Cost of Quality Analysis: Driving Bottom-line Performance

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Abstract

Cost of Quality (COQ) analysis enables organizations to identify, measure and control the consequences of poor quality. The major goal of a COQ approach is to improve the bottom-line by eliminating poor quality. Among the various factors contributing to COQ, hidden costs such as opportunity costs are difficult to quantify. This paper describes an effort to estimate the opportunity costs in manufacturing. A case study, based on process interruptions in continuous casting of steels, is in progress.

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. It is indicated that the COQ estimation can be used to decide on the budgetary limits for installing prevention mechanisms / devices.

2. COQ

The concept of COQ was first mentioned by Juran (1951) as the ‘cost of poor quality’. According to Crosby (1979), COQ is the ‘price of non-conformance’. The term 'Cost of poor Quality' refers to the costs associated with providing poor quality product or service. COQ is the amount of money a business loses because its product or service was not done right in the first place. It has been suggested that the cost of poor quality can range from 15%-40% of business costs.

3. The categories of COQ

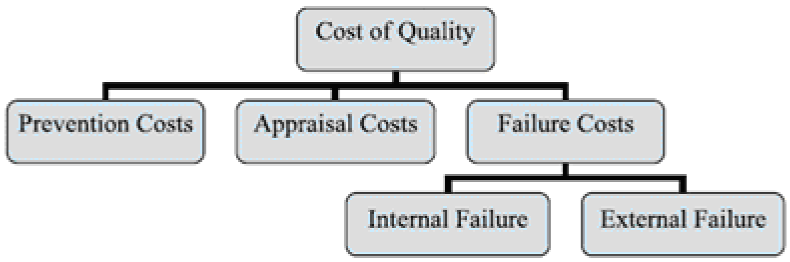
*Internal Failure Costs***:** The costs that would disappear if no defects existed prior to shipment to the customer. These costs include rework, scrap, re-inspection**,** re-testing, corrective action, redesign, material review, material downgrades, vendor defects, and other like defects.

*External Failure Costs***:** The costs that would disappear if no defects existed in the product after shipment to the customer. These costs include processing customer complaints, customer returns, warranty claims and repair costs, product liability and product recalls.

*Appraisal Costs***:** The costs incurred while performing measuring, evaluating, or auditing to assure the quality conformance. These costs include first time inspection, checking, testing, process or service audits, calibration of measuring and test equipment, supplier surveillance, receipt inspection etc.,.

Prevention Costs: The costs related to all activities to prevent defects from occurring and to keep appraisal and failure to a minimum. These costs include new product review, quality planning, supplier surveys, process reviews, quality improvement teams, education and training and other like costs (Gary Zimak, 2000).

Figure 1.
Quality Costs Categories (Suhansa Rodchua, 2006)



The COQ Models

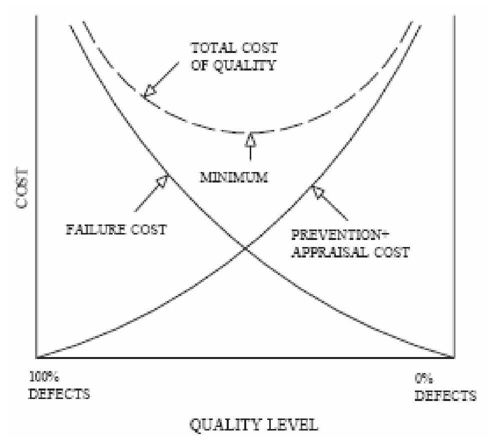
In general, COQ models are classified into four groups (Schiffauerova and Thomson, 2006).
P-A-F models: Prevention costs+ Appraisal costs+ Failure costs
Crosby's model: Cost of conformance+ Cost of non-conformance
Opportunity or intangible cost models: [Prevention costs+ Appraisal costs + Failure costs + Opportunity costs] / [Cost of conformance+ Cost of non-conformance+ Opportunity costs] / [Tangibles + intangibles] / [P-A-F (failure costs includes opportunity costs)]
Process cost models: Cost of conformance + Cost of non-conformance

Most COQ models are based on the *P-A-F* classification and the basic suppositions of the *P-A- F model* are that investment in prevention and appraisal activities will reduce failure costs, and that further investment in prevention activities will reduce appraisal costs. Opportunity and intangible costs are hidden and can only be estimated as profits not earned (or revenue not earned), because of lost customers. e.g, under-utilization of installed capacity, downtime, insufficient material handling and poor delivery of service.

