Given the peculiarities of the oil transportation companies activities, the business processes digitalization impact will be carried out directly on the tariffs. Thus, the model for determining the effectiveness of digitization must be built taking into account the sequence of the researched enterprise business processes. Figure 2 defines the sequence of JSC "Ukrtransnafta" business processes.

At each of the above stages of oil transportation in the conditions of digitalization it is necessary to enter the digitization coefficient, which will eventually be reduced to an integrated indicator of activities digitization, which will reflect the synergistic impact of each stage digitization coefficients. Thus, taking into account the peculiarities of the oil transportation company business processes, the integrated indicator of digitalization, which must be taken into account when forming the main performance indicator – the tariff will take the form:

$$k_d = \prod_{i=1}^{n} k_i \qquad (2)$$

where k_d – synergetic digitization factor; k_i – digitization ratio on the i-th business process; i=1, …, n – the number of oil transportation business processes.

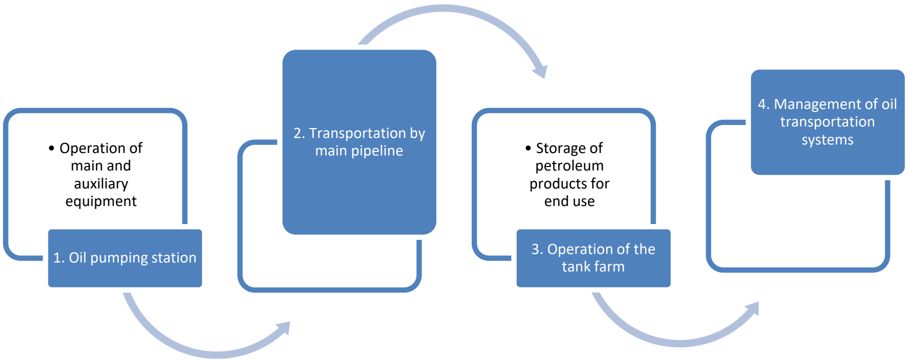

Fig. 2. The sequence of JSC "Ukrtransnafta" business processes.

It should be noted that tariffs for transportation of oil and oil products are established by the general rules of "Tariffs formation methods", which does not account for the development of alternative transportation markets, digitalization of the economy, accounting standards used time, resources, materials, regulated by the old technology, operating in the early 2000s.

Given that all of the above business processes form cost centers, it is necessary to determine the synergy of costs that arises from the digitalization of business processes. This synergetic effect of cost reduction will have a direct impact on the overall digitization ratio, which will increase economic efficiency. It is interesting for this company to form a correlation-regression model of the enterprise efficiency dependence through the introduction of ICT and reduce costs in each business process (fig. 2) of the studied enterprise. Based on the results of previous studies in the work, which indicate that for the investigated enterprise financial efficiency is at an average level and it increases at the end of the period, we consider it necessary to assess the economic efficiency of the oil company business model using computer economy methods to determine key success factors of the researched enterprise.

Therefore, the resulting indicator in the proposed correlation-regression model will be the efficiency as the ratio of net income from sales to the cost of goods sold. After all, when assessing the result of management must take into account not o nly the statement of the goal achievement, but also the optimal ways to achieve it. The choice of the regression or multifactor model type (analytical expression) depends on the type of factor features connection with the effective one. Thus, the initial form of the resulting function is reflected as a dependence:

$$Y = f(x_1; x_2; x_3 \dots, x_n), \qquad (3)$$

where Y – effective feature-function of the enterprise efficiency; x_1, x_2, x_3, …, x_n – factor features.

Figure 3 shows the dynamics of the JSC "Ukrtransnafta" business model efficiency and the volume of transported oil in UAH million for 2010-2019.

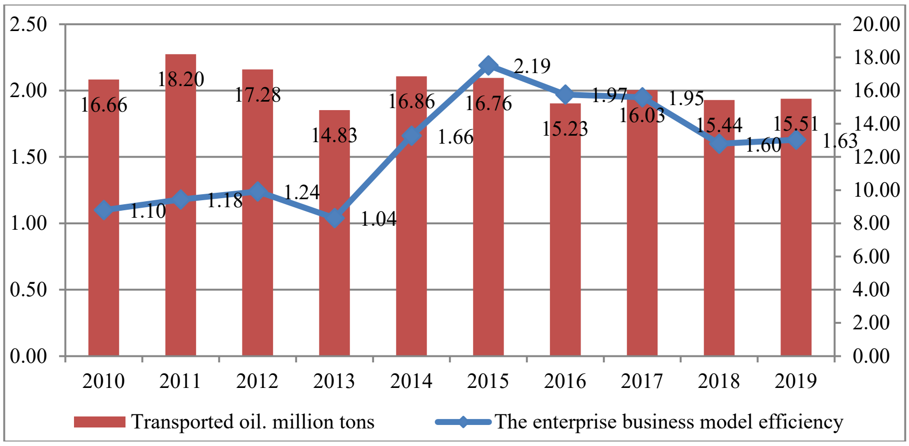

Fig. 3. Dynamics of JSC "Ukrtransnafta" business model efficiency and volume of transported oil.

