Available online www.jocpr.com

Journal of Chemical and Pharmaceutical Research, 2014, 6(6):348-353

Research Article

ISSN : 0975-7384
CODEN(USA) : JCPRC5

Application of improved entropy, catastrophe progression and set pair analysis method in extracting fuzzy rules of enterprise quality management system operation effectiveness

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ABSTRACT

Evaluating enterprise quality management system operation effectiveness, mining and extracting the fuzzy rules of affecting factors of enterprise quality management system operation effectiveness are important ways to solve practical quality problems and improve quality performance. This study integrates and combines statistical analysis methods of improved entropy method, catastrophe progression method and set pair analysis methods to evaluate quality management system operation effectiveness of specific manufacturing enterprises in the form of specific practical examples and extract fuzzy rules of enterprise quality management system operation effectiveness, evaluation and operation results reveal that combinations of improved entropy method, catastrophe progression method and set pair analysis method possess feasibility and maneuverability in evaluating enterprise quality management system operation effectiveness, extracting fuzzy rules of enterprise quality management system operation effectiveness.

Key words: quality management system; operation effectiveness; influencing factors; fuzzy rules extraction

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INTRODUCTION

The concept of “quality is enterprise life” drives and triggers enterprises to implement total quality management practices, integrate the existing quality management tools, conform to PDCA cycle and DAMIC operation logic, operate, upgrade and certify the current quality management system effectively, establish the existing quality management system, establish quality management information and quality information delivery channels, improve quality information feedback mechanism, adopt a series of continuous improvement measures, preventive measures and corrective measures in order to make efforts to improve quality performance, produce high-quality products, continue to improve customer satisfaction, enterprise achieves some results. Finally, set the final evaluation results of catastrophe progression method as dependent variable, set the affecting factors of enterprise quality management system operation effectiveness as independent variables, integrates and fuses the guideline ideas and concepts of set pair analysis method and rough set method, centralize, unify and consider uncertainties and uncertainties, extract and mine fuzzy rules of enterprise quality system operation effectiveness, determine the affecting factors of affecting enterprise quality management system operation effectiveness.

2. Enterprise quality management system operation effectiveness evaluation indicators system and affecting factors

Supported by the related literatures[1-4], this study conducts comprehensive evaluation of the operation effectiveness of quality management system from 4 aspects, criterion are quality policy objectives (C1), product quality stability (C2), quality improvement and innovation (C3), resource Management (C4). The evaluation index of (C1) are product quality policy (C11), product quality goals (C12) , product quality planning（C13）and user satisfaction (C14), the evaluation index of (C2) are the rate of qualified products (C21), product return rate (C22) and stable increase rate of product quality (C23), the evaluation index of (C3) are management review the implementation (C31), the internal implementation (C32), corrective and preventive measures(C33) and system suitability(C34), the evaluation index of (C4) are human resource management (C41), infrastructure management(C42) and working environment management(C43).

3. The selection of evaluation method
3.1 Improved en tropy method
Improved entropy method comprises the following steps[5-6], it is the important steps of catastrophe progression method.

(1)Collect data and the non dimensional data processing, complete the standardization of evaluation index.

$$x_{ij}^{'} = \frac{(x_{ij} - x_j)}{\sigma_j} \quad (1)$$

Of which, $x_{ij}^{'}$ stands for the normalized index values, x_{ij} stands for the original value of the index j of the object i, x_j stands for the mean j index, σ_j stands for the j index of standard deviation. $i = 1, 2......n$, $j = 1, 2......m$.

(2) Eliminate the negative effect of translational coordination according to the following formula.

$$x_{ij}^{''} = x_{ij}^{'} + D \quad (2)$$

Of which, $x_{ij}^{''}$ stands for Post-translational index value, D stands for translation of the amplitude.

(3)To calculate the index $x_{ij}^{''}$ weight r_i .

$$r_{ij} = \frac{x_{ij}^{''}}{\sum_{i=1}^{m} x_{ij}^{''}} \quad (3)$$

(4)Calculate the entropy e_j of j indicators.

$$e_j = -k \sum_{i=1}^{m} r_{ij} \ln r_{ij} \quad (4)$$

Of which, $k = \frac{1}{\ln m}$, m stands for evaluation object number, $i = 1, 2......m$.

