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## **EMPLOYING A LINEAR PROGRAMMING METHOD AND SENSITIVITY ANALYSIS IN ORDER TO ESTIMATE THE OPTIMAL PRODUCTION VOLUME WITH APPLICATION**

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### **ABSTRACT**

The study aims to find the optimal production volume for some products of the General Company for Electrical and Electronic Industries through the use of a method. Sensitivity analysis in the linear programming model and achieving the maximum possible profit. The company, analyzing and studying the reasons for the delay in production in previous years, and identifying the most important recommendations necessary to improve the company's factories, improve their industrial performance, and meet the needs of local demand. The General Company for Electrical and Electronic Industries is one of the most important companies in the Iraqi economy that supplies all economic sectors with the most important intermediate and consumer goods as well as the local demand for them.

**KEYWORDS:** Linear programming, sensitivity, resources and production stages.

### **1. INTRODUCTION**

The electrical industries are among the important industries of the economy that supply various productive sectors and institutions with various electrical materials and devices. However, the conditions of the Iraqi economy after 2003 prevented widespread interest in these industries in terms of the difficulty of obtaining primary production requirements and various spare parts.

Given the importance of these industries in Iraq and the necessity of improving the quality of products with the maximum profits and the lowest possible costs in keeping with global technological development, one of the quantitative planning methods has been relied upon, which is the linear programming method, which is one of the basic quantitative methods in operations research and used in planning production and distributing economic resources between... Alternative uses to maximize profits and reduce costs for the General Company for Electrical and Electronic Industries.

### **2. Objective of Research:**

The research aims to develop a mathematical model for linear programming with sensitivity analysis

to determine the most important products in the company to improve its products within the resources available to it to achieve the maximum possible profit.

### **3. RESEARCH HYPOTHESIS:**

It will be done through a sensitivity analysis in the linear programming method to prove the theory that occurs in the objective function coefficients and the constraints of the company's products, represented by the available resources, affect the production volume of those products according to the mathematical model that has been formulated.

### **4. RESEARCH METHODOLOGY:**

The research was divided into two sections. The first section dealt with the nature of production in the General Company for Electrical and Electronic Industries. The second section dealt with the method of linear programming and analysis.

Allergy to some of the company's products, after which some conclusions and recommendations were reached.

### **5. The first topic:**

The nature of the products in the General Company for Electrical and Electronic Industries.

#### **1-5 brief history:**

The first establishment of this company was under the name of the General Company for Electrical Industries in 1965 through the conclusion of a technical cooperation agreement between Iraq and the former Soviet Union in 1959. The name of the company was changed to the General Company for Electrical and Electronic Industries in accordance with Cabinet Resolution No. 360 of 2015 in order to implement the policy of merging companies with each other, including Al-Ezz General Electronic Company.

Thus, the company consisted of six factories, five of which were located in Baghdad Al-Waziriyah, and the sixth factory was located in the Taji area. (1) The company has different production lines, especially in the main feeder factory, the most important of which are:

- 1- A production line for spare parts and tools dedicated to manufacturing molds and tools.
- 2- Piston production line, which specializes in producing metal parts.
- 3- Regular plastic and cork production line.
- 4- Plumbing workshop that specializes in aluminum plumbing.
- 5- Painting and lathing workshops.
- 2- 5 The nature of the company's products:

The nature of the company's products is not fixed annually. It changes according to the size of local demand and production costs. Some of its products will be discussed within the company.

The most important of them are: (2)

- 1- Air cooled engine production line
- 2- Water pump production line
- 3- Ceiling fans production line - Al Naseem
- 4- Production line for water coolers of different sizes
- 5- Large air intake production line.

There are other production lines that are not fixed annually, as is the case in the production lines of early warning devices, fire trucks and safety equipment, large electronic screens, as well as the production of various electric lamps. Therefore, the focus will be on some of the company's products for which the level of demand is more stable, as it is noted that most the company's products have specialized use and cover the needs of the various ministries and economic sectors within the public and private sectors, as public sector demand constitutes about 80% of the company's total customers and the rest of the percentage is distributed between requests from the private sector, the local market and citizens. (3)

For the purpose of identifying the most important products that will be covered in the research, it is necessary to know the nature of some of the company's products and the nature of the costs and prices for each product, based on the company's final statements in 2016.: (4)

### **3- 5 Company sales:**

The volume of annual demand, which is [a single-tap water cooler, a water pump, an air-breeze refrigerated motor, and a ceiling air fan (Al-Naseem)], is almost stable.

