



Measuring Cost of Quality (C.O.Q) and Quality Improvement (Case study: A Steel Company in I.R.IRAN)

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ABSTRACT

The purpose of this study is to measure the value of quality improvements in one of the two greatest steelmaking factories in middle east during the six months period since June to December,2020 and has used a new method (introduced by dahlgaard & setijono) for transforming quality cost measurements into value of quality improvements(ROQI). The two used models in this paper have been theoretically developed and examined in a Swedish wood-flooring manufacturer. The data analysis results in present study suggest that quality improvement efforts do affect on quality improvement indicators, and model validation is reconfirmed.

By converting quality costs measurements into value, a better explanation concerning the effect of prevention and appraisal activities on the quality improvement indicators would be provided. Thus, the value of quality improvements is a measure of return on quality improvements (ROQI), which reveals whether the quality improvement efforts gave higher, fair, or lower return.

Keywords:

cost of Quality, Quality improvement, Value analysis

1. Introduction

Many companies in the world gradually have promoted quality as the central customer value and regard it as a key concept of company strategy in order to gain the competitive edge. Measuring and reporting cost of quality (CoQ) is the first step in a quality management program (Tsai, 1998). The existing concept of quality costs has been criticized as:

- It is reactive rather than proactive, i.e. it deals with the consequences of failures and losses; and
- It is based on producer's way of defining quality and it does not adequately take customer's perspectives into account.

Value of conducting a quality cost analysis is through highlighting non-value adding activities or waste and pinpointing potential improvements. Quality costs are an indicator (or a measure of the effectiveness of a quality management system, and the identification of the potential failures lead to the identification of improvement opportunities. Using only quality costs for improvement is inadequate; it is necessary to broaden the narrow perspective of quality costs into a customer value analysis to capture a broader impact of quality and adopt a continuous improvement approach to "sense" the improvement opportunities. So, quality costs should be measured in a proactive way, i.e. to consider the customer's perspective, which often either may be difficult to measure or is unknown (setijono, 2007).

Based on the extensive database derived from thousands of business units, they revealed that improved relative perceived quality was associated with significantly increased profitability, whether measured as return on sales (ROS) or return on investment (ROI). Also, achieving superior conformance quality yields both lower costs and superior perceived quality- a double benefit (Visawan, 2003).

Describing customer perceived value as a dynamic term makes it possible to deduct an analytical model. This specifies implications of company's efforts for improving design & conformance quality on customer perceived value about the Product. Quality costs as a performance indicator of improved design and conformance quality (as a result of appraisal and preventive actions) can be explained as value, (i.e. trade-off between benefits & sacrifices). The improvement benefits consist of higher product quality

and lower failure costs. The sacrifices include costs of doing improvement efforts (prevention & appraisal costs). Expressing quality costs in this method, makes a relation between the producer's efforts to improve quality & customer's perception about the product value (Dahlgard, 2007).

Research purpose

This research, has used a new proactive method of measuring quality costs which describes value of quality improvements and its implications on customers' perception about product value. It is a mechanism which clarifies quality improvements are valuable or not, and it indicates that probably producer's efforts & actions about quality improvement would affect on customers' perception of product value. And this knowledge that producers have active roles in creating customer value will be strengthened.

Literature review on quality costs

The used model in this research has been first developed & tested in a wood-flooring manufacturer in Sweden.

But about relation between quality cost & value should be noted that for the first time, Tsai (1998) initiated this relation through classifying quality costs factors to value—added & non value—added based on activity based costing. But he didn't mention the relation between producer efforts regarding quality improvement, customer value & effect of value—added activities on customer value. He introduced prevention & appraisal costs as Value—added and failure costs as non value—added quality costs. With this reasoning, he corresponded and matched PAF & ABC model and with this basis, has suggested COQ-ABC integrated model.

Under the ABC perspective, only prevention costs in the PAF approach and only some of conformance costs in the process cost approach are value added (Tsai, 1998).

Definitions of cost of quality

Quality related cost is defined in BS 6143: Part 1 as: cost in such categories as prevention cost; appraisal cost; internal failure cost and external failure cost. Also quality related cost in BS 6143: Part 2 it is defined as: Cost in ensuring and assuring quality as

well as loss incurred when quality is not achieved (Dale and Plunkett, 1995)

According to the American Society for Quality Control (ASQC), quality costs are a measure of costs specifically associated with the achievement or non-achievement of product or service quality, as defined by all product or service requirements established by the company and its contracts with customers and society (Krishnan, 2006).

