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Optimization Of Resources in a PYME Of the Textil Sector: An Lineal Programming Approach

Ing. Jorge Manuel Barrios Sanchez
Master Degree Student
Department of Multidisciplinary
Sede Yuriria, Universidad de Guanajuato
Yuriria Mexico
Jm.barriossanchez@ugto.mx

Dr. Roberto Baeza Serrato
Research Profesor
Department of Multidisciplinary
Sede Yuriria, Universidad de Guanajuato
Yuriria-Mexico
r.baeza@ugto.mx

***Abstract*—A linear programming model is presented as a tool to maximize profits in a SME located in the south of Guanajuato. An Excel spreadsheet was designed and developed to solve the model, using the revised simplex model. Time, inputs and demand constrictions were integrated for the seven main products. Ten iterations of the revised simplex method were made to obtain the model optimization; the right sequence of processes results in a $11,830 MXN daily gain. This model can be replicated in any textile SME and be a prototype for any productive enterprise.**

Keywords—lineal programming; optimization ; revised simplex method.

The textile sector is considered one of the most developed activities, nevertheless it shows a high capacity of innovation and new development, like the ones needed for season changes, functional and aesthetical modifications required by the cultural evolution, and specially the pressure of demanding customers, and the arrival of new competitors; that's the reason innovation is a continuous process, making it a stable course in the sector and a strategic point for the SMEs [1]. In México, the SMEs are the 42% of the country enterprises, contributing to 31.5% of the employment and almost 37.0% of the Gross Domestic Product(GDP), also it is the backbone of the national economy, the reason being the trade agreements of the last years [2].

Decision making in this sector is a difficult task in which the efficient use of inputs, time and money is crucial. Linear programming models are a powerful tool to reach the optimization objectives. Many problems of operation research can be solved as linear programming applications. Special cases as the flux in a network or the movement of merchandises are so important that the research in those areas has produced many algorithms to solve them [3].

Today, optimization is a normal procedure in sciences, engineering and business [4]. The revised simplex method requires less calculation than other methods. Basically, it performs calculations only in the vector of the non-basic variables and registers in memory all the information of the basic ones [5].

In the city of Moroleón, located at the south of Guanajuato, lies a great quantity of SMEs that specialize in the knitting process. These have become the main center of textile production and commercialization in the region.

The case study is focused in a textile enterprise called *NAVY SEAL S. DE R.L. DE C.V.* in the city of Moroleón, that produces clothes and knitted outerwear. The objective is to optimize the resources of the enterprise, having as a reference the time needed for each process, the inputs and the minimal sales needed to continue its operation.

I. LITERATURE REVIEW

In this section the results of an exhaustive investigation for previous works involved in operation research with the revised simplex model are presented.

At reference [6], the simplex method is used to develop a mathematical model that optimizes the profits in milk production and its derivatives, by small and medium producers. At [7] the research is focused in the need for tools that help to identify the optimal management strategies for the cultivation of prawns: a mathematical programming model was developed as a flexible help for decision making in the production process and used to economically optimize the enterprise. The calculations for the intercellular flux in biological systems is made at [8]: a revised simplex model is implemented in an HYDRA system, that allows to simulate the distribution of a metabolic flux minimizing or maximizing a function in biological systems. At [9] an optimization of a mechanical irrigation control system is developed using linear programming and the revised simplex method, obtaining the optimal type and numbers of machinery (under constrictions). This last was implemented in México and shows that linear programming is of great help for the decision takers pertaining natural resources and risk assessment. At [10] the case of Éxito S.A. of Santa Rosa is studied: an enterprise that fabricates several types of car bodyworks but doesn't know if its gains are covering the predicted expectations. The revised simplex is implemented as a tool to take better decisions and use its resources in a more efficient manner. At [11] a simplex method is used for multiple answer problems. The proposed method applies standardized loss functions to the simplex method, producing an efficient tool for the system optimization with several levels of quality. At [12] four data sets were used representing a containers lot located in Villa Clara, Cuba. The space assignment problem is studied within an acceptable time frame in the normal operation of the lot, using a revised simplex model.

