THOMSON REUTERS ENDNOTE

[Santos* *et al.*, 5(11): November, 2016]
IC™ Value: 3.00

ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

IJESRT

INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

APPLICATION OF THE BRANCH AND BOUND ALGORITHM IN THE PLANNING AND PRODUCTION CONTROL IN A TEXTILE INDUSTRY

Marcos dos Santos*, Isis Coelho Lima, Carlos Francisco Simões Gomes, Fabrício da Costa Dias, Marcone Freitas dos Reis, Bruna Russo Bahiana

* PhD student, Department of Industrial Engineering, Federal Fluminense University, Niterói/RJ, Brazil.
Industrial Engineer, Department of Industrial Engineering, SENAI CETIQT, Rio de Janeiro/RJ, Brazil.
Assistant Professor, Department of Industrial Engineering, Federal Fluminense University, Niterói/RJ, Brazil.
PhD student, Department of Civil Engineering, Federal Fluminense University, Niterói/RJ, Brazil.
PhD student, Department of Civil Engineering, Federal Fluminense University, Niterói/RJ, Brazil.
Industrial Engineer, Department of Industrial Engineering, SENAI CETIQT, Rio de Janeiro/RJ, Brazil.

DOI: 10.5281/zenodo.167101

ABSTRACT

As part of the Operations Research (OR), Linear Programming (LPI) is characterized as an optimization technique aimed at solving models described by linear equations, benefiting from the increasing processing power of computers. The article in screen gives a linear programming problem (LPPI) classic, formulated from information from the textile industry. In this sense, the objective is to propose a production mix to maximize revenues from a female underwear factory located in the mountainous region of Rio de Janeiro, from a given amount of available inputs. Comparing the current practice of the company and the scenario proposed by the model, optimized by the Simplex Method, there was an improvement in the annual report of the order of 8,8%, which, in 2015, would be from US$ 54,041.06 to US$ 60,978.03.

KEYWORDS: Branch and Bound Algorithm; Optimization; Production Mix.

INTRODUCTION

The mountainous region of Rio de Janeiro (called 'Região Serrana') is considered the national capital of underwear because there are more than 1,000 lingerie factories, which together produce about 125 million pieces per year, representing 25% of the national production. From this total, 14% of companies work with exportation, mainly to the United States, Portugal, Argentina and Uruguay. Thus, the textile activity along with tourism are the main economic activities in such region, which generate thousands of direct and indirect jobs.

Nevertheless, the entry of foreign textile products, mainly from China, in addition to the Brazilian political and economic crisis worsened in 2015, made that region lose 1,901 jobs, according to official data from the General Register of Employed and Unemployed (CAGED). In this troubled and competitive context, Brazilian textile companies need to reinvent themselves every day in order to survive in their market, through leaner and/or optimized processes.

This paper has the purpose of, from the Branch and Bound Algorithm method, planning the "optimal" portfolio of products to be produced, maximizing revenues and, consequently, the company's profits.

ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

JUSTIFICATION

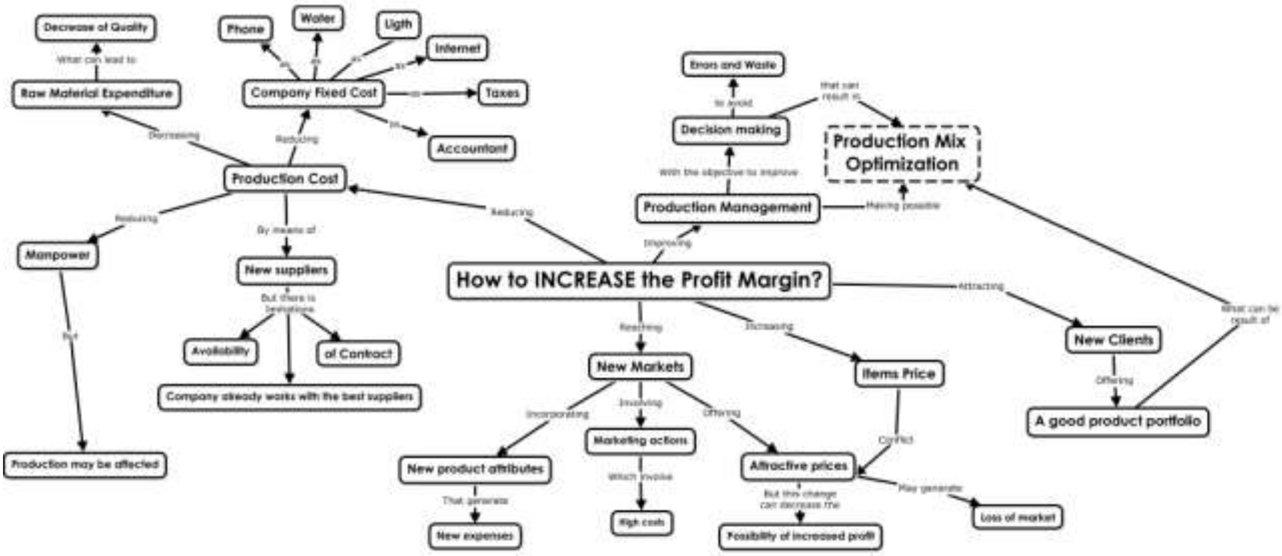
The usage of Operations Research (OR) in the solution of the problem presented is justified by the fact that it is a science composed of numerous techniques and closely related models with the optimization of production systems, ie, producing more and in a better way, from a given quantity of inputs. Thus, OR is an optimization tool seeking for excellence. Even though OR uses a number of tools to support the decision, pointing to the pessimistic, optimistic and most likely scenario, it will never replace the decision maker. This is a key point of the decision-making process, because it involves risks and uncertainties that will be evaluated within the managerial context of the organization.

