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Review of the evaluation of the key nodes in quality system management based on the uncertainty quantification method

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Abstract. To explore the relatively weak link of the quality management system, the evaluation of the key nodes in quality system management is the crucial method for the enterprises and organizations. However, due to inadequate understanding of the goals and principles, the evaluation results are difficult to meet the requirements. Therefore, in this paper we normalize the evaluation of the quality management system and discuss the methods of uncertainty quantification as the supplementary for evaluation which brings the more accurate results for improvement suggestions.

1 Introduction

As the market becomes more competitive, the need for the better evaluation in quality system management is becoming more urgent based on system engineering theory and method, which could identify and quantify control. Namely, it can explore the outstanding issues such as the relatively weak quality infrastructure and team capacity. Countries and organizations around the world are promoting the the quality control evaluation of key nodes as an important mean, which is committed to improving the effectiveness, stability, reliability and sustainable growth of quality management.

At present, the researches on the evaluation of enterprise quality management are generally divided into three categories: Phil Crosby, ISO 9004:2000, Quality Award and Criteria for Performance Excellence.

Philip Bayard "Phil" Crosby, one of the most influential quality gurus of the 20th century. Crosby wrote many books including his famous 1979 "Quality is Free"[1], in which there is the quality management evaluation grid[2]. This is the earliest model to evaluate the quality of the production process in an enterprise. However, it only summarizes the characteristics of the five main aspects of quality management and does not carry out a detailed evaluation process and results, which leads to the weak practicability and operability. There is a self-evaluation in ISO 9004:2000 that can help enterprises to check and self-evaluate the operation status of quality management system[3]. Of all the national quality awards in the world, the most famous and influential are the Edward Deming Quality Award in Japan, the European Quality Award and the Malcolm Baldrige Quality Award in the United States. In

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order to guide Chinese enterprises to participate in international competition and improve their management, The China Quality Association has also launched the National Quality Award Review and officially issued the Criteria for Performance Excellence[4], providing specific framework and guidelines for Chinese enterprises in pursuit of performance excellence.

In this paper, we would discuss the evaluation of the quality management system based on the quantization of uncertainty methods. Firstly, the conception of evaluation has been defined in sec. 2 in order to clarify the evaluation objectives and goals. Secondly, this paper introduces the evaluation principles and perspectives of quality management system. At last, based on national standard and related management documents as well as the mathematical method, the common evaluation process and method are described and discussed.

2 Conception of evaluation of the key nodes in quality system management

By the widely application of evaluation theory in various fields of our society, the evaluation plays a critical role in the improvement of the availability, stability and reliability of quality management.

It is a evaluation model of the key nodes in quality system management that describes how to acquire or improve capabilities. Namely, in order to be consistently successful in competition, the ability must be improved over time. The improvement process can be decomposed into several levels by the capability evaluation model.

Much attention has been given to this area study, there are several well-known evaluation models from McKinsey[5], Phil Crosby[6], Baldrige National Quality Award (MBNQA)[7], and ISO 9004 in China[8, 9] as mentioned above. In multi-version ISO 9004, the quality management system self-evaluation as an important content with an appendix to introduce the detailed standards and criterion, which illustrates the necessity of quality managements system evaluation to confirm the advantage and weaknesses and take the improvement measures. As to aerospace field, the quality management system in GJB 9001B has been built based on the high requirement of reliability and quality of products. However, after the quality management system certification, it is more significance that the evaluation could find the perfection and inadequacy of quality management system.

3 Evaluation principles of quality management system

As described above, the operation of enterprise is stable and well-organized under the Quality Management System Standard, but the hidden problems and the further improvement could not be given under the supervision and vetting exercise[10]. Therefore, the evaluation principles of quality management system need to target existing problems.

3.1 Do not limited to the standard

The evaluation of quality management system should include not only the details in the management standard but also the related documents, administrative rules and the contract. Moreover, the domestic and overseas managerial experience also can be added in the evaluation content. In addition, the qualitative judgment is subjectivity that whether the relevant items are in accordance with the procedures required by the standard. The quantitative analysis is the basement of the evaluation of quality management system.

3.2 Carry out the evaluation according to the process

The evaluation of quality management system should keep the quality control of the realization process of product and service as the central task. The implementation flow of different products or services need to be identified that brings the correspondingly changes to the evaluation criteria.

3.3 Combine the results and the process evaluation

There are two points of the evaluation target, one is focus on the quality of product, the other concern at the process of implementation, management and security. It is worth noting that the product quality is the most principal that can defeat all the results of process evaluation. Hence, we need to combine the process evaluation and result evaluation.

3.4 Oriented towards improvement

It is important to be clear that the evaluation results are in service of the improvement of the quality management process. In order to achieve the change in the management system, all previous results need to be used into the contrastive analysis and synthetic analysis.

4 Evaluation perspectives of the evaluation of quality management system

According to the evaluation principles of quality management system (Sec.4), evaluation should be divided into process evaluation and result evaluation.