(5) Calculate the index j weight w_j .

$$w_j = \frac{1 - e_j}{\sum_{j=1}^{n} (1 - e_j)} \quad (5)$$

3.2 Catastrophe progression method
Catastrophe progression method is one of the popular methods of evaluation, catastrophe progression method comprises the following steps: index dimensionless, a hierarchical structure model, established the index system of evaluation of mutation model, to evaluate the assessment object using the normalized formula[7-10]. Variables in catastrophe progression method consist of state variables and control variables. Mutation model commonly used include the cusp catastrophe model, swallowtail catastrophe model and the butterfly catastrophe model [7-10].

$$f(y) = y^4 + a y^2 + by, \quad f(y) = y^5 + a y^3 + b y^2 + cy, \quad f(y) = y^6 + a y^4 + b y^3 + c y^2 + dy \quad (6)\text{-}(8)$$

Of which, y stands for variables, $f(y)$ stands for the potential function of y, a, b, c and d stands for control variables of state variables of y .

The cusp catastrophe model includes two parameters, swallowtail catastrophe model includes three parameters, the butterfly catastrophe model includes four parameters [7-10], different mutation models with different equation of structure is different. Difference equation and solving process are given below the cusp catastrophe model, the swallowtail catastrophe and the butterfly catastrophe model[10].

Firstly, solve the Cusp catastrophe model differences Equations.

The derivative of the function $f(y) = y^4 + a y^2 + by$, for within the equilibrium surface.

$\frac{dy}{dx} = 4y^3 + 2ay + b = 0$ （9） . The singularity set is $\frac{dy^2}{dx^2} = 12y^2 + 2a = 0$ （10） .

$$y = -\frac{3b}{4a} \quad (11)$$

Put (10) into (11) , we can get difference equations of cusp catastrophe,

$$8a^3 + 27b^2 = 0 \quad (12)$$

Bifurcation equation of cusp catastrophe decomposition form, $a = -6y^2, b = 8y^3$

Secondly, solve the swallowtail bifurcation equation.

The derivative of the function $f(y) = y^5 + ay^3 + by^2 + cy$, for within the equilibrium surface,

$$\frac{dy}{dx} = 5y^4 + 3ay^2 + 2by + c = 0 \quad (13)$$

Fuzzy rules extraction

$$\frac{dy^2}{dx^2} = 20y^3 + 6ay + 2b = 0 \quad (14)$$

By (13) and (14),we can have swallowtail catastrophe bifurcation equation decomposition form.

Thirdly, solve the butterfly catastrophe model bifurcation equation.

The derivative of the function $f(y) = y^6 + ay^4 + by^3 + cy^2 + dy$, for within the equilibrium surface,

$$\frac{dy}{dx} = 6y^5 + 4ay^3 + 3by^2 + 2cy + d = 0 \quad (15),$$

The singularity set is $\frac{dy^2}{dx^2} = 30y^4 + 12ay^2 + 6by + 2c = 0$ （16）

Normalized formula for cusp model, $y_a = a^{\frac{1}{2}}, y_b = b^{\frac{1}{3}}$ （17）

Normalized formula for Swallowtail model ,

$$y_a = a^{1/2}, y_b = b^{1/3}, y_c = c^{1/4} \quad (18)$$

Normalized formula butterfly model,

$$y_a = a^{1/2}, y_b = b^{1/3}, y_c = c^{1/4}, y_d = d^{1/5} \quad (19)$$

Of which, $y_a, y_b, y_c, y_d \cdots$ stands for mutant numerical system variables.

3.3 set pair analysis method and the fuzzy rule extraction

(1) Set pair analysis takes certainty (same, opposite) and uncertainty (difference) of system into account, which is a evaluation method that can simultaneously include uncertainty and uncertainty. Same degree (a , S/N), opposition degree(c , P/N) and difference degree(b , F/N) of set pair interrelate and affect each other[11-13] .

$$\mu_i = \frac{S}{N} + \frac{F_1}{N}i_1 + \frac{F_2}{N}i_2 + \frac{F_3}{N}i_3 + \frac{P}{N}j \quad (20)$$

$$\mu = a + b_1i_1 + b_2i_2 + b_3i_3 + cj \quad (21)$$

The six element connection number is

$\mu = a + b_1i_1 + b_2i_2 + b_3i_3 + b_4i_4 + cj$ （22） μ is contact degree.

