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METHODOLOGY OF MODELLING STRATEGIC ACTIONS OF ENTERPRISES IN THE INTERNATIONAL MARKET

МЕТОДИКА МОДЕЛЮВАННЯ СТРАТЕГІЧНИХ ДІЙ ПІДПРИЄМСТВ НА МІЖНАРОДНОМУ РИНКУ

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In today's conditions of globalization and dynamic changes in international markets, enterprises face a number of challenges that require the application of effective management strategies. The constant increase in the stochastic nature of the underlying processes that determine the functioning of enterprises in the international market necessitates the search for and testing of innovative methods for modeling strategic actions. Particular importance is attached to tools that enable enterprises to develop optimal action plans, taking into account the influence of numerous factors. Therefore, the purpose of this article is to substantiate the feasibility of using linear programming methodology for modeling all possible strategic actions of enterprises in the international market and to determine the main approaches to its implementation. The study confirms that the advantages of modeling the strategic actions of enterprises in the international market using linear programming tasks lie in the informativeness regarding the optimization of a series of sequential actions, decisions, or operations that the enterprise applies or plans to apply to achieve its strategic goals.

Keywords: sustainable development, linear programming tasks, objective function, cost optimization, enterprise's reserve capabilities.

У сучасних умовах глобалізації та динамічних змін на міжнародних ринках підприємства стикаються з низкою викликів, що вимагають застосування ефективних стратегій управління. Постійне підвищення стохастичності основних процесів, що визначають засади функціонування підприємств на міжнародному ринку, зумовлює необхідність пошуку та апробування інноваційних методів моделювання стратегічних дій. Особливого значення набувають інструменти, що дозволяють підприємствам розробляти оптимальні плани дій з урахуванням численних факторів. Відтак метою цієї статті є обґрунтування доцільності застосування методики лінійного програмування для моделювання всіх можливих стратегічних дій підприємств на міжнародному ринку та визначення основних підходів до її реалізації. У межах дослідження констатовано, що перевагами моделювання стратегічних дій підприємств на міжнародному ринку за задачами лінійного програмування (ЗЛП) є інформативність щодо оптимізації сукупності послідовних заходів, рішень або операцій, які підприємство застосовує або планує застосувати для досягнення своїх стратегічних цілей. Основою моделювання є оптимізаційне перетворення через методи ЗЛП низки субмоделей для кожної стратегічної задачі з урахуванням чутливості їх вхідних умов до дії ключових факторів. Дієвість лінійного програмування зумовлена тим, що кожен із визначених наборів стратегічних дій завжди відповідає вимогам і обмеженням ринку. Констатовано, що за таких умов можливо побудувати алгоритми керування, релевантні змісту зовнішньоекономічної діяльності підприємств – від виробництва та логістики до маркетингу і продажів. Авторами проілюстровано, що навіть коректний запис субмоделі кожної досліджуваної стратегічної задачі допомагає керівництву підприємства швидко оцінити її ефективність та, за потреби, відкоригувати з урахуванням чутливості до змін у різних параметрах (наприклад, ціни на сировину, курсу валют, податків тощо). Коректний запис субмоделі надає можливість програмувати її поведінку та чітко контролювати кожен етап реалізації стратегічної дії підприємств на міжнародному ринку.

Ключові слова: сталий розвиток, завдання лінійного програмування, цільова функція, оптимізація витрат, резервні можливості підприємства.

Problem statement. In the modern context of globalization and dynamic changes in international markets, enterprises face a number of challenges that require the application of effective management strategies. The constant increase in the stochasticity of fundamental processes that determine the principles of enterprise operations in the international market necessitates the search for and testing of innovative methods for modeling strategic actions. Globalization processes, increasing competition, and the instability of internal and external operating environments compel business entities to adapt their strategies and management methods to meet changing requirements.

In this regard, tools that enable enterprises to develop optimal action plans considering numerous internal and external factors become particularly important. The most optimal approach for this is the linear programming method. Its application allows solving optimization problems characterized by linear relationships between variables, as well as developing effective methods for solving such problems. Considering the complexity and multifactorial nature of the international environment, the use of linear programming becomes particularly relevant for ensuring the competitiveness of enterprises in global markets.

