

## Managing Quality: Modeling the Cost of Quality Improvement

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### Abstract

*Now more than ever, competition, slim profit margins and stakeholder expectations are compelling managers to scrutinize the return on quality investment and reexamine the sensitivity of quality improvement decisions in terms of market impact per quality dollar. Although the costs associated with achieving and sustaining quality has been the subject of research and discussion for many years, the costs associated with quality improvement initiatives have not been adequately modeled. The paper presents an expanded quality cost model that depicts the cost implications of extraordinary quality improvement activities such as a concerted quality problem solving effort or a Six-Sigma program.*

### Introduction

Quality improvement efforts may be initiated in response to quality problems, to exploit opportunities for quality improvement due to innovation or technology, or as a strategic quality improvement program such as Six Sigma. Quality improvement activities are different from other quality-related management and control activities such as process management, inspection, or control (associated with prevention and appraisal or conformance activities), because they are goal based and the efforts are in addition to routine quality activities. This distinction allows managers to clearly identify the quality improvement activities along with the cost of resources used in the activities. In turn, managers can evaluate cost reductions attributable to the quality improvement activities and evaluate the return on investment (ROI). For this reason, the costs of quality improvement are unique costs that need to be identified separately in the overall quality related cost structure.

Quality is inexorably linked to profitability (Summers, 2003; Deming, 1986). In the past decade, improved quality techniques and technological advances in quality control have resulted in higher levels of product quality in both manufacturing and service sectors. Gyryna (2001) observed that companies that have attained competitive levels of quality are seeking trade-offs in terms of marketability and quality costs. It is therefore important to be able to assess all aspects of quality-related costs and find a balance between quality costs, product competitiveness, and profitability (Gyryna, 2001).

Philip Crosby (1984) describes quality costs as the price of making things right the first time plus the price of making things right if they are not. Heinloth (2000) advocates a return on investment approach to determining the cost of quality. He states that the effect of quality on profit is dependent on the way in which quality affects income or expenses. Bland (1998) suggests the cost of poor quality represents the difference between the operating costs when there are no system failures and when there are system failures. Finally, the American Society for Quality (ASQ) defines the cost of quality as those costs associated with the achievement or non-achievement of quality (Bland et al. 1998).

Identifying sources of quality-related costs is a critical step in determining the quality cost structure and ultimately developing a quality costing system to support a quality cost management strategy. The information generated by such quality cost analysis helps managers to identify quality costs, prioritize quality cost reduction activities, and measure the success of such activities. If quality improvement efforts can be evaluated separately from other more routine or operationally integrated quality efforts, managers can measure the return on investment of quality improvement and determine the value-added component in terms of profitability.

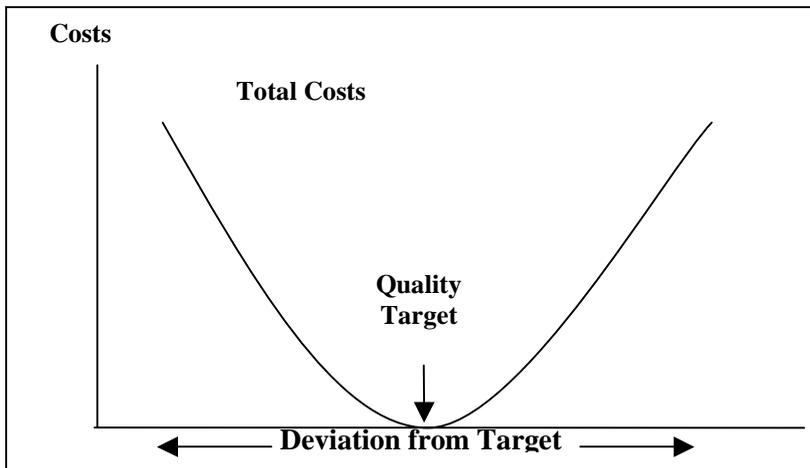
Existing “cost of quality” or “cost of poor quality models” do not address the impact of quality improvement efforts on the quality-related cost structure. A more robust model for describing the influences of quality improvement activities on quality-based cost structures is articulated in this paper.