Horngren et al. defined the costs of quality as "those costs that are incurred to prevent a shortfall in quality and a failure to meet customer requirements, as well as costs incurred when quality does in fact fail to meet customer requirements"(krishnan, 2006).

Models and definitions of quality cost elements

In order to collect, categorize and measure quality costs, several methods can be No matter which quality costing approach is used, the main idea behind the CoQ analysis is the linking of improvement activities with associated costs and customer expectations, thus allowing targeted action for reducing quality costs and increasing quality improvement benefits.

The traditional PAF model suggested by Juran and Feigenbaum classifies quality costs into prevention, appraisal and failure costs. Prevention costs are associated with measuring the level of quality attained by the process, and failure costs are incurred to correct quality in products and services before (internal) or after (external) delivery to the customer. The PAF model which is accepted by ASQC and BSI (British Standard Institution, is used by the most of the companies implementing quality costing system (Schiffauerova, 2006).

In order to identify and separate quality costs in this research the PAF model has been used.

The applications of quality costing

Campalella (1999) has indicated to a very important point about implementation of quality costing system:

Quality cost measurement and publication do not solve quality problems

He has emphasized that quality costing is not the only solution of any quality shortcomings, but also measuring quality costs must be complemented by the quality improvement methods to be succeeded. In order to sum up the different functions of quality costing,

three overall areas are identified. The first area of use is that it translates the oftentimes confusing field of quality management into a dimension that everyone understands-money. By doing this it makes the quality concept more tangible and helps

to change the attitudes towards quality management on all levels in the company. Secondly, with the use of quality costing the company can unveil which areas that have great improvement possibilities and help you prioritize between these. This way the quality management function can allocate resources to where they make the best use. The third area is that quality costing makes it possible to evaluate and follow up the quality efforts that are being made. This makes the calculations of returns from quality investments rather straightforward (brekke, 2007)

According to Campanella (1999) the goal of quality cost system is to facilitate quality improvement efforts that will cause operating cost reduction opportunities, and presents a basic strategy for achieving this:

- 1) Take direct attack on failure costs in an attempt to drive them to zero
- 2) Invest in the "right" prevention activities to bring about improvement
- 3) Reduce appraisal costs according to results achieved
- 4) Continuously evaluate and redirect prevention efforts to gain further improvement This strategy is based on the following assumptions:
 - for each failure there is a root cause,
 - causes are preventable, and
 - Prevention is always cheaper (campanella, 1999).

The purpose of quality management is to meet and satisfy customers requirements through quality of design and quality of production (conformance to satisfaction), or similar to Ishikawa s forward-looking and backward-looking quality. The existing concept of quality costs is very much influenced by conformance quality or backward-looking (must-be) quality but is less influenced by design quality or forward-looking (attractive) quality. Hence, quality costs depend on how the quality is defined and who (producer or customer) defines it. Therefore, quality cost normally presents a measure seen from the producers perspective but seldom from customer's perspective.

In order to capture the "true essence" of quality, it is suggested that quality costs should be put in another context and measured in a new way, i.e. in terms of value. By doing so, the measurement can be used to model the contribution of improvements on the change in customer value (Dahlgard, 2007).

Customer value & its dynamic model:

From the producer's perspective, customer value is described as customer economic value for company which is different from customer value description based on demand, as the company value or its products value for customers. A comprehensive understanding & perception of customer value should include all of various aspects of customer role in company success (Rahnamay, 2008).

Impact of Quality improvement on quality costs

We now discuss the dynamic concept of analyzing quality costs and the manner in which the analysis is affected by the continuous quality improvement philosophy. First, with continuous improvement, not only is there a reduction in the unit cost of the product or service, but also a change in the shape of prevention and appraisal cost function. Usually, the rate of increase of this function with the level of quality will be smaller than in the original situation. Ignoring, for the present, the other impacts of quality improvement figure 1 shows the shifted prevention and appraisal cost function. Note that the optimum level of quality desired improves (from q_1 to q_2). Rationalizing along these lines, the target level of quality to strive for, in the long run, should be total conformance.

