A Simple Model for Identifying Costs of Quality

Dr. Mustafa Shraim, Ohio University

Dr. Mustafa Shraim is an Assistant Professor in the Department of Engineering Technology & Management at Ohio University in Athens, Ohio. He received both of his B.S. and M.S. degrees from Ohio University in 1986 and 1989, respectively. He received his Ph.D. in Industrial Engineering from West Virginia University in 1996.

Dr. Shraim's research interests are in the area of quality engineering. Specifically, they cover Lean and Quality methods and including incorporating experimental design and statistical process control to optimize operations. Other research interests include the Deming System of Profound Knowledge (SoPK), developing continuous improvement programs as well as sustainable management systems based on ISO 9001, ISO 14001, and other international standards.

He has over 25 years of experience in the quality management field as a quality engineer, corporate quality manager, consultant and trainer. His experience is extensive in quality management systems as wells as Lean and Six Sigma methods. In addition, he coached and mentored Green & Black Belts on process improvement projects in the manufacturing and service industries.

Dr. Shraim is a Certified Quality Engineer (CQE) & a Certified Six Sigma Black Belt (CSSBB) by The American Society for Quality (ASQ). He is also a certified Quality Management Systems (QMS) Lead Auditor by the International Register of Certificated Auditors (IRCA) in London. He was elected a Fellow by ASQ in 2007.

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Abstract

Customer satisfaction drives quality improvement and innovation initiatives for many organizations. Sources of data for such initiatives come from both internal processes as well as the customer. Costs of quality (COQ), with emphasis on failure costs, have been used for managing quality and prioritizing actions for decades because of their appeal to top management. These costs are divided into two groups: conformance and nonconformance. Conformance costs can belong to either the *prevention* or *appraisal* categories while nonconformance or failure costs can be either internal or external. External failure costs result from the negative experience customers have with products and services. Typical COQ programs include readily identifiable costs such as product returns or scrap. However, many hidden costs can be challenging to correctly identify or may seem to belong to more than one category. In any case, failure to identify a given cost as a quality cost or incorrectly categorizing it may result in misleading decision on actions to improve quality.

In this paper, a model will be proposed for correctly categorizing costs of quality. If the cost does not belong to any category, it will be identified as such (not a quality cost). The proposed model will be used as a teaching tool in a senior-level quality improvement course at Ohio University. The model will be tested with cost examples using the following questions: Can students using this model correctly identify whether a given cost is a quality cost? and (2) Do students using the model achieve significantly better results in correctly categorizing COQ than the traditional method for teaching the subject? The same set of costs will be used to answer these questions.

Introduction

As consumers continue to demand higher levels of quality in products and services at reasonable prices, producers are challenged to decrease their production costs without compromising quality [1]. However, W. Edwards Deming had warned that cutting costs to improve productivity and profitability without established methods will only lead to disaster [2]. If costs are cut by arbitrarily reducing labor hours or using unverified sources of materials and components, it would adversely impact quality. When this happens, customer satisfaction and loyalty would suffer without immediate warning. For this reason, if no other, quality must be the starting point for improvement in productivity and profitability as Deming illustrated in his chain-reaction model in Figure 1 [3]. Accounting for costs of poor-quality would help focus attention on the real problems.

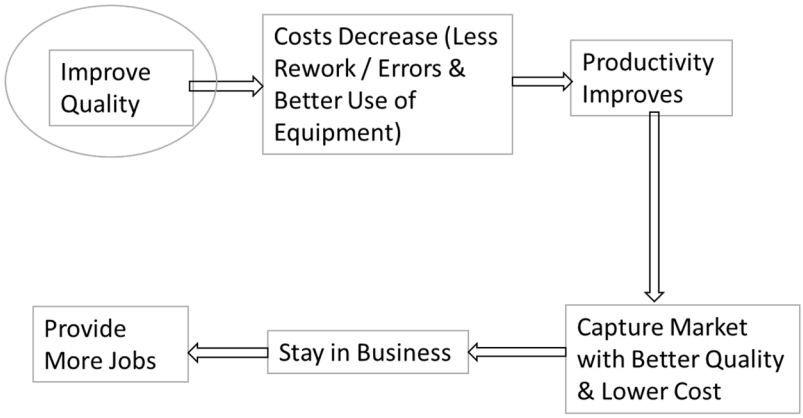

Figure 1: Deming's Chain-Reaction Model

The earliest reference to quality costs can be found in Juran's *Quality Control Handbook* [4]. The concept of quality costs was first presented in detail by Feigenbaum [5]. He classified quality costs into four categories:

