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MODELING OF INDICATORS OF THE CHEMICAL INDUSTRY ENTERPRISES' STRATEGY

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The article is devoted to the formation of a mathematical model of the volume of production of competitive products as one of the main indicators that determines the strategy of the chemical industry enterprises to ensure their sustainable development. It is noted that the volume of production determines the enterprise's share in the competitive market, on the one hand, and the level of resource use - on the other. In the chemical industry, the volume of production (sales) and profitability of activities in the sectors of the industry are indicators that used to characterize the strategy. It is offered to study the influence of factors on production volumes using multifactor linear correlation-regression models, and to form the composition of factors according to their impact on the competitiveness of products in strategic areas of management of the chemical industry enterprises. The components of the mathematical model for determining the production volumes of chemical industry enterprises (target function and system of restrictions) are proposed to be formed on the basis of multifactor models of influence on production volumes in strategic areas of management taking into account the risks that exist in production and sales. On the basis of the developed mathematical model it is offered to solve a task of definition of optimum volumes of manufacture of competitive products of the chemical industry enterprise for each assortment unit in strategic areas of management by a method of linear programming. Taking into account the influence on the competitiveness of products in tire production, multiple correlation-regression models of volumes of production in groups of passenger, truck and agricultural tires, as well as a mathematical model of production volumes of competitive tire products have been built. Within this model, a set of management decisions to increase the competitiveness of products has been applied. It has been proved that the use of the built model in the competitiveness management system contributes to the increase the gross profit and providing sustainable development of the tire production enterprise.

Keywords: chemical industry, strategy of the enterprise, product competitiveness, mathematical model, linear programming, tire production.

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Introduction and problem statement

The formation of the enterprise's strategy involves making decisions about the optimal development option in the face of complex and rapidly changing external and internal environment. The modern chemical industry consists of a large number of sectors and various industries that have their own strategic characteristics. In terms of increasing competition in domestic and foreign markets, the basis for the formation of the enterprise's strategy is to justify the range of competitive products, the production of which would provide maximum profit in the short and long term. An important indicator of the enterprise's strategy is the volume of production, as it determines the company's share in a competitive market, on the one hand, and the level of resource use – on the other. Therefore, the

formation of optimization models of production volumes, taking into account external and internal environmental factors and risks of production and sales in target markets, is one of the methodical tasks of strategic management in the chemical industry.

Analysis and research of publications

The works of well-known domestic and foreign scientists are devoted to the problems of strategic management of chemical industry enterprises (CIE). In the work [7] it is concluded that in the conditions of Chemicals 4.0 concept sustainable development challenges constitute the starting point of most innovations in chemical manufacturing. The works of T.V. Kovenia [4, p. 32-34], I.I. Pavlenko [5, p. 9-12], H.Z. Shevtsova, N.V. Shvets [8, p. 115-122] are devoted to the investigation of the issues of analysis, estimation and increase the competitiveness of the chemical industry enterprises'. An estimation of the dynamics of chemical industry development and functioning has been conducted in the work of S. Ishchuk [3, p. 70-75], wherein the necessity of the increasing of production and export potential in the in the conditions of destructive action of factors of macroeconomic, market and political character has been underlined. The necessity of the including the raw materials, energy and ecological factors to the formation of the strategy of development of the chemical industry enterprises has been highlighted in the work of P.G. Pererva [6, p. 115–117]. In the article [1, p. 90-91] the methodical approach to an estimation of the financial and economic support of the chemical industry enterprises strategy has been offered. This approach involves estimation of the state of resource management and financial condition, resource efficiency and profitability of the enterprise. The estimation corresponds to the directions of the strategic development of the enterprise (market, marketing, production, and resource) and is the basis for decision-making of the elements of enterprise portfolio strategy (geographical vector of growth (market geography, demand, technology, and resources), competitive advantages, synergy and balance of strategic areas of management). In this case, the volumes of production and sale as well as the enterprises' profitability in sectors of the industry are used as main indicators of the enterprises' strategies.