Hiller and Liberman (2006) state that OR is a model-based science that aims to plan and coordinate the operations of an organization. It works by analyzing the variables and constraints of a given real problem, in order to find a solution to reach a certain goal. For Loesch and Hein (2009), using OR is a way to bring knowledge to an organization, since it acts as an analytical tool and as a study of the problems of the organizational processes. The usage of OR as a science structures processes, proposing a set of alternatives and actions, making predictions and the comparison of values, efficiency and cost.
According to Ackoff and Sasieni (1977), the term "Operations Research" appeared in 1939 during the World War II. To Gomes et al (2009), making complex decisions is generally one of the most difficult tasks faced individually or by groups of individuals, because often such decisions must meet multiple objectives.
The method proposed in this paper is justified because it uses a versatile tool, with moderate mathematical complexity and requiring little computational effort to determine the "optimal solution", as it is about a polynomial algorithm. Moreover, it can be applied in various sectors of goods and services, working with analytical models and numerical data, giving great credibility to its results.
Santos et al (2016) claim that the use of quantitative methods in any company, in supporting decisions in complex scenarios, helps to prevent them from happening in a injudicious manner, providing them with greater rationality, objectivity and entailing better monitoring in their execution, which can lead to more efficiency and effectiveness in their production processes, bringing profitability and solidness to the company in the market, adding value to the society when generating jobs and driving the economy.

METHODOLOGY

In an attempt to understand and structure the main problem, a Mind Map presented in Figure 1 was elaborated - which led to the cluster "Production Mix Optimization".

Figure 1:



Mind map – structure of the problem (increase in the company's revenues)

ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

Santos (2015) stares that OR makes use of mathematic and/or logical model in order to solve real problems, presentig a highly multidisciplinar. Thus, Santos (2013) says according to the type and complexity of the problem studied, we will look for the best model that adhere to reality.

Every OR problem has a relatively simple and logically linked methodology, starting with a problematic situation, that is, with a mismatch between what one wants and what one has, whether for a person, a group of people or an organization. Thus, the first step in solving a problem is the perfect understanding of the problem and its boundary conditions. From there on, a goal can be determined. Having set the objective, it is necessary to define the operational effectiveness measure (MEO), that is, a measure that allows measuring how much a certain measure contributes to the achievement of the objective function. In order to fulfill this function, the MEO must have three indispensable characteristics: it must be quantifiable, measurable and complete. Quantifiable refers to being able to represent it by means of a number. Measurable means being possible to measure it, directly or indirectly, because there is no point of a MEO that can be quantified, but not being able to be measured. And, last but not least, an MEO must be complete, ie, it must contain all the information necessary to measure the effectiveness of a system. From this, a model is constructed, being it analytical or not. However, for a model to be used, especially the mathematician, it must be fed by data, which must be as reliable as possible. The structuring and formation of consistent, coherent and reliable database is of fundamental importance for the model to present results adhering to the context that one wishes to intervene.

