COST OF QUALITY AND TAGUCHI LOSS FUNCTION

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Abstract: *An organization must take into account the costs associated with achieving quality because one of the important objective of continuous improvement programs is to meet customer requirements at the lowest possible cost. Hence, an organization needs to adopt framework to classify costs and to focus on existing cost of quality (CoQ) models. The objective of this paper is to give a survey of research literature and models on the topic of CoQ and to provide a basic understanding of quality costs.*

Keywords: *Quality Costs* , *Cost of Poor Quality, Cot of Good Quality, The Taguchi Quality Loss Function.*

Jel classification: *M11*

1. Introduction

Many organizations consider improving quality as the best way to enhance customer satisfaction, to reduce manufacturing costs and to increase productivity. For this, the CoQ must be reduced. All quality management consultants tend to have quality cost programs as an integral part of their repertoire (Suhansa Rodchua, 2006). Monitoring and controlling CoQ are becoming critical activities of quality improvement programs. Manufacturing companies tend to measure visible costs and ignore significant hidden costs that are difficult to measure such as opportunity costs. An approach for quantifying the opportunity costs is presented here.

2. Literature review

Three noted authors on quality management, Deming, Crosby and Juran each have a different attitude to cost of quality (CoQ). Deming's view is that cost analysis for quality is a misguided waste of time and measuring quality costs to seek optimum defect levels is evidence of failure to understand the problem. Crosby argues that quality costs need to be measured, not for management control, but for the development of "quality" thinking within the organization. The more popular approach is that of Juran who advocates the measurement of costs on a periodic basis as a management control tool.

To collect quality costs a firm needs to adopt a framework to classify costs. The Feigenbaum classification system is almost universally accepted (Plunkett & Dale, 1988). Feigenbaum(1974) identified three cost categories : prevention , appraisal and failure. Juran divided the failure costs into two categories: internal failure and external failure (Juran & Gryna, 1970). Many writers such as Morse and Roth (1983), Ponemon (1990), Youde (1992), Ross(1993) have used Juran's classification system in their research.

To further facilitate understanding of cost of quality trends over time, the four cost categories are analyzed and presented in Figure 1.

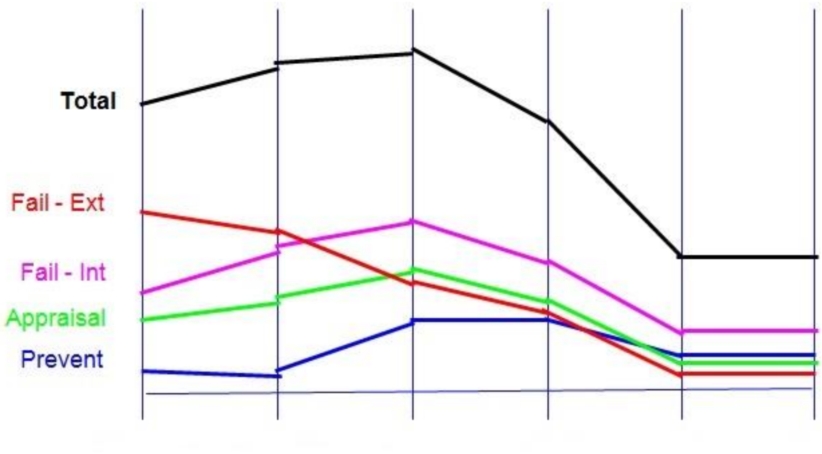


Figure 1: Hypothetical Quality Costs Trends over Time

2.1. The COQ Models

In general, COQ models are classified into four groups:

1. P-A-F models: Prevention costs+ Appraisal costs+ Failure costs
2. Crosby's model: Cost of conformance+ Cost of non-conformance
3. Opportunity or intangible cost models: [Prevention costs+ Appraisal costs + Failure costs + Opportunity costs]/ [Cost of conformance+ Cost of non-conformance+ Opportunity costs] / [Tangibles + intangibles] / [P-A-F (failure costs includes opportunity costs)]
4. Process cost models: Cost of conformance + Cost of non-conformance

2.2. Cost of Quality categories

The cost of quality can be separated into three categories , namely:

- the cost of conformance to customer requirements;
- the cost of non-conformance to customer requirements;
- basic operational costs.