Improvements in technology and advances in knowledge will initially affect the prevention and appraisal cost function, shifting it to the right with a reduction in slope. Also such advancements start out in incremental steps (i.e., the Kaizen concept of continuous improvement), after the achievement of a certain quality level, management must focus on technological breakthroughs to further improve quality. Such major innovations may lead to a reduction in the rate of change in the level of prevention and appraisal cost function and consequently, a change in the slope of the prevention and appraisal cost function. The shape of the prevention and appraisal cost function changes from concave to convex after a certain level of quality

(inflection point). Due to such a change the shape of the total quality cost function will also change and will show a decreasing trend with the level of quality (Mitra, 2008).

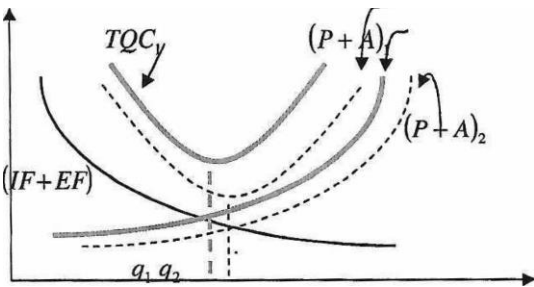


Figure 1: The dynamic concept of the impact of quality improvement

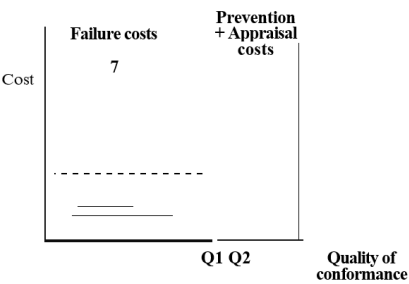


Figure 2: Creative quality improvements

So, we can conclude that:

- A discussion about quality improvement should include PA (the effort), an indicator that explains quality-construct from the positive side(in this case, it is simply defined as Q), and an indicator that explains quality-construct from the negative side, i.e. the failure cost; (F) and
- The prevention-appraisal activities (PA) have a direct effect on quality performance (Q) and subsequently affect the failure costs (F) because changes in quality performance will influence changes in failure costs.

Using these two points, a general model of the value of quality improvement will be constructed.

For more knowledge about the used models and their factors, a brief description about the Dahlgard and

setijono's prototype has been adopted in the next section.

General model of the value of quality improvements

From the producer's view, assessing quality improvements is [essentially] a comparison between the benefits (i.e. changes in quality (*Q*) and failure costs (*F*)) gained from the improvements and the expenses to perform prevention and appraisal activities (*PA*). The ratio between benefits of improvement and the expense is defined as the value of quality improvements considering that the value is the ratio between benefits and costs.

$$V = \frac{(RQ)^2}{RPA} + \frac{(RF)^2}{RPA}$$

R_{PA}: The relative change in prevention and appraisal related costs;

R_e: The relative change in quality performance results;

R_F: The relative change in failure costs

The change in quality (*Q*), will likely influence customer's perception regarding the benefits of product, while the change in failure costs (*F*) will likely influence customer's perception regarding the sacrifices to acquire the product. In the present paper the changes in (*PA*), (*F*), and (*Q*) are measured in a relative term.

The analytical model above suggests that changes in prevention and appraisal activities affect both the benefits from the changes in failure costs and quality performance. The former part of the equation *RdR_{PA}* indicates the direct effect of improvement efforts, while the later part of the equation *R_F I RPA* indicates the subsequent effect of improvement efforts (meaning that the quality performance must be improved first before the failure cost can be reduced). Although the model does not accommodate the time lag of performance improvements, the value measurements indicate whether the overall relative benefits achieved through improvements are higher than the relative expenses to perform the improvement activities. As long as the relative change in the expenses related to prevention and appraisal does not exceed the relative change in the benefits gained from the improvements (i.e. improved quality and reduction of the failure costs), the

value of improving quality is higher than one. However in this measurement, the lower limit of value is *V_i*, =1.41, because it is the calculated value when the *PA*, *Q* and *F* are the same between period *i* and (*i* + 1) [thus, *R_{PA}* =1, *R_Q* =1, and *R_F* =1] Therefore, a cut-off point of 1.41 should be used to determine whether the efforts of improving quality have resulted in a valuable return or not.

