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MATHEMATICAL MODELLING MANAGEMENT OF ECONOMIC ACTIVITIES OF SMALL SIZE WOOD PROCESSING MILL IN UKRAINE

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Introduction. The actual economic development of Ukraine requires the increase of effectiveness for management of economic activities at enterprises, especially in wood processing industry. This industry is set upon different manufacturing and production processes, which associate altogether the needs for various raw materials.

The wood processing industry performs the treatment of raw wood in order to manufacture a vast assortment of semi-processed materials or ready-to-use goods for households and national consumers. The utilization thus of chemicals by the wood processing industry, *i.e.* resins, polymers, glues, dyes, plastics, fibers *etc*. is very extensive. The main assortment of semi-processed materials, that are being manufactured by wood processing mills, are rough sawn wood products, preprocessed beams and planks for dwellings construction, shaped wooden pieces for automotive industry, wooden packages and casings for storage and transportation. Finally, the ready-to-use goods assortment includes office and house furniture.

The wood processing industry releases yearly a high volume of wood waste. The recycling of waste allows to rationalize the number of concerned processes, such as paper production, post-processing of milled and ripped wood wastes for wood-plastic and fiber-reinforces composite materials manufacturing.

The biggest mills for manufacturing of wooden composite materials are situated in Kyiv, Kharkiv, Donetsk, Dnipro, Odesa, Svaliava, Drohobych of Ukraine.

The technical and economic grounds for the development of wood processing industry within unstable/uncertain economic conditions and restricted investing are the following ones: implementation of novel technologies for the quality enhancement, energy efficiency incentives, rational utilization of raw materials, reduction of hand labor, shift towards processes automation and computer-aided management, application of mathematical and economical modelling methods for efficient management and improvement of economic activities at both the processing and enterprise scales.

Literature review. The state-of-art of the wood processing industry in Ukraine has been investigated in the works by M.P. Sahaniuk [1, pp. 46 – 50], O.A. Pokhylchenko [2, p. 245]. The authors have demonstrated the weak and strong sides, as well as pointed out the prospects of economic growth in the conditions of economic crisis. The problem of logistics at a wood processing enterprise is studied by A.H. Chornyi [3, pp. 668 – 671].

I.H. Hurniak investigated the problems related to the calculation of key performance indicators (KPI) of life-cycle and economic activity analysis of wood processing mills [4, pp. 357 – 362; 5, pp. 353 – 357]. The algorithms for the KPI forecasting, using the economical and mathematical modelling, have been developed. The optimization of manufacturing processes for the wood processing industry has been proposed, which are based on the theory of finite antagonistic games and take into account the considerations of Prof. Yu. Tunyts (National Academy of Science of Ukraine) concerning the life-cycle efficiency.

N.P. Yavorska investigated the problem of the increase of economic effectiveness of a wood processing mill [8, pp. 260 – 269].

Problem statement. Develop the economic and mathematical model for the calculation of optimal gross domestic product (GDP) and maximal gross domestic profit (GDPF) of «Poltava Actioners Center» limited liability company (LLC) for the manufacturing of several kind of furniture boards.

Using the developed model, calculate the optimal value of GDP (maximal value of GDPF) for two types of case studies: before and after implementation of modernization at the mentioned wood processing mill. Compare the benefits of the modernization that includes the utilization of alternative energy sources and installation of automated wood treatment equipment. Take into account the extra-purchase by the mill of raw materials and the volume of sales of end products.

The nomenclature of raw materials required for the manufacturing of every kind of product by the wood processing mill is presented in Table 1.

Table 1

Nomenclature and composition of materials needed for the manufacturing of furniture boards (nominal resources needs)

Materials nomenclature	Composition					
	Oak		Ash		Pine	
	Solid	Composite	Solid	Composite	Solid	Composite
Timber (%)	85,0	82,0	86,0	84,0	90,0	87,0
PVAC Glue (%)	3,0	4,0	3,0	3,5	1,5	2,0
Urea resin adhesive (%)	--	--	--	--	6,0	8,0
Melamine resin adhesive (%)	9,0	10,5	--	--	--	--
Water (%)	3,0	3,5	3,0	4,0	2,5	3,0
Polyurethane resin adhesive (%)	--	--	8,0	8,5	--	--

Main findings and results. The economic and mathematical model for the calculation of the optimal GDP (maximal GDPF) within the enterprise modernization incentives has been designed. The modernization accounts the utilization of the alternative energy sources. The possibility of raw materials extra-purchase by the wood processing mill, as well as the influence on the volumes sales of end products, has been investigated. The developed model represents the enhanced version of the original economic and mathematical modelling of the wood processing mill «Rhumo International» Ent. [6, pp. 323 – 325; 7, pp. 155 – 159].