Thus, from the results of calculating the enterprise business model efficiency and its relationship with the dynamics of transported oil, we can conclude that the change of the first indicator does not have a stable trend, in addition, at the end of the period there is an increase in the efficiency of the business model production efficiency (volumes of transported oil). Therefore, it is necessary to investigate and identify the factors that affect the growth of the business model economic efficiency, along with the decline in production activity of the enterprise, which is associated with both the global crisis and unstable international economic relations. To further enhance the positive impact and level the negative, provided it is impossible to turn it into a positive impact.

To determine the main factors influencing the performance indicator, it is advisable to use the method of correlation-regression analysis. The indicator of enterprise activity efficiency was chosen as the resulting indicator (Y). As mentioned above, the key determinants that affect the efficiency of the investigated enterprise are costs, the cost of petroleum products transportation, the organizational structure of the volume in table 1 we will summarize the quantitative indicators of each of the identified key evaluation determinants and include their correlation-regression model of the studied enterprise business model economic efficiency.

Summary data for correlation-regression analysis of the influence of certain factors influence on the efficiency of the oil transportation company business model are given in table 2. Given the fact that all production and non-production areas of activity, including the pipeline system will consistently move to a digital display of activities, it is advisable to introduce methods of experiments in the study of improving the efficiency of the enterprise through optimization of input, significant parameters.

Table 1. Quantitative indicators for assessing the enterprise business model effectiveness and its key determinants.

Determinants	Quantitative indicators of evaluation
The enterprise business model efficiency	1. Profitability, %; 2. Economic efficiency (Y); 3. Profit, UAH million
Costs (business processes, digitalization)	1. The level of fixed assets depreciation (x_6) 2. Share of electricity costs in the total amount of costs, % (x_8); 3. The share of costs for diagnostics and defectoscopy of equipment in the total cost, % (x_9); 4. The level of intangible assets depreciation (x_{11}); 5. The level of actual implementation of R&D (x_{12})
Cost	1. Residual value of fixed assets (x_3); 2. Volumes of oil product transit transportation, thousand tons (x_5); 3. Average tariff for transit transportation of oil products by main pipelines, UAH for 1 ton net (x_1); 4. Average tariff for transportation of oil products to Ukraine's refineries by main pipelines, UAH for 1 ton net (x_2); 5. The share of intangible assets in the total assets of the enterprise, % (x_{10}); 6. Share of capital investments in equipment repairs (x_{13}); 7. Financing of capital investments, UAH million (x_{14})
The organizational structure	1. The average number of employees, persons (x_4); 2. The share of wage costs in total costs, % (x_7)

To build an adequate regression model of the studied enterprise business model economic efficiency, it is necessary to check the selected factors-indicators for the phenomenon of multicollinearity. Using the Data Analysis package in Excel, a correlation matrix was constructed, which demonstrates the strength of the relationship between the selected factor values and the performance indicator.

The calculation of the correlation matrix allows us to conclude that there is a close relationship between the performance indicator (Y) and the factor values, except for the pair (Y and x_4, x_5, x_9, x_{10}, x_{11}, x_{12}, x_{14}). These factors will be excluded from the study when constructing the regression equation. In addition to the study of the correlation between the performance indicator and the factors, it is advisable to determine the interdependence (multicollinearity) of the factor quantities-features among themselves. The phenomenon of multicollinearity occurs when the coefficients of pairwise correlation of trait factors are equal to 0.7 or more according to the Chedok scale, which indicates a close and very close relationship between certain trait factors. In this case, those factor features between which the phenomenon of multicollinearity was established should be excluded from the correlation-regression model. Those indicators of the relationship between which remains weak, are included in the economic-mathematical model for further construction of the regression equation.

Further conducted regression analysis between the effective rate and factor variables x_1, x_2, x_3, x_6, x_7, x_8, x_{13} using the Regression tool of Data analysis package in MS Excel.

To verify the formed regression model for adequacy, significance in general and regression coefficients, in addition to identifying correlation-regression relationships between performance and factor values, the coefficient of determination, multiple regression, standard error, and Student's t-test were calculated. The multiple regression coefficient $R = 0.998$ indicates a close relationship between the performance indicator and the factors. Regarding the value of the determination coefficient R^2 of the obtained correlation-regression model $R^2 = 0.996$, the dependence of the resulting feature by 99.6% is due to the selected factor values. The remaining 0.4% are due to other factors that affect the efficiency of the enterprise, but are not included in the regression model.