Formula (21)(22)can be expressed as follows

$$\mu = a + bi + cj + dk + el \quad (23)$$

$$\mu = a + bi + cj + dk + el + fm \quad (24)$$

of which, a , b , c , d , e , f stands for Contact component connection number, i , j , k , l , m referred to as the coefficient of contact component.

(2) Extraction of fuzzy rules [14-16].

Step1, n group y_G, x_i ,data y_{G1}, x_{i1}, y_{G2}, x_{i2}, … y_{Gt}, x_{it}, y_{Gn}, x_{in} ,carry out standardization treatment,the formula is shown as follows (25) and (26).

$$\tilde{y}_{Gt} = \frac{y_{Gt}}{\max y_{Gt}} \quad (25)$$

$$\tilde{x}_{it} = \frac{x_{it}}{\max x_{it}} \quad (26)$$

Step 2, calculate the same degrees among $\tilde{x}_{1t}$、$\tilde{x}_{2t}$、$\tilde{x}_{3t}$、$\cdots$and $\tilde{y}_{Gt}$ respectively, calculation formula is shown as follows[14].

$$a_{it} = \frac{\min(\tilde{x}_{it}, \tilde{y}_{Gt})}{\max(\tilde{x}_{it}, \tilde{y}_{Gt})} \quad (27)$$

Step 3, conform to sharing principle to have characterization of a_{it} [14].

Step 4, coordination determination of a_{it} on the microscopic level, characterization of coordination degree table is when poor is 0,it is coordination, when poor is 1-2, it is partial coordination, when poor is 3-4, it is slight coordination, when poor is 5-6,it is critical partial difference, when poor is 7-8, it is difference partial opposite, and when poor is 9-10, it is opposite [14]. Step 5, fuzzy rules extraction on the macro-level. For t number of a_{it}, average is $\bar{a}_i$, contribution of relatively higher $\bar{a}_i$ to y_G is higher than contribution of relatively lower $\bar{a}_i$ to y_G, we can obtain fuzzy rules extraction on the macro-level, the calculation formula $\bar{a}_i$ is shown as follows[14].

$$\bar{a}_{it} = \frac{1}{p}\sum_{t=1}^{p} a_{it} \quad (28)$$

4. Case study

4.1 Determine weight of evaluation index based on improved entropy method

This study uses improved entropy method to determine the entropy weight of evaluation indicator of enterprise quality management system operation effectiveness evaluation index system, the results are shown in table 4 and the entropy criterion layer is as: C1=0.02761, C2=0.01783, C3=0.02145, C4=0.93311. The entropy weight of the evaluation index from C11 to C43 is 0.00428, 0.00543, 0.00552, 0.01239, 0.00576, 0.00675, 0.00531, 0.00498, 0.00639, 0.00491, 0.00517, 0.00461, 0.00640, 0.92209.

4.2 Quality management system operation effectiveness evaluation based on catastrophe progression method

Based on catastrophe progression method steps, this study evaluates the effective operation of the quality management system of 30 representative manufacturing enterprise in Heilongjiang Province.

C11,C12,C13,C14 form butterfly catastrophe model, according to the principle of complementarity.

$$x_{c1} = (x_{c14}^{1/2} + x_{c13}^{1/3} + x_{c12}^{1/4} + x_{c11}^{1/5})/4 \quad (29)$$

C21,C22,C23 form swallowtail catastrophe model, according to the principle of complementarity.

$$x_{c2} = (x_{c22}^{1/2} + x_{c21}^{1/3} + x_{c23}^{1/4})/3 \quad (30)$$

C31,C32,C33,C34 form butterfly catastrophe model, according to the principle of complementarity.

$$x_{c3} = (x_{c32}^{1/2} + x_{c34}^{1/3} + x_{c31}^{1/4} + x_{c33}^{1/5})/4 \quad (31)$$

C41,C42,C43 form swallowtail catastrophe model, according to the principle of complementarity.

$$x_{c4} = (x_{c43}^{1/2} + x_{c42}^{1/3} + x_{c41}^{1/4})/3 \quad (32)$$

C1,C2,C3,C4 form butterfly catastrophe model, according to the principle of complementarity.

$$x_c = (x_{c4}^{1/2} + x_{c1}^{1/3} + x_{c3}^{1/4} + x_{c2}^{1/5})/4 \tag{33}$$

4.3 Fuzzy rules extraction of enterprise quality management system operation effectiveness based on set pair analysis and fuzzy rules operation

This study uses set pair analysis and fuzzy rule extraction operation steps, the relevant results are shown in table 1. Set the operation function of set pair analysis and fuzzy rules as $y_{Gt} = F(x_{1t}, x_{2t}, \cdots, x_{5t}, t)$, $\tilde{y}_{Gt}$ is evaluation value of quality management system operation effectiveness generated by catastrophe progression method, $\tilde{x}_{1t}$, $\tilde{x}_{2t}$, $\tilde{x}_{3t}$, $\tilde{x}_{4t}$ and $\tilde{x}_{5t}$ are affecting factors of affecting enterprise quality management system operation effectiveness, followed by top management, quality management system planning, awareness and participation of employees, continuous improvement of quality management system, quality culture.