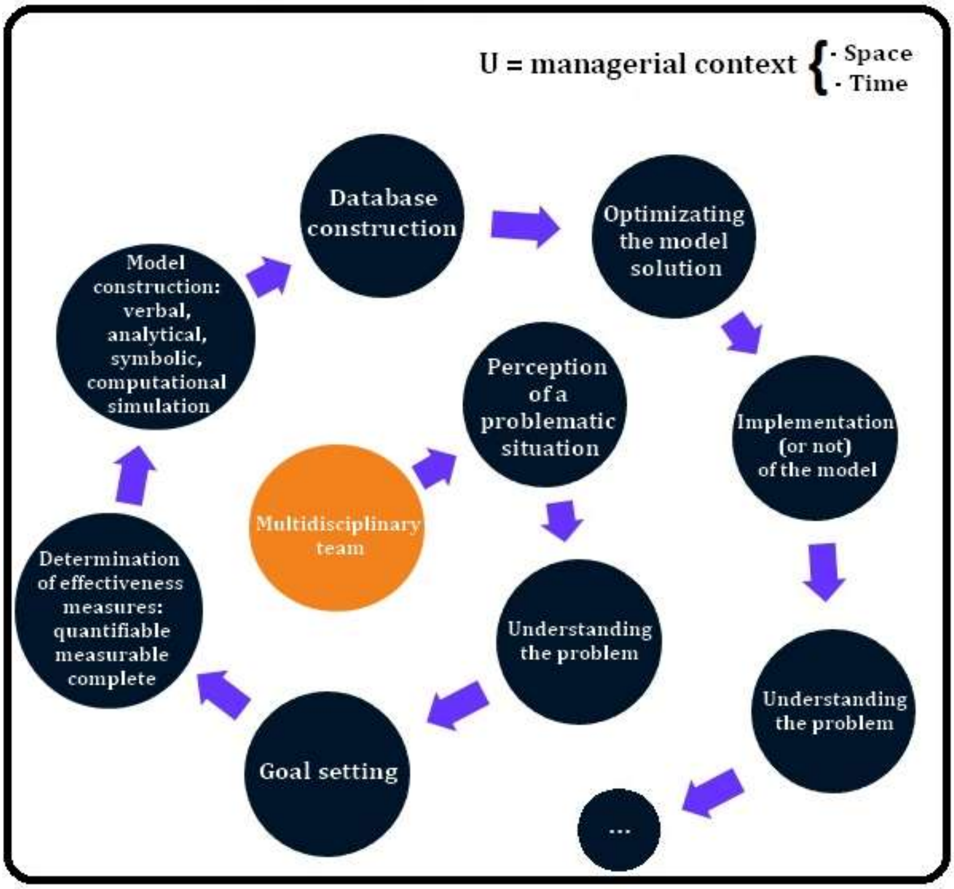
In OR, the data collection phase plays a critical role, because the availability, quantity and quality of the available data will, in some way, influence the choice of the model to be applied, whether analytical or not. Moreover, regardless of the model to be used, hardly any poor quality data will generate results that deserve great consideration. There is a maxim in Engineering called GIGO, which means "Garbage In, Garbage Out", ie "if garbage enters, garbage leaves". So, however sophisticated an analytical model may seem, it will hardly generate good results, and ultimately support the decision to the satisfaction. In this context, it must be considered that on some occasions it is preferable to take a decision blindly than to take it with incorrect subsidies.

In the possession of the model and the database, one starts the optimization of the model, that is, under what circumstances that system will produce the maximum possible, if the function is a maximization function. Closing the "first round" of the decision making process, comes the implementation (or not) of the model. It is worth mentioning that this decision rests solely with the decision maker. Most of the time, one dominates other relevant information, which for some reason were not transmitted to who did the mathematical modeling of the problem. Figure 2 below presents the spiral of the decision-making process, conceived as a mental abstraction, since the decision-making process about a problem unfolds in the first eight stages, starting from a problematic situation (1st stage) to the implementation or not of the model (8th stage) when, then, the perception of the problematic situation takes on a new dimension, incorporating new facts of the underlying reality that had not previously been taken into account.

This will lead to a new understanding of the problem, and, perhaps, will lead to a new goal, making the whole process repeat itself. Therefore, the decision-making process is iterative and growing. It is added that every model has validity within a given managerial context, which, in addition to taking into account the specificities of the organization studied, also has a "space-temporal" validity. In other words, what would be a solution in the year 1930 may not be admissible in the year 2016, or a viable solution in India may not be a viable solution in Brazil.

ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

Figure 2:



Spiral of the decision making process

Perception in decision making

Perception permeates several sensitive points when referred to the decision-making process. The first is the issue of understanding the problem. Given the complexity of modern organizations, it is not uncommon to find problems that even the decision maker did not understand all of its boundary conditions. Without this understanding, the goal to be achieved can not be determined, and so inappropriate tools are selected that will not solve the problem, or will solve it only partially.

Another relevant aspect with regard to perception is the phase of data collection. It is often necessary to collect subjective information from specialists. The problem occurs because each person has a different perception regarding each situation. For example, a doctor may consider a fever of 38.2 °C to be high, while another doctor may evaluate that the same fever is moderate. This question becomes even more pressing when the evaluations are qualitative, permeated by the vagueness of human thought; as an example, an architect is called upon to comment on the façade of a building regarding the attributes ugly, beautiful or harmonious.