Despite the achievements of scientists in solving the problems of strategic management of CIE, the issues of modeling indicators of the strategy of enterprises in the industry for the production of competitive products under the influence of external and internal factors remain out of the attention of scientists.

Purpose of the article

Taking into account the relevance of the strategic management problems for the current stage of the development of the industry, the purpose of the article is to build a mathematical model of the volume of production of competitive products as one of the main indicators that determines the strategy of the chemical industry enterprise to ensure their sustainable development.

Presentation the main material

The sectoral structure of the chemical industry determines the feasibility of forming the strategic characteristics of the industry in terms of individual sectors and industries. In work [8, p. 114-115] it was noted that the productions of the chemical industry differ in size, purpose, market capacity, export potential, profitability, technology, equipment, level of competition and industry barriers, availability of raw materials. In the study [1, p. 88-90] it was revealed the contradictions in the development of sectors of the industry – the volume of sales is not consistent with the financial and economic support – it does not allow to achieve profitability of economic growth.

Conducted in work [7] study of the experience of implementation of Industry 4.0 paradigm by Leading Global Chemical Companies proved that Chemicals 4.0 concept is associated with smart modernization of the chemical industry value chain. Carried out in the work [9, p. 180-187] comparative analysis of concepts and approaches to strategic management demonstrates that the value chain concept is a tool for formation of the enterprise's competitive advantages in the conditions of branch competition. Therefore, when forming a CIE strategy, it is advisable to take into account the components of the process of creating added value.

Consequently, when forming the strategy of enterprises in the industry it is necessary to solve the problem of determining production volumes to ensure the profitability of a diversified enterprise with available resources under the influence of factors controlled, uncontrolled or partially managed by the enterprise.

In scientific and practical support to the formation of enterprise strategy it is necessary to form a mathematical model for determining the volume of production of competitive products, which would take into account management decisions at all levels to increase product competitiveness (strategic, tactical and operational), influence factors on the production in each assortment group as well as financial and economic results of the enterprise as the final goal of increasing the competitiveness of

products.

It is proposed to investigate the influence of factors on the volume of production by means of multifactor linear correlation-regression models for strategic areas of management of chemical industry enterprises. All influencing the volume of production factors should be divided into internal (managed at the product level and at the enterprise level), external partially controlled and uncontrolled. In should be noted that the dynamics of volume of production also demonstrates the product competitiveness dynamics and enterprise's market share in relevant strategic area of management. Whereas the composition of factors reflects the impact on the competitiveness of products within the level of controllability of factors by the enterprise.

The components of mathematical model for determining the optimal production volumes of CIE are proposed to be formed on the basis of multifactor models of influence on the production volumes in strategic areas of management taking into account the risks that exist in the production and sale of products.

The assortment unit as a base of the product competitiveness estimation is a unit for the model components formation, gross profit of the enterprise as the purpose of the strategy is a target function, the resources of the enterprise taking into account the composition and structure of equipment are the system of restrictions (also are the parameters of the product competitiveness management and the base for application of the management decisions for it increase), risks in the system of restrictions and target function reflect the influence of partially controlled and uncontrolled factors, respectively, on the conditions of production and sale of products

Based on the results of the analysis of the functioning of CIE, analysis of product consumption in strategic areas of management, the main provisions that should be the basis for building a mathematical model for determining the optimal volume of production are following:

– the main resources of CIE used in production are material and labor, as those that determine the cost of production and reflect the level of production technology;

– the cost of material resources is determined by the cost of raw materials and energy resources, as the main items of production costs;

– the cost of labor resources reflects both the composition and structure of the equipment of the enterprise, as it is determined depending on the complexity of production and the required qualifications of workers;

– restrictions on the cost of resources are determined by the annual ratio of working capital of the enterprise for the relevant types of raw materials and energy, the annual wage fund of the main production workers;

– the minimum production volumes are determined by the minimum batch of the order, which ensures the break-even point of production of each type of product, and are the actual estimates of the enterprise;

– maximum production volumes are determined by consumption indicators and are preliminary estimates of CIE;

– profitability of products is determined by the actual data of the enterprise in the manufacture of each unit;

– the target function should solve the problem of profit maximization as the main indicator that ensures the sustainable development of CIE;

– the risks that exist in the sale of CIE products (in domestic and foreign markets), reflect the probability of obtaining the planned amount of profit for each assortment unit in accordance with the strategic areas of management;

– the risks that exist in the supply of resources, reflect the probability of obtaining the planned supply of resources of each type and relate to the main types of raw materials (including imported) used in the manufacture of tire products;

– the optimal volume of production of each product range should provide maximum profit by using the available resources of the enterprise.

