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THE USE OF MATHEMATICAL MODELING AND LINEAR PROGRAMMING IN AGRIBUSINESS
UPOTREBA MATEMATIČKOG MODELIRANJA I LINEARNOG PROGRAMIRANJA U AGROBIZNISU

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Abstract

This study focuses on the theoretical analysis of the application of modeling and mathematical, particularly linear programming, in managerial processes within the agro-industrial complex. The authors have dedicated themselves specifically to defining planning processes, classifying models, and organizing production structures, including vertical and horizontal structures.

Despite the fact that the benefits of linear programming have been proven, it is still not widely accepted and applied in our region. The reasons for this can be found in the relative complexity of the process, both in creating logical and mathematical models, and in interpreting results. Although there are specialized software and add-ons such as Solver in MS Excel, they are still not accessible enough to a wider range of users in the agro-industrial sector.

It is evident that there is a need for the development of new specialized software solutions with user-friendly interfaces, which would make them more accessible, primarily to advisors, and then to agricultural producers.

Sažetak

Ova studija se fokusira na teorijsku analizu primene modeliranja i matematičkog, posebno linearnog programiranja, u upravljačkim procesima u agroindustrijskom kompleksu. Autori su se posebno posvetili definisanju procesa planiranja, klasifikaciji modela i organizovanju proizvodnih struktura, uključujući vertikalne i horizontalne strukture.

Uprkos činjenici da je dobrobit linearnog programiranja dokazana, ono još uvek nije široko prihvaćeno i primenjeno u našim krajevima. Razlozi za to se mogu naći u relativnoj složenosti procesa, kako u kreiranju logičkih i matematičkih modela, tako i u tumačenju rezultata. Iako postoje specijalizovani softveri i dodaci kao što je Solver u MS Excel-u, oni još uvek nisu dovoljno dostupni širem krugu korisnika u agroindustrijskom sektoru.

Evidentno je da postoji potreba za razvojem novih specijalizovanih softverskih rešenja sa korisničkim interfejsima, koji bi ih učinili dostupnijim, pre svega savetodavcima, a potom i poljoprivrednim proizvođačima.

Key words: *Modeling, linear programming, optimization, profit maximization, agribusiness*

Ključne reči: *Modeliranje, linearno programiranje, optimizacija, maksimizacija profita, agrobiznis*

Introduction

In today's agro-complex, modeling techniques and linear programming are gaining increasing importance, being applied in various segments of this complex industry. While some researchers focus on developing state and regional models, an increasing number are concentrating on creating models applied directly at the level of individual farms.

This research trend often encompasses a wide range of topics, including optimizing production structures to maximize economic results. This involves strategies for more efficient resource utilization, as well as identifying optimal combinations of crops or livestock that will generate the highest income. Additionally, researchers address optimizing animal nutrition to minimize production costs while ensuring adequate health and performance of livestock.

In addition to economic factors, research also addresses reducing the negative environmental impacts of agriculture. This includes finding sustainable farming practices, reducing emissions of harmful gases, preserving biodiversity, and more.

Through the lens of competitiveness, researchers analyze the role of individual inputs and outputs in agricultural production. This includes studying the efficiency of different inputs such as seeds, fertilizers, pesticides, as well as analyzing output factors such as yield, product quality, and market price.

These topics represent only a fraction of the wide spectrum of research focusing on the application of modeling techniques and linear programming in agribusiness. This research aims to enhance the efficiency, sustainability, and competitiveness of agricultural production, providing a basis for informed decision-making and the development of future strategies in this vital industry.

Methodology

Various general research methods were used in the research process to achieve a deeper analysis and understanding of the subject area. Among these methods, description, synthesis, analysis, induction, and deduction were highlighted. The descriptive method aimed to emphasize the importance of applying linear programming. This method provided the basis for a systematic approach to solving complex problems and optimizing resources. Synthesis was crucial for understanding theoretical approaches and practical experiences in the research area. By combining theory with real examples, researchers were able to better understand the complexity of problems and possible approaches to solving them. Content analysis was used to present existing literature and describe the relevant database. This analytical method enabled the systematization of information and the identification of key themes and trends in the research.

Conclusions were drawn through a combination of induction and deduction. Based on the analysis of collected data and applied methods, researchers drew general conclusions and implications for further research. In addition, data sources were used from relevant literature directly related to the research subject. These sources provided the theoretical framework for the research and supported the argumentation of our conclusions.

Research Results and Discussion

According to [25] research based on the application of linear programming in optimizing agricultural production in this region was conducted in the 1960s [10] [14] [5] [6] [3]. Linear programming is a method used in creating and researching macroeconomic models for agricultural development [7] [11] [2][13] [4] [23].