- *Prevention Costs*: Costs associated with activities to prevent poor quality in products and services. Examples of prevention costs include quality training, mistake-proofing techniques, preventive maintenance on equipment, etc.
- *Appraisal Costs*: Costs associated with measuring, evaluating, or auditing products / services to ensure conformance to established standards. Examples of appraisal costs include regular inspection and testing on the product.
- *Internal Failure Costs*: Costs associated activities when product or process fail internally (before and product / service has not been experienced by the customer). Examples include scrap, rework, equipment unscheduled downtime, etc.
- *External Failure Costs*: Costs associated with activities resulting from product or service not conforming to requirements after being experienced by to the customer. Examples include processing and replacement of customer returns, warranty charges, etc.

The above costs can be divided into conformance (prevention and appraisal) and nonconformance (internal and external failures). The conformance costs are associated with activities that are normally planned while the failure costs are not. External failure costs are the most significant since they are found by the customer and would likely impact their level of satisfaction. Their true impact in the long run is unknown or unknowable [1]. Overall, Juran estimated that unplanned quality-related costs could be as high as 20% of sales [4]

Since their inception as a quality management concept in the 1950's, research on quality costs ensued with models developed for optimization. The PAF, which refers to prevention (P), appraisal (A), and failure (F) is the first of such models. The PAF model shows the total quality cost function as the sum of costs of conformance (P and A) and costs of nonconformance (F) [5]. The three functions (cost of conformance, cost of nonconformance and total quality costs) are

represented as functions of the fraction or percentage nonconformance. Other models soon appeared in the literature, notably by Juran e.al., which suggested the use of costs of intangibles [6]. Intangible costs refer to those that are not readily recognized as failure costs. In 1979, Crosby suggested that the total cost of quality should be the sum of costs of conformance and nonconformance [7]. In 1998, opportunity cost was introduced to Juran's updated PAF cost model by Sandoval-Chavez & Beruvides [8].

Quality cost programs have been utilized in industry for decades but to a limited degree. A quality cost survey conducted worldwide reported a small number of companies with formal cost of quality (COQ) programs. The survey stated that only some firms implement a COQ measurement system but do not report these costs systematically, nor do they use reports properly as an opportunity for improvement [9]. This is partially true due to the fact that traditional accounting systems do not categorize costs by activities [10]. For example, labor hours that go into correcting defects are considered a part of production hours and, consequently, direct labor hours. Many companies utilize external systems, such as spreadsheets, to report their COQ figures. In such cases, companies may report obvious failure costs such as costs of scrap, rework, and warranty, but not the ones that are intangible or, as often called, "hidden" costs. Examples of hidden costs include management time for a corrective action to handle a customer complaint, analysis of returned products, premium shipping cost to replace a defective product, and so on. If not flagged, hidden costs of quality are usually included as indirect labor, miscellaneous, and fixed costs, as well as admin and general costs portions of the traditional accounting system as illustrated in Figure 2.