The task of determining the optimal production of competitive CIE products is solved using the method of linear programming, and the mathematical model taking into account the established provisions will have the following general form.

Target function - gross profit of CIE:

$$P = \sum_{i=1}^{n} p_i x_i \alpha_i \to \max, \quad (1)$$

by the restrictions:

$$G = \begin{cases} \sum_{i=1}^{n} m_{ij} x_i \le M_j \beta_j, \\ \sum_{i=1}^{n} h_{ij} x_i \le H_j, \\ \sum_{i=1}^{n} l_{ij} x_i \le L_j, \\ Q_i^{min} \le x_i \le Q_i^{max}, \\ i = \overline{(1,n)}, \\ j = \overline{(1,k)}, \end{cases} \quad (2)$$

where G – area of restrictions; x_i – quantity of production on each i-th assortment unit; n – the number of assortment units of competitive products planned for production; k – the number of names j-th types of main resources of CIE used for the production of competitive products; p_i – profit from the sale of a unit of production i-th assortment unit; a_i – the probability of obtaining the planned amount of profit from sales of products i-th assortment unit; m_{ij} – material costs for the production of the unit i-th assortment unit of production when using the j-th type of material resources of the enterprise; h_{ij} – the cost of energy in the production of the unit i-th assortment unit of production when using the j-th type of energy resources of the enterprise; l_{ij} – labor costs in the production of the unit i-th assortment unit of production when using the j-th type of labor resources of the enterprise; M_j – the volume of delivery j-th type of material resources of the enterprise; β_j – the probability of receiving the planned volume of delivery j-th type of material resources from delivers of the enterprise; H_j – the cost of purchasing the j-th type of energy resources of the enterprise; L_j– wage fund of the j-th category of the personnel of the enterprise; Q_i^{min} – the minimum volume of production of the assortment i-th unit, according to the break-even point of its production; Q_i^{max} – the maximum volume of production of the assortment i-th unit, according to market demand for these products.

The paper [1, p. 90] noted that there is a contradiction in the development of the rubber products sector – despite the accelerated growth of sales, the sector remains unprofitable, and one of the industries in need of in-depth research is tire production, as it tends to decline.

Multifactor linear correlation-regression models of tire production volumes are built according to strategic areas of management (passenger, truck and agricultural tires) and take into account the factors managed and not controlled by the enterprise individually for each group of tires. Internal influence factors on the production of tires at the product level are average price of tire products as a structural price factor of sales revenue, export price of 1 ton of tires in the group, at the enterprise level – assets and gross profit of tire enterprise (for all tire groups). External partially controlled influence factors on the production of tire products are the import price of 1 ton of tires in the group, the volume of exports and imports of tires by groups, and external uncontrolled factors – the average wage in Ukraine (for passenger tires), passenger and freight traffic (for a group of truck tires), production volumes of agricultural products (for a group of agricultural tires), the price of 1 ton of natural and synthetic rubbers, the level of GDP per capita and the price of imported gas (for all groups of tires).