[22] emphasizes that modern planning methods ensure optimal spatial distribution of agricultural production and maximization of available production resources. [24] state that linear programming is the most widespread method of operations research used in livestock production. It is mostly used to solve optimization problems related to feed mixtures and animal nutrition, optimal intensity of fodder crop production, optimal production plans for farms with livestock production, and optimal assortment of processing industries, where basic raw materials are livestock products. According to [17], the basic specifics of agro-management, especially in large and complex business systems in agribusiness, arise from the existence of horizontal and vertical production structures in agriculture.

Horizontal production structure refers to the production linkage (dependence) of individual related production lines within the same production branch. This linkage is achieved through the common use of production factors. The necessity of horizontal production structure in agriculture arises from the need for rational and economically efficient use of production factors. The economic efficiency of the business system largely depends on how efficiently production factors are used.

[21] points out that creating models using linear programming could be one of the options for solving problems in the meat industry, and the approach in slaughterhouse management could contribute to a better position in the market. [12] dealt with defining livestock farming as a subsystem of agricultural households and, based on that, examining its role in the competitiveness of the entire household. [1] used a systemic approach in researching the production orientation of family agricultural households. By using modeling methods and linear programming, a mathematical model was defined in which the relationships between individual production lines were translated into a system of linear equations and inequalities. [18] studied the problem of optimal structure of vegetable production along with defining a general theoretical model. [26] optimize production on a cattle farm using minimization of labor input as a task criterion for optimality. According to these authors, linear programming models using input and output as criteria represent adequate tools for preparing quality information, all with the aim of making better business decisions on dairy-producing farms.

[27] conducted research on multi-criteria decision-making in crop production, successively using two types of research methods. In the first research phase, they created and solved a linear programming model according to different optimality criteria. Three solutions were obtained, which represented alternatives in the second research phase. The research results indicate the possibility of successful use of these methods in agro-economic research. Also, some of the authors used multi-criteria optimization in agribusiness in their earlier research [19] [20] [15].

Furthermore, [28] created a linear programming model for optimizing livestock production, setting various optimization goals. The authors analyzed the sensitivities of prices for livestock feed, mineral fertilizers for crop farming, seeds, and diesel fuel. According to their findings, post-optimal analysis is crucial for efficient management and achieving more economical performance in livestock production. The information obtained from post-optimal analysis is of great importance to managers considering market turbulence.

[29] emphasize that cattle production planning is a complex process that needs to consider multiple criteria. The authors compared the total amount of variable costs calculated through different optimality criteria, as well as the amounts of specific types of costs within the total variable costs.

[8] formulated a linear programming model for optimizing milk and dairy production to achieve maximum financial results while considering a range of production, technological, and market constraints. Initially, a logical model was defined, outlining the key elements of the system being modeled, as well as the relationships between individual elements. Based on the logical model, a mathematical model was formulated, serving as the basis for its solution. The previously formulated task was entered into the MS Excel program and solved using the Solver software add-in. After obtaining the solution, post-optimal analysis was performed. Linear

programming involves finding the optimum (minimum or maximum) of a linear function with multiple variables connected by linear relationships through equations and/or inequalities. Linear programming is one of the most commonly used quantitative methods in operational research to solve optimization problems (minimum or maximum) in managerial processes in agricultural and food industry business systems [25].