Known parameters:

n is number of raw materials types;

m is number of end products types;

j is the index of raw material type used for the manufacturing of end product;

i is the index of the end product type;

a_{ij} is reference volume of j-type raw material necessary for the manufacturing of i-type end product;

c_i is unitary cost of i-type end product;

p_j is purchase price of j-type raw material;

q_j is the selling price of j-type raw material;

a_j is the minimal quantity of raw material purchase;

b_j is the stock quantity of raw material;

N_E is the unitary electric energy consumption for manufacturing the product;

P_E is the unitary cost of electric energy;

P_W is the wage payment;

P_K is the cost of alternative energy;

P_A is the depreciation from product manufacturing;

P_L is the capital expenditure for the automated assembling equipment.

Input variables:

x_i is the production volume of i-type of end product;

y_j is the extra-purchase of the j-type of raw material;

z_j is the volume of sales of j-type of raw material;

δ'_j is the indicator for the material demand, which is equal to 0, if there is no need for the raw material, otherwise it is equal to 1;

$\delta_j^{''}$ is the indicator of sale of raw material, which is equal to 0 if there is no sale of the raw material, otherwise it is equal to 1.

Output variables:

1) Utilization volume of j-type of raw material in tons:

$$v_j = \sum_{j=1}^{n}\sum_{i=1}^{m} a_{ij}x_i ; \quad (1)$$

2) Wastes of j-type of raw material in tons:

$$l_j = b_j - v_j ; \quad (2)$$

3) Net profit from products selling in UAH:

$$D = \sum_{i=1}^{n} c_i x_i ; \quad (3)$$

4) Costs for the used raw materials in UAH:

$$P_j = v_j \cdot p_j = \sum_{i=1}^{n}(\sum_{i=1}^{m} a_{ij} \cdot p_j) \cdot x_i ; \quad (4)$$

5) Selling price of materials in UAH:

$$P_{m.s.} = \sum_{j=1}^{n} z_j \cdot q_j \cdot \delta_j^{''} ; \quad (5)$$

6) Costs for the extra-supply of raw materials in UAH:

$$P_{m.d.} = \sum_{j=1}^{n} y_j \cdot p_j \cdot \delta_j^{'} ; \quad (6)$$

7) Electric energy consumption in MWh:

$$E_i = x_i \cdot N_E ; \quad (7)$$

8) Costs of the used electric energy in UAH:

$$P_{tot,E} = \sum_{i=1}^{m} E_i \cdot P_E ; \quad (8)$$

9) Expenses for the manufacturing of end products in UAH:

$$S = P_j + P_W + P_E + P_K + P_L + P_A . \quad (9)$$

Model restrictions:

1) Utilization of raw materials should not exceed the stock volume in tons:

$$\sum_{j=1}^{n}\sum_{i=1}^{m} a_{ij}x_i \le b_j + y_j \cdot \delta_j^{'} - z_j \cdot \delta_j^{''}, C_j = \sum_{j=1}^{n} a_{ij}x_j \le Z_j, i = \overline{1,n}; j = \overline{1,m} ; \quad (10)$$

2) Production volume is a positive value:

$$x_i \ge 0 \ , j = \overline{1,m} ; \quad (11)$$

3) Production volume is natural positive number:

$$x_i \in \mathbb{N}^+, \ j = 1,m; \quad (12)$$

4) Extra-supply materials quantity should not exceed minimal and maximal stock volume:

$$\alpha_j \le y_j \le \beta_j, \ j = 1...n ; \quad (13)$$

5) Selling volume of raw materials should not exceed the minimal and maximal stock volume:

$$\alpha_j \le z_j \le \beta_j, \ j = 1...n ; \quad (14)$$

6) Purchase and sale indicators are logic values:

$$(\delta_j^{'}, \delta_j^{''}) \in \{0, 1\} . \quad (15)$$

Cost function: maximize the income from products sales that stands as the difference between net income and manufacturing expenses:

$$W = D - S + P_{m.s.} - P_{m.d.} \to \max . \quad (16)$$

Using the developed economical and mathematical model, the maximum of GDPF has been calculated for the case study of «Poltava Actioners Center» LLC without taking into account the modernization of wood processing mill and without the possibility of extra purchase of raw materials.