Table 2. Summary data for correlation and regression analysis of the factor values impact x_1, x_2, x_3, x_4, x_5, x_6, x_7, x_8, x_9, x_{10}, x_{11}, x_{12}, x_{13}, x_{14}, on the JSC "Ukrtransnafta" business model economic efficiency (Y).

Period	Y – efficiency of the enterprise	x_1 – average tariff for transit transportation of oil products by main pipelines, UAH for 1 ton net	x_2 – average tariff for transportation of oil products to refineries by main pipelines, UAH for 1 ton net	x_3 – residual value of fixed assets, thousand UAH	x_4 – the average number of employees, persons	x_5 – volumes of oil transportation transit, thousand tons	x_6 – level of fixed assets depreciation	x_7 – the share of wage costs in total costs, %	x_8 – the share of electricity costs in total costs, %	x_9 – the share of costs for diagnostics and defectoscopy of equipment in the total amount of costs, %;	x_{10} – the share of intangible assets in the total assets of the enterprise,%;	x_{11} – the level of depreciation of intangible assets	x_{12} – the level of actual implementation of R&D	x_{13} – the share of capital investment for equipment repairs	x_{14} – financing of capital investments, UAH million;
2010	1.10	69.61	15.88	1849.21	5726	14567.00	0.55	11.45	5.50	2.30	0.03	0.56	0.65	1.00	48.1
2011	1.18	78.16	11.15	1885.52	5113	16789.0	0.56	16.56	4.50	4.50	0.03	0.79	0.76	1.00	90.7
2012	1.24	79.48	11.51	1886.06	4865	15670.0	0.58	15.45	6.95	2.19	0.06	0.87	0.50	1.00	86.4
2013	1.04	88.45	12.37	1799.96	4414	12980.0	0.60	12.69	5.93	3.51	0.03	0.93	0.40	1.00	99.5
2014	1.66	128.22	12.53	1583.89	4447	13456.0	0.62	24.46	11.38	8.63	0.01	0.92	0.30	1.00	70.0
2015	2.19	210.65	42.58	15376.29	4312	13640.0	0.01	27.71	12.71	0.00	0.01	0.90	0.51	0.68	233.3
2016	1.97	241.38	74.89	14977.46	4535	13822.2	0.06	27.45	10.90	0.00	0.01	0.91	0.57	0.61	285.4
2017	1.95	256.40	78.89	14750.85	4529	13937.1	0.01	25.97	9.75	0.36	0.01	0.84	0.24	0.35	143.8
2018	1.60	277.78	76.62	13947.10	3917	13334.8	0.07	26.59	7.98	4.89	0.68	0.24	0.04	0.56	598.8
2019	1.63	249.67	82.31	8428.94	3666	13126.6	0.04	32.61	11.33	2.57	0.72	0.40	9.33	0.59	1809.9

According to the results of the multiple regression coefficient calculation and determination, the relationship between the resulting indicator and the factors-features is quite natural. Analysis of the constructed model variance shows that the factors included in the regression model are significant, as the residual sum of squares, as it is indicated in table 2, is less than 1% of the total sum of squares, i.e. 99% of the resulting indicator variation is due to the studied factors and only 1% variation of the resulting indicator is caused by the action of random variables. Since F (71.37)>Significance of F (0.013) and F (0.013)<0.05, it can be stated that the results of the regression model correspond to the empirical data and the number of independent variables included in the regression model is sufficient to describe the dependent variable. The values of F and the significance of F indicate a sufficient level of the evaluation results reliability and the significance of the developed equation.

Table 3 shows the results of regression coefficients calculations and statistics of their significance. Based on the calculations, we can conclude that all factors included in the regression model are reliable, because $t_K > t_{crit}$, where the critical value of t_{crit} at the set level of significance is 0.15 and was determined using the STEERING function of the MS Excel. The data in table 3 allow obtaining the following regression model:

$$Y = 0.8843 - 0.0047x_1 - 0.0013x_2 + 0.000000078x_3 + 0.9470x_6 + 0.0394x_7 + 0.0519x_8 - 0.8867x_{13}$$

Thus, based on the results of the correlation-regression analysis, it can be concluded that the greatest influence on the oil transportation company business model efficiency is exerted by the following factors: average tariff on the transit transportation of petroleum products by main pipelines per 1 ton net; average tariff on the transportation of petroleum products to refineries by main pipelines, UAH for 1 ton net; residual value of fixed assets, thousand UAH; level of fixed assets depreciation; proportion of wage costs in the total costs, %; proportion of electricity costs in the total amount of costs, %; proportion of capital investment in equipment repair.

