An Introduction of COQ Models and Their Applications

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Abstract

We conduct a comprehensive survey of existing Cost of Quality (COQ) models: PAF model, process cost model, opportunity cost model, activity-based cost model, Taguchi loss function, and cost-benefit model. A COQ element categories are also employeed to examine and analyze the COQ applications by searching through online database. By reviewing around 30 cases, we finded out most of companies spent prevention and appraisal cost on design, education, and inspection. Besides, for tangible industries, most of the failure costs came from internal failure cost; for intangible industries, external failure cost occupied the most part of failure costs.

Keywords: Cost of Quality, COQ Model, COQ element

Introduction

The saving of quality costs is believed to be vast from the evidences: the Department of Trade and Industry quotes 5-25% of turnover as the total costs in its publication "Quality Costs" (Plunkett, Dale et al. 1985); a survey from PA consultancy even indicated that the total costs is up to 40% of turnover (Carson 1986). Those levels have been demonstrated by quality gurus like Deming, Juran and Crosby. There is a term called "quality leverage effect". The rough idea is that in terms of pursuing a specific amount of net profit, company would need to double its sales to achieve the level. But company may easily earn the same amount of money by just halving its failure costs. This concept shows the importance of cost of quality in an organization. Dr. Juran calls it "quick and dirty" approach because there is no doubt on the effectiveness for focusing on the potential cost-saving area directly. Even it is no need for an accurate estimation of quality costs. An initial broad estimation give robust indicators like to where corrective action could bring a great rewards (Carson 1986). The collection and analysis on cost of quality data is also considered a benefit of being a performance measuring tool when company implements a Quality Improvement Program. However, Crosby stated that he had never seen an

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organization successfully bring a property usage of COQ into realization. He confessed that the failure of promoting COQ to companies is one of his regrets in 30 year's career of being a quality professional (Crosby 1983). Most of companies have no realistic idea on the total loss caused by poor quality.

In academia, not many quality cost literatures have been reviewed. A literature survey was conducted by Plunkett and Dale (1987). Focusing on quality related cost measurement, collection and usage, many published information was summarized by them. From country oriented, a survey was conducted by Kumar et al. (1998) in various countries. The result shows the concept of reporting quality cost data is not widely adopted by businesses in any part of the world. Some surveys emphasizing on quality costing models also have been conducted. Five classifications of literatures under P-A-F model were grouped by Plunkett and Dale in 1988. A more comprehensive survey was present by Porter and Rayner (1992) with a detail elaboration of quality cost models, but still mainly focusing on P-A-F model and its limitation. Hwang and Aspinwall (1996) published a survey on a comparison of those various COQ models of a total quality management environment. Tsai (1998) carried out a review based on activity-based cost comparing with the known COQ models. Schiffauerova and Thomson (2006) surveyed on the literatures of COQ models and summarized a great number of case studies of successful practices in COQ field. Wang and Chen (2009) presented a more comprehensive survey, especially elaborating on the new advances and emerging trends in COQ development.

Development of COQ

The COQ concept was formally demonstrated with the parallelism "gold in mine" in the late 1940s. Juran (1951) indicated that there are two types of cost related to quality; they are avoidable cost and unavoidable cost. Waste, rework and failure are included in avoidable cost; and unavoidable costs are those cost associated with quality improvement measures. Now the widely accepted COQ classification was firstly presented by Feigenbaum in 1956, the Prevention-Appraisal-Failure model. Another quality guru Crosby simplified PAF classification in his bibliography *Quality in free*. He defined prevention cost and appraisal cost as the cost of conformance, and failure cost as non-conformance cost (Crosby, 1979). Ostrenga thought there is added-value in prevention cost. Companies can save cost by investing in those activities with added-value (Ostrenga, 1991). From the view of manufacturer, prevention and appraisal cost can be grouped into control cost, and the costs left are out-of-control cost (Morse, Harold, & Poston, 1987).

Review of existing COQ models

PAF model

In 1962, J.M. Juran contrasted prevention plus appraisal costs with failure costs and then proposed the traditional tradeoff. Normally in quality textbooks, this model will be discussed and reproduced in the very beginning chapter. Many researches show that there are several difficulties in this model even thought it had a factual basis (Bajpai and Willey 1989). No general measure of quality is the first problem in the model. Quality was defined "the totality of features and characteristics that bear upon its ability to satisfy stated or implied need" in BS 4778. However, this definition leaves room for further discussion. As a management principle, "totality" would be fine. But the rough idea may confuse people in practical use. A single product have separate scales and different units in terms of quality if measure at all. Only in manufacturing the "de-merit ratings" are well developed to measure the totality of quality, and they can't be claimed as a universal measure. Furthermore, a good performance on the totality of quality does not represent "satisfy". The only one who decides "satisfy" is customer and this concept has been considered as a basis index in proposed literatures (Bajpai and Willey 1989). There are so many indices for the horizontal axis in the model. But for the vertical axis, it has already been identified that the measure of quality costs are usually not kept. However, this traditional tradeoff model cannot explain the economics of quality for products in other development stages and can only be applied to finished products because the limit to quality of conformance.

Kume (1985) and Schneiderman (1986) disputed the validity of this traditional tradeoff. They raised a discussion on the traditional tradeoff model including some level of defectives to reach the minimum total cost. In traditional tradeoff, people may put emphasis on inspection instead of prevention by the time the model was developed. It would bring large expenditures on inspection, and the benefits of prevention in this stage had not been recognized yet. Investments in prevention are critical element nowadays in highly competitive business environment, but the static traditional construct would obstruct additional investments in prevention activities. Besides, empirical evidence was revealed against the traditional tradeoff model (Carr 1992). It refuted that each curve represents 50% of the total cost of quality. Furthermore, the shape of these curves would be varied with the corresponding shift with the optimal cost point if intangible costs were taken into consideration (Harrington 1987). A modified model was proposed which the optimum solution is at 100% of quality of conformance.

Process cost model

The concept of process cost model was first found in the study of Ross (1977) and developed by Crosby (1980). Cost of quality (COQ) is the sum of cost of conformance (COC) and cost of non-conformance (CONC). Thus, COQ = COC + CONC, where COC is defined as "under a given specified process, the actual process cost of providing products or services to required standards in a fully effective method" and CONC is "the cost of resources as wasted time, materials and capacity associated with the process not being executed to required standards."

Understanding the related process sufficiently is the first step in implementing the process cost model because the cost element, like people, equipment, material and the environment, can be measured at any step of the process as either COC or CONC (Hwang and Aspinwall 1996).

The process cost model can be used to determine whether high CONC reveals the need for investment on failure prevention or whether the process should redesign to reduce the excessive conformance costs (Porter and Rayner 1992). It pursues a continuous improvement on key processes and can be applied to both service and manufacturing industries. A modeling method called IDEF, the computer-aided manufacturing integrated program definition methodology, was developed for experts use in system modeling (Ross 1977). However, it's too complex for common use by supervisors or staff. In order to overcome this limitation, some simpler methods were conducted (Crossfield and Dale 1990; Goulden and Rawlins 1995). It's suggested that process cost model is better than P-A-F model because it presents a more integrated approach to quality (Porter and Rayner 1992) and quickly responds on quality problems and their causes. Although process model helps the collection and analysis of quality costs effectively, it is not widespread use in fact (Goulden and Rawlins 1995).

Opportunity cost model

Opportunity cost is one of the cost elements had been ignored in many literatures (Plunkett and Dale 1987). Opportunity cost is a kind of intangible costs which can only be estimated like profits not earned resulting from customer dissatisfaction and reduction in revenue because of non-conformance. The importance of incorporating opportunity cost into quality costing model has been emphasized recently. A generic model was proposed showing the COQ is the sum of cost of prevention activity (C_P), cost of appraisal activity (C_A), cost of failure in failure items (C_F) and losses caused by opportunity factors, i.e. $COQ = C_P + C_A + C_F + C_O$. According to this model, COQ is deemed the total of revenue lost and profit not earned; three components are included in opportunity costs: underutilization of installed capacity, inadequate material handling and poor delivery of service (Sandoval-Chavez and Beruvides 1998). The traditional PAF model was also suggested to accommodate opportunity cost as extra dimensions which are the cost of inefficient resource utilization and quality design cost (Modarress and Ansari 1987). The perception of process cost incorporate with opportunity cost model as well. Three categories which are cost of conformance, cost of non-conformance and cost of lost opportunity are defined as quality costs elements and had a successfully implementation in a quality program (Carr 1992).

Activity-Based model

Since traditional cost accounting sets up a system of cost accounts by classifying the categories in terms of expenses (Schiffauerova and Thomson 2006), neither the PAF model nor the process cost model can serve as appropriate methods to cover overhead costs in cost of quality system (Tsai 1998). Activity-based costing (ABC) which was first developed (Cooper and Kaplan 1988) to identify and assign every cost activity (such as departments, products, customers and so on) to products and services in a company and to assist executives to make decisions, for example, pricing, outsourcing, identification and measurement of process improvement strategies. It assigns more overhead expenditures into direct costs.

In order to understand more clearly the processes in an organization, activity-based management (ABM), an extension of ABC, was introduced to monitor continuous improvement and manage the business from the standpoint of process, instead of departments (Letza and Gadd 1994). ABM chooses the cost and nonfinancial/operational information acquirement from ABC in various analyses (Tsai 1998).

Taguchi loss function

In traditional perspective, only when the products fall outside the specification range or services incur customers' dissatisfaction, the quality losses occurred. Differ with traditional view, Taguchi loss function emphasizes that the failure costs occurred when products or services didn't hit the target value or standards accurately. Taguchi (1987) developed these failure losses into a loss function according to his industrial experiences. The generic formula is that $L = C(X - T)^2$; where L = loss, C = constant coefficient, X = quality characteristic and T = target.

However, Taguchi loss function only reflects the influenced by finished product. Avoidable costs and quality costs incurred within the manufacturing firm were not included in this loss function. Further, this function is hard for applying because the probability distribution of product defects is difficult to identify accurately, especially it influences the loss after delivering to customer (Hwang and Aspinwall 1996).

Cost-benefit model

Benefit enhancement from the increased market share and reduction of quality costs are the ultimate goal of quality improvement. Studies show that a modified level of quality incurs a large market share and higher profits (Schoeffler 1974). Quality related costs would decrease if quality is improved and it results in improved productivity, market share growth, stability (Deming 1986). Since quality improvement is a gradual procedure, the investment in TQM would not bring quality improvement for a product or a service in a short term (Kanji 1990; Berry 1991). According to this principle, together with a quality and a management accounting element, Baston (1988) structured a dynamic flow system for a quality cost system including complaints and managerial pressure. A simulation model with system dynamics techniques was developed by Bajpai (1989) in a manufacturing company with different costs and benefits parameters relating to preventive activities. A simple cost-benefit model was proposed by Porter and Rayner (1992) to monitor the effect of a TQM program but didn’t reflect the dynamics of quality activities.

Return on investment (ROI) has been used to estimate the effect while the investment in prevention and appraisal activities increased and the reaction to failure activities. However, the concept of ROI only copes with a part of many benefits incurring from investment in a TQM program. Most models only handle the quality costs related to single produce, service or process and the long-term benefit by investing in a TQM program doesn’t been explained. In addition, the model inspects activities or departments independently. The interacting effect is hard to be revealed among those activities or departments especially a few detailed cost elements are included. Moreover, the life cycle of product or service is too short to do cost and benefit data collection; and because of both quality costing systems and traditional accounting departments make no provision for a long-term investment for quality improvement, it’s difficult to access the real cost data (Bajpai and Willey 1989; Porter and Rayner 1992). Nevertheless, it has been demonstrated that cost-benefit model helps firms on decision making; where, when and how to do preventive activities and equipment investment. This enables related departments or business units to take part in strategic programming. Although a high level of investment only results in a slow progress on quality improvement, a simulation is suggested to be necessary after modeling the system dynamic flows.

COQ elements categories

This study investigates the cost items in different companies and industries based on the PAF Model and the PAF constituent components are revised from the book, *Quality* (Summers 1997). Originally, Summers (1997) categorized cost of quality into prevention costs, appraisal costs, internal failure costs, external failure costs, and intangible costs. However, most of the companies do not look into intangible items due to the fact that it is hard to calculate those items, for example, customer dissatisfaction, company image, loss sales, and loss of customer goodwill. The COQ parameters (Table 1) are summarised as follows (Wang and Chen 2009):

Table 1. COQ parameters of PAF model

Prevention Costs	- Quality Planning/Quality Meeting - Quality Program Administration - Supplier-rating Program Administration/Purchasing/Vendor Quality - Customer Requirements/Expectations Market Research - Product Design/Development Reviews/Process Improvement - Quality Education Programs/Training - Equipment and Preventive Maintenance
Appraisal Costs	- In-process Inspection - Incoming Inspection - Testing/Inspection Equipment - Audits - Product Evaluation
Internal Failure Costs	- Reworking - Scrape/Waste - Repair - Material-failure Review/Re-inspection - Design Changes to Meet Customer Expectations - Corrective Actions/Trouble Shooting
External Failure Costs	- Returned Goods - Corrective Actions - Warranty Costs - Customer Complaints - Liability Costs/Litigation - Penalties

Reviewing result and conclusion

There have been a considerable number of publications relating to quality costs over the past three decades. Papers have mainly focused on definitions and elements of various COQ models. Furthermore, the majority of case studies were based on the P-A-F model rather than others. A few literatures have been conducted comprehensively neither in the review of COQ models nor the practices of COQ. This study proposes a comprehensive introduction to COQ models, including PAF model, process cost model, opportunity cost model, activity-based costing model, Taguchi loss function and cost and benefit model. COQ was originally practiced in the manufacturing industry and then was extended to various other industries like, for instance, the service and high-tech industries.

Amongst the manufacturing, high-tech and service industries, there are some similarities and differences. Concerning prevention costs, all three industries pay the most attention to “quality planning/quality meeting”, “quality education programs/training”, and “product design/development reviews/process improvement” and they care least about “customer requirements/expectations market research”. It is critical to emphasize quality education for implementing the quality system. Especially since COQ is one of the important quality techniques in implementing TQM. In this way continuous improvement constituted by “regular meeting and reviews” is a necessity in facilitating quality activities. “Customer requirements/expectations market research” is least commonly selected, as when the economy slumps, customers become more demanding with their products and it is not easy to please customers. One can therefore draw the conclusion that in the current market customer satisfaction is an indicator for making more profits. With regard to appraisal costs, the item that merited the least attention was “audits”. But, both the manufacturing and the high-tech industries look into the “in-process inspection” and “incoming inspection” the most although the service industry did not deem them important.

As to internal failure costs, all of them attend rigorously to “scrape/waste” and care least about “design changes to meet customer expectations”. “Design changes to meet customer expectations” also suffers in comparison to the attention customer satisfaction has drawn in recent years.

In the external failure costs, “customer complaints” is the most regarded item while “penalties” are the least regarded. This indicates that all the companies need to take notice of is their “customer complaints” and they can neglect the “penalties”. Even if penalties occur, they may not be able to respond to them simultaneously. To conclude based on the observation from the analysed results, we can see the homogeneity and heterogeneity among different industries in terms of cost of quality in the PAF category.

Even though the COQ approach commonly implemented in practice is classical P-A-F model, evidences have also been published with success in using other COQ categories. A result from the study was revealed that COQ practice can transfer from one organization to anther only within same industry; and each individual costing system are considerably different. Implementation model is adjusted according to firm’s need. Any quality management should deem COQ measurement as a serious concern. It’s not complex for businesses to implement and lots of successful cases have been published in literatures. Advanced education and training on executives are necessary for appreciating the benefit of quality costing approach, for instance, saving money or improving quality without cost increase.

References

Bajpai, A. K. and P. C. T. Willey, 1989. Questions about Quality Costs. *International Journal of Quality & Reliability Management*, 6(6).

Baston, R., 1988. Discovered: quality’s missing link. *Quality Progress., October*: 61-4.

Berry, T., 1991. *Managing the total quality transformation*. New York McGraw-Hill

Carr, L., 1992. Applying cost of quality to a service business. *Sloan Management Review*, 33(4): 72-7.

Carson, J. K., 1986. Quality Costing — A Practical Approach. *International Journal of Quality & Reliability Management*, 3(1): 54 - 63.

Cooper, R. and R. Kaplan, 1988. Measure costs right: make the right decisions. *Harvard Business Review*, 66(5): 96-103.

Crosby, P., 1980. *Quality is free*. Signet Book

Crosby, P., 1983. Don’t be defensive about the cost of quality. *Quality Progress*, 16(4): 39.

Crossfield, R. and B. Dale, 1990. Mapping quality assurance systems: a methodology. *Quality and Reliability Engineering International*, 6(3): 167-178.

Deming, W., 1986. Out of the crisis, Massachusetts Institute of Technology. *Center for Advanced Engineering Study, Cambridge, MA.*

Goulden, C. and L. Rawlins, 1995. A hybrid model for process quality costing. *International Journal of Quality and Reliability Management*, 12(8): 32-47.

Harrington, H. J., 1987. *Poor-quality cost*. CRC

Hwang, G. and E. Aspinwall, 1996. Quality cost models and their application: a review. *Total Quality Management*, 7(3): 267-282.

Kanji, G., 1990. Total quality management: the second industrial revolution. *Total Quality Management & Business Excellence*, 1(1): 3-12.

Kumar, K., R. Shah, et al., 1998. A review of quality cost surveys. *Total Quality Management*, 9(6): 479-86.

Kume, H., 1985. Business Management and Quality Costs: the Japanese View. *Quality Progress*, May: 13-18.

Letza, S. and K. Gadd, 1994. Should activity-based costing be considered as the costing method of choice for total quality organisations? *The TQM Magazine*, 6(5): 57-63.

Modarress, B. and A. Ansari, 1987. Two New Dimensions in the Cost of Quality. *International Journal of Quality & Reliability Management*, 4(4): 9 - 20.

Plunkett, J. J. and B. G. Dale, 1987. A review of the literature on quality-related costs. *International Journal of Quality & Reliability Management*, 4(1): 40-52.

Plunkett, J. J., B. G. Dale, et al. (1985). Quality Costs. D. o. T. a. Industry.

Porter, L. and P. Rayner, 1992. Quality costing for total quality management. *International Journal of Production Economics*, 27(1): 69-81.

Ross, D. T., 1977. Structured analysis (SA): A language for communicating ideas. *IEEE Transactions on software engineering*: 16-34.

Sandoval-Chavez, D. and M. Beruvides, 1998. Using opportunity costs to determine the cost of quality: a case study in a continuous-process industry. *The Engineering Economist*, 43(2): 107-124.

Schiffauerova, A. and V. Thomson, 2006. A review of research on cost of quality models and best practices. *International Journal of Quality and Reliability Management*, 23(6): 647-669.

Schneiderman, A., 1986. Optimum quality costs and zero defects: are they contradictory concepts? *Quality Progress*, 19(11): 28-31.

Schoeffler, S., 1974. Impact of strategic planning on profit performance. *Harvard Business Review*, (March/April): 137-145.

Summers, D. C. S., 1997. *Quality*. Upper Saddle River, NJ: Prentice Hall, c1997.

Taguchi, G., 1987. *System of experimental design: engineering methods to optimize quality and minimize costs*. UNIPUB/Kraus International Publications

Tsai, W., 1998. Quality cost measurement under activity-based costing. *International Journal of Quality and Reliability Management*, 15(6): 719-752.

Wang, M.-T. and J. C. Chen (2009). A Literature Review on Cost of Quality: Applications, Advancement, and Trends. Taiwan, Taipei.