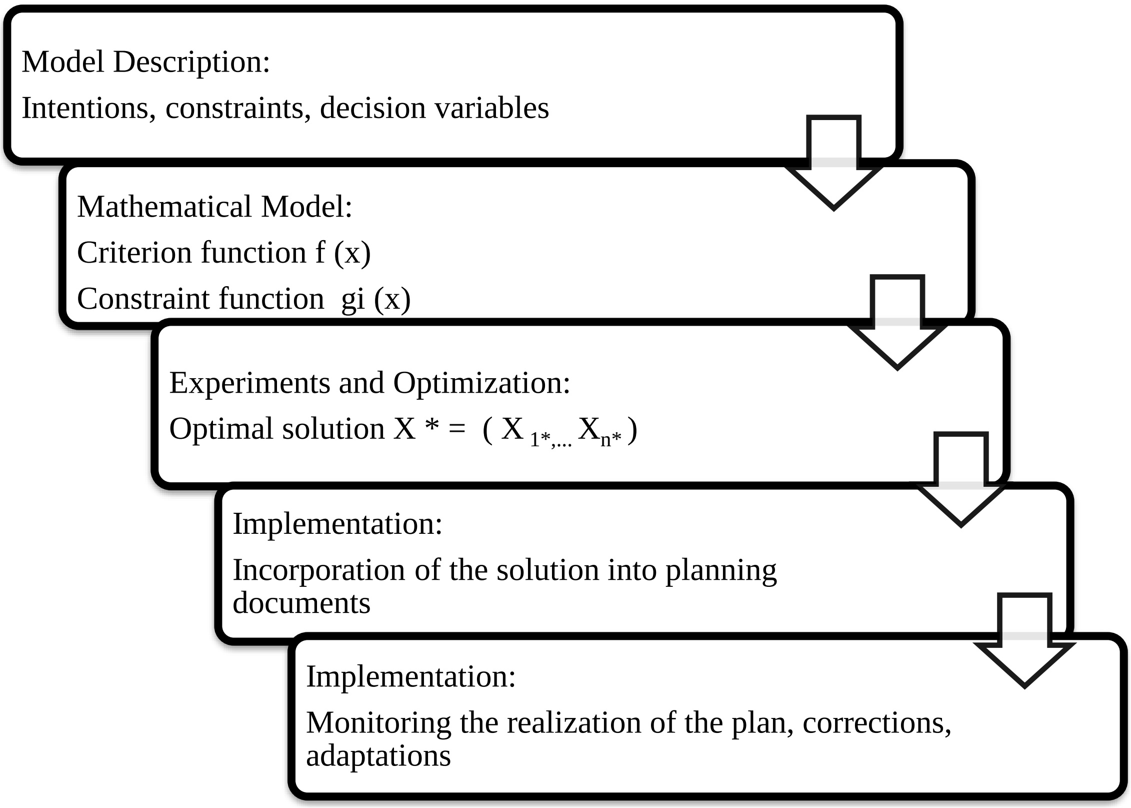

Figure 1. Planning Process Model [30].

To solve a problem using linear programming, two key assumptions need to be satisfied: proportionality and additivity. Proportionality implies the existence of proportional relationships between inputs and outputs within the model. Additivity, on the other hand, enables the total value of the objective function or individual constraints to be calculated as the sum of the values of individual activities that constitute the basic elements of the linear programming model [21].

The general formulation of the linear programming problem starts from the problem of linear programming in its most general form, that is, certain values of variables x1, x2, …, xn, are determined to achieve an extreme value of the given optimality function, under conditions of non-negativity and constraints of linear equations and/or inequalities:

a11 + a12 + … + a1j xj + …. + a1n x1n= { ≥;=;≤ } b1

a21 + a22 + … + a2j xj + …. + a2n x1n= { ≥;=;≤ } b2

.

.

aix1 + ai2x2 + … + aijxj + …. + ainx1n= { ≥;=;≤ }bi

.

.

am1x1 + am2x2 + … + amjxj + …. + amnx1n = {≥;=;≤}bm

So that the linear objective function:

F(x1, x2,…, xn) = c1x1 + c1x2 + … + cjxj + …. + cnx1n

has an extreme value, i.e., minimum or maximum.

The symbols' meanings are: Xj - independent variables, Cj - coefficients in the objective function, aj - technical coefficients, bi - constraints.

According to [21], the optimal solution obtained by solving the linear programming problem has a quantitative character, while post-optimal analysis provides insight into the quality of the optimal solution.

The quality of the optimal solution encompasses characteristics of the system related to:

1. Stability of the system when changing the values of financial results or other parameters per unit variable,
2. Stability of the system when changing available production capacities, and
3. Range of values of individual parameters for which the optimal solution applies.

[25] present three possible functional components of post-optimal analysis:

- Response report: This part of post-optimal analysis examines the satisfaction of individual constraints. For production managers, this is an important source of information about the rational use of production capacities. The analysis provides information about actual production constraints, as well as production capacities that are not fully utilized. Additionally, it explores the possibility of alternative use of unused capacities.
- Sensitivity analysis: This analysis provides information about the reliability of the optimal solution. It determines the interval for individual parameters in the objective function within which there is no change in the optimal value, but only an increase in the value of the objective function. Sensitivity analysis can determine the competitiveness of variables in the objective function.
- Constraint sensitivity analysis: This part of the analysis allows for an understanding of the impact of changes in individual constraints on the optimal solution. The analysis provides information about the interval of constraints within which there is no change in the optimal solution. Additionally, it explores the dual variable or shadow price, which represents the value by which the objective function will change if the given constraint increases by one unit.

Conclusion

In conclusion, while linear programming has proven its utility, its application in our regions is still not widespread enough. The reason for this lies in the relative complexity of the process, both in creating logical and mathematical models and interpreting results. Although there are specialized software and add-ons like Solver in MS Excel, they often are not accessible enough to a wider range of users in the agri-food sector.

There is an evident need for the development of new dedicated software solutions with user-friendly interfaces, available to advisors and agricultural producers. Such solutions could take the form of desktop or web applications, enabling users to input initial model parameters and clearly interpret results through understandable and graphically presented reports.

Furthermore, data visualization and graphical representation of solutions would significantly facilitate understanding for users. Utilizing such tools, similar to those already present in applications designed for broader user groups, could significantly contribute to the wider use of linear programming in various fields of agricultural production and the food industry.

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