
A Microeconomic Approach to Quality Cost Control

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Theoretically, the optimal level of quality is obtained when overall quality costs are minimized. Practically, however, the operating manager tries to obtain the lowest defective rate possible by using the quality control budget at his disposal. This article applies the microeconomic theory on consumer choice (the indifference curve approach) to demonstrate how the quality control budget should be allocated to the various steps of the quality control process so as to maximize the efficiency of quality control operations. The analysis is limited to only two cost categories—prevention and appraisal—because these costs can be controlled by the company.

Product quality is generally defined as the degree of conformance to the design specifications of a product. Product quality is considered good if the design of a product conforms to customer expectations. Thus, product quality can be measured by the defective rate of finished products.

Exceeding customers' expectations

In today's competitive global market environment, a commitment to excellence in product quality is essential to the long-term success of a business. The striving for excellence has come to the point now where simply *meeting* customers' needs is not enough: "Quality First: Beyond Customer Satisfaction" was the primary slogan of the National Quality Month campaign for 1988 sponsored by the American Society for Quality Control. In other words, to create customer loyalty, the quality of a product should *exceed* the customer's expectations.

Measuring quality cost

Measuring quality cost is a critical step in the quality control process because an improvement in quality is meaningful only if it benefits the company in the long run.

It has been argued that the optimal level of quality is obtained at the point where overall quality costs are minimized. In the real world, however, there are some practical measurement problems in obtaining optimal quality by using this approach. In this article, it is assumed that management sets a budget for quality costs each period. Therefore, the operating manager tries to obtain the lowest possible defective rate by using this budget most efficiently.

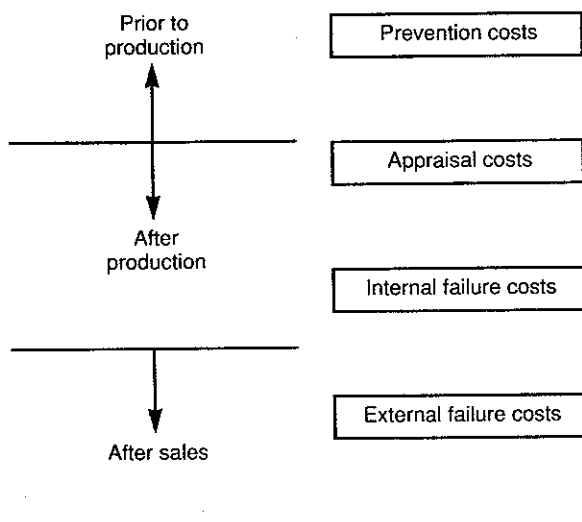
This article then applies the microeconomic theory on consumer choice (the indifference curve approach) to demonstrate how the quality control budget should be allocated to the various steps of the quality control process so as to maximize the efficiency of quality control operations.¹ The analysis will be limited to only two cost categories—prevention and appraisal—because these costs can be controlled by the company.

Classification of quality costs

Even though quality costs can be classified differently in different organizations, they are commonly categorized in four ways according to the order of their incurrence (as shown in Exhibit 1):

- *Prevention costs*, which are incurred prior to production and during the manufacturing process to prevent defective units from being produced.
- *Appraisal costs*, which are incurred after production but before sales to identify defective items.

Exhibit 1. Categories of Quality Costs



- *Internal failure costs*, which are incurred to fix or dispose of the defective items before sales are made to the customers.
- *External failure costs*, which are incurred to respond to customers' complaints on defective items.

Prevention and appraisal costs are incurred because defective items *may* exist. Internal and external failure costs are incurred because defective items *do* exist.

Exhibit 2 reports typical cost elements in each category. Note that this classification is strictly based on the time of cost incurrence, which is slightly different from the traditional classification scheme. For example, test or inspection costs of incoming materials and in-process inspection costs are included in prevention costs, instead of appraisal costs, because these costs are incurred before production is completed.²

Characteristics of quality costs

Prevention and appraisal costs are controllable costs because a company can decide the allowable level of spending. Some elements of internal failure costs, such as costs of reinspection, disposal or rework, are essentially *noncontrollable* by the operating manager because, once defective items are found in the appraisal process, the company must either repair or dispose of them. Other costs, such as defect cause analysis and investigation, are *controllable*.