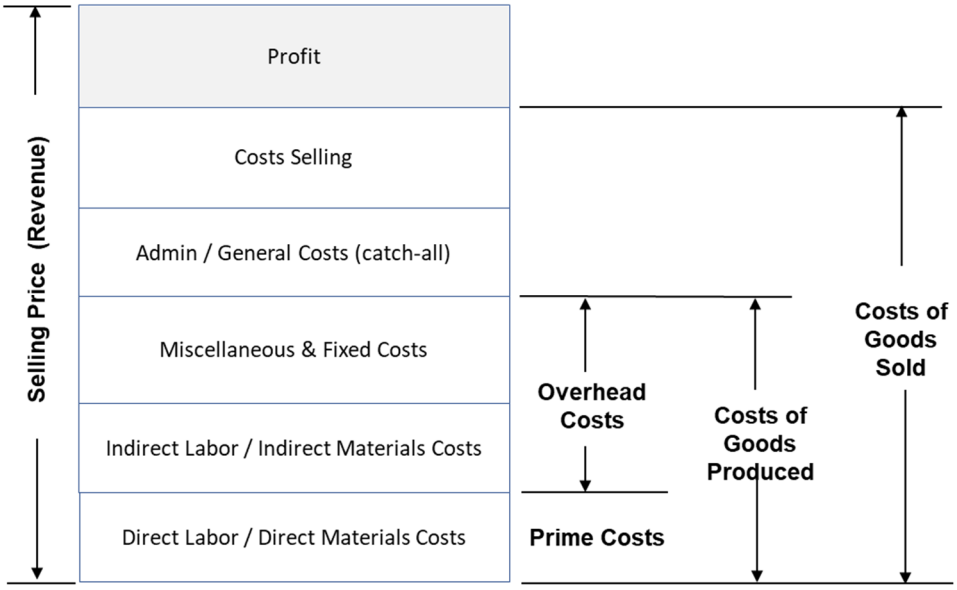

Figure 2: Traditional Cost / Revenue Structure

The ISO 9001:2015 international standard for quality management systems emphasizes the use of risk-based thinking [11]. The premise is to enable organizations to determine the factors that could cause their quality management system to deviate from planned results. For some organizations, initiating a limited quality cost program, mainly focusing on failure costs, may be a way to show an objective evidence of meeting the requirements stated in this standard. Shifting from a reactive to a proactive risk-based quality management system (QMS) would likely result in taking action to reduce the number of failures and lower costs of poor quality [12].

Costs of failure (both internal and external) could reach as much as 70% of total costs of quality [13]. However, most companies report obvious costs such as scrap, returns, and rework and not hidden ones. It is more challenging to isolate all the hidden costs and account for them as activities. Westinghouse Electric Corporation reported a multiplier of 3 to 4 between measured quality costs and hidden ones [7].

In addition to the direct accounting of prevention, appraisal, and failure costs, two other methods were also proposed in the literature for accounting quality-related costs for intangible or hidden costs. One is the quality loss function (QLF) method, which was a concept first introduced by Taguchi [14]. In its original form, QLF quantifies the impact of deviating from target from the time the product is shipped. As the performance characteristic moves away for the target value, loss to society is determined through a quadratic function. As a result, loss would be accounted for product even if it is produced within specifications but off target, as shown in Figure 3. As the QLF was utilized by researchers on quality-related costing, it is assumed that its quadratic nature is inclusive of intangible or hidden costs associated with lack of customer satisfaction and loyalty. In other words, the “loss to society” includes the cost of customer dissatisfaction that leads to damage to company reputation. Therefore, much of the estimated hidden costs would be attributed to external failure.

The other method of estimating quality costs related to conformance comes from the process approach. This approach considers the process as the source of nonconformance and, consequently, costs of poor quality and the resulting lack of efficiency are estimated [7]. Costs of conformance in the process approach of costing is different from the traditional definition which includes only prevention and appraisal costs. In the process approach, costs of conformance are costs of all process activities incurred in the absence of failure. Included under this approach are not only costs related to prevention such as process control, but also costs of raw materials, utility, etc. What is important here is that the process is stable and running without any failure.

Proposed Model

The aim of this research is to develop a model that can be used in the traditional approach of quality costs for two purposes. The first is to identify whether a given cost is in fact quality-related cost and, if so, the second is to classify it correctly. Since most companies only include obvious costs of nonconformance or failure, such as scrap and warranty costs, a model is needed to identify other costs, particularly those that are hidden or intangible.

