

Profit Maximization through Product Mix Management in Argentinean SME¹

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Abstract: Companies usually participate in diverse markets with different product lines, which -sometimes- are very similar and based on kindred production technologies, but -in other cases and because of their diversification- all these structures are very different. Thus, every product integrates a portion in the total production and sales mix, providing distinct benefits due to their dissimilar costs and prices. In this way, multi-producer companies face important challenges while determining the optimal product quantity to be manufactured and sold that, in the total sum, provide the maximum profit to their shareholders. Moreover, it becomes necessary to consider that there are market, technological, financial, productive, and logistic conditions which limit the participation of each product within the total mix.

It was performed a bibliographical review, complemented by a field work.

The hypothesis of this investigation -which was corroborated- indicates that it is possible to maximize profits through product mix management in Argentinean multi-production SME, understanding and applying properly simple concepts like the linear programming method. It provides SME's executives the possibility to find the optimal mix that magnifies the firm's economic outcomes.

The methodology used was quali-quantitative, with a qualitative predominance. The research design was non-experimental -as variables were not operationalized- and transversal, as the information was obtained at a given moment in time.

Keywords: Marginal Contribution; Profit Maximization; Product Mix Management; SME, Production; Manufacturing; Sales; Cost; Linear Programming.

Date of Submission: 08-11-2019

Date of Acceptance: 23-11-2019

I. Introduction

Multi-production companies face the challenge of demanding global markets and make them compatible with profit maximization for their shareholders. Specifically, Giménez et al. (2015) state that -in these firms- the search for profit maximization through product mix will not be achieved with the products that contribute with the highest margin per unit, but with those that register the highest benefit per unit of the limiting or critical factor.

In addition and in order to maximize profits, Horngren et al. (2012), indicate that companies must take into account certain restrictions, such as capacity and demand when determining the product mix to be manufactured and sold.

Muñoz-Negrón (2017) suggests that -in cases of multi-production, without commercial or technical conditioning- each product will be independent from others in terms of access to markets and the possibility of being produced. But, when there are technical and/or commercial conditions it is necessary to know the Marginal Contribution (MC) per unit of the scarcest factor in order to determine the mix that optimizes the total MC.

The hypothesis of this study indicates that it is possible to maximize profits through product mix management in Argentinean multi-production SME, understanding and applying properly simple mathematical concepts. Specifically, it is pointed out that the implementation of the Linear Programming (LP) method provides SME's executives the possibility to find the optimal mix that magnifies the firm's economic outcomes.

The objective of this study is to deepen in profits maximization in Argentinean multi-producer SME, considering the product mix management and proposing simple ideas in order to achieve the maximum MC.

The following questions have allowed guiding the present work:

- What is the indicator that best weighs a product within a mix of products?

¹ SME: Small & Medium Enterprises.

- What methods can be applied in order to achieve the optimal production and sales mix that maximizes profits in SME?
- In the sense of what is being analyzed, are there simple tools that could be implemented in Argentinean SME?

1.1 Research Methodology

The study is exploratory descriptive, with a quali-quantitative methodology, but with a qualitative predominance.

The design of the research is non-experimental, due to the non-operationalization of variables, and - within this type of designs- it is transversal, as the information was gathered at a given moment in time.

The analysis unit refers to profit maximization through product mix management in Argentinean multi-production SME.

Information was obtained from relevant secondary sources; authors and prestigious specialists who studied the composition of the optimal production and sales mix in all types of organizations. In order to widen the analysis, it was done also a field work in an Argentinean SME in order to test linear programming when maximizing profits through the production and sales mix.

The research was developed during the period February 2018 – May 2019, in Buenos Aires, Argentina.

1.2 Limitations / Clarifications of this study

It is pointed out that -throughout the present study- the following limitations/ clarifications have been observed:

- The disciplines that are part of this work refer to costs' management and operations. It was observed a scarce bibliography that emerged from product optimization models and methods related to SME and - especially- for Argentina, although the tools found are applicable to this type of companies as well as to large firms.
- The data collection techniques used and the cited authors are those that had been judged opportune to support the present study.
- The final conclusions are based on the elements that were analyzed and detailed in this investigation.

In spite of the foregoing, the mentioned limitations/clarifications have not become an impediment to carry out the present investigation and achieving satisfactory results.

II. Theoretical Framework: Product Mix And Profit Maximization

The purpose of this section is to present a technical-theoretical frame for this investigation. In this sense, the contribution of Hernández Sampieri et al. (2010) is appropriate when they indicate that the theoretical perspective provides a vision of where the proposed approach lies within the field of knowledge.

Also, it will be analyzed the cost accounting and operations disciplines contributions with respect to existing methods that maximize profits when there are multiple combinations of products, and where each of them have limitations in their manufacturing and restrictions in terms of satisfying market demand.

Cost Systems' analysis

According to Cárdenas-Nápoles (2016) and from the accounting point of view, the result of a sale represents a profit if what is obtained exceeds its costs. Therefore, it is reasonable to sell at higher prices than the sum of the sacrifices necessary to make such a sale. In turn, the author suggests that the costs incurred can be classified as fixed and variable, as follows:

- Variable Costs (VC) are those that have a directly proportional behavior when there are changes in the volume of production; i.e.: labor and electric power.
- Fixed Costs (FC) are those that do not show variations when changes in production levels exist. That is, without production or with capacity overutilization, they remain unchanged; i.e.: linear method amortizations, the surveillance staff and the rent of the plant. It is necessary not to consider this understanding in absolute terms since -with major changes- they do vary; for instance, when expanding the plant machinery.

In addition, the author indicates that costs classification, in variables and fixed, gives rise to two costing models:

- The Direct Costing (DC): determines the cost of a product, assigning only the VC, where the result of the sale (MC) must reach to cover the total of FC and provide a profit. This system is used for internal management purposes.
- The Full Costing or Absorption Costing: the cost of a product includes the VC and the fixed production costs. The result of a sale will give rise to a gross profit that must be reached to cover the administration and sales expenses of the period and provide a profit. This system is useful when showing results to third parties.

In the following Figure, it is observed the structure that each costing system causes in the Income Statement:

Direct Costing	Absorption Costing
Sales	Sales
- Variable costs	- Variable costs and fixed production costs
= Contribution Margin	= Gross profit
- Fixed costs	- Administration expenses and selling expenses
= Profit	= Profit

Figure 1 – Costing systems and Income Statement

Source: Own

In connection with the above, Ostengo (2014) says that the direct costing system is very useful, specially when making or buying certain parts or products; decisions that involve price changes and discounts; elimination of products; product mix design; capital investments and -in addition- when determining inventory levels. The preference for direct costing results from MC calculation; it is a figure that reflects the true products' profitability. In other words, represents the remaining income once the VC are covered.