Specific models of value measure

Model 1; the value of improving forward-looking quality The benefit that the producer expects from the performed quality improvements is that the customers' perception regarding the quality of the product will be increased. Thus, customers' judgment on quality (*Q*(1)) is the indicator of forward-looking quality.

$$V = \frac{(RQ)^2}{RPA} + \frac{(RF)^2}{RPA}$$

Considering the practicality aspect, *Q*(1) may be measured, e.g. every six months or annually. If we first measure it at month 1 (i.e. period *i*) then the next measurement is at month 7 (i.e. period (*i* + 1)). The measurement of *v_i* in (7) requires that the distance between period *i* and period (*i* + 1) of *R*(*QI*) should be equal to the distance between period *i* and period (*i* + 1) of *R_{REF}* and *R_P*(*CCV*) is a measure of customers' perceptions regarding the quality of a company's product or service. (*CCJQ*) is the sum of multiplication between the product performance score (*P*) and the weight of importance score (*VV*) of each selected Quality attribute. In order to eliminate the ambiguity of interpretation, which is caused by the use of different measurement scales (e.g. a 1-5 scale, a 1-7 scale, or a 1-10 scale), we can use a normalized score (*NP*) for *P*.

$$CCJQ = \sum W_j * NP_i \text{ where:}$$

The weight (importance) is the ratio between the importance score of a certain attribute and the sum of importance scores for all selected attributes. Normalized performance score (*NP*) is the ratio

between the distance of original performance score (P) from the minimum possible score in the performance score measurement (P_{min}) and the range of the measurement scale.

$$NP_i = \frac{P_i - P_{min}}{P_{max} - P_{min}}$$

Model 2: the value of improving conformance quality performance

Quality improvement efforts may bring benefits such an increase in the percentage of the produced products that conforms to specifications or backward-looking quality (OD).

Therefore, the value of improving backward quality (v_2) is defined as:

Y_{i+i} : The yield (the percentage of conforming products) at period ($i + 1$)

Y_i : The yield at period i

R_i is measured in a similar way as R_{E_i} . Considering the practicality aspect Q(2) may be measured, e.g. every month or quarterly, while Q(1) may be measured every six months or annually. This means that the distance between the period i and period ($i + 1$) for Q(1) and Q(2) may not be equally long, but the distance between the period i and period ($i + 1$) of $R_{Q(2)}$ should be equal to the distance between period i and period ($i + 1$) of $R_{Q(1)}$. In the case Q(2) is measured quarterly, if we first measure it at month 1 (i.e. period i) then the next measurements at month 4 (i.e. period ($i + 1$)).

Research questions

- 1. How do the changes in customers' cognitive judgment on quality, appraisal and prevention costs, and external failure costs variables affect on value of quality improvement efforts in the forward-looking model?
- 2. How do the changes in yield, prevention and appraisal costs, and internal failure costs affect on value of quality improvement in the backward-looking model?

where: Q_i

Research method

The general method of present research in terms of purpose is practical, about deduction method is descriptive, regarding research project related to functional variables is Ex-post Facto research and about customers' perspective is Field research.

Statistical Population & sample

The statistical population of present research is the tinned sheet produced by a steelmaking factory in Iran at biannual time limit from July to December, 2010. It should be noted that in Iran, financial year/period begins in April and ends in March, so the time period of this research is within one financial year.

Statistical sample

In variable CCJQ as reference of customers' cognitive Judgment on quality, the 20-80 Rule has been used and the customers who allocated 80% of the product sale to themselves were asked to fill the questionnaire forms at the beginning and ending of the time period, i.e. in July and January. Final statistical sample number was determined 36 customers

Data collection tools

This research has used: the questionnaire tool to evaluate the customer's cognitive judgment on quality; interview with industrial accounting staff, quality control units, industrial engineering, production engineers, customers, sale technical support; and also data summary table, check list, receipt & SPSS statistical soft ware have been used.

Collected data analysis:

Model I: value of improving forward looking quality:

Method of calculating variable CCJQ is that first we calculate average customer scores to importance & performance, and after calculating normalized importance and performance scores and then importance weight, we calculate normalized performance product in importance weight, which sum of multiplications indicates the customers' cognitive judgment on quality. The calculations of the relative change in customer cognitive judgment on quality and the value of improving forward-looking quality are following.

$$\begin{aligned} CCJQ_1 &= 0.6273 & CCJQ_2 &= 0.6183 \\ R_{oo} &= 0.986 & R_i &= 0.875 & R_{EF} &= 0.303 \\ \frac{0.986 \times 0.303}{11(0.875) + (0.875)} &= 1.179 \end{aligned}$$