Table No. (1) shows the value and volume of the company's sales of the above products in 2016, as it is noted that the value of the company's total sales of these products amounted to 840 million dinars in 2016, and the sales value of both the water pump and the air-cooled engine occupied a relative importance of 61.5% of the total. Company sales.

### **4 – 5 Variable costs:**

According to the theory of variable costs, Table No. (2) was adopted, which shows the variable industrial costs per unit and for each of the five products. These costs were isolated individually after sorting them from the company's accounts department to determine the company's actual variables. Through Table No. (2), it is noted the cost of one unit of the five products varies with each other according to the nature of the commodity produced. The water cooler requires a larger percentage of

raw materials in its production than the rest of the products, and this results from the nature of the components of the material produced. (5) .

**Table No.-1- Value and volume of sales of some of the company's products for the year 2016.**

<b>Sales value/million dinars 12*=3</b>	<b>the price Thousand dinars (2)</b>	<b>Sales volume unit/ (1)</b>	<b>Product type</b>
14	70	200	<b>1-</b> Water dispenser - one tap
120	20000	6	<b>2-</b> Water pump
120	6000	20	<b>3-</b> Cooled engine
36	400	90	<b>4-</b> Air puller
100	4000	25	<b>5-</b> Breeze fan
390			Total sales value

Source: Ministry of Industry and Minerals, Electrical and Electronic Industries Company, Marketing Department, 2017.

**Table No.-2- Total variable costs for some products in 2016/thousand dinars**

<b>Total costs</b>	<b>Maintenance Services</b>	<b>Packaging</b>	<b>Spare tools</b>	<b>Fuel and oils</b>	<b>raw materials</b>	<b>Product type</b>
<b>150.65</b>	<b>0.2</b>	<b>-</b>	<b>0.3</b>	<b>0.15</b>	<b>150</b>	<b>Water cooler</b>
<b>4.565</b>	<b>0.125</b>	<b>0.02</b>	<b>0.38</b>	<b>0.04</b>	<b>4</b>	<b>Water pump</b>
<b>15.31</b>	<b>0.35</b>	<b>0.1</b>	<b>0.76</b>	<b>0.1</b>	<b>14</b>	<b>Cooled engine</b>
<b>70.625</b>	<b>0.2</b>	<b>0.07</b>	<b>0.25</b>	<b>0.1</b>	<b>70</b>	<b>Air puller</b>
<b>21.34</b>	<b>0.515</b>	<b>0.15</b>	<b>0.6</b>	<b>0.075</b>	<b>20</b>	<b>Breeze fan</b>
	<b>1.390</b>	<b>0.34</b>	<b>2.29</b>	<b>0.465</b>	<b>258</b>	<b>Total</b>

Source: Ministry of Industry and Minerals, General Company for Electrical and Electronic Industries.

#### **4- 5 Income statement:**

Through Table No. (3), it is clear that the volume of industrial costs increases with the increase in production volume, which is the result of multiplying the cost of one unit of each product by the total production volume of each commodity produced. It is noted that the total costs of the water pump constitute more than 35% of Total total costs of other products.

**Table No.-3 Total variable costs for some products in 2016/thousand dinars**

<b>Total costs 3=2*1</b>	<b>Unit cost (2)</b>	<b>Production Volume (1)</b>	<b>Product type</b>
4278426	15726	284	1- Water cooler
12977929	42565	28414	2- Water pump
96682265	15231	6315	3- Cooled engine
317725	772625	44	4- Air puller
94927232	21234	4448	5- Breeze fan
367274297			the total

Source: Ministry of Industry and Minerals, General Company for Electrical and Electronic Industries, Industrial Costs Report, 2017.

#### **4 -5 The size of the total profits:**

##### **Table 4 shows that the company's total profits are from products**

The five are estimated at approximately 75 million in 2016, and the company's profits were from the sale of water pump and coolant engine is higher than the profits of the other three commodities, as Their percentage amounted to more than 75% of total profits in 2016, and this resulted from: Increased overall demand for them.