4. Optimum quality cost model

Many economic and mathematical models have been developed to find the optimum COQ. The traditional model detailed by Brown and Kane (1984) (as cited by Kazaz et al, 2005) has got widespread acceptance. According to this model, shown in Figure 2, there is an inverse relationship between prevention and appraisal effort and failure cost. The optimum conformance to quality or defect level is where the increasing costs of the prevention and appraisal curve converges with the curve of decreasing failure costs. Total quality costs are minimized to the point where the cost of prevention plus appraisal equals the cost of failure. The total quality cost curve represents the sum of the other two curves, and the location of the minimum point on the total quality cost curve, sometimes referred to as the optimum point (Kazaz et al, 2005).

Figure 2.
The basic model of optimum quality cost (Kazaz et al, 2005)



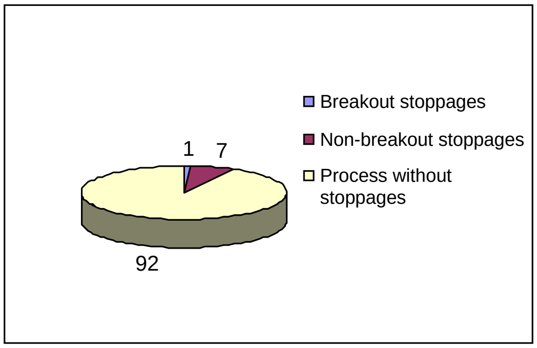
5. Continuous Casting of Steels

Liquid steel is produced in steel making furnaces, then subjected to refining / secondary treatments and then taken up for continuous casting. The continuous casting process is used to convert liquid steel into solid steel of simple geometrical shapes (of different section sizes) such as slab, bloom or billet (using one or more moulds simultaneously). A steel plant can have more than one continuous casting machine and each machine can have more than one mould. During continuous casting, certain difficulties are encountered – some of which result in stoppage of the process, while some others result in quality problems in the cast product. Full economic benefits of continuous casting could be achieved if the "process quality" is very high and process stoppages are kept to a minimum. In some steel plants, the volume of production may be very high (such as three to four million tones of steel per annum), but process stoppages may be frequent.

The process of continuous casting gives maximum benefits only when heats (batches) can be cast continually, within each heat and between consecutive heats. Any stoppage / interruption of the casting process is undesirable; and, is treated as a "defect, with respect to process quality". Typical annual production (such as in the plant where this study was carried out) may be made up of more than twenty thousand heats. The trends in process stoppages (process defects), compiled over an extended period of time, are presented in

Figure 3 (Mohandas, 2008). It may also be stated for the record that all process stoppages do not have identical impact on the shop floor activities.

Figure 3.
Pie Chart of process stoppages in continuous casting (Mohandas, 2008)



Process without stoppages = 92% (situation OK)
Process stoppages due to breakouts = 1% (NOT OK; stoppage - Low frequency, high nuisance value)
Process stoppages due to causes other than breakouts = 7% (NOT OK; stoppage - Moderate frequency, low nuisance value)

One of the process stoppages is “breakout”, wherein the partly solidified steel shell gets ruptured and the casting activity, from that particular mould, is aborted. Once a breakout occurs, it becomes necessary to divert the remaining liquid steel to other moulds, for casting. The liquid steel which has flowed into the sections of the machine needs to be cleared, by removing some segments / sections of the machinery. Further, the inside of the mould needs to be cleaned, after removing the breakout piece which may be left in the mould. In addition, the details of the breakout need to be documented and the cause of the breakout needs to be identified. i.e., there are considerable costs related to internal failure and appraisal. From the plant engineers’ point of view, the breakout is a big nuisance and results literally in a mess in the casting platform. The “firefighting” consequent to the breakout is considered a big headache by operators in the shop-floor.

