МЕНЕДЖМЕНТ

UDC 338.31

L. T. Horal, Doctor of Economics, Professor,
I. V. Perevozova, Doctor of Economics, Associate Professor,
V. I. Shyiko, Candidate of Economic Sciences, Assistant

MODELLING BUSINESS PROCESSES OF NATURAL GAS TRANSPORTATION

Urgency of the research. *Active market competition and world integration of the domestic economy put the business entities in demand of optimizing their activities by moving from functional to the processing management, which is based on the studying of production business processes and top economic-mathematical modeling business processes effectiveness in gas transportation companies.*

Target setting. *It is advisable economic-mathematical modeling business processes of gas transportation system for identify production bottlenecks and efficient use of hidden opportunities.*

Actual scientific researches and issues analysis. *Authors: L. T. Goral, I. G. Fadeeva, V. S. Ponomarenko, S. V. Minukhin, S. V. Znhur, P. Luis, M. Lopez, M. Gaska, D. Gelbing, M. Hammer , J. Champi, M. Rother, J. Shuk have made significant contribution to the development of the modern approaches to business modeling.*

Uninvestigated parts of general matters defining. *At the same time very few of scientific papers highlights the peculiarities implementation of business process modeling for gas transport companies.*

The research objective. *Formation optimization model of business processes effectiveness on the basis system research technology of pipeline transportation natural gas*

The statement of basic materials. *It is proved the necessity of economic-mathematical modeling business processes of pipeline transportation natural gas. It is established the stage of business modeling. It is constructed the model of the main streams forming the enterprise productivity. It is presented the multifactor model of the performance enterprises in the industry.*

Conclusions. *The current model assumes a phased optimization of the performance indicator on the basis reducing the expenditure activity and allows to determine the most important objects of its formation, which, as the research shows, are different in individual business processes.*

Keywords: *modeling; pipeline transport; costs; profitability; model of efficiency; business process.*

УДК 338.31

Л. Т. Гораль, д. е. н., професор,
І. В. Перевозова, д. е. н., доцент,
В. І. Шийко, к. е. н., асистент

МОДЕЛЮВАННЯ БІЗНЕС-ПРОЦЕСІВ ТРУБОПРОВІДНОГО ТРАНСПОРТУВАННЯ ПРИРОДНОГО ГАЗУ

Актуальність теми дослідження. *Активна ринкова конкуренція та світова інтеграція вітчизняної економіки ставлять перед суб'єктами господарювання вимогу оптимізації своєї діяльності шляхом переходу від функціонального управління до процесно-орієнтованого, який базується на дослідженні бізнес-процесів виробництва та актуалізує економіко-математичне моделювання результативності бізнес-процесів стратегічних підприємств.*

Постановка проблеми. *Доцільним є здійснення економіко-математичного моделювання бізнес-процесів газотранспорної системи для визначення вузьких місць виробництва та ефективного використання прихованих можливостей.*

Аналіз останніх досліджень і публікацій. *Значний внесок у розвиток сучасних підходів до бізнес-моделювання здійснили автори: Л. Т. Гораль, І. Г. Фадєєва, В. С. Пономаренко, С. В. Мінухін, С. В. Знахур, П. Луїса, М. Лопез, М. Гаска, Д Гелбінг, М. Хаммер, Дж. Чампі, М. Ротер, Дж. Шук.*

Виділення недосліджених частин загальної проблеми. *У той же час недостатньо наукових праць висвітлюють особливості здійснення моделювання бізнес-процесів для газотранспортних підприємств.*

Постановка завдання. *Формування оптимізаційної моделі результативності бізнес-процесів на основі системного дослідження технології трубопровідного транспортування природного газу.*

Виклад основного матеріалу. *У статті доведено необхідність економіко-математичного моделювання бізнес-процесів газотранспортних підприємств. Встановлено етапність бізнес-моделювання. Побудована модель основних потоків, що формують результативність підприємства. Наведено мультифакторну модель результативності діяльності підприємств галузі.*

Висновки. *Сформована модель передбачає поетапну оптимізацію показника результативності на основі зниження витратності діяльності та дозволяє визначити найбільш вагомі об'єкти його формування, які як показують дослідження бувають різними на окремих бізнес-процесах.*

Ключові слова: *моделювання; трубопровідний транспорт; витрати; дохідність; модель результативності; бізнес-процес.*

DOI: *10.25140/2410-9576-2018-2-1(13)-141-148*

Urgency of the research. Terms of active market competition and global integration processes of domestic economy pose to entities the requirement of optimizing their operation. This problem has led to a transition from functional management of economic systems to process-oriented, based on the study of business processes of production. The objective of this approach is to increase the efficiency and quality of business processes. Business modeling for domestic enterprises is an important stage of their development and effective competition in international markets, especially for those businesses that are guarantors of energy, environmental and economic security. There is the important role of the gas transportation system among them, which provides national and world economy with energy. Making business modeling at these enterprises will enable identifying production bottlenecks (growing expenditures) and efficient usage of hidden possibilities.

Target setting. Given that imported natural gas in the energy balance of Ukraine is about 60% of the total consumption of natural gas and of it 12% is spent on the implementation of its transportation, so the problem of optimizing the performance and efficiency of its transportation on the basis of process-oriented management is urgent and necessary to resolve. Besides gas transportation system is one of the main filling the state budget. Natural gas transmission through main pipelines is technologically complicated process and therefore business modeling for each manufacturing process separately will help to optimize the activity of the enterprises on the basis of sustainable use of power and reduce the cost of manufacturing, and this in turn will lead to economic and energy security of oil and gas complex, in particular, and the country in general. Gas transportation system is an important economic potential for national economy.

Actual scientific researches and issues analysis. A significant number of publications of foreign and domestic authors were devoted to survey questions of current approaches to business modeling. Among these authors we should note the works of L. Horal [1], I. Fadeeva [2], V. Ponomarenko, C. Minuhina, S. Znahura [3] revealing methodological and methodical questions of activity-based management companies in terms of the use of a process approach; P. Luis, M. Lopez, M. Gasquet [4], D. Helbinh [5], revealing descriptions modern standards and performance of hybrid modeling of business processes; M. Hammer, J. Ciampi. [6] Mike Rother and John Shuk [7] and many others whose works were focused on the description of the sequence of operations and business procedures, structuring, classification of business processes, search for relationships and interdependencies between them justification of reengineering as the main tool of strategic management. Research of scientific work in this area led to the conclusion that they have paid little attention to the design and modeling of business processes in vertically integrated companies, namely at the enterprises of pipeline transportation of natural gas which today in active European integration are becoming competitively vulnerable, and therefore they face the problem of optimization of process-based business modeling to reduce costs.

Uninvestigated parts of general matters defining. To move to a process-oriented management should be solved the task of modeling business processes, which is a necessary condition for justification of constituents and their structure. However, existing approaches to solving this issue are imperfect: different classifications of business processes are used; the principles of their selection aren't substantiated; various models of their description are applied. Theory and practice of business modeling substantiated the presence of a wide range of models of strategic management and planning, in which depending on the particular environment and separate companies the basic principles, tools and components were implemented.

The research objective. The purpose of the article is to build the optimum model of business processes performance on the basis of systematic research of natural gas pipeline transportation technology.

The statement of basic materials. Modeling business processes of main gas transportation is to determine and optimize the input parameters of each stage of business modeling to achieve optimum values of performance criteria. Formation of the final results of efficiency is based on the integral functions of each of the specified criteria and thus the pattern of performance indicators is formed:

$$\begin{cases} \text{Function of expences } \mathrm{E} = \int f(\mathrm{a}, b) \to min, \text{where } a \ \ , b \ \ \geq 0, \mathrm{a}\epsilon x_i, b\epsilon x_j, \\ \text{Function of profitability } \mathrm{P} = \int f(a, c) \to max, \text{where } a \ \ , \mathrm{c} \ \ \geq 0\,, c\epsilon x_k \\ \text{Function of effectiveness } \mathrm{E} = \int f(a, b, c) \to min, \text{where } a, b, \mathrm{c} \geq 0, \end{cases} \quad (1)$$

where a - a group of parameters (factors) that affect all functions of performance (performance indicators);

b - group parameters (factors) that influence the expediture of business processes;

c - a group of parameters (factors) that affect the profitability of the business processes.

Efficiency (effects) activity is determined by two parameters expediture and profitability and therefore they are integrated into the performance index, which is expressed through profitability of activity. At the enterprises of gas transportation system the natural gas pipeline transportation technology as a system of business process consists of the following elements [1]: transportation through the linear part, gas compression, its distribution and storage (Fig. 1).

The first phase includes business modeling simulation of the production process facilities of linear constructions, they are: pipeline; shut-down devices (linear faucets, valves, water and condensate exstractors, starting and receiving cameras) [8]. The object of forming business process efficiency at this stage is the energy of gas flow.

The second stage of business simulation includes modeling of gas compression manufacturing process and it is carried out on the compressor stations main and auxiliary facilities. Compressor stations (CS) are used to increase gas energy and pumping it to the linear part. Gas pressure increase is taking place in the compressor shop (CS), which is the basis of the CP.

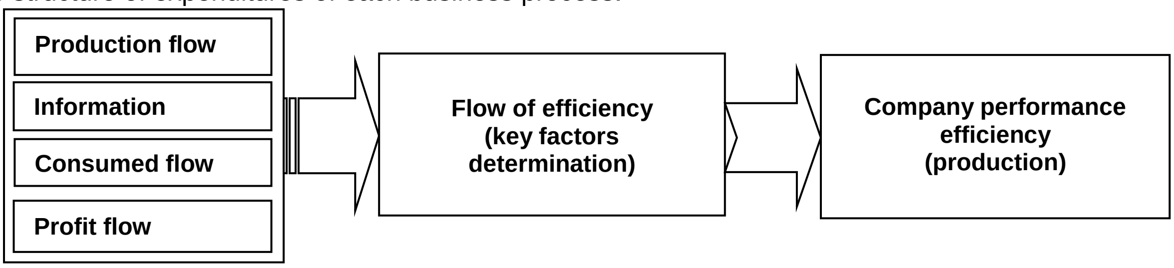
At the entrance to the compressor station a gas processing plant (GPP) is installed, and after the compressor shop – gas cooling unit (GCU). Therefore, business modeling of gas compression manufacturing process includes three main subprocesses: gas processing; gas compression; gas cooling; measurement, control and management of technological parameters of the CS and the pipeline before and after CS [9]. The object of the business process efficiency forming is the amount of transported gas.

Gas treatment for its transportation is conducted at the several stages: in the bottomhole formation zone, in the field, on the linear part at the main gas pipelines CS and finally - at gas distribution stations (GDS). Gas flow treatment from solid and liquid impurities occurs before CS at gas processing plants through dustcatchers and separator filters, the main production parameter which has influence on the production flow (flow of natural gas) - gas flow pressure.

Gas compression is carried out by using gas compressor units (GCU) installed at compressor stations. At the national gas transportation enterprises GSU of the following types are installed: turbine, electrical, piston. The main parameter of the compressor performance is productivity, the degree of compression, the gas temperature at the outlet and the power consumed by the compressor.

The principal production stream at the main gas pipeline facilities is natural gas flow. The effectiveness of the whole production process depends on its quality. The profit of the company is set on the scope of performed gas transportation work by consignment, which is calculated by multiplying the volume of transported gas at plot length through which transportation is carried out. However, alongside with the production flow it is important to examine the entire information stream qualitative and quantitative parameters that ultimately will shape the simulation model of company performance efficiency (Pic. 1). The quality of gas flow movement is formed under the influence of two basic factors - the volume of transported gas and transportation time.

The types of flows, shown in Pic. 1, are available in all business processes and they are formed under the total influence of factors of basic business processes, thus, the flow efficiency is an integral synergistic indicator of business processes effectiveness and coherence. Each flow passing through a separate business process acquires new qualities, properties and quantative parameters. The principal result of our proposed business model is a functional dependence of enterprise profitability on the structure of expenditures of each business process.



Pic. 1. Simulation of main flows that form enterprise performance

In the process of business modeling it is important to note stream-lining of manufacturing operations, that is, with each step of the business process the change of every type of technical, industrial and economic indices occurs. Even if the index characterizing the business process of the first stage, has no relation to the third stage, in accordance with the laws of conservation of energy, the given index is converted (transformed) to other indices reflecting the activities of the respective stage. However, it should be noted that there is a universal index accompanying any production process throughout the whole life cycle. It is expenditure. While business modeling of natural gas pipeline transportation, especially during the development of a market economy based on the principles of self-financing and self-sufficiency, it is important to find bottlenecks of production, namely the centers of critical expenditure that carry the greatest negative impact on the company performance efficiency. It is also important to determine the structural impact on the performance effectiveness, i.e. to show how the structure of expenditures of particular business process affects the production efficiency of the enterprise.

Consequently, profitability is determined by the formula:

$$\mathrm{P} = \frac{\sum_{\mathrm{i}=1}^{n} P_{\mathrm{i}}}{\sum_{\mathrm{i}=1}^{n} E_{\mathrm{i}}} * 100 = \frac{\sum_{\mathrm{i}=1}^{n} I_{\mathrm{i}} - \sum_{\mathrm{i}=1}^{n} E_{\mathrm{i}}}{\sum_{\mathrm{i}=1}^{n} E_{\mathrm{i}}} * 100, \quad (2)$$

where P - profitability of the enterprise, %;

Pi - profit of other business process, thousand UAH.;

Ii - income of other business process thousand UAH.;

Ei - expenditure of other business process, thousand UAH.

Because every business process performance obtains increment of growth, positive or negative, and each performance index is a function that depends on a certain number of factors (parameters). Using the methods of profitability (many variables) functions derivation determine how it varies with the cumulative impact of the factors. Functional dependence of expenditure parameter on the factors affecting it will be determined by the analytical modeling techniques, so, the general view of the expenditure function E is as follows:

$$E = F(x_1, x_2, .., x_n) \quad (3)$$

where x1, x1, xn, - factors influencing the production expenditures.

Compression (compression) of natural gas is performed to increase the gas flow energy due to the change of its volume in the pipeline. Such researchers as Yu. Hrudz [10], M. Zhidkov [11], S. Shcherbakov [12], Ye. Yakovlev [13] are engaged in the study of energy costs, losses of gas flow movement through pipelines and forming energy balance of gas flow. In his book [10] Yu. Hrudz determined the equation of gas flow energy balance being transported through the pipeline. According to his study energy losses on natural gas pipeline transportation can be divided into useful energy application and energy losses. Energy losses directed to the provision of the given pipeline gas capacity in conditions of constant gas flow should be referred to useful gas application. This assertion is based on the main purpose of the pipeline designation. All other types of energy expenses should be referred to energy losses during transportation [11]. Thus, energy balance for the gas flow in the pipeline can be presented as the sum of all energy losses:

$$EB = EEu + \Delta Ein + U + \Delta ELin \quad (4)$$

where EEu - useful energy expenditure;

ΔEin - internal energy of the gas flow;

U - power consumption to maintain the pipeline stress-strain state; ΔELin - inertial energy loss.

According to the above equation balance [11] the authors calculated ratio of energy consumption data, which showed that the share of energy consumption to provide a given capacity of the pipeline is negligible compared to the energy losses in transportation. Energy costs to maintain the pipeline stress-strain state are minor (3%) and to cut them is almost impossible. The most important are dissipative (70%) and inertial energy losses (27%), the reduction of which will help to increase the efficiency of gas pipelines. [11] To determine the costs of natural gas transporting through mains it is necessary to set the price of energy consumption. Since we are talking about energy losses of the gas flow, then energy expenditure will be determined going through the cost of natural gas.

At the first stage of natural gas transportation directly through the main natural gas transmission pipeline network, and in which the object of expenditure calculation is the energy of production flow, such functional relationship between the performance index of expenditure and the factors of impact on it is obtained taking into account the energy balance of pipeline transportation of natural gas. In this case, we can talk on the costs of business process of natural gas transmission through the main pipeline in a separate section of length L.:

$$E(1st\ stage)=F(Q, a, L, F, M, z, R, Tav, Pav, De, Ta, k, V, T, Cen) \quad (5)$$

where Q – gas pipeline capacity mln. M3 / day, F- cross-sectional area of the pipeline m^2;
L - pipeline length in km;
M - mass flow of gas;
Z - compressibility factor;
Rair - gas constant of air J / kg * K;
Pi, Pf - initial and final pressure;
i, Tf - initial and final gas temperature;
De - external diameter of pipe, mm;
Ta – ambient temperature;
K, k - full coefficient of heat transfer from gas to the environment;
V - total volume of metal of the pipeline walls, m^3;
T - duration of unsteady process, hr.;
Cen - the cost of energy, UAH.

At the next stage input consumption will be received, determined by considering the effect of different types of factors, so the following functional model will look like:

$$E\ (2nd\ stage) = E\ (1st\ stage) + \Delta E, \text{ where} \quad (6)$$

where E (1st stage) - the expenditure of the first phase of the business process or the expenditure production flow, which enters the following business process;

ΔE - gain of expenditure at the next stage of business processes modeling (2nd stage) is determined on the basis of functional dependence which is formed depending on the mode of the compressor station operation and equipment installed on it:

$$\Delta B = F(qfgc, qtn, qe, Png) \quad (7)$$

where qfgc - fuel gas consumption for each GPU, thous. m^3 / h;
qtn - gas consumption for technological needs and technical losses CS (cost of starting and stopping GPU) thous. m^3;
qpsgc - power stations gas consumption for their needs, thous. m^3;
Png - the price of natural gas, UAH.

In the study of parameters affecting the consumption process of gas compression depending on the using type of gas compressor units, the following system of functional relationship will be obtained:

$$\Delta B=\begin{cases} F(n, q_{fg}^r, N, N_r^n, T_a, \mathrm{T}_a^r, D_p, Q_{cv}^r, Q_p, q_t, q_e, P_{fg}) \\ F(n, q_{fg}^r, N, N_r^n, Q_p^n, Q_p, a, q_t, q_e, P_{fg}) \\ F(N, \tau, \eta_e, \eta_t, P_{el}) \end{cases} \rightarrow \begin{cases} F(n, q_{fg}^r, N, N_r^n, T_a, \mathrm{T}_a^r, D_p, Q_{cv}^r, Q_p, q_t, N_{op}, \mathrm{H}_3, P_{fg}) \\ F(n, q_{fg}^r, N, N_r^n, Q_p^n, Q_p, a, q_t, N_{op}, H_{cav}, P_{fg}) \\ F(n, N, \tau, \eta_e, \eta_t, P_{el}) \end{cases} \quad (8)$$

where n - number of GPU installed in CY;

q_{fg}^{r} - rated fuel gas consumption considering corrections for allowance and technical state;
N - power consumption obtained by calculating the parameters of an injector;
N_{r}^{n} - rated power of gas turbines (GPBC), kWT;
T_{a}, T_{a}^{r} – design and rated temperature of air at the inlet to GTC, K;
Dp - design pressure of ambient air, MPa;
Q_{cv}^{r} - rated calorific value of fuel gas kJ / m^3;
Qp – lower calorific value of the fuel gas, kJ / m^3 at 293.15 K and a pressure of 0.1013 MPa;
a - coefficient considering loading;
Nop - operating power, kWT;
H_{cav} - average specific consumption, m^3 / (kWh);
N - power of consumption obtained by calculating the parameters of an injector;
τ - time of drive operation h.;
ηe and ηt - correspondingly performance factor of an electric motor and transformer substations;
Pfg - the price of fuel gas, UAH;
P_{el} - the price of electricity, UAH.

The uniqueness of this model expenditure gain at the second stage is that it takes into account the operation of various types of gas compressor units. For CS, which installed the same type of GPU, this model will have a simplified view.

The third business process is identical to the first, so to simplify the simulation, only a part of the pipeline that includes two typical business processes is choosen, as this is their principal combination and within this section the most consuming center – CS was selected. Yield of natural gas pipeline transportation is determined by three factors:

$$Y=F(Q, L, Ptr) \quad (9)$$

where Q - the volume of transported gas, thous.,m^3;
Ptr - the price of natural gas transportation;
L - length of the pipeline, km.

So, considering the above mentioned factors impact on the basic performance of business processes the integrated model of determining the profitability of natural gas pipeline transportation can be build a with limited production function, defined for a particular section of natural gas pipeline transportation and has the form:

$$Q = F(\rho a, Ra, d, Pi, Pf, \lambda, \Delta, Z, Ti, Tf, L), \quad (10)$$

Where Q - pipeline performance mln. m^3 / day;
ρa - density of air;
Ra - gas constant of air J / kg * K;
d - pipeline diameter, mm;
Pi, Pf - initial and final pressure, Pa;
λ - hydraulic resistance;
Δ - relative density of gas;
Z - compressibility factor;
Ti, Tf - initial and final gas temperature K;
L - length of pipeline, km.

The profitability of the company is determined by integrating the profitability of individual business processes:

$$P = \int_{i=1}^{n} P_{n}, \quad (11)$$

where P - profitability of the company, %;
Pn - return of the n business process in the production system, %.

Process-object approach to business modeling of natural gas pipeline transportation allows to fully appreciate the yield and expenditures of the main natural gas transportation. Based on this approach an integrated model of the company performance definition can be formed considering parameterization of each business process, and as a result of which we receive:

$$\begin{cases} R = \oiiint_{Q}^{Q_{\text{ном}}} \dfrac{\mathrm{F(Q, L, Цтр)} - (\mathrm{F(Q, a, L, F, M, z, R, Tav, Pav, D, Ta, k, V, T,} P_{el}) + \left[\begin{cases} F(n, q_{fg}^{r}, N, N_{r}^{n}, T_{a}, \mathrm{T}_{a}^{r}, D_{p}, Q_{cv}^{r}, Q_{p}, q_{t}, N_{op}, \mathrm{H_з}, P_{fg}) \\ F\left(n, q_{fg}^{r}, N, N_{r}^{n}, Q_{p}^{n}, Q_{p}, a, q_{t}, N_{op}, H_{cav}, P_{fg}\right) \\ F(n, N, \tau, \eta_{e}, \eta_{t}, P_{el}) \end{cases} \right])}{(\mathrm{F(Q, a, L, F, M, z, R, Tav, Pav, D, Ta, k, V, T,} P_{el}) + \left[\begin{cases} F(n, q_{fg}^{r}, N, N_{r}^{n}, T_{a}, \mathrm{T}_{a}^{r}, D_{p}, Q_{cv}^{r}, Q_{p}, q_{t}, q_{e}, P_{fg}) \\ F\left(n, q_{fg}^{r}, N, N_{r}^{n}, Q_{p}^{n}, Q_{p}, a, q_{t}, q_{e}, P_{fg}\right) \\ F(N, \tau, \eta_{e}, \eta_{t}, P_{el}) \end{cases} \right])} dx \\ \mathrm{Q} = \mathrm{F}(\rho_{\mathrm{a}}, \mathrm{Rin}, \mathrm{d}, \mathrm{P_{in}}, \mathrm{Pf}, \lambda, \Delta, \mathrm{Z}, \mathrm{Tin}, \mathrm{T_f}, \mathrm{L}) \rightarrow max, Q_{max} \leq Q_{\text{ном}} \end{cases}$$

Conclusions. The result of business processes modeling of any company is to optimize its production activities entailing: the change of organizational structure; optimization of functions of departments and employees; redistribution of rights and responsibilities of managers; changing domestic regulations and technology operations; new requirements for automating performed processes, and so on. Business processes modeling which uses a systematic and phased process approach involves optimizing the performance indicators based on expenditure reduction activities. Focusing on expenditures is explained by the fact that given characteristic is more dependent on endogenous factors, as well as profitability for vertically integrated structures, in particular for gas transportation systems it is an endogenous factor and depends largely on decisions taken at the highest levels of management: approval of tariffs for natural gas pipeline transportation through mains or determining the volume of natural gas transportation under the contracts. Therefore, optimizing production in the context of expenditures reduction is relevant and important to solve. Modeling business processes of production allows determining the most significant objects of activity efficiency formation that as practice testifies are different in individual business processes. This model performance of the company is multifactorial and can be applied to a hypothetical pipeline, so the next step is to build a model for adaptive real pipeline, and its solution will be implemented in a software environment.

References

1. Horal, L. T. (2011). *Teoriia i praktyka restrukturyzatsii hazotransportnoi systemy [Theory and practice of restructuring the gas transportation system].* Ivano-Frankivsk: IFNTUOG [in Ukrainian].
2. Fadeeva, I. G. (2014). Osnovni napriamy udoskonalennia biznes-protsesiv ta suchasna metodolohiia yikh modeliuvannia ta rehlamentatsii na zasadakh nechitkoi lohiky [The main directions of business processes improvement and modern methodology of modeling and regulation based on nondistinct logic]. *Ekonomika ta derzhava - The economy and the state*, *11*, 11-19 [in Ukrainian].
3. Ponomarenko, V. S. (2013). *Teoriia ta praktyka modeliuvannia biznes-protsesiv [Theory and practice of business process modeling].* Kharkiv: KhNUE [in Ukrainian].
4. Parody, L., Gómez-López, M. T. & Gasca, R. M. (2016). Hybrid business process modeling for the optimization of outcome data. *Information & Software Technology, 70*, 140-154 [in English].
5. Helbing, D. (2003). Modeling and Optimization of Production Processes: Lessons from Traffic Dynamics. SFI Working Paper Abstract. *santafe.edu.* Retrieved from http://www.santafe.edu/research/working-papers [in English].
6. Hammer, M. & Champy, J (2004). *Reengineering the Corporation: A Manifesto for Business Revolution.* New York: HarperCollins [in English].
7. Rother, M. & Shook, J. (1999). *Learning to see Val-*

Література

1. Гораль, Л. Т. Теорія і практика реструктуризації газотранспортної системи : монографія / Гораль Л. Т. ; Івано-Франків. нац. техн. ун-т нафти і газу. - Івано-Франківськ : ІФНТУНГ, 2011. - 327 с.
2. Фадєєва, І. Г. Основні напрями удосконалення бізнес-процесів та сучасна методологія їх моделювання та регламентації на засадах нечіткої логіки. Економіка та держава. – 2014. – № 11. – С.11-19.
3. Пономаренко, В. С. Теорія та практика моделювання бізнес-процесів : монографія / В. С. Пономаренко, С. В. Мінухін, С. В. Знахур. – Х. : Вид. ХНЕУ, 2013. – 244 с.
4. Luisa Parody, María Teresa Gómez-López , Rafael M. Gasca Hybrid business process modeling for the optimization of outcome data. Information & Software Technology 70: 140-154 (2016)
5. Dirk Helbing Modeling and Optimization of Production Processes: Lessons from Traffic Dynamics. SFI Working Paper Abstract Oct. 1, 2003 http://www.santafe.edu/research/working-papers.
6. Hammer M. Reengineering the Corporation: A Manifesto for Business Revolution / M. Hammer, J. Champy. – New York : HarperCollins, 2004. – 302 p.
7. Mike Rother & John Shook (1999) Learning to see Value stream mapping to create value and eliminate muda. A Lean tool kit and workbook, Lean Enterprise Institute
8. Розгонюк, В. В. Довідник працівника газотранспортного підприємства / В. В. Розгонюк, А. А. Руднік,

ue stream mapping to create value and eliminate muda. The Lean Enterprise Institute, Inc. [in English].

8. Rozhoniuk, V. V., Rudnik, A. A. & Kolomieyev, V. M. (2001). *Dovidnyk pratsivnyka hazotransportnoho pidpryiemstva [Manual for staff of gas transportation enterprise]*. A. A. Rudnik (Ed.). Kyiv: Rostock [in Ukrainian].

9. Nakaz Derzhavnoho komitetu Ukrainy z promyslovoi bezpeky, okhorony pratsi ta hirnychoho nahliadu Pro zatverdzhennia pravyl bezpechnoi ekspluatatsii mahistralnykh hazoprovodiv: vid 27.10.2010 [Decree of State Committee of Ukraine for Industrial Safety, Health and Safety and Mining Supervision About the rules for the safe operation of the main gas pipelines: from 27.01.201]. *zakon.rada.gov.ua*. Retrieved from http://zakon4.rada.gov.ua/laws/show/z0292-10 [in Ukrainian].

10. Hrudz, Ya. V. (2012). Enerhetychnyi balans truboprovidnoho transportuvannia hazu [Energy balance of gas pipelines transportion]. *Rozvidka ta rozrobka naftovykh i hazovykh rodovyshch - Exploration and development of oil and gas fields, 3*, 64-70 [in Ukrainian].

11. Zhidkova, M. O., Biluk, S. F. & Rudnik, A. A. (2004). Metodychni zasady rozrakhunku pokaznykiv efektyvnosti ta tsiny truboprovidnoho transportuvannia hazu [Methodical principles of calculating performance and price of gas pipeline transportation]. *Naftova i hazova promyslovist - Oil and gas industry*, *1*, 43-46 [in Ukrainian].

12. Shcherbakov, S. G. (1982). *Problemu truboprovidnogo transportu naftu i gasu [Problems of pipeline transportation of oil and gas].* Moscow: Nauka [in Russian].

13. Yakovlev, Ye. I. (1968). Analyz neustanovyvshykhsia protsessov v nytkakh mahystralnoho hazoprovoda statystycheskymy metodamy [Analysis of unsteady processes in gas pipeline strings of the main by statistical methods]. *Izvestiia vuzov. Neft i haz - News of Higher Educational Institutions. Oil and gas, 2*, 72-76 [in Russian].

В. М. Коломєєв [та ін.]; під редакцією А. А. Рудніка. – Київ, РОСТОК – 2001. – 1082 с.

9. Про затвердження правил безпечної експлуатації магістральних газопроводів : Наказ Державного комітету України з промислової безпеки, охорони праці та гірничого нагляду, від 27.01.2010 [Електронний ресурс]. – Режим доступу: http://zakon4.rada.gov.ua/laws/show/z0292-10.

10. Грудз, Я. В. Енергетичний баланс трубопровідного транспортування газу [Електронний ресурс] / Я. В. Грудз. // Розвідка та розробка нафтових і газових родовищ. – 2012. – № 3. – С. 64-70.

11. Жидкова, М. О. Методичні засади розрахунку показників ефективності та ціни трубопровідного транспортування газу / М. О. Жидкова, С. Ф. Білик, А. А. Руднік // Нафтова і газова промисловість. – 2004. – №1. – С. 43-46.

12. Щербаков, С. Г. Проблемы трубопроводного транспорта нефти и газа / С. Г. Щербаков. – М. : Наука, 1982. – 206 с.

13. Яковлев, Е. И. Анализ неустановившихся процессов в нитках магистрального газопровода статистическими методами / Е. И. Яковлев // Изв. вузов. Нефть и газ. – 1968. – № 2. – С. 72–76.

Received for publication 25.12.2017

Бібліографічний опис для цитування :

Horal, L. T. Modelling business processes of natural gas transportation / L. T. Horal, I. V. Perevozova, V. I. Shyiko // Науковий вісник Полісся. – 2018. - № 1 (13). Ч. 2. – С. 141-148.