Analysis of recent research and publications. Modern issues of strategic management of enterprise activities, including in the international market, are quite comprehensively covered by Krasnyak O.P., Kurylo N. F., Lisenyi Ye., Vynnychenko L., and Raikovska I. T. These researchers, in particular, study aspects such as: the development and implementation of enterprise development strategies in a dynamic market environment; competitiveness analysis and identification of key success factors; formation of effective control systems and evaluation of results.

Highlighting previously unresolved parts of the overall problem. At the same time, the methodology for modeling strategic actions of enterprises in the international market remains largely overlooked by researchers due to the overall complexity of this process. Many strategic actions must be developed considering internal aspects of enterprises, such as optimizing production processes or making financial decisions. However, there are also specific strategic actions in the international market that require consideration of an external set of factors.

Formation of the objectives of the article (task statement). The purpose of this article is to substantiate the feasibility of applying the linear programming method for modeling all possible strategic actions of enterprises in the international market and to determine the main approaches to its implementation.

Summary of the main research material. Within the study, the authors draw attention to the fact that an enterprise operating in multiple countries may face the problem of low effectiveness of strategic actions if their content does not ensure the optimal distribution of production capacities and resources among different segments of the international market (which may include various geographical regions, countries, consumer groups, or industry niches) [3–4; 6].

Therefore, modeling strategic actions of enterprises in the international market should include [1–2]:

1. Problems of determining the optimal volume of production for each market, considering its inherent demand, production costs, transportation, and customs tariffs.
2. Problems of optimal logistics organization, including minimizing transportation costs between countries, taking into account available transport routes and their costs.
3. Problems of labor resource utilization, considering different productivity standards, labor costs, and legal restrictions in various jurisdictions.
4. Problems of forming an investment portfolio that allows for the efficient allocation of financial resources among different projects or regions, considering risk levels and expected returns.

At the same time, linear programming makes it possible to construct a highly sensitive comprehensive mathematical model that is represented by sets of submodels for individual strategic actions, developed for each strategic task. In the general case, each such submodel includes [1–2; 6]:

1. A poly-variant objective function is a function that needs to be maximized or minimized (for example, maximizing profit for a specific market or minimizing logistics costs). For instance, if the primary goal of the enterprise is to maximize profit, the poly-variant objective function of the submodel may take the form:

$$\text{Maximize } Z = \sum_{i=1}^{n} pi \cdot xi - \sum_{j=1}^{m} cj \cdot xj \,, \qquad (1)$$

where: pi – the selling price of one unit of product type i; xi – the quantity of units of product type i; cj – the cost of supplying or producing one unit of product type j; m – the number of different types of products.

Algorithm (1) allows within the submodel to find the optimal resource allocation, determine the number of units of product required for each market to achieve maximum profit, and so on [4].

In contrast, if the primary goal of the enterprise is to minimize costs, the submodel poly-variant objective function will take the following form:

$$\text{Minimize } Z = \sum_{i=1}^{n} ai \cdot xi - \sum_{j=1}^{m} bj \cdot xj \,, \qquad (2)$$

where: ai – the cost of producing or supplying one unit of product type ii; xi – the quantity of units of product type ii; bj – additional costs, such as storage, logistics, etc.

Through (2), the enterprise can optimize its costs while maintaining competitiveness in the international market [4].

2. The system of constraints, which consists of a set of linear inequalities or equations. It is important to note that the constraints in linear programming problems (LPP) are conditions that define the possible solution options for available strategic actions.

Specifically, if we have a linear programming problem with multiple variables, the system of constraints can be written as follows:

$$\begin{array}{l} 1.\ a11x1+a12x2+...+a1nxn \le b1 \\ 2.\ a21x1+a22x2+...+a2nxn \le b2 \\ ...\ n.\ am1x1+am2x2+...+amnxn \le bm \end{array} \qquad (3)$$

where: x1,x2,…,xn – variables (e.g., production volumes of different product types); aij – coefficients corresponding to resource costs; b1,b2,…,bm – resource constraints (e.g., maximum available materials or time).

