Available online at www.sciencedirect.com

SciVerse ScienceDirect

Procedia Engineering 15 (2011) 4377 – 4381

Procedia Engineering

www.elsevier.com/locate/procedia

Advanced in Control Engineering and Information Science

Equipment Support Quality Management Effectiveness Evaluation based on FCE Method

Xiang Zhao[a *], Gang Chen[b], QiangbinYue[c]

[a,c]Dep. Management Engineering , Shijiazhuang Mechanical Engineering College, 97Heping WestRoad, Shijiazhuang, China
[b]Hebei Providence Military Area, 107Yuhua East Road, Shijiazhuang, China

Abstract

For multi-criteria and multi-factors evaluating, the paper put forward a new fuzzy comprehensive evaluation model about equipment support quality management effectiveness evaluation (ESQMEE). An index system is presented. AHP method is applied to ascertain the index weight. At the end of the paper, a real example is given. The results of the example evaluation indicated the model is feasible and effective. It can give a support to improve the complex equipment management effectiveness.

© 2011 Published by Elsevier Ltd. Open access under CC BY-NC-ND license.
Selection and/or peer-review under responsibility of [CEIS 2011]

Keyword: quality management; effectiveness evaluation; AHP; fuzzy comprehensive evaluation

1 Introduction

Management effectiveness is the effect and benefit result of the running mechanism. The mechanism often expresses its effect as one or several forms, otherwise economic benefit. The equipment support quality management effectiveness evaluation (ESQMEE) system evaluating the quality management effectiveness of the whole equipment support process. It is a multi-criteria and multi-factors complicated evaluation. It's hardly to build a uniform and examinable criterion. The FCE method suits with the ESQMEE. In order to satisfy the equipment support quality management multi-dimension and multi-view request, a hierarchical index system is built. The AHP method is applied to calculate the index weight. ESQMEE system is established by the qualitative analysis and the quantitative computing.

2 Establishment of ESQMEE index system

According to the ISO9001 standard procedure model and after analyzing the characters in the operation process of the equipment supply support, we can assess the ESQMEE from four aspects which include daily management, resources management, implemental management and quality check management. The paper established the index system according to the reasonable and scientific

* * Corresponding author. Tel.: 13383318607.
E-mail address: zxcg2001@sina.com.

1877-7058 © 2011 Published by Elsevier Ltd. Open access under CC BY-NC-ND license.
doi:10.1016/j.proeng.2011.08.822

principles. It is shown in Fig. 1. Based on the AHP thought, the evaluation index system is divided into three levels. They are the target level, the sub-target level and the index level. The target level factor set is $U=\{u_1,u_2,u_3,u_4\}$. The sub-target level has four factor sets, including daily management $u_1=\{u_{11},u_{12},u_{13},u_{14},u_{15}\}$, resources management $u_2=\{u_{21},u_{22},u_{23}\}$, implemental management $u_3=\{u_{31},u_{32},u_{33},u_{34}\}$, and quality check management $u_4=\{u_{41},u_{42},u_{43},u_{44}\}$.These factor sets reflect the factors' influence on the ESQMEE.