### The Value- Added Aspect of Quality Improvement

Dale and Plunkett (1999) argue that improving quality is a strategic imperative because it reduces all aspects of quality related costs. There are two popular perspectives on the dynamic effect of quality improvement on quality costs: the Taguchi loss function and the cost-process capability curve.

Taguchi (1989) presents a loss function that describes the effect of deviation from quality targets on costs. The concept can be used to describe the dynamic effect on error and poor quality on total costs. Taguchi views quality loss as a quadratic function similar to Figure 1.

**Figure 1: Taguchi Loss Function**



In a general sense, the Taguchi curve can be interpreted as a phenomenon where any deviation from a quality measure target incurs costs that increase at an increasing rate as the actual measure moves away from the target value. From the quality cost perspective, the closer a company can get to its quality targets, the more it reduces quality related costs. Theoretically, if a company can consistently attain its quality targets, quality-related costs will be minimized and will consist only of those costs incurred to sustain the target quality level.

### Cost-Process Capability Curve

Quality improvement can be evaluated in terms of process capability. Harry and Schroeder (2000) present a Six Sigma approach to quality improvement that uses process capability to measure quality cost reduction (As depicted in Figure 2, an increase in process capability leads to a decrease in prevention and appraisal costs.

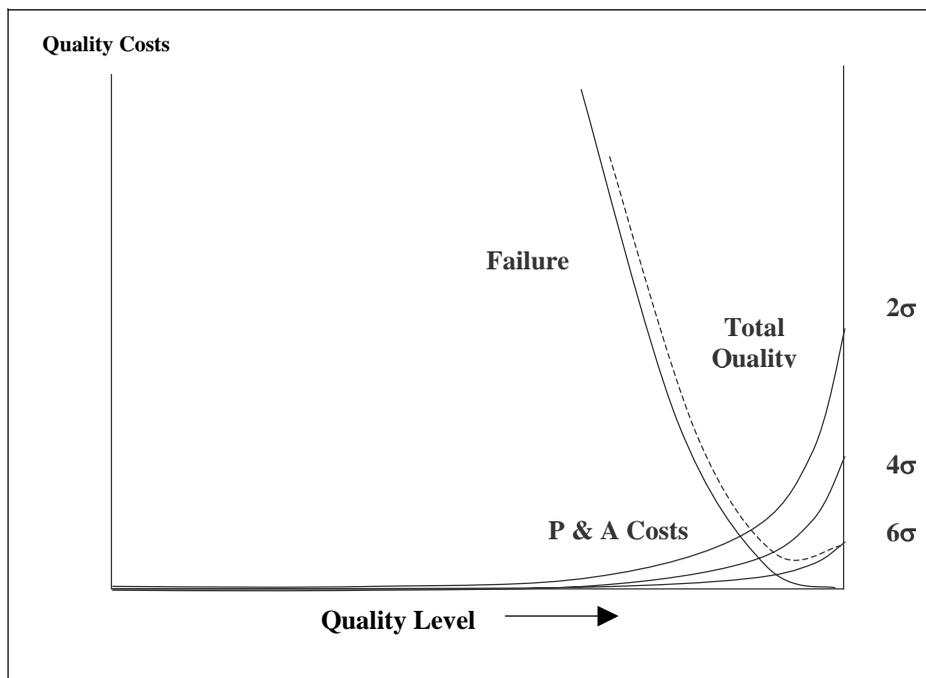
## Quality Improvement

The impact of quality improvement from the value-added perspective suggests that progressive quality improvement leads to progressive reduction in quality-related costs. However, extraordinary quality improvement efforts beyond the routine operational quality activities would at first incur additional costs but if successful would eventually benefit from the value-added effect and ultimately reduce all quality-related costs.

## Cost of Quality

The PAF (prevention, appraisal and failure) cost of quality model is probably the most common model used to describe costs associated with quality and the first to describe quality-related costs as a type of double-edged sword. Harrington (1999) credits Joseph Juran, Armand Feigenbaum, Phillip Crosby, and W.J. Masser as major contributors in postulating the cost of quality concept in the 1950s.