3. Non-negative variables, or variables representing the quantity of resources or production/sales volumes, which cannot take negative values (i.e., their values are bounded below by zero). These variables are represented by the condition:

$$xi \ge 0,$$

where xi — the variable representing the quantity of units of a product, resource, or other quantity, and must be no less than zero.

It should be noted that the outlined modeling methodology is carried out through the solution of linear programming problems (hereafter referred to as LPP), which employ a wide range of methods chosen depending on the user's needs.

Among the methods that are frequently used in strategic management of enterprise operations in international markets are:

1. The Simplex method, which is effective in determining the paths for the sequential improvement of enterprise actions in the international market, as it allows, within a limited number of steps with known function estimates, to obtain the optimal plan for its long-term actions.

2. The Dual Simplex Method (or P-method) is effective in determining ways to improve the strategic actions of enterprises in the international market under conditions where the initial solution is not feasible or may be ineffective.

The Simplex method, in fact, refers to an iterative process aimed at solving a system of balanced steps, starting from a basic feasible solution and moving along the corner points of the feasible region in search of a better alternative, improving the value of the objective function until it reaches the optimal value. It should be noted that the solution of linear programming problems using this method is possible in the following forms of representation:

1. Simplex table (or Jordan transformation submethod), which involves constructing a table where the rows correspond to the constraints of the problem, and the columns represent the variables.

2. Basic form of representation, where the solution is expressed through basic and non-basic variables, using matrix operations.

3. Modified Simplex method, where part of the problem is changed, for example, by adding or modifying constraints.

4. In column form. In this form, the solution is presented in terms of column vectors, which are either in the basis or not.

5. In row form. This form of representation is similar to the column form, but uses row vectors.

More detailed modern approaches to the forms of recording solutions to linear programming problems using the Simplex method are presented in Table 1.

Table 1

Modern approaches to forms of recording solutions to linear programming problems (LPP) using the simplex method

<table>
<tr><th>Forms of recording solutions to problems using the simplex method</th><th>Content of recording solutions to problems using the simplex method</th><th>Conditions for Applying the Recording of Solutions to Problems Using the Simplex Method</th><th>Features of the simplex method solution</th></tr>
<tr><td>Simplex table (or jordan transformation submethod)</td><td>Involves constructing a table where rows correspond to the constraints of the problem, and columns represent the variables.</td><td>It is used when it is important to gradually change the basic variables using Jordan transformations until the optimal value of the objective function is reached.</td><td rowspan="5">The selection of the number of variables that affect strategic actions in the international market and the number of rows (the number of constraints). At the same time, constraints of the type xi≥0x_i \geq 0 should be ignored.</td></tr>
<tr><td>Basic form of representation</td><td>The solution is expressed through basic and non-basic variables, using matrix operations.</td><td>The notation is convenient for programming the Simplex method algorithm on a computer.</td></tr>
<tr><td>Modified simplex method</td><td>The solution is applied when part of the problem changes, such as when a constraint is added or modified.</td><td>It allows making changes to the current solution without the need to recalculate from scratch.</td></tr>
<tr><td>Column form</td><td>The solution is presented in terms of column vectors, which are either in the basis or not in the basis.</td><td>The notation is convenient for solving large problems where the number of variables may significantly exceed the number of constraints.</td></tr>
<tr><td>Row form</td><td>The solution is presented similarly to the column form but using row vectors.</td><td>The notation is especially convenient for problems where the number of constraints greatly exceeds the number of variables.</td></tr>
</table>

Note:

* If there are no constraints for some xix_i in the tasks, the LPP must be transformed into a canonical linear programming problem, or this service should be used. The solution automatically determines the use of the M-method (Simplex method with an artificial basis) and the two-phase Simplex method.

Source: created by the authors based on [6]

It should be noted that the algorithm for solving linear programming problems (LPP) using the Simplex method within the submodels of strategic actions is classical and includes the following stages [1]:

Stage 1. Developing the initial reference strategic action plan for the international market. Regardless of the form of the problem's representation, it must be transformed into canonical form. This is done by introducing non-negative auxiliary variables, which allow the transition from inequalities to equalities.

Stage 2. Checking the strategic action plan for the international market for optimality. In this stage, the index row of the Simplex table is analyzed. If all the coefficients are non-negative, the plan is optimal. If there are negative coefficients, the plan is not optimal and requires improvement.