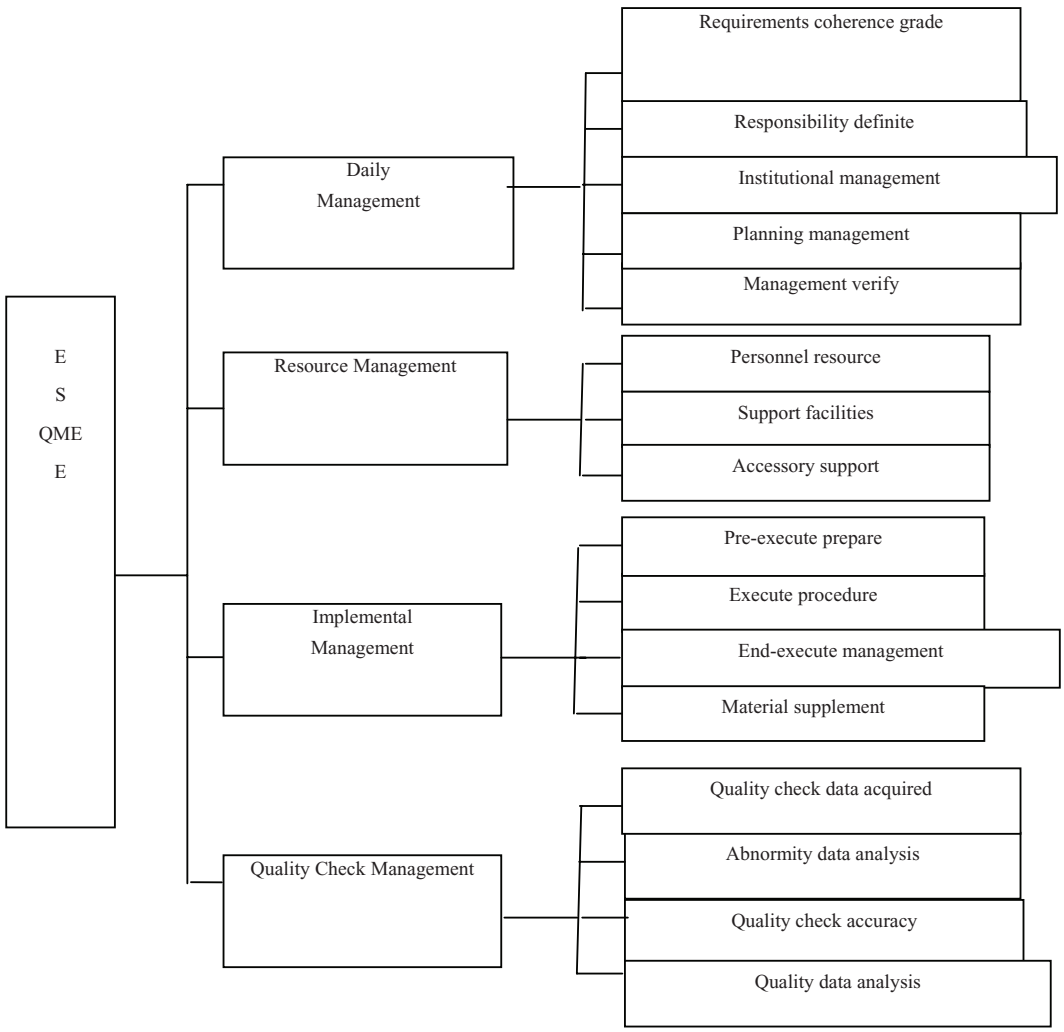

Fig. 1. The index system of the ESQMEE

3 The ESQMEE procedure based the FCE method

FCE is one of the application methods of fuzzy mathematics. Currently it has been applied in many fields. The main idea of the FCE method is: firstly, define a group of remarks (remark grade set), such as excellent, good, middle and bad. Secondly, obtain the index's evaluation results from the evaluation scores given by the experts. The results are translated to the dependent degree with the help of dependent function. Finally, we can get the final evaluation result by the fuzzy transform computing. That is making the fuzzy calculation about the index weight matrix and factor fuzzy evaluation matrix. The advantage of this method is that it can obtain the evaluation result by analyzing and computing the dependent degree and the index weight of the multi-factors which are difficult to quantify. The steps of establishing the model by applying FCE method are given as follows.

3.1 Constructing the evaluation factor set and remark set

The evaluation factor is the criterion to estimate the evaluation object. The actual evaluation factor sets are set up by analyzing and selecting the main requirements and restricted conditions, which can affect the process of effectiveness evaluation. According to the operation process of the equipment supply support effectiveness evaluation, the fuzzy comprehensive evaluation factor set can be constructed. For example, in the formula $U = \{u_1, u_2, u_3, u_4\}$, the daily management is u_1, the resource management is u_2, the implement management is u_3, and the quality check management is u_4. According to the system architecture, the scientific and independent principle, the remark set is divided into four grades:

$$v = \{v_1, v_2, v_3, v_4, v_5\} = \{excellent, good, middle, bad\}$$

3.2 Building the index weight matrix based on the AHP

There are a great number of methods to confirm the index weight, such as the expert evaluation method, minimum square sum method, AHP method and etc. The AHP is preferable and widely used by the analyzers. This method can analyze the important degree of the index more logically than other methods. Correspondingly, the result is more reliable which is treated with mathematics. The process of AHP to astern the index weight matrix is as follows:

(1)Assuming the factors at current factors are $A_1, A_2, ...A_n$, and their parent factor is C. Aimed at factor C, the comparison among the elements in A is made to obtain aij (described by nine-ranks[1]), which are recorded as A. A is the judgmental matrix be build. Then the judgmental matrix's largest latent root $\lambda_{\max}$ and the corresponding normalized latent vector $w = (w_1, w_2, ..., w_n)^T$ are figured out. At last, $w = (w_1, w_2, ..., w_n)$ is the index weight coefficient of the factors $A_1, A_2, ...A_n$ relative to the factor C.

(2) Consistency test (CI)

CR (Consistency Ratio) determines whether the index weight is reasonable. If CR is less than 0.1, the judgmental matrix is consistent. Otherwise the judgmental matrix must be adjusted. RI can be look from the table 1.

$$CR = CI / RI, \quad CI = (\lambda_{\max} - n)/(n - 1) \tag{1}$$

Table 1. Average random coincidence indicator

Matrix Rank n	1	2	3	4	5	6	7	8
R.I.	0	0	0.52	0.89	1.12	1.26	1.36	1.41

3.3 Building the matrix of dependent degree

The dependent degree is describes the dependent degree that an index is subject to a remark grade. First step using the FCE method is to build dependent degree function. Then the experts scrolled the factor's dependent degrees. The dependent degree vectors are calculated from the function transform. Finally, the fuzzy evaluation matrix is constituted by the dependent degree vectors. Assuming u_i is a single factor, we defined r_{ij} is the dependent degree of the factor i corresponding to the remark lever j. So the dependent degree matrix is R_i which is composed by m factors' dependent degree vector.

$$R_i = \begin{bmatrix} r_1 \\ r_2 \\ \cdots \\ r_m \end{bmatrix} = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ r_{m1} & r_{m2} & \cdots & r_{mn} \end{bmatrix}$$

3.4 Obtaining the fuzzy comprehensive evaluation result

Based on AHP method described in the above section, we can figure out the index weight

coefficient vector $w=(w_1, w_2, ...w_m)$. Make the fuzzy calculation about the index weight matrix and factor fuzzy evaluation matrix, the single factor's fuzzy comprehensive evaluation. The final FCE result vector B can be attained from following equation.

$$B = w \bullet R = [w_1, w_2 ... w_m] \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ r_{m1} & r_{m2} & \cdots & r_{mn} \end{bmatrix} = [b_1, b_2, ...b_n] \quad (3)$$

The process of calculating and comprehensive evaluating the result vector B includes five kinds of synthesis algorithms ($M(\wedge,\vee)$、$M(\bullet,\vee)$、$M(\vee,\oplus)$、$M(\oplus,\bullet)$、$M(\bullet,\oplus)$).Each kind of algorithm has its own characteristic and scope of application.

The ultimate evaluation result vector is $W_b = (W_{b1}, W_{b2}, ...W_{bm})$. Here W_{bj} (j=1, 2, 3, 4) means the percentage the dependent degree to the remark grade j. According to the maximal dependent degree principle, the grade where the maximal value W_{bj} belongs will be the final evaluation result.

4 The Evaluation Example

In this subsection, we will give an example to show how to finish the ESQMEE of a storehouse. The AHP is introduced into its effectiveness evaluation to obtain the index weight. According to the fact which has been investigated, the example employed expert investing method to scoring. The expert group has ten persons which are composed with senior engineers, college professors and department's managers.

