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Using The Simplex Method For Optimizing Some Economic Functions Of The Enterprise "MSA Kompani" Dooel-Skopje

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Abstract – In science, in economics, in practice, problems are often encountered in which it is required to find the largest (smallest) value of a numerical function with real values of the type $f: E \to \mathbb{R}$. More precisely, the elements of the set E are required, where the function f reaches the optimal value. For this reason, such problems are called optimization problems. Optimization problems are also solved by so-called linear programming methods.

Linear programming is a mathematical programming that deals with the problem of system optimization within given constraints, it is a method for solving production planning problems.

The manufacturer wants to determine how to use the limited quantities of raw materials with maximum profit, the manager how to distribute the assigned work among his employees so that it is done in the shortest possible time, that is, to be as effective as possible. The goal of these problems is optimization, profit maximization or cost minimization [1].

Making profit is the main goal of the company, but many companies still need to learn the maximum profit that can be achieved by optimizing their resources, one of which is the company "MSA KOMPANI". This research focuses on the products of "MSA KOMPANI" DOOEL-SKOPJE

different according to the price. The purpose of this paper is to optimize the company's profits and costs. In this paper we will use the simplex linear programming method to solve our problem in "MSA KOMPANI".

Modeling a real-life problem as a linear programming problem requires teamwork of experts from several fields.

Keywords – Optimation, Profit, Income, Enterprise, Simplex Method, Linear Programming.

I. INTRODUCTION

The focus of this research is on the products of the company "MSA KOMPANI" DOOEL-SKOPJE. This study aims to optimize profits, revenues, by determining the composition of the number of products produced. There are many ways to solve this problem, one of which is using linear programming, specifically the simplex method.

A linear program is a mathematical model for determining the optimal combination of products to maximize benefits or minimize costs. A linear program has three essentials: the objective function, the decision variable, and the constraints.

In the beginning, we build the mathematical model from the data of the real problem and then from these data we form the first simplex table. There is often more than one way to describe a particular algorithm. The simplex method is one of the techniques for determining the optimal solution used in linear programming. The simplex method is a general method, which means that it solves any linear programming problem.

The simplex method is an iterative method with a finite number of steps starting from an initial solution and in the last step of the iterations, the optimal solution is obtained. This is the reason why the simplex method is easily applied to the computer as well.

II. Formulation of the linear programming problem. Mathematical model

In science, in economics, in practice, problems are often encountered in which it is required to find the largest (smallest) value of a numerical function with real values of the type $f: E \to \mathbb{R}$. More precisely, the elements of the set E are required, where the function f reaches the optimal value. For this reason, such problems are called optimization problems. Such a function is called a goal function. In general it is a function of n variables $x_1, x_2, \dots x_n$, t.e. its starting set is a subset of Euclidean space $\mathbb{R}^n$ of vectors $x = (x_1, x_2, \dots x_n)$ with n dimensions, t.e. $E \subset \mathbb{R}^n$. Wide practical use represents the case when the objective function f is a linear function of the variables $x_1, x_2, \dots, x_n$:

$$f(x) = c_1 x_1 + c_2 x_2 + \dots + c_n x_n, \qquad (1)$$

for $x = (x_1, x_2, \dots, x_n) \in E$. The starting set E is determined by imposing various conditions on the variables x_j for $j = 1, 2, \dots, n$. In particular, E is the set of solutions of the following m system of linear equations or inequations of variables x_j :

$$\begin{cases} \alpha_{11}x_1 + \alpha_{12}x_2 + \dots + \alpha_{1n}x_n \{\le, =, \ge\} \beta_1, \\ \alpha_{21}x_1 + \alpha_{22}x_2 + \dots + \alpha_{2n}x_n \{\le, =, \ge\} \beta_2, \\ \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \\ \alpha_{m1}x_1 + \alpha_{m2}x_2 + \dots + \alpha_{mn}x_n \{\le, =, \ge\} \beta_m. \end{cases} \qquad (2)$$

Usually variables x_j in practice they take non-negative values, therefore the condition is added to the system (2) of conditions:

$$x_1 \ge 0, x_2 \ge 0, \dots, x_n \ge 0. \qquad (3)$$

Any solution of system (2) that satisfies condition (3) is called an *allowed solution* of system (2), while the its allowed solution $(x_1^0, x_2^0, \cdots x_n^0)$, where the function f reaches the largest or smallest value is called the *optimal solution of the problem* (1), (2), (3). The set of allowed solutions of system (2) is denoted Ω and is called the *allowed set (area) of problem* (1), (2), (3).

