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The Role of Quantitative Methods in improving the Economic Institutions' Performance Case Study of Valve Unit at POVAL (Berrouaghia unit) by applying the Linear Programming

Esselimani mohamed [1*]

[1] University of Yahia Fares in Medea, (Algeria),
esselimani@windowslive.com

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Abstract:

Quantitative Methods were among the applied sciences that spread remarkably after WWII. Their applications expanded to include both the industrial and services sectors. These methods are practical ways that help in the process of elaborating accurate decisions. They rely on appropriate information to choose the best alternative for solving problems and improving the performance of the institutions.

This study aims at shedding the light on the role and effectiveness of the use of quantitative methods in improving the performance of Algerian industrial enterprises, taking POVAL Company as a case study. Firstly, the study deals with quantitative methods and their historical development. Secondly, it touches upon the linear programming and optimization issue. Thirdly, it verifies the contribution of linear programming in improving the performance of Valve Unit at POVAL company through the attempt of finding out that the use of the quantitative methods contributes to enhancing the economic performance of the company.

Keywords: Quantitative Methods, Linear Programming, Improving the Economic Performance Of He Company.

Jel Classification Codes: C44.

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[*]**Corresponding author**: Esselimani mohamed

1. Introduction

The large size of the companies, the limitation of the available resources, and the different values and attitudes of the decision-maker can directly complicate the decision making process if they are not compatible with the company's goals. Moreover, there are other complication factors, such as the multiple available alternatives of information and communication technology, high cost, and the increased competition between companies as well.

All these factors have stimulated the necessity of developing the managers' skills at various administrative levels along with modern management trends based on quantitative methods. This will enhance measurable and factual information to benefit from the power of the quantitative models and to analyze them without any personal bias to achieve the best decision.

Considering what has already been said, this study comes to demonstrate the effectiveness of the process of applying linear programming technology in improving the performance of Algerian industrial companies (case study of Valve Unit at POVAL company-Berrouaghia - using linear programming). The following question is posed

How can the linear programming contribute in improving the performance of the Valve Unit at POVAL company-Berrouaghia?

To address the above-mentioned question, the study sets the following hypothesis: The use of linear programming helps in improving the performance of economic companies through the optimal use of the companies' resources.

1.2- Objective of the study:

This study seeks to improve the ways of managing problems that industrial and economic enterprises face. This comes from the fact that choosing the right tools and methods is the key condition of work success and optimization. It also seeks to develop decisions-making techniques in the industrial institutions in order to increase their outcome and urge them to continuously search for better methods to enhance the practice of their activities.

1.3- Methodology:

To address the above-mentioned problem, the study uses the descriptive approach with the aim of clarifying the theoretical aspects of this topic. It also uses the method of linear programming (being one of the most important quantitative methods) because it corresponds to the nature of this research. In addition to that; this study relies on Win Qsb program to perform technical calculations and processes.

2. The Concept of Quantitative Methods and its Historical Development

2.1 Quantitative Methods Definition

There are several definitions of the science of quantitative methods and process research. It has been defined as a set of tools or techniques used by the decision maker to solve problems using sufficient data, or as mathematical and quantitative models that regulate the administrative or economic problems by representing them in mathematical relationships. It is also defined as a mathematical way that solves marketing problems by providing all the available data and methods used by the decision maker.(David, 1985, p. 119)

However, the definition adopted by the British Operations Research Association was the following: "the use of scientific methods to solve complex problems in managing large systems of the workforce, equipment, raw materials, and money in plants, government institutions, and armed forces" (Michael Carter, 2018, p. 221)

Quantitative methods and research processes are based on the quantitative treatment of management problems since measurements require a quantitative set of elements, mechanisms, and the relations interrelated with the performance.(Wisniewski, 2014, p. 198)

