

## **ECONOMICAL ENGINEERING ASPECTS APPLIED IN THE MANAGERIAL DECISION FOR THE IMPLEMENTATION OF AN OPTIMIZATION METHOD TO STREAMLINE THE PROCESSES IN THE WOOD INDUSTRY**

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### **Abstract:**

*The quality and cost of products in general and of wood products in particular is a crucial condition both in selling them on the market and also in attracting buyers and satisfying their desires and exigencies.*

*The quality and value of the products depends heavily on the technical performance of the equipment, the skill level of the workforce, the organization of the manufacturing and processing processes.*

*A higher quality level can be achieved by eliminating as much as possible elements that negatively affect yields, raw materials, materials, and energy consumption. Some of them lead to the need to re-technologize the production lines with the ultimate effect of raising the quality of the products from a technical point of view.*

*Evaluations can refer to both the technical parameters and the economic or combined parameters to facilitate process management, positively influencing both the loss of material, energy, but also the growth of the company's profit. Following the research carried out, the authors of this paper have found technical and economic solutions that contribute to the optimization of the company's activity.*

*Process optimization can be done by applying different methods to evaluate the performance of the studied process, such as: Target-Costing Method; Taguchi method; Six Sigma Method; and so on.*

**Key words:** *optimizing; technological streamline; efficiency; management; production.*

### **INTRODUCTION**

The grinding process, which occupies a significant percentage of the products in this company, has been studied. It is linked to the milling process that has to be optimized and one of the important efficiency criteria is energy consumption. The most eloquent parameter for wood milling that has a major influence on energy consumption is Wood Specific Resistance or Specific Cutting (K), which characterizes the processed wood material and which can be calculated based on the absorbed power (equation 1):

$$P = f(K) \Rightarrow K = f(P) \quad (1)$$

Knowing that:

$$P = \frac{K \cdot b \cdot h \cdot u}{6 \cdot 10^3} \quad (2)$$

In which: P = cutting power, measured in kW;

K = specific wood resistance daN / mm<sup>2</sup> or specific workpiece [daNm / cm<sup>3</sup>]

B = cutting width, measured in mm;

H = cutting depth, measured in mm;

U = feed rate, measured in m / min.

It results that the specific resistance is directly proportional to the absorbed power and can be calculated with the formula 3:

$$K = \frac{P \cdot 6 \cdot 10^3}{b \cdot h \cdot u} \text{ [N/mm}^2\text{]} \quad (3)$$

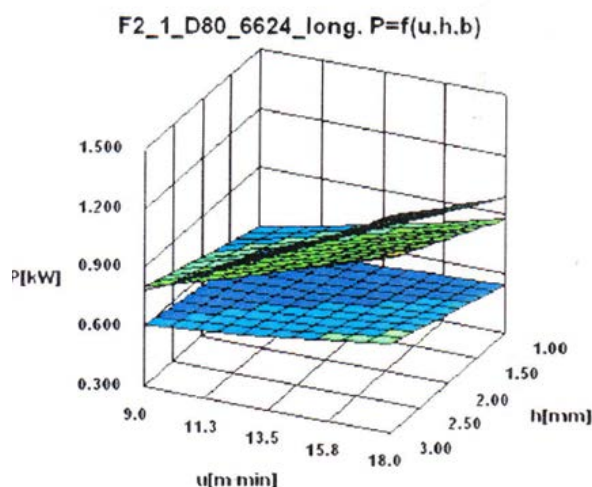
## OBJECTIVES

Optimization criteria once applied to the studied process will inevitably lead to finding technical solutions to meet the requirements of the market. Optimizing a process can be done by applying various methods of assessing the performance of the studied process, such as the Target Costing method, the Taguchi Method, the Six Sigma method and so on.

As a result of the unfolded researches, the authors of this paper have found the answer to two questions (which of the applied assessment methods are most effective? and which of them would lead to those improvements that converge towards a real optimization?) an answer that will be detailed in the presentation below.