In this case the problem of optimizing the function, using the symbol Σ of an adder, takes the form of the following mathematical model:

- To find the largest (or smallest) value of a function

$f(x)=\sum_{j=1}^{n} c_j x_j$, where $x=(x_1,x_2,...,x_n)$ and variables $x_1,x_2,..., x_n$ meet the conditions

$\sum_{j=1}^{n} a_{ij}x_j$ $(\leq, =, \geq)$ β_i, $i=1, 2, ..., m$ and $x_j \geq 0$, $j=1, 2, ..., n$.

The theory that studies problems of the type (1), (2), (3) is called *Linear Programming*, while the problem presented according to the model (1), (2), (3) is called *a linear programming problem* (LPP for short) in general form, in particular *a minimization* problem when the smallest value of the function f is required and *a maximization* problem when its largest value is required.

III. THE SIMPLEX METHOD

Definition 3.1. [2]. The standard form of LPP is called the form:

Minimize the function

$f(x)=c_1x_1 + c_2x_2 +...+ c_nx_n$, for $x=(x_1, x_2, ..., x_n) \in \mathbb{R}^n$ (4)

in the conditions when
$$\begin{cases} a_{11}x_1 + a_{12}x_2 + ... + a_{1n}x_n = b_1, \\ a_{21}x_1 + a_{22}x_2 + ... + a_{2n}x_n = b_2, \\ .... \\ a_{m1}x_1 + a_{m2}x_2 + ... + a_{mn}x_n = b_m. \end{cases} \quad (5)$$

and $x_j \geq 0$, $j = 1, 2, ..., n$. (6)

We consider the system of conditions (5) of a LPP in standard form. It is known that it has no solution, if the rank of the matrix A its is different from the rank of the expanded matrix A^*; there is only one solution, if $rg(A) = rg(A^*) = n$; and there is an infinity of solutions with $n - r$ degrees of freedom, if $rg(A)= rg(A^*) = r < n$. Of interest for the LPP solution is the third case. In this case the system contains r basic variables and $n - r$ free variables. To find them, with the Gauss-Jordan method, we bring the system to the system below, equivalent to it. From here we find that the basic variables are $x_1, x_2,..., x_r$ and free the other variables $x_{r+1}, x_{r+2},..., x_n$

$$\begin{cases} x_1 \quad + \alpha_{1\ r+1}x_{r+1} + ... + \alpha_{1\ n}x_n = \beta_1, \\ \quad x_2 \quad + \alpha_{2\ r+1}x_{r+1} + ... + \alpha_{2\ n}x_n = \beta_2, \\ .... \\ \qquad x_r + \alpha_{r\ r+1}x_{r+1} + ... + \alpha_{r\ n}x_n = \beta_r. \end{cases} \quad (7)$$

If the free terms β_i in system (11) are $\beta_i \geq 0$, then the system (7) is called *the canonical form* of the system of conditions (5).

We substitute the basic variables found according to (7) in the form (4) of the objective function.

Reception:

$f(x)=c_1[\beta_1-(\alpha_{1\ r+1}x_{r+1}+....+\alpha_{1\ n}x_n)]+...+c_r\Big[\beta_r-\Big(\alpha_{r\ r+1}x_{r+1}+.....+\alpha_{r\ n}x_n\Big)\Big]+\quad +c_{r+1}x_{r+1}+...+c_nx_n$

$\Rightarrow\ f(x) = d_0 - (d_{r+1}x_{r+1}+...+d_nx_n)$.