Therefore, among the obtained results, the level of fixed assets depreciation has the greatest positive influence on the resulting indicator. The growth of this indicator by 1 unit will increase the resulting figure by 0.94 units. The biggest negative impact on the industrial enterprise business model efficiency has the proportion of capital investment in equipment repair, namely the growth of this factor by 1 will reduce the efficiency of the business model by 0.88 units. We calculated the elasticity for each factor by the formula:

$$E_j = b_j \frac{\overline{x_j}}{\overline{y_j}}, \tag{4}$$

where b_j – the corresponding coefficient of the regression equation; $\overline{x_j}$ – the arithmetic mean of the variable x_j; $\overline{y_j}$ – the arithmetic mean of the endogenous variable y_j.

In practice, it is often necessary to compare the separate effect on the dependent variable of different explanatory variables, when the latter ones are expressed in different units. In this case, the coefficients of elasticity are used. The coefficient of elasticity E_j shows how many percent Y will change on the average if x_j is increased by 1%. Since further calculations require additional statistical indicators for the resulting feature and factors, we will use the Statistics package of MS Excel, the obtained intermediate calculations for further analysis are summarized in table 3.

Table 3. Results of elasticity calculation for the factors of the regression model

Factor	The average value of the factor for the study period ($\overline{x_j}$)	Regression coefficient (b_j)	Coefficients of elasticity (E_j)
x_1 – average tariff for transit transportation of oil products by main pipelines, UAH for 1 ton net	167.98	-0.0047326	-0.51
x_2 – average tariff for transportation of oil products to refineries by main pipelines, UAH for 1 ton net	41.87	-0.0013603	-0.04
x_3 – fixed assets residual value, thousand UAH	7648527.70	0.0000001	0.38
x_6 – the level of fixed assets depreciation	0.31	0.9470437	0.19
x_7 – the share of wage costs in the total costs, %	22.10	0.0394198	0.56
x_8 – share of electricity costs in the total amount of costs ,%	8.69	0.0519409	0.29
x_{13} – share of capital investments in equipment repairs	0.78	-0.8867077	-0.44

Thus, based on the results of the elasticity coefficient factors calculation of the regression model, we can conclude that the growth of the average tariff on the transit transportation of petroleum products by main pipelines, UAH per 1 ton of net, by 1% will reduce the economic efficiency of the business model by 0.51%, and an increase in the average tariff on the transportation of petroleum products to refineries by main pipelines, UAH for 1 ton net, by 1% will reduce the economic efficiency by 0.04%. In this case, the management of the investigated enterprise should take measures to reduce the tariffs, especially their cost. Another factor that reduces the economic efficiency of the business model of the studied enterprise is the proportion of capital investment in equipment repair, its increase by 1% will reduce the resulting indicator by 0.44%. Of the eight factors studied, four have a positive effect on increasing the economic efficiency of the oil transportation company business model. In particular, an increase in the residual value of fixed assets by 1% will lead to an increase in the resulting indicator by 0.38%, which shows the need to update the fixed assets base. An increase in the level of fixed assets depreciation by 1% will increase the economic efficiency by 0.19%. An increase in the proportion of wage costs by 1% will increase the resulting indicator by 0.56%, and an increase in the proportion of electricity costs in total costs by 1% will increase the economic efficiency of the business model by 0.29%. Thus, the increase in the studied costs leads to an increase in the efficiency of the business model to a greater extent than the increase in the tariff on transportation, as it is proved by the developed correlation-regression model.

To determine the factors that have the greatest reserve for improving the resulting indicator, taking into account the degrees of the factors-indicators variation, we use the calculation of standardized regression β coefficients by the formula:

$$\beta_j = a_j \frac{\sigma_{xj}}{\sigma_y} \quad (5)$$

where σ_{xj} – quadratic mean deviation of the i-th factor-indicator; σ_y – quadratic mean deviation of the resulting indicator.

The delta coefficient indicates what part of the contribution the studied factor makes in the total influence of all selected factors. It is determined by the formula:

$$\Delta_j = \beta_j \frac{R_j}{R^2} \quad (6)$$

where R_j – matching correlation coefficient; R^2 – coefficient of multiple determination.

It should be noted that the increase in the number of factors-indicators, which are included in the multifactor correlation-regression model, allows establishing the additional resources of the studied resulting indicator.

The results of the obtained calculations of Δ and β coefficients are summarized in table 4.

Table 4. Δ_j and β_j coefficients of the developed correlation-regression model.