4.1 Process evaluation

Process evaluation was established according to national standard items. Enterprises and organizations complete the addition and deletion of evaluation items according to their own characteristics. The relative evaluation items are set up in the process evaluation, and the weight score corresponds to the relevant evaluation item. The process of relative key evaluation should have more detailed evaluation items, that is, a relatively large weight score.

4.2 Result evaluation

The result evaluation is a characteristic project of the evaluation of the quality management in aerospace industry, which mainly refers to the evaluation model of criteria for performance excellence [4]. Result evaluation mainly involves product results (including product performance, number of quality problems, competitive advantage, flight test results, etc.), business performance results, customer satisfaction results, resource results, etc. Additionally, the evaluation items can be adjusted according to their own characteristics. Compared with the process evaluation, the result evaluation has the relative quantification evaluation criterion.

5 Discussion of common evaluation process and methods

There are various kinds of the evaluation of the quality management system. However, in this paper,we would discuss the basic flow and corresponding methods as shown in Fig.1.

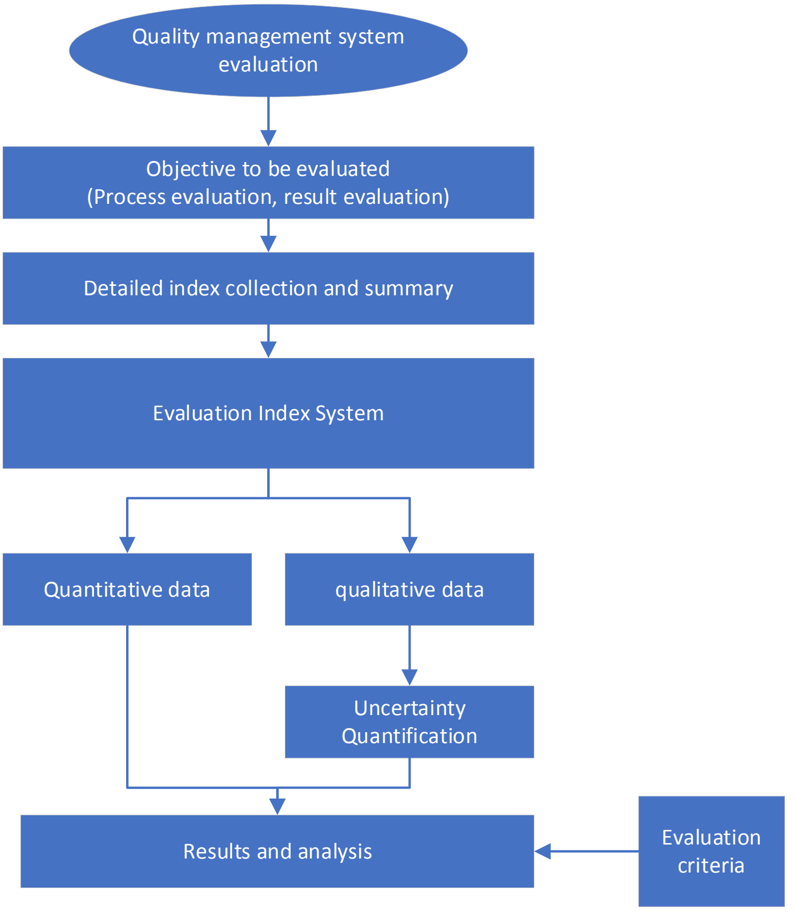

Fig. 1. Flow chart of the evaluation of the quality management system based on the uncertainty quantification method.

5.1 Construction of the indicator system

The construction of indicator system is the foundation of the evaluation and this step can determine the evaluation direction and the final goal. In general, the evaluation objective is crucial to the choice of indicators and the references. For instance, to guarantee the quality of aerospace products, we need to explore the weak links in the production and management process. GJB 9001C, the technical documents and quality insurance management documents are used as the basics of the establishment of indicator system. Meanwhile, the theoretical analysis and expert consultation could also offer assistance. The architecture of the indicator system is usually built into a hierarchy of 3: destination layer (TOP), criterion layer (Middle) and indicator layer (Bottom). The top level is the destination layer that is used to describe the purpose of evaluation. The middle layer includes the criterions which indicates the specific description and the extension content. The bottom level contains all the measures which is the detailing and concretization of evaluation criteria. Additionally, the specific process and content of the evaluation indicator needs to be shown in a separate chapters or tables.

5.2 Quantization of the indicator system

5.2.1 Expert evaluation

Through research and consultation with relevant experts, the different evaluation contents are given the different score weighting. Simultaneously, according to the completion of the evaluation element, each evaluation module gets the corresponding score value. In this method, the assessing experts would give each item a score refer to the set criteria.

5.2.2 Uncertainty quantification

In practice, many indicators are hard to quantify which cannot be measured by concrete measures. This type of indicators is called uncertainty information that mainly divided into the following categories: random information, fuzzy information and grey information[11, 12]. We could choose the special method for the different types of uncertain information.

(1) random information: this kind of information can be associated with uncertainty by the means of entropy, which reflects the probability of occurrence of a particular information or the probability of occurrence of a discrete radon event.