There are many techniques and models of research processes. However, the most significant ones are; liner programming, grids theory, dynamic programming, correct programming, transportation forms, inventory forms, Markov chain, queuing theory and so many others. Those models and forms provide the decision maker with many benefits such as finding alternatives to solve a particular problem by making the right decision based on appropriate circumstances and factors, and they also contribute to making decisions in a more specific and accurate manner, avoiding as such any randomness occuring because of trial and error.(Christy Chuang-Stein, 2017, p. 122)

2.2 The Historical Development of Quantitative Methods

Quantitative methods and process research are among the sciences that contributed to the victory of the British Ground and Air Forces during the Second World War (1936). At that time, the idea was about improving the use of weapons to have more practical results. (Mik Wisniewski, 2019, p. 239)

All credit went to G. Dentizing, a scientist who discovered the Simplex algorithm that has promoted capabilities in solving linear programming problems for the military operations research science in Britain. However; in America it was due to both B. James, the head of

the National Defense Research Committee, and B. Rannivar, the head of the Committee on New Weapons and Equipment, who conducted studies that are similar to the British ones. They formed a special team to deal with some complex issues, such as equipment and materials transportation and distribution to the various military units deployed in different regions of the world.(Gupta M. P., 2011, p. 107)

In October 1942, General Spaatz, Commander-in-Chief of the Eighth Air Force sent a letter to other Air Forces Commanders-in-Chief asking for a group of scientists to analyze the processes in their units. A first team of scientists was formed in Britain, followed by another team from the US Navy. Two huge projects were created: the Naval Equipment Laboratory and the Tenth Fleet headed by M.Philip and J.Ellisa. The success achieved on that day drove military leaders to demonstrate a continuous interest in this science through the Operations Research Agency, which was later transformed into the Operations Research Corporation. This encouraged the use of this science in so many other countries, led by Canada, which formed a team tasked with producing military equipment through the optimal use of available resources. (Jaiswal, 2012, p. 256)

3. Linear Programming

3.1-Linear Programming's Definition

Linear programming is a mathematical technique that searches for a solution to a specific problem so that it contributes to finding the optimal solution by allocating the limited resources for different uses, but taking into consideration some commitments and restrictions such as; the working hours number, the produced or distributed a quantity of a particular product, and the number of raw materials available, etc. Linear programming addresses some problems like; determining the formation of products, Production scheduling, and inventory planning, organizing the assembly lines of goods and products, preparing machine operating schedules, analyzing traffic, transportation,

agricultural and military sector problems, and also evaluating the jobs.(Jaiswal, 2012, p. 294)

The term linear programming is composed of two words. Programming means the use of logical and scientific methods in the analysis and treatment of problems; however, linear means that there is a fixed relationship between the basic variables involved in the structure of the model. The stage of formulating and forming the linear model (or formulating the problem) is considered one of the most important and difficult stages; because at this stage, the economic problem is transformed into a mathematical model that can be solved with the use of linear programming.(H. A. Eiselt, 2010, p. 144)

3.2 Linear programming' Formulation and Configuration

Several situations require the allocation of some amounts of limited resources to their alternative uses, so the linear programming method is concerned with the process of distributing these resources to those alternative uses in a convenient way. The need for using linear programming varies according to the situation needed, such as allocating means of production on the products, distributing aviation fuel on aviary flights, planning investments, programming product transportation, scheduling production, and solving games models, in addition to many other problems that linear programming solves.(Michael Carter, 2018, p. 208)

Linear programming has basic features and conditions. It can be described and put into the form of a mathematical model. Some of these conditions are: (Ravindran, 2016, p. 83)

- There should be a goal of maximizing profit or minimizing costs. This goal is expressed in a function called: the objective function or the economic function.
- To have limited resources that have multiple uses, and the way of its use is called technical limitations

Let's suppose that we have (n) as a variable. For instance, we express the relationships between variables and **available resources or production conditions with equations or inequalities their number is (m).** So, the general form of these technical limitations is as follows:(David R. Anderson, 2015, p. 287)

$$\mathbf{a_{1j}.x_1 + a_{2j}.x_2 + a_{3j}.x_3 + \ldots + a_{nj}.x_n \leq = \geq b_i}$$

