# MAKING THE COST OF QUALITY

Companies will often declare that quality or customer satisfaction is now their top priority while still obviously needing to deliver financial returns. These quality goals seem to conflict with the financial goals and are frequently met with employee and even supply chain skepticism. This uncertainty is often a result of past quality efforts that have been abandoned as financial pressures have, no doubt, taken top priority or the quality programs haven't yielded tangible results.

Fortunately, you can avoid this scenario by understanding the cause-and-effect relationship between quality and financial performance—i.e., the cost of quality (COQ). COQ is a tool for determining the optimal level of investment in preventative and appraisal activities that yield at least offsetting reductions in failure costs while improving customer satisfaction.

If your company can't answer the following questions, then it will benefit from a COQ system.

1. If an improvement in reliability increases customer satisfaction, where is the point of diminishing returns?
2. What level of quality will optimize both financial returns and customer satisfaction?
3. How can we align the goal-setting process for business and quality metrics?
4. To what extent will meeting more of your customer needs improve revenue or reduce customer turnover, and, therefore, how much should you be willing to invest to meet these needs?
5. Do you have any budgetary tools to forecast the financial impact of necessary quality-improvement goals?
6. How can we make the quality-cost information actionable?
7. How do we balance the quality of components from suppliers and their costs?
8. How much is a customer willing to pay for the more timely receipt of products or services or for more reliable products?

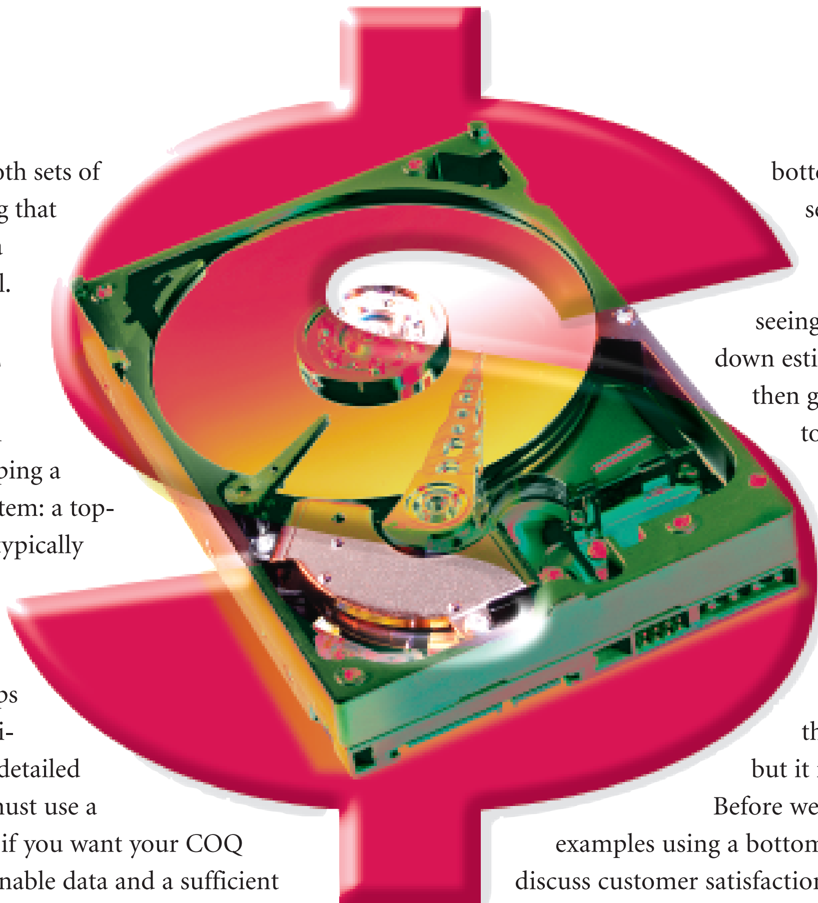
COQ has the potential to be a useful tool in optimizing both quality and financial returns, yet it frequently turns into a high-level estimate of the costs associated with poor quality without providing the operational-level decision-making tools truly needed. Costs are often analyzed and controlled within each division, while quality problems, underlying root causes, corrective actions, related costs, and long-term preventative activities will span multiple divisions. That's why it becomes important to recognize when decisions impacting quality are made in one division but generate costs in another division, typically downstream.