Stage 3. Among the negative coefficients in the index row, the one with the largest absolute value is selected. After this, the elements in the right-hand column of the Simplex table are divided by the corresponding positive elements of the same key column.

Stage 4. Constructing a new strategic action plan for the international market. The transition to a new reference plan is made by recalculating the Simplex table using the Jordan–Gauss method.

It should be noted that the Simplex method allows finding both the minimum value (F(x) → min) and the maximum value (F(x) → max) of the objective function. This depends on the problem set in the submodel and the objective function. In such problems, the optimal (extremal) solution is always found:

1. At one of the vertex points of the polygonal region of feasible solutions.
2. On the segment between two adjacent vertices (when the objective function is parallel to some side of the polygon).

Regarding the dual Simplex method, it involves an iterative process of forming the submodel. It is based on the application of duality theory, specifically solving the dual problem to find optimal solutions for the strategic actions of enterprises in the international market over several balanced steps. In this process, the free members in the problem can take any values, and the system of given constraints can have values of "≤", "≥", or an equality sign "=".

It should be noted that solving linear programming problems using this method is possible in the basic form of the Simplex method, in the form of a Simplex table, or with the modified Simplex method. In this case, constraints of the type xi≥0x are not considered in these solutions.

The optimal strategic action plan for enterprises in the international market within this method is formed by moving through pseudo-plans. A pseudo-plan is a plan that satisfies the conditions of optimality but contains negative values among the basic variables xix_i.

The algorithm of the dual Simplex method consists of the following stages [1–2]:

Stage 1. Constructing a pseudo-plan for the strategic actions of an enterprise in the international market. Initially, the system of constraints is transformed into a system of inequalities of the "≤" type, which allows the formation of an initial pseudo-plan according to the specifications provided in Table 2. This stage aims to bring the problem into a form that, within the submodel of strategic actions, defines the direction for further improvement of the solution.

Stage 2. Checking the strategic actions of enterprises in the international market for optimality. If the obtained basic plan does not satisfy the optimality condition, the problem is solved using the simplex method.

Stage 3. Selecting the pivot row and column. The most negative values of the basic variables are selected as the largest in absolute value. The row corresponding to this value is the pivot row.

Stage 4. Calculation of a new basic plan of strategic actions for enterprises in the international market or solving a specific strategic task. The new plan is obtained by recalculating the simplex table using the Jordan-Gauss method.

In the submodel, the dual simplex method is required to build an optimal infeasible plan,

Table 2

Features of constructing a pseudo-plan for the submodel of strategic actions of an enterprise in the international market.

Sequence of constructing a pseudo-plan	Features of pseudoplan construction
Transformation of constraints into inequalities of the type «≤»	All constraints must be converted to inequalities of the type "≤". This can be achieved by adding artificial variables or free variables: If the constraint is of the form a1x1+a2x2≥b, it is transformed into −a1x1−a2x2≤−b. If the constraint is a1x1+a2x2=b, it is left as an equation, but additional variables are introduced to convert it into the appropriate form for the simplex method.
Formation of the initial pseudoplan	The pseudoplan is formed through transformed inequalities. This means that: • Artificial variables are introduced for those constraints that cannot be represented as non-negative variables (in the case of equations or inequalities of the type "≥"). • All variable values xix_i in the pseudoplan can be non-negative, but basic variables may have negative values at the initial stage (this is one of the characteristics of a pseudoplan).

Note:

*In linear programming problems (LPP), constraints can be written in various forms, such as "≥", "≤", or as equations.

Source: created by the authors based on [1; 6] followed by its transformation into a feasible one without violating optimality.

For example, the company LLC Fischer Ukraine, for the years 2025-2027, within the framework of its strategic action plan in the international market, needs to solve the following strategic task – selecting an approach for the production of three different types of cross-country skis: Sbound 112 Crown / Dual-Skin Xtralite, Speedmax 3D Double Polling IFP, and Sbound 98 Crown / Dual-Skin Xtralite, in volumes of 500 units, 300 units, and 450 units, respectively. Each type of product can be supplied to two countries – Germany and Austria. Considering the need to determine how to distribute work in external markets so that the overall costs of implementing actions are minimized, we propose to present the submodel of the studied strategic task in a form that allows the use of the P-method (Table 3).

