# Comparative Study on the Evaluation Methods of Product Quality Level

Yueyi Zhang, Mingshun Song, Lijun Zhou & Xinghua Fang

College of Economics and Management, China Jiliang University, Hangzhou 310018, China

Tel: 86-571-8691-4514 E-mail:zyysh@163.com

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**Abstract**

The evaluation of the product quality level is the premise of quality improvement. When the quality characteristics are not related with the quality cost, or the relationship between them is not obvious, the evaluation results obtained from different evaluation methods of product quality level have not significant difference. But in the practice, the evaluation results are largely different when adopting different evaluation methods of product quality level. In this article, various evaluation methods are comparatively studied through examples, and the result shows that under some particular situations, the evaluation method of quality loss function is better than other methods.

**Keywords:** Product quality, Evaluation, Comparison of methods, Quality loss function

## 1. Introduction

With the further enhancement of the science and technology level, people pay attention to the quality of commodity more and more. “Quality is the life of enterprise” has been the motto of many enterprises, and the first problem is how to measure and evaluate the quality for many enterprises. Even if when improving the product quality, the quality level should be first evaluated objectively, and whether the method evaluating the quality level is correct and effective also should be evaluated definitely. The evaluation methods which have widely applied for the product quality level include the fraction defective comparison method, the process capability analysis method, the heuristics of judgment, the analytic hierarchy process, and the quality loss function method. In the practice, though the effect of the fraction defective method and the process capability index method is good, but the successive works of enterprise are very inconvenient, and consumers will suffer large losses. Based on practical problems, the comparison of the evaluation methods of product quality level will be studied as follows.

## 2. Practical problems

For those enterprises with perfect quality management, their idea of quality management is “customers are the focus of attention”. When the quality characteristics are not related with the quality cost, or the relationship between them is not obvious, the evaluation results obtained from different evaluation methods of product quality level have not significant difference. But in the practice, following problems still exist.

First, in the practical manufacturing domain of industrial products, most enterprises adopt the counting test method to test their products. The only standard to judge the product quality is the specification limit of product, and the result is qualified or unqualified, and their idea is “quality is conformity”.

Second, for the labor-intensive industry, most enterprises adopt the piece-rate system. To realize the maximization of profit, employees may not always consider the quality of product in the process, and they may produce the products only from the testing standards of product.

Third, some enterprises control the quality based on the minimization of product cost, and the deviation of average value will often occur. For some evaluation indexes such as thickness, size, gold-plating technique, and the thickness of the valuable metal board, enterprises always only emphasize the lower limit of the specification.

Fourth, for those evaluation indexes to show the exterior characteristics of product, such as the content of the harmful and toxic substance in the food, and the content of the impurity in the product, after considering the effect of quality control and economic benefit, enterprises will always approach the upper limit of the standard.

## 3. Comparative research of evaluation methods

To comparatively study various evaluation methods of product quality level, concrete examples are used to distinguish the differences among three methods including the fraction defective method, the process capability analysis method, and the quality loss function method in the evaluation of product quality level.

The thickness of certain one plastic board is required for 20±4mm, and when the thickness of this kind of plastic board exceeds the limit of specification, the loss is 100 Yuan. The like products from four enterprises are evaluated. In each enterprise, 30 plastic boards with same type are measured, and these plastic boards are measured under the condition that the production process is stable, and the measurement result is seen in Table 1.

*3.1 Evaluation method of fraction defective*

Because these plastic boards are measured under the condition that the production process is stable, the data of thickness can be approximately thought to obey the normal distribution. To evaluate the fraction defectives of the plastic boards from four enterprises, the average value and the standard deviation of the thicknesses are computed first, and the computation result is seen in Table 2.

After confirming the average value and the standard deviation, the normal distribution of the thicknesses is confirmed, and the fraction defective is the probability that the measurement results exceed the specification limit, and the concrete computation result is seen in Table 3.

Generally, the product with lower fraction defective has better quality, and according to this concept, Enterprise C is the enterprise with the best quality in four enterprises, then Enterprise B, and Enterprise C, and the last one is Enterprise D.

*3.2 Method of process capability analysis*

The process capability is the important parameter to reflect the process manufacturing capability, and it is often used in the evaluation of product quality or the selection and evaluation of suppliers. The computation formula of the process capability index is

$$C_p = \min\left(\frac{USL-\overline{y}}{3S}, \frac{\overline{y}-LSL}{3S}\right)$$

If the standard center coincides with the center of normal distribution (i.e. $\overline{y} = m$ ), the computation formula of the process capability index can be simplified as

$$C_p = \frac{USL-LSL}{6S}$$

Through respectively computing the process capability indexes of the plastic boards from four enterprises, and the result is seen in Table 4.

Generally, the process capability index is bigger, the quality is better. Therefore, the plastic board produced by Enterprise C has the best quality in four enterprises, then Enterprise B, and Enterprise A, and the last one is Enterprise D, and its quality rank ordering is same with its fraction defective.

*3.3 Evaluation method of quality loss function*

The quality loss function of the nominal-the-best characteristic is

$$L(y) = k\left(y-m\right)^2$$

Beg the mathematical expectation of both sides of this loss function,

$$E\left(L\left(y\right)\right) = kE\left(y-m\right)^2 = k\left(\left(\mu-m\right)^2 + \sigma^2\right)$$

The above formula is the average loss of product quality.

In this example, when the thickness of the plastic board exceeds the specification limit, the loss is 100 Yuan, so

$$k = \frac{A}{\Delta^2} = \frac{100}{4^2} = 6.25$$

Therefore, the computation formula of the average loss is

$$E\left(L\left(y\right)\right) = 6.25\times\left(\left(\mu-m\right)^2 + \sigma^2\right)$$

By respectively substituting the above formula by the target value of the thickness and the average value and the standard deviation in Table 2 to compute the average loss, the computation result is seen in Table 5.

Obviously, the average loss is lower, the quality is better. Therefore, Enterprise A has the best quality in four enterprises, then Enterprise D, and Enterprise B, and the last one is Enterprise C. The result evaluated from the quality loss function is completely different with the results from the fraction defective method and the process capability evaluation method.

To further analyze and explain the problem, the computation results obtained from three evaluation methods are combined in Table 6.

First, for Enterprise A, from the thickness distribution of plastic board in Table 6, Enterprise A is a good manufacturer. The average thickness of the products of this enterprise approaches the target value (20mm) very much, and the tolerance ($USL - LSL = 8mm$) basically contains 6 times of standard deviation ($8/1.37 = 5.84$), which is standard process requirement (the fraction defective is 0.27% and the process capability index is 1.0).

Second, Enterprise B has advanced process equipment, because the standard deviation of the plastic boards produced by this enterprise is less than the half of the standard deviation of the plastic boards produced by Enterprise A. If Enterprise B would control the average thickness of plastic board in the standard thickness, the process capability index can be enhanced to above 2, and the fraction defective will approach 0. However, this enterprise didn't do that, it controlled the average thickness in 17.81mm, and in this way, it maintained the process capability index in 0.88, and the fraction defective was also reduced to 0.43% (lower than the fraction defective of Enterprise A), and the more important is that this enterprise saved many raw materials, because the average thickness of the plastic boards is less than the target value in hundred. As viewed from the fraction defective or the process capability index, Enterprise B is right, but the problem is whether is this view right. It can be imaged that if consumers purchase these plastic boards to build their houses such as greenhouse or workroom, and after a strong typhoon, the house made by the plastic boards from Enterprise B would suffer larger loss than the house made by the plastic boards from Enterprise A, because most plastic boards from Enterprise B are thinner than the plastic boards from Enterprise A. Here, consumers all will agree that the plastic boards from Enterprise A are much better than the plastic boards from Enterprise B (and most quality management experts also agree that the final judger of quality is consumer). But the fraction defective and the process capability index in Table 6 cannot reflect this fact, only the average quality loss can reflect the fact that Enterprise A has better quality products than Enterprise B. The plastic boards from Enterprise C are thinner than the plastic boards from Enterprise A and Enterprise B, and they are easier to be destroyed, and they have worse quality, but the fraction defective and the process capability index show that they have better quality, and only the average loss reflects that the quality of the products from Enterprise C is worse.

Third, as viewed from the fraction defective or the process capability index, the quality of product from Enterprise C is better than the products from Enterprise D, but as viewed from the average loss, the quality of the products from Enterprise C is obviously worse than the products from Enterprise D. In the same way, because the thickness of the plastic boards from Enterprise C is less than the thickness of the plastic boards from Enterprise D, so the quality of the products from Enterprise C is better than the quality of the products from Enterprise D.