Before we continue, what exactly are quality costs? They're the costs associated with preventing, appraising, finding, and correcting defective work (Table 1 provides more details). Although revenues aren't directly included in this definition, they will be factored into any mature analysis. Quality can certainly impact customer loyalty and customer acquisition costs.

Figure 1 shows optimal quality costs. There are an infinite number of process designs and investment levels in conformance activities that will generate differing combinations of the curves in Figure 1 (representing investment in conformance activities and nonconformance costs). The optimal combination will generate the lowest total

# PRACTICAL

By Steve Ball



COQ when adding both sets of costs together. Finding that combination is both a challenge and the goal.

## HOW TO DEVELOP A COQ SYSTEM

There are two general approaches to developing a COQ process and system: a top-down approach that typically relies on macro estimates of quality costs or a bottom-up approach that develops specific models to estimate costs at a more detailed level. Typically, you must use a bottom-up approach if you want your COQ analysis to yield actionable data and a sufficient understanding for driving operational decisions.

The only scenario where a top-down approach might make sense would be when senior management doesn't support using a COQ system until they see the magnitude of costs involved. In this case, I would use the eight questions I posed earlier to illustrate the need. If this doesn't stimulate senior management commitment, then you can either take a couple of specific issues and develop decision-making tools that could become part of a broader COQ system later or develop a top-down macro estimate of quality costs. Later I'll discuss examples of tools developed around specific issues that are part of a bottom-up approach. If senior management makes a commitment to this process after seeing a macro-level top-down estimate of quality costs, then go back and create the tools and COQ measurement system from the bottom up. If your company uses activity-based costing (ABC), it will make the development of the COQ system easier, but it isn't a substitute.

Before we look at practical examples using a bottom-up approach, let's discuss customer satisfaction feedback. The other critical factor that you should integrate into your analysis is the impact on the customer, both in terms of customer satisfaction and their cost impact. To drive internal decision making, many companies create a customer satisfaction index (CSI) based on various forms of feedback to better understand the elements of customer satisfaction. If your firm has developed any organized customer feedback and understanding like a CSI, then you should use it in conjunction with the quality-cost analysis to guide decision making. Even though some of these factors will be hard to quantify, you should know what's driving customer satisfaction and dissatisfaction.

**Table 1: Quality Costs = Sum of Conformance + Nonconformance Costs**

| | | |
|---|---|---|
| **Conformance Costs** | Prevention Costs | Costs incurred to prevent and mitigate quality problems. |
| | Appraisal Costs | Costs associated with activities to measure, evaluate, or audit products, processes, or services to ensure conformance to either internal or external customer requirements. |
| **Nonconformance Costs** | Internal Failure Costs | Costs incurred prior to the shipment of a product or delivery of services due to the failure of the product or service to meet customer requirements. |
| | External Failure Costs | The sum of all quality costs incurred after a customer receives a product or service. |

Remember, it's usually less expensive to maintain existing customers than to acquire new ones. The exceptions are usually in commodity-driven businesses where purchase transactions are sourced at the time of need based primarily on price and to a lesser extent on availability.