**Figure 2: Sigma Level Effect on Total Cost**



## Quality Level

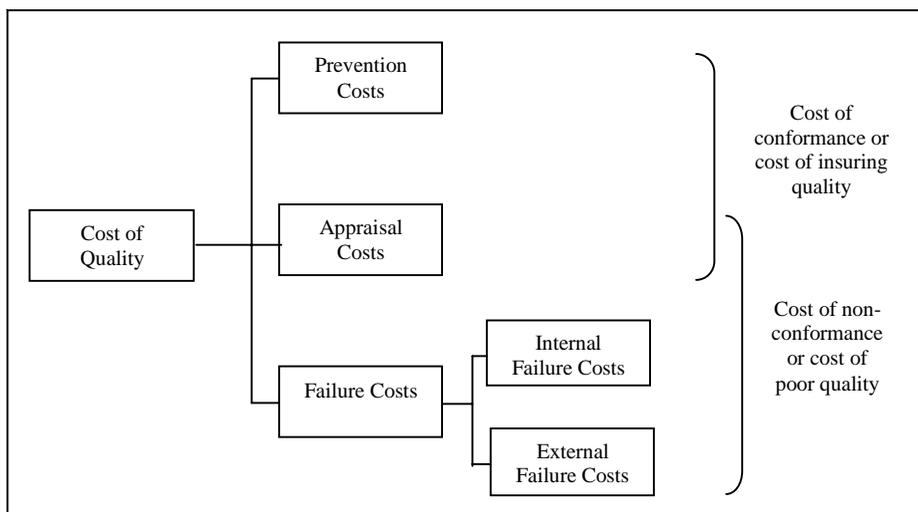
According to Juran (1988), appraisal costs are those costs associated with evaluating the degree of quality conformance such as testing, inspection, and auditing. Failure costs as internal or external, depending on where they occur; during the production process or upon distribution.

In the 1960s, Phillip Crosby developed the process cost model (PCM) that describes the quality costs as the combination of the price of conformance and the price of nonconformance (Harrington, 1999). Crosby (1984) identifies the price of conformance (POC) represents the costs of making things right, and the price of non-conformance (PONC) represents the cost of doing things wrong. Zairi (1992) characterizes the PCM model as process oriented and activity based.

The PAF and the process cost models are probably the most commonly used general cost of quality models in the United States (Campanella, 1999), Great Britain (BSI 1990, 1992), and based on the frequency of reference in the literature, world-wide (Plunkett & Dale, 1987). A graphical depiction of the general COQ model is shown in Figure 3.

There are other perspectives for quality related costs. Feigenbaum (2001) describes the two primary components of quality costs as the cost of quality disconnects (failure costs) and the costs of quality investment (prevention and appraisal costs). Giakatis, Enkawa, and Washitani (2001) have focused on the distinction between quality cost and quality loss. This idea of quality loss and its importance is similar to that of Merrill (1997), who suggests that process problems create wasted resources and the cost of waste constitutes a key component of the cost of quality. Other researchers have expanded the PAF model to include quality system management (QSM) costs. These costs are indirect costs associated with the creation and management of the quality system. QSM costs are a type of prevention costs but are separate from direct production quality costs such as appraisal costs because QSM costs are integrated into the overall operational costs (Hwang & Aspinwall, 1999). In the public service sector, Bland, Maynard, and Herbert (1998) developed a modified process cost model that supported cost analysis of administrative processes. Their model established eight process cost categories: productive work, checks, systematic weakness, internal error, external error, projects, support, and waste (Bland, Maynard, and Herbert 1998). Finally, there are researchers who point out shortcomings in the COQ models such as the oversight of the cost of inefficient utilization of resources and the cost of designing for quality (Modarres & Ansari, 1985). The cost of quality improvement has not been specifically addressed in the literature as a cost component, although the analytic activities that support quality improvement efforts can be considered a type of appraisal costs.

**Figure 3: General COG Model**



## **Cost of Poor Quality (COPQ)**

### ***The Penalty for Poor Quality***

Managers often find that focusing on the reduction of costs associated with poor quality or failure costs the most direct approach to achieving high quality and also targets the most consequential aspect of quality. Juran (1989) described the cost of poor quality as the cost that exists because of quality problems and suggested that appraisal and failure costs are usually much higher than prevention costs. Crosby (1984) estimated that the price of nonconformance could represent 20 percent of sales by manufacturing companies and 35 percent of operating costs in service companies. Additionally, Crosby estimated that the price of conformance in most well run companies represented 3-4 percent of sales.

