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Application of the MOORA method for the evaluation of the industrial maintenance system

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Abstract: In the industries it is quite important to evaluate the parameters of the maintenance system, with the main objective to design continuous improvement plans helping to maintain the operation processes working efficiently. In this respect, the proposed method that we will use in the current research is the multi-criteria decision making named as MOORA. Moreover, we propose an analysis and evaluation for the maintenance system, by using the metric data collected during the process. Such evaluation determines the optimal operation conditions of the machine, and, in the same way one can be able to establish its worse operational conditions; it might help to the management to take into account the best decisions with regard to each machine. The aim of this paper is to tackle the study in the decision making in the industrial area, specifically in the maintenance of molding machines. Finally, an experimental case is developed to validate that the MOORA method is feasible to evaluate the performance of the machines.

1. Introduction

Maintenance focused on the reliability environment (RCM) with the objective of preserving operational efficiency in critical sectors such as power plants, the artillery system, the aviation industry, the rail networks, the oil industry and the gas and boat maintenance, manufacturing industries, among others [1]. On the other hand, the term of manufacture implies a process in which the final product with the characteristics desired by the final consumers is sought, adding value. In addition, manufacturing systems combine raw materials and manufacturing processes following a procedure, to carry out it requires personnel and equipment, the layout of the equipment that comes in contact with the material is determined by the number of pieces to be manufactured annually [2]. Similarly, in the exploration for the competitiveness of the manufacturing companies, interest has arisen in the analysis of the machines that are part of these industrial processes, since they directly influence the quality of the finished product and reduce operational costs. On the other hand, the main objective of carrying out the maintenance activities is to guarantee the reliability of the machines and the treatment to reduce the costs of the operations due to downtime. [3]. Nevertheless, the main objective of maintenance is to achieve a minimum breakdown and keep the plant in good working condition at the lowest possible cost. Therefore, maintenance should not be considered as a cost center, but as a profit-generating function [4].

In general, the process of plastic injection is an irreversible physical process, in which raw material is melted as thermoplastic, by the effect of heat by an injection machine. In such a way, that the plastic injection process is one of the most common mass productions, because it reveals low cost and high efficiency [5]. Hence, the total effectiveness of the equipment (OEE), is a performance measurement metric that will indicate the rate of return with very simple calculations [6]. In this sense, to achieve a good efficiency of the machines it is necessary to have an optimal maintenance system since the main maintenance function is to sustain the functionality of the equipment and the good condition of the machines over time [7]. Day by day we see in situations that make decisions and take us most of the time we do it automatically, but when it comes to industrial processes is best to rely on mathematical models of decision making [8]. In the same way, the literature indicates that the maintenance system can be evaluated through multi-criteria decision analysis [9]. In this sense, the Multi-Objective Optimization on the basis of Ratio Analysis (MOORA) method introduced by [10], is planned to be used for the development of this document, which consists in evaluating the maintenance of plastic injection machines, in order to estimate their optimum performance. Finally, the aim of this paper is focused to help maintenance managers make decisions to evaluate the maintenance of the machines and prepare the proper maintenance strategy focused to reduce fails and operation costs. In addition, it is considering the environment where complex decision making and uncertainty, increased pressure of time, conditions that change more hastily and higher risks [11].

2. MOORA method

This section presents the MOORA method, which is used to evaluate the maintenance of the machines of the manufacturing process to develop continuous improvement [12]. The following steps describe the MOORA method.

2.1. Step 1

Define the decision matrix with the alternatives and sets of criteria involved (Equation 1).

$$MDF_{ij} = \begin{matrix} A^1 \\ A^2 \\ \vdots \\ A^n \end{matrix} \begin{bmatrix} x_1^1 & \cdots & x_K^1 & x_{K+1}^1 & \cdots & x_{K+L}^1 \\ x_1^2 & \cdots & x_K^2 & x_{K+1}^2 & \cdots & x_{K+L}^2 \\ \vdots & & \cdots & \cdots & \cdots & \cdots \\ x_1^n & \cdots & x_K^n & x_{K+1}^n & \cdots & x_{K+L}^n \end{bmatrix} \tag{1}$$

2.2. Step 2

Normalize the decision matrix (Equation 2)

$$|\ddot{Y}_j| = \sqrt{\sum_{i=1}^{n} x_i^2} \tag{2}$$

Henceforward, the normalization of MDF_{ij} is calculated using the Equation 3.