Various technical (and human) causes for breakouts have been identified (widely reported in the open literature) and remedial measures have been taken in steel plants to reduce breakouts (such as in Mohandas, 2008). One of the strategies, to overcome the problem of breakouts, involves the installation of breakout detection system – which alerts the operator about imminent breakout. Such breakout detection system is useful in detecting and possibly preventing “sticker / sticking” type of breakouts. In the cited plant, about 60% of breakouts were of the sticker type. Therefore, in the spirit of 80:20 Principle and Paretto analysis, elimination (or reduction in frequency) of sticker breakouts will be a big boon for the plant engineer. However, the design and installation of breakout detection systems, is in itself, a major project in the continuous casting of blooms (with indicative value of 300 mm square section) and is also expensive. The cost associated with the breakout detection system is to be treated as the prevention cost.

6. Analysis of Breakouts

While analyzing the (rather frequent) occurrence of breakouts in the plant (where the study was carried out), the authors felt that the plant engineers had been more concerned about the "problem of breakouts" than the "economic implications of breakouts". An effort was made to convince them that the "economic consequences of poor process quality" were much higher than what they were assuming. In other words, the COQ associated with hidden aspects was much more than what they had visualized. The following item-wise approach was then adopted:

Cost of downtime: The mould wherein breakout occurred becomes unusable for the next few hours of production. Considering the planned rate of production and the utilization of the different casting machines in the plant, a cost figure (equivalent to six hours of production in one casting mould) was deduced, based on the "lost opportunity for production".

Cost of unused liquid steel: Despite the efforts made to divert liquid steel to other moulds, certain amount of liquid steel gets wasted. A detailed analysis indicated that the cost of liquid steel wasted is equivalent to two tonnes of salable product.

Cost of solid steel scrap: The scrap generated after a breakout, including the discarded breakout piece and spillage scrap, was found to be equivalent to two tonnes of salable product.

Cost of mould repair: The inside of the mould gets damaged after breakout; and a good deal of mould repair needs to carried out in the workshop. This also requires transporting of the mould / breakout piece to the workshop. This activity was estimated to be equivalent to one tonne of salable product.

Cost of breakout characterization: This has not been quantified, so far, in this plant. [The breakout piece of the casting is removed from the mould, inspected by technician and engineer – documenting the overall appearance, as well as the discernible features (such as markings on the surface). Technical report is then prepared and discussed in meetings involving engineers from production, quality assurance and research – in order to identify the root cause. In case the problem is traced to "consumables in the process", then the details are also conveyed to the supplier of the cited consumable in the given case. Further work is in progress, in this plant, involving academic institutes – to enable rigorous metallurgical analysis.]

Consequently, the hidden costs of a typical breakout could be calculated (with four of the five cited aspects, at present). Then, considering the indicative number of breakouts occurring per year, it was observed that the COQ (in the above perspective) was equivalent to about one half percent of the annual turnover. It was also pointed to the plant that the prevention cost would be lower by nearly an order of magnitude. The authors have convinced the plant to seriously examine the option of installing a breakout detection system. It has been visualized that the cost of investment in detection system could be recovered even if only 10% of (imminent) breakouts are detected and prevented.

Further investigation is in progress to fine-tune the COQ estimation; and to study, in detail, the potential cost benefit in terms of the breakout detection system/s (may be installed in stages, in the multiple moulds / machines in the plant). In other words, the <u>COQ approach can help define the developmental priorities in manufacturing</u>. The authors have been able to sensitize the plant engineers to the **COQ** (in particular production process) and to look at "**process quality**" and also to look at the relations between COQ and the **bottom-line performance** of the plant. The authors believe that strategic analysis of costs, including the cost of process failures, is a pre-requisite to operational excellence.

7. Conclusions

COQ programs provide a good method for identification and measurement of quality costs, and thus allow targeted action for reducing the COQ and thus improving the quality. The significant costs that are hidden and difficult to measure such as opportunity costs like down-time cost, cost of lost material and repair cost (in a steel plant) have been estimated. The findings are then used as criteria for decision making, in the context of suitable prevention techniques.

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