Since these estimates of Juran and Crosby were made, advances in technology, global emphasis on quality, the widespread application of ISO 9000, the proliferation of quality awards, and a higher level of sophistication of quality techniques have reduced nonconformance costs dramatically. Nevertheless, Defeo (2001) suggests that the total cost of poor quality could represent as much as 15-25 percent of total operational costs. Dale and Plunkett (1999) have reported that quality costs can represent 5-25% of annual sales. Finally, Feigenbaum (2001) suggests that reducing nonconformance or failure costs could result in cost reductions equivalent in value to as much as 10% of revenues.

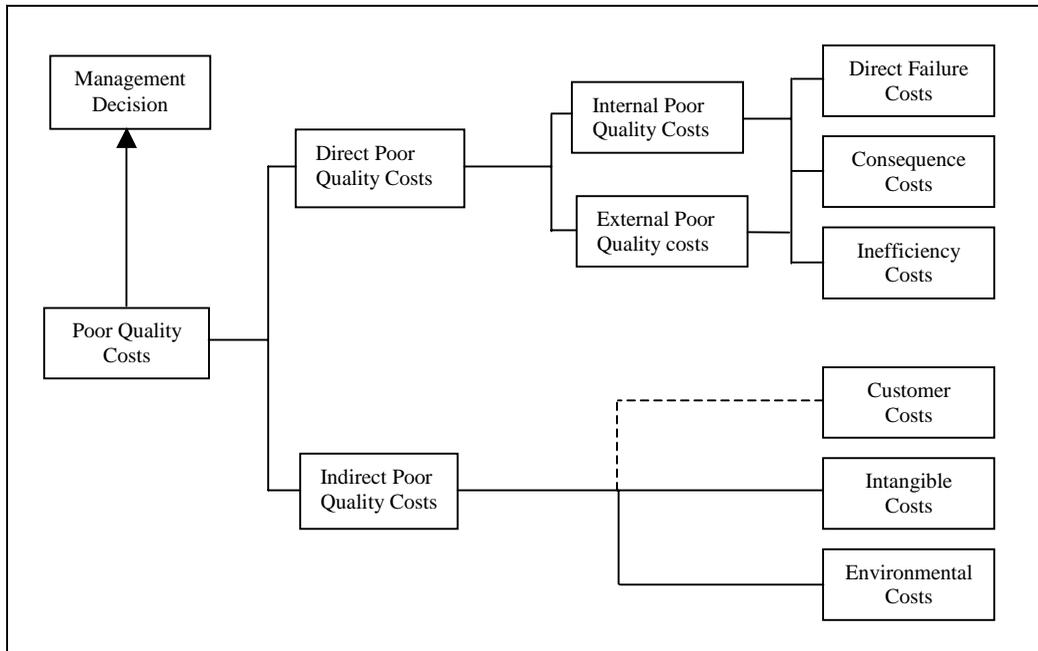
### ***Cost of Poor Quality Model***

The traditional cost of quality model is seen as inadequate by some researchers. Moen (1998) identifies several shortcomings in traditional cost of quality models including:

- Cost based on internal cost accounting system that are primarily reactive and rely on traditional accounting information which may not adequately identify and correctly specify measurement for cost elements, or fail to reveal all costs, particularly intangible costs such customer dissatisfaction or the impact of poor quality on the company reputation
- Improvement activities initiated primarily on identifiable measures that ignore hidden cost structures including administrative costs
- Failure costs addressed under the Pareto principle, leaving minor problems unattended yet still posing problems for the customer
- Customer requirements not used proactively to reduce quality costs
- Prevention activities are difficult to define and price
- Appraisal activities with no optimal value, because their value depends on the purpose of the appraisal and if an appraisal cost is incurred because of inadequate quality it is actually part of failure cost (Moen, 1998)

Because of these shortcomings, Moen offers a customer and process focused PQC (poor quality cost) model. The model is depicted in Figure 4. Of note in this model is the classification of indirect poor quality costs. Customer costs are those costs incurred in response to the customer such as warranty or adjustment costs and costs involved dealing with the customer because of poor quality. Intangible costs are the consequence of customer dissatisfaction such as lost sales and diminished reputation of the company or product. Environmental costs are those costs incurred because of effects on the environment. In this sense, negative environmental impact constitutes poor quality (Moen, 1998).