$$\xi_{ij} = \frac{x_{ij}}{|\ddot{Y}_j|} \tag{3}$$

2.3. Step 3

Raise the weighted standard decision matrix (Equation 4).

$$T_{ij} = w_i \cdot \xi_{ij} \tag{4}$$

2.4. Step 4
Proceed to determine the classification of the benefits criteria Equation (5) and the costs criteria Equation (6) respectively.

$$\sum_{i=1}^{g} T_i \tag{5}$$

Then,

$$\sum_{j=g+1}^{m} T_j \tag{6}$$

2.5. Step 5
Calculate the contribution index β_i^-.

$$\beta_i^- = \sum_{i=1}^{g} T_i - \sum_{j=g+1}^{m} T_j \tag{7}$$

2.6. Step 6
Establish the order of the alternatives.

The Figure 1 describe the model proposes (Multi-Objective Optimization on the basis of Ratio Analysis - MOORA) in order to appraisal the machines and develop an improvement action plan.

Step 1. Define the decision matrix with the alternatives and sets of criteria involved → **Step 2.** Normalize the decision matrix → **Step 3.** Raise the weighted standard decision matrix

Step 4. Proceed to determinate the classification of the cost criteria and the benefit criteria respectively → **Step 5.** Calculate the contribution index α_i^-

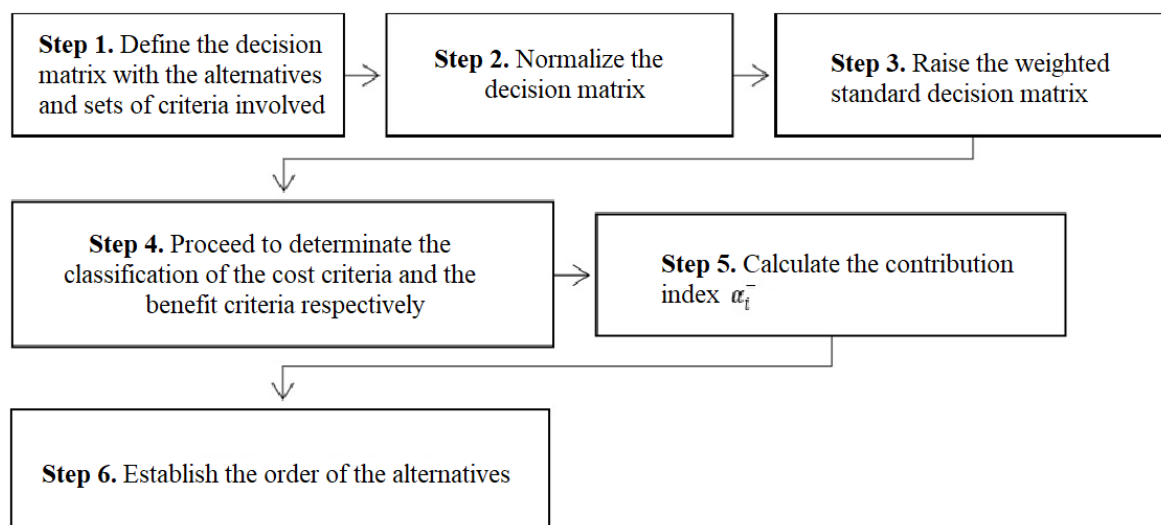**Step 6.** Establish the order of the alternatives

Figure 1. MOORA method.

3. Experimental case

The case study considers the evaluation about the performance of plastic injection machines to outline continuous improvement strategies. Likewise, a set of four machines and four criteria is proposed. The alternative A_1, it is a plastic injection Demag 85T machine which has an injection pressure of 85tons, clamping force of 1000KN and a heating capacity of 11.1K. Alternative A_2, belong to Cincinnati machine which is a plastic injection machine and has an injection power of 85 tons. Alternative A_3 depict the Toshiba machine which has a pressure of injection of 220t, how much with a diameter of the screw: 50 mm, performs a stroke opening: 800mm, produces an injection volume: 490 cm^3 and a firing weight of 450g. Alternative A_4 represents the fourth option that consists of an injection pressure of 250tons.

At the same time, the set of criteria involved in the problem are the following:

3.1. OEE

Represent criterion is used to measure the quality, productivity and availability of the machines, this type of criterion and belong to quantitative criteria.

3.2. Setup

Depict criterion gives us the waiting times in the part number changes, the criterion is quantitative.