Definition 3.2 [2]**.** The canonical form of LPP is called the form:

Minimize the function $f(x) = d_0 - (d_{r+1}x_{r+1}+...+d_nx_n)$ (8)

in the conditions when
$$\begin{cases} x_1 \quad +\alpha_{1r+1}x_{r+1}+...+\alpha_{1k}x_k+...+\alpha_{1n}x_n=\beta_1\ge 0,\\ x_2 \quad +\alpha_{2r+1}x_{r+1}+...+\alpha_{2k}x_k+...+\alpha_{2n}x_n=\beta_2\ge 0,\\ \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\\ x_r+\alpha_{rr+1}x_{r+1}+...+\alpha_{rk}x_k+...+\alpha_{rn}x_n=\beta_r\ge 0, \end{cases} \tag{9}$$

and $x_j \ge 0,\ j=1, 2, \dots, n.$ (10)

Taking $x_{r+1}= x_{r+2} = ...= x_n= 0$ in system (9) we find its solution $(\beta_1, \beta_2,..., \beta_r, 0, \dots, 0)$, which is an allowed solution of system (4) of the standard LPP (since $x_j \ge 0,\ j=1, 2, \dots, n$). The ranked system $(x_1, x_2, ..., x_r)$ of the basic variables of the system (9) is called the *basis* of LPP, while the allowed solution $(\beta_1, \beta_2,..., \beta_r, 0, \dots, 0)$ is called its *basic solution*. It also seems easy that, d_0 is the value of the objective function f in the basic solution of LPP in canonical form.

We emphasize that the condition that the free terms of the system (9) are ≥ 0 is essential for the canonical form of the LPP, according to the Gauss-Jordan method, system (5), when there is a solution, always behaves in the form (7), even in many ways. Therefore, the question arises: For what conditions does the standard LPP have at least one canonical form and is it the only one?

For now we can say, convinced and from the examples, that in general the canonical form of the standard LPP is not unique. However, such LPP cannot have more than C_n^r canonical form, because one of its bases is a combination of variable r from n that are total.

Note: We will explain the simplex algorithm in detail in the solution of our problem.

IV. The use of the simplex method for the optimization of some economic functions of the enterprise MSA KOMPANI DOOEL-SKOPJE

The company MSA KOMPANI DOOEL SKOPJE is a medium-sized manufacturing company, which deals with the production of equipment and toys for kindergartens. This company has 23 employees, of which 15 are in production. From the company's products, we have singled out 5 types of its products, which are: SCS 01 playground; Pencil fence; Swing; Soft blocks; seesaw, which we will refer to as production A;B;C;D and E respectively. The official person of the company A.S. was very kind and willing to provide us with the following information about the company:

PRODUCE	PRODUCTION TIME FOR UNIT	ASSEMBLY TIME FOR UNIT	NUMBER OF WORKERS PER UNIT	REQUEST/ DAY	OFFER / DAY	PROFIT/ UNIT	SELLING PRICE/ UNIT	COST/ UNIT
A) SCS 01 playground	8 hour	4 hour	4	1	5	30000 den	80600.00 den.	50600 den
B)Pencil fence	10 minutes	5 minutes	3	30	10	800 den	2800.00 den	2000 den
C) Swing	3 hour	1 hour	4	1	5	12000 den	45000.den	33000 den
D) Soft blocks	24 hour	0	1	0.5	2	35000 den	150000 den	115000 den
E) seesaw	3 hour	1 hour	3	1	5	5000 den	18000 den	13000 den

The company works in one shift. From the above data we calculated that the company has available 120 hours of work per day, of which Production and Assembly are in the ratio P:M=38,25:6,083. We solve the system $\begin{cases} P+M=120 \\ P:M=38,25:6,083 \end{cases}$ and we get that the company has 103,5 hours of daily capacity for production and 16,083 daily capacity hours for assembly.

- *We compile the mathematical model for maximizing the company's daily profit according to the offer presented:*

Decision variables:

$x_1 =$ Quantity to be produced of the type A

$x_2 =$ Quantity to be produced of the type B

$x_3 =$ Quantity to be produced of the type B

$x_4 =$ Quantity to be produced of the type B

$x_5 =$ Quantity to be produced of the type B

Mathematical modeling of our case

Determine the quantities x_1, x_2, x_3, x_4 and x_5, with restrictions:

Total units of production: $x_1 + x_2 + x_3+x_4+x_5 \leq 27$

Total cost: $50600\, x_1 + 2000\, x_2 + 33000\, x_3 +115000\, x_4+13000\, x_5 \leq 733000$