## PRACTICAL EXAMPLES

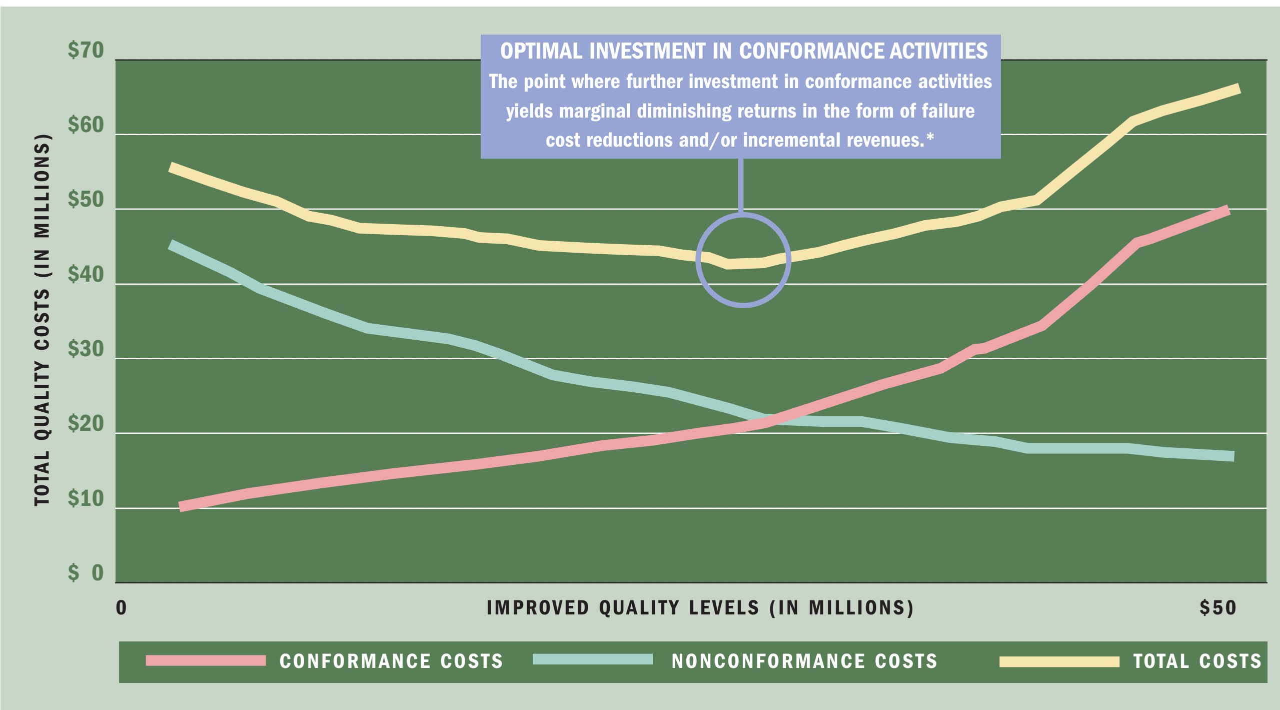
The following analysis provides you with four examples of cost-based decision models for common scenarios that arise when you attempt to simultaneously optimize quality and financial returns. These could be used as a start in constructing a COQ system using a bottom-up approach.

### 1. Cost vs. Reliability of Purchased Components and Subassemblies

In the PC manufacturing industry, procurement engineers often ask financial analysts, "How much should we be willing to pay for a hard disk drive (and other subassemblies) with better reliability?"

*Example:* There are six vendors who submit proposals to supply hard disk drives (HDDs) for a new product. Assuming they have the same drive speeds and other features, which is typically the case, but different levels of reliability, which HDD should we choose—the lowest-cost product that meets our minimum quality specifications? We need to determine the differential failure rates forecasted for each hard drive. The most common measurement used in the PC industry to measure reliability and failure rates is the meantime between failure (MTBF). Your reliability, design, or procurement engineering staff should develop reliability data that can be

**Figure 1: Optimizing Quality Costs**




* Incremental revenues (if any) would also need to be factored in but aren't depicted here.

## Table 2: Vendor Comparisons

| | VENDOR A | VENDOR B | VENDOR C | VENDOR D |
|---|---|---|---|---|
| **Return Rate Factors (RRF) for the New Desktop** | | | | |
| Processor | 1.95% | 1.95% | 1.95% | 1.95% |
| System Board | 9.20% | 9.20% | 9.20% | 9.20% |
| HDD | 6.10% | 5.20% | 4.97% | 4.70% |
| Modem | 3.60% | 3.60% | 3.60% | 3.60% |
| All Other Components | 8.35% | 8.35% | 8.35% | 8.35% |
| Total—Lifetime Return Rate Factor | 29.20% | 28.30% | 28.07% | 27.80% |
| **Reduction in Repair Events** | | **-0.90%** | **-0.23%** | **-0.27%** |
| | | (vendor B vs. A) | (vendor C vs. B) | (vendor D vs. C) |
| Parts Cost per HDD per Service Event | $62.50 | $62.50 | $62.50 | $62.50 |
| Labor Cost per HDD per Service Event | $66.85 | $66.85 | $66.85 | $66.85 |
| Call Support and Parts Dispatch | $13.50 | $13.50 | $13.50 | $13.50 |
| Total Cost per HDD per Service Event | 142.85 | 142.85 | 142.85 | 142.85 |
| Lifetime Warranty Cost per Unit | $41.71 | $40.43 | $40.10 | $39.71 |
| (RRF * Total Cost per Service Event) | | (vendor B vs. A) | (vendor C vs. B) | (vendor D vs. C) |
| Expected Warranty Savings per Unit Shipped | | $ 1.29 | $ 0.33 | $ 0.39 |
| Product Projected Sales Volume | | 84,585 | 84,585 | 84,585 |
| **Reduction in Warranty Repair Costs for the Product** | | | | |
| (Shipments * warranty savings/unit) | | **108,747** | **27,791** | **32,624** |
| Purchase Price per Unit | $69.45 | $70.20 | $70.56 | $71.67 |
| Increased Purchase Price per Unit | | $ 0.75 | $ 0.36 | $ 1.11 |
| | | (vendor B vs. A) | (vendor C vs. B) | (vendor D vs. C) |
| **Increased Materials Cost for Product at Projected Shipment Levels** | | **$63,439** | **$30,451** | **$93,889** |
| **Projected Savings** | | **$45,308** | **($2,660)** | **($61,265)** |