(2) fuzzy information: the imprecise and non-quantitative information obtained by the fuzzy phenomenon. The uncertainty measure can be derived from the probability distribution function or membership function associated with the data[13].

(3) grey information: in grey system theory, greyscale could reflect the uncertainty of the object. The grey number representing data is generally the finite discrete. The grey uncertainty quantization technology of data has been studied and the grey uncertainty quantization theory has been formed[14].

5.2.3 Weight fixing

(1) Analytic Hierarchy Process

Firstly, we need construct the judgment matrix. According to the index of the middle layer, using the pairwise comparison method, the pairwise comparison judgment matrix B can be obtained[15]. In this paper, set $C_1, C_2, \ldots, C_n$ as the element of the i – layer and C_{ij} is the numerical representation of the relative materiality between C_i and C_j. Secondly, the component W_i of the eigenvectors of the judgment matrix is normalized:

$$\sum_{i=1}^{n} W_i = 1 \tag{1}$$

W_i is the weight of each middle layer. $W = [W_1, W_2, W_3, \ldots, W_n]^T$ is the eigenvector and the weight of C_{ij}.

(2) Coefficient of Variation

Coefficient of variation is an objective weighting method. By comparing the different samples corresponding to the same parameter, the importance of the parameter can be distinguished[16]. Firstly, the coefficient of each parameter was calculated:

$$\eta_k^{'} = \frac{\sigma_k}{\bar{X}_k} \tag{2}$$

$\bar{X}_k$ is the sample mean and σ_k is the standard deviation of the type k parameter.

$$\sigma_k = \sqrt{\sum_{i=1}^{n} (X_{ki} - \bar{X}_k)^2 / n} \tag{3}$$

The weight vector is obtained by normalizing the coefficient of variation:

$$\boldsymbol{\eta} = (\eta_1, \eta_2, \ldots, \eta_k) \tag{4}$$

When calculating the coefficient of variation, the influence of sample size on the result should be taken into account, and the influence of sample size on weight should be analyzed with similar historical data as an example.

(3) Game Theory

The traditional comprehensive weighting is usually obtained from the preference coefficient to determine the influence of subjective weight on the evaluation result.

$$\omega_k = \lambda\eta_k + (1\text{-}\lambda)\rho_k \tag{5}$$

$\lambda(0 \leq \lambda \leq 1)$ is the preference coefficient. It is more arbitrary that the proportion of subjective and objective weights determined by experts through preference coefficient. Therefore, the game theory method is introduced to deal with the comprehensive weighting[17].

First of all, two groups of weight vectors were obtained by analytic hierarchy process and coefficient of variation method are $\boldsymbol{\rho}$and $\boldsymbol{\eta}$. Then the comprehensive weight model of parameters is:

$$\omega_k = \theta_1\eta_k + \theta_2\rho_k, \theta_1, \theta_2 > 0 \tag{6}$$

We need to get the Deviation minimization between ω and $\boldsymbol{\eta}, \boldsymbol{\rho}$ by optimizing θ_1 and θ_2:

$$\begin{cases} \theta_1\boldsymbol{\rho}\boldsymbol{\rho}^T + \theta_2\boldsymbol{\rho}\boldsymbol{\eta}^T = \boldsymbol{\rho}\boldsymbol{\rho}^T \\ \theta_1\boldsymbol{\eta}\boldsymbol{\rho}^T + \theta_2\boldsymbol{\eta}\boldsymbol{\eta}^T = \boldsymbol{\eta}\boldsymbol{\eta}^T \end{cases} \tag{7}$$

According to equation, the linear combination coefficient θ_1 and θ_2 can be obtained and the two parameters are for normalized:

$$\theta_1' = \frac{\theta_1}{\theta_1+\theta_2},\ \theta_2' = \frac{\theta_2}{\theta_1+\theta_2} \tag{8}$$

At last, the comprehensive weight of the evaluation parameter index can be obtained:

$$\omega_k = \theta_1'\rho_k + \theta_2'\eta_k \tag{9}$$

5.3 Evaluation results

According to the indicator system, standard for evaluation and the hierarchy weighting, we would get the scores of the evaluation factor as the follow equation:

$$S_0 = \sum_{i=1}^{n} S_i * W_i \tag{10}$$

S_0 is the score of the evaluation subject. S_i is the i layer indicator scores and W_i is the corresponding weight. At last, the evaluation results of quality management system are carried out according to the score and evaluation level comparison table. According to the scores of every layer in the quality management system, the weak links is mined, based on which, the related rectification would be carried out according to expert analysis and result discussion.

6 Conclusions

Based on the in-depth analysis of uncertainty quantification, this paper analyzes and summarizes the evaluation of the quality management system. Four basic evaluation principles of quality management system target existing problems to guide the establishment of the indicator system and the choice of evaluation methodology. Additional, based on the discussion of multiple approaches of uncertainty quantification, a more scientific and quantitative normalized process would be used to evaluate the evaluation in order to explore the relatively weak links of the quality management system in the enterprises or organizations.

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