**Figure 4: Customer and process focused cost of poor quality model**



Harrington (1999) describes a model that also focuses on the impact of poor quality (Figure 5). Harrington’s description of direct and indirect costs is similar to internal and external failure costs. Harrington identifies five advantages of using a model of poor quality costs:

- Greater impact on management
- Employee awareness of the cost of poor quality
- Better return on the problem-solving effort
- Measurable impact of corrective action
- Simplified measure of the impact of poor quality

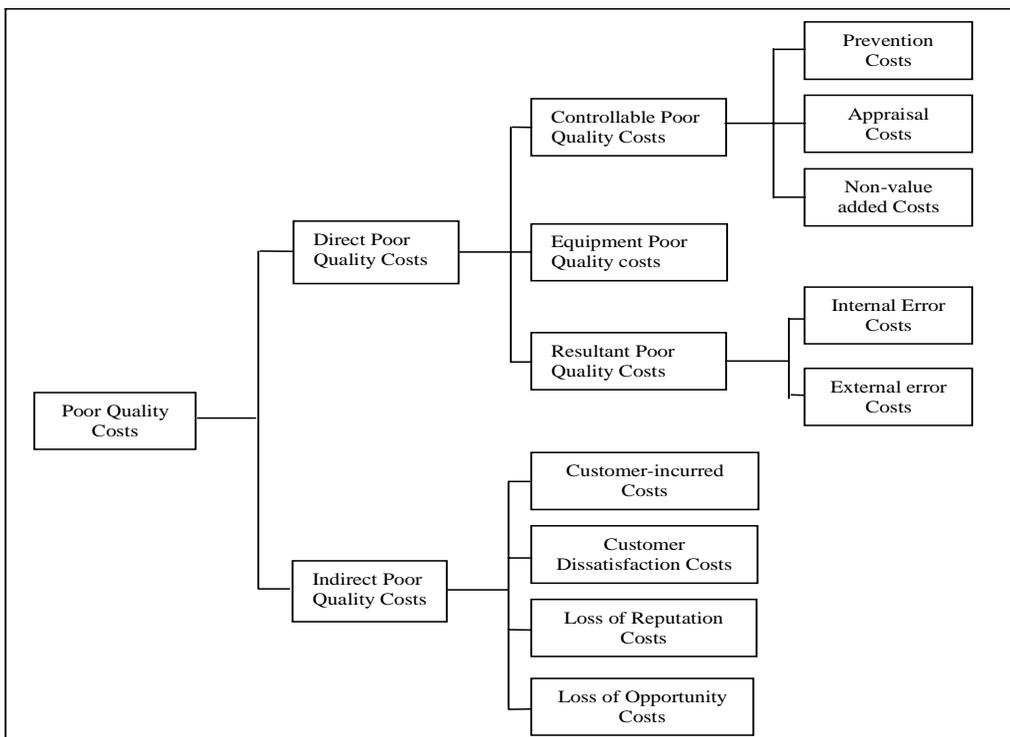
***Indirect Poor Quality Cost***

In Harrington’s model, indirect poor quality costs include the intangible costs of customer dissatisfaction, loss of reputation, and resultant loss of sales. This structure of indirect quality costs are supported by other researchers. Bhote (1995) argues the value of customer loyalty and suggests that the loss of repeat sales from dissatisfied customers or the inability to win new customers because of unfavorable word-of-mouth publicity is the most important yet least known aspect of quality costs. He further argues that companies must somehow understand their customer loyalty situation in order to make sound quality management decisions. Defeo (2001) also recognizes the importance of customer loyalty as a hidden cost of quality and the difficulty in calculating these costs. He suggests that failures that lead to customer dissatisfaction are the most expensive to correct. Not only are customers lost due to the quality problems and costs incurred to fix the problems, but additional costs are incurred to regain lost customer confidence.