Additionally, Giménez et al. (2015) insist that direct costing establishes a difference between the costs directly attributable to an operation and those that correspond to the company structure. The former are only used to value manufactured products, whether if they go to inventories or directly to the sales cost. The cost structure is sent to the Income Statement of the period regardless the existence of sales or not. On the other hand, absorption costing is characterized by allocating all costs that are involved with production, including FC related to manufacturing.

For Morales-Bañuelos et al. (2018) the direct costing has an advantage that consists in costing the products at the true value of what each one of them consumes directly, without distortions caused by the arbitrary assignment of the FC. In this way, the result of each sale provides a MC which will be used -first- to cover the FC and -then- as a benefit for the company. They indicate that direct costing model is an essential tool for decision making.

In contrast, Amat-Salas & Soldevilla-García (2018) explain that in order to avoid the arbitrary allocation of FC when these can be perfectly assigned to the development of a line or type of product -as in the case of a rented machine- this should be considered in direct costing as product cost because it is an avoidable item. From this point of view, there is no distortion of the unit MC since the assigned FC are those that are directly related to the production line. The authors call it an advanced direct costing system, in which it is considered the product costs, the VC plus the FC perfectly identifiable with the product.

According to the information provided by Cárdenas-Nápoles (2016), Ostengo (2014), Giménez et al. (2015) and Morales-Bañuelos et al. (2018) it can be concluded that direct costing represents a model applicable to managerial decision making that allows a better comparison between products or production lines through the MC; it arises from costing the products at the true value of what each one of them consumes in a direct way, without distortions caused by the arbitrary allocation of FC.

Moreover, Amat-Salas & Soldevilla-García (2018) suggest an advanced direct costing system that considers the FC perfectly identifiable with the production line or product, but when those FC are not incurred in the manufacturing of such product is suppress.

In the following Figure, are shown the main differences of the costing systems analyzed above:

Direct Costing	Absorption Costing
All variable costs are included in the value of the inventories	All production costs are considered inventoriables
Variable production costs are part of the cost of the product	All production costs are product costs
Fixed costs are considered costs of the period	Administration expenses and sales expenses are considered costs of the period
The income statement is prepared for internal purposes (management)	The income statement is prepared for external use
The marginal contribution is correlated with the sale and is not affected by the level of production	Gross profit is affected by production
Profit is high when sales exceed production	Profit is high when production exceeds sales

Figure 2 – Comparison between costing systems

Source: Own

Marginal Contribution (MC)

It has been previously said that the MC represents the measurement unit that best reflects the comparison between products or production lines.

Ostengo (2014) indicates that cost accounting recurs to other areas and sciences in order to maximize benefits. Thus, this discipline has used concepts developed and studied by economic sciences such as "marginal or incremental", which establishes the relevant amount of income, costs and benefits that have a direct relationship with a decision, and expresses the difference between what would happen if a certain course of action was undertaken or if another was followed. In this way and in cost accounting, the use of MC is considered and shows the increase in total benefits for each additional unit of product sold.

For a correct understanding, Horngren et al. (2012) indicate that it is necessary to consider the following common sense arithmetic approach: each unit sold causes a unitary MC or marginal revenue that turns out to be the unit sale price minus the unit VC.

Products with the highest MC

Giménez et al. (2015) suggests that -for the determination of a products' ranking according to their highest MC- it becomes necessary to know the unitary MC of the limiting factor in order to make possible a comparison between each unit, giving the following example:

In company X, there are two products (A and B) that provide unit MC of \$ 400 and \$ 200, respectively. The above is not enough to affirm that product A is more convenient than product B because 4 hours of plant work are needed to obtain article A, and only one plant hour is enough to obtain product B. Product B, for equal manufacturing time, provides a unit MC of \$ 200; ergo, B is more convenient than A. According to the above, it can be perceived that the unitary MC by scarce factor -in this case the hours of activity- is that element to which the unitary contribution must be allocated for the purpose of making a products' comparison and obtaining valid conclusions for decision making.

The author explains that -in certain circumstances- other products must be accepted that are not necessarily those of better MC by scarce factor, and that it has nothing to do with one's own desires, but with market tendencies. In such case, it is probable that the market does not absorb the total production of the item with the highest contribution per scarce factor and, consequently, the company must limit and choose the best possible mix or combination.

In accordance with what was exposed in the present section, it is concluded that:

- The MC shows the total benefits increase for each additional unit of product sold.
- The highest product MC turns out to be the one with the greatest MC per scarcest or limiting factor.

Product mix and limiting or critical factor

Multi-producer companies face challenges while searching the optimum quantity of each manufactured and sold product that, in the total amount, generates the maximum profit.

In this regard, Muñoz-Negrón (2017) states that:

- Multiple production firms without commercial or technical conditioning between each other, every product will be independent of the others in terms of their access to markets and the possibility of being produced. But, when there are technical and/or commercial conditions, such as market, capacity, input supplies, installed energy, labor availability and working capital there will be -among them- a scarcer resource that will condition -in the first place- the production level; in other words, it will be the key factor. In this case, it will be necessary to know the scarcer factor's MC per unit in order to determine the optimum MC mix.
- The procedure that should be used to achieve the optimum mix is to dedicate as much as possible of the product with the highest MC per unit of the scarcer factor up to the limit absorbed by the market, and then to allocate the remaining capacity to the second product of greater MC per unit of the scarcer factor, also up to the limit of absorption of the market and -thus- successively with the rest of the products until, if possible, exhaust the total capacity. In this way, a ranking -ordered from highest to lowest products- will be made, according to their MC per unit of the scarcest factor.
- In cases where there are multiple restrictions, it is pointed out that the principles applied previously would be the same, with the only exception that it would be necessary to identify and evaluate which restrictions determine the optimum mix and -simply- determine the intersection between the two straights that act as conditioning factors. In this sense, Linear Programming (LP) application becomes necessary in order to solve the mix problem.

In this regard, Giménez et al. (2015) insist that in cases of multi-production companies, the search for the product mix that maximizes profits will not be achieved with the products that provide the highest MC per unit, but with those that register the highest MC per highest unit of the limiting or critical factor. In addition, indicate that multi-production companies, in the search to maximize their profits, must consider that there are technological, financial, productive, logistical and market conditions that limit the mix. In this case, LP becomes an applicable model to these firms. It takes into account the different critical factors, allowing to find the maximum product mix benefit.

Moreover, Horngren, Datar & Rajan (2012) suggest that -in order to maximize profits with the product mix to be manufactured and sell- companies must consider certain restrictions, such as capacity and demand. In this case, the MC will be used and not the net profit of each product, considering that the only costs that change are those that are variable with respect to the number of units produced and sold.

Coinciding with Giménez and when there are multiple restrictions, the authors explain that optimization techniques, such as LP, help to solve complex problems that can be found in different companies.