Factor-indicator	The standard deviation	Regression coefficient	β_j coefficients	Paired correlation coefficient	Δ_j coefficients
Y – the enterprise business model efficiency	0.4030771	0.8842506	-	-	-
x_1 – average tariff for transit transportation of oil products by main pipelines, UAH for 1 ton net	86.4343677	-0.0047326	-1.0148456	0.7866235	-0.8014970
x_2 – average tariff for transportation of oil products to refineries by main pipelines, UAH for 1 ton net	32.6194806	-0.0013603	-0.0005133	0.6624873	-0.0003414
x_3 – fixed assets residual value, thousand UAH	6456617.74	0.0000001	0.0154706	0.8575565	0.0133200
x_6 – the level of fixed assets depreciation	0.2879776	0.9470437	0.0000000	-0.8124769	-0.00000003
x_7 – the share of wage costs in the total costs, %	7.3646677	0.0394198	1.0081115	0.8389036	0.8490938
x_8 – share of electricity costs in the total amount of costs, %	2.8927203	0.0519409	0.0204015	0.8894378	0.0182185
x_{13} – the share of capital investment in equipment repairs, %	0.2479886	-0.8867077	-0.0760161	-0.7471013	0.0570191

Based on the obtained results of calculating Δ_j and β_j coefficients, it can be concluded that the vectors of the calculated β_j and coefficients are proved by the results of elasticity coefficients calculation in table 4. However, according to the results of the latter calculations, the greatest negative impact on the studied enterprise business model efficiency by the standard deviation is the factor of the average tariff on the transit transportation of petroleum products by main pipelines, UAH for 1 ton net. The greatest positive impact on the resulting indicator by the standard deviation is exerted by the factor the proportion of wage costs in the total amount of costs, %. Based on the results of Δ_j calculation and coefficients, it can be concluded that this statistics are confirmed by the results of β_j calculation and characteristics.

Recently, along with traditional methods of analyzing the socio-economic indicators, the use of neural networks, which belong to artificial intelligence systems, is becoming more widespread. After all, their scope is extremely large: forecasting changes in the stock exchange, making credit plans, making decisions when landing a damaged aircraft, approximating functions, solving optimization problems, managing complex processes, forecasting, etc. That is why the use of neural networks is relevant for the analysis of factors influencing the efficiency of oil transportation companies, along with traditional methods. In a series of recent works [3; 1; 14; 13], the authors have demonstrated the possibility of using the theory of complex systems and a set of developed analysis tools to calculate the corresponding measures of system complexity. These complexity measures make it possible to differentiate the systems according to the degree of their functionality, to identify and prevent critical and crisis phenomena.

Let us move on to the development of the neural network. For this purpose, use the module Neural Networks of the Statistica software package.

Table 5. Detailed results of neural network models.

Summary of active networks (Spreadsheet1_(Recovered))											
Index	Net. name	Training perf.	Test perf.	Validation perf.	Training error	Test error	Validation error	Training algorithm	Error function	Hidden activation	Output activation
1	MLP 6-10-1	0,996503	0,966398	),999999	0,001489	,016893	0,006213	BFGS 8	SOS	Logistic	Identity
2	MLP 6-7-1	0,930660	0,970936	),999934	0,014347	,007955	0,012498	BFGS 8	SOS	Logistic	Tanh
3	MLP 6-11-1	0,954370	0,973305	),999893	0,010534	,012491	0,005659	BFGS 7	SOS	Logistic	Exponential
4	MLP 6-5-1	0,955839	0,967683	),999891	0,011195	,010368	0,011513	BFGS 5	SOS	Identity	Tanh
5	MLP 6-7-1	0,958716	0,967189	),999960	0,011143	,009940	0,011811	BFGS 5	SOS	Identity	Tanh

In the Neural Networks window, we set the following parameters:

- type of problem – “Regression”;
- as input parameters, according to the correlation analysis, we use: the average tariff on the transit transportation of petroleum products by the main pipelines for 1 t. net; average tariff on the transportation of petroleum products to refineries by main pipelines, UAH for 1 ton net; residual value of the fixed assets, thousand UAH; level of fixed assets depreciation; proportion of wage costs in the total amount of costs, %; proportion of electricity costs in the total amount of costs, %; proportion of capital investment in equipment repairs;
- the economic efficiency is taken as the input parameter (the resulting feature).

Then, with the help of the Solution Wizard, we go to the window for building Neural Networks.

In the Solution Wizard window, we set the parameters for creating neural networks:

- test 100 networks and save only the top 5;
- the types of neural network architectures, used for modeling, are multilayer perceptron, generalized regression network and linear network;
- run the analysis. We analyze the results of neural network modeling aimed at maintaining regression based on the detailed model results (table 5).

Table 5 shows that the Master created and proposed 5 multilayer perceptrons of neural network architectures. We choose the best model using the results of Descriptive Statistics, which are in table 6.