Most of the external quality costs are noncontrollable because of the following:

Exhibit 2. Elements of Quality Costs

- Prevention costs*
 - System development
 - Quality engineering
 - Quality training
 - Test and inspection of incoming materials
 - In-process inspection
 - Supervision of prevention activities
- Appraisal costs*
 - Final product inspection and testing
 - Supervision of appraisal activities
 - Depreciation of test equipment
 - Supplies used in test and inspection
- Internal failure costs*
 - Net cost of scrap and spoilage
 - Disposal of defective product
 - Rework labor and overhead
 - Reinspection of reworked product
 - Retest of reworked product
 - Defect cause analysis and investigation
- External failure costs*
 - Product recalls
 - Product liability
 - Warranty repairs
 - Lost sales due to bad quality reputation

- Explicit costs (such as warranty repairs, product recalls, and product liability) are imposed by customers and incurred in the process of fulfilling the legal obligation of the company; and
- Implicit costs (such as lost sales due to bad reputation) are imposed solely by customers.

Noncontrollable internal costs, however, can be affected indirectly, to some extent, by controlling prevention and appraisal costs. For example, increasing prevention and appraisal cost would reduce the defective items in the final products and thereby decrease rework or disposal costs. Internal quality costs, in turn, can affect external quality costs. For example, by increasing controllable internal quality costs, the company can reduce the number of defective items shipped to customers, which will decrease external quality costs. This functional relationship is presented in Exhibit 3.

The traditional approach: optimal quality level

The traditional approach of controlling quality costs is to find the optimal quality level at which total quality costs are minimized. J.M. Juran's optimal quality costs model, which is depicted in Exhibit 4, has been widely used as a theoretical guideline to show how the lowest quality costs can be obtained.

Exhibit 3. Functional Relationship of Quality Costs

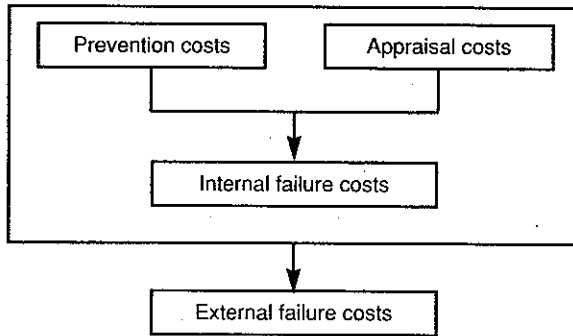
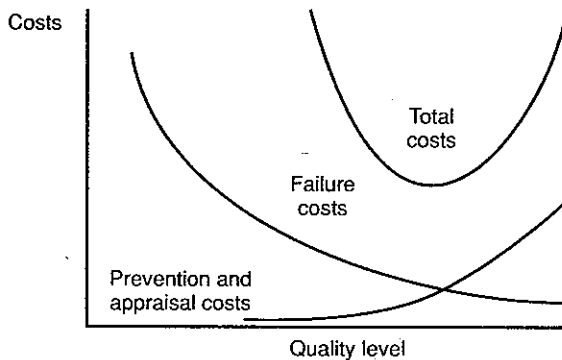


Exhibit 4. Optimal Quality Costs



SOURCE:
J.M. Juran, *Quality Control Handbook* (New York: McGraw-Hill, 1979), pp. 5-12.

As Exhibit 4 shows, at low quality levels, total quality costs are very high because of high failure costs. By increasing investments in prevention and appraisal costs at these levels, failure costs will decrease at a faster rate. Consequently, total quality costs fall as quality is improved. As quality approaches perfection, further investments in prevention and appraisal stages will be offset by slower decreases in the failure cost rate, which will increase total quality costs. Thus, minimum quality costs can be obtained at the point where the prevention and appraisal cost curve and the failure cost curve intersect.

According to this approach, there is a theoretically preferred distribution of quality costs. Movements toward this theoretically preferred distribution result in a reduction of total quality costs. This assertion, however, has not been empirically verified. One reason for this lack of

empirical evidence is the lack of quality cost information needed for empirical analysis.³ Another reason is the difficulties encountered in computing some of the quality costs, such as lost sales due to a poor quality reputation.