Multiple linear correlation-regression models of tire production volumes, which take into account significant factors of influence in each group of tires, have the following form, respectively, for groups of passenger, truck and agricultural tires:

$$Y^{pass} = 6.2832X_{\substack{gross\\profit}} + 0.6673X_{assets} + \\ +1.3491X^{pass}_{export} - 0.9911X^{pass}_{\substack{price\\import}} + 3287.07, \quad (3)$$

$$Y^{truck} = 0.1628X_{\substack{average\\price}} - 0.0948X^{truck}_{\substack{price\\export}} + \\ +1.752X_{\substack{grass\\profit}} + X_{assets} + 0.2523X^{truck}_{export} + \\ +0.1635X^{truck}_{\substack{price\\import}} + 0.5435X_{\substack{synthetik\\rubber}} + \\ +0.4185X_{\substack{natyral\\rubber}} - 0.04X_{GDP} + 624.897, \quad (4)$$

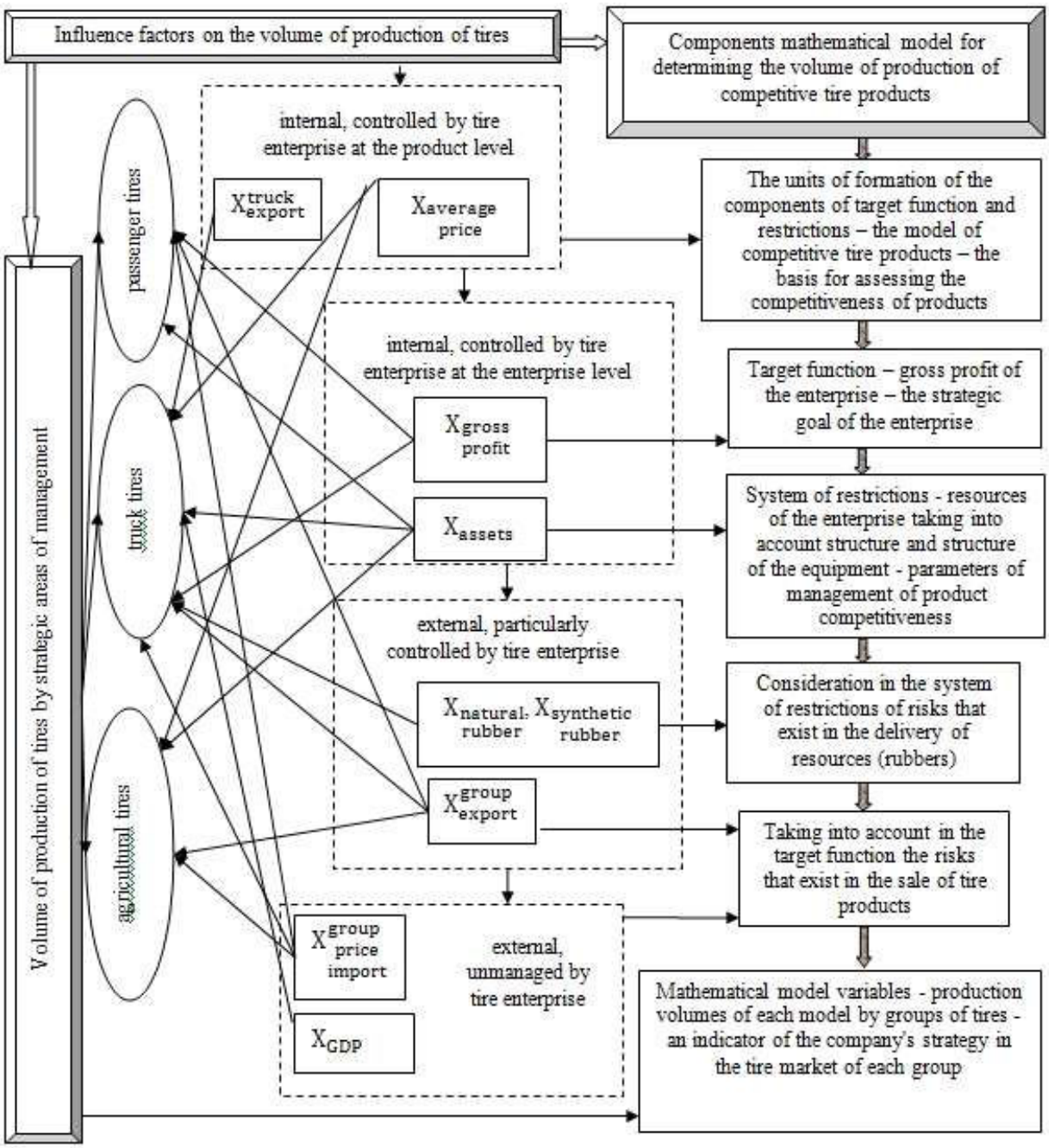
$$Y^{agr} = -0.4427X_{\substack{average\\price}} - 0.03X_{assets} + \\ +2.9953X^{agr}_{export} + 0.0591X^{agr}_{\substack{price\\import}}, \quad (5)$$

