International Journal of Industrial Engineering & Production Research December 2021 Vol. 32, No. 4: 1-9
DOI: 10.22068/ijiepr.32.4.3

RESEARCH PAPER

Proposal of An Oee Target Prediction Model Based on the Company's Strategy

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Received 20 October 2020; Revised 10 February 2021; Accepted 27 September 2021;

ABSTRACT

Overall Equipment Effectiveness (OEE) is a very powerful indicator for the performance evaluation of a manufacturing organization. However, determining the OEE target remains subjective and it's usually based on the decision of concerned managers. In this paper, we tested the OEE target determination model based on the measured OEE. Such a method is based on the fuzzy logic principle and on two other decision-making support methods. To do this, we began with a literature review on OEE and its constituents. Then, a detailed description of the research methodology and the proposed model is provided. Thus, a case study in a manufacturing agri-food organization was conducted to test the proposed model and validate the obtained results.

KEYWORDS: *OEE, Strategy, Productivity, Performance, Quality, Decision-making support*

1. Introduction

In recent decades, production tools have conquered mostly all industries and have gradually ignored human intervention in the production process. Hence, the challenge facing the industries these days is related to building a more sustainable mastering complex production system. To fulfill this need, the maintenance function emerged in the 1970s, and it has gradually been imposed in most industries and services and even within the tertiary sector (property maintenance, hospital maintenance, etc.). The need to manage the production system is largely explained not only by the increase in the failure costs and their consequences, but also by the spread of globalization. This creates a need to maintain and optimize the performance level of the production tool. This is what makes the industrial maintenance plays an important role in supporting production and maintaining quality, safety, environment, timeliness and productivity. This is what makes industrial maintenance a means of competitiveness among organizations. The performance and the level of competitiveness of an organization are judged by its performance measurement systems. In this regard, the OEE is introduced as one of these performance measurement tools. It measures different types of production losses and indicates areas for improvement. Thus, to ensure that manufacturing organizations remain competitive, most of them are shifting to Total Productive Maintenance (TPM) and lean manufacturing to ensure seamless operations. The 'OEE' performance indicator is the basis for improvement strategies in a manufacturing organization. Indeed, it is an indicator which reveals the losses relating to equipment. [1]–[3] [4]. OEE is a powerful indicator in production and maintenance management. It is an indicator for evaluating and measuring productivity. This indicator is made up of three sub-indicators: Performance (P), Quality (Q) and Availability (A) [5]–[7].

A lot of research has been published to determine the interest of this indicator and define its calculation. Indeed, [1] presents the importance of managerial issues relating to the deployment and use of OEE in industry. They also identify how manufacturing organizations employ the information provided by OEE and how the data for its computation are collected. The analysis of

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the results presented in the study [1] shows clearly that empirical research on the deployment and use of OEE is very limited. Thus, the authors provide organizations and managers with a better understanding of the different factors that affect the successful implementation and management of this highly used measure in industry [1]. However, when the production tool work jointly in a manufacturing process, Overall Equipment Effectiveness indicateur is not sufficient to improve the system performance of the as a whole. The authors show how to surmount this constraint by presenting a new indicator (Overall Equipment Effectiveness of a Manufacturing Line – OEEML) and an overall approach to evaluate the performance of a production process [8]. [9] highlights the most relevant benefits of the OEE indicator and calibrates the performance of AIL with other uses of OEE presented in the literature. [10] formulated a model for estimating and forecasting OEE using the constant-time learning curve model. An OEE forecast can be considered as a process and, therefore, can be managed by Statistical Process Control (SPC). A control chart, i.e. an EWMA (Exponentially Weighted Moving Average) in this study, is easily used to monitor the forecast errors. If the forecast errors go over the control limits, this indicates that something wrong has happened to the TPM (Total Productive Maintenance) and that the managers should be informed and that necessary actions should be taken to ensure the successful adoption of the TPM. Furthermore, [7] states that OEE indicator provides a quantitative measurement based on the three elements : performance, quality and availability to determine the efficiency of the performance of an entire processes or individual equipment. [11] identifies maintenance improvement potentials using an OEE assessment within the manufacturing industry. According to the results of a literature review, [12] affirms that the performance elements measured by the OEE indicator are not enough to identify the advantage of TPM deployment. Hence, these authors aim at developing and evaluating new performance measures to quantify TPM implementation effectiveness under fuzzy environment. To evaluate each performance measure in TPM, the nominal group technique has been used. First, to determine whether these performance measures are statistically significant, conjoint analysis based on an experimental design has been applied. In the second step, Complex Proportional Assessment of alternatives with Grey relations (COPRAS-G) and the fuzzy COPRAS method has been developed. [12] and [8] estimate manufacturing losses are decomposed into elementary causes and modeled as LR fuzzy numbers. Next, in order to compute the Fuzzy Overall Equipment Effectiveness (FOEE), single losses are aggregated using the 'fuzzy transformation model'. This approach limits the fuzzy overestimation phenomenon and assures both results' accuracy and robustness.