Introduction to Linear Programming (LP)

Horngren, Datar & Rajan (2012) point out that the LP technique is used when multiple constraints are present in the analysis. The approaches or models that exist for only two objective variables are trial and error, and graphical solution.

Trial and error approach

According to Horngren, Datar & Rajan (2012), the present approach works with the coordinates of the feasible solutions corners area. It allows finding the optimal solution by means of a trial and error mechanism, which can be seen in the following process:

$$2X + 5Y = 600 \quad (1)$$

$$1X + 0.5Y = 120 \quad (2)$$

Multiplying (2) por 2:

$$2X + Y = 240 \quad (3)$$

Subtracting (3) from (1):

$$4Y = 360$$

Therefore,

$$Y = 360 / 4 = 90$$

Substituting Y in (2):

$$1X + 0.5 (90) = 120$$

$$X = 120 - 45 = 75$$

When X = 75, Y = 90, Total CM = \$ 51.750

Graphic approach

Continuing with the example of the previous section, Taha (2012) and Hiller & Lieberman (2010) suggest that the graphic solution can be solved in the following way:

1. Determine the space of possible solutions, where it is necessary to consider the non-negativity constraints $X > 0$ and $Y > 0$, which limit the variables to the first quadrant (on the X axis and to the right of the Y axis). To graph the rest of the constraints, it is needed first to substitute each inequality with an equation, and then draw the resulting straight line by locating two different points, replacing $X = 0$ and then $Y = 0$ in that

equation. In this way, a polygon will be obtained, represented in this case, by the points ABCDE that are illustrated in the following table, which encloses the space of feasible solutions.

2. Determine the optimal solution within the solution space. Consequently, a systematic procedure is required, where -in the first place- the direction in which the utility function $z = \$ 240X + \$ 375Y$ is increased, it will be achieved by assigning arbitrary increasing values to Z. For example, $Z = \$ 27,500 = \text{line } i$, $Z = \$ 51,750 = \text{line } j$, which would be equivalent to drawing two lines that identify the direction in which Z increases. The optimal solution occurs at point C, the point in the solution space beyond which any additional increment will result in an unfeasible solution. The solution $X = 75$ and $Y = 90$ with $Z = 75 * 240 + 90 * 375 = 51.750$, is always associated with a corner point, even if the objective function is parallel to a restriction. In that case, it will be said that the optimal solution occurs at any point in the segment that represent two corner points.

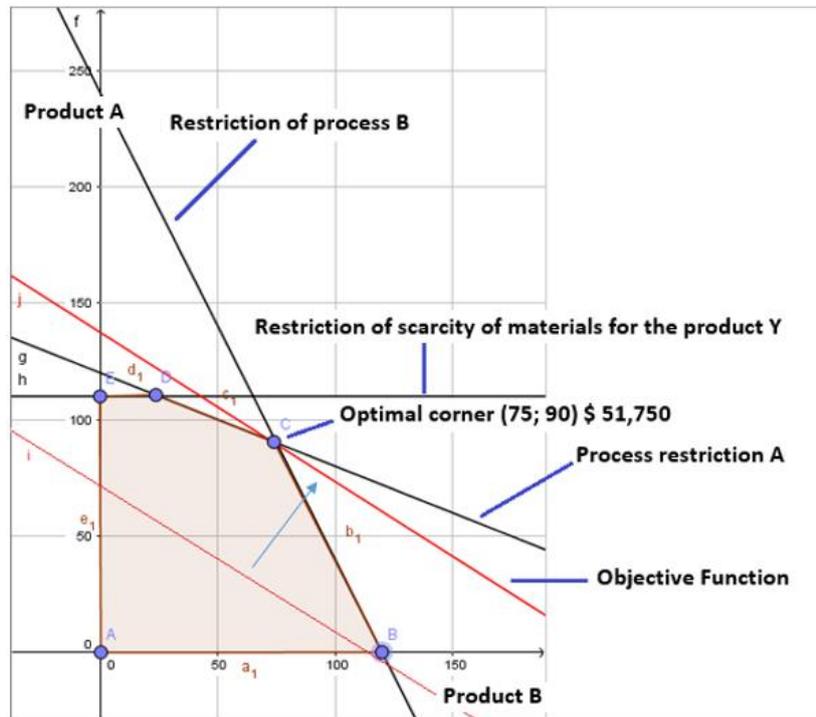


Figure 3 – Linear programming: graphic solution
 Source: Own, adapted from Horngren, Datar & Rajan (2012)

In this sense, Taha (2012) indicates that LP consists of three basic components:

1. The decision variables that are intended to determine.
2. The objective that are needed to maximize or minimize.
3. The restrictions that the solution must satisfy.

Also, the author says that -in search for the optimal solution- it is necessary to determine the space of feasible solutions and then find the point in that space that provides a maximization or minimization.

The simplex algorithm

In the case of working with more than two variables, the simplex algorithm² or software that facilitates resolution should be used. The procedure consists of the following three steps:

- Step 1: Determine the objective function. It expresses the goal or goal that seeks to maximize or minimize. The objective is to find the product mix that maximizes the total MC. The FC remain the same - regardless the product mix- and are irrelevant. When there are two products X and Y, and their unit MC are \$ 240 and \$ 375 respectively, the linear function that will express the objective for the total MC will be the following: Total MC = \$ 240X + \$ 375Y = objective function.
- Step 2: Specify the restrictions. Following the example of X and Y in Step 1, there will be capacity restrictions for each product. It will be assumed then, that each product must comply with two different

² The Simplex Method is an iterative method that allows improving the solution in each step. For further details, consult Taha (2012).

processes. In process A product X requires 2 machine hours per unit manufactured and product Y, requires 5 machine hours per unit manufactured. In process B, product X requires 1 machine-hour per manufactured unit and product Y requires 0.5 machine-hours per unit manufactured. In process A, there are 600 machine hours and in process B, 120 machine hours. In addition, there is a restriction of scarcity of materials for the product Y of 110 product units. The present case does not have restrictions regarding the demand of each product, if they exist, they would be considered in the calculation in the same way as the rest of the restrictions. The following linear inequalities express the relationships of the present example:

- Process A restriction $2X + 5Y \leq 60$
- Process B restriction $1X + 0.5Y \leq 120$
- Material shortage restriction for product Y materials $Y \leq 110$
- Negative production is impossible $X \geq 0, Y \geq 0$

• Step 3: Calculate the optimal solution using the models mentioned above.