**Hidden Costs**

The cost of poor quality is fraught with hidden costs. Defeo (2001) suggests that the more visible and easily measurable quality costs consume 4-5 percent of sales, yet the true cost of poor quality that includes the difficult to measure and intangible costs such as additional administrative costs and customer response to poor quality is much higher. Articulating the importance of the cost of poor quality or quality loss, Giakatis, Enkawa, and Washatane (2001) identified several types of hidden quality losses. Prevention and appraisal losses occur if the attempt to initiate quality sustaining or improving efforts in the form of prevention and appraisal activities are not successful. Manufacturing loss and design loss occur when a company attempts to create a system compensation to reduce failure losses. Finally, “idle loss” occurs when time spent on prevention, appraisal, or correction activities create an operating loss due to delays or interruptions to operations.

**Figure 5: Harrington’s Total Cost of Poor Quality Model**



The costs of poor quality (COPQ) models offer a simplification of the quality-related cost issue. By focusing on the elimination of poor quality, the other components of quality costs, prevention and appraisal costs should diminish automatically. These models may also make the quality cost structure easier to understand. Recent surveys reflect a significant amount of confusion among managers with terms and concepts associated with quality-related costs, suggesting that a simpler approach to the cost of quality conundrum would be welcomed (Roden & Dale, 2000; Shah & Fitzroy, 1998).

Harrington’s model is arguably the most robust examined so far because it integrates prevention, appraisal, and failure costs-making it consistent with the basic cost of quality model, and it subsumes the attributes of the other models. However his model does not identify the costs associated with quality improvement efforts.

## **Costs of Quality Improvement**

The quality-related cost models examined to this point provide a description of the relationship between the general costs associated with producing a quality product and the costs associated with failing to produce a quality product. These models do not address the costs associated with ordinary quality improvement activities such as employing a quality improvement task force or more extraordinary quality improvement efforts such as a formal Six-Sigma project. These costs are in addition to normal quality management costs. They need to be identified as such in order to be recognized as a decision variable in the decision process employed to determine if the extraordinary quality improvement effort will be launched.

Quality improvement involves defining the problem or opportunity for improvement, measurement and data collection, analysis, improvement planning, improvement implementation, and control (Pande, Neuman, & Cavanagh 2002). Costs associated with the identification, measurement, analysis, planning, and implementation activities of a quality improvement effort would constitute the elements of a cost of quality improvement model that would be adjunct to the existing quality-related cost structure model. These costs are different than the cost elements identified previously in the other quality-related cost models.

Quality improvement costs would be the costs associated with activities such as assessing the process for improvement opportunities, measuring the quality performance of the process, designing and planning for quality improvement, implementation, and stabilization.