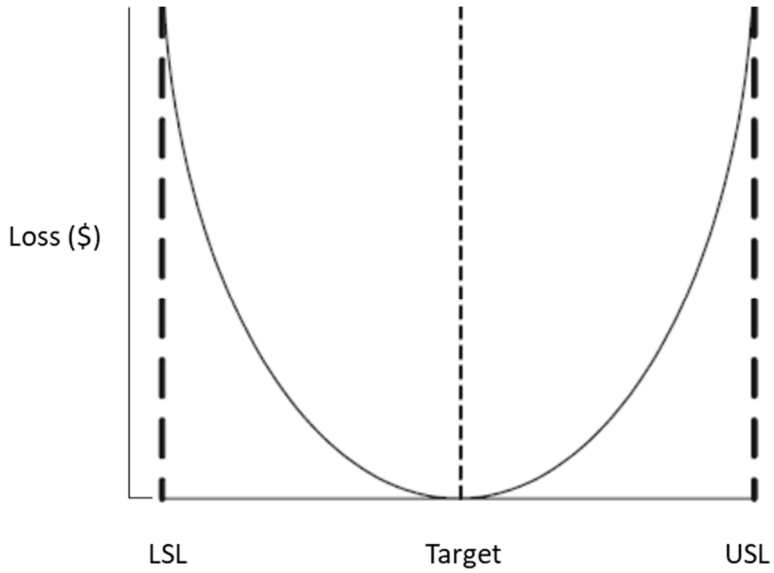

Figure 3: Taguchi's Quality Loss Function (QLF)

As more costs of quality are correctly identified, a clearer picture of issues and opportunities would be achieved. By doing so, management would be able to prioritize initiatives and allocate resources to improve quality and customer satisfaction. A model in the form of a flow diagram is proposed.

Flow diagrams can be highly effective in in documenting processes. It is a picture showing a sequence of actions or process steps. It can be used when a process is being studied for improvement opportunities, as well as means for communication between people [15]. Many organizations use flowcharts for documenting internal procedures and work instructions and are used for training purposes. They vary in their complexity and the number of shapes that can be used. However, basic shapes of flowcharts such as operation, decision, terminal step, and flow arrows, can describe most processes sufficiently.

The first step in developing a flow diagram is to list the steps that make up the process. In this case, most of the steps are in the form of questions which, on a flow diagram, are depicted using the decision (diamond) shape. Therefore, the diagram is constructed by asking a series of questions that lead the user to making the correct decision. Since most of the hidden costs are associated with failure, it is logical that from the outset, the first question should be as to whether the cost is related to failure. If not, other questions related to prevention and appraisal would follow. Figure 1 displays the proposed model.

Methodology

The methodology for this research consists of developing and evaluating the model. Issues concerning development was addressed in the preceding sections. The evaluation of the model included developing potential costs for classification, testing them using students in a senior-