де Y^{pass}, Y^{truck}, Y^{agr} – production volumes of passenger, truck and agricultural tires, respectively, thousand units; X_{assets} – value of assets of tire enterprises, million UAH; X^{group}_{profit} – gross profit of tire enterprises, million UAH; $X^{pass}_{price\ import}$, $X^{truck}_{price\ import}$, $X^{agr}_{price\ import}$ – import price of 1 ton of passenger, truck and agricultural tires USD USA / ton; X^{pass}_{export}, X^{truck}_{export}, X^{agr}_{export} – export volumes of passenger, truck and agricultural tires, thousand units; $X_{\substack{average\\price}}$ – average price of domestic tire products, UAH / unit; $X^{truck}_{\substack{price\\import}}$ – export price of truck tires, USD USA/ton; $X_{\substack{natural\\rubber}}$, $X_{\substack{synthetic\\rubber}}$ – price of natural and synthetic rubbers, USD USA

/ ton; X_{GDP} – GDP per capita in Ukraine, million UAH / person.

The obtained multifactor correlation-regression models have a strong correlation between the factors of influence and the volume of tire production in each group (coefficient of determination is from 0.9784 to 0.9998), adequate for the study conditions (proven by Fisher's test), as well as take into account the most significant factors (proven by Student's criterion), the composition and impact of which on production volumes is individual for each group of tires.

Therefore, the price of tires, rubber value, asset value and gross profit of enterprises should be taken



Legend: $X^{group}_{price\ import}$ and X^{group}_{export} – respectively, the import price and export volumes in the group of tires

Formation of the components of the mathematical model for determining the volume of production of competitive products of the chemical industry (in the case of tire production)

Sourse: developed by author

into account among the internal and external factors managed by the enterprise in the formation of the strategy, as well as in scientific and practical support to the strategy of tire enterprises.

The components of the mathematical model for determining the optimal production volumes of tire production enterprises (Fig.) are formed on the basis of multifactor models of influence on tire production volumes in each group (formulas 3-5) taking into account the risks that exist in the production and sale of tire products.

The application of the optimization model in the conditions of the tire production enterprise contributes to the increase of production volumes by 11.28%, and the volume of gross profit by 12.14%.

Restrictions of the mathematical model in terms of resources and equipment structure simultaneously act as parameters of production volume management in the implementation of management decisions to increase the product competitiveness and change the delivery strategy.

Complex of management decisions to increase the product competitiveness of the tire enterprises was offered in work [1, p. 190]. These decisions impact on the quality index of the product competitiveness in the conditions of production and are classified by level of management (strategic, tactical, operational), term of implementation (short-, medium- and long-term), object of influence (concerning separate models, standard sizes, groups or all assortment of tire products), center of responsibility (structural subdivisions corresponding for the development of solutions) and magnitude of the impact on the cost of production (Table)

Implementation of operational decisions allows increasing gross profit of enterprise by 23.66%. At the same time, there is a decrease in production by 15.77%, which indicates the ability of management decisions to increase the production of products with higher profitability. The implementation of tactical decisions is able to increase gross profit by 24.21% compared to operational decisions and increase volume of production by 14.68%, and the implementation of strategic decisions – to increase profits by 15.65% and increase volume of production by 2.86% in comparison with tactical decisions.

Taking into account the risks that exist in the production and sale of tire products reduces the possibility of obtaining the planned amount of profit by 32.47% for the forecast value and by 35.92%, 29.45% and 29.66%, respectively, in the implementation of operational, tactical and strategic decisions to increase the product competitiveness. At the same time, the production of tire products is reduced by 7% for the forecast value and by 25.46%, 11.02% and 45.6% in the implementation of these management decisions to increase the product competitiveness.

