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A structured approach based on AHP and Fuzzy Logic to estimate value of industrial assets

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Abstract. Today the importance of the evaluation of assets within an industrial company depends mainly by the influence they have on production costs and, thus, on profit of goods and services. The literature suggests the industrial appraisal for rational assessment of tangible assets of industrial company. The estimation method does not permit to analyze technical and operating parameters that affect the value of the asset. The determination of the value of a machinery, makes by a buyer, results to be a process that considers two aspects: a technical/economic aspect, related to characteristics and to performances of the good, and a subjective aspect, that concerns the perception and the value given to specific characteristics that define the value by the side who acquires it. The technical/economic aspect can be deduced across analytical evaluations of characteristics of object; the subjective aspect, instead, that has bearing upon the relations that the previous characteristics have on the final value of the good, must be gotten necessarily by qualitative evaluations that must however, leaving from same considerations, conduct to non discordant evaluations. The aim of this work, therefore, is to propose a structured model able to determine the residual value of industrial assets through the analysis of technical and managerial factors.

Keywords: AHP, Fuzzy Logic, industrial appraisal, “second-hand” asset

1. Introduction

The determination of the value of a machinery made by a potential buyer appears as a process that considers two aspects: a technical/economic aspect, based on its characteristics and performances, and a subjective aspect, based on the perception of the value given by the buyer to these characteristics. While the technical/economical aspect can be obtained by analytical assessments of the asset’s characteristics, the subjective aspect, that affects the connections between characteristics and value of the final good, must necessarily be obtained through qualitative assessments. However, starting from the same specifications, the appraisal must lead to results without significant differences.

The assessment of industrial assets is a problem studied by the “industrial appraisal” discipline that arises from the need to provide estimates (ie, judgments of value) of property. The value opinion is conditioned by the practical purpose of the appraisal, in fact it should be valid independently from the operator who evaluates the asset (the two aspects of the judgment, in practice, must not be manifestly inconsistent). Often the classical appraisal theory needs to be based on a thorough assessment of the market but, in other cases, other types of evaluation, based on cost/effectiveness analyses, can be applied. The estimation method is the procedure that determines the value of an asset. Traditionally it is divided into the following phases:

1) Recognition of the problem. Need to understand the practical purpose of the assessment;

2) Choice of the estimation time. The estimation, in fact, depends on the time at which it is made;

3) Choice of the economic aspect. This phase is crucial because the value of property changes with the point of view from which it is estimated. Indeed, determining the market value or the production cost changes completely the view, as well as the transformation value compared to the subrogation value.

4) Determination of the method. It must be consistent with the quantity and quality of available data.

The purchase of a “second-hand” good requires managerial skills and techniques to assess with good approximation, the wear conditions and therefore the actual value of the property in relation to a similar new asset available on the market. The definition made by the buyer of a realistic value for the good on sale (value associated with its utility for the specific purpose), reduces the scope for uncertainty and conducts to more effective negotiations [1, 2, 3]. Similarly, the definition of the value, compared to a similar new good, made by the seller can get an assessment little influenced by subjective phenomena which, generally, tend to drive up the estimated value and make more difficult the negotiations [4, 5].

The present work fits in with this background by proposing a procedure able to estimate the most likely value of an asset at the moment of the estimate and aimed to provide a reference model for sharing the experience on the evaluation methodology within the organization [6, 7, 8]. The value of an industrial asset depends on many parameters that can be grouped according to some evaluation purposes. The goals identified in this work are:

1) Exploitation (measures the wear according on the hours of use of the machinery);

2) Exercise (measures the charges for maintenance, energy, depreciation and operators);

3) Obsolescence (measures the impact of production performances, degree of automation, versatility, environmental impact, safety and flexibility on the value of the machinery);

4) Start-up (loop check and testing);

5) Relocation (transport, disassembly and assembly, installation, equipment).

The “aim parameters” provide a measure of the specific requirements. These aims, in order to be analyzed, need to be decomposed into multi-level evaluation structures. The structure of the parameters leads to the detection of characteristics which are easily assessable by comparing asset to surrogate that represents the best technical solution available at the time of the evaluation.

2. Schematization and problem formulation

The proposed estimation model is based on a method of comparison with a surrogate asset. The residual value of the machinery *V(t)* is defined by the following formula:

$$V(t) = V_S(t) \cdot I_v(t) - O_t(t) \tag{1}$$

Where $V_S(t)$ is the value of the surrogate asset, $I_v(t)$ is the parameter of the residual value of the machinery and $O_t(t)$ is the transfer expense. It measures the loss of value of the machinery due to the utilization and to the age, at the time *t* of the estimation. To this value the expenses for the physical transfer (disassembly, transport, reassembly and other accessory costs) have been subtracted. Depending on the evaluation purposes, the value $V_S(t)$ of the surrogate asset can be obtained by considering incentives and promotions that may reduce the purchasing cost. The $I_v(t)$ value is based on specific indicators ("aim parameters”) designed to measure the following technical aspects:

1) Utilization (I_s). It measures the degree of wear of the machinery being assessed

2) Operation (I_e). It evaluates the operating costs resulting from the use of the machinery

3) Obsolescence (I_o). It measures the speed of production, automation, versatility and safety.

4) Start-up (I_a).

The “appraisal parameter” is expressed by the following formula.

$$I_v(t) = f(I_s(t), I_e(t), I_o(t), I_a(t)) \tag{2}$$

Equation (2) considers that the parameters are not comparable in absolute terms and neither by weighted averages because they measure different aspects of the machinery value. Since there is no correspondence between value of the “aim parameters” and their effect on the global evaluation, the function that defines the “appraisal parameter” starting from the “aim parameters” has been defined through the Fuzzy Logic theory. The Fuzzy Logic has been applied to compare couples of “aim parameters” and, through simple linguistic rules, to obtain a set of 6 "summary indexes" (Example: I_{se}) which, opportunely weighed (eg: through the value p_{se}), will provide the “appraisal parameter”.

$$I_v(t) = f(I_s(t), I_e(t), I_o(t), I_a(t)) = p_{se} \cdot I_{se} + p_{so} \cdot I_{so} + p_{sa} \cdot I_{sa} + p_{eo} \cdot I_{eo} + p_{ea} \cdot I_{ea} + p_{oa} \cdot I_{oa} \tag{3}$$

The “summary indexes” are utilized to measure the subjective aspects of the appraisal. The use of fuzzy logic for determining the “summary indexes” will be shown in the following paragraphs. The “aim parameters”, which determine the “summary indexes”, are organized in a multilevel structure in order to measure more specific aspects within the same aim area.

3. “Aim parameters” structure

After a deep analysis of technical and managerial factors that may affect the value of the used machinery, the parameters has been defined and organized in a multi-level structure able to achieving, at lower levels, the definition of easily measurable technical parameters (see Table 1).

TABLE I. TABLE 1 – STRUCTURE OF “AIM PARAMETERS”

Level 0	Level 1	Level 2
I_s – Utilization	I_{s1} – Availability	
	I_{s2} – Scraps	
I_e – Operating costs	I_{e1} – Operator cost	
	I_{e2} – Energy	
	I_{e3} – Amortization	
	I_{e4} – Maintenance direct costs	I_{e41} – Internal maintenance operators
		I_{e42} – External maintenance operators
		I_{e43} – Materials
	I_{e5} – Maintenance indirect costs	I_{e51} – Prevention maintenance
		I_{e52} – Breakdown
I_c – Obsolescence	I_{o1} – Capacity	
	I_{o2} – Automation	
	I_{o3} – Versatility	
	I_{o4} – Safety & Environmental	I_{o41} – Vibration
		I_{o42} – Noisiness
		I_{o43} – Emissions
		I_{o44} – Effluents
I_a – Start-up	I_{a1} – Loop check	
	I_{a2} – Tuning	

The indicators above defined shall be calculated starting from the lowest levels of the structure. Table 2 describes the low-level parameters. They are determined by comparing the asset object of the appraisal and the surrogate asset whose value $V_s(t)$ is known. For each indicator, the low-level parameter must be compared to the equivalent surrogate value (*SA*) (see Figure 1).

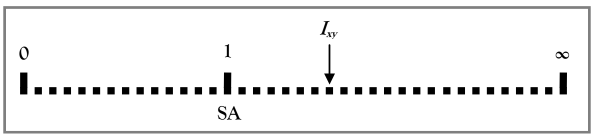

Figure 1 – Value assignment of low-level indicators

TABLE II. LOW-LEVEL PARAMETERS

Parameter	Technical/Economical aspect
I_{s1}	Operating time
I_{s2}	Average scraps
I_{e1}	Operator cost
I_{e2}	Nominal power
I_{e3}	Amortization
I_{e41}	Internal maintenance costs
I_{e42}	External maintenance costs
I_{e43}	Spare parts + consumption of materials
I_{e51}	Loss production costs for preventive maintenance
I_{e52}	Loss production costs for break down
I_{c1}	Average capacity
I_{c2}	Automation
I_{c3}	Typology of workable product
I_{c41}	Level of vibration
I_{c42}	dB level
I_{c43}	Emissions
I_{c44}	Effluents
I_{a1}	Loop Check costs
I_{a2}	Tuning costs

The values assigned to the parameters in their aim area can have opposing effects on the value of machinery. For example, a value greater than 1 for the parameter which measures the "average capacity" has a positive effect on the value of machinery; vice versa, a value exceeding 1 of the "average scraps" has an absolutely negative effect.

3.1. AHP method to define weights of the parameters

Once the low-level parameters are known, the high-level parameters and the "aim parameters" can be calculated. At every level of the structure, the weight of each parameter must be evaluated. So the subjective aspects affect the weights which measure the relative importance of the parameters. The decision maker will draw a comparison with the indicators of the same level and will assign the importance value according to the Saaty's semantic scale [9] (see Table 3).

TABLE III. SAATY'S SEMANTIC SCALE

Grade	Semantics
1	Equal (equally important)
3	Moderate (moderately/weakly/slightly more important)
5	Strong (strongly more important)
7	Very strong (very strongly/demonstrably more important)
9	Absolute (extremely/absolutely more important)
2,4,6,8	Compromises/between

With reference to one of the parameters (for the others the procedure is the same), if a_{ij} is the semantic value of I_{ai} parameter respect to I_{aj}, a_{ij} is equal to $1 / a_{ji}$ (the coefficient matrix a_{ij} is a square and reciprocal matrix). In addition, indicated with w_i the relative weight of I_{ai}, and with n the number of indicators to compare, it is possible to determine the value of w_i through the following system:

$$\begin{cases} \sum_{j=1}^{n} a_{ij} \cdot w_j = \gamma \cdot w_i \\ \sum_{i=1}^{n} w_i = 1 \end{cases} \tag{4}$$

The consistency index $CI = (\gamma-n) / (n-1)$, which measures the internal consistency of the a_{ij} values, can be calculated through w_i and γ. The determination of the weights of the "summary indexes" is calculated similarly using the just described AHP method.

3.2. Fuzzy Logic to define the "summary indexes" (Use "Header 2" style)

Once the value of the "aim parameters" have been determined the assessment parameter has been calculated through the fuzzy logic.

The steps for the implementation of the method are:

1) Definition of fuzzy sets;

2) Fuzzification;

3) Definition of inference rules;

4) Defuzzification.

The definition of fuzzy sets permits to associate the value of a parameter to a set of verbal predicates that express the value in a “faded” way. To simplify the subsequent definition of inference rules, each parameter is expressed as a function of three verbal predicates in accordance with the fuzzy logic rules. The predicates chosen for this application are: “High”, “Medium” and “Low”. Therefore an “obsolescence parameter” will say high, medium and low with a membership value defined by the fuzzification step. This step defines the so-called membership functions [10] and, therefore, allows to associate the belonging values to the predicates of each “aim parameter”. The rules of inference, however, define the value of the predicates associated with output variables. As above mentioned, the output variables are represented by the “summary indexes” (see Table 4).

TABLE IV. SUMMARY INDEXES

“Summary Index”	**“Aim parameters”**
I_{se}	$I_s \otimes I_e$
I_{sc}	$I_s \otimes I_c$
I_{sa}	$I_s \otimes I_a$
I_{ec}	$I_e \otimes I_c$
I_{ea}	$I_e \otimes I_s$
I_{ca}	$I_c \otimes I_a$

Table 5 shows the inference rules.

TABLE V. INFERENCE RULES

		I_a			I_c			I_e		
		H	M	L	H	M	L	H	M	L
I_s	H	L	L	L	M	M	L	L	L	M
	M	M	M	H	H	M	L	L	M	H
	L	M	H	H	H	H	M	M	H	H
I_e	H	L	L	M	M	H	L			
	M	L	M	H	H	M	L			
	L	M	H	H	H	H	M			
I_c	H	M	H	H						
	M	M	M	H						
	L	L	L	L						

In the defuzzification step “faded” values of the “summary indexes” are reconverted in numerical values. (see Figure 2).

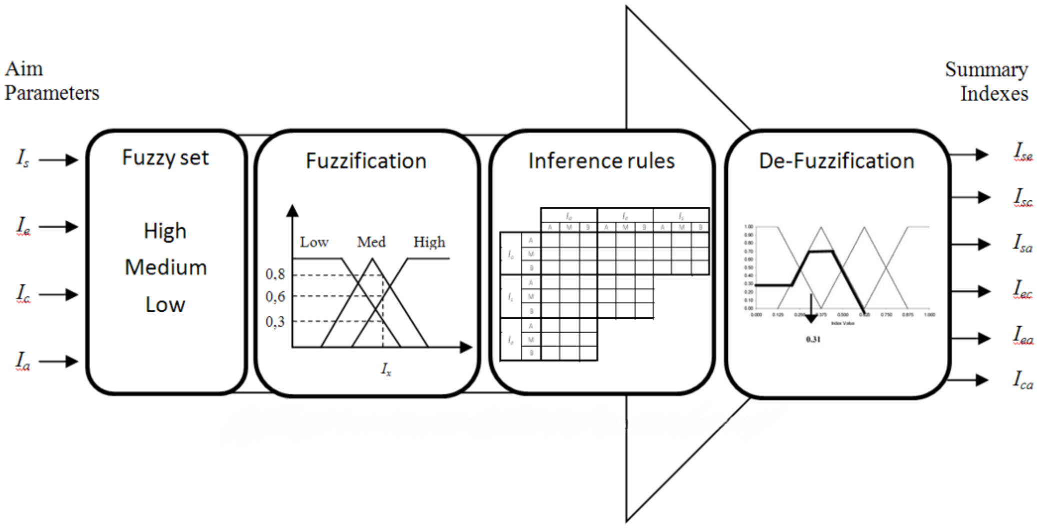

Figure 2 – Procedure to calculate the "summary index"

4. Experimentation

In order to verify correctness and effectiveness of the proposed model, an experimentation aimed at verify the estimated residual value of a machinery in 2 different companies, has been conducted. The selection of the companies was carried out considering the common characteristics of the machinery, such as type of material (dedicated machines), no need of special disposal and availability of spare parts. Both companies are engaged in the manufacture of rubber components (household appliances and automotive).

4.1. Case study 1

The first company produces technical components in rubber. The injection molding is made through the utilization of a latest generation press (Rutil® RSSX 2000/250). All the machineries has been recently renovated, their lifetime does not exceed 2 years. The company has organized the production in 3 shifts of 8 hours, the production volume (single product) is quite high. The machinery allows a production with very low waste, with little need for staff, whose role is limited to the extraction phase and maintenance. The maintenance is provided by internal operators, because of the simplicity of the interventions. The preventive maintenance plans have a very low incidence on production faults. Regarding environmental impact and work safety, the hydraulic machinery reuses the water through a recycling system, so no dangerous substances flow to the environment. Also the noise is within the limits and the vibrations are very low. It was also possible to quantify the costs related to the machinery start-up. Assuming, then, a physical transfer of the press for a distance of 30 km, the transferring cost was also quantified. It results rather high because of 2 vehicles are necessary: a truck equipped with crane to lift the machinery and another truck to transport it. The cost of the surrogate new machinery (*SM*) is equal to 150,000 €. The values calculated for parameters and weights are reported in Table 6.

TABLE VI. "AIM PARAMETERS" (CASE 1)

Level 1	Value	Level 2	Value	W	Level 3	Value	W
I_s	1.13	I_{s1}	1.10	0.72			
		I_{s2}	1.20	0.28			
I_e	1.03	I_{e1}	1.00	0.20			
		I_{e2}	1.00	0.30			
		I_{e3}	0.70	0.10			
		I_{e4}	1.19	0.20	I_{e41}	1.00	0.38
					I_{e42}	1.00	0.00
					I_{e43}	1.30	0.62
		I_{e5}	1.10	0.20	I_{e51}	1.10	0.83
					I_{e52}	1.10	0.17
I_c	0.80	I_{c1}	0.90	0.10			
		I_{c2}	0.90	0.10			
		I_{c3}	0.90	0.50			

Level 1	Value	Level 2	Value	W	Level 3	Value	W
		I_{c4}	0.86	0.20	I_{c41}	0.80	0.25
					I_{c42}	0.65	0.25
					I_{c43}	1.00	0.25
					I_{c44}	1.00	0.25
I_a	1.10	I_{a1}	1.10	0.50			
		I_{a2}	1.10	0.50			

The membership functions of the parameters are chosen basing on the expert knowledge about the analyzed parameters. Table 7 shows the values of the "summary indexes" and their weights.

TABLE VII. "SUMMARY INDEXES" (CASE 1)

Fuzzy sets	*Value*	*p*
I_{se}	0.896	0.23
I_{sc}	0.876	0.15
I_{sa}	0.272	0.05
I_{ec}	0.873	0.20
I_{ea}	0.876	0.30
I_{ca}	0.675	0.07

Therefore, using equation (1), the residual value of machinery is:

$$V = 150'000 * 0,836 - 6'000 = 119'400 €$$

This value reflects the estimates provided by the managers of the company, for whom the residual value of the machinery should be included between 80% and 83% of the subrogation value, that means between 120,000 € and 125,000 €. The value obtained with the suggested model has been also compared with the value obtained through classical appraisal methods. This comparison is shown in the chart of Figure 3.

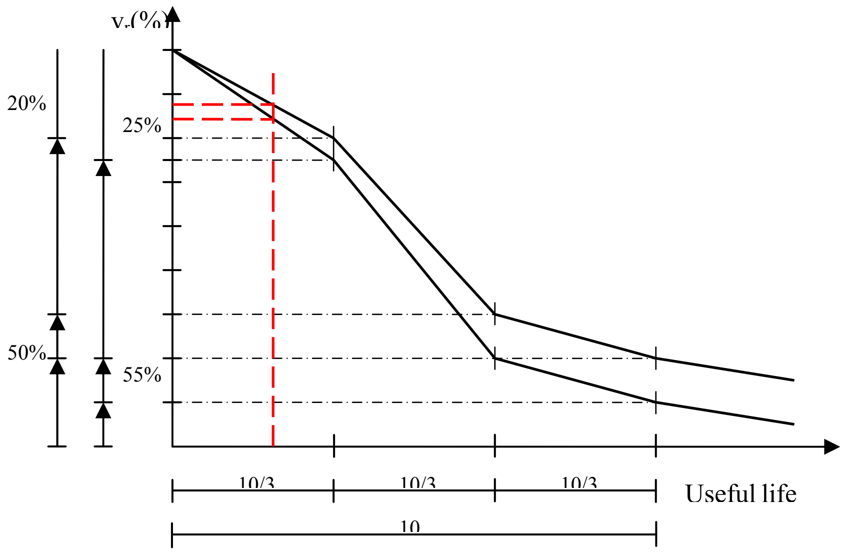

Figure 3 – Residual value with classical appraisal method (Case 1)

The classical methods puts the residual value in a range of 85% - 88% of the value of subrogation, not exactly corresponding to the examined reality, for which a range from 80% to 83% is considered.

4.2. Case study 2

The second company is a global leader in developing and manufacturing of sealing systems for chassis and guide systems for windows, with plants in America, China and Europe. In Italy there are two plants, one in the province of Turin and the second in province of Salerno. The plant of Salerno has currently 430 employees; the production is divided into three main stages: mixing, extrusion and finishing. At the last stage of the process presses "gooseneck" injection are present. They are currently used for the production of the seals mounted on the doors of the "new Punto" (199). The machinery is located within the finishing department. Following the logical scheme of the proposed model, we proceeded to the determination of its residual value. The table 8 shows the values of parameters and weights.

TABLE VIII. "AIM PARAMETERS" (CASE 2)

Level 1	Value	Level 2	Value	w	Level 3	Value	w
I_s	1.35	I_{s1}	1.40	0.52			
		I_{s2}	1.30	0.48			
I_e	0.96	I_{e1}	1.00	0.31			
		I_{e2}	0.90	0.23			
		I_{e3}	0.80	0.18			
		I_{e4}	1.13	0.14	I_{e41}	1.00	0.21
					I_{e42}	1.20	0.54
					I_{e43}	1.10	0.25
		I_{e5}	1.03	0.14	I_{e51}	1.00	0.74
					I_{e52}	1.10	0.26
I_c	0.89	I_{c1}	0.80	0.48			
		I_{c2}	0.90	0.11			
		I_{c3}	0.80	0.12			
		I_{c4}	1.08	0.29	I_{c41}	1.10	0.25
					I_{c42}	1.20	0.25
					I_{c43}	1.00	0.25
					I_{c44}	1.00	0.25
I_a	1.10	I_{a1}	1.10	0.49			
		I_{a2}	1.10	0.51			

Being the machinery over than the half of its useful life, the utilization factor takes a relevant value; the maintenance costs are quite important, but within an acceptable range; the technology has remained substantially unchanged for this type of production; start-up is rather expensive because the machine is composed by elements which need to be adjusted with extreme precision.