The applications cited show applications of the simplex and simplex method revised, in various productive and service sectors. There is a shortage of developments of linear programming models in SMEs, due to the tacit knowledge they have, reason for the present research to present an application of a linear programming model that what contributes to the review of literature for small and medium enterprises in the textile sector.

II. METHODOLOGY

In this section, the methodology designed for performing the research is presented. See Table 1.

TABLE I. RESEARCH METHODOLOGY.

PHASE	AIM	PROCEDURE
Case study Identification.	Identify the processes, costs and sales of every one of the products of the case study for a better knowledge of every one of these products.	Through a visit to the firm and by studying the products offered by the textile company.
Theoretical Base	Examine the state of the art from applications of the revised simplex method in order to have a guide on how it has been implemented.	Through databases, scientific articles.
Decide decision variables	Identify the decision variables to know the elements on which to decide.	Through a selection of the best selling garments in the company.
Decide objetive function	Establish the objective function to express what is intended to maximize	The utility of each of the decision variables is determined
Decide Restrictions	Define the restrictions of resources, production and demand to denote the limitations that are available.	Through an interview with the head of production, the restrictions that are had.
Results and conclusions.	Application of the revised simplex method to obtain maximum utility when optimizing resources and time.	Excel Template.

A. *Case study identifaction*

To perform this research, the PYME NAVY SEAL S. DE R.L DE C.V was selected as case study. The company has different processes for the making of each of the garments produced by the company; 1- Weaving process that is performed by a circular textile machine 2- Cutting process 3- confection 4- finished of the garment and finally the packaging for shipment to the products manufactured by the company, were selected which are the most manufactured and sold by the company. See table 2.

TABLE II. BESTSELLING PRODUCTS OF THE COMPANY TEXTILES NAVY SEAL S. DE R.L DE C.V

Product	Sale price	Sale cost
Tank top	25	17
Short sleeve blouse	35	25
Large sleeve blouse	60	44
Basic boxer	37	28
Fajilla	36	22
Scarlett blouse	46	33
Boxer designs	55	39

B. *Time restriction*

The production manager assisted in the data acquisition of the times of each one of the products. The standardized times in the processes of each of the aforementioned products can be seen in Table 3.

Table III. TIME RESTRICTION.

	Minutes			
Product	**Knitting**	**Cutting**	**Making**	**Finished**
Tank Top	04:00	00:00	01:00	00:30
Short Sleeve Blouse	06:30	01:12	02:00	01:00
Large Sleeve Blouse	12:00	01:30	02:30	01:30
Basic Boxer	04:30	00:18	01:30	01:00
Fajilla	06:30	00:00	03:30	01:30
Scarlett Blouse	05:30	00:00	04:00	02:00
Boxer Designs	05:30	00:09	01:30	01:00
Time Restriction	96 hours	28:30 hours	80 hours	80 hours

In the table of times it can be observed that there are products that have associated times of zero, this means that for the elaboration of such products these processes do not need to be performed.

C. *Resourses restriction*

The amount of thread required for each of the garments can be seen in table 4.

Table IV. TIME RESTRICTION.

Product	Thread Quantity (Kg)
Tank top	0.07
Short sleeve blouse	0.11
Large sleeve blouse	0.16
Basic boxer	0.1
Fajilla	0.13
Scarlett blouse	0.1
Boxer designs	0.11

There is a daily amount of 125 kg of thread for the realization of the garments. The amount of thread is mainly used in the weaving process.

D. *Production restriction.*

To produce the seven products, there is a minimum production of each of these garments that are sold daily to different customers that the company has, mainly to Coppel company. The minimum sales that each of the products must have are shown in table 5.

TABLE V. MINIMAL GARMENT PRODUCTION

Product	Demand
Tank top	>=140
Short sleeve blouse	>=120
Large sleeve blouse	>=80
Basic boxer	>=140
Fajilla	>=80
Scarlett blouse	>=90
Boxer designs	>=130

III. RESULTS.

Mathematical models in linear programming have three basic components that are: Decision variables, objective function and constraints. The decision variables are defined, which represent the elements on which they must be decided.