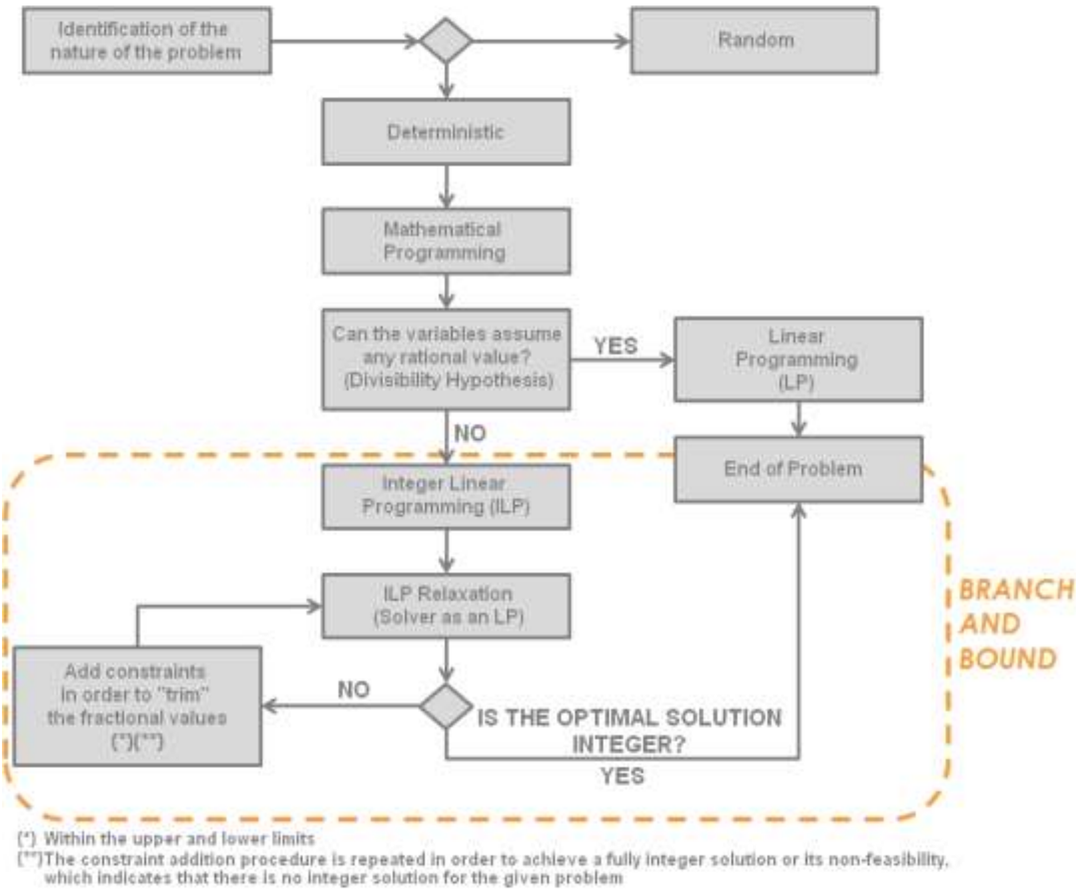
Thus, perception influences the understanding of the problem, the definition of the objective, the selection of the model and the data collection. Therefore, it will have a direct influence on the generation of results that will support the decision.

The choice of model

For the development of modeling a problem, it should be noted that there are many possibilities that lead to several applicable models. In this context, taking into account that the problem has a deterministic nature, it was decided by a model of Integer Linear Programming (ILP), using the Branch and Bound method. According to Silva et al. (2007), Linear Programming (LP) is one of the most used techniques for solving problems in the OR field. Because it is a simple model, based on linear equations, it can be programmable in a computer, which makes it an easy tool to be used in any decision making.

In this direction, Santos and Quintal (2015), complement that the accelerated progress of the computers contributed to that the PL happened to be used like tool of business management. Mirshawka (1981) describes the Branch and Bound Method in a simple and didactic way, without losing the methodological rigor required by the subject. The author also mentions that a natural method of solving a LP is ignoring the condition of xi belonging to the set of integers, and solve it as if it were a LP. When optimality is achieved, if all variables have integer values, there is a optimal solution for the original LP. Otherwise, a new constraint is added to the LP. This additional constraint will cut or "trim" the optimum current solution of the entire non-ILP. When adding a new constraint to the LP, you must apply the Simplex Method again in order to "re-optimize" the new LP. The new solution will be whole or not. The procedure for adding the constraints is repeated until a completely whole solution or non-feasibility of the problem is reached, indicating that there is no complete solution satisfying all constraints, as shown in Figure 3.

Figure 3:



Branch and Bound method flowchart.

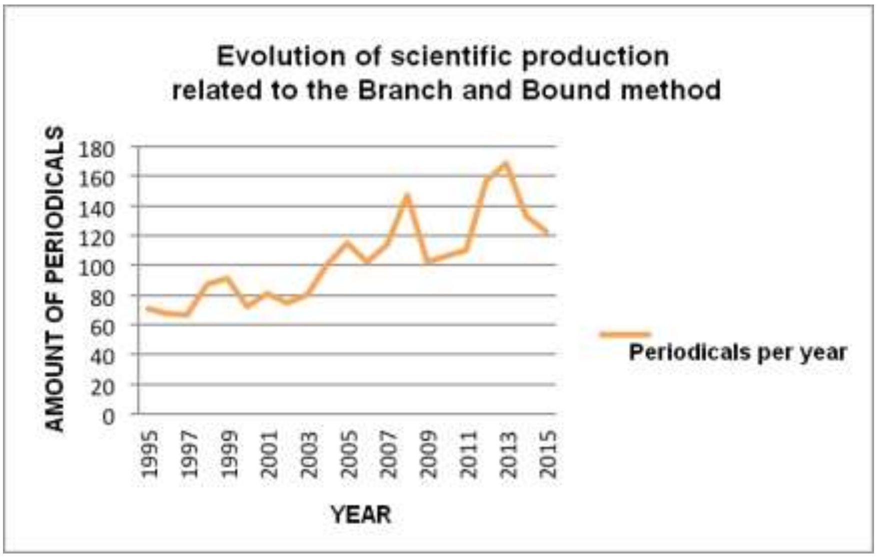
The accelerated progress of the computers contributed to the ILP to become widely used as a management tool. The Linear Interactive and Discrete Optimizer (LINDO) software was used in the calculation of the iterations and the optimal solution of the problem. In calculating the solution, it was taken into account the amount of material used to make the pieces, without considering the number of employees, lay out, time spent on each piece etc.