Microeconomic approach: indifference curve analysis

Even though the ultimate objective of the company is to achieve a zero-defect rate, current technology and limited resources force management to accept a certain level of defective products. Therefore, one of the most important purposes of measuring costs of quality is to allocate a budget to various quality cost categories, as is pointed out by some cost classification experts:

“Quality cost information helps managers evaluate the relative importance of quality problems and provides a guide as to which to tackle first. While management might like to work on all quality-related problems immediately, resources are limited, and a scheme of prioritizing quality problems is useful. In the absence of quality cost information, a ranking of quality problems should probably key on the number of defects, the percentage of defects, or management’s general awareness of quality problems. Because different kinds of quality problems have differing costs per occurrence, quality cost information is likely to give a different ranking of quality problems. Assuming it is possible to measure all quality costs, ranking on the basis of quality costs indicates which quality problems have the greatest immediate impact on costs and profits.”⁴

Within the budget constraint, a rational manager will try to achieve the lowest possible defect rate using the budget most efficiently.

The budget line

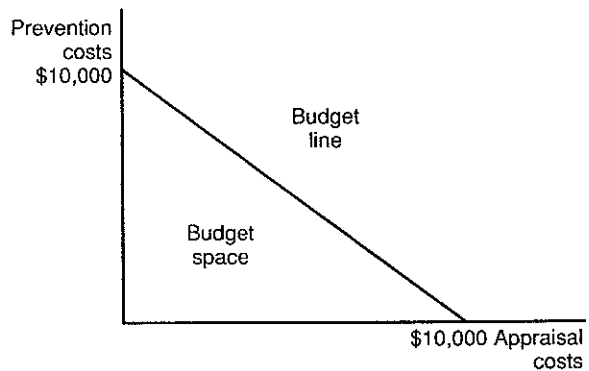
Since the manager is assumed to operate within a budget constraint, the issue becomes *how* to allocate the budget for quality costs among various categories of quality costs. For the purpose of a budget, however, the two cost categories of prevention and appraisal are the major decision variables for the following two reasons:

1. Product quality measured by a defective rate is determined immediately after production is completed. Hence, prevention and appraisal costs are major factors determining the quality of a product.
2. Internal and external quality costs are often noncontrollable by the operating manager.

Suppose, for example, that \$10,000 is budgeted for quality costs of this period. The allocation

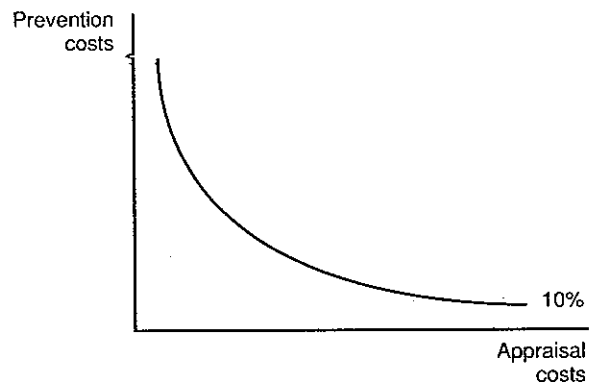
options available are shown in Exhibit 5. The budget line is defined as a locus of points, each of which shows a combination of prevention costs and appraisal costs that total the \$10,000 allocated for the two types of costs. The operating manager can choose any point along the budget line. Thus, the manager could invest all of the \$10,000 for prevention and forgo the appraisal step of finished products. Without appraisal, no internal failure costs will be incurred. The budget space is the area bounded by the budget line and the two axes. This space represents the area of all possible combinations of prevention costs and appraisal costs within the budget. The slope of the budget line is -1 .

Exhibit 5. Budget Line



What happens to the budget line if the budget changes? For example, an increase in budget will (all other things being equal) shift the budget line outward from the origin parallel to the original budget line. Similarly, a decrease in budget will shift the budget line inward toward the origin parallel to the original line. As the budget expands, the manager has more combinations of prevention costs and appraisal costs from which to choose because the budget line becomes longer and the budget space becomes wider.