The optimization problem has been programmed and solved in the EXCEL environment. The results of the calculations of the production volumes from oak wood, the stock volume, the expenses, the wastes volume and GDPF are demonstrated in the Table 2. The same calculations have been carried out for others sorts of wood.

Table 2

Production volume of oak furniture board and gross domestic profit of «Poltava Actioners Center» LLC

Nomenclature	Composition		Stock volume (kg)	Materials utilization (kg)	Wastes (kg)	Unitary costs of raw material (UAH/kg)
	Oak board					
	Solid	Composite				
Timber (%)	85,0	82,0	5500	5500	0,0	400,00
PVAC Glue (%)	3,0	4,0	3700	227,02	3472,98	35,40
Urea resin adhesive (%)	--	--	4000	--	4000	78,00
Melamine resin adhesive (%)	9,0	10,5	2400	636,44	1763,56	92,00
Water (%)	3,0	3,5	5100	212,15	4887,85	0,50
Polyurethane resin adhesive (%)	--	--	2200	--	2200	204,00
Unitary costs of end product (UAH/kg)	1350,00	1100,00	**Total production volume (kg)**			
Production volume (kg)	3600	29,76	**6576**			
Net profit (million UAH)	**8,133**					
Expenses for materials (million UAH)	1,258	1,009	**2,267**			
Electric energy consumption (MWh)	4,032	3,333				
Electricity costs (thousand UAH)	0,766	0,633	**13,993**			
Production expenses (million UAH)	2,281					
GDPF (million UAH)	**5,852**					

The total production expenses and the gross domestic product of the «Poltava Actioners Center» LLC have been calculated:

- Total volume production is 82,08 tons;
- Net profit is 50,81 million UAH;
- Wage payment is 0,65 million UAH;
- Depreciation expenses are 2,70 thousand UAH;
- Production expenses are 22,34 million UAH;
- Gross domestic profit is 28,47 million UAH.

The results of the calculations allowed determining the total production volume as 8,208 tons (27 thousand furniture boards). The enterprise can manufacture the following volumes: 1200 oak solid boards

(4%), 992 oak composite boards (4%), 3000 ash solid boards (11%), 3000 ash composite boards (11%), 10 thousand pine solid boards (37%) and 9167 pine composite boards (33%).

The developed model allowed also calculating the GDPF value of «Poltava Actioners Center» LLC for the situation of the utilization of alternative energy sources, installation of automated wood treatment equipment and extra demand of raw materials.

The results of the calculations of the production volumes from oak wood, the stock volume, the expenses, the wastes volume and GDPF after the mill modernization are demonstrated in the Table 3. The same calculations have been performed for others sorts of products.

The total production expenses and the gross domestic product after the modernization of the «Poltava Actioners Center» LLC have been calculated:

- Total volume production is 66.32 tons;
- Net profit is 44,14 million UAH;
- Investments into automated equipment are 0,975 million UAH;
- Boiler investments are 0,42 million UAH;
- Wage payment is 0,58 million UAH;
- Depreciation expenses are 2,70 thousand UAH;
- Expenses for raw materials purchase are 0,4 million UAH;
- Sale costs of raw materials by enterprise are 5,756 million UAH;
- Production expenses are 19,278 million UAH;
- Gross domestic profit is 30,218 million UAH.