converted into an annual return rate factor for service repair and financial forecasts.

For this example, let's assume six prospective suppliers give you proposals, but two don't meet your minimum requirements after performing reliability testing. You now have only four suppliers to choose from.

As you can tell from Table 2, the higher material cost of buying from vendor B vs. A ($.075 per unit) means an extra $63,439. But vendor B's more reliable HDDs will reduce warranty repairs by $108,747, resulting in a $45,308 net savings, and will provide higher levels of customer satisfaction via the reduced need for repair events. Vendor C will provide better reliability and thus fewer customer service events, but your total estimated costs of doing business are $2,660 higher than with vendor B. Is vendor C preferable to vendor B? Vendor D's product is probably not worth the large incremental purchase price—$1.11 more per unit than vendor C—when compared to the incremental reliability gained.

Of course, you can't always make these decisions by simply running the data through a model that provides a definitive binary output proclaiming that, yes, you should absolutely buy the HDD from vendor C. Often you need to consider other qualitative factors, such as the following in this case:

◆ Customer satisfaction surveys told us a service event involving an HDD was a much more serious problem for the customer than a power supply, system board, or any other component. The reason? The customer would have to restore all their software and user data, and they might lose data if it isn't backed up. Because the subassembly is an HDD, vendor C would make more sense even with slightly higher total costs.

◆ The vendor's location and ability to react to changing needs or replace defective shipments were also important. In this case the HDDs were being manufactured in China, and the standard mode of transport was literally a "slow boat from China." So is it cost prohibitive to ship HDDs via the expedited ship mode of airfreight if necessary when problems with schedules are encountered? The answer for HDDs was, no, but it would be cost prohibitive for other assemblies like a chassis. Yet if we encountered technical issues that created a need for our engineers to visit the vendor's site in China, this could consume all of the savings relative to another vendor who may be in the U.S. or Mexico.

### 2. Reusing Repaired Parts

Manufacturers must manage another common problem—the repair of products in their service operations. It's common to use refurbished parts for warranty repair on many manufactured products, but how many times should these parts be recycled?

*Example:* Staying with the PC example, let's assume we're trying to determine if we should repair and redeploy or throw away a defective system board pulled out of a PC needing repairs. Some kinds of repairs will cause you to throw away the defective system board because the repair would be cost prohibitive, but let's assume this isn't the case.

If you know the probability of failure for the repaired system boards vs. the new ones, you can calculate the incremental probability that the customer will experience a failure event as a result of using the repaired system board instead of putting a brand new one in the customer's PC. The cost savings from using the repaired boards can then be compared to the costs of any incremental service events that may be generated by using the less reliable repaired boards. This assumes that you can track system boards in PCs, how many times they have been repaired, type of repair, and failure rates. Thanks to bar-coding technology, this is becoming increasingly easy and cost effective, and the calculations are similar to the HDD example.

### 3. Product Design Team Quality

In the electronics industry (and some other industries), product features are changing and are being upgraded so rapidly that product development teams are under great pressure to design products and ramp-up production volumes quickly. This may be the result of a couple of factors:

◆ Profit margins on products in industries with short product life cycles and accelerating rates of innovation typically have much higher profit margins at the beginning of the product's life cycle and then diminishing returns as the product matures. Therefore, it's critical to go to market quickly.