Interpretation: 123% reduction in quality improvement activities (PA) in period 1 and 2 has decreased customer satisfaction by 1.4% and increased external

failure costs by 69.7%, which means value of quality improvement is 16.65% below the cut-off point. Model 2: the value backward-looking quality In this section quality improvement results for July and January (month 1 and month 7, to be compared with first model), are presented. Then monthly results are presented separately

$$\begin{aligned} R_{Q(2)} \cdot 1.012 \cdot R_{IF} &= 0.153 \\ \frac{1012 - 0.875 \cdot 153}{v2} &= (0.875) + (0.875)2 = 1.170 \end{aligned}$$

Interpretation: 12.5 percentage of reduction in quality improvement activities (PA) between period 1 and 2, increased internal failure costs 84.7%. Thus, value of quality improvements is 17.28% below the cut—off point. Table of monthly results is following:

Table 1: Value of improving the conformance quality

July-August	<i>R_{PA}</i>	<i>REF</i>	<i>R_{Q(2)}</i>	<i>v₍₂₎</i>
July-August	0.885	0.357	1.016	1.217
August-September	0.970	1.232	1.010	1.641
September-October	0.920	0.219	0.989	1.101
October-November	1.083	1.600	0.987	1.737
November-December	0.970	0.996	1.013	1.465
December-January	1.145	1.465	1.010	1.554

Model validation:

Data analysis shows that quality improvement activities influence on quality improvement indicators (*R*²= 87.5%: Cubic equation), which confirms validation of

equation 2. Figure 3 illustrates concept of creative quality improvements. With the same amount of efforts (X 0.97) higher results from (y 1.42) to (y 1.59) can be achieved.

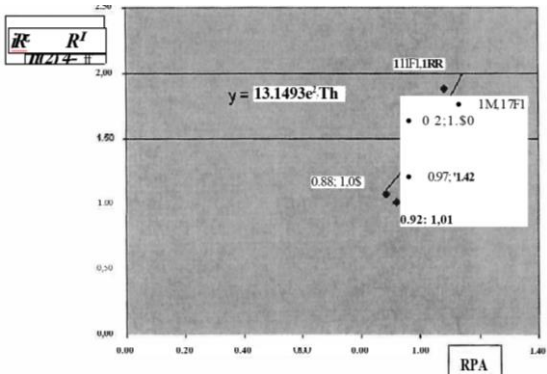


Figure 3: The effect of quality improvement efforts on quality improvement indicatorsDiscussion

Customer's perceived value of a product is a function of the value of quality improvements, and the function is positive and increasing. This implies that valuable quality improvements influence the perceived customer value of the product. Changes in appraisal-prevention costs, failure costs, and yield are determining variables whether the improvements are higher than fair return ($v > 1.41$), relatively fair return ($v = 1.41$), or lower than fair return ($v < 1.41$). In other words, the value of quality improvements is the indicator of return on quality.

improvement (ROQI), which measures the return on investments (based in staff's knowledge and efforts such as other resources) to achieve a higher level of quality performance.

In recent research we found that in first model ($v_1 = 1.179$), improvements were less than fair return. **22.5%** reduction in quality improvement activities (PA) during the period has decreased customer satisfaction by 1.4% and increased external failure costs about **70%** the value of quality improvements was **16.65%** lower than the cut-off point.

In the second model, separate values were calculated for each month. We saw that in July and September, improvements were lower than the fair return and in other months the improvements were above the fair value.

Thus the quality improvement efforts during these months relatively satisfy the expectations, which clarifies that benefits were higher than the expenses. It is important to note that when ($v < 1.41$) it should not be interpreted as a symptom of failure in quality improvement. Instead, it can mean that the quality improvement efforts should have been more intelligently performed to strongly influence the customer value and also producer value.

Conclusions

As study explained, the basic purpose of quality management is to meet and satisfy customer's requirements. But When we focus on this purpose, the insufficiency of the concept of quality costs is unveiled. Therefore, quality performance measurement should not just consider costs from the producer's view, but also it should also take

the customer's view into account. Perception and improvement of quality cost in a value-field requires proactive thinking, because measuring quality costs:

- Can be used to evaluate whether the improvement efforts are valuable (i.e. provide higher benefits versus expenses)
- Can reveal this fact that improving product and process quality, also affects on customer perception of product value.

This paper has used a new method for converting quality cost measurements into quality improvement value (ROQ/). The value measure (ROQ/) suggests that if the total of acquired benefits (increase of quality indicator such as yield and decrease of failure costs), be higher than costs of implementing improvement actions or with the same amount or less of costs, same or higher benefits result, quality improvement efforts are valuable.

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