4.1 Constructing the factor set and remarks set

We consider the daily management, resources management, implemental management and quality check management are affecting the ESQMEE. The factor set $U = \{u_1, u_2, u_3, u_4\}$ is set up and it can be divided into four subsets which are classified by different attributions. $u_1 = \{u_{11}, u_{12}, u_{13}, u_{14}, u_{15}\}$, $u_2 = \{u_{21}, u_{22}, u_{23}\}$, $u_3 = \{u_{31}, u_{32}, u_{33}, u_{34}\}$, $u_4 = \{u_{41}, u_{42}, u_{43}, u_{44}\}$

$v = \{v_1, v_2, v_3, v_4\} = \{\text{excellent}, good, middle, bad\}$ is the evaluation remark set.

4.2 Setting up index weight matrix and fuzzy evaluation matrix

We obtained the indexes weight above by the marks of the expert scoring or polling which depends on the complexion of the unit. We asked the experts to fill the consultative form. The index important degree is measured by Saaty's nine grade method [1]. Based on the AHP model, the relative importance of each index is defined quantitative [2, 3]. After the consistency test, the index weight matrix is ascertained. For instance, the first level index weight set is A_1=(0.1，0.15，0.3，0.2，0.25).

We selected the factor daily management and its subordinate indexes to show how to use the FCE method. We defined the factor's dependent degree function is: r_{ij} = n /10(n is the number of persons who has selected this remark grade).There are seven experts think the factor as excellent (70% on grade one), two experts think the factor as good (20% on grade two), one expert think the factor as middle (10% on grade three), and zero as bad (0% on grade four). Other factors' fuzzy evaluation is the similar. The fuzzy evaluation matrix is constructed by the experts judging.

4.3 Calculating fuzzy comprehensive evaluation of the single factor

We adopt $M(\bullet,\oplus)$ algorithm to carry through the single factor fuzzy calculation of A_1[4]. The

evaluation result vector is B_1.

$$B_1 = A_1 \bullet R_1 = (0.1 \quad 0.15 \quad 0.3 \quad 0.2 \quad 0.25) \bullet \begin{bmatrix} 0.7 & 0.2 & 0.1 & 0.0 \\ 0.2 & 0.4 & 0.3 & 0.1 \\ 0.2 & 0.4 & 0.2 & 0.2 \\ 0.2 & 0.6 & 0.2 & 0.0 \\ 0.3 & 0.5 & 0.1 & 0.1 \end{bmatrix} = (0.25 \quad 0.3 \quad 0.2 \quad 0.2) \tag{4}$$

Same to the calculating process of B_1, we can obtain the result vectors of other factors B_2, B_3, B_4.

4.4 Confirming the final evaluation result

The whole storehouse's ESQMEE is comprehensive evaluated by using the FCE method. The result vector that we obtained need to be normalized.

$$B = A \bullet R = [0.26 \quad 0.32 \quad 0.21 \quad 0.21] \tag{5}$$

The result reflects that the second scale membership degree value (32%) is the largest value of this vector. Therefore we can consider the evaluation result is good.

5 Conclusions

This paper applied the FCE method to the ESQMEE. In order to figure out impersonal and entire evaluation result, it scientifically combined the qualitative analysis with the quantitative analysis. The essay provided a new fuzzy comprehensive evaluation mathematical model about ESQMEE. The analytical procedure of the final example reveals the feasibility and usability of this model. Based on the result of the evaluation, the quality management level was obtained and the weakness in the equipment support quality management can be found easily.

References

[1] Saaty T L.Fundamentals of Decision Making and Priority Theory with the Analytic Hierarchy Process.*RWS Pubications*; 1994.

[2] Zhao Liu, A Fuzzy Synthetic Evaluation Model for Bidding Assessment Based on AHP, *China High Technology*, 2010; **12:** p.24–25

[3] Ming Jin, The Application of AHP in Economic Efficiency Evaluation, *Journal of Zhengzhou Textile Institute*, 1997;**8:** p.67–70 ,.

[4] Zhen hua Hu, Evaluation for Equipment Technology Supporting Ability Based on Fuzzy Method, *Ordnance Industry Automation,* 2009; **1:** p.10–11.

[5] Yong Wang, Jun Hou. The Evaluation Method of Combat Effectiveness of C4ISR System based on Game Theory .*Fire control and command control*, 2006; **31:** p.60–62.