Total time: $12\, x_1 + 0.25\, x_2 + 4\, x_3 +24\, x_4+4\, x_5 \leq 120$

$x_1, x_2, x_3, x_4, x_5 \geq 0$

To maximize the profit function

$F = 30000\, x_1+800\, x_2 + 12000\, x_3+35000\, x_4 + 5000\, x_5$

So we have:

To maximize the objective function

$$F(x) = 30000x_1 + 800x_2 + 12000x_3 + 35000x_4 + 5000x_5$$

Under the conditions:

$$\begin{cases} x_1 + x_2 + x_3 + x_4 + x_5 \leq 27 \\ 50600x_1 + 2000x_2 + 33000x_3 + 115000x_4 + 13000x_5 \leq 733000 \\ 12x_1 + 0.25x_2 + 4x_3 + 24x_4 + 4x_5 \leq 120 \end{cases}$$

Where, $x_1, x_2, x_3, x_4, x_5 \geq 0$.

We take the additional variables and build the system:

$$\begin{cases} x_1 + x_2 + x_3 + x_4 + x_5 + s_1 = 27 \\ 50600x_1 + 2000x_2 + 33000x_3 + 115000x_4 + 13000x_5 + s_2 = 733000 \\ 12x_1 + 0.25x_2 + 4x_3 + 24x_4 + 4x_5 + s_3 = 120 \\ -30000x_1 - 800x_2 - 12000x_3 - 35000x_4 - 5000x_5 + F(x) = 0 \end{cases}$$

We build the first simplex table:

Base	**x1**	**x2**	**x3**	**x4**	**x5**	**s1**	**s2**	**s3**	**F**	**T.L**
s1	1	1	1	1	1	1	0	0	0	27
s2	50600	2000	33000	115000	13000	0	1	0	0	733000
s3	12	0.25	4	24	4	0	0	1	0	120
F	-30000	-800	-12000	-35000	-5000	0	0	0	1	0

Step 1:

In the fourth row and the columns of *x*, we look for the largest negative number in absolute value, which is |-35000|=35000 and the x_4 column is the key column. We divide the free terms by the corresponding coefficients of the x_4 column and get:

$$\frac{120}{24} = 5; \frac{733000}{115000} = 6.374, \frac{27}{1} = 27$$

We look for the smallest factor which is 5 and fix the row of s_3, we see that the fixed element is 24. Since the key must always be 1, then we divide the third row (the s_3) with 24 and we get:

Base	x1	x2	x3	↓x4	x5	s1	s2	s3	T.L
s1	1	1	1	1	1	1	0	0	27
s2	50600	2000	33000	115000	13000	0	1	0	733000
←s3	0.5	1/96	1/6	[1]	1/6	0	0	1/24	5
F	-30000	-800	-12000	-35000	-5000	0	0	0	0

Get out of the base s3, enter on the base x4. We perform the transformations: $R_1 - R_3$, $R_2 - 115000R_3$ and $R_4 + 35000R_3$ and we get:

Base	x1	x2	x3	x4	x5	s1	s2	s3	T.L
s1	0.5	0.99	0.83	0	0.83	1	0	-0.04	22
s2	-6900	802.08	13833.33	0	-6166.67	0	1	-4791.67	158000
x4	0.5	0.01	0.17	1	0.17	0	0	0.04	5
F	-12500	-435.42	-6166.67	0	833.33	0	0	1458.33	175000

Thus the first step of the simplex algorithm is completed.

Step 2: We act the same as in the step 1 and fix the element 0.5. To make it 1, we multiply the third row (the x4) with 2.

Base	↓x1	x2	x3	x4	x5	s1	s2	s3	T.L
s1	0.5	0.99	0.83	0	0.83	1	0	-0.04	22
s2	-6900	802.08	13833.33	0	-6166.67	0	1	-4791.67	158000
←x4	[1]	0.02	0.34	2	0.34	0	0	0.08	10
F	-12500	-435.42	-6166.67	0	833.33	0	0	1458.33	175000

Get out of the base x4, enter on the base x1. We perform the transformations: $R_1 - 1/2R_3$, $R_2 + 6900R_3$ and $R_4 - 12500R_3$ and we get:

Base	x_1	x_2	x_3	x_4	x_5	s_1	s_2	s_3	T.L
s_1	0	0.98	0.67	-1	0.67	1	0	-0.08	17
s_2	0	945.83	16133.33	13800	-3866.67	0	1	-4216.67	227000
x_1	1	0.02	0.33	2	0.33	0	0	0.08	10
F	0	-175	-2000	25000	5000	0	0	2500	300000

Thus the second step of the simplex algorithm is completed.