In which **bi** is the available quantity of the resource or raw material. However, **xi** is the model variables whose values or amounts we search for, and it represents the quantities produced of certain commodities.(Gupta M. P., 2011, p. 134)

$\mathbf{a_{1j}}$ represents the quantity of used resources **bi** to produce one unit of the first product. Then, **a2j** represents the quantity of used resources **bi** to produce one unit of the second product, and so on.(David, 1985, p. 296)

There are non-negative constraints, meaning negative values are not allowed in the linear model.

Finally, the economic function, also called the objective function, it is either a maximizing or a minimizing function. It is written as follows: (Ravindran, 2016, p. 248)

$$\mathbf{Opt\ Z = c1.x1 + c2.x2 + c3.x3 + \ldots + cn.xn}$$

For instance, **Z** represents the profit value if the function is a maximizing function, but in the case of a decrease, **Z** may be a cost.

The values of **cj** represent the selling price per unit or the profit margin if the economic function is a maximizing function. However, in the case of low, they represent the cost of production per unit.

The complete linear program for linear programming is as follows: : (Mik Wisniewski, 2019, p. 281)

(max &min) $\mathbf{Z = \sum c_j\ x_j}$ It represents the objective's function

$$\begin{cases} \sum \mathbf{a_{ij}\ .\ x_j} \leq = \geq \mathbf{b_i} & \text{It represents the technical limitations} \\ \mathbf{x_j \geq 0} & \text{It represents the Non-negative constraint} \end{cases}$$

4. The contribution of linear programming in improving the performance of POVAL's valve unit (Berrouaghia)

In this part of the study, we will first consider POVAL Company and its goals. Then, in the applied study, we will try to collect some data related to the production plan of the Valve Unit at the company where we analyze the production method based on the data provided by the Production Unit. After that, we will suggest a linear programming model as an alternative to the plans made by POVAL Company, with the aim of highlighting the importance of the quantitative methods positive impact (linear programming) on improving the performance of the company

4.1 A glance at POVAL Company, Berrouaghia Unit

4.1.1 Defining the Company

POVAL was founded in 1975 under the Socialist Management Act. At that time, it was called the National Corporation for Mechanical Industries *SONACOME*. On the 5th of August 1997, POVAL become a public economic company under the name of *Pumps and Valves –Algeria (POVAL)*. Then, it was divided into six specialized production units in the field of irrigation and fuel. Today, POVAL is an autonomous company in its internal and external affairs management, but it is still owned by the state in which it directly contributes to the development of the national economy. It produces various types and shapes of pumps and valves. Moreover, it has workshops for maintaining the equipment, and units for converting raw materials into products. Its products are marketed to various states of the country, and also exported abroad to several countries such as Italy, Senegal.... etc. Now, the institution in Berrouaghia includes four production units instead of six, which are, valve unit, foundry unit, maintenance unit, and the pump unit.

4.1.2 POVAL Institution's Objectives

Like other industrial institutions, POVAL was founded with a number of goals to be achieved, including:

- Meeting the requirements of the national and international market, with various valves and pumps products used in the irrigation sector, which is an important sector in the national and global economy

- Supplying the hydrocarbon sector with products (resources) such as valves for fuels that contribute in financing of the petroleum industries.

- Supplying the internal market with various products that meet the sectors' requirements to get rid of dependence on the outside markets.

- Integrating with major national institutions, and contributing to the realization of the development of the Algerian economy plan.

4.2 Production –Actuality Analysis and Evaluation of POVAL Valve Unit in Berrouaghia

4.2.1 The Analysis of the Available Data at the Valve Unit

This analysis was based on the data provided by the company's production unit of the expected and actual production by analyzing the expected production actualization rate for the years 2019 and 2020, with some modifications submitted by the company. The unit of measurement was the kilograms (kg).