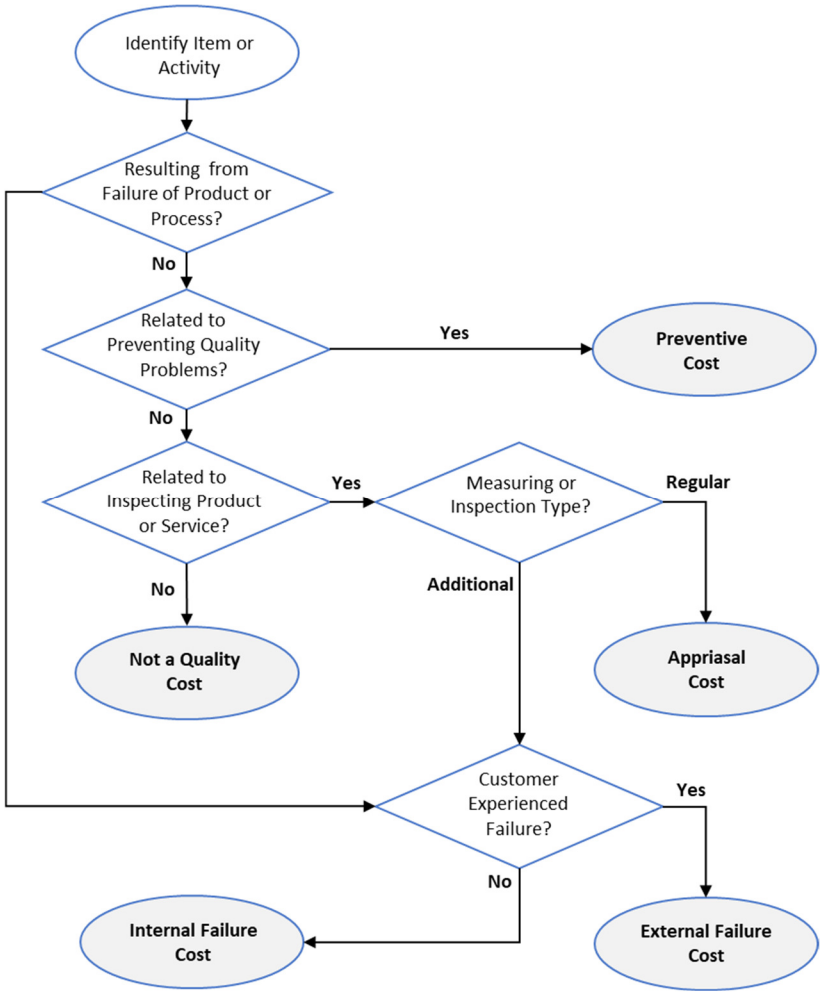

Figure 4: Proposed Model for Identifying Costs of Quality

level *Quality Improvement* course at a Ohio University in the United States. The methodology for evaluation is detailed in this section.

1. Tested Hypotheses:
   - *H_O: There is no association between correctly identifying quality and using the proposed model*
   - *H_A: There is no association between correctly identifying quality and using the proposed model. In other words, the proposed model significantly helps users (students) in correctly identifying potential costs as opposed to referring the descriptions of the costs*

2. A list of 20 potential quality costs were generated and randomly given to 30 students (class size) for a potential of 600 identification opportunities. These opportunities were given to students with and without the model. Examples of potential costs include:

- *Emergency repair of processing equipment*
- *Statistical Process Control (SPC) Training*
- *Premium freight to replace a customer's product*
- *Sales demo for a new product*

Table 1 below shows the distribution of potential costs used for identification and total opportunities.

Table 1: Distribution of Opportunities for Identification

Category	Questions	Students	Total
Prevention	4	30	120
Appraisal	3	30	90
Internal Failure	5	30	150
External Failure	5	30	150
Not a Quality Cost	3	30	90
Total Opportunities for Identification			600

3. Before the evaluation, an overview lecture of 20 minutes was given by the instructor on quality costs followed by the evaluation:
    a. During the first round, students were given the definitions of quality costs and asked to identify them as to whether each of them is a quality cost. If a potential cost is identified as a quality cost, students would then have to classify it as prevention, appraisal, internal failure, or external failure cost.
    b. The second round of identification was done using the proposed model with the same questions in random order. Students were asked to use the proposed model for validation if they already knew the answer and change it to what the model suggested, if different.

4. Chi-Square (χ^2) test of association was used to determine whether the proposed model helped students identify the potential costs correctly. The Chi-Square (χ^2) is calculated from observed and expected values for the cells based on the formula:

$$\chi^2 = \sum \frac{(O-E)^2}{E}$$

Where O is the observed count and E is the expected value obtained by multiplying the row total by the column total and divided by the observed count of the cell.

Results and Analysis

Table 2 shows the observed counts and expected values (between parenthesis) for questions answered correctly and incorrectly when presented to students with the proposed model (flowchart)

Table 2: Overall Results of Observed and Expected Values

	Correct	Incorrect	Total
Description only	403 (424.5)	197 (175.5)	600
Proposed Model	446 (424.5)	154 (175.5)	600
Total	849	351	1200

With the Pearson Chi-square statistic of 7.45 and p-value of 0.006, the results indicate that there is a statistically significant association when classifying the potential cost correctly as to whether the proposed model is used or not. When using the model, students were able to make more correct decisions.

There was also a significant impact on categorizing the types of COQ. The proposed model performed particularly well in identifying external failure costs. Table 3 shows the breakdown of identification by category when the proposed model is used.