Bibliometrics

Bibliometrics is the statistical tool that measures bibliographic productions in a given scientific community. According to Mostafa and Máximo (2003, p. 97), bibliometrics is an area of information science that roughly "measures" science. Figure 4 shows the number of publications with the keyword "Branch and Bound", from 1995 to 2015. Such survey was done in the Portal of Periodicals of the Commission for the Improvement of Higher Education Personnel (CAPES).

ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

Figure 4:



Research conducted in the CAPES Journal Portal

MATHEMATICAL MODELING

Decision Variables

As it is desired to know the quantity to be produced of each piece of the basic line of the company, the decision variables were listed as follows:

x_1: amount of shiny bra;
x_2: amount of bra with wrapped handle;
x_3: amount of bra without bulge;
x_4: amount of lycra bra without bulge;
x_5: amount of basic bra/removable handle;
x_6: amount of bicolor bra with wrapped handle;
x_7: amount of swim bra with back lace;
x_8: amount of microfiber panties with wrapped sides;
x_9: amount of microfiber panties;
x_{10}: amount of laser front and back lace panties;
x_{11}: amount of lasered dental-floss panties;
x_{12}: amount of larger laser panties;
x_{13}: amount of shiny microfiber panties;
x_{14}: amount of zeromax microfiber panties;
x_{15}: amount of front lace laser panties;
x_{16}: amount of thong panties with side adjustment; and
x_{17}: amount of thong panties with eyelet and side adjustment.

Constraints

Non-negativity Constraints

Considering x_i as the amount of each piece to be produced, for every i = {1,2,3,4...17}.

Integrality Constraints

$x_i \in \mathbb{N}$, for every i = {1, 2, 3, 4 ...17}.

Technical Constraints

The annual raw material flow, based on the quantities acquired, imposes 69 technical constraints, where each represents the availability of an input that can be used in one or more parts, thus generating a linear equation.

ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

Objective Function

In order to maximize the company's revenue, the objective function is defined by the sum of the revenues generated by the sale of each piece. Thus, there is:

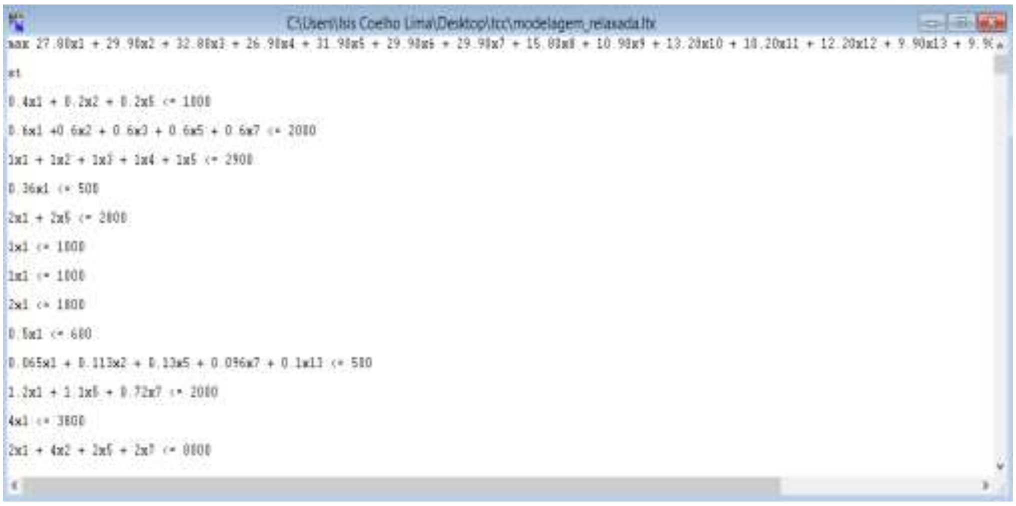
O.F. = Max $\{8.69x_1 + 9.34x_2 + 10.25x_3 + 8.41x_4 + 9.97x_5 + 9.34x_6 + 9.34x_7 + 4.94x_8 + 3.41x_9 + 4.12x_{10} + 3.19x_{11} + 3.81x_{12} + 3.09x_{13} + 3.09x_{14} + 4.66x_{15} + 3.41x_{16} + 3.41x_{17}\}$.

Model Solution

Using LINDO software in the Model Solution

LINDO software was used in the determination of a optimal solution of the problem, that is, the production mix that maximizes the company's revenue, based on a given quantity of raw material available in stock. Part of the modeling of the problem is shown in Figure 5.