However, determining the OEE target remains subjective and it's usually based on the decision of concerned managers. Thus, we propose an OEE target determination model based on the measured OEE. Such a method is based on the fuzzy logic principle and on two other decision-making support methods.

The rest of the paper is organized as follows. In section 2 we describe OEE, its constituents and the calculation method. In section 3, we focus on the research methodology. Next, we propose and describe the proposed model in section 4. A case study to test this model is presented in section 5. Section 6 is devoted to discuss and interpret the results. The last section aims at making general conclusions and providing certain recommendations for future research.

2. Overall Equipment Effectiveness

2.1. Presentation

Overall Equipment Effectiveness was proposed by Nakajima [13] as an approach to evaluate the progress achieved through the improvement initiatives carried out as part of TPM. Nakajima defines OEE as a metric or measure for the evaluation of equipment effectiveness. Accordingly, OEE identifies production losses and other indirect costs. These losses are formulated as a function of a number of mutually exclusive components[14], namely: Availability (A), Performance (P) and Quality (Q). Thus, OEE is:

$$OEE = Availability \times Performance \times Quality \quad (1)$$

The OEE is also a steering tool in a Lean maintenance approach. This is considered more than an evolution or update of the TPM. The figure 1 [15] summarizes the principles and steps of Lean maintenance. It shows OEE as a means of piloting:

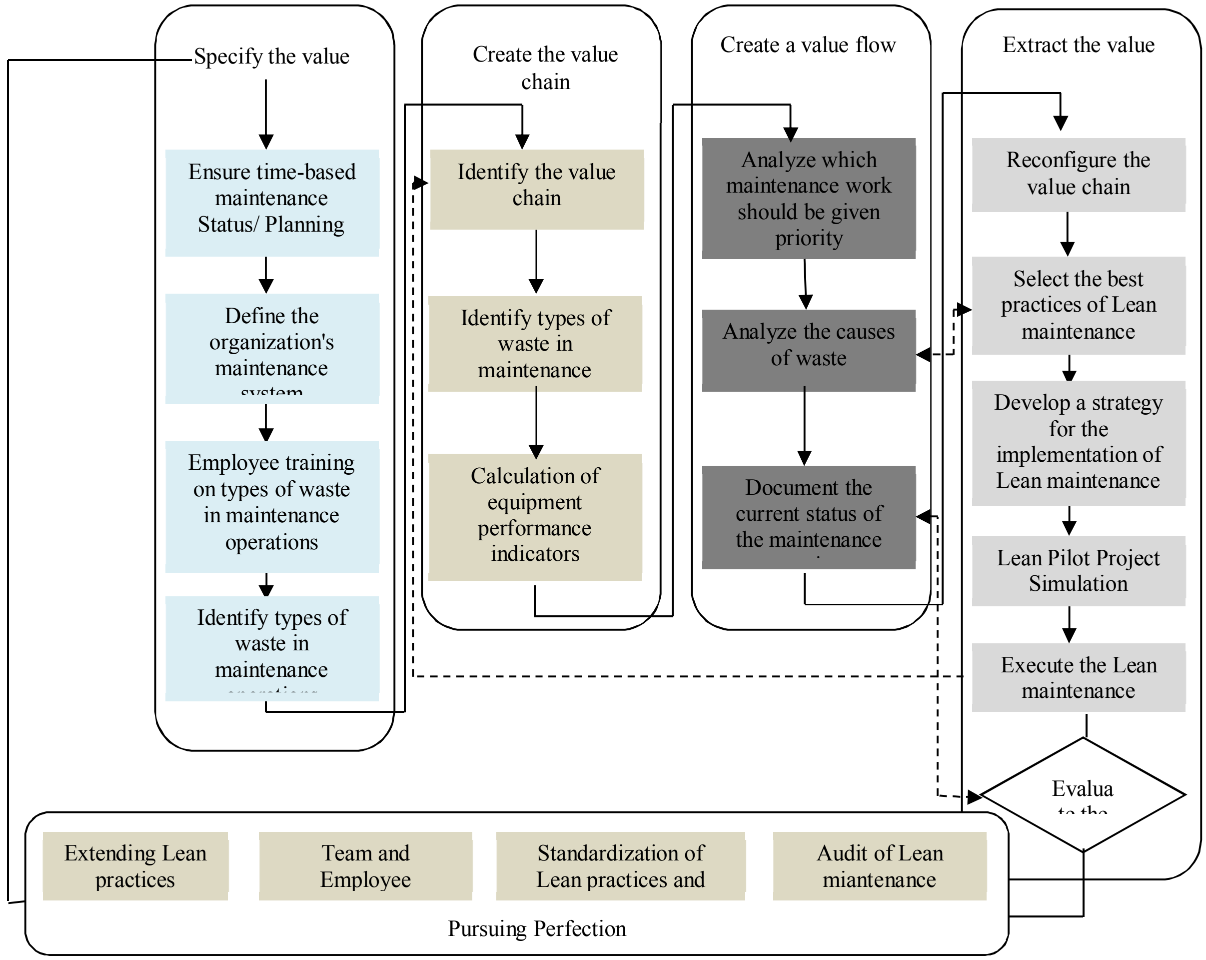

Fig. 1. Lean maintenance Roadmap (Mostafaa et al., 2015)

2.2. OEE factors

The availability factor measures the total time that the system is not operating because of breakdowns, set-ups, adjustments and other stoppages [16]. It is traditionally calculated using the Nakajima's formula presented below. In this formula, loading time refers to the equipment's total length of operation after any deduction of planned activities that may have disrupted production. Such activities include: scheduled and planned maintenance, official production breaks, process improvement initiatives or equipment tests, maintenance performed by production tool operators:

Availability is:

A = Run Time / Planned Production Time (2)

Performance (P) is:

P = (Ideal Cycle Time × Total Count) / Run Time (3)

Quality (Q) is:

Q = (Input – Volume of quality defects)/Input

2.3. Synthesis

In brief, a lot of research has been published on OEE. However, we found that there is a lack on a model to predict OEE target in accordance with the organization's strategy if the current OEE is known. Indeed, fixing a target is a management act because the choice of the objective to be obtained guides the managers to have an idea about individual performance. The Strategic Visions can be complex to communicate, but breaking down the objectives into concrete ones will facilitate the communication process management. In this way, objectives form a crucial link between the strategy and day-to-day operations. OEE target is a powerful management tool that can help to develop an action plan to better control the process. The OEE target can be achieved by means of the objectives of maintenance, production, and quality. It should be noted that the absence of a predefined method for setting the OEE targets is an obstacle facing organization managers to perform better. This is what justifies our interest to determine the OEE target. The use of an efficient model to determine the OEE target allows to control process and therefore to gain in production efficiency, quality, and lead time. Therefore, a model that would be based on a decision-support method seems to be a relevant tool to determine the target to be reached by OEE. It is a matter of developing a model that calculates the OEE target in accordance with the organization's strategy based on the comparing pairs of decision criteria method. The OEE target can be set by taking into account the relative weights of the three main components of the OEE in the organization's strategy. Consequently, the OEE target provides a synthetic vision to guide operational decision-makers (maintenance, production...) to better control their resources and achieve their objectives.