Table 6. Correlation coefficients.

	Correlation coefficients (Spreadsheet1_(Recovered))		
	Y - efficiency of the enterprises business model Train	Y - efficiency of the enterprises business model Test	Y - efficiency of the enterprises business model Validation
1.MLP 6-10-1	0,996503	0,966398	0,999999
2.MLP 6-7-1	0,930660	0,970936	0,999934
3.MLP 6-11-1	0,954370	0,973305	0,999893
4.MLP 6-5-1	0,955839	0,967683	0,999891
5.MLP 6-7-1	0,958716	0,967189	0,999960

According to the correlation indicators, shown in table 6, the best model is the first model – a multilayer perceptron, with the architecture MLP 6-10-1. The MLP 6-10-1 architecture identifies a model with 6 input variables, one output variable and one hidden layer containing 10 hidden neurons. Having investigated and analyzed the results obtained in table 6, we can make conclude that the constructed models work evenly as the correlation coefficients of the test sample are approximately at the same level. The Statistica Neural Networks program provides the ability to analyze the sensitivity of the network to input variables. This procedure allows us to make conclusions about the relative importance of the input variables for a particular neural network and, if necessary, to remove the inputs with low sensitivity. Sensitivity analysis can be used for purely informational purposes, or to remove entries.

Sensitivity analysis brings some clarity to the usefulness of the certain variables. It allows identifying the key variables, without which analysis is impossible, and identifying those that can be safely excluded from consideration.

Therefore, let us analyze the results of the input variable sensitivity to the output variable and see which variables are included in our model (table 7), and the standard prediction of the neural network, i.e. the predicted values for the resulting variables in the proposed models (table 8).

Thus, we can see that the chosen model has minor errors, and therefore it can be called reliable. The rest predicted results of the neural network models calculations are presented in tables 9-11.

Table 7. Sensitivity analysis.

Networks	Sensitivity analysis (Spreadsheet1_(Recovered)) Samples: Train, Test, Validation x7 - the share of electricity costs in total costs,%;	x6 - the level of depreciation of fixed assets;	x7 – the share of salary costs in total costs,%;	x2 – average tariff for transportation of oil products to refineries by main pipelines, UAH for 1 t. netto;	x13 – the share of capital investment in equipment repairs;	x1 – average tariff for transit transportation of oil products by main pipelines, UAH for 1 t. netto, грн. за 1 т нетто;
1.MLP 6-10-1	3,544210	2,504670	1,218176	1,826351	1,485822	1,084455
2.MLP 6-7-1	2,299395	1,350893	1,478483	1,041965	1,092716	0,991620
3.MLP 6-11-1	1,943351	1,292521	1,055444	1,128046	1,071157	0,932827
4.MLP 6-5-1	2,620613	1,509926	1,466700	1,099757	1,161099	1,028567
5.MLP 6-7-1	2,729713	1,548415	1,502538	1,080967	1,223184	1,023498
Average	2,627456	1,641285	1,344268	1,235417	1,206796	1,012194

Table 8. Predicted values of the oil transportation company efficiency based on the developed multi-architectural neural networks.

Case name	Predictions spreadsheet for Y - efficiency of the enterprises business model (Spreadsheet1_(Recovered)) Samples: Train, Test, Validation Sample	Y - efficiency of the enterprises business model Target	Y - efficiency of the enterprises business model - Output 1. MLP 6-10-1	Y - efficiency of the enterprises business model - Output 2. MLP 6-7-1	Y - efficiency of the enterprises business model - Output 3. MLP 6-11-1	Y - efficiency of the enterprises business model - Output 4. MLP 6-5-1	Y - efficiency of the enterprises business model - Output 5. MLP 6-7-1	Y - efficiency of the enterprises business model - Output Ensemble
1	Train	1,100000	1,082962	1,056674	1,158425	1,061849	1,072921	1,086566
2	Test	1,180000	1,076189	1,087971	1,159720	1,085584	1,093730	1,100639
3	Validation	1,240000	1,221474	1,226861	1,180044	1,234785	1,243894	1,221411
4	Test	1,040000	1,105908	1,098549	1,161789	1,108089	1,117473	1,118362
5	Train	1,660000	1,666791	1,661751	1,620909	1,648881	1,650108	1,649688
6	Train	2,190000	2,083504	1,861664	1,937052	1,896471	1,894925	1,934723
7	Validation	1,970000	1,832867	1,777675	1,840524	1,786291	1,781861	1,803844
8	Validation	1,950000	1,815363	1,755506	1,833396	1,762113	1,761710	1,785618
9	Train	1,600000	1,584646	1,671356	1,723884	1,642662	1,635257	1,651561
10	Test	1,630000	1,923665	1,819298	1,874339	1,850579	1,844931	1,862562

Table 9. Absolute results of the predicted values of the oil transportation enterprise activity efficiency based on the various developed architectural neural networks.