Defining each element in turn, the cost of conformance is the cost an organization incurs in meeting the requirements of its customer. A strong element of this cost is the money a company spends on preventing products or services going wrong or checking that they are right before they reach the customer. The costs of non-conformance are failure costs , the costs incurred by a company in repairing what has gone wrong. The third category basic operational costs are the costs an organization cannot avoid encountering during the normal performance of its business. Those categories are represented in Figure 2.

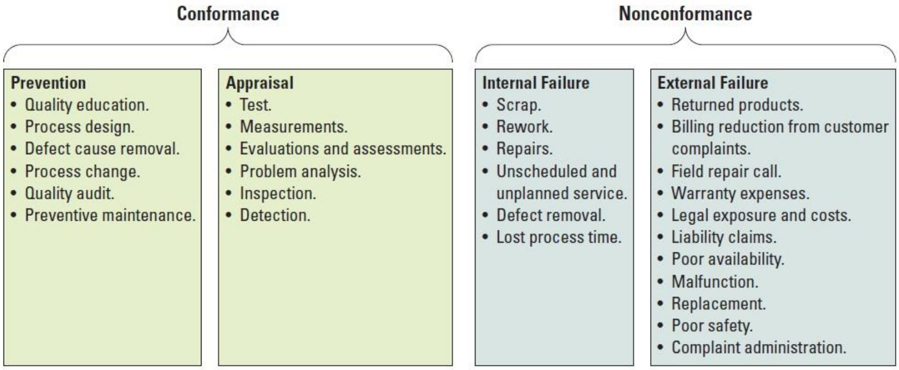


Figure 2: Cost of quality categories

2.3. Cost of Poor Quality and Cost of Good Quality

There are two main elements to focus on : the Cost of Good Quality (CoGQ) and the Cost of Poor Quality (CoPQ). The CoGQ relates to costs incurred to assure the quality of products and prevent poor quality. The CoGQ should be viewed as an investment in reducing the CoPQ, whereas the CoPQ can be viewed as a direct measurement of the failure costs incurred in producing a product. Together, these two variables make up the cost of quality.

CoQ = CoGQ + CoPQ

The CoPQ measures internal and external failure costs and the CoGQ measures appraisal and prevention costs.

The CoPQ quantifies traditional quality costs companies measure and includes rework, returned materials, scrap, and originate both internally and externally. Hence, the CoPQ variable is divided into two sub-variables: Internal Failure Costs (IFC) and External Failure Costs (EFC).

CoPQ = IFC + EFC

On the other end of the spectrum, the Cost of Good Quality (CoGQ) measures costs related to areas such as people and technology involved in the production of high quality products.

These costs are much less likely to be accounted for by executives and plant managers in respect to the cost of quality equation. They are often measured disparately rather than in a standardized way that can facilitate enterprise-wide comparison. The CoGQ has two central components: Appraisal Costs (AC) and Prevention Costs (PC).

CoGQ = AC + PC

2.3. The Taguchi Quality Loss Function (QLF) and the Hidden Costs of quality

Taguchi Methods was developed by Dr Genichi Taguchi. It combined engineering and statistical methods that achieve rapid improvements in cost and quality by optimizing product design and manufacturing processes. There are three statements that apply for the methods:

- we cannot reduce cost without affecting quality;
- we can improve quality without increasing cost;

- we can reduce cost by reducing variation or by improving quality. Therefore, when we do so, performance and quality will automatically improve.

Taguchi defined quality as “the loss imparted to society from the time the product is shipped.” Fundamental to this approach to quality engineering is this concept of loss. He associated loss with every product that meets the customer’s hand. This loss include, among other things , consumer dissatisfaction, added warranty costs to the producer, and loss due to a company’s bad reputation , which leads to eventual loss of market share.

Quality costs or poor quality costs are usually quantified in terms of scrap and rework, warranty, or other tangible costs.