Figure 5:


C:\Users\Isis Coelho Lima\Desktop\tcc\modelagem_relaxada.ltx

```
max 27.80x1 + 29.90x2 + 32.80x3 + 26.90x4 + 31.90x5 + 29.90x6 + 29.90x7 + 15.80x8 + 10.90x9 + 13.20x10 + 10.20x11 + 12.20x12 + 9.90x13 + 9.9
st
0.4x1 + 0.2x2 + 0.2x5 <= 1000
0.6x1 +0.6x2 + 0.6x3 + 0.6x5 + 0.6x7 <= 2000
1x1 + 1x2 + 1x3 + 1x4 + 1x5 <= 2900
0.36x1 <= 500
2x1 + 2x5 <= 2800
1x1 <= 1000
1x1 <= 1000
2x1 <= 1800
0.5x1 <= 600
0.065x1 + 0.113x2 + 0.13x5 + 0.096x7 + 0.1x13 <= 580
1.2x1 + 1.1x6 + 0.72x7 <= 2000
4x1 <= 3800
2x1 + 4x2 + 2x5 + 2x7 <= 8000
```

Modeling of the problem in the LINDO software

Figure 6 shows the optimum solution of the ILP generated by the LINDO software after 5,560 iterations.

Figure 6:

```
LAST INTEGER SOLUTION IS THE BEST FOUND
RE-INSTALLING BEST SOLUTION...

       OBJECTIVE FUNCTION VALUE

       1)      210333.0

 VARIABLE        VALUE          REDUCED COST
       X1       845.000000        -27.799999
       X2       935.000000        -29.900000
       X3       195.000000        -32.799999
       X4       250.000000        -26.900000
       X5       555.000000        -31.900000
       X6       165.000000        -29.900000
       X7       368.000000        -29.900000
       X8       833.000000        -15.800000
       X9       467.000000        -10.900000
      X10      1600.000000        -13.200000
      X11       749.000000        -10.200000
      X12       354.000000        -12.200000
      X13         0.000000         -9.900000
      X14      5232.000000         -9.900000
      X15       238.000000        -14.900000
      X16       500.000000        -10.900000
      X17         0.000000        -10.900000
```

Optimum problem solution computed by the LINDO software

Current Scenario

For the year of 2016, the company acquired US$ 27,500.00 in raw material. The pieces were produced and generated a gross revenue of US$ 55,835.16, as shown in Table 1.

Table 1:

Table 1. Current scenario of sales – without optimization

ANTIQUE PORTFÓLIO	amount	cost	revenue	profit
amount of shiny bra (x1)	836	US$ 1,894.69	US$ 7,262.75	US$ 5,368.01
amount of bra with wrapped handle (x2)	972	US$ 2,398.05	US$ 9,082.13	US$ 6,684.08
amount of bra without bulge (x3)	181	US$ 402.82	US$ 1,855.25	US$ 1,452.43
amount of lycra bra without bulge (x4)	192	US$ 355.26	US$ 1,614.00	US$ 1,258.74
amount of basic bra/removable handle (x5)	496	US$ 1,302.05	US$ 4,944.50	US$ 3,642.45
amount of bicolor bra with wrapped handle (x6)	106	US$ 320.71	US$ 990.44	US$ 669.73
amount of swim bra with back lace (x7)	248	US$ 856.61	US$ 2,317.25	US$ 1,460.64
amount of microfiber panties w/ wrapped sides (x8)	512	US$ 641.90	US$ 2,528.00	US$ 1,886.09
amount of microfiber panties (x9)	540	US$ 566.98	US$ 1,839.38	US$ 1,272.39
amount of laser front and back lace panties (x10)	989	US$ 1,309.16	US$ 4,079.63	US$ 2,770.47
amount of lasered dental-floss panties (x11)	363	US$ 343.65	US$ 1,157.01	US$ 813.42
amount of larger laser panties (x12)	524	US$ 504.07	US$ 1,997.75	US$ 1,493.68
amount of shiny microfiber panties (x13)	453	US$ 345.30	US$ 1,401.47	US$ 1,056.17
amount of zeromax microfiber panties (x14)	4197	US$ 1,946.88	US$ 12,984.47	US$ 11,037.58
amount of front lace laser panties (x15)	76	US$ 72.83	US$ 353.88	US$ 281.05
amount of thong panties with side adjustment (x16)	242	US$ 204.51	US$ 824.31	US$ 619.81
amount of thong panties with eyelet and side adjustment (x17)	177	US$ 181.54	US$ 602.91	US$ 421.37
TOTAL	**11,104**	US$ 13,647.05	US$ 55,835.16	US$ 42,188.11

The data show that, without optimizing the production, there was a profit of US$ 42,188.11 associated with US$ 13,852.96 of material inventoried in stock, totaling US$ 56,041.06 in company assets for the year of 2016.

