COST OF QUALITY - THEIR DETERMINATION AND RELATIONSHIPS

By

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ABSTRACT

With a renewed emphasis on Management of Quality, the question of collecting and quantifying Cost of Quality (COQ) has assumed special significance. It is realized that organizations intending to launch quality improvement programs need to first deploy a suitable COQ system to support and direct the quality improvement process. Although the various components of COQ i.e. prevention, appraisal, external and internal failure costs have been recognized for a long time, it is only recently that the various issues connected with it have been systematically studied.

In this paper we take a comprehensive look at the COQ issues and the kind of answers that research has yielded. More specifically, we are interested in the analysis of the following questions:

i) What are the various elements of quality costs and how are they classified into COQ Components? What are the company practices regarding these?

ii) What are appropriate indicators of COQ? In general, how much do companies spend on quality, as reflected by COQ indicators?

iii) What are the relationships between the COQ Components? How do they influence the COQ?

iv) What are the effects of COQ on unit product cost and product profitability?

v) Can suitable analytical model be developed to predict the effect on COQ of changes in company efforts on prevention and appraisal?

vi) How should a quality cost system be set up?

The above issues are analyzed in detail. The results from prevailing research are reviewed in seeking answers to the above issues. Finally we summarize the conclusions drawn from the study.

COST OF QUALITY - THEIR DETERMINATION AND RELATIONSHIPS
-PROF. MANGESH G. KORGAONKER

With a rapid growth in the introduction of highly advanced, new manufacturing technologies known for their precision, and a growing appreciation of the competitive role of quality by organizations worldwide, the management of quality is receiving a kind of top management attention, perhaps never before witnessed in the past. As managements attempt to grapple with the quality problem several new approaches to quality managements, at least some of them of Japanese origin, have emerged. Examples include approaches like Total Quality Control(TQC), Company Wide Quality Control (CWQC), Zero Defect (ZD), Total Quality Management (TQM), Strategic Management of Quality etc. It is not the purpose of this paper to go into the details of these approaches. Nevertheless, a common feature of all the approaches is the heavy emphasis they have laid on the "total involvement" of the organization in the quality management process. The aim is to take quality out from the province of narrow specialist consideration and view it from a much broader, company wide perspective as a key strategic task.

An improvement aspect of the quality management process in any organization pertains to the framework and methodologies adopted to measure the "Cost of Quality" or (COQ). While the general nature of these costs have been known for a long time, little else was known about these except for some judgmental estimates.

With a renewed emphasis on Quality Management, organizations are focussing much more attention on systematic methodologies to define, collect, appraise quality costs, monitor them and. take corrective actions. Indeed a thorough knowledge of the quality costs being incurred by an organization is found to provide a sound basis to direct the quality improvement process within the organization.

The purpose of this article is to study in detail the various issues connected with quality costs and the methodologies available for their collection, measurements and analysis. Finally an approach is put forth for setting up a quality cost system in an organization.

1. What are quality Costs?

Clearly the key issue in quality cost analysis is "What are quality costs?" The general nature of these costs have been known for a long time. For example, Juran [1] as early as 1951 in his handbook titled " Quality Control Handbook" and later in the book titled "Quality Planning and Analysis" [2] discussed Cost of quality in the context of the economics of quality. Similarly Feibenbaum [3] in his famous book "Total Quality Control" devoted a full chapter to a discussion of quality costs. These early writings led to a categorization of quality costs as those relating to the following activities:

