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A Method for Evaluating Efficiency of Electronic Equipment with Environmental Impact

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Abstract. It is extremely important to evaluate the efficiency of equipment. There are some papers studying the method of evaluating efficiency, while they don't consider environmental impact. In this article a method for evaluating efficiency of electronic equipment with environmental impact is put forward, based on environmental impact model and the method of AHP, which is defined as E3IM. Every equipment has its own capacity index, representing the capacity that equipment can meet. First, we introduce environmental factors to each capacity index separately. Then we give formalized definition of environment and set environmental impact model based on the utility function of Logistic regression model. With environmental impact model, we can get the value of environmental impact. Finally we evaluate the efficiency of equipment with method of AHP. What is more, we apply C3IM to evaluate some equipment and compare the result with the result of ignoring environmental impact. By the research we can conclude that E3IM can be used in the evaluation of equipment and can make evaluation result more accurate and credible.

I. INTRODUCTION

With the development of technology, equipment with electronic information system is widely used in every aspect of society, which brings benefits to people. The evaluation of equipment can provide suggestions for people to pick up better equipment. Meanwhile, the fact that electronic equipment can be affected by both its internal factors and external environment factors must be considered.

There are many articles studying the impact of electromagnetic environment around equipment [1-4], which do not consider other environment factors, such as topography. Efficiency is a basic index to evaluate equipment. Several methods are applied for evaluating efficiency of equipment [7-8], which ignore environmental impact, making the result of evaluation ideal but untruthful.

We propose a method for evaluating the efficiency of electronic equipment with environmental impact, which is defined as E3IM. First, the environmental factors are classified and summarized. Then we set environmental impact and get the equipment capability index value. Finally, with the comprehensive evaluation model, the result of evaluating efficiency of equipment with environmental impact is calculated.

The main contributions of this paper are as follows. E3IM reflects the actual application environmental influences on electronic equipment and makes evaluation result more accurate and credible compared with other methods ignoring environmental impact. What's more, E3IM provides a comprehensively and rationally scientific basis for evaluating electronic equipment.

II. PRELIMINARIES AND DEFINITIONS

In this section, preliminaries and definitions are given to be a basic of E3IM.

A. Definitions of Environment

Environment represents material elements in science. In this paper we give a formalized definition of environment. We take environment as triples $E = \langle S, A, R \rangle$, where:

(1) S is geographical environment, which is the sum of all kinds of natural conditions.
(2)A is meteorological environment, which describes conditions and phenomenon of atmosphere.
(3) R is electromagnetic environment, which is the sum of electromagnetic phenomenon.

B. Environmental Impact Model

To give the digital depression of environment, environmental impact model is set. According to environmental impact model, exact value of environmental impact can be gotten. In this paper, Q is used to represent environmental impact model, namely:

$$Q = \frac{QE_a}{QE_i} \tag{1}$$

Where:

(1) QE_a is the efficiency of equipment considering environmental factors.
(2) QE_i is the efficiency of equipment ignoring environmental factors.

In this way, we describe the difference of equipment efficiency among the situation considering environment and the situation ignoring environment. Besides, Q is based on utility function, which will be introduced in Section III. Considering formalized definition of environment, we take environmental impact as triples $Q = \langle Q_r, Q_s, Q_a \rangle$, where:

(1) Q_r is electromagnetic environmental impact.
(2) Q_s is geographical environmental impact.
(3) Q_a is meteorological environmental impact.

Q_r、Q_s and Q_a represent the value of electromagnetic、geographical and meteorological environmental impact separately.

III. DESCRIPTION OF EVALUATING METHOD

Against the existing problems of current evaluating methods, E3IM uses environmental impact model technique to evaluate practical efficiency of equipment, making evaluation result accurate and credible. The main evaluating process is shown in Fig.1.

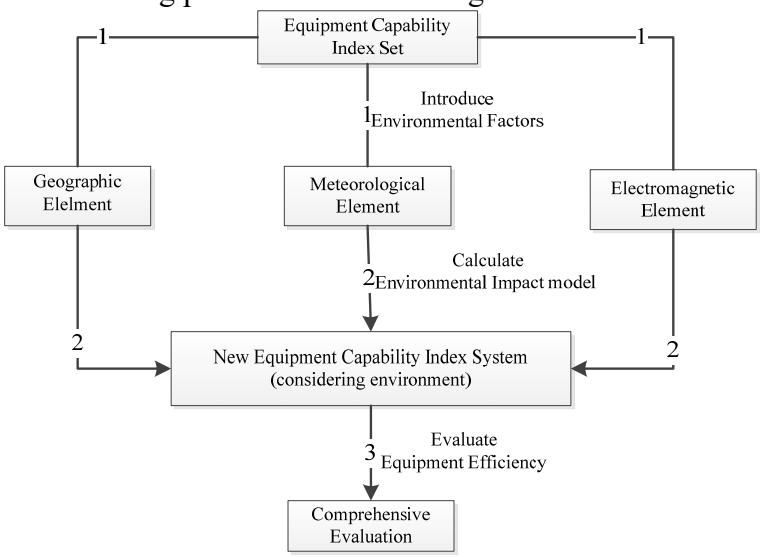

Fig.1. Equipment efficiency evaluating process with environmental impact

A. Introduce Environmental Factors

Efficiency evaluation of equipment must consider environment, for the reason that environment has a good effect on the efficiency of equipment. Each equipment has its own capacity indexes,

which are used to calculate efficiency. Therefore, evaluating efficiency of equipment with environmental impact is equal to calculate capacity indexes after introducing environmental factors. But it deserves to notice that different capacity index is related to different environmental factor.

B. Calculate Environmental Impact Model

(1) Establish the utility function

Utility function, which is objective physical value mapping to utility value, can reflect the subjective preferences of decision. In this paper, we take Logistic regression model as utility function for the reason that environmental factors are independent variables, while the change of efficiency is dependent variable. The expression is similar to $f(x) = \frac{e^{a+bx}}{1+e^{a+bx}}$. The shape of utility function is shown in Fig 2, which are based on historical data about the impact of environment on efficiency.

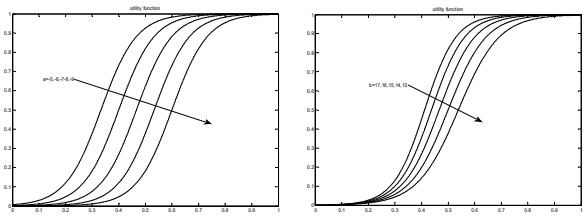

Fig.2. Shape of S curve utility function

Taking MLE to analyze historical data, we can get when a = -7 and b = 15, utility function can better reflect the change of $f(x)$. We pick up some utility functions that can better reflect the change of impact, such as:

$$f_1(x) = \frac{e^{-9+15x}}{1+e^{-9+15x}} \tag{2}$$

$$f_2(x) = \frac{e^{-7+14x}}{1+e^{-7+15x}} \tag{3}$$

$$f_3(x) = \frac{e^{-7+14x}}{1+e^{-7+14x}} \tag{4}$$

(2) Establish Environmental Impact Model

The practical environmental impact model is a descending type, so the relationship between environmental impact model and utility function is as:

$$Q(x) = 1 - f(x) \tag{5}$$

Therefore, the electromagnetic environmental impact model:

$$Q_m(x) = \frac{1}{1+e^{-9+15x}} \tag{6}$$

The geographical environmental impact model:

$$Q_s(x) = \frac{1}{1+e^{-7+15x}} \tag{7}$$

The meteorological environmental impact model:

$$Q_a(x) = \frac{1}{1+e^{-7+14x}} \tag{8}$$

Besides, x is the degree of natural environment, whose value space is [0, 1]. And the value of 0 refers to environment is well and has little effect on capacity index, and the value of 1 is opposite.

C. Evaluate Equipment Efficiency

(1) Calculation of equipment capability index ignoring environmental impact

Actually, each equipment capability index has a reached level, representing a level that capacity index has reached, and a required level, representing a level that capacity index is expected to reach. Though, required level is different from each other for the reason of personal preferences. Therefore, we make the capability index normalization by the equation:

$$u_{ij} = \begin{cases} min\left\{L, \frac{(L-1)s_{ij}+n_{ij}-L}{r_{ij}-1}\right\}, r_{ij} > 1 \\ 1, r_{ij} = 1 \end{cases} \tag{9}$$

Where:

- L refers to the level that capability index totally has, which is defined as 5 .
- s_{ij} refers to the level that each index has reached, whose range is [1,5].
- r_{ij} refers to the level that each index is required to reach, whose range is [1,5].
- n_{ij} refers to the level that normalization processing has been done, whose range is [1, 5].

(2) Calculation of equipment capability index considering environmental impact

The value of equipment capability indexes considering environmental factors, which is expressed as u_{ij}^*, are calculated by the equation:

$$u_{ij}^* = \begin{cases} u_{ij}, & Q = 0 \\ Q \cdot u_{ij}, & Q > 0 \end{cases} \tag{10}$$

(3)Calculation of comprehensive efficiency of equipment

In this step, we make use of AHP model technology to comprehensively evaluating equipment capacity. First of all, we get the weight of each capacity index by judgement matrix. Then combining the weight and capacity index, we can get the evaluation result of practical equipment efficiency considering environmental factors.

IV. EVALUATION EXAMPLE

In this section we take some equipment as an example to describe the evaluation method in detail. And then compare the result of E3IM with the result of ignoring environmental impact.