Proposed Scenario

After modeling the problem and inserting the equations into the LINDO software, the following "optimal production mix" was reached: $x_1 = 845$; $x_2 = 935$; $x_3 = 195$; $x_4 = 250$; $x_5 = 555$; $x_6 =165$; $x_7 = 368$; $x_8 = 833$; $x_9 = 467$; $x_{10} = 1{,}600$; $x_{11} = 749$; $x_{12} = 354$; $x_{13} = 0$; $x_{14} = 5{,}232$; $x_{15} = 238$; $x_{16} = 500$; $x_{17} = 0$. Table 2 shows that, after optimizing the production, there was a profit of US$ 49,603.54 associated with US$ 11,374.48 of material inventoried in inventory, totaling US$ 60,978.03 in assets.

Table 2:

Table 2. Optimized production.

NEW PORTFOLIO	amount	cost	revenue	profit
amount of shiny bra (x_1)	845	US$ 1,915.14	US$ 7,340.94	US$ 5,425.80
amount of bra with wrapped handle (x_2)	935	US$ 2,306.76	US$ 8,736.41	US$ 6,429.64
amount of bra without bulge (x_3)	195	US$ 433.97	US$ 1,998.75	US$ 1,564.78
amount of lycra bra without bulge (x_4)	250	US$ 462.58	US$ 2,101.56	US$ 1,638.98
amount of basic bra/removable handle (x	555	US$ 1,456.93	US$ 5,532.66	US$ 4,075.73
amount of bicolor bra with wrapped	165	US$ 499.22	US$ 1,541.72	US$ 1,042.50

ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

handle (x_6)				
amount of swim bra with back lace (x_7)	368	US$ 1,271.09	US$ 3,438.50	US$ 2,167.41
amount of microfiber panties with wrapped sides (x_8)	833	US$ 1,044.35	US$ 4,112.94	US$ 3,068.59
amount of microfiber panties (x_9)	467	US$ 490.33	US$ 1,590.72	US$ 1,100.38
amount of laser front and back lace panties (x_{10})	1,600	US$ 2,117.95	US$ 6,600.00	US$ 4,482.05
amount of lasered dental-floss panties (x_{11})	749	US$ 709.07	US$ 2,387.44	US$ 1,678.37
amount of larger laser panties (x_{12})	354	US$ 340.54	US$ 1,349.63	US$ 1,009.09
amount of shiny microfiber panties (x_{13})	0	US$ 0.00	US$ 0.00	US$ 0.00
amount of zeromax microfiber panties (x_{14})	5,232	US$ 2,426.99	US$ 16,186.50	US$ 13,759.51
amount of front lace laser panties (x_{15})	238	US$ 228.06	US$ 1,108.19	US$ 880.13
amount of thong panties with side adjustment (x_{16})	500	US$ 422.53	US$ 1,703.13	US$ 1,280.59
amount of thong panties with eyelet and side adjustment (x_{17})	0	US$ 0.00	US$ 0.00	US$ 0.00
TOTAL	13,286	US$ 16,125.52	US$ 65,729.06	US$ 49,603.54

When comparing the two situations, it is noted that the Branch and Bound method provided an increase in the assets of the company from US$ 56,041.06 to US$ 60,978.03, bringing an increase of 8.8%.

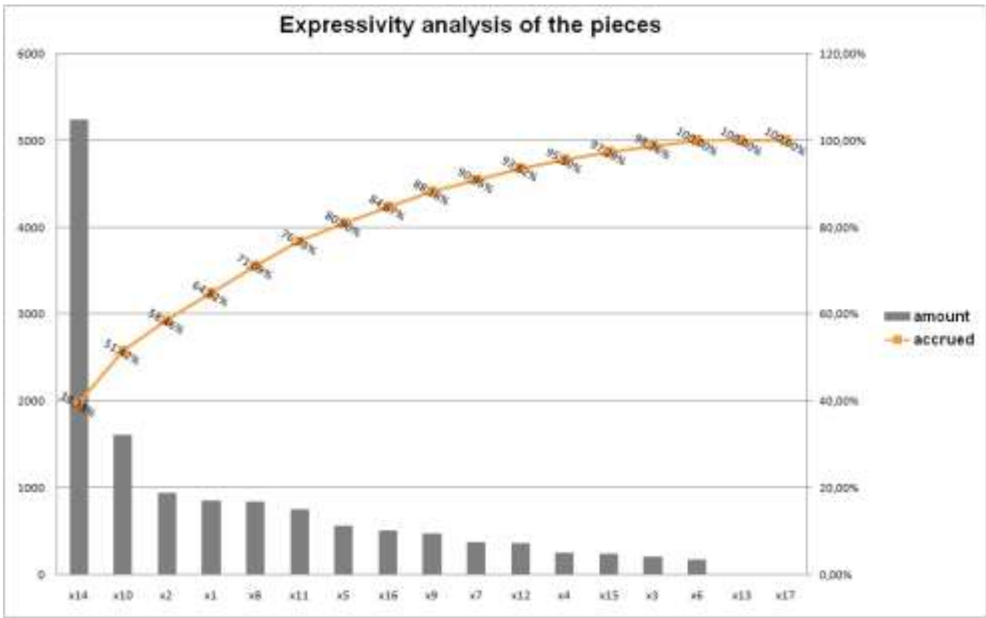
Discussion of Results

In the optimal solution, the pieces x_{13} and x_{17} were set to zero, indicating that their production should be discontinued for not contributing to the maximization of the revenue. However, the Branch and Bound method, as well as any other PO tool, does not decide for the decision maker. Therefore, the decision to discontinue or not the production of the parts must be taken within a managerial context. Even though it does not contribute to maximizing revenues, management can choose to continue producing these pieces for a variety of reasons, such as entering a new niche of market or maintaining the training of specialized seamstresses, among other reasons unrelated to the modeling of the OR analyst.