## METHOD, MATERIALS AND EQUIPMENT

It is known that in the cross-sectional processing of the wood material compared to its longitudinal directional processing it is noticed a significant difference in the energy consumption. The veracity of this statement is also confirmed by the values obtained for the cutting power required for the transverse and longitudinal cutting of the wood in the experimental researches [...] and which have been recorded in the table (Table 1). The processed data were represented graphically (Fig. 2a and 2b)



**Fig. 1.**

In cross-sectional wood processing, apart from the high energy consumption difference with respect to longitudinal section milling, the processing technology also requires additional machining phases in order to finish the products of the same quality as the processing of the wood after processing in the direction longitudinal.

These steps are generating additional costs and are also responsible for prolonging production times. At the same time, more waste is generated during the additional finishing phases and can increase the risk of generating more scrap (needing more complicated models of manual finishing).

The quality of the product or process is indirectly proportional to energy consumption and power absorption. So:

Table 1

**Values of power consumption and amount of dust resulting from grinding**

Grit	Depth of cutting [mm]	Type of wood	Advance speed (u) 4,5 m/min	Advance speed (u) 9 m/min
			(Pa) Average power consumed at cutting [kw]	(Pa) Average power consumed at cutting [kw]
P40	0,4	Spruce	4.687935	7.168482
		Beech	8.298308	11.20128
		MDF	2.150012	2.61206
P40	0,3	Spruce	4.687935	6.820808
		Beech	6.097583	10.15306
		MDF	2.471298	4.103166
P60	0,4	Spruce	5.73899	7.547807
		Beech	8.884849	N/A
		MDF	4.523018	5.117319
P60	0,3	Spruce	4.085989	6.739016
		Beech	6.444596	11.60971
		MDF	2.738578	3.119402
P80	0,4	Spruce	6.347257	7.995917
		Beech	9.693495	N/A
		MDF	3.134177	3.170587
P80	0,3	Spruce	5.06474	7.634242
		Beech	7.712464	11.86412
		MDF	2.023131	3.323742
P100	0,3	Spruce	4.858144	7.749881
		Beech	7.94103	11.98587
		MDF	1.777011	4.610409
P150	0,3	Spruce	6.744672	10.67864
		Beech	9.906182	N/A
		MDF	4.993595	6.216813

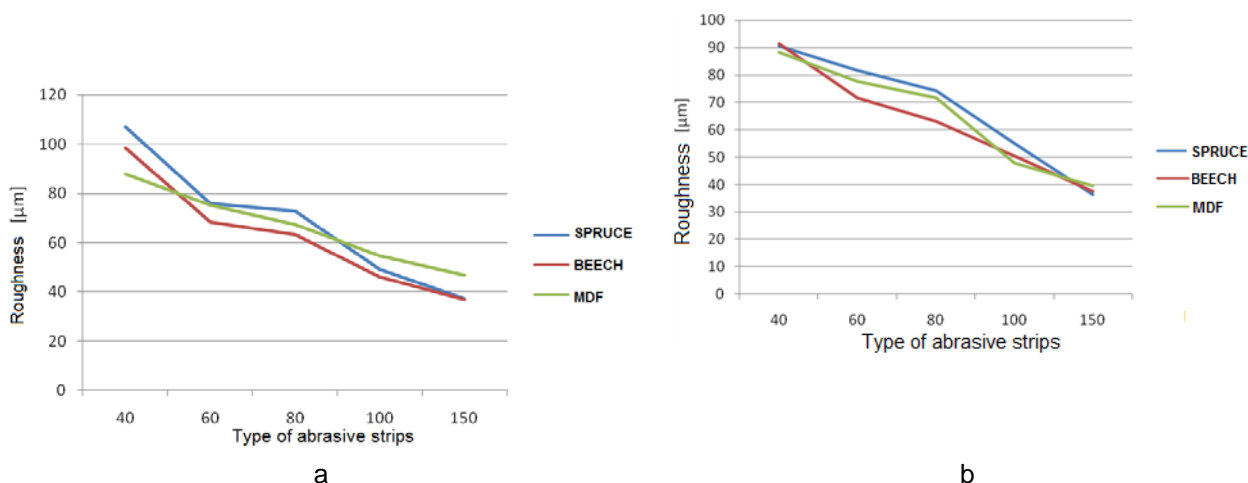


Fig. 2.