As a result of the formulation of the outlined submodel for the studied strategic task, it is clear that it is necessary to produce and supply to the international market: Sbound 112 Crown / Dual-Skin Xtralite – 500 units; Speedmax 3D Double Polling IFP – 167 units; Sbound 98 Crown / Dual-Skin Xtralite – 450 units. Additionally, it is recommended to produce and supply accessories for the Speedmax 3D Double Polling IFP, such as the Mounting Plate Junior short screw – 133 units. The management of the outlined strategic task should be implemented through the objective function F(X) = 2500 + 3167 + 4133 + 1450 = 2483.33 euros. Under these conditions, it is possible to ensure minimal supply costs to the markets of Austria and Germany, which will amount to 2483.33 euros.

It should be noted that, considering the outlined specifics of the submodel for the studied strategic task, it can be effectively used for the parallel adjustment of the sustainable development strategy of the enterprise within its strategic actions on the international market.

Table 3

Submodel representation of the studied strategic task in a form allowing the use of the P-method, 2025–2027

Matrix of parameters for the studied strategic task					Mathematical model of solving the strategic task*
Countries	Types of Products			Supply costs for delivering products to consumers, euros (factor basis of the objective function) **	
	Sbound 112 Crown / Dual-Skin Xtralite (x1)	Speedmax 3D Double Polling IFP (x2)	Sbound 98 Crown / Dual-Skin Xtralite (x3)		
Germany – 1	2	3	3	1500	2x11+ 3x12+3x13≤ 1500; 5x21+ 4x22+x23≤ 1000; x11+ x21≥ 500; x12+ x22≥ 300; x13+ x23≥ 450. In this case, the objective function is: 2x11+ 3x12+3x13+ 5x21+ 4x22+x23→ euros
Austria – 2	5	4	1	1000	
Production / Supply Plan, units	500	300	450		

Note

*xijx_{ij} represents the supply volume (the number of units of product type ii to country jj).

** These are determined based on the conditions for transportation and delivery of products from the manufacturer to the final consumer (distributor or company store). In the context of mathematical modeling for optimizing strategic actions in the international market, these costs become the basis for the objective function that needs to be minimized or optimized.

Source: created by the authors

In fact, this method allows for clear structuring and optimization of various aspects of the company's activities, taking into account numerous constraints and objectives, which, according to existing research [3; 5; 7–8], may change depending on market conditions, technological changes, or other factors.

Conclusion. Within the study, it has been noted that the advantages of modeling the strategic actions of enterprises in the international market through linear programming tasks (LPT) are the informativeness regarding the optimization of the sequence of measures, decisions, or operations that the enterprise applies or plans to apply to achieve its strategic goals in the international market. The foundation of the modeling process is the transformation of a series of submodels, ideally formed for each strategic task, and the determination of the sensitivity of their input conditions to the influence of key factors. Each of the sets of strategic actions formed within the submodel:

1. Corresponds to specific requirements and constraints in the market. Under these conditions, it is possible to build a management algorithm that is relevant for various aspects of the enterprise's foreign economic activity – from production and logistics to marketing and sales.

2. Management of various aspects of the enterprise's activities within the submodel using LP (Linear Programming) should be implemented through the objective function, which not only allows for cost optimization but also enables the proper allocation of resources, both primary and reserve capacities, to achieve the desired result.

The authors illustrate that the correct formulation of the submodel for each studied strategic task helps the management of the enterprise quickly assess its effectiveness and, if necessary, adjust it by considering the sensitivity to changes in various parameters (e.g., raw material prices, exchange rates, taxes, etc.). Given this focus, it is clear that the use of mathematical modeling provides the opportunity to clearly control each stage of the implementation of strategic actions for enterprises on international markets.

The prospects for future research lie in expanding the application of linear programming (LP) methods for modeling complex strategic tasks, taking into account dynamic changes in the international market, multi-criteria assessments, and the integration of machine learning algorithms to improve forecasting accuracy and the effectiveness of managerial decision-making.

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