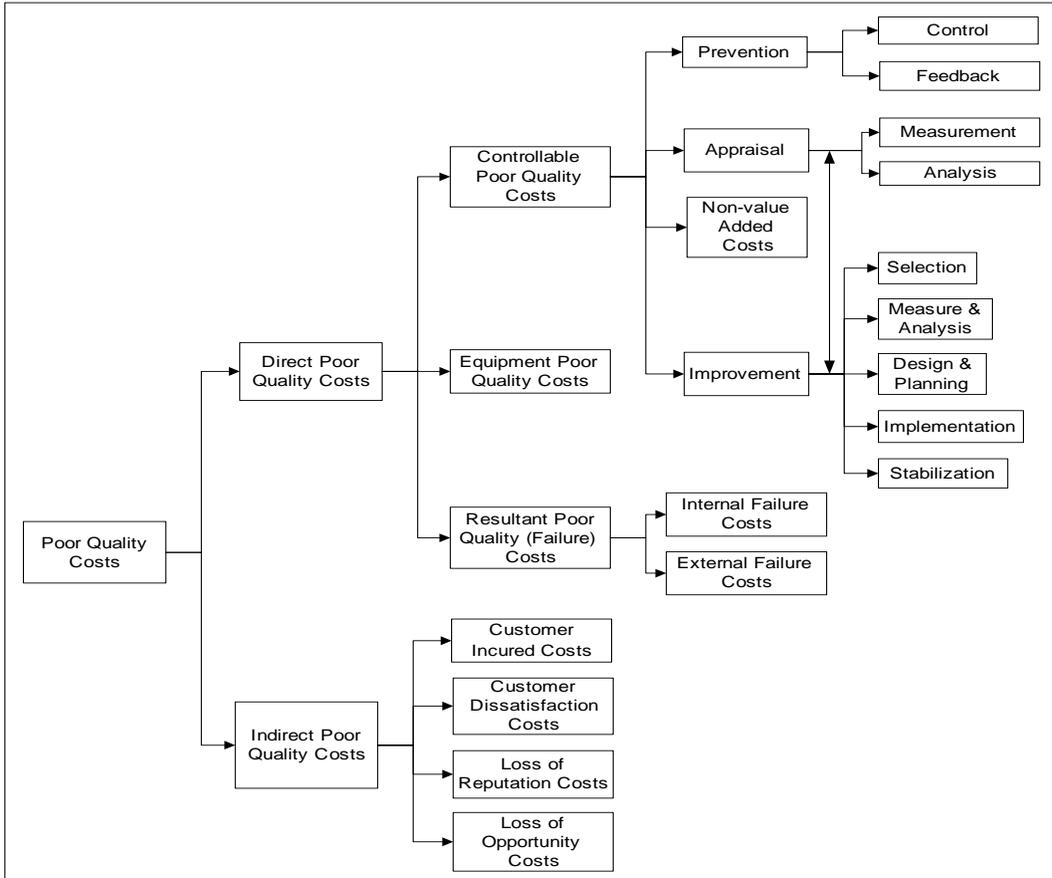
From the perspective of the cost of poor quality, quality improvement activities can be considered failure cost reduction or nonconformance cost reduction costs. As such, they can be classified as direct poor quality costs as identified in Harrington's model. However, the specific activities performed in the improvement process should be identified as discrete events to make it easier to assign costs to the quality improvement activities.

## **An Extended Cost of Quality Model**

Quality improvement activities can be integrated into any quality cost model. Figure 6 depicts Harrington's model modified to accommodate the costs associated with specific quality improvement activities. The specific activities normally associated with extraordinary quality improvement efforts are integrated into the controllable quality cost component. Some routine appraisal efforts can be used in the front-end analysis employed to assess and select a process for improvement. This relationship is depicted by the connecting arrow between the appraisal component of sustainment and the assessment component of improvement shown in Figure 6.

The advantage of this model is that it separates routine quality control and improvement costs from exceptional efforts to improve quality such as Six-sigma. Since the quality improvement activities are clearly defined, managers can easily determine costs associated with a specific quality improvement effort. Managers can then determine the cost/benefit or ROI by determining the net cost savings due to the successful application of the improvement in response to the investment in the quality improvement efforts.

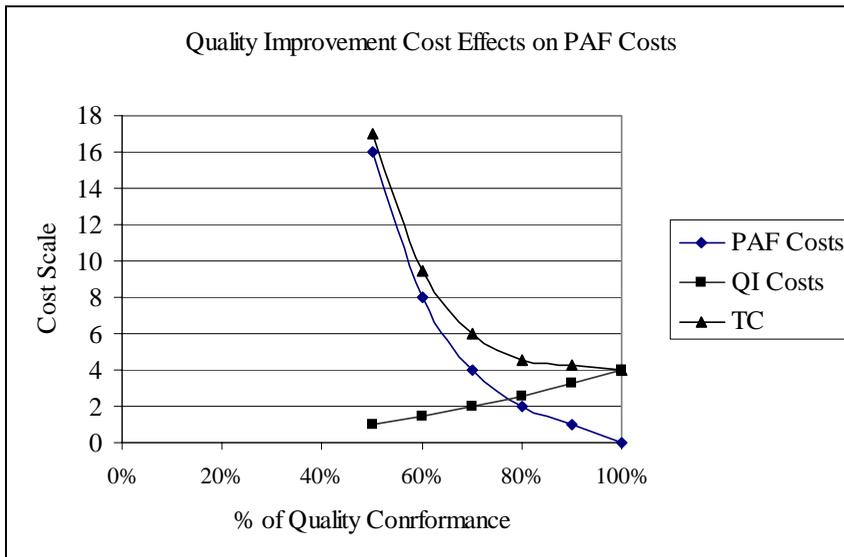
**Figure 6: Extended Total Quality Cost of Quality Model**