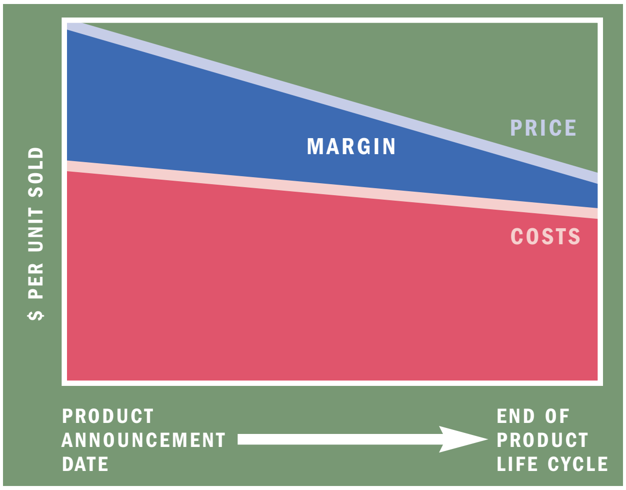
◆ Since the product team members are now participating on several product teams due to the shorter product life cycles and proliferation of models for each product, they have to focus on the next set of new products sooner. Figure 2 illustrates factors that can lead to tremendous pressure on the product development teams to rush the product to market.

How do you incent the product development teams to optimize quality and complete the development cycle quickly? I have witnessed situations where the product development teams were so pressured to get the product completed and production ramped-up that the development cycle progressed with known problems or potential problems past the point where it should.

Designers may presume or rationalize that minor problems can be resolved before any significant production volumes are reached. In some cases they may be focused on getting the product out the door in the short term because that's what senior management will notice. In many companies, everyone immediately knows if a new product release date slips. Many times, though, senior management and others may not correlate a specific product development team's poor quality to downstream product problems when they rush to market with known issues. These problems can manifest themselves in the following metrics being worse than expected:

- ◆ A higher percentage of customer calls being escalated to second-level support or case management;
- ◆ Increasing the time it takes to resolve the calls and cases;
- ◆ Product holds and returns;
- ◆ Engineering changes to the original design specifica-

**Figure 2: Time-to-Market Pressures**



tions driven by quality problems;

- Lower yields in manufacturing, labor variances, and/or a greater amount of time required to ramp-up the product to production volumes in the factories;
- A higher quantity of service/warranty events; and
- Products shipped that are dead-on-arrival (DOA).

Some of these problems don't become evident until many months or even a year or two later. To provide balanced incentives to these product design teams, they should be judged on making development goals *and* on their downstream long-term quality performance.

Their product plans should include goals for initial and long-term quality that are compared to actual performance at multiple points in time after their product enters the market. To do this you can select quality metrics that the design team significantly impacts (like the ones listed above) and have the design team stand up in front of management and report their product's long-term quality performance. This is just one step in creating ownership and recognizing the product development team for the lifetime performance of their products. You can also take additional actions. The end result? Creating a balance for the product's quality performance during its entire life cycle so product development teams aren't primarily incented by getting the product out the door.

### 4. Materials Purge

Often you'll have a process to contain quality problems where the costs and effort involved in resolving the problem vary widely from one occurrence to the next. Since you can't spend the time and effort to perform a cost analysis each time a failure event occurs, should you simply calculate an average for all events? No, you can analyze the process under varying conditions by isolating different factors that contribute the largest variance in resources required to resolve the problem from one occurrence to the next. This may enable you to derive a manageable number of scenarios that can be costed out, and then, as the events occur, each transaction can be grouped into one of these costed scenarios.

*Example:* A materials purge (isolating suspect material/product, stopping shipment or production, determining root cause, providing needed repairs, etc.) generates costs at numerous points throughout the process and is managed differently depending on circumstances. As Table 3 shows, three predominant factors will determine the magnitude of resources required to purge the defective materials.

There are other factors that don't materially alter the magnitude of resources required to correct the failure event, so our cost model won't differentiate based on these factors. The next step is to make sure you can collect the necessary data related to the key factors that you have already identified so you can properly classify purges when they occur. Now you need to create a financial model to calculate the costs of each scenario by analyzing your process in relation to these key factors. It's a good practice to design these models to include costs on a variable and fully burdened basis for different applications, thus adding more practical value when creating these tools for later use. For example, Table 4 shows the analysis for purged materials where they escape into work-in-process (WIP) and finished goods inventory with a minor supply interruption.

**Table 3: Factors Influencing Purges**

| |
|---|
| **How Far the Defective Materials Have Escaped** |
| ◆ Raw materials |
| ◆ Work-in-process |
| ◆ Finished goods inventory |
| ◆ Distributor/customer |
| **The Degree of Supply Interruption** |
| ◆ None |
| ◆ Minor |
| ◆ Major |
| **The Type of Component/Subassembly** |
| ◆ ASICs |
| ◆ Mass storage |
| ◆ Memory |
| ◆ Microprocessors, etc. |

The analysis of ASIC and mass storage devices in Table 4, if shown in its entirety, provides the details for the numbers found in Table 5 containing the total purge cost for each scenario and subassembly.