Step 3. We act the same as in the step 1 and fix the element 16133.33. To make the key 1, we divide the second row (the s_2) with 16133.33 and we get:

Base	x_1	x_2	$\downarrow x_3$	x_4	x_5	s_1	s_2	s_3	T.L
s_1	0	0.98	0.67	-1	0.67	1	0	-0.08	17
$\leftarrow s_2$	0	0.06	[1]	0.86	-0.24	0	0	-0.26	14.07
x_1	1	0.02	0.33	2	0.33	0	0	0.08	10
F	0	-175	-2000	25000	5000	0	0	2500	300000

Get out of the base s_2, enter on the base x_3. We perform the transformations: $R_1 - 0.67R_2$, $R_3 - 0.33R_2$ and $R_4 + 2000R_2$ and we get:

Base	x_1	x_2	x_3	x_4	x_5	s_1	s_2	s_3	T.L
s_1	0	**0.94**	0	-1.57	0.83	1	0	0.09	7.62
x_3	0	0.06	1	0.86	-0.24	0	0	-0.26	14.07
x_1	1	0	0	1.71	0.41	0	0	0.17	5.31
F	0	-57.75	0	26710.74	4520.66	0	0.1 2	1977.27	328140.5

Thus the third step of the simplex algorithm is completed.

Step 4. We act the same as in the step 1 dhe fiksojmë elementin **0.94.** To make the key 1, we divide the first row (the s_1) with 0.94 and we get:

Base	x_1	↓x_2	x_3	x_4	x_5	s_1	s_2	s_3	T.L
←s_1	0	[1]	0	-1.67	0.88	1.06	0	0.1	8.11
x_3	0	0.06	1	0.86	-0.24	0	0	-0.26	14.07
x_1	1	0	0	1.71	0.41	0	0	0.17	5.31
F	0	-57.75	0	26710.74	4520.66	0	0.12	1977.27	328140.5

Get out of the base s_1, enter on the base x_2. We perform the transformations: $R_2 - 0.06R_1$, $R_4 + 57.75R_1$ and we get:

Base	x_1	x_2	x_3	x_4	x_5	s_1	s_2	s_3	T.L
x_2	0	1	0	-1.67	0.88	1.06	0	0.1	**8.11**
x_3	0	0	1	0.95	-0.29	-0.06	0	-0.27	**13.6**
x_1	1	0	0	1.72	0.41	0	0	0.17	**5.3**
F	0	0	0	26614.29	4571.43	61.43	0.12	1982.86	**328608.57**

Since the row of F has no negative values, then the algorithm ends.

We conclude that the optimal solution is reached for x_1=5.3, x_2=8.11. x_3=13.6, x_4=0 and x_5=0 as well as the maximum profit per day that can be achieved is max F=328608.57 den.

V. CONCLUSIONS:

Based on the calculation using the simplex linear programming method and verifying the results also with the help of the online software https://linprog.com/, the following conclusions can be drawn:

1. To maximize profits, the company should produce 5.3 units of type A) SCS01 playground, 8.11 units of type B) Pencil fence and 13.6 units of type C) Swing, while from two other products from 0 units

2. The maximum profit received in one day in this case will be 328608.57 den. from 178000den that it was at the beginning according to the offer made, representing an enormous increase in profits of 185%.

3. Under optimal conditions, the total production cost increased to 733200 den (initially 733000 den) and the required production time was the same as before the study, which represents a negligible cost increase of 0.03%.