### Impact on Quality-Process Capability

Assuming that improvement activities yield the intended long-term improvement, failure costs would diminish as would long-term prevention and appraisal costs. This would imply an inverse relationship between quality improvement costs and traditional quality costs-increases in extraordinary quality improvement efforts should result in diminished prevention, appraisal, and failure costs. Although the exact nature of the cost curves depend on the specific situation, the approximate combined effect of extraordinary quality improvement costs on the combination of prevention, appraisal and failure costs shown in Figure 7.

**Figure 7: Quality Improvement Vs PAF Costs**



The graph in Figure 7 depicts a total quality cost curve with a minimum point at 100% quality conformance. This is consistent with argument offered by Schneiderman (1986) that quality costs are probably not minimized at conformance levels under 100%. However, there may be circumstances where total quality costs might be reduced at some optimal quality conformance level less than 100%. In practice, a system that is operating at very high quality performance levels and is incurring very small performance, appraisal, and failure costs, may find that additional extraordinary quality improvement costs will indeed not provide a return on the invested quality improvement dollar. Once cost data is collected, the true nature of the cost curves can be determined and the optimal quality level mathematically derived. Managers must be attuned to the impact of intangible costs associated with poor quality when making quality conformance level decisions. These intangible costs are often not quantifiable and may impart a random error into the optimization calculations.

If the extraordinary quality improvement efforts are successful and permanent, PAF costs should be permanently reduced, with some costs eliminated and other costs replaced by new procedures implemented by the improvement effort. This is a significant effect because extraordinary quality improvement efforts tend to be one-time or incremental costs while prevention and appraisal tend to be perpetual. This means that the cost of the quality improvement effort will be short-lived but should have significant long-term quality related cost reduction effects.

Is it necessary to separate quality improvement costs from other quality-related costs? Indeed, not all quality improvements come from extraordinary quality improvement efforts. Appraisal and prevention efforts can lead to changes in the product or process in order to improve quality and possibly reduce quality related costs across the board. Normally, there is no distinction made between appraisal and prevention costs associated with fixing a quality problem or creating a quality improvement. Fixing a quality problem may only succeed in maintaining a certain level of quality, with little change in the quality-related cost structure. On the other hand, fixing a quality problem may actually be a quality breakthrough, with significant reduction

in all quality-related costs. Attributing costs to appraisal and prevention efforts that result in quality improvement and subsequent poor quality cost reduction is often difficult because these efforts can not always be defined adequately as to what contribution had been made and what the contribution cost.

Prevention and appraisal efforts may result in product and process changes, but primarily in reaction to quality problems or potential problems. A deliberate effort to improve quality levels through planned product or process changes suggest a different quality-related cost component. Because of the problems associated with tying routine prevention and appraisal costs to poor quality cost reductions, it can be beneficial to isolate specific quality improvement activities and their costs from the routine prevention and appraisal costs. This makes it easier to assess the return on investment of a specific quality improvement effort.

By using the emerging cost of quality model presented here, the cost of the effort to improve quality can be determined by identifying the specific resources involved in the quality improvement effort. Therefore, a measure of “quality productivity” can be developed that provides a ratio of quality level improvement to amount of resources dedicated to the quality improvement effort.

The key is to clearly differentiate quality improvement activities from those activities more appropriately classified as prevention and appraisal.

## Conclusion

Companies may make significant investments into quality improvement programs such as Six-Sigma or Kaizen, and managers need to be able to assess the return on investment of these programs. For this to happen, costs associated with the quality improvement effort need to be clearly identified and the reduction in the cost of poor quality need to be determined as well. Existing models provide the structure for assessing the cost of poor quality, but don't clearly identify the quality improvement costs.

Quality improvement costs can be considered internal, controllable, quality-related costs. However, they are different than traditional prevention and appraisal costs. Prevention and appraisal costs are associated with efforts to prevent poor quality assess quality at a given quality level. Quality improvement costs should be considered value-added in that they are incurred as a program initiative and are a clear departure from

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