LP Solution with Excel Solver

According to Taha (2012), in practice, the cases in which LP can be applied involve working with multiple variables and restrictions, with the computer being the only viable means to solve this type of problem. The author indicates that there are two commonly used software systems: Excel Solver and AMPL. Solver is particularly attractive to users of spreadsheets and does not require a high degree of knowledge in terms of language, such as AMPL and similar languages. The following Table shows the data distribution for the example that has been developed in the previous sections. At the top of the spreadsheet, four types of information are included:

1. Cells to enter data (B5: C8 and F6: F8);
2. Cells representing the variables and the objective function (B13: D13);
3. Algebraic definitions of the objective function and the left side of the constraints (cells D5: D8),
4. Cells that provide explanatory names and symbols. This fourth type, improves readability, although it is not necessary to run the tool.

	Algebraic expression	Formula	Entry into the cell
Objective Z	$240X + 375Y$	$=B5*\$B\$13+C5*\$C\13	D5
Restriction 1	$2X + 5Y$	$=B6*\$B\$13+C6*\$C\13	D6
Restriction 2	$X + 0,5Y$	$=B7*\$B\$13+C7*\$C\13	D7
Restriction 3	Y	$=B8*\$B\$13+C8*\$C\13	D8

	A	B	C	D	E	F
1						
2	Data entry:					
3						
4		X	Y	Totals		Limits
5	Objective	240	375	51750		
6	Restriction 1	2	5	600	<=	600
7	Restriction 2	1	0,5	120	<=	120
8	Restriction 3	0	1	90	<=	110
9		>=0	>=0			
10						
11	Results:					
12		X	Y	Z		
13	Solution	75	90	51750		
14						

Figure 4 – Data entry in Excel Solver
 Source: Own, adapted from Taha (2012)

Continuing with the procedure, Taha indicates that -to link the Solver complement with the data of the spreadsheet - the following procedure must be followed:

- a) Enter the objective function and the left side of the restrictions using the input data: (B5: C8 and F6: F8), as well as the objective function and variables (B13: D13).

b) The resulting formulas will be placed appropriately in (D5: D8). To start the process, you must select the Solver plug-in from the toolbar and enter the data as shown in the following table:

- a) Objective Set: \$ D5 \$
- b) To: Max.
- c) By changing variable cells: \$ B \$ 13: \$ C \$ 13

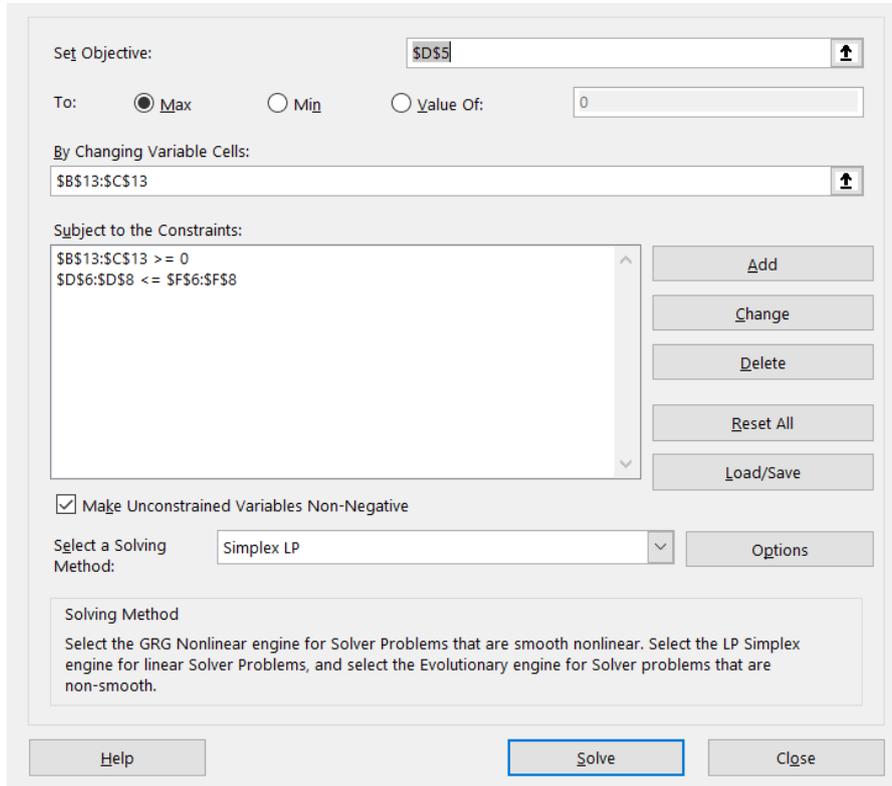


Figure 5 – Solver configuration
Source: Own, adapted from Taha (2012)

a) The restrictions of the problem will be entered, selecting Add in Table nº 5, where the system will show in next data entry that is displayed in the following Table, where will be entered the case restrictions, as follows:

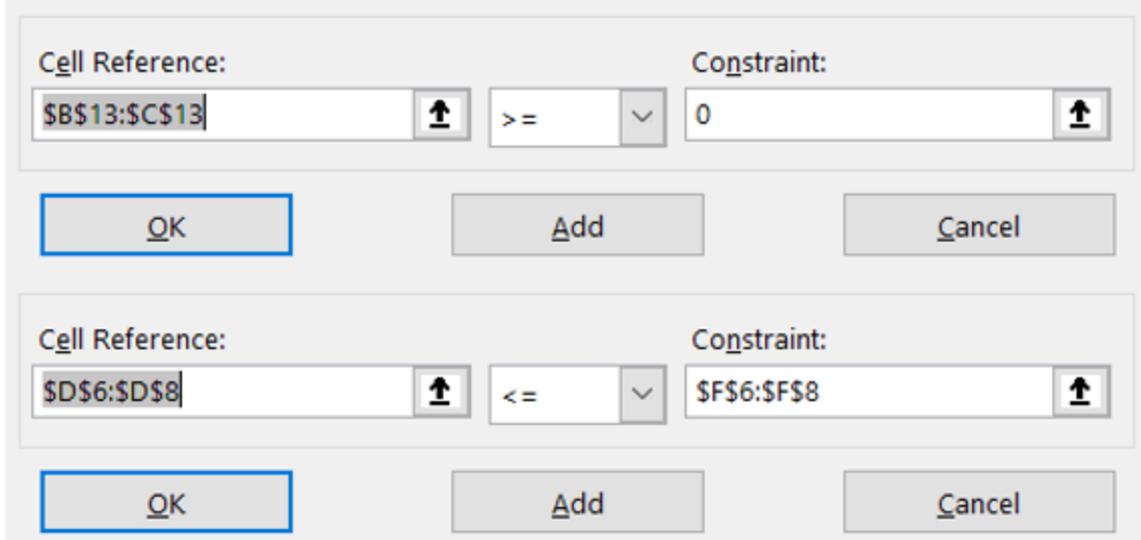


Figure 6 – Restrictions
Source: Own, adapted from Taha (2012)

b) Finally, it will be indicated to the application to solve the problem by clicking on solve of Table 5. The optimal solution found is equal to X = 75, Y = 90 and Z = 51,750.