The use of a mathematical model in the scientific and practical support of the tire enterprise strategy allowed determining the maximum value of gross profit in the implementation of management decisions to increase product competitiveness, as well as the optimal volume of tire production.

Therefore, the gradual increase in gross profit compared to the optimal production plan proves that the including of mathematical model in the scientific and practical support of the strategy contributes to the sustainable development of tire enterprise in the implementation of management decisions at various levels to increase product competitiveness taking into account the risks of production and sale.

Conclusions

It has been proved that volumes of production

Complex of management decisions to increase the product competitiveness of the tire enterprises by quality of tires in the conditions of production [1, p. 190]

Classification attribute of decision	Constructional decision	Decisions for constructional materials and rubbers	Decision for technology of production
Level of management	operative	tactical	strategic
Term of introduction	short-term – up to 1 year	mid-term – 1–3 years	long-term – over 3 years
Content of management decision	change the compounding of rubber within available recourses	transition to new materials, increasing the service life the diaphragms	change the vulcanization and rubber-mix modes, replacement of equipment, using the recycled materials
Object of influence	model, standard size of tires	group of tires	group and whole assortment of tires
Responsible department	protector and frame groups of central plant laboratory	frame, vulcanization and exploratory groups of central plant laboratory	scientific-technical center
Decreasing the unit cost	up to 3,5%	3,5–7,0%	7–10%

by strategic areas of management and enterprise profit are indicators used in the formation of enterprise strategy. A mathematical model of CIE production volumes, which takes into account the influence factors on the product competitiveness and the risks that exist in its production and sale, as well as provides to maximize the enterprise's profit in the production of competitive products, has been proposed. The application of this model in terms of tire production allows increasing the gross profit of enterprise by 12.14%, and volume of production by 11.28%. The use of the model in the implementation of management decisions at various levels (operational, tactical and strategic) to increase the tire products competitiveness contributes to the sustainable development of the enterprise taking into account the risks that exist in the production and sale of tire products.

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МОДЕЛЮВАННЯ ПОКАЗНИКІВ СТРАТЕГІЇ ПІДПРИЄМСТВ ХІМІЧНОЇ ПРОМИСЛОВОСТІ

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Статтю присвячено формуванню математичної моделі обсягів виробництва конкурентоспроможної продукції як одного з основних показників, що визначає стратегію підприємств хімічної промисловості для забезпечення їх сталого розвитку. Відзначено, що обсяг виробництва визначає частку підприємства на конкурентному ринку, з одного боку, та рівень використання ресурсів – з іншого. У хімічної промисловості для характеристики стратегії використовуються обсяги виробництва (реалізації) та рентабельність діяльності у секторах галузі. Запропоновано досліджувати вплив факторів на обсяги виробництва за допомогою багатофакторних лінійних кореляційно-регресійних моделей, а склад факторів формувати у відповідності з їх впливом на конкурентоспроможність продукції за стратегічними зонами господарювання підприємств хімічної промисловості. Складові математичної моделі обсягів виробництва продукції підприємств хімічної промисловості (цільову функцію та систему обмежень) пропонується формувати на основі багатофакторних моделей впливу на обсяги виробництва продукції у стратегічних зонах господарювання з урахуванням ризиків, що існують при виробництві та реалізації продукції. На основі сформованої математичної запропоновано вирішувати задачу визначення оптимальних обсягів виробництва конкурентоспроможної продукції підприємств хімічної промисловості для кожної асортиментної одиниці продукції у стратегічних зонах господарювання моделі методом лінійного програмування. З урахуванням факторів впливу на конкурентоспроможність продукції у шинному виробництві побудовано множинні кореляційно-регресійні моделі обсягів виробництва у групах легкових, вантажних та сільськогосподарських шин, а також математичну модель обсягів виробництва конкурентоспроможної шинної продукції. В межах даної моделі застосовано комплекс управлінських рішень з підвищення конкурентоспроможності продукції. Доведено, що використання побудованої моделі в системі управління конкурентоспроможністю сприяє підвищенню валового прибутку та стійкому розвитку підприємства шинного виробництва.