This isn't the entire process, but it gives you an understanding of a method of costing each major step in the process to create a model that provides the cost of executing the purge process under the different scenarios. This model doesn't differentiate based on factors that don't significantly affect the magnitude of resources required to execute the purge. This cost model is designed to calculate the cost of purges, enabling you to determine how much should be invested in conformance activities to avoid purge events.

## CREATE RELEVANT COMPARISON POINTS FOR SENIOR MANAGEMENT

Now that you have a detailed understanding of the quality cause and effect for some aspects of your organization's

## Table 4: WIP & Finished Goods—Minor Supply Interruption

VARIABLE COSTS ○
FULLY BURDENED COSTS ◉

Select the costing method that is most appropriate for your analysis—fully burdened or only the variable costs

| SCOPE | PROCESS STEPS | RESOURCE = FUNCTION COMMODITY | % OF PURGES ACTIVITY APPLIES TO | ASICS | MASS STORAGE |
|---|---|---|---|---|---|
| Hours | Suspect material identification | Yes | 100% | 32 | 15 |
| Hours * Frequency | | | | 32 | 15 |
| Dollars for Task | | | | 1,280 | 600 |
| Hours | Is a Purge required? | Yes | 100% | 40 | 20 |
| Hours * Frequency | | | | 40 | 20 |
| Dollars for Task | | | | 2,000 | 1,000 |
| **Hours** | **Initiate the Purge Process (complete Purge form and submit it)** | | | | |
| **Hours * Frequency** | | | | | |
| **Dollars for Task** | | | | | |
| Hours | Reason for the Purge | **Yes** | 100% | 6 | 6 |
| Hours * Frequency | | | | 6 | 6 |
| Dollars for Task | | | | 240 | 240 |
| Hours | Enter other relevant information | **Yes** | 100% | 3 | 3 |
| Hours * Frequency | | | | 3 | 3 |
| Dollars for Task | | | | 120 | 120 |
| Hours | Purge date range | **No** | 100% | 10 | 10 |
| Hours * Frequency | | | | 10 | 10 |
| Dollars for Task | | | | 400 | 400 |
| Hours | Undetermined? | **Yes** | 100% | 30 | 15 |
| Hours * Frequency | | | | 30 | 15 |
| Dollars for Task | | | | 1,350 | 675 |
| Hours | Procurement Engineering working with suppliers on the nonconformance | **Yes** | 85% | 30 | 15 |
| Hours * Frequency | | | | 25.5 | 12.75 |
| Dollars for Task | | | | 1,020 | 510 |
| Hours | If the Purge is deemed Vendor Fault then an RSA is created | **No** | 85% | 1 | 1 |
| Hours * Frequency | | | | 0.85 | 0.85 |
| Dollars for Task | | | | 34 | 34 |
| Hours | Identification of an "accumulate at" location | **No** | 100% | 0.5 | 0.5 |
| Hours * Frequency | | | | 0.5 | 0.5 |
| Dollars for Task | | | | 20 | 20 |
| Hours | Sort instructions—detailed work instructions (from EM—or other work instructions) | **Yes** | 80% | 90 | 50 |
| Hours * Frequency | | | | 72 | 40 |
| Dollars for Task | | | | 3,600 | 2,000 |
| Hours | Determine all sites/areas impacted by Purge | **No** | 100% | 30 | 30 |
| Hours * Frequency | | | | 30 | 30 |
| Dollars for Task | | | | 1,200 | 1,200 |
| Hours | Interruption < 1 shift/1 site | **No** | 100% | 50 | 50 |
| Hours * Frequency | | | | 50 | 50 |
| Dollars for Task | | | | 2,000 | 2,000 |

## Table 5: Indirect Cost per Purge Transaction

The analysis of ASIC and mass storage devices in Table 4, if shown in its entirety, would provide the details for the numbers found in Table 5 containing the total fully burdened purge cost of each scenario and subassembly.