**Table No.-4 Total variable costs per unit and total profits for the year 2016/thousand dinars**

<b>Profits the college million Dinar (5)=3*4</b>	<b>Sales volume (4)</b>	<b>Profit per unit (3) =1-2</b>	<b>Cost per unit (2)</b>	<b>Price per unit (1)</b>	<b>Product type</b>
<b>3.545</b>	<b>70</b>	<b>49.35</b>	<b>150.65</b>	<b>200</b>	<b>1- Water cooler</b>
<b>28.70</b>	<b>20000</b>	<b>1.435</b>	<b>4.565</b>	<b>6</b>	
<b>28.14</b>	<b>6000</b>	<b>4.69</b>	<b>15.31</b>	<b>20</b>	<b>2- Water pump</b>
<b>0.775</b>	<b>40</b>	<b>19.375</b>	<b>70.625</b>	<b>90</b>	<b>3- Cooled engine</b>
<b>14.64</b>	<b>4000</b>	<b>3.66</b>	<b>21.31</b>	<b>25</b>	<b>4- Air puller</b>
					<b>5- Al Naseem ceiling fan</b>
<b>75.8</b>					<b>Total</b>

Source: Ministry of Industry and Minerals, General Company for Electrical and Electronic Industries, Marketing Department, 2017

## **2- The second topic**

Applying linear programming and sensitivity analysis methods in the company's products in order to build an appropriate mathematical model through which the optimal distribution of available resources is achieved, as well as achieving the maximum profits for the company, we will rely on a program' In linear programming in order to apply the mathematical model and analysis WinQSB Model sensitivity.

First: The general mathematical formula for the linear programming model.

The general model for linear programming is as follows:

Max/Min.  $Z = C_1X_1 + C_2X_2 + \dots + C_nX_n$  objective function

Subject to:<sup>(6)</sup>

$$\begin{array}{cccc|c|c}
 a_{11} & a_{12} & \dots & a_{1n} & X_1 & B_1 \\
 a_{21} & a_{22} & \dots & a_{2n} & X_2 & B_2 \\
 \vdots & \vdots & \dots & \vdots & \vdots & \vdots \\
 a_{m1} & a_{m2} & \dots & a_{mn} & X_n & B_n \\
 h & & & & hX_n & hB_n
 \end{array}
 \quad (\leq, =, \geq) \quad \text{Constraints}$$

**And  $X_1, X_2, \dots, X_n \geq 0$  Non negativity Constraint**

We find that it is composed of an objective function, structural constraints, and a non-negativity constraint. Linear programming occupies an important place in dealing with dilemmas in various aspects of economic activity, and its applications have spread throughout the world as it is a differentiation method that allows planners the opportunity to choose several possible alternatives to solve the problems they face, and then building The mathematical model by setting data for the variables used along with formulating the objective function and structural constraints in order to extract and analyze the final results, and then using sensitivity analysis, which paves the way for the planner to develop alternatives to solve the problems within the limits of the optimal solution by changing the objective function parameters and the constraints parameters if necessary.

**Second: Apply the model and analyze the results**

In order to apply the mathematical model according to the previous general formula of the programming model

Linear analysis for the company's five products, using data for each product as mentioned In the previous tables, the mathematical model used will be as follows:

**Max.  $Z = 65X_1 + 67.7X_2 + 343.4X_3 + 9.5X_4 + 11X_5$**

Subject to:





Objective function: Max.Z=88327030

**Table (6)**

Constr.	Left hand side	Right Hand side	Slack Or surplus	Shadow price	Allow . Min. RHS	Allow . Max. RHS
B <sub>1</sub>	260	260	0	0.328	255.8	309.8
B <sub>2</sub>	0.4448	0.4850	0.04	0	0.445	+M
B <sub>3</sub>	2.43	2.43	0	0.33	0.52	2.845
B <sub>4</sub>	0.103	0.36	0.26	0	0.103	+M
B <sub>5</sub>	0.961	1.5	0.539	0	0.961	+M

From the results in Table No. (5) above, it is noted that the company can produce 1,596 water coolers, 5,134 water pumps, and 3,241 ceiling breeze fans, according to the resources available to the company, in order to achieve a total profit of approximately 88.3 million dinars in 2016. As for

The refrigerant motor and air extractor are restricted and not included in the optimal solution. It is possible to reduce their costs in order to raise the profit per unit by (0.15, 3.66) for each of them, respectively, as shown in Table N

**Third: Model sensitivity analysis**

Sometimes the data used in applying linear programming to address certain statistical or economic problems is insufficient to determine the optimal solutions without using the sensitivity analysis method, and hence it is necessary to make some special adjustments in the values of the objective function coefficients or in the right side of the model constraints for each commodity. Productively, the method followed is to change the parameters an From Table No. (6) above, which shows the results of the sensitivity analysis of the model in coefficients

The objective function and the values of the right side of the constraints. We observe the results of the following changes:d the values of the constraints without affecting the optimal solution o. 5.