Table 1. The production capacity- utilization -rate of the production workshop for the year 2019/ 2020 (kg).

	2019			2020		
	Expected production	**Actual production**	**P%**	**Expected production**	**Actual production**	**P %**
1° trio	88800	55115	62.06	100400	64486	64.22
2° trio	90200	30439	33.74	107100	31351	29.27
3° trio	98500	66704	67.71	102200	81654	79.89
4° trio	93000	77823	83.68	97240	136025	139.88
Total	**370500**	**230081**	**62.10**	**406940**	**313516**	**77.04**

Source : POVAL's Valve unit, Production Department.

The data of year 2019/2020 show that there is a big difference between the expected production and the actual production. On that basis, it can be said that the expected production is not studied or analyzed through accurate scientific methods because the expected rate of production did not exceed 100% except for the fourth third of 2020. The achievement rate decreased significantly during the second third of the 2019 and 2020, in which it didn't exceed 30%. In addition, it is clear that the overall achievement rate for the year 2020 is much better than 2019. In 2020 the amount increased to 77.04%, compared to 2019 which was only 62.10%.

4.2.2 The Evaluation of the Company's Production Plan

It is difficult to accurately estimate the percentage of achievement, which indicates that the company's work is not built on a strong scientific method during the estimation process. The encountered difficulties were neither addressed nor studied in previous periods in order not to repeat the same mistakes. In addition to that, it is noticed that the expected production for each trio is not much different in terms of quantity, and this indicates that there is no flexibility or alignment with the market's demand or technological development. The company depends mainly on determining the produced quantities on the order system registered in the Marketing Department, and it doesn't observe scientific methods such as linear programming.

This calls for the need to improve the company's production planning by using scientific models such as linear programming as one of the modern quantitative methods in order to improve the institution's performance.

4.3 The Role of Linear Programming in improving the Valve Unit's Performance

4.3.1 Analyzing and defining the model variables

The objective from using the linear programming model is to calculate the quantities which need to be produced, to know the amount of raw materials needed for production, to also know and the possible outcomes results, and lots of other advantages.

Our proposed model variables should be first defined by knowing the products, which were at the number of four:

Valve 145 m1, It is referred to herein by **So 1** so that **x1** represents the produced quantity from this type of product.

Valve 175 p8 It is referred to herein by **So 2** so that **x2** represents the produced quantity from this type of product.

Valve 52 It is referred to herein by **So 3** so that **x3** represents the produced quantity from this type of product.

Valve 961 er4 It is referred to herein by **So 4** so that **x4** represents the produced quantity from this type of product.

4.3.2. Linear Model's Configuration of the Production Process

Objective Function

The study aims at developing a production plan based on the available data provided by the production department. It relies on the data of this following table regarding the expected and actual quantities of the four products during the year 2020, which are as follows:

Table 2. The production capacity - utilization - rate of the production workshop for 2019/ 2020 (kg).

Product		Expected production	Actual production
So 1	X1	25000	28700
So 2	X2	29800	21750
So 3	X3	22900	17500
So 4	X4	31200	33240
Total		**101190**	**108900**

Source : POVAL's Valve Unit, Production Department.

The total revenues for the same year are shown in this following table:

Table 3. The actual production, the quantity of sold production for 2020, and the revenues for the four products

Product	Actual production(kg)	Sold quantities(kg)	Unit (DZD)	Revenues (DZD)
X1	28700	19300	8900.00	171770000.00
X2	21750	21750	7750.00	168562500.00
X3	17500	17500	12500.00	218750000.00
X4	33240	29500	9500.00	280250000.00
Total	**108900**	**88050**	**-**	**839332500.00**

Source: POVAL's Valve Unit, Sales Department.

From the previous table it is clear that:

-The selling price per one unit of the first type x1 is 8900.00 DZD.

-The selling price per one unit of the first type x2 is 7750.00 DZD; all the produced quantity was sold.

-The selling price per one unit of the first type x3 is 12500.00 DZD, all the produced quantity was sold as well.