3.3. Operation time

This criterion gives us information about the run time of the machine per piece generated. This type of criterion is quantitative.

3.4. PPM

This criterion tells us the pieces per million produced with a quality that does not approve the quality criteria this criterion is evaluated qualitative.

3.5. Waste (Scrap)

Indicates the waste generated by this process was evaluated qualitatively.

The development of the Multi-Objective Optimization method on the basis of Ratio Analysis – MOORA – for the experimental case under consideration is shown step by step from Table 1 to Table 5 and ends with the comparison of alternatives in step 6.

3.5.1. Step 1. Definition of the decision matrix with the alternatives and sets of criteria involved.

Table 1. Matrix MDF$_{ij}$

Machine	OEE	SETUP	Operation time	PPM	ESCRAP
M_1	78.7d1%	1.200	0.007	5	2
M_2	81.21%	1.083	0.006	2	4
M_3	83.75%	1.500	0.012	4	3
M_4	91.46%	1.303	0.009	3	3

3.5.2. Step 2. Normalization of the decision matrix.

Table 2. Normalized matrix ξ_{ij}

Machine	OEE	SETUP	Operation time	PPM	ESCRAP
M_1	0.469	0.468	0.384	0.680	0.324
M_2	0.484	0.423	0.312	0.272	0.649
M_3	0.499	0.586	0.694	0.544	0.487
M_4	0.545	0.509	0.523	0.408	0.487

3.5.3. Step 3. Elevation of the weighted standard decision matrix.

Table 3. Matrix T_{ij}

Machine	OEE	SETUP	Operation time	PPM	ESCRAP
M_1	0.117	0.094	0.077	0.136	0.065
M_2	0.121	0.085	0.062	0.054	0.130
M_3	0.125	0.117	0.139	0.109	0.097
M_4	0.136	0.102	0.105	0.082	0.097

3.5.4. Step 4. Determination of the classification of the Equation of benefit criteria (5) and the Equation of cost criteria (6), respectively.

Table 4. Classification T_i and T_j

$\sum T_i$	$\sum T_j$
0.117	0.278
0.121	0.247
0.125	0.345
0.136	0.284

3.5.5. Step 5. Calculation of the contribution index β_i^- .

Table 5. Matrix $\boldsymbol{\beta_i^-}$

Machine	α_i^-	Ranking
M_1	-0.160	3
M_2	-0.126	1
M_3	-0.220	4
M_4	-0.147	2

3.5.6. Step 6. Establishing the order of alternatives.

$$M_2 > M_4 > M_1 > M_3 \tag{8}$$

According to result M_2 depict he best option.

4. Analysis of results

This paper proposes to appraisal the maintenance system applied in a set of plastic injection machines, with the main objective of using the MOORA method, evaluating the key performance indicators of the different machines that operate in the manufacturing process.

At the same time, in Table 6 a comparison with (Technique for Order Preference by Similarity to Ideal Solution) TOPSIS method was carry out and we detected the same results on raking.

Table 6. Comparisons MOORA and TOPSIS.

MOORA method	$M_2 > M_4 > M_1 > M_3$
TOPSIS method	$M_2 > M_4 > M_1 > M_3$

It can be explored on this analysis the reliable of the ranking about M_2 represent the best option. The comparison with TOPSIS method versus MOORA method are depicted in Table 6 and the detailed information is consistent to demonstrate the results about the best alternative. In this sense, the evidence

is used to prepare the continuous improvement strategy and action plan to implement an improvement project. Finally, we demonstrated that MOORA is a suitable approach for the appraising of the key performance indicators of the different machines that operate in the manufacturing process.

Our contribution is mountable to encounter a variety of conditions by adjusting the machine parameters, i.e., it has very good flexibility and organized manner to provide solutions to appraisal of the performance of plastic injection machines.

5. Conclusions

This document shows the analysis of maintenance system via MOORA method. Hence, the appraisal will bring efficient information in order to maintenance managers can determine the best strategy to implement improvements to reduce operation cost regarding to stop line due to machine fails.

Finally, the overall appraisal of the maintenance system allows you to find the best of the machines. In this sense, implement action plan focused to increase the efficiency about worst performance. MOORA method is mathematically very simple, systematic comprehendible, and suitable to maintenance system appraisal, while present a more objective and reasonable appraisal method.

For future work can be recommendable to explore different MCDM methods to validate the results and compare other environment regarding to uncertainty of the decision making.

Acknowledgments

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