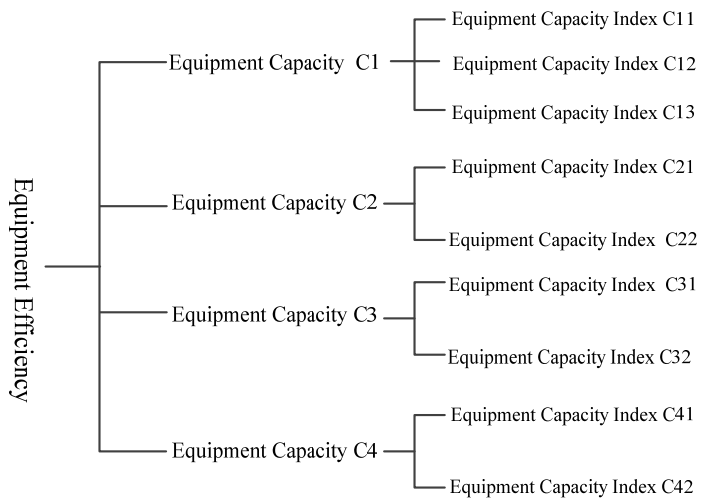

Fig.3. Equipment capability index sets

Fig.3 is equipment capability index sets ignoring environment with the method of Delphi [9-10]. Then we get the weight of every capability index by AHP method [5-6], which is shown is Tab.1.

Tab. 1. Total weight

Index	C11	C12	C13	C21	C22	C31	C32	C41	C42
w_{ij}	0.074	0.223	0.223	0.167	0.034	0.05	0.151	0.069	0.009

Then we make a consistency check on the result. Finding that the weight is able to be accepted.

A. Evaluating Efficiency with Environmental Impact

a. Introduce Environmental Factors

In practical application, the relationships between environmental factors and capability index are

as follows. Capacity index C11、C32 and C42 are mainly affected by Q_s. Capacity index C31 is influenced by Q_r. Capacity index C41 is easily impressed by Q_a. While others need not consider environmental factors. All these are shown in Tab 2(× represents none impact).

Tab.2. Environmental Factors on Capability Index

Index	C11	C12	C13	C21	C22	C31	C32	C41	C42
Environmental factor	Q_s	×	×	×	×	Q_r	Q_s	Q_a	Q_s

b. Calculate Environmental Impact Model

According to Tab.2 and environmental impact model, the value of environmental impact can be calculated based on the survey of environmental conditions. On the basis of observation and research, we take x as 0.6、0.6 and 0.5 in the Q_r、Q_s and Q_a separately. What's more, x is picked from [0, 1] respectively. Under the circumstance:

(1) The value of Q_r is 0.269, which affects equipment capability index C31.

(2) The value of Q_s is 0.881, which affects equipment capability index C11、C32 and C42.

(3) The value of Q_a is 0.5, which effects equipment capability index C41.

c. Evaluate Equipment Efficiency

(1)Calculation of equipment capability index ignoring environmental impact

Based on the equation (9), we make equipment capability index normalization, getting the values of capability index, which are shown in Tab.3. Besides, the value of capability index is integer, whose range is [1, 5].

Tab.3. Capability index value

capability index	C11	C12	C13	C21	C22	C31	C32	C41	C42
reached level s_{ij}	3	2	4	4	3	5	2	4	2
required level r_{ij}	5	3	4	4	5	5	3	5	5
level conversion u_{ij}	3	3	5	5	3	5	3	4	2

(2)Calculation of equipment capability index considering environmental impact

According to the value of environmental impact and equation (10), we can get the value of capability index considering environmental factors, which is expressed as u_{ij}^* and shown in Tab.4. (× refers to none environmental impact)

Tab.4. Capability index value considering environment

capability index	C11	C12	C13	C21	C22	C31	C32	C41	C42
level conversion u_{ij}	3	3	5	5	3	5	3	4	2
Impact model Q	0.881	×	×	×	×	0.269	0.881	0.5	0.881
level conversion u_{ij}^*	2.643	3	5	5	3	1.345	2.643	2	1.762

(3)Calculation of comprehensive efficiency of equipment

According to the equation:

$$C_{ce} = u_{ij}^* \times w_{ij} \tag{11}$$

And make use of Tab.4 and Tab.2, we can get the efficiency of equipment with environmental impact, whose value is 3.537.

B. Evaluating Efficiency without Environmental Impact

Evaluating efficiency of equipment without environmental impact only needs the third step of the method that the paper introduces, which considers environmental impact.

Through weight of each index in Tab.2 and the capacity indexes in Tab.3, we can calculate the value of efficiency of equipment ignoring environmental impact by the equation:

$$C_{te} = u_{ij} \times w_{ij} \tag{12}$$

And the value is 3.94.

C. Discussion

Now, we turn to the discussion of the results. In the experiment, it is easily to see that the value considering environmental factors of 3.537, is smaller than the value ignoring environmental factors of 3.94. For the fact that everything is not alone in the world, it must be affected by some external factors. For equipment, environmental factors will directly affect the efficiency of equipment. Then 3.94 represents the ideal equipment efficiency, while 3.537 refers to the actual equipment efficiency.

V. CONCLUSIONS

This paper puts forward E3IM, an evaluating method of electronic equipment with environmental impact. Example shows that the result of E3IM agrees with the reality and makes the efficiency result of electronic equipment more accurate and credible. What is more, the method provides certain references for the maintenance strategy of electronic equipment with environmental factors and is worth to spread. In the future, we aim to consider the resource problem, namely the quantity and species of resource, in the process of operating equipment [11]. Considering the operation process of electronic equipment under the combination of resource and environment contributes to control electronic equipment.

Acknowledgement

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