Another aspect that is worthy of detailed analysis is the fact that the volumes calculated in the "optimal solution" are very different from one piece to another, suggesting that it is more advantageous to focus the production on a smaller variety of pieces, that is, those that contribute more to the revenue maximization. In order to identify the most representative products to maximize revenue, a Pareto chart, as shown in Figure 7, was used.

ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

Figure 7:



Pareto chart

In Figure 7, it can be seen that pieces x_{14}, x_{10}, x_2, x_1, x_9, x_{11} and x_5 represent approximately 80% of the total sales volume of the basic line. Such value suggests that the confection production mix could be reevaluated. On the other hand, restricting the production mix of the company could be a dangerous strategy, since the company would be susceptible to the demands of these few pieces. Therefore, it should be noted again that the decision to change the production mix or not must be taken within the managerial context of the company, aligned with the market strategy defined by its managers.

CONCLUSION

Although the Branch and Bound method is not exactly a novelty, there is some resistance from the Brazilian productive sector, especially from small and medium-sized companies, regarding the implementation of academic techniques and/or tools. Many entrepreneurs and managers are disbelieving that an analytical method is capable of bringing some practical results to their organizations. Comparing the two scenarios, before and after the optimization provided by the Branch and Bound method, it is possible to improve the company's assets, increasing from US$ 56,041.06 to US$ 60,978.03 – an increase of 8.8% without any type of investment. The potential of the mathematical tool presented in this paper is that it is able to increase the productivity of a system from the existing resources in the organization, that is, it is possible to increase the output while maintaining the same input.

REFERENCES

[1] HILLIER, F. S., LIBERMAN, G. J. Introdução a Pesquisa Operacional. 8ª Ed. - Porto Alegre, RS: Mc Graw-Hill, 2006.
[2] LOESCH, C.; HEIN, N. Pesquisa Operacional – Fundamentos e Modelos. São Paulo: Saraiva, 2009.
[3] ACKOFF, Russell L.; SASIENI, Maurice W. Pesquisa Operacional. 3.ed. Rio de Janeiro: Livros Técnicos e Científicos Editora S.A., 1977.
[4] GOMES, Luiz Flavio Autran Monteiro; GOMES, Carlos Francisco Simões.; ALMEIDA, Adiel Teixeira. Tomada de decisão gerencial: enfoque multicritério. 3ª ed. revista e ampliada. São Paulo. Ed. Atlas, 2009.
[5] SANTOS, Marcos et al. Fuzzy logic application in the evaluation of performance of a prototype vehicle powered from solar energy and water electrolysis process. International Journal of Applied Mathematical Research, vol. 5, issue 4, p. 176-181, 2016.
[6] SANTOS, Marcos dos et al. Proposta de otimização do mix de produção utilizando o Método Simplex: um estudo de caso de uma confecção de moda íntima do município de Cordeiro – RJ. In: Anais do IV Simpósio de Engenharia de Produção: Lean Cost Management como filosofia global de otimização em organizações. Recife (PE): FBV, 2016.

[7] SANTOS, M. et al. Simulation of Operation of an Integrated Information for Emergency Pre-hospital Care in Rio de Janeiro Municipality. Elsevier - Procedia Computer Science, v. 55, p. 931-938, 2015.
[8] SANTOS, Marcos. Simulação da Operação de um Sistema Integrado de Informações para o atendimento pré-hospitalar de emergência no município do Rio de Janeiro. Dissertação de M.Sc., COPPE/UFRJ, Rio de Janeiro, Brasil, 2013.
[9] SILVA, E. M.; GONÇALVES, V.; MUROLO, Carlos A. Pesquisa Operacional para os cursos de Economia, Administração e Ciências Contábeis, 3ª Ed. São Paulo: Atlas, 2007.
[10] SANTOS, M. e QUINTAL, R. S. Problema de Programação Linear da Dieta aplicado à nutrição de suínos. Revista em Agronegócio e Meio Ambiente, Maringá, v. 9, n. 2, p. 251-271, 2015.
[11] MISSHAWKA, Vitor. Aplicações de Pesquisa Operacional, volume 1. São Paulo: Nobel, 1981.
[12] MOSTAFA, S. P.; MÁXIMO, L. F. A produção científica da ANPED e da INTERCOM no GT Educação e Comunicação. In: Ciência da Informação v. 32, n. 1, p. 96-101, Brasília, IBICT, jan./abr.