Case name	Predictions spreadsheet for Y - efficiency of the enterprises business model (Spreadsheet1_(Recovered)) Samples: Train, Test, Validation Sample	Y - efficiency of the enterprises business model - Abs. Res. 1. MLP 6-10-1	Y - efficiency of the enterprises business model - Abs. Res. 2. MLP 6-7-1	Y - efficiency of the enterprises business model - Abs. Res. 3. MLP 6-11-1	Y - efficiency of the enterprises business model - Abs. Res. 4. MLP 6-5-1	Y - efficiency of the enterprises business model - Abs. Res. 5. MLP 6-7-1	Y - efficiency of the enterprises business model - Abs. Res. Ensemble
1	Train	0,017038	0,043326	0,058425	0,038151	0,027079	0,013434
2	Test	0,103811	0,092029	0,020280	0,094416	0,086270	0,079361
3	Validation	0,018526	0,013139	0,059956	0,005215	0,003894	0,018589
4	Test	0,065908	0,058549	0,121789	0,068089	0,077473	0,078362
5	Train	0,006791	0,001751	0,039091	0,011119	0,009892	0,010312
6	Train	0,106496	0,328336	0,252948	0,293529	0,295075	0,255277
7	Validation	0,137133	0,192325	0,129476	0,183709	0,188139	0,166156
8	Validation	0,134637	0,194494	0,116604	0,187887	0,188290	0,164382
9	Train	0,015354	0,071356	0,123884	0,042662	0,035257	0,051561
10	Test	0,293665	0,189298	0,244339	0,220579	0,214931	0,232562

Tables 9-11 show that the model MLP 6-10-1 does have small residues, which indicates a fairly high accuracy of the forecast. The graphs of actual and predicted values of the business model efficiency of the oil transportation enterprise in the period from 2010 to 2019 are presented in figure 8.

Table 10. Squared results of the predicted values of the oil transportation enterprise activity efficiency based on the various developed architectural neural networks.

Case name	Sample	Y - efficiency of the enterprises business model - Squared Res. 1. MLP 6-10-1	Y - efficiency of the enterprises business model - Squared Res. 2. MLP 6-7-1	Y - efficiency of the enterprises business model - Squared Res. 3. MLP 6-11-1	Y - efficiency of the enterprises business model - Squared Res. 4. MLP 6-5-1	Y - efficiency of the enterprises business model - Squared Res. 5. MLP 6-7-1	Y - efficiency of the enterprises business model - Squared Res. Ensemble
	Predictions spreadsheet for Y - efficiency of the enterprises business model (Spreadsheet1_(Recovered)) Samples: Train, Test, Validation						
1	Train	0,000290	0,001877	0,003414	0,001455	0,000733	0,000180
2	Test	0,010777	0,008469	0,000411	0,008914	0,007442	0,006298
3	Validation	0,000343	0,000173	0,003595	0,000027	0,000015	0,000346
4	Test	0,004344	0,003428	0,014833	0,004636	0,006002	0,006141
5	Train	0,000046	0,000003	0,001528	0,000124	0,000098	0,000106
6	Train	0,011341	0,107805	0,063983	0,086159	0,087069	0,065166
7	Validation	0,018805	0,036989	0,016764	0,033749	0,035396	0,027608
8	Validation	0,018127	0,037828	0,013596	0,035302	0,035453	0,027022
9	Train	0,000236	0,005092	0,015347	0,001820	0,001243	0,002659
10	Test	0,086239	0,035834	0,059702	0,048655	0,046195	0,054085

Table 11. Studied results of the predicted values of the oil transportation enterprise activity efficiency based on the various developed architectural neural networks.

Case name	Sample	Y - efficiency of the enterprises business model - Std. Res. 1. MLP 6-10-1	Y - efficiency of the enterprises business model - Std. Res. 2. MLP 6-7-1	Y - efficiency of the enterprises business model - Std. Res. 3. MLP 6-11-1	Y - efficiency of the enterprises business model - Std. Res. 4. MLP 6-5-1	Y - efficiency of the enterprises business model - Std. Res. 5. MLP 6-7-1	Y - efficiency of the enterprises business model - Std. Res. Ensemble
	Predictions spreadsheet for Y - efficiency of the enterprises business model (Spreadsheet1_(Recovered)) Samples: Train, Test, Validation						
1	Train	0,44151	0,36172	-0,56925	0,36058	0,25653	0,13611
2	Test	2,69010	0,76832	0,19759	0,89236	0,81726	0,80407
3	Validation	0,48007	0,10970	0,58417	0,04929	-0,03688	0,18834
4	Test	-1,70790	-0,48881	-1,18662	-0,64353	-0,73392	-0,79394
5	Train	-0,17598	-0,01462	0,38088	0,10509	0,09371	0,10448
6	Train	2,75967	2,74118	2,46454	2,77423	2,79533	2,58640
7	Validation	3,55357	1,60567	1,26151	1,73629	1,78230	1,68346
8	Validation	3,48889	1,62377	1,13610	1,77578	1,78373	1,66548
9	Train	0,39789	-0,59573	-1,20703	-0,40321	-0,33400	-0,52240
10	Test	-7,60985	-1,58039	-2,38066	-2,08476	-2,03610	-2,35627