Ключові слова: хімічна промисловість, стратегія підприємства, конкурентоспроможність продукції, математична модель, лінійне програмування, шинне виробництво.

МОДЕЛИРОВАНИЕ ПОКАЗАТЕЛЕЙ СТРАТЕГИИ ПРЕДПРИЯТИЙ ХИМИЧЕСКОЙ ПРОМЫШЛЕННОСТИ

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Статья посвящена формированию математической модели объемов производства конкурентоспособной продукции как одного из основных показателей, определяющих стратегию предприятий химической промышленности для обеспечения их устойчивого развития. Отмечено, что объем производства определяет долю рынка предприятия на конкурентном рынке, с одной стороны, и уровень использования ресурсов – с другой. В химической промышленности для характеристики стратегии используются объемы производства (реализации) продукции и рентабельность деятельности в секторах отрасли. Предложено исследовать влияние факторов на объемы производства при помощи многофакторных линейных корреляционно-регрессионных моделей, а состав факторов формировать в соответствие с их влиянием на конкурентоспособность продукции в стратегических зонах хозяйствования предприятий химической промышленности. Составляющие математической модели объемов производства продукции предприятий химической промышленности (целевую функцию и систему ограничений) предлагается формировать на основе многофакторных моделей влияния на объемы производства продукции в стратегических зонах хозяйствования с учетом рисков, существующих при производстве и реализации продукции. На основе сформированной математической модели предложено решать задачу определения оптимальных объемов производства конкурентоспособной продукции предприятий химической промышленности для каждой ассортиментной единицы продукции в стратегических зонах хозяйствования методом линейного программирования. С учетом факторов влияния на конкурентоспособность продукции в шинном производстве построены множественные корреляционно-регрессионные модели объемов производства в группах легковых, грузовых и сельскохозяйственных шин, а также математическую модель объемов производства конкурентоспособной шинной продукции. В рамках данной модели применен комплекс управленческих решений по повышению конкурентоспособности продукции. Доказано, что использование данной модели в системе управления конкурентоспособностью продукции способствует повышению валовой прибыли и устойчивому развитию предприятия шинного производства.

Ключевые слова: химическая промышленность, стратегия предприятия, конкурентоспособность продукции, математическая модель, линейное программирование, шинное производство.

MODELING OF INDICATORS OF THE CHEMICAL INDUSTRY ENTERPRISES' STRATEGY

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The article is devoted to the formation of a mathematical model of the volume of production of competitive products as one of the main indicators that determines the strategy of the chemical industry enterprises to ensure their sustainable development. It is noted that the volume of production determines the enterprise's share in the competitive market, on the one hand, and the level of resource use - on the other. In the chemical industry, the volume of production (sales) and profitability of activities in the sectors of the industry are indicators that used to characterize the strategy. It is offered to study the influence of factors on production volumes using multifactor linear correlation-regression models, and to form the composition of factors according to their impact on the competitiveness of products in strategic areas of management of the chemical industry enterprises. The components of the mathematical model for determining the production volumes of chemical industry enterprises (target function and system of restrictions) are proposed to be formed on the basis of multifactor models of influence on production volumes in strategic areas of management taking into account the risks that exist in production and sales. On the basis of the developed mathematical model it is offered to solve a task of definition of optimum volumes of manufacture of competitive products of the chemical industry enterprise for each assortment unit in strategic areas of management by a method of linear programming. Taking into account the influence on the competitiveness of products in tire production, multiple correlation-regression models of volumes of production in groups of passenger, truck and agricultural tires, as well as a mathematical model of production volumes of competitive tire products have been built. Within this model, a set of management decisions to increase the competitiveness of products has been applied. It has been proved that the use of the built model in the competitiveness management system contributes to the increase the gross profit and providing sustainable development of the tire production enterprise.

Keywords: chemical industry, strategy of the enterprise, product competitiveness, mathematical model, linear programming, tire production.

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