The following Table summarizes the LP techniques analyzed above:

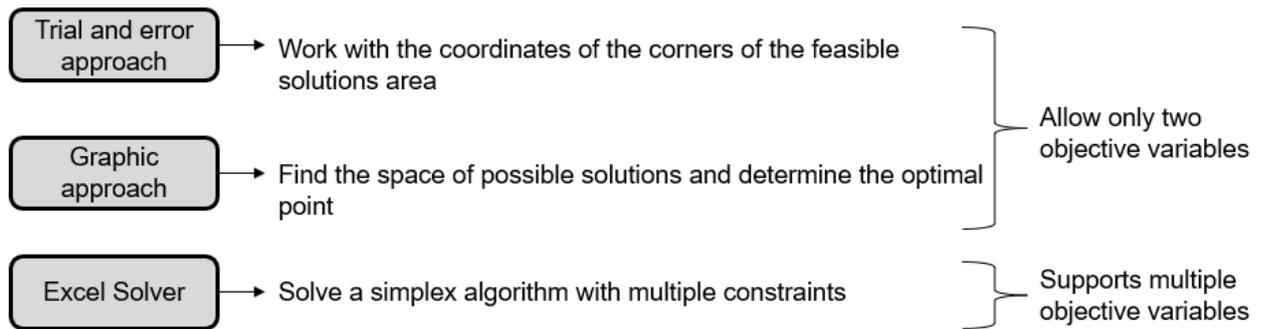


Figure 7 – Linear programming

Source: Own

According to the above, it is possible to conclude that it is found an agreement between the different authors analyzed, as they suggest that -in terms of obtaining the product mix that maximizes the MC, when there are technical / commercial constraints- it is necessary to know the MC per unit of the scarcest resource and, when multiple constraints are present, it becomes important to use the LP method.

Sensitivity analysis of the optimal mix

In this section, it will be performed an analysis to detect how sensitive the optimal product mix is, given changes in variables and/or restrictions.

According to Taha (2012) the optimal product mix -determined by the LP method application- may suffer variations in their parameters within certain limits, without affecting the optimum quantity of products. The causes are originated in one of the following reasons:

- The optimal solution sensitivity to changes in resources' availability, the right side of restrictions.
- The optimal solution sensitivity to changes in the MC, coefficients of the objective function.

On the other hand, Giménez et al. (2015) indicate that it is useful for those who have to decide the production plan to have information that allows them to know that as long as the variations remain within a certain range, they should not modify their decision about how much of each product it should be manufactured, since -although it may suffer variations- the MC will be the maximum that can be achieved. In other words, the range of admissible variation for the different coefficients of the problem is determined, in which the current solution -quantities of each product in the mix - remains feasible and optimal.

According to Hiller & Lieberman (2010), in LP it is assumed that the parameters used are known constants. In reality, these parameters arise from estimates based on a prediction of future conditions. Frequently, the parameters of the original formulation may only represent the opinion provided by line personnel. The data may be optimistic or pessimistic, but -in general- they are estimates that protect the estimators' interests. Consequently, it is reasonable to consider the original data as a starting point for the subsequent problem analysis, and an optimal solution does not become a reliable solution for the action until it corroborates its behavior.

For these reasons, the authors indicate that it is important to carry out a sensitivity analysis to investigate what causes the parameters' variations in the optimal production mix, highlighting that there are parameters to which can be assigned any value without affecting the optimal mix. However, there are also parameters with probable values that cause a new optimal mix.

Sensitivity analysis solution with Excel Solver 2010

Continuing with the contribution of Hiller & Lieberman (2010), they argue that the spreadsheets provide a relatively direct alternative which allows a sensitivity analysis without the simplex algorithm manual calculation. In this sense, one of its great strengths is the feasibility with which it can be used interactively to perform various types of analysis.

Next, it is considered the case study of the previous section in which the optimal solution is given by X = 75, Y = 90 and Z = 51.750, to which the sensitivity analysis will be added as follows:

- The following dialog box opens when Solver is instructed to solve the problem. In it, the Sensitivity option will be selected and then the Accept one:

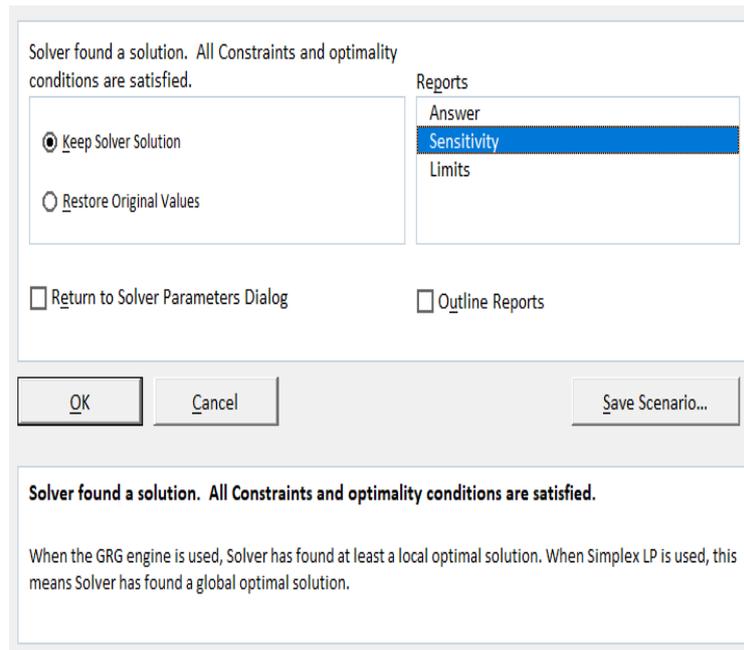


Figure 8 – Solver Dialog box

Source: Own, adapted from Hiller y Lieberman (2010)

• Next, the Excel generates a sensitivity report which is observed in the following Table, with the following information:

- How much the MC of the objective function can vary without affecting the composition of the mix?
- Is the amount used of each restriction the optimal mix?
- How much the CM varies when one unit of each restriction increases?
- How much the amounts of the restrictions can increase or decrease without affecting the shadow price³?