X1= # of tank top to produce

X2=# of short sleeve blouse to produce

X3=# of large sleeve blouse to produce

X4=# of basic boxer to produce

X5=# of fajilla to produce

X6=# of scarlett blouse to produce

X7=# of boxer designs to produce

Function Objective:

The objective function expresses what you want to maximize. the profit from the sale of the seven main products. See Equation 1

$$Z = 8x1 + 10x2 + 16x3 + 9x4 + 14x5 + 13x6 + 16x7 \qquad (1)$$

The restrictions count the resources that are available which are limited. Table VI shows the restrictions of time, material and demand.

TABLE VI. SHOWS THE TIME, MATERIAL AND DEMAND RESTRICTIONS.

X1	X2	X3	X4	X5	X6	X7	B
4	6.5	12	4.5	6.5	5.5	5.5	<=5760
0.07	0.11	0.16	0.1	0.13	0.1	0.11	<=125
0	1.2	1.5	0.3	0	0	0.3	<=1710
1	2	2.5	1.5	3.5	4	1.5	<=4800
0.5	1	1.5	1	1.5	2	1	<=4800
1	0	0	0	0	0	0	>=140
0	1	0	0	0	0	0	>=120
0	0	1	0	0	0	0	>=80
0	0	0	1	0	0	0	>=140
0	0	0	0	1	0	0	>=80
0	0	0	0	0	1	0	>=90
0	0	0	0	0	0	1	>=130

It can be analyzed that the values that are worth zero within the matrix of restrictions are processes that are not necessary in the elaboration of each of the garments.

Rows 1,3,4 and 5 are the times of the processes explained in table 3. Row 2 is the resource restriction in Kilograms and row 6 through 12 are the minimum production constraints that the company has in the seven products.

The next step is to perform the extended matrix with their respective margin or artificial variables depending on the type of inequality. See the following equations.

$$4x1 + 6.5x2 + 12x3 + 4.5x4 + 6.5\,x5 + 5.5x6 + 5.5\ x7 + S1 = 5760 \quad (2)$$
$$0.07x1 + 0.11x2 + 0.16x3 + 0.1x4 + 0.13x5 + 0.1x6 + 0.11x7 + S2 = 125 \quad (3)$$
$$+1.2x2 + 1.5x3 + 0.3x4 + \quad + 0.3\,x7 + S3 = 1710 \quad (4)$$
$$1x1 + 2x2 + 2.5x3 + 1.5x4 + 3.5x5 + 4x6 + 1.5\,x7 + S4 = 4800 \quad (5)$$
$$0.5x1 + x2 + 1.5x3 + x4 + 1.5x5 + 2x6 + x7 + S5 = 480 \quad (6)$$
$$x1 + \quad + \quad + \quad + \quad + \quad + \quad - S6 + A1 = 140 \quad (7)$$
$$+x2 \quad - S7 \quad + A2 = 120 \quad (8)$$
$$+x3 \quad - S8 \quad + A3 = 80 \quad (9)$$
$$+x4 \quad - S9 \quad + A4 = 140 \quad (10)$$
$$+ \quad x5 + \quad + \quad - S10 \quad + A5 = 80 \quad (11)$$
$$x6 \quad - S11 \quad + A6 = 90 \quad (12)$$
$$+x7 \quad - S12 \quad + A7 = 130 \quad (13)$$

The next step is to define the matrix (B) that has the identity and It will be the one that is initially in the base on the revised simplex method.

To perform the revised Simplex Method, the following operations must be followed in order.

1- Find (B^{-1})
2- $Xb = B^{-1} * b.$
3- $Zii = Cb * B^{-1}$
4- $gain = Cj - Zj$
5- $Z = Cb * Xb$
6- $Zi = Zii * A$

7- The input variable is selected according to the highest value obtained.

8- Xb is divided by b (Xb/b) to calculate teta and the lowest value is selected as output variable.

9- The input variable is selected and replaced by the output variable and its values in the base are changed. The above steps are repeated to find the optimal pattern.

The variables found within the base can be seen in the first column of Table VII. The cost coefficients of the variables within the base are located in row CB. It can be observed the base matrix of the first iteration.

Table VII. Matrix identity base of the first iteration.