In a sum, it is more reasonable to apply the quality loss function to evaluate the quality of the products than the fraction defective method or the process capability analysis method. But in particular situation, the results from three kinds of evaluation methods may be consistent. For example, for Enterprise A and Enterprise D, no matter which one evaluation method we use to evaluate the quality of product, the results all show that the quality of the products from Enterprise A is better than the quality of the products from Enterprise D. In fact, only from the average thickness of plastic boards, Enterprise D is better than Enterprise A, but the standard deviation of the plastic board thickness of Enterprise D is too big, so three methods all consider the influence of standard deviation.

## 4. Conclusions

In the quality management, whether for the quality control or for the quality improvement, the quality actuality should be evaluated first. There are many evaluation methods to measure the product quality level, and when the quality characteristics are not related with the quality cost, or the relationship between them is not obvious, the evaluation results obtained from different evaluation methods of product quality level have not significant difference. But for some particular situations, for example, the quality conflicts with the cost, the evaluation results will be largely different. Based on the research of these particular situations, various evaluation methods of product quality level are comparatively studied. The result shows that under some particular situations, the quality loss function evaluation method has better evaluation effect.

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Table 1. Measurement results of the plastic boards from four enterprises (Unit: mm)

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Enterprise A | 18.65 | 17.44 | 18.59 | 18.15 | 20.73 | 16.83 | 21.36 | 19.95 | 18.65 | 20.94 |
| | 20.90 | 21.52 | 17.82 | 20.14 | 17.61 | 19.02 | 19.67 | 20.20 | 19.54 | 20.43 |
| | 20.87 | 20.09 | 21.41 | 21.66 | 20.78 | 19.33 | 19.42 | 21.24 | 18.09 | 20.73 |
| Enterprise B | 18.65 | 17.38 | 18.19 | 19.21 | 18.63 | 17.85 | 17.15 | 17.62 | 17.25 | 17.18 |
| | 17.67 | 17.54 | 17.06 | 17.51 | 18.01 | 17.42 | 17.74 | 17.08 | 17.14 | 18.79 |
| | 17.65 | 18.71 | 17.75 | 18.09 | 17.18 | 17.28 | 18.32 | 18.71 | 18.18 | 17.47 |
| Enterprise C | 16.94 | 16.32 | 17.67 | 17.55 | 17.95 | 17.27 | 17.32 | 17.23 | 16.94 | 16.79 |
| | 16.98 | 17.40 | 17.37 | 16.48 | 17.05 | 16.98 | 17.51 | 18.17 | 17.40 | 16.81 |
| | 17.21 | 16.88 | 17.36 | 17.01 | 17.27 | 17.30 | 17.44 | 17.02 | 17.06 | 17.36 |
| Enterprise D | 18.79 | 19.48 | 19.47 | 20.10 | 20.18 | 20.09 | 17.62 | 22.34 | 24.30 | 19.03 |
| | 21.91 | 21.35 | 18.08 | 17.64 | 19.46 | 21.99 | 23.46 | 20.94 | 21.60 | 19.93 |
| | 18.59 | 19.71 | 16.60 | 21.29 | 14.77 | 17.54 | 17.87 | 23.52 | 19.35 | 20.44 |

Table 2. Average values and standard deviations of the plastic board thicknesses from four enterprises

| Enterprise | A | B | C | D |
|---|---|---|---|---|
| Average value | 19.725 | 17.81 | 17.20 | 19.91 |
| Standard deviation | 1.37 | 0.6061 | 0.383 | 2.142 |

Table 3. Fraction defectives of the plastic boards from four enterprises

| Enterprise | A | B | C | D |
|---|---|---|---|---|
| Fraction defective | 0.60% | 0.43% | 0.08% | 5.67% |

Table 4. Process capability indexes of four enterprises

| Enterprise | A | B | C | D |
|---|---|---|---|---|
| Process capability index | 0.87 | 0.88 | 1.05 | 0.62 |

Table 5. Average losses of the plastic boards from four enterprises

| Enterprise | A | B | C | D |
|---|---|---|---|---|
| Average loss | 12.20 | 32.27 | 49.92 | 28.73 |

Table 6. Comparison of three evaluation methods

| Enterprise | A | B | C | D |
|---|---|---|---|---|
| Average value | 19.725 | 17.81 | 17.20 | 19.91 |
| Standard deviation | 1.37 | 0.6061 | 0.383 | 2.142 |
| Fraction defective | 0.60% | 0.43% | 0.08% | 5.67% |
| Process capability index | 0.87 | 0.88 | 1.05 | 0.62 |
| Average loss | 12.20 | 32.27 | 49.92 | 28.73 |