-The selling price per one unit of the first type x1 is 9500.00DZD.

Now if the objective function is referred to with the letter Z, which represents the organization's goal in achieving total revenue (it is only the sold quantities in the price of one unit for the four products), then the objective function will be written as follows:

$$\textbf{Max } Z = 8900\ x1 + 7750\ x2 + 12500\ x3 + 9500\ x4$$

The technical limitations are as follows:

Technical limitations of production time:

The production process passes through four workshops. This following table represents the working hours for each workshop:

Table 4. The actual and expected number of working hours for the year 2020

workshop	Expected working hours	Actual working hours
First workshop	1540	1325
Second workshop	1620	1410
Third workshop	1220	880
Fourth workshop	980	730

Source: POVAL's Valve Unit, Production Department.

As for the number of theoretical working hours, it was calculated as follows: the number of daily hours multiplied by the number of days of the week, multiplied by the number of weeks of the month multiplied by the months of the year; and that depends on the privacy of the workshop and the way it works.

Considering that all products go through the first workshop, and therefore the time is taken to produce one unit of each of the four products is as follows:

The total production of the four products = **28700 +21750 +17500 +33240 = 108900 kg**

Thus, the time required to produce one unit of each type in the first workshop is as follows:

The time required to produce one unit of each type in the first workshop **=1325/108900=0.01216 hour**

The same thing can be done for all the remaining workshops in order to calculate the time required to produce one unit of the three remaining types in each workshop.

As for the second workshop, the four products also go through the workshop; so, the production of one unit of the four species is: **1410/108900= 0.01294 hour**

Thus, we calculate all production times of one unit of each product in the same previous way:

For the third workshop, only the second and fourth products go through the workshop; so, the production of one unit of the two types is as follows: The production of one unit of the second and fourth types **=880/ (21750+33240) =0.01600 hour**

In the fourth workshop, only the third product passes through the workshop, and therefore the production of one unit of this type is as follows: The production of one unit of the third type **=730/17500=0.04171 hour**

The previous data can be summarized in the following table, which shows the production's time for each unit of each of the four products in the entire workshops.

Table 5.The number of working hours required to produce one unit of each type in each workshop (hour).

workshop	Products			
	X1	X2	X3	X4
Workshop 1	0.01216	0.01216	0.01216	0.01216
Workshop 2	0.01294	0.01294	0.01294	0.01294
Workshop 3	-	0.01600	-	0.01600
Workshop 4	-	-	0.04171	-

Source: by the researcher based on previous data.

Now, based on the existing data in the above table, the technical constraints of time can be formed as follows:

$0.01216\ x1 + 0.01216\ x2 + 0.01216\ x3 + 0.01216\ x4 \leq 1540$

$0.01294\ x1 + 0.01294\ x2 + 0.01294\ x3 + 0.01294\ x4 \leq 1620$

$0.01600\ x2 + 0.01600\ x4 \leq 1220$

$0.04171\ x3 \leq 980$

Technical limitations of the raw material:

he raw material used in the production process is a metallic material that takes the form of alloys, and it is available at 8,685,000 kg during the year 2020. The four products use the same raw material in their production, this means that the technical constraint of the raw material is as follows:

$x1 + x2 + x3 + x4 \leq 8685000$

Technical limitations of the application:

$x1 \leq 25000$
$x2 \leq 29800$
$x3 \leq 22900$
$x4 \leq 31200$

The company must imperatively produce positive units. According to that, the quantities produced must be positive or of zero values, so it is necessary to add non-negative constraints to the linear program, which means:

$x1 , x2 , x3 , x4 \geq 0$

Through all of the mentioned information above, the complete linear program for the valve unit activity can be written as follows:

Max Z = $8900 x1 + 7750 x2 + 12500 x3 + 9500 x4$
$0.01216 x1 + 0.01216 x2 + 0.01216 x3 + 0.01216 x4 \leq 1540$
$0.01294 x1 + 0.01294 x2 + 0.01294 x3 + 0.01294 x4 \leq 1620$
$0.01600 x2 + 0.01600 x4 \leq 1220$
$0.04171 x3 \leq 980$
$x1 + x2 + x3 + x4 \leq 8685000$
$x1 \leq 25000$
$x2 \leq 29800$
$x3 \leq 22900$
$x4 \leq 31200$
$x1 , x2 , x3 , x4 \geq 0$

4.3.3 Solve the Linear Program Solution and the Interpretation of the results

After finishing the configuration of the linear program, it can be solved using one of the ready-made programs. We will use the ready-made program Win Qsb because the program is specialized in solving problems of operations research and quantitative methods.

Table 6. The outputs of the results of solving the linear program using the program win Qsb

Products	Produced quantity	Unit price (DZD)	Realized revenues(DZD)	The product' nature in the optimal state activity
So 1	25000	8900.00	222500000.00	Produce
So 2	29800	7750.00	230950000.00	Produce
So 3	22900	12500.00	286250000.00	Produce
So 4	31200	9500.00	296400000.00	Produce
Total			**1036100000.00**	

Source: by the researcher based on previous data.

According to table, the company should produce all four products in the optimal mode of activity according to the available raw materials and the demand constraints.

The results of the optimal solution can also be compared with the organization's plan, so they can be summarized in a common table to monitor and analyze all the values.

Table 7.Comparison between the production plan of the organization and the plan of the linear program

Product	Unit price (DZD)	According to the proposed linear program		According to the program of the institution	
		Produced quantity	Realized revenues(DZD)	Sold quantity	Realized revenues(DZD)
So 1	8900.00	25000	222500000.00	19300	171770000.00
So 2	7750.00	29800	230950000.00	21750	168562500.00
So 3	12500.00	22900	286250000.00	17500	218750000.00
So 4	9500.00	31200	296400000.00	29500	280250000.00
Total	-	-	**1036100000.00**	-	**839332500.00**

Source: by the researcher based on previous data.

According to the table, the revenue generated from the proposed production plan for the linear program is **1036100000.00** DZD. However, the revenue realized by the company's plan is **839332500.00** DZD.

The revenue of the proposed plan using linear programming exceeds the revenue of the company's plan.

The rate of the annual revenue increase can be calculated if linear programming is used in production planning as follows:

The rate of annual revenue increase =[(The annual revenue of the optimal plan using linear programming – the annual revenue for the company's plan)/ Annual revenue for the company's plan] x 100

The rate of annual revenue increase=

[839332500.00 /(839332500.00 –1036100000.00)]**x100**

The rate of increase in the annual revenue = **23.4433 %**

This means that the rate of increase in the case of using linear programming will be **23.4433%** in the annual revenue.

5. Conclusion

Algerian economic companies, including POVAL, encounter many variables that force them to develop their performance through the use of management modern methods such as quantitative methods in order to achieve the efficiency of their economy. Among these methods is the linear programming used in this study.

Based on the aforementioned results, quantitative methods, especially linear programming, have an effective role in improving and developing the performance of economic companies to increase the organization's ability in facing its the surrounding challenges, developing its competitive advantages and achieving its best performance. Thus, the validity of the hypothesis of this study is proved.

Recommendations:

In light of these findings, the study recommends these following recommendations:

- The need to improve the performance level of Algerian economic companies through the use of quantitative methods

- Developing the management methods of the organization with the same line that deals with the developments of its surroundings.
- Reviewing the extent to which the available quantitative methods are actually applied.
- Modernizing the means used in the management, through the use of more advanced methods that meet the needs of the company.
- Paying attention to the effectiveness of applying quantitative methods in its management.
- Expanding the scope of information programs use, which assists in the effective information use that is available in the institution.
- Being open to the external environment and cooperation with universities and applied research centers.
- The necessity of training human resources on how to apply these methods in the reality of the Algerian company.

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