Table 3: Breakdown by Type of Quality Costs for Proposed Model

	Correct	Incorrect	Total
Prevention	87 (85.88)	33 (34.12)	120
Appraisal	54 (64.41)	36 (25.59)	90
Internal Failure	91 (107.35)	59 (42.65)	150
External Failure	133 (107.35)	17 (42.65)	150
Total	365	145	510

With the Pearson Chi-square statistic of 36.28 and p-value of 0.000, the results show an association. That is, the model performs better for at least one of the types of quality costs. By looking at the numbers, there are wider gaps between observed and expected values for the nonconformance (failure) costs than for the conformance (prevention and appraisal). For example, the proposed model was expected to identify about 107 cases correctly, when in fact it identified 133 as such.

When comparing results involving opportunities that are not quality costs, results show that by using the model, the students were able to identify 81 out of 90 opportunities correctly (or 90%), while only 60 out of 90 were identified correctly when only description (definitions) were available (67%). As shown on the proposed model, reaching a decision that a given cost is not quality-related is a result of going through questions related to quality costs. In other words, the user, without the availability of the model, would have to decide on whether the cost is not-quality related from the outset. With the model, however, the user does not have to make that decision, answering the questions will automatically do this. Overall, the model performed better for identifying certain categories but did not all categories, as shown in Table 4

Table 4: Percentage of Correct Identification

	% Correct Identification	
	Using Model	Description Only
Prevention	73%	73%
Appraisal	60%	44%
Internal Failure	61%	61%
External Failure	89%	82%
Not a Quality Cost	90%	67%

Concluding remarks

It is imperative for organizations to assess the current conditions of their processes and systems accurately for their improvement initiatives and resource allocation. While initiating a COQ program will not solve quality problems, it provides management with the necessary data-based information to prioritize actions based on bottom line figures. The drawback for using figures like these is that they become a part of how companies manage or as Deming called it "management by objective." If not used correctly with clear definitions, such programs become models for assigning blame and become ineffective if not abusive.

For the current conditions to be assessed objectively, clear definitions and effective models must be used. The proposed model in this paper is only an attempt to move in that direction. It moves from identifying quality costs based on subjective definitions into a series of questions in a flow diagram with clear outcomes. Some costs are easy to identify and may not need a model to discover them. However, many others may not be that obvious. The proposed model is mostly intended for intangible or hidden costs. Without a proper method to flag them and report on them correctly, such costs would reside in one of the typical accounting cost categories shown in the

traditional cost and revenue structure in Figure 2. As a result, they are often thought of as costs of goods produced or sold and, therefore, not used as important data for improvement initiatives

While the results of this study are modest, they can be viewed as a step in the right direction. Further improvements and testing will be needed to make this model more reliable so it can be used in industry. From Table 4 above, it is evident that the model did not do well for the appraisal and internal failure costs. One explanation is that some students believe that testing the product is a way to prevent problems from moving to the next step or customer. In fact, 38% of responses that incorrectly identified appraisal costs thought they were prevention costs. As for internal failure category in Table 4, one item: "Re-inspecting suspect product before shipping" had 15% of responses as *Prevention* or *Appraisal*.

Students were asked whether the proposed model was helpful in categorizing costs and if they thought there were ways to improve it. All students thought the model was useful, organized, and easy to follow. Some students thought it was particularly useful in identifying failure costs through the questions asked. However, students also provided feedback for future improvements. One comment was specific on adding "more criteria to distinguish between *Appraisal* and *Prevention* costs." This aligns with the 38% of misclassification of *Appraisal* as *Prevention* costs reported above. Additionally, some students thought it would be more helpful if examples are given at certain points on the flowchart. This could be incorporated but probably more easily achieved if the model is used electronically, so examples can only appear when triggered or hovered over.

One of the potential changes to the proposed model is the elaboration of the questions in the flow diagram while keeping it simple. Additionally, more emphasis should be placed on questions related to *Appraisal* and *Internal Failure* classification.

Another potential improvement may be realized by converting the series of questions in the model into an expert system where, based on additional and clearer questions, higher accuracy of identification can be achieved. Additionally, the model should also be validated where an actual cost of quality program is being used.

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