**a - Graphic representation of roughness values of the Rz parameter, in the grinding transverse direction with a feed rate of 4.5m/min, for 5 types of abrasive strips (P040, P060, P080, P100, and P150); b - The roughness values of the Rz parameter in a direction perpendicular to grinding, depending on the feed rate of 9 m / min and the abrasive tape (Dariu 2011).**

From the multitude of techniques and methods of economic analysis used to optimize production costs, following a meeting with the company management together with the engineers directly involved in production, we reached the conclusion of using the Multicriteria Analysis method in which the following three Methods for Economic Efficiency of SC Famos SA:

**The Target Costing method:** is part of a strategic management approach according to which each cost carrier is analyzed throughout their life cycle. The target or objective cost is a cost management concept used and developed in Japanese companies, especially in the automotive industry since the 70s. Underlying this target cost concept there was the need to produce smaller series of products that can better adapt to the market needs, the introduction of the new production organization methods (Just In Time operating system) and the introduction of automation-based technologies (CIM - Computer Integrated Manufacturing - systems).

**The Taguchi method** imposed itself as being more effective than other methods of experiment planning. It derives from the method of factorial experiments and proposes an alternative method for calculating the average effects of factors and interactions, thus making mathematical modeling much easier. Its efficiency is due to reducing the number of tests given by the split plan method, which allows modeling with much less experiments than the full plan method. The Taguchi method is one of these split plan methods and has also the advantage that it is easy to apply in practice. When determining the number of experiments involving the study of a phenomenon by this method, stricter conditions must be applied.

**The Six Sigma Method** represents the standard deviation in statistics and it is a management methodology aimed at increasing product quality by determining and removing the continuous causes of defects and process variability (potential or detected) in order to ensure customer satisfaction, based on the methods FMEA (Failure Mode and effect and Analysis) and QFD (Quality Function Deployment) and modern management methods applied to the joint teams made up of manufacturer, supplier, client, professional, research centers etc.

Each of the three methods aims to achieve the economic efficiency of the company by taking into account certain parameters that significantly or less significantly influence the process optimization. Among the projected (common and / or different) parameters for each method, there were studied only the parameters that the three methods have in common, so that a managerial decision can be taken on the method to be applied within the company.

The optimal decisions for the company management, since there are several alternatives (methods), can be obtained by applying a multi-criteria analysis method (AMC). The goal of this method is to conduct a comparative evaluation of the proposed options (methods). For the AMC, all common parameters of the selected methods were taken into account simultaneously in a complex situation. The method is designed to assist decision makers by integrating different options, reflecting the views of the actors involved in a prospective or retrospective framework. The analyzed parameters reflect how objectives are achieved. The best option will be the one that will be closest to achieving most objectives and that will obtain the highest scoring.

The comparison was made between the efficiency models that could be selected taking into account the specific characteristics of the wood processing industry.

The analysis consists of the calculation of value hierarchizing coefficients, for the performance of the objects under comparison. The result of the multi-criteria analysis, properly applied, provides scientific and effective results for optimal solutions in the technological process which will be reflected in the economic cost/price of the final product.

**RESULTS AND DISCUSSION**

The multi-criteria analysis (MCA) describes any structured approach to be used in determining the general preferences of several alternative options, options that lead to achieving a number of objectives. In the current case, our main goal is to optimize production by reducing costs at SC Famos SA. The steps that were followed are:

**1. Establishing methods and evaluation criteria in the decision-making context.**

For identifying the optimization method with the greatest applicability in the wood processing industry, the research was based on the use of brainstorming techniques and multi-criteria analysis. Within this step there were identified the alternative criteria to be taken into account. In our case the options considered are: alternative 1 the Target Costing method; alternative 2 the Taguchi method, alternative 3 the 6 Sigma method.

Through the multi-criteria analysis (MCA) there will be eliminating the subjectivity, since the order of the criteria is determined by comparing each criterion relative to other selected criteria.