Exhibit 6. Isoquality Curve



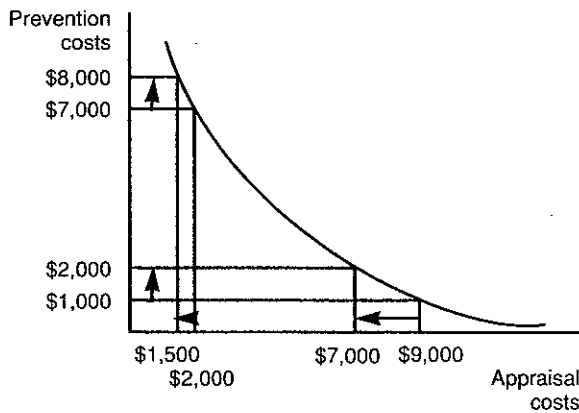
The isoquality curve

In microeconomics, the isoquality curve is called an *indifference curve* because customers will be indifferent to a company's moving along a particular isoquality curve (in this case, by changing the allocation of a budget between prevention and appraisal costs). The isoquality curve in Exhibit 6 is a hypothetical isoquality curve of a company that shows combinations of prevention costs and appraisal costs to achieve a certain level of product quality. Each combination on it results in the same 10 percent defective rate. The downward slope of the isoquality curve indicates that, to reduce prevention costs, the company must increase appraisal costs to maintain the same level of quality, and vice versa. The manager's choice of budget can be represented by the indifference curve. The budget line curve represents simply the dollar amount allocation available for quality control without regard to actual results while the indifference (or isoquality) curve reflects the results of applied quality control with respect to the dollar amount input.

The indifference curve is oblate inward, which implies that the slope becomes flatter as the company prevention costs move down and to the right. The slope of the curve represents the marginal rate of substitution of prevention costs for appraisal costs. It is the rate at which the company trades off prevention costs for appraisal costs.

The example in Exhibit 7 shows that, when prevention costs are low, a \$1,000 increase in prevention costs (i.e., from \$1,000 to \$2,000) will result in a \$2,000 savings in appraisal costs (which fall from \$9,000 to \$7,000). This is because, when prevention costs are low, a small investment in prevention will improve the quality significantly, which, therefore, reduces appraisal costs significantly (assuming that the company reacts and eliminates some inspectors, for example). But when prevention costs are high, a \$1,000 increase in prevention costs (i.e.,

Exhibit 7. Marginal Rate of Substitution



from \$7,000 to \$8,000) will result in only a \$500 decrease in appraisal costs (i.e., from \$2,000 to only \$1,500). Therefore, the company has reached its technological limit in improving quality during the manufacturing process, and additional investment in prevention will further improve quality.

A complete description of a company's choice for two cost items is provided by the isoquality map in Exhibit 8. This is also a set of indifference curves that give the same levels of satisfaction to customers. All points on any of the curves indicate alternative combinations of prevention costs and appraisal costs that give the same level of quality. The further the curve is from the origin, the higher the level of quality it represents.

The optimal allocation of budget

To find the optimal spending level of a budget, a budget line and isoquality curves are put together in Exhibit 9. The operating manager can move along the budget line to choose a combination that gives the highest level of quality. The 10 percent isoquality curve cuts across the budget line at points X and Y. This means the manager can choose the combination of either X or Y to achieve a 10 percent defective rate. But by moving along the budget line, higher isoquality curves can be reached. Within the budget, the highest level of quality is obtained at point Z, which is where an indifference curve is tangent to the budget line. At that point, the company can achieve a 5 percent defective rate, which is the best this company can do under these circumstances. It is impossible to reach a

Exhibit 8. Isoquality Map

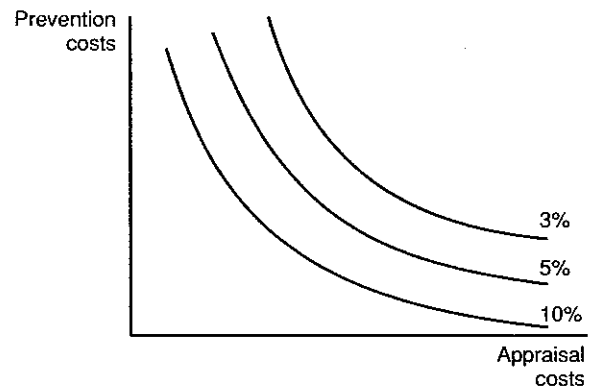
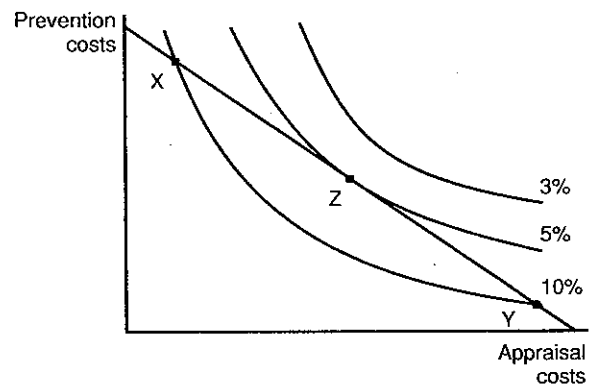


Exhibit 9. Optimal Allocation of a Budget



higher curve (the 3 percent curve, in this case) by moving along the budget line.