3. Methodology

In this study, a model that allows to calculate the OEE target to be reached has been developed. The target is therefore to highlight the weights distribution concerning the three main components of the OEE in the organization's strategy in order to determine the target to be set. In order to achieve the objective of this study, the methodology adopted is based on the following:

- **Step 1:** The formulation of the OEE target is based on the fuzzy logic principle and two other decision support methods. Such a formulation takes into consideration the three components of OEE as well as the importance of each constituent in relation to the others according to the organization strategy.
- **Step 2:** An experiment is conducted to test the relevance of the proposed model in a manufacturing organization that operates in the agri-food sector. Next, the obtained results were presented and discussed.

4. Proposed Model

4.1. Proposed model for setting the OEE target

Determining the OEE target is calculated with reference to its three values resulting from each main constituent and their corresponding weights. The OEE target is quantified by the following mathematical formula:

$$\mathrm{OEE(target)} = T_P * w_p + T_A * w_a + T_Q * w_q \geq \mathrm{OEE(classic)}\big(= T_P * T_A * T_Q\big) \quad (5)$$

$$w_p + w_a + w_q = 1(5) \quad (6)$$

$$0 < T_P, T_A, T_Q \leq 1 \quad (7)$$

$(T_P, T_A, T_q,)$: Three main OEE constituents

(w_p, w_a, w_q): Relative weights of the main OEE constituents

These weights are determined using the decision criteria pair-wise comparison method described as follows:

Either X_{ij} : the importance of criterion "i" in relation to criterion "j".

And B_{3*3} is the matrix of the three criteria considered: maintenance, production and quality.

$$B_{3*3} = \begin{bmatrix} X_{11} & X_{12} & X_{13} \\ X_{21} & X_{22} & X_{23} \\ X_{31} & X_{32} & X_{33} \end{bmatrix} \quad (8)$$

The weights are calculated by the normalized geometric mean of each line:

$$\mathrm{GM_i} = \left[\prod_{j=1}^{N} X_{ij}\right]^{1/N} \quad (9)$$

$$w_i = \frac{\mathrm{GM_i}}{\sum_{i=1}^{N} \mathrm{GM_i}} \quad (10)$$

With GM_i is the Geometric Mean of the line "i" and w_i the criterion "i" weight.

And to define the X_{ij} (scores), the approach suggested by [18] was adopted, which is based on two steps:

Step 1: This step represent graphically the linguistic variables with their fuzzy sets, then subdivide the discourse universe [0 i] into a number varying from two to eleven fuzzy sets.

And then represent the max and min functions to define the maximum and minimum score values.

$$\mu_{\max(x)} = \begin{cases} x & \text{if } 0 \leq x \leq i \\ 0 & \text{otherwise} \end{cases} \quad (11)$$

$$\mu_{\min(x)} = \begin{cases} i - x & \text{if } 0 \leq x \leq i \\ 0 & \text{otherwise} \end{cases} \quad (12)$$

The intersection of each membership function with the two max and min functions allows to determine the maximum and minimum score values.

$$\mu_L(M_i) = \mathrm{Sup}_x(\mu_{\min}(x) \cap \mu_{M_i}(x)) \quad (13)$$

$$\mu_R(M_i) = \mathrm{Sup}_x(\mu_{\max}(x) \cap \mu_{M_i}(x)) \quad (14)$$

Step 2: This step converts verbal judgments (fuzzy sets) to scores (deterministic values).