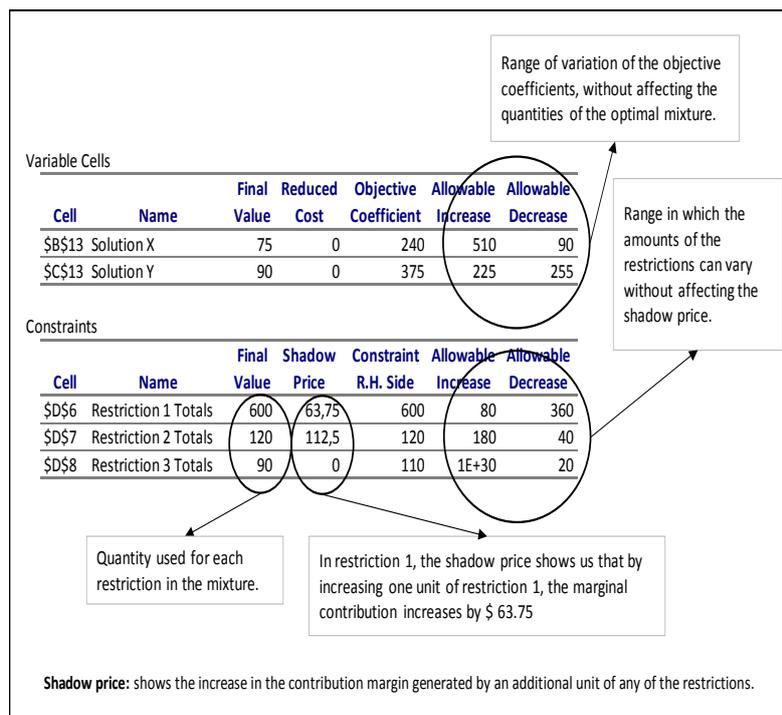


Figure 9 – Sensitivity Report

Source: Own, adapted from Hiller y Lieberman (2010)

³ The shadow price shows the increase in the CM generated by an additional unit of some of the restrictions.

In agreement with what it was said in this section, it is concluded that the different authors express the importance of the sensitivity analysis as an indicator that allows knowing the range in which the variables or restrictions can undergo variations, without altering the composition of the optimal product mix.

On the other hand, it is worth mentioning the contribution of Hiller & Lieberman (2010) on the analysis' importance because the changes tend to be dynamic in a company. As a consequence, it is a useful tool to plan the mix modifications, taking into consideration capacity, input's availability or market demand variations.

Application cases

This section is aimed to mention and analyze companies that have implemented the LP method in their daily operation. As will be seen, this method is not confined to large companies; it is applicable to SME, too. In this sense, Ortiz-Triana & Caicedo-Rolón (2012) explain that in a soft drinks bottling plant –located in the city of San José de Cúcuta, Colombia- there were observed production capacity restrictions for which it was applied the LP technique. As a result, it was obtained an optimal product mix production quantity and its production sequencing, obtaining greater operational profits. Additionally, Ortiz-Triana & Caicedo-Rolón (2014) say that in a small footwear production firm -that manufactured products for girls and women, located in the same city- it was possible to optimize profits through the product mix management applying the LP method, too.

Finally and in agreement with Gonzáles, Zamudio & Rojas (2016), a Mexican company -that manufactures lighting products-, implemented a LP system in high demand and limited production capacity conditions, considering market size, availability of raw materials and production capacity restrictions. It was obtained an advantageous product mix result.

Conclusion

Starting from the direct costing method, it should be maximized the MC. Therefore, the search for the adequate product mix that magnifies profits will be the one that provides the maximum MC.

However, it is wrong to prioritize the products considering only their MC; it is necessary to know the MC per unit of the scarcest resource.

Consequently, the method that allows obtaining the optimal product mix -when there are multiple restrictions and variables- is the LP, both in SME and in large companies.

III. Field Work: Applicability Of The Lp Method In An Argentinean Sme

In this section, it will be carried out the LP method application to an Argentinean SME⁴, producer of toilet paper and kitchen paper rolls, both in different sizes and versions. The company had a system in which the production and sales mix was determined empirically, so this situation prevented from achieving optimal levels of profits through the product mix.

Taking into account this inconvenience, it was proposed the LP method implementation that could optimize the production level and had an impact on its profits. The next steps were established and followed:

- Decision variables identification: they were represented by the range of products that the company offered to the market.
- Objective function determination: Regarding this point, it was necessary to establish the unit MC of each of the units sailed, information provided by the company's Cost Specialist.
- System restrictions identification: The investigation process disclosed different restrictions, such us production capacity, market demand and daily delivery capacity. The availability of raw materials and labor did not represent a restriction because the company had -on one hand- the possibility of increasing the amount of raw material purchased and -on the other hand- that of contracting more employees, in case of increases in production levels.

⁴ For confidentiality reasons, the studied SME will not be named.

As a summary, the following Table shows the data that was necessary for the LP model application:

PRODUCT	KIND	SHEET	FOOTAGE / CLOTHS	CODE	MARGINAL CONTRIBUTION	M3 PER UNIT	MINUTES PER MACHINE	MARKET DEMAND
Toilet Paper	White	Double sheet	Low footage	TP - W - DS - LF	\$ 99,30	0,0715	0,1680	13.513
Toilet Paper	White	Simple sheet	High footage	TP - W - SS - HF	\$ 106,36	0,0812	0,3520	75.013
Toilet Paper	White	Simple sheet	Low footage	TP - W - SS - LF	\$ 54,87	0,0695	0,1260	190.452
Toilet Paper	Decorated	Double sheet	High footage	TP - D - DS - HF	\$ 80,17	0,0864	0,3920	3.152
Toilet Paper	Decorated	Double sheet	High cloths	TP - D - DS - HC	\$ 36,84	0,0691	0,2016	24.315
Toilet Paper	Decorated	Double sheet	Low footage	TP - D - DS - LF	\$ 97,86	0,0700	0,2016	15.208
Toilet Paper	Decorated	Simple sheet	High footage	TP - D - SS - HF	\$ 93,21	0,0640	0,2100	5.174
Toilet Paper	Decorated	Simple sheet	Low footage	TP - D - SS - LF	\$ 94,33	0,0691	0,1680	13.187
Paper Towel	White	Simple sheet	High cloths	PT - W - SS - HC	\$ 31,67	0,0691	0,2064	49.312
Paper Towel	White	Double sheet	High cloths	PT - W - DS - HC	\$ 54,08	0,0779	0,2360	23.768
Paper Towel	White	Simple sheet	Low cloths	PT - W - SS - LC	\$ 44,30	0,0775	0,1596	270.488
Paper Towel	Decorated	Simple sheet	High cloths	PT - D - SS - HC	\$ 57,94	0,0691	0,2188	12.500
Paper Towel	Decorated	Double sheet	High cloths	PT - D - DS - HC	\$ 58,96	0,0751	0,2502	26.842
Paper Towel	Decorated	Simple sheet	Low cloths	PT - D - SS - LC	\$ 49,11	0,0783	0,1692	102.198

Figure 10 – Argentinean SME data

Source: Own

In regard to maximum capacities, the factory had three conversion lines that worked 30 days a month, 24 hours a day, totaling 129,600 minutes a month. The delivery capacity per month amounted to 52,351 cubic meters, considering -for each of the products- the cubic capacity occupied by a bag (a sales unit).