At point Z, the slope of the budget line is the same as that of the 5 percent isoquality curve. Since the slope of the budget line is -1 , the slope of the 5 percent isoquality curve (which is the marginal rate of substitution) must also be -1 . This implies that an optimal allocation of the budget is obtained at the point where a \$1 increase in prevention costs is exactly offset by a \$1 decrease in appraisal costs.

Example

The basic concept of this model can be applied to budgeting quality costs. For example, suppose that a company plans to set an initial budget for prevention and appraisal costs. In the last year, the company had a 5 percent defective rate during the months shown in Exhibit 10. Exhibit

Exhibit 10. Prevention and Appraisal Costs Used in Example*

	Prevention Costs	Appraisal Costs
February	\$5,700	\$3,887
April	5,200	4,267
July	5,300	4,187
August	4,900	4,630
September	5,900	3,763
November	4,500	5,290
December	4,300	5,670

Note:

*See related graphs in Exhibits 11 and 12.

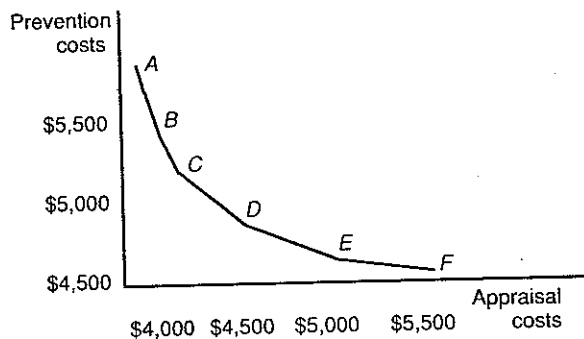
Exhibit 12. Calculated Marginal Rates of Substitution*

Segment	Marginal Rate of Substitution
A	$(\$5,670 - \$5,290) / (\$4,300 - \$4,500) = -1.90$
B	$(\$5,290 - \$4,630) / (\$4,500 - \$4,900) = -1.65$
C	$(\$4,630 - \$4,267) / (\$4,900 - \$5,200) = -1.21$
D	$(\$4,267 - \$4,187) / (\$5,200 - \$5,300) = -0.80$
E	$(\$4,187 - \$3,887) / (\$5,300 - \$5,700) = -0.75$
F	$(\$3,887 - \$3,763) / (\$5,700 - \$5,900) = -0.62$

Note:

*See related graph in Exhibit 11.

Exhibit 11. The Isoquality Curve for the Example*



Note:

*See related graphs in Exhibits 10 and 12.

10 also shows the prevention and appraisal costs incurred during those months.

The numbers in Exhibit 10 are plotted as an isoquality curve in Exhibit 11. The marginal rate of substitution for each segment of the isoquality curve is computed by taking the change in appraisal costs of each segment and dividing it by the change in prevention costs of the same segment. The result is shown in Exhibit 12.

In segment A, for example, the marginal rate of substitution is -1.90 , which implies that, as prevention costs increase by \$1, appraisal costs will decrease by \$1.90. This means that the company will be better off investing more in prevention costs. Moving down along the curve, the marginal rate of substitution becomes less than \$1 in segments, D, E, and F. In these segments, a \$1 increase in prevention costs will result in a decrease in appraisal costs of less

than \$1. Therefore, the company will be better off investing more in appraisal costs.

It is apparent that the initial budget for prevention and appraisal costs should be set between segments C and D where the marginal rate of substitution of -1 can be obtained. What this means is that budgeted prevention costs should be between \$4,900 and \$5,300 and budgeted appraisal costs should be between \$4,187 and \$4,630.

Conclusion

Finding the optimal quality level that will maximize total quality costs is still largely a theoretical concept. This article explains how a company can allocate its budget most efficiently by taking certain quality cost considerations into account. The analysis is limited to only two cost categories—prevention and appraisal—because of the uncontrollable nature of internal and external failure quality costs. A budget can be most efficiently allocated between prevention costs and appraisal costs at the point where the marginal rate of substitution is -1 . ▲

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Notes

1. For a more comprehensive, traditional classification of cost elements, see W. Morse, H. Roth & K. Poston, *Measuring, Planning, and Controlling Quality Costs* (Montvale, NJ: National Association of Accountants, 1987), p. 20.
2. *Ibid.*
3. *Ibid.*, p. 30.
4. *Ibid.*, p. 18.