| SCOPE = SUPPLY DISTANCE MATLS ESCAPE IN PROCESS | ASICS | MASS STORAGE | MONITORS | MICRO PROCESSORS | MECHANICAL/ OEM | MEMORY | MICRO PERIPHERALS | ELECTRICAL | COST LEVEL APPLIED |
|---|---|---|---|---|---|---|---|---|---|
| Raw materials and no supply interruption | $ 5,893 | $ 3,662 | $ 2,225 | $ 4,170 | $ 2,017 | $ 4,555 | $ 3,842 | $ 3,055 | Fully burdened costs |
| Raw materials and minor supply interruption | $ 9,643 | $ 7,017 | $ 5,383 | $ 7,723 | $ 5,174 | $ 8,108 | $ 7,276 | $ 6,410 | Fully burdened costs |
| WIP/FG and no supply interruption | $13,963 | $ 9,122 | $ 6,480 | $11,068 | $ 6,389 | $11,933 | $10,313 | $ 8,710 | Fully burdened costs |
| Raw materials and major supply interruption | $10,130 | $ 8,181 | $ 6,987 | $ 8,677 | $ 6,831 | $ 8,987 | $ 8,346 | $ 7,727 | Fully burdened costs |
| WIP/FG and minor supply interruption | **$15,963** | **$11,122** | $ 8,480 | $13,068 | $ 8,389 | $13,933 | $12,313 | $10,710 | Fully burdened costs |
| WIP/FG and major supply interruption | $19,963 | $15,122 | $12,480 | $17,068 | $12,389 | $17,933 | $16,313 | $14,710 | Fully burdened costs |
| Field and minor supply interruption | $21,688 | $16,847 | $14,205 | $18,793 | $14,114 | $19,658 | $18,038 | $16,435 | Fully burdened costs |
| Field and major supply interruption | $25,688 | $20,847 | $18,205 | $22,793 | $18,114 | $23,658 | $22,038 | $20,435 | Fully burdened costs |

**Not included—asset utilization and customer satisfaction. You may also need to add transportation, packaging, and duty expenses depending on your operations.**

This isn't the entire process, but it gives you an understanding of a method of costing each major step in the process to create a model that provides the cost of executing the purge process under the different scenarios. This model doesn't differentiate based on factors that don't significantly affect the magnitude of resources required to execute the purge. This cost model is designed to calculate the cost of purges, enabling you to determine how much should be invested in conformance activities to avoid purge events.

financials, it may be helpful to place these metrics in a relevant perspective for senior management. Examples include a situation where I had calculated the majority of failure costs that could be confidently quantified for a company and then made the comparative calculations in Table 6.

This illustrates the opportunity cost of what is given up by incurring these failure costs in terms that senior management is typically focused on. Your metrics may be different, but it shouldn't be difficult to determine what metrics senior management depends on in your organization and then compare reductions in failure costs on a basis relative to those metrics.

## BE SPECIFIC TO CREATE ACTIONABLE DATA

Most organizations are better off developing a cost-of-quality process starting from the bottom up by developing some specific analysis and cost-estimating models as opposed to macro-level estimates of quality costs (a top-down approach). Accountants are so often focused on the obvious measures of cost effectiveness like labor and overhead cost per unit or total sales and administrative expenses by division, product line, or sales region. Then you have quality (and other operating departments) focusing on product rework and scrap, production yields, service events, customer retention, etc., without understanding the cost impact of their decisions. This often leads to frustration because the operational staff may not be able to correlate specific events they deem important from a quality perspective to the financial metrics that management is looking at. And even if they can understand this correlation at some macro level, do they have any tools to make better informed decisions that optimize both quality and costs for the organization as a whole? Remember, cutting costs in one division may create a greater amount of costs elsewhere in the organization. You need specific tools—cost-of-quality tools—to help with these issues, not just macro estimates. ■

## Table 6: Comparative Calculations

| % REDUCTION IN ANNUAL FAILURE COSTS | INCREMENTAL PBT $(000)S | % INCREASE IN GROSS MARGIN | INCREASE IN EARNINGS PER SHARE | % OF R&D SPENDING | EQUIVALENT HEAD COUNT |
|---|---|---|---|---|---|
| 10% | $ 84,314 | 0.5% | $0.21 | 20% | 1,297 |
| 20% | $168,627 | 0.9% | $0.42 | 40% | 2,594 |
| 30% | $252,941 | 1.4% | $0.63 | 60% | 3,891 |
| 40% | $337,255 | 1.9% | $0.85 | 80% | 5,189 |
| 50% | $421,569 | 2.3% | $1.06 | 100% | 6,486 |

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