The brainstorming consisted in organizing a work meeting with a group consisting of the company management and 10 engineers from SC Famos SA Odorheiu Secuiesc. During the brainstorming session, held in the company's meeting hall, there were presented several ways to optimize production from which there were chosen the 3 mentioned methods and the participants generated a number of ideas regarding the applicability of these methods in the technological process.

After continuing the brainstorming session, there were generated following evaluation criteria that must be followed in the process of multi-criteria analysis:

1. Cost of implementing the methods (C);
2. The simplicity of using the method (S);
3. The effect of applying the method reflected in a reduction of the energy consumption (E);
4. Acceleration of the technological process - eliminating some steps in the process => reducing the time and costs that are reflected in the price (A);
5. Ease of implementing the methods (U);
6. The quality of the product (A);
7. Number of failures / waste (N).

**2. Determining the share of criteria common for the three methods selected for relative quantifying.** At this stage, after identifying the 7 common criteria which are relevant for solving the problem in selecting the decisional problem for the optimization method, they have been ranked. This ranking took into account the major categories of costs and benefits resulting from the options considered. The scoring was done according to the principle – a criterion is more important than the other (= 1), as important (= 1/2), less important (= 0)

Table 2 presents the calculation of points, the level and the weighting coefficient  $Y_i$ .

Table 2

*Point calculation, the level and the weighting coefficient  $Y_i$*

Criteria	C(1)	S(2)	E(3)	A(4)	U(5)	O(6)	N(7)	points	level	$Y_i$
<b>C(1)</b>	0.5	0	0.5	0	0	0.5	0	1.5	7	0.27
<b>S(2)</b>	1	0.5	0.5	0.5	1	1	0	4.5	2	2.89
<b>E(3)</b>	0.5	0.5	0.5	0	0.5	1	0	3	5	1.17
<b>A(4)</b>	1	0.5	1	0.5	1	0	0	4	3	2.2
<b>U(5)</b>	1	0	0.5	0	0.5	0	0.5	2.5	6	0.77
<b>O(6)</b>	0.5	0	0	1	1	0.5	0.5	3.5	4	1.64
<b>N(7)</b>	1	1	1	1	0.5	0.5	0.5	5.5	1	4.57

**3. Hierarchizing the options.** As a result of the inter-criteria comparison process, there resulted a matrix whose sum by lines (sum of each criterion in part) (column 9) resulted in a hierarchy (column 10) of the criteria's significance as seen in Table 2.

The next step in the MCA procedure was calculation of the weighting coefficient (Yi) column11, which is calculated using the FRISCO equation (4):

$$\gamma_i = \frac{p + \Delta p + m + 0,5}{-\Delta p' + \frac{N_{crit}}{2}} \quad (4)$$

where:

p - is the sum of points obtained on the line by the considered item;

Δp - the difference between the score of the considered item and the score of the item at the last level.

m - represents the number of surpassed criteria, i.e. the number of criteria with scores below the item;

NCRT - number of criteria taken into account;

Δp' - the difference between the score of the considered element and the score of the element in the first rank (a negative result).

**4. The standardization of scores for each criteria** was made in a common scale ranging from 1 to 10 and taking into account the effect that it will have on the company's activity. The result of the analysis is presented in Table 3.

Table 3

*Criteria and their value range*

CRITERIA	INDICATOR	VALUE RANGES	EFFECT
C1(C)	1. Cost of implementing the methods (C);	1-10	-
C2(S)	2. The simplicity of using the method (S);	1-10	+
C3(E)	3. Effect of applying the method reflected in a reduction of the energy consumption (E);	1-10	+
C4(A);	4. Acceleration of the technological process (A);	1-10	+
C5(U)	5. Ease of implementing the methods (U);	1-10	+
C6(O);	6. The quality of the product (A);	1-10	+
C7(N).	7. Number of failures / waste (N).	1-10	-

**5. The creation of the performance matrix** describes the expected performances of each option according to the chosen criteria. The information on the dimension of each criterion can be expressed in units. Table presents the performance matrix and the assigned values were determined by the personnel of SC Famos SA within the organized brainstorming session

Table 4

*Performance matrix*

	TC Method	T Method	6S Method
C(1)	8	9	10
S(2)	9	8	10
E(3)	9	10	9
A(4)	10	8	9
U(5)	10	9	10
O(6)	10	10	10
N(7)	9	10	9

**6. Examining of results.** Considering the performance matrix and the weighting coefficient there was calculated the product between the Yi coefficient and the performance degree Ni, then the products were added by criterion to achieve the final result. The data obtained are presented in Table 5 and can be compared.