What about the hidden costs or long-term losses related to engineering, management time, inventory, customer dissatisfaction, and lost market share? Can we quantify these? Perhaps, but not accurately. Indeed we must find a way to approximate these hidden and long-term losses, because they are the largest contributors to total quality loss. Taguchi Methods uses the Quality Loss Function (QLF) for this purpose. QLF depends on the type of quality characteristic involved like:

- Nominal-the-best (achieving a desired target value with minima variation: dimension and output voltage)
- Smaller-the-better (minimizing a response: shrinkage and wear)
- Larger-the-better (maximizing a response: pull-off force and tensile strength)
- Attribute (classifying and/or counting data: appearance)
- Dynamic (response varies depending on input: speed of a fan drive should vary depending on the engine temperature)

Loss can occur not only when a product is outside the specifications, but also when a product falls with specifications. Further, it is reasonable to believe that loss continually increases as a product deviates further from the target value, as the parabola (QLF) as shown in Figure 3.

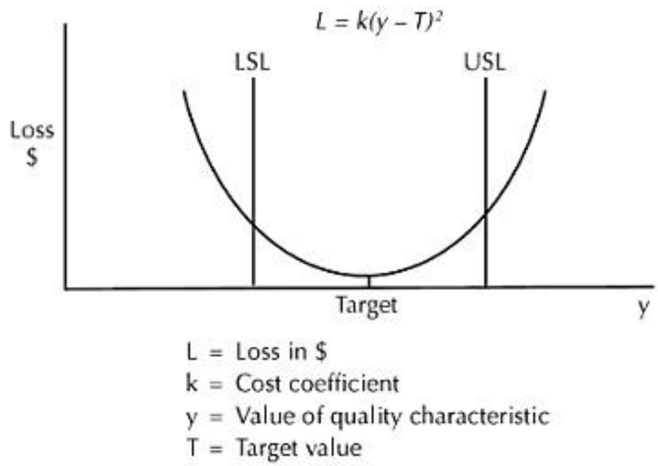
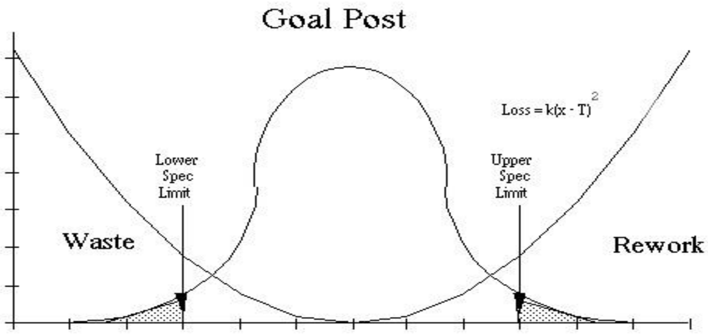


Figure 3: The Taguchi Quality Loss Function (QLF)

The loss isn't linear. Taguchi theorized that the loss is proportional to the square of the distance from the target value.



3. Research metodology

We present the modeling approach used to define customer waiting time improvement model for evaluating service quality.

By using the Taguchi Loss Function, we can determine the cost of quality caused by customer dissatisfaction from waiting in queue. In this research, the model combines the

Taguchi loss function with the components of waiting time and customer dissatisfaction.

The model is derived for a single channel single server for M/M/1, Ek/M/1 and M/G/1 queuing model. We assume the queuing line has single channel single server and customers are selected from the line in a first come, first served fashion.

Waiting time from each queuing model is defined by its probability density function. The function is combined with Taguchi Loss Function to define quality loss of customer waiting and learning curve.

The Taguchi loss function for customer waiting time can be expressed in (1) which taken from Fink and Gillett (2006).

$$QC = \int_0^\infty f(t)Kt^2 dt \qquad (1)$$

Where

$$f(t) = probability\ density\ function\ of\ customer\ waiting$$
$$K = penalty\ cost\ per\ unit\ time\ waiting$$
$$t = time$$

In above equation, the value of K represents the cost of customers to wait in queue. By direct integration of (1), expressions for the Taguchi loss of customer waiting time for M/M/1, Ek/M/1 and M/G/1 queuing model can be obtained. The Taguchi cost for M/M/1 queuing model (Fink and Gillett, 2006) is expressed in (2).

$$QC = \int_0^\infty \lambda(1-\rho)e^{-\mu(1-\rho)t}Kt^2 dt \quad (2)$$

In the equation, ρ denotes the utilization which can be expressed by (3).

$$\rho = \frac{\lambda}{\mu}$$

where λ and μ denote arrival and service rate respectively.