	0	0	0	0	0	-16	-16	-16	-16	-16	-16	-16
Xj	***S1***	***S2***	***S3***	***S4***	***S5***	***A1***	***A2***	***A3***	***A4***	***A5***	***A6***	***A7***
	MATRIX B											
S1	1	0	0	0	0	0	0	0	0	0	0	0
S2	0	1	0	0	0	0	0	0	0	0	0	0
S3	0	0	1	0	0	0	0	0	0	0	0	0
S4	0	0	0	1	0	0	0	0	0	0	0	0
S5	0	0	0	0	1	0	0	0	0	0	0	0
A1	0	0	0	0	0	1	0	0	0	0	0	0
A2	0	0	0	0	0	0	1	0	0	0	0	0
A3	0	0	0	0	0	0	0	1	0	0	0	0
A4	0	0	0	0	0	0	0	0	1	0	0	0
A5	0	0	0	0	0	0	0	0	0	1	0	0
A6	0	0	0	0	0	0	0	0	0	0	1	0
A7	0	0	0	0	0	0	0	0	0	0	0	1
	S1	**S2**	**S3**	**S4**	**S5**	**A1**	**A2**	**A3**	**A4**	**A5**	**A6**	**A7**
CB	0	0	0	0	0	-16	-16	-16	-16	-16	-16	-16
ZJ	0	0	0	0	0	-16	-16	-16	-16	-16	-16	-16
CJ-ZJ	0	0	0	0	0	0	0	0	0	0	0	0

Table VIII shows the inverse matrix of the base, vector b of the available resource, column Xb of solution. The input variable in the first iteration is selected from the match between X3 and X7 with the most positive values, in this case with a value of 32, which are located in column four and eight, the input variable X3 is selected. The output vector with the lowest value of the Xb/Ve ratio was the artificial variable A3.

Table VIII. Inverse Matrix and first iteration results.

	8	10	16	9	14	13	16	0	0	0	0	0	0	0		
Xj	**X1**	**X2**	**X3**	**X4**	**X5**	**X6**	**X7**	**S6**	**S7**	**S8**	**S9**	**S10**	**S11**	**S12**		
	INVERSE OF B												***b***	***Xb***	***Ve***	***Teta***
S1	1	0	0	0	0	0	0	0	0	0	0	0	5760	5760	12	480
S2	0	1	0	0	0	0	0	0	0	0	0	0	125	125	0.16	781.25
S3	0	0	1	0	0	0	0	0	0	0	0	0	1710	1710	1.5	1140
S4	0	0	0	1	0	0	0	0	0	0	0	0	4800	4800	2.5	1920
S5	0	0	0	0	1	0	0	0	0	0	0	0	4800	4800	1.5	3200
A1	0	0	0	0	0	1	0	0	0	0	0	0	140	140	0	----------
A2	0	0	0	0	0	0	1	0	0	0	0	0	120	120	0	----------
A3	0	0	0	0	0	0	0	1	0	0	0	0	80	80	1	80
A4	0	0	0	0	0	0	0	0	1	0	0	0	140	140	0	-----------
A5	0	0	0	0	0	0	0	0	0	1	0	0	80	80	0	----------
A6	0	0	0	0	0	0	0	0	0	0	1	0	90	90	0	----------
A7	0	0	0	0	0	0	0	0	0	0	0	1	130	130	0	----------
															Z	-12480
Zj	-16	-16	-16	-16	-16	-16	-16	16	16	16	16	16	16	0		
Cj-Zj	24	26	32	25	30	29	32	-16	-16	-16	-16	-16	-16	0		

In the next iteration non-negative solutions for Xb are validated. The objective function gives a solution of -12840, which will be increased in each iteration.

Table IX shows that the last row Cj-Zj in the tenth iteration all values are less than or equal to zero. Therefore, It is the last iteration and the optimal solution to the problem will be obtained. The variables in the base in addition to the 7 decision variables were: s11, s2, s3, s4 and s5 that correspond to the margin variable of equation 11 that expresses an excess in decision variable X6, in S2 the amount of resources that were allowed to be used, and with S3, S4 and S5, a smaller amount of time is used than the company owns. See table IX.

Table IX. Matrix identity base of the tenth iteration.