Table 5

**Calculation of the products between the grades N and the weighting coefficients**

Criteria	Yi	Method TC		Method T		Method 6S	
		Ni	Ni*Yi	Ni	Ni*Yi	Ni	Ni*Yi
<b>C(1)</b>	0.27	8	2.16	9	2.43	10	2.7
<b>S(2)</b>	2.89	9	26.01	8	23.12	10	28.9
<b>E(3)</b>	1.17	9	10.53	10	11.7	9	10.53
<b>A(4)</b>	2.2	10	22	8	17.6	9	19.8
<b>U(5)</b>	0.77	9	6.93	9	6.93	10	7.7
<b>O(6)</b>	1.64	10	16.4	10	16.4	10	16.4
<b>N(7)</b>	4.57	9	41.13	10	45.7	9	41.13
<b>Final Score</b>			<b>125.16</b>		<b>123.88</b>		<b>127.16</b>

The final analysis was done taking into account the sums of all criteria that influence each method. It can be noticed that 6S is the most effective method, totaling the highest value.

In MCA procedure, there is also a sensitivity analysis stage that was not required to be unfolded here, given that the sensitivity of the criteria in relation to changing the method is very close.

**CONCLUSIONS**

As a result of the multi-criteria analysis applied in the wood domain at SC Famos SA in order to choose the evaluation method for the optimization of the technological flow, the result is that the most efficient method that the company management has to choose for its application in production is the 6 sigma method. Achieved the highest score of 59.61 against the Target Costing method which achieved 58.38 and the Taguchi method which only achieved 56.33.

These results confirmed the discussions and opinions of the engineers at SC Famos SA during the brainstorming session that confirmed that the Taguchi method is an obsolete method due to the managerial principles that takes them into account and the Target Costing method is limited to its application to certain industrial branches. Being incomplete in relation to the many aspects and management decisions that management has to take into account in the woodworking industry.

Following the application of the 6S method to optimize the cutting process found in SC Famos SA's manufacturing technology and which mainly influences production, one of the criteria was energy consumption. The most eloquent parameter for energy consumption in wood milling is the specific resistance (K), which characterizes the processed wood material and which, when milling, can be calculated according to the absorbed chipping power.

It has been found that a significant difference in the energy consumption is recorded in the processing in the transversal direction of the wood material compared to the longitudinal direction of its processing, the power being consumed being much higher in the first case.

In order to achieve minimal thickness variability and a minimization of waste in the case of an even wood lamella, the feed rate of the wood in the class varies according to the classes, which will be the subject of further research.

Also, in cross-sectional processing, besides higher energy consumption, it also requires additional processing phases, in order to finish the products obtained with the same quality as the woodworking in the longitudinal direction. These steps are generating additional costs and are also responsible for prolonging production times. At the same time, additional waste generates more waste and can increase the risk of generating more scrap (needing more complicated manual finishing).

Based on the results of the study, the company implemented a process of wood equalization before the cutting process and is ready to make refurbishments for a start on a production line, the first stage was the acquisition of a new saw blade machine to optimize the process equalization of wood.

The authors of this article are currently preparing to evaluate the new process, namely, to investigate process capacity, optimal debit rates, and assess the level of material losses after implementing the proposed changes.

Despite the slightly higher costs to implement the management decision through the 6 sigma method noted in the implementation, they will finally be annihilated and will have the effect of cost optimization by minimizing the volumes of waste and waste produced.

A unanimous opinion was on the ease with which this method can be applied at all stages of production, especially as it involves the involvement of workers in the measurement, evaluation and continuous improvement of parameters.

The methodology presented for the optimization of technological processes to make the furniture production process more efficient is universal and can be applied to other similar processes in the wood industry (wood panels, parquet etc.).

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