Among which, A stands for high, B stands for relatively high ,C stands for slightly high, D stands for middle relatively high ,E stands for middle, F stands for middle relatively low, G stands for relatively low, H stands for low , I stands for very low, J stands for extremely low.

Table 1. Same degrees among a_{1t}, a_{2t}, a_{3t}, a_{4t} and a_{5t}

	a_{1t} a_{2t}	a_{1t} a_{3t}	a_{1t} a_{4t}	a_{1t} a_{5t}
1	0.9334(A)	0.9723(A)	0.9636(A)	0.7778（C）
2	0.84（B）	0.9334(A)	0.8928（B）	0.7（C）
3	0.9115(A)	0.9723(A)	0.7（C）	0.9723(A)
4	0.9338(A)	0.9727(A)	1(A)	0.7782（C）
5	0.9334(A)	0.9649(A)	0.9334(A)	0.9722(A)
6	0.8399（B）	0.8572（B）	0.8399（B）	0.8572（B）
7	0.9974(A)	0.7778（C）	0.9974(A)	0.9974(A)
8	0.9593(A)	1(A)	1(A)	0.7995（C）
9	0.9333(A)	0.7778（C）	0.9333(A)	0.9722(A)
10	1(A)	0.9944(A)	0.9547(A)	0.7956（C）
11	0.8929（B）	0.7001（C）	0.84（B）	0.8572（B）
12	0.7301（C）	0.9862(A)	0.8571(B)	0.9862(A)
13	0.8929（B）	0.9333(A)	0.8929（B）	0.9333(A)
14	0.9406(A)	0.7778（C）	0.9406(A)	0.9406(A)
15	0.8998（B）	0.9722(A)	0.9334(A)	0.9722(A)
16	0.9334(A)	0.7779（C）	0.9334(A)	0.9722(A)
17	0.8928（B）	0.9334(A)	0.8401（B）	0.8927（B）
18	0.9334(A)	0.7779（C）	0.4667（F）	0.7779（C）
19	0.9334(A)	0.7779（C）	0.9918(A)	0.5834（F）
20	0.9698(A)	0.7779（C）	0.9698(A)	0.9722(A)
21	0.9334(A)	0.7779（C）	0.9334(A)	0.9415(A)
22	0.7（C）	0.7778（C）	0.9333（A）	0.9722（A）
23	1(A)	0.9866(A)	1(A)	0.811（B）
24	0.7001（C）	0.9723(A)	0.9334(A)	0.7779（C）
25	0.56（E）	0.7（C）	0.8929（B）	0.7（C）
26	0.9734(A)	0.8113（B）	0.9734(A)	0.9862(A)
27	0.893（B）	0.9333(A)	0.84（B）	0.8573（B）
28	0.9033(A)	0.9722(A)	0.7（C）	0.5833（F）
29	0.7（C）	0.7779（C）	0.9334（A）	0.9722（A）
30	0.9369(A)	0.7808（C）	0.9369(A)	0.976(A)

Therefore, enterprises should attach importance to establish enterprise quality culture and strengthen quality awareness of employees in order to enhance quality competitiveness of enterprise products.

CONCLUSION

This study constructs enterprise quality management system operation effectiveness evaluation indicators system, summarizes five affecting factors of affecting enterprise quality management system operation effectiveness(top management, quality management system planning, awareness and participation of employees, continuous improvement of quality management system and quality culture). The combinations of three statistical model can effectively evaluate enterprise quality management system operation effectiveness and extract the fuzzy rules of enterprise quality management system operation effectiveness, which can identify and clarify the affecting factors of enterprise quality management system operation effectiveness, determine influence degrees of affecting factors .

Acknowledgements
This paper is supported by grant NO.71271063 from the National Natural Science Foundation.

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