4 Results

Based on the investigation of JSC "Ukrtransnafta" business model economic efficiency it is possible to draw conclusions that the accompanying process of digitalization of production for the given enterprise is characterized by a number of problems which arise both at initial stages and in adaptation process. In addition, it has been proposed to use a synergetic coefficient of digitalization efficiency, which takes into account the sequence of the enterprise business processes and partial indicators of digitalization efficiency of each individual business process. However, it cannot be calculated for the enterprise under study, as the processes at JSC "Ukrtransnafta" production digitalization are currently underway. Taking into account these circumstances, a system of the previously determined key determinants factors-features of the impact on the company business model economic efficiency of the oil transportation enterprise and the resulting features has been developed. According to the analysis of the impact levels of the selected factors, the main ones have been determined, which have been used to develop the neural network models of the enterprise's business model economic efficiency. The main factors influencing the business model efficiency of the studied enterprise are the average tariff on the transit transportation of petroleum products by main pipelines, UAH for 1 t. net; average tariff on the transportation of petroleum products to refineries by main pipelines, UAH for 1 t. net; level of fixed assets depreciation; proportion of salary costs in total costs, %; proportion of electricity costs in total costs, %; proportion of capital investment in equipment repair. The regression neural network analysis has proved six factors that can be used to predict the economy of the oil transportation company business model economic efficiency. The performed analysis of the neural networks sensitivity, which indicates the direction and strength of the influence of factors, will allow the surveyed enterprise to manage the economic efficiency, and the state, in its turn, to find directions for industry development.

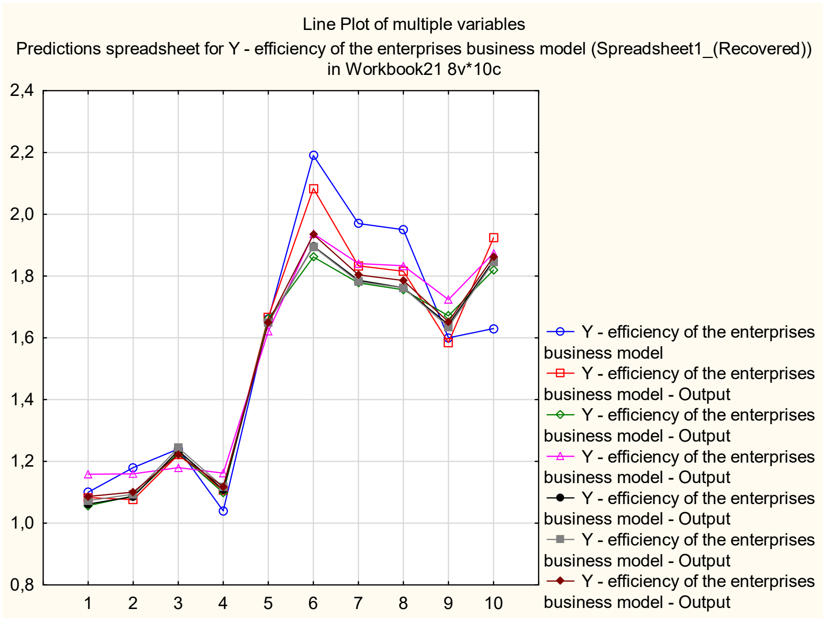

Fig. 4. Graphs of actual and predicted values of the business model of the industrial enterprise efficiency for different neural network models.

5 Conclusion

Thus, comparing the results of this research work and the previous work [4] we can draw unambiguous conclusions that according to [4], the financial efficiency of the studied enterprise is at the average level, it increases at the end of the analyzed period mainly due to the profitability component, which is usually a positive trend. Based on the results of regression neural network analysis, the key factors influencing the economic efficiency have been identified and ranked, and the optimal neural network model for forecasting the resulting indicator has been developed, which can be used for predictions and will allow the company's management to rationally manage the economic efficiency at relatively low costs.

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