TABLE IX. "SUMMARY INDEXES" (CASE 2)

Fuzzy sets	*Value*	*p*
I_{se}	0.524	0.200
I_{sc}	0.648	0.200
I_{sa}	0.250	0.100
I_{ec}	0.721	0.100
I_{ea}	0.541	0.200
I_{ca}	0.320	0.200

The residual value of machinery is:

$$V = 54'000 * 0{,}505 - 2'000 = 25'270 \text{ €}$$

Also in this case the obtained value reflects the appraisal provided by the company managers, for whom the residual value of machinery should be about 25,000 €. The scheme proposed by the classical appraisal methods is shown in Figure 4. According to the classical appraisal method, the residual value of the machinery is to be included in the range 33% - 42% of the value of subrogation, while the expected percentage based on experience is about 45.5%, much closer to the 46,68% obtained with the proposed model.

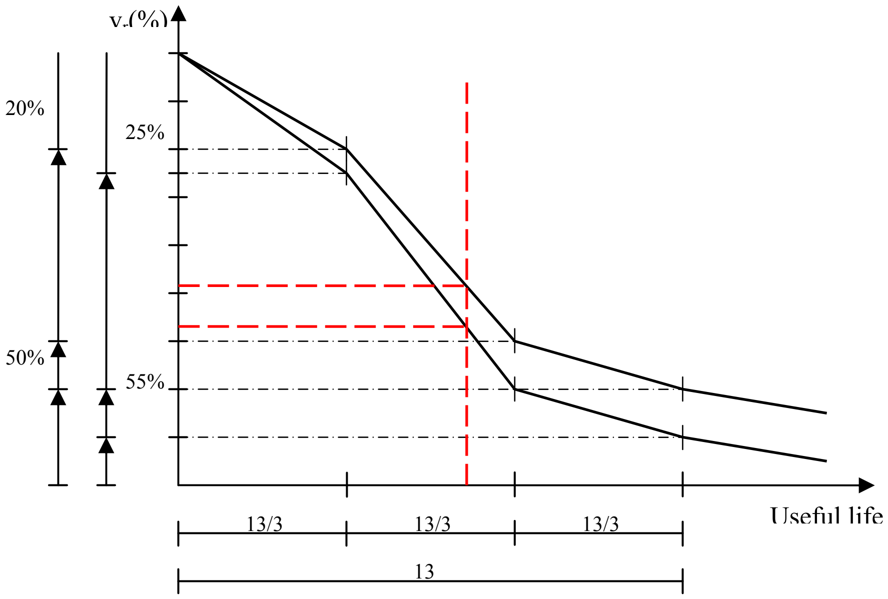

Figure 4 - Residual value with classical appraisal method (Case 2)

5. Conclusions

The proposed model has been structured to allow the definition of parameters able to give an objective appraisal of an industrial asset. It makes possible, through the application of the described procedure, to obtain an evaluation close to the real value from both the points of view of the owner and of the buyer. This aspect appears to be essential to restrict the domain of bargaining and to get a rapid conclusion of the negotiations. This accuracy has been achieved through the use of AHP and Fuzzy Logic theories, applied with the objective to provide an assessment consistent with the technical characteristics of the asset and, at the same time, close to the technician way of reasoning. The method permits an assessment of the value by combining the advantages of technical analysis, reasoning and experience. The experimentation has shown a better capacity to estimate correctly the value of industrial machineries. The results obtained from two similar machines, evaluated at different periods of their life, show an average improvement of the estimate, with an error that is around to 2.6%. Such error appears not only to be significantly lower than the average error of the classical methods (11.8%), but is also invariant with the age of the property. Vice versa, the error committed by the traditional method increases with the age of the asset (5.9% in case study 1 and 17.6% for the older machinery of case study 2).

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