The total score of each fuzzy set is defined by :

$$\mu_T(M_i) = \frac{\mu_R(M_i) + 1 - \mu_L(M_i)}{2} \quad (15)$$

Finally, Table 1 summarizes the relative scores of each criterion in relation to each other:

Tab. 1. Fuzzy sets with their scores

Linguistic terms	$\mu_R(M_i)$	$\mu_L(M_i)$	Score : $\mu_T(M_i)$
…..	…	…	…
…..	….	….	…

4.1. Case stady

The study presented here concerns a production tool in a manufacturing organization operating in the agri-food sector. This production tool is a bottleneck in the production line and it is used in a continuous production line. This organization was chosen following a multi-criteria cooperation between our research structure and this company.

The proposed model is applied in two phases:

1st phase: define the X_{ij} scores

Using the approach described above, we can convert linguistic terms into scores. Such an approach simplifies the definition of fuzzy sets relating to the decision criteria. The proposed approach can be applied in two steps:

Step 1: The linguistic terms have to be transformed into fuzzy numbers in order to calculate the associated deterministic values. Given the choice of the type two scales, we were able to calculate the deterministic "score" values associated with the linguistic terms whose values are shown in table 2.

Step 2: To standardise and simplify the interpretation given by different resources,convert fuzzy sets (verbal judgments) to deterministic values (scores).

Either the fuzzy sets M1 and M2 are described by the triangular membership functions (16) and it's represented in figure (2):

$$\mu_{M_x}(x) = \begin{cases} 3.33x \text{ if } 0 \le x \le 0.3 \\ 1.75 - 2.5.x \text{ if } 0.3 \le x \le 0.7 \\ 0 \text{ otherwise} \end{cases} \quad (16)$$

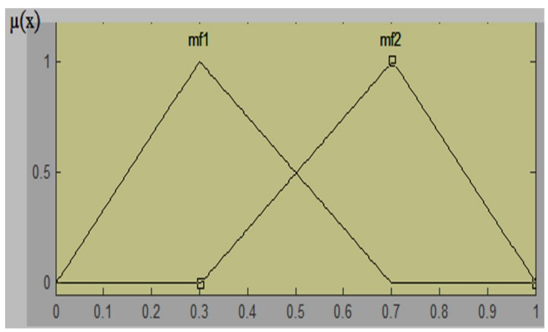

Fig. 2. The membership functions corresponding to the two fuzzy sets

Taking into account the position of the membership function in the discourse universe, the max and min functions determine the maximum and minimum values (Figure 3).

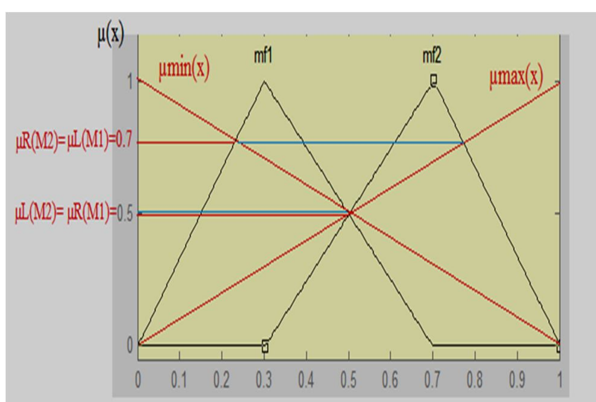

Fig. 3. The minimum and maximum scores of the fuzzy sets "M1" and "M2".

The intersection of each membership function with the two functions max and min allows to determine the maximum $\mu_L(M_i)$ and minimum $\mu_R(M_i)$ score values and then to calculate the total score of each fuzzy set $\mu_T(M_i)$.