As for the unitary MC and in order to solve the freight problem due to the different destinations and the problem of discounts driven by the classification of customers, a weighted average of both concepts and for each unit was carried out. Then, it was assigned to the VC by product in order that the MC includes the final benefit that each product would provide.

Finally, while determining the demand and making an adequate calculation it was considered the average demand of the last 6 months, increasing or decreasing the resulting values according to the variations in sales that the company estimated in the short term.

Optimum mix determination

In search for the product mix that provided the maximum profit, it was used Excel Solver 2010 (see calculation in APPENDIX I) in accordance with the provisions made in the Theoretical Framework of the present investigation. It should be noted that such a computer tool was simple to be operated, allowing to obtain the quantity that each product unit should contain within the mix, and to produce the maximum total MC.

In order to compare the outcomes that the LP model showed with prior company results, the following Table shows the variations in each product quantities and the difference between the total MC corresponding to the two scenarios, giving -as a result- an optimal mix that provided a greater total MC with a lower quantity of products sold:

CODE OF PRODUCT	UNITARY MARGINAL CONTRIBUTION	SITUATION BEFORE THE ANALYSIS		SITUATION AFTER THE ANALYSIS	
		AMOUNT OF UNITS SOLD	TOTAL MARGINAL CONTRIBUTION	AMOUNT OF UNITS SOLD	TOTAL MARGINAL CONTRIBUTION
TP - W - DS - LF	\$ 99,30	13.513	\$ 1.341.805	13.513	\$ 1.341.805
TP - W - SS - HF	\$ 106,36	62.659	\$ 6.664.379	75.013	\$ 7.978.336
TP - W - SS - LF	\$ 54,87	184.831	\$ 10.140.971	190.452	\$ 10.449.374
TP - D - DS - HF	\$ 80,17	3.152	\$ 252.696	3.152	\$ 252.696
TP - D - DS - HC	\$ 36,84	15.352	\$ 565.549	0	\$ -
TP - D - DS - LF	\$ 97,86	15.208	\$ 1.488.276	15.208	\$ 1.488.276
TP - D - SS - HF	\$ 93,21	5.174	\$ 482.327	5.174	\$ 482.327
TP - D - SS - LF	\$ 94,33	13.187	\$ 1.243.870	13.187	\$ 1.243.870
PT - W - SS - HC	\$ 31,67	45.126	\$ 1.429.140	0	\$ -
PT - W - DS - HC	\$ 54,08	23.768	\$ 1.285.346	23.768	\$ 1.285.346
PT - W - SS - LC	\$ 44,30	180.711	\$ 8.005.113	215.943	\$ 9.565.817
PT - D - SS - HC	\$ 57,94	12.500	\$ 724.285	12.500	\$ 724.285
PT - D - DS - HC	\$ 58,96	26.842	\$ 1.582.685	26.842	\$ 1.582.685
PT - D - SS - LC	\$ 49,11	102.198	\$ 5.018.699	102.198	\$ 5.018.699
TOTALS		704.221	\$ 40.225.141	696.950	\$ 41.413.515

Figure 11 – Linear programming outcomes

Source: Own

Optimum mix sensitivity analysis

Thanks to the sensitivity analysis of Excel Solver 2010 it was obtained the optimal product mix that magnified profits, and having –afterwards- a report that is shown in the next Table, in which it is highlighted the following information:

- How much the MC of the objective function can vary without affecting the mix composition?
- How much of each restriction is used in the optimal mix?
- How much varies the MC when one unit of each restriction increases?
- How much it is possible to increase or decrease the amounts of the restrictions, without affecting the shadow price?

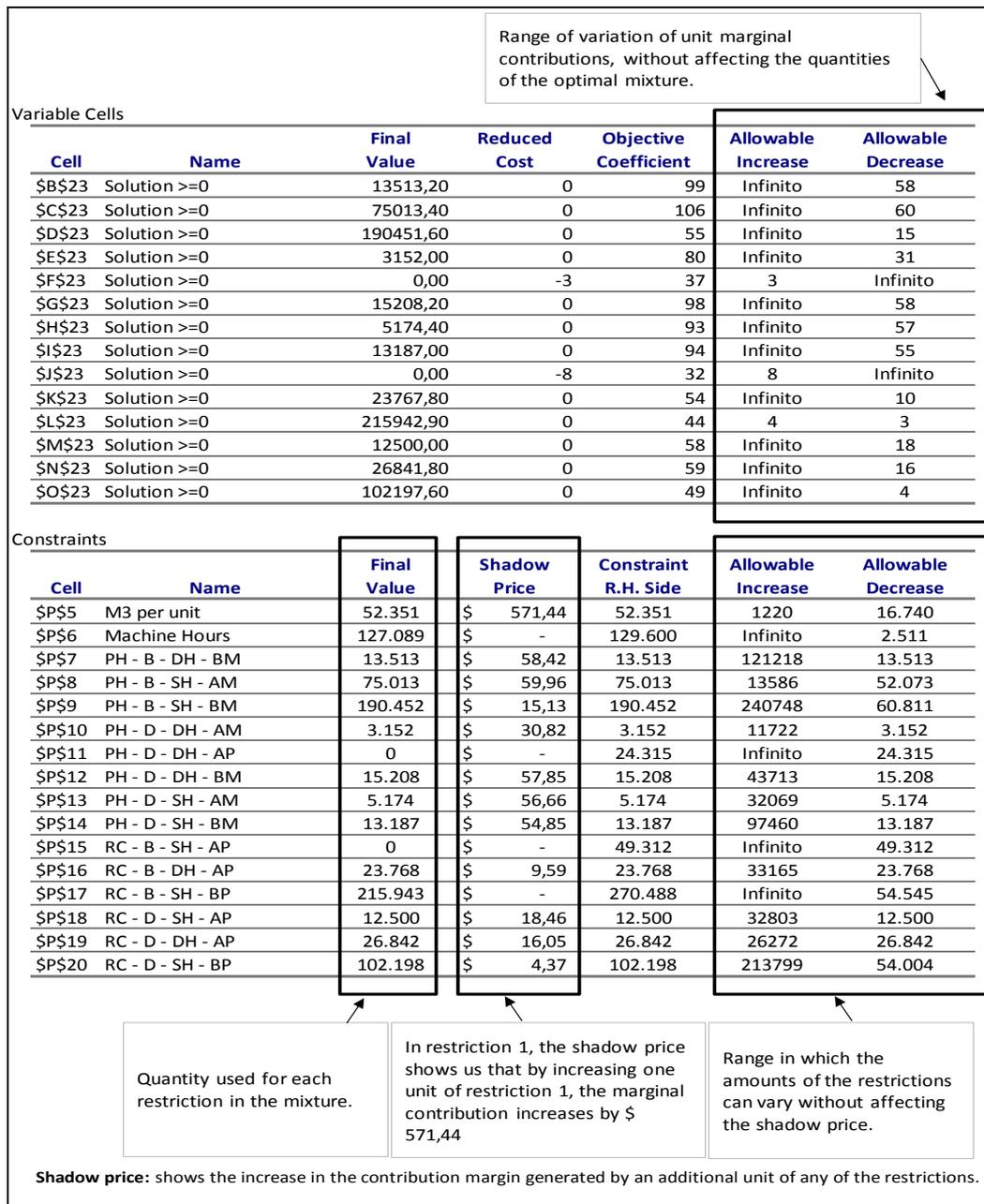


Figure 12 – Sensitivity analysis
Source: Own

IV. Conclusion

For what was analyzed in the present work, the following final considerations are raised:

- According to the direct costing method, the MC should be maximized. Therefore, the product mix should prioritize those that have the highest MC per unit of the scarcest resource.

- LP represents a mathematical model that solves the product mix problem -both in SMEs and in large companies- whatever the quantities of the restrictions and the target variables may be. In addition, it was demonstrated -applying the method in an Argentinean SME- that there is not a huge difficulty if this method is utilized; although being a complex algorithm it is possible to be solved with ease, using the Solver complement of Excel 2010.

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APPENDIX I
Linear programming calculation

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	
1																				
2	Data entry in Excel:																			
3																				
4	Objective	\$99,30	\$106,36	\$54,87	\$80,17	\$36,84	\$97,86	\$93,21	\$94,33	\$31,67	\$54,08	\$44,30	\$57,94	\$58,96	\$49,11	Totals	\$	-		
5	M3 per unit	0,0715	0,0812	0,0695	0,0864	0,0691	0,0700	0,0640	0,0691	0,0691	0,0779	0,0775	0,0691	0,0751	0,0783	0	<=	52.351	Limits	Unit per month
6	Minutes per machin	0,168	0,352	0,126	0,392	0,202	0,202	0,210	0,168	0,206	0,236	0,160	0,219	0,250	0,169	0	<=	129.600	Minutes machine	M3
7	TP - W - DS - LF	1														0	<=	13.513	Demand for units	
8	TP - W - SS - HF		1													0	<=	75.013	Demand for units	
9	TP - W - SS - LF			1												0	<=	190.452	Demand for units	
10	TP - D - DS - HF				1											0	<=	3.152	Demand for units	
11	TP - D - DS - HC					1										0	<=	24.315	Demand for units	
12	TP - D - DS - LF						1									0	<=	15.208	Demand for units	
13	TP - D - SS - HF							1								0	<=	5.174	Demand for units	
14	TP - D - SS - LF								1							0	<=	13.187	Demand for units	
15	PT - W - SS - HC									1						0	<=	49.312	Demand for units	
16	PT - W - DS - HC										1					0	<=	23.768	Demand for units	
17	PT - W - SS - LC											1				0	<=	270.488	Demand for units	
18	PT - D - SS - HC												1			0	<=	12.500	Demand for units	
19	PT - D - DS - HC													1		0	<=	26.842	Demand for units	
20	PT - D - SS - LC														1	0	<=	102.198	Demand for units	
21		>=0	>=0	>=0	>=0	>=0	>=0	>=0	>=0	>=0	>=0	>=0	>=0	>=0	>=0					
22																				
23	Solution	0	0	0	0	0	0	0	0	0	0	0	0	0	0					RESULTS
24																				
25																				

Table 13 – Data entry in Excel Solver (Argentinean SME)
 Source: Own

Set Objective:

To: Max Min Value Of:

By Changing Variable Cells:

Subject to the Constraints:

\$B\$23:\$O\$23 >= 0

\$P\$5:\$P\$20 <= \$R\$5:\$R\$20

Make Unconstrained Variables Non-Negative

Select a Solving Method:

Solving Method

Select the GRG Nonlinear engine for Solver Problems that are smooth nonlinear. Select the LP Simplex engine for linear Solver Problems, and select the Evolutionary engine for Solver problems that are non-smooth.

Table 14 – Configuration
Source: Own

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S			
1																						
2	Data entry in Excel:																					
3																	Totals					
4	Objective	\$99,30	\$106,36	\$54,87	\$80,17	\$36,84	\$97,86	\$93,21	\$94,33	\$31,67	\$54,08	\$44,30	\$57,94	\$58,96	\$49,11	\$41.413.515,33	Limits	Unit per month				
5	M3 per unit	0,0715	0,0812	0,0695	0,0864	0,0691	0,0700	0,0640	0,0691	0,0691	0,0779	0,0775	0,0691	0,0751	0,0783	52.351	<=	52.351	M3			
6	Minutes per machin	0,168	0,352	0,126	0,392	0,202	0,202	0,210	0,168	0,206	0,236	0,160	0,219	0,250	0,169	127.089	<=	129.600	Minutes machine			
7	TP - W - DS - LF	1														13.513	<=	13.513	Demand for units			
8	TP - W - SS - HF		1													75.013	<=	75.013	Demand for units			
9	TP - W - SS - LF			1												190.452	<=	190.452	Demand for units			
10	TP - D - DS - HF				1											3.152	<=	3.152	Demand for units			
11	TP - D - DS - HC					1										0	<=	24.315	Demand for units			
12	TP - D - DS - LF						1									15.208	<=	15.208	Demand for units			
13	TP - D - SS - HF							1								5.174	<=	5.174	Demand for units			
14	TP - D - SS - LF								1							13.187	<=	13.187	Demand for units			
15	PT - W - SS - HC									1						0	<=	49.312	Demand for units			
16	PT - W - DS - HC										1					23.768	<=	23.768	Demand for units			
17	PT - W - SS - LC											1				215.943	<=	270.488	Demand for units			
18	PT - D - SS - HC												1			12.500	<=	12.500	Demand for units			
19	PT - D - DS - HC													1		26.842	<=	26.842	Demand for units			
20	PT - D - SS - LC														1	102.198	<=	102.198	Demand for units			
21		>=0	>=0	>=0	>=0	>=0	>=0	>=0	>=0	>=0	>=0	>=0	>=0	>=0	>=0							
22																						
23	Solution	13.513	75.013	190.452	3.152	0	15.208	5.174	13.187	0	23.768	215.943	12.500	26.842	102.198							
24																						
25																						

Table 15 – Optimum mix
Source: Own

Leandro A. Viltard. " Profit Maximization through Product Mix Management in Argentinean SME." IOSR Journal of Business and Management (IOSR-JBM), Vol. 21, No. 11, 2019, pp