• *We compile the mathematical model for minimizing the cost of production, so that the daily profit according to the company's request is preserved:*

Mathematical modeling:

Determine the quantities x_1, x_2, x_3, x_4 and x_5, with restrictions:

Total units of production: $x_1 + x_2 + x_3 + x_4 + x_5 \leq 27$

Profit: 30000 x_1+800 x_2 + 12000 x_3+35000 x_4 + 5000 x_5=88500

Total time: 12 x_1 + 0.25 x_2 + 4 x_3 +24 x_4+4 $x_5 \leq$ 120

$x_1, x_2, x_3, x_4, x_5 \geq 0$

So we have:

To minimize the cost function

$$C = 50600x_1 + 2000x_2 + 33000x_3 + 115000x_4 + 13000x_5$$

Under the conditions:

$$\begin{cases} x_1 + x_2 + x_3 + x_4 + x_5 \leq 27 \\ 30000x_1 + 800x_2 + 12000x_3 + 35000x_4 + 5000x_5 = 88500 \\ 12x_1 + 0.25x_2 + 4x_3 + 24x_4 + 4x_5 \leq 120 \end{cases}$$

Where, $x_1, x_2, x_3, x_4, x_5 \geq 0$.

We also verified the results of this linear programming minimization problem in the online software https://linprog.com/. Take:

We add the additional variables and get:

$$C = 50600x_1 + 2000x_2 + 33000x_3 + 115000x_4 + 13000x_5 + 0s_1 + 0s_2 + \mathrm{M}s_3$$

Under the conditions:

$$\begin{cases} x_1 + x_2 + x_3 + x_4 + x_5 + s_1 = 27 \\ 30000x_1 + 800x_2 + 12000x_3 + 35000x_4 + 5000x_5 + s_3 = 88500 \\ 12x_1 + 0.25x_2 + 4x_3 + 24x_4 + 4x_5 + s_2 = 120 \end{cases}$$

The initial table is:

Basis	**x1**	**x2**	**x3**	**x4**	**x5**	**s1**	**s2**	**s3**	**T.L**
s1	1	1	1	1	1	1	0	0	27
s3	30000	800	12000	35000	5000	0	0	1	88500
s2	12	0.25	4	24	4	0	1	0	120
Min C	30000M -50600	800M-2000	12000M-33000	35000M-115000	5000M-13000	0	0	0	88500M

Step 1. We set the key which is 35000, we divide the corresponding row by 35000.

Basis	x_1	x_2	x_3	↓x_4	x_5	s_1	s_2	s_3	T.L
s_1	1	1	1	1	1	1	0	0	27
←s_3	0.86	0.02	0.34	[1]	0.14	0	0	0	2.53
s_2	12	0.25	4	24	4	0	1	0	120
Min C	30000M -50600	800M-2000	12000M-33000	35000M-115000	5000M-13000	0	0	0	88500M

We perform the necessary transformations. At the base enters x_4, while s_3 exits.

After the appropriate calculations are done, we move on

Step 2. We set the key which is **0.86**, we divide the corresponding row by 0.86.

Basis	↓x_1	x_2	x_3	x_4	x_5	s_1	s_2	s_3	T.L
s_1	0.14	0.98	0.66	0	0.86	1	0	0	24.47
←x_4	[1]	0.03	0.4	1.17	0.17	0	0	0	2.95
s_2	-8.57	-0.3	-4.23	0	0.57	0	1	0	59.31
Min C	47971.43	628.57	6428.57	0	3428.57	0	0	-M+3.29	290785.71

We perform the necessary transformations. At the base enters x_1, while x_4 exits.

After the appropriate calculations are done, we move on

Step 3:

Basis	x_1	x_2	x_3	x_4	x_5	s_1	s_2	s_3	T.L
s_1	0	0.97	0.6	-0.17	0.83	1	0	0	24.05
x_1	1	0.03	0.4	1.17	0.17	0	0	0	**2.95**
s_2	0	-0.07	-0.8	10	2	0	1	0	84.6
Min C	0	-650.67	-12760	-55966.67	-4566.67	0	0	-M+1.69	**149270**

The algorithm is completed and the results obtained are: Min C=149270 which is achieved for x_1=2.95 and others 0.

From which we get that the cost can be reduced to 149270 den for the same profit of 88500 den from 214100 den that was at the beginning, if we manage to sell 2.95 units of production SCS01 playground. So, in this case, we will have a cost reduction of 64830 den, which would be transferred to the coffers of the enterprise as profit, and the total amount of profit will be 153330 den.

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