Finally, Table 2 summarizes the fuzzy set scores:

Tab. 2. Fuzzy sets and their corresponding scores

Linguistic terms	Interpretation	$\mu_R(M_i)$	$\mu_L(M_i)$	Score : $\mu_T(M_i)$
Not important	Criterion is less important than another	0.5	0.7	0.4
Important	Criterion is more important than another	0.7	0.5	0.6

Phase 2: Determining the decision criteria weights

The organization's strategy considers that quality is less important than maintenance, production is more important than maintenance, and quality is less important than production. Taking into account this strategy deployed by the organization and the scores presented in Table 2, the weights of the three criteria are extracted by using the comparison by criteria pair method:

Consider X_{ij}: the importance of criterion "i" in relation to criterion "j" and it corresponds to Score : $\mu_T(M_i)$. And the considered matrix B_{3*3} of the three criteria:

$$B_{3*3} = \begin{bmatrix} 1 & 0.6 & 0.6 \\ 0.4 & 1 & 0.6 \\ 0.4 & 0.4 & 1 \end{bmatrix} \quad (17)$$

Therefore, Table 3 summarizes the three criteria weights:

Tab. 3. Weights of the three criteria

Criterion	GMi (Geometric Mean)	Wi (Weights)
Production	0.63	0.34
Maintenance	0.71	0.38
Quality	0.54	0.28

5. Results and Discussion

The Overall Equipment Effectiveness is a means to control and improve the manufacturing process efficiency. The purpose of this study is to give a new method to calculate the OEE target of critical production tool. This will help and guide organization managers to pilot their activities correctly.

In order to do this, the first step is to collect data on the different OEE components: performance, availability and quality. Thus, Table 4 summarizes the experimental results of the proposed OEE target calculation model:

Tab. 4. Comparison of the results of the new proposed model and the classical method

	Onput				OEE objective by the proposed model
				OEE=Tp*Td*Tq	
Week	Tp	Td	Tq		
1	60,50 %	59,50 %	70,00 %	25,20 %	
2	62,00 %	58,00 %	72,50 %	26,07 %	62,78 %
3	63,00 %	59,00 %	72,00 %	26,76 %	63,42 %
4	65,00 %	61,00 %	75,00 %	29,74 %	64,00 %
5	67,00 %	60,00 %	72,00 %	28,94 %	66,28 %
6	70,00 %	62,00 %	76,00 %	32,98 %	65,74 %
7	69,00 %	65,00 %	74,00 %	33,19 %	68,64 %
8	72,00 %	66,00 %	76,00 %	36,12 %	68,88 %
9	71,00 %	63,00 %	71,00 %	31,76 %	70,84 %
10	74,00 %	67,00 %	77,00 %	38,18 %	67,96 %

11	75,00 %	68,00 %	79,00 %	40,29 %	72,18 %
12	76,00 %	68,00 %	78,00 %	40,31 %	73,46 %
13	78,00 %	67,00 %	81,00 %	42,33 %	73,52 %
14	78,50 %	71,00 %	83,00 %	46,26 %	74,66 %
15	81,00 %	70,00 %	87,00 %	49,33 %	76,91 %

Using the formula (5), the OEE target for the first week is : $\text{OEE (Target) week N°2} = 60.5 * 0{,}34 + 59.5 * 0{,}38 + 70 * 0{,}28 = 62.78\ \%$

Then, the obtained results were represented graphically (Figure 5) to show the current OEE with the target determined by the proposed model:

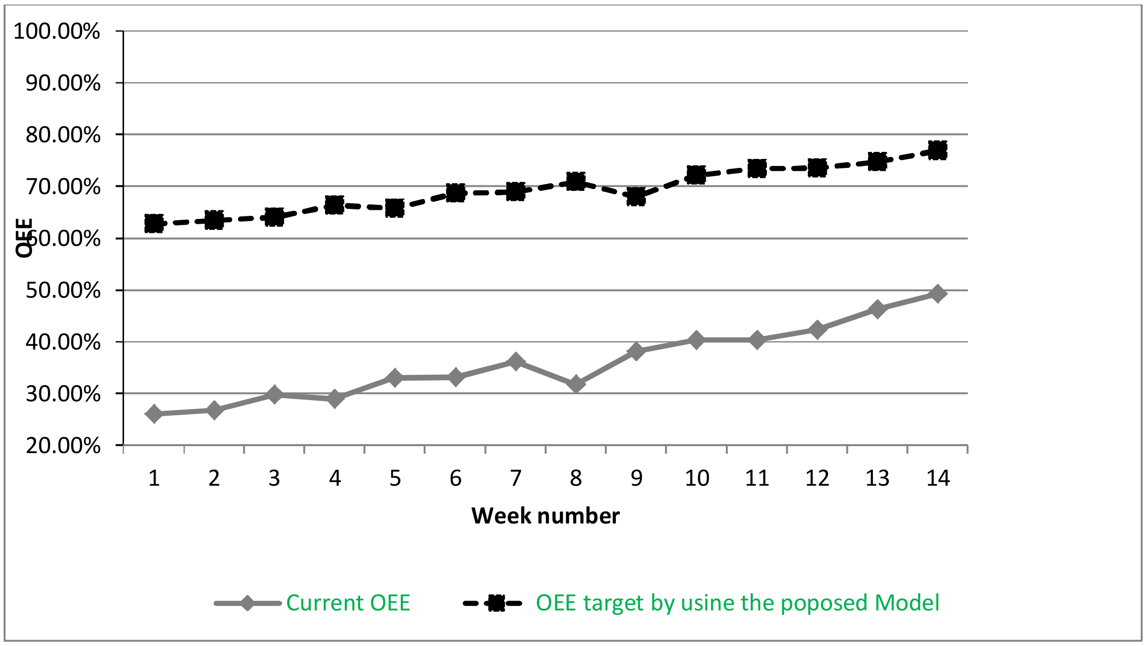

Fig. 4. Graphical representation of the OEE target calculated by the proposed model

The analysis of the data collected over a fourteen-week period shows that the result of the proposed model sets 81.71% as the target to be attained in the second week (near to OEE =74.05% obtained). On the one hand, the pertinence of the proposed model resides in its ability to help managers to identify the influence of various major losses on the OEE. On the other hand, it also helps to define the important points to organize the resources towards an improvement of the three performance rates.

It is clear that in the classical approach, the OEE target is set only on the basis of the organization's history and the managers' views without using a scientific and a quantitative method. Also, they consider that the three input elements of OEE have identical weight. Thus, this can generate a disruption in the organization's strategic orientations. This, therefore, puts into question the OEE target exactitude and precision if this classical approach is adopted.

On the contrary, the proposed model makes it possible to overcome all the imprecision of the classical approach. The proposed model defines the OEE target in accordance with the organization's strategy. This is done by giving the weights to the three main OEE constituents. Consequently, this model makes it possible to provide a synthetic vision to guide the operational decision-makers (maintenance, production...) to better control their resources and achieve their objectives.

The results of the study imply that the proposed model will be useful for companies to initiate the activities improvement for the good performance, availability, and quality management of their equipments.

6. Conclusion

In this paper, we have proposed and tested a model based on a decision-support method to calculate the OEE target. To illustrate the application of this model, a case study was

carried out in an industrial organization. The data used in this study were obtained by a technical team. Such a team is made up of experts and staff who know and use the production tool that is the subject of the case study. The experiment allowed as to verify and validate the proposed model.
The obtained results show that the OEE target determined by the proposed model is closer to the attained results. This makes it very easy to guide managers in their action plans to control the equipment such as gains in efficiency, quality, and lead time reduction.
This study can serve as a starting point for further future research. The results of the current study are applicable in other sectors. Future research should be directed towards testing the proposed model over a longer period of time employing other membership functions in the 4.0 Industry.

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