**1- Changing the coefficients of the objective function:**

It is possible to change the model's objective function coefficients for commodities without affecting

the optimal solution, as the coefficient values for each commodity are between the lower limit and the upper limit, according to the following figure:)

<b>Allowable</b>		<b>Allowable</b>
<b>Min.RHS</b>		<b>Max.RHS</b>
45.68<	C1<	54
1.363<	C2 <	62.51
-M<	C3 <	4.85
-M<	C4 <	23.07
0.16<	C5 <	0.72

That is, the company can increase the profit per unit of these products According to the lower limits and upper limits of the values shown above.

For example, after the production of the water cooler was 1,596 units when the profit per unit was 49.35, the total profit will be approximately 78.7 million dinars, as can be seen in the previous table No. 5. When the profit per unit of the water cooler changes to a value of 54 at the same volume of output, the total profits for selling Water cooler for 86 million dinars.

The same applies to the company's other products, namely the water pump and the breeze fan, whose production results show 5134 and 3241, respectively. When the product of the profit per unit is multiplied by the volume of production for the three commodities, the value of the objective function will be approximately 409 million dinars if the upper limits for the profit per unit are calculated. From each of the previous three products, as noted in Table No. 5.

**Third: Changing the right side of the restrictions: -**

We can also make some changes to the right side of the structural constraints without affecting the optimal solution, that is, the values of the constants for the five constraints range between the minimum and the maximum, according to the following figure)

<u>Min. RHS</u>		<u>Max.RHS</u>	
255.8<	B1<	309.8	
0.445<	B2	<	+M
0.52<	B3	<	2.845
1.03<	B4	<	+M
0.961<	B5	<	+M

It is noted from the changes on the right side of the structural constraints of the model that it is possible to increase

The resources available to the company while the solution remains optimal, meaning that there is a wide scope for increasing product resources

(Water pump, air extractor, breeze fan), thus improving the company's products better so that this does not affect the size of the costs nor the optimal solution.

## **CONCLUSIONS AND RECOMMENDATIONS:**

### **First: Conclusions:**

- 1- It was noted that the company calculates the costs of materials involved in production at the end

The production stages are taken as a whole, meaning that the cost of each stage is not calculated separately

Separate from other stages, which results in many problems within the process

Productivity, as the company considers damage occurring during production as damage

Naturally, regardless of whether this damage is within normal permissible limits

This means charging the cost of damage to the cost of the unit produced.

- 2- The company is responsible for not separating the direct raw materials from the non-materials

Direct, which leads to incorrect measurement of the cost of direct production.

- 3- Irregular daily follow-up of materials issued from warehouses in operations

Productivity, as the company assumes that the quantities issued from the stores

It is fully used, although part of it remains inside the halls Productivity without usage.

- 4- Through analyzing the sensitivity of the linear programming model, it was shown that the company can

Further increasing the resources available for its air extractor and breeze fan products Ceiling.

- 5- Obsolescence of equipment and machinery due to the lack of financial allocations necessary for purchases

And ongoing maintenance in many of the company's factories"

### **Second: Recommendations:**

- 1- The company must separate direct raw materials from indirect materials To accurately calculate costs in direct production.
- 2- Paying attention to the planning department and marketing department within the company to provide more data Accurately and in detail for the purpose of calculating the cost of each stage of production.
- 3- Since advanced and modern mechanization, as well as skilled manpower, represent... The two important elements in reducing the rates of damage occurring during the production process the company must pay serious attention to these two elements to reduce production costs and improve Products better. The two important elements in reducing the rates of damage occurring during the production process the company must pay serious attention to these two elements to reduce production costs and improve Products better.
- 4- The company must open continuous training courses to keep pace with modern industrial development In order to raise the skills of the workforce inside the factories.
- 5- Achieving a suitable investment environment for the company for investors to secure contracts for them  
In order to participate in the operation and production process as well as marketing.
- 6- It is possible for some researchers (especially postgraduate students) to turn towards: Using mathematical and planning methods to identify the most important problems that arise the company is struggling to develop its work to meet the need of local demand without resorting to recourse to import from abroad and waste the country's hard currency.

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