	0	0	0	0	0	-16	-16	-16	-16	-16	-16	-16
Xj	***S1***	***S2***	***S3***	***S4***	***S5***	***A1***	***A2***	***A3***	***A4***	***A5***	***A6***	***A7***
	MATRIX B											
S11	0	0	0	0	0	4	6.5	12	4.5	6.5	5.5	5.5
S2	0	1	0	0	0	0.07	0.11	0.16	0.1	0.13	0.1	0.11
S3	0	0	1	0	0	0	1.2	1.5	0.3	0	0	0.3
S4	0	0	0	1	0	1	2	2.5	1.5	3.5	4	1.5
S5	0	0	0	0	1	0.5	1	1.5	1	1.5	2	1
X1	0	0	0	0	0	1	0	0	0	0	0	0
X2	0	0	0	0	0	0	1	0	0	0	0	0
X3	0	0	0	0	0	0	0	1	0	0	0	0
X4	0	0	0	0	0	0	0	0	1	0	0	0
X5	0	0	0	0	0	0	0	0	0	1	0	0
X6	-1	0	0	0	0	0	0	0	0	0	1	0
X7	0	0	0	0	0	0	0	0	0	0	0	1
	S11	**S2**	**S3**	**S4**	**S5**	**X1**	**X2**	**X3**	**X4**	**X5**	**X6**	**X7**
CB	0	0	0	0	0	8	10	16	9	14	13	16
ZJ	2.36364	0	0	0	0	-1.455	-5.364	-12.3636	-1.6364	-1.3636	0	3
CJ-ZJ	-2.3636	0	0	0	0	-14.55	-10.64	-3.63636	-14.364	-14.636	-16	-19

The results and the objective value of the gain with the products analyzed can be seen in Table X. The final profit is $ 11830. The solution vector Xb gives the optimal solution respecting the limitations that we have. See Table X.

Table X. Matrix identity base of the tenth iteration.

	8	10	16	9	14	13	16	0	0	0	0	0	0	0
Xj	***X1***	***X2***	***X3***	***X4***	***X5***	***X6***	***X7***	***S6***	***S7***	***S8***	***S9***	***S10***	***S11***	***S12***
	INVERSE OF B												***B***	***Xb***
S11	0	0	0	0	0	-1	-1	-2	-1	-1	-1	-1	5760	200
S2	0	1	0	0	0	0	0	0	0	0	0	0	125	22
S3	0	0	1	0	0	0	-1	-2	0	0	0	0	1710	1365
S4	-1	0	0	1	0	2	3	6	2	1	0	3	4800	2375
S5	0	0	0	0	1	1	1	3	1	1	0	1	4800	3520
X1	0	0	0	0	0	1	0	0	0	0	0	0	140	140
X2	0	0	0	0	0	0	1	0	0	0	0	0	120	120
X3	0	0	0	0	0	0	0	1	0	0	0	0	80	80
X4	0	0	0	0	0	0	0	0	1	0	0	0	140	140
X5	0	0	0	0	0	0	0	0	0	1	0	0	80	80
X6	0	0	0	0	0	-1	-1	-2	-1	-1	0	-1	90	290
X7	0	0	0	0	0	0	0	0	0	0	0	1	130	130
													Z	11830
Zj	8	10	16	9	14	13	16	1.45	5.36	12.36	1.64	1.36	0	-3
Cj-Zj	0	0	0	0	0	0	0	-1.45	-5.36	-12.36	-1.64	-1.36	0	3

The result for the tank top is 140 garments, for the short sleeve blouse is 120, for the long sleeve blouse is 80, the basic boxer is 140, for the Fajilla is 80, Scarleth blouse is 290 and for the boxer with designs is 130.

V. CONCLUSIONS.

In this research paper a linear programming model was developed, using the revised simplex model in an Excel spreadsheet. Several visits were made to a textile SME to record data pertaining to each one of its manufacturing steps. Time cycle, inputs and demand constraints were implemented in each step. A gain of $11,830.00 MXN was obtained in the process. In the model there was no consideration of the quality control process. The simplicity of the revised simplex model allows to work in Excel spreadsheets, with the added portability in other economical activities. The results allowed the enterprise to take better decisions in the assignation of order priorities. Future works will design a neural network to predict the demand of its main products.

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