A numerical example is given to illustrate the implementation of the model. We assume the time horizon is t= 2, the arrival rate is λ= 12 customer/hour, the service rate μ is 16 customer/ hour. Hence, the server utilization is ρ= 0.75.
The model will find the least total cost. Let *t* equal to the time horizon for a continuous improvement program to reduce customer waiting time.

4. Findings and discussions

We investigate customers waiting time improvement using Taguchi Loss Function. The cost incurred in this research includes quality loss. The decision variable of this research is learning rate which describe the level of learning that must be performed by a company to improve their service quality in term of waiting time.

5. Conclusions

In recent years organizations have been focusing much attention on quality management. Also, manufacturing environments have changed enormously so today's consumers are becoming more and more complex and they require high quality and diversified products. Therefore, companies should produced new, innovative and high quality, yet cheap products that today's customers want to buy. To maximize the profits of an organization it is necessary to monitor quality costs. Quality costs are important considerations for information management and information technology. In global world, the most important way to survive in the competitive environment for firms is using quality as a core strategy. All successful companies have a strong quality strategy in order to survive in the competitive world. Now, many successful companies promote quality as the central customer value and consider it to be a critical success factor for achieving competitiveness. The successes of multinational corporation depend on their successes in using quality cost systems

References

Anand, K. (2003). *High Quality at Economical Cost* .New Delphi, India: Response Books.
Ansari, S. (1999). *Measuring and Managing Quality Costs*, SUA : Irwin, McGraw-Hill.
Beecroft, D. (2000). *Cost of Quality . Quality Planning*, Canada : GDB Inc
Blocker , E. (2005). *Cost Management –A Strategic Emphasis,* SUA, New York: McGraw-Hill/ Irwin.
Campanella, J.(1999). *Principles of Quality Costing* , SUA : ASQ Quality Press, Milwaukee, Wisconsin.
Carr, L. (1992). *Applying Cost of Quality to a Service Business,* SUA, Sloan Management Review.
Crosby, P.B. (1979), *Quality is Free,* New York: McGraw-Hill.
Crosby, P.B. (1983), *Don't be defensive about the Cost of Quality*, Quality Progress.
Dale, B. (1999). *Quality Costing ,* Great Britain, Gower Publishing Limited.
Douglas,C. (2012).*Principles of Quality Costs,* USA, ASQ Quality Management Division.
Edmons, T. (1991). *Quality Cost in a Dynamic Environment*, New York, SUA, Journal of Managerial Issues.
Feigenbaum, A.V. (1956). *Total quality control*, Harvard Business Review.

Fowlkes, W.Y. & Creveling, C.M. (1995). *Engineering Methods for Robust Product Design*. Reading, MA: Addison-Wesley, pp.34-51.
Harrington, J. (1990). *Poor Quality Cost,* New York, SUA, ASQC Quality Press.
Israeli, A. & Fisher, B. (1991). *Cutting quality costs*, Quality Progress.
Ittner, C.D. (1996). *Exploratory evidence on the behavior of quality costs*, Operations Research.
Juran, J.M.(1995). *A History of Managing for Quality ,* SUA, ASQC Quality Press.
Juran, J.M. & Godfrey, B. (1999). *Juran's Quality Handbook,* SUA, McGraw-Hill.
Machowski, F.& Dale, B.G. (1998). *Quality Costing: An examination of knowledge*, *attitudes and perceptions*, Quality Management Journal.
Mandel, B.J. (1972).Quality *costing systems,* Quality Progress.
Montgomery, D.(1996), *Introduction to Statistical Quality Control*, Wiley, New York
Rodchua, S. (2005). *Quality Costs and Enterprise Size in the Manufacturing Industry*: A Survey of American Society for Quality (ASQ) Members.
Schneiderman, A.M. (1986). *Optimum quality costs and zero defects*, Quality Progress.
Shah, K.K.R. & FitzRoy, P.T. (1998).*A review of quality cost surveys*", Total Quality Management.
Vaxevanidis, N.M. & Petropoulos, G.(2008) *A Literature Survey of Cost of Quality Models,* Annals of the Faculty of Engineering Hunedoara –Journal of Engineering.