Table 3

Gross domestic product, production volume and expenses of oak furniture board manufacturing at "Poltava Actioners Center" LLC

Nomenclature	Composition						Unitary expenses for production (UAH/kg)	Production volume (kg)	Electric energy consumption (MWh)	Electricity costs (thousand UAH)
	Timber (%)	PVAC Glue (%)	Urea resin adhesive (%)	Melamine resin adhesive (%)	Water (%)	Polyurethane resin adhesive (%)				
Solid oak board	85,0	3,0	--	9,0	3,0	1,0	1350	7647	2,83	5,876
Composite oak board	82,0	4,0	--	10,5	3,5	--	1100	0,0	0,0	0,0
Stock volume (tons)	5,5	3,7	4,0	2,4	5,1	2,2				**5,376**
Lower boundary of raw materials (tons)	0,5	0,9	0,4	0,7	1,0	0,6				
Upper boundary of raw materials (tons)	1,0	2,0	0,8	1,5	3,0	1,0				
Unitary costs of materials purchase (UAH/kg)	4000,00	35,40	78,00	92,00	0,50	204,00				
Unitary price of materials sales (UAH/kg)	380,00	33,00	74,00	82,00	0,00	200,00				
Raw materials utilization (tons)	6,5	0,23	0,0	0,69	0,23	0,0				
Total costs of materials (million UAH)	2,6	0,008	0,00	0,63	0,0001	0,00	**2.67**			
Sales volume (tons)	0,5	0,0	0,0	1,0	0,0	0,0				
Sales indicator	0	0	0	1	0	0				
Purchase volume (tons)	1,0	0,9	0,4	0,7	1,0	0,6				
Purchase indicator	1	0	0	0	0	0				

Continued Table 3

Costs of materials purchase (million UAH)	4,0	0,00	0,00	0,00	0,00	0,00	**4,0**			
Stock volume (tons)	6,5	3,7	4,0	1,4	5,1	2,2				
Benefit of materials sales (million UAH)	0,00	0,00	0,00	0,82	0,00	0,00	**0.82**			
Wastes (tons)	0,0	3,47	4,0	0,71	4,87	2,2				
Net income (million UAH)	**103,23**									
Production expenses (million UAH)	**2,67**									
Gross domestic profit (million UAH)	**7,32**									

The total production volume has been determined as 6.63 tons (22 thousand furniture boards). The enterprise is able to manufacture several kinds of boards: 2549 oak solid boards (11%), 7059 ash solid boards (32%) and 12.5 thousand pine solid boards (57%).

Calculation of economic efficiency from the modernization and extra volume purchase of raw materials. The interest rate r of the enterprise is 18%.

The fixed tax from the end product sales is:

$$Tax = GDPF \times r = 28,47\,millionUAN \times 18\% = 5,12\,millionUAN; \quad (17)$$

$$Tax_{over} = 30,22\ millionUAN \times 18\% = 5,44\,millionUAN.$$

Net income is:

$$NIC = GDPF - Tax = 28.47 - 5.12 = 23.35\,millionUAN: \quad (18)$$

$$NIC_{over} = 30.22 - 5.44 = 24.78\,millionUAN.$$

The enterprise is considered to be profitable if the revenues from the sales volume are bigger than the expenses and, moreover, the total income covers all the expenditures for the normal service. The profitability ratio of the studied case is the following one:

$$PR = \frac{NIC}{EXP} = \frac{23.34\,millionUAN}{19.28\,millionUAN} = 1.21. \quad (19)$$

The volume of investments needed for the modernization of the wood processing mill are given in Table 4.

Table 4

Investments for the modernization of wood processing mill

Equipment	Costs (thousand UAH)
Solid fuel burner	42
Automated wood treatment line	975
Drying chamber	24
Universal 4-sided drilling machine	12
Two-sided marking gauge	20
Surface treatment machine	106
Glue pumping station	73
Clamp	115
Total investments	**1367**

The total investments for the wood processing mill modernization are 1,367 million UAH. The verification of the mill modernization meaningfulness has been provided by calculating the income coefficient:

$$k_{in} = \frac{23.35\,million UAN}{1.367\,million UAN} = 17.07 \cdot \quad (20)$$

The economic effectiveness has been determined as follows:

$$k_{eff} = \frac{23.35\,million UAN}{22.34\,million UAN} = 1.04. \quad (21)$$

The effect from the mill modernization is calculated as follows:

$$NIC_{eff} = NIC_{over} - NIC = 24.78 - 23.35 = 1.43\,million UAN\,. \quad (22)$$

The coefficient of economic effectiveness is:

$$e = \frac{NIC_{eff}}{NIC} = \frac{1.43\,million UAN}{28.47\,million UAN} = 0.05 \quad (23)$$

The payback period from the implementation of the modernization is determined on the basis of the following relation:

$$T = \frac{1.367\,million UAN}{1.43\,million UAN} \approx 1.0\,year. \quad (24)$$

Conclusions. The economical and mathematical model of the wood processing mill has been developed. The model is used to determine the optimal production volumes of the enterprise in order to maximize the gross domestic product and profitability within the implementation of the modernization (utilization of alternative energy sources and installation of process automation equipment for wood treatment), as well as to analyze the possibility of the purchase of extra volumes of raw materials. The model has been applied to the «Poltava Actioners Center» LLC.

The implementation of the mill modernization and the extra purchase of raw materials can increase altogether the income of the enterprise on 1.43 million UAH.

The application of the developed model allowed calculating the profitability of the wood processing enterprise (being determined as 1,21), the income coefficient (that is equal to 17,07), the coefficient of economic effectiveness (found as 0,05) and the payback period (nearly 1,0 year).

The results of the present work can be used for the management of economic activities at the wood processing mill, as well as for the teaching purposes of «Economic and mathematical modelling» matter.

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Iryna Skrylnyk, Senior Lecturer. Poltava National Technical Yuri Kondratyuk University. **Mathematical Modelling Management of Economic Activities of Small Size Wood Processing Mill in Ukraine.** The economical and mathematical model of the wood processing mill has been developed. The model is used to determine the optimal production volumes of the enterprise in order to maximize the gross domestic product and profitability within the implementation of the modernization (utilization of alternative energy sources and installation of process automation equipment for wood treatment), as well as to analyze the possibility of the purchase of extra volumes of raw materials. The model has been applied to the «Poltava Actioners Center» LLC.

The results of the calculations of the production volumes, the stock volume, the expenses, the wastes volume and GDPF after the mill modernization. The total production expenses and the gross domestic product after the modernization of the «Poltava Actioners Center» LLC have been calculated.

The implementation of the mill modernization and the extra purchase of raw materials can increase altogether the income of the enterprise on 1,43 million UAH.

The application of the developed model allowed calculating the profitability of the wood processing enterprise (being determined as 1,21), the income coefficient (that is equal to 17,07), the coefficient of economic effectiveness (found as 0,05) and the payback period (nearly 1,0 year).

The results of the present work can be used for the management of economic activities at the wood processing mill, as well as for the teaching purposes of «Economic and Mathematical Modelling» matter.

Keywords: model, test, gross profit, net profit, cost price.

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Скрильник Ірина Іванівна, старший викладач. Полтавський національний технічній університет імені Юрія Кондратюка. **Математичне моделювання управління економічною діяльністю малого підприємства деревообробної промисловості в Україні.** Розглянуто побудову математичної моделі управління економічною діяльністю ТОВ «Полтавський акціонерний центр», зокрема отримання оптимального обсягу виробництва для досягнення максимального валового прибутку цим підприємством. За результатами моделювання виконано розрахунки для виготовлення продукції при впровадженні модернізації підприємства, а також за наявності можливості додаткової закупівлі та продажу сировини. Визначено економічну ефективність упровадження результатів дослідження.

Ключові слова: моделювання, модель, критерій, валовий прибуток, чистий дохід, собівартість.

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Скрыльник Ирина Ивановна, старший преподаватель. Полтавский национальный технический университет имени Юрия Кондратюка. **Математическое моделирование управления экономической деятельностью малого предприятия деревообрабатывающей промышленности в Украине**. Рассмотрено построение математической модели управления экономической деятельностью ТОО «Полтавский акционерный центр», в частности, получения оптимального объема производства для достижения максимальной его валовой прибыли. По результатам моделирования произведены расчеты для изготовления продукции при внедрении модернизации предприятия, а также возможности дополнительной закупки и продажи сырья. Определена экономическая эффективность внедрения результатов исследования.

Ключевые слова: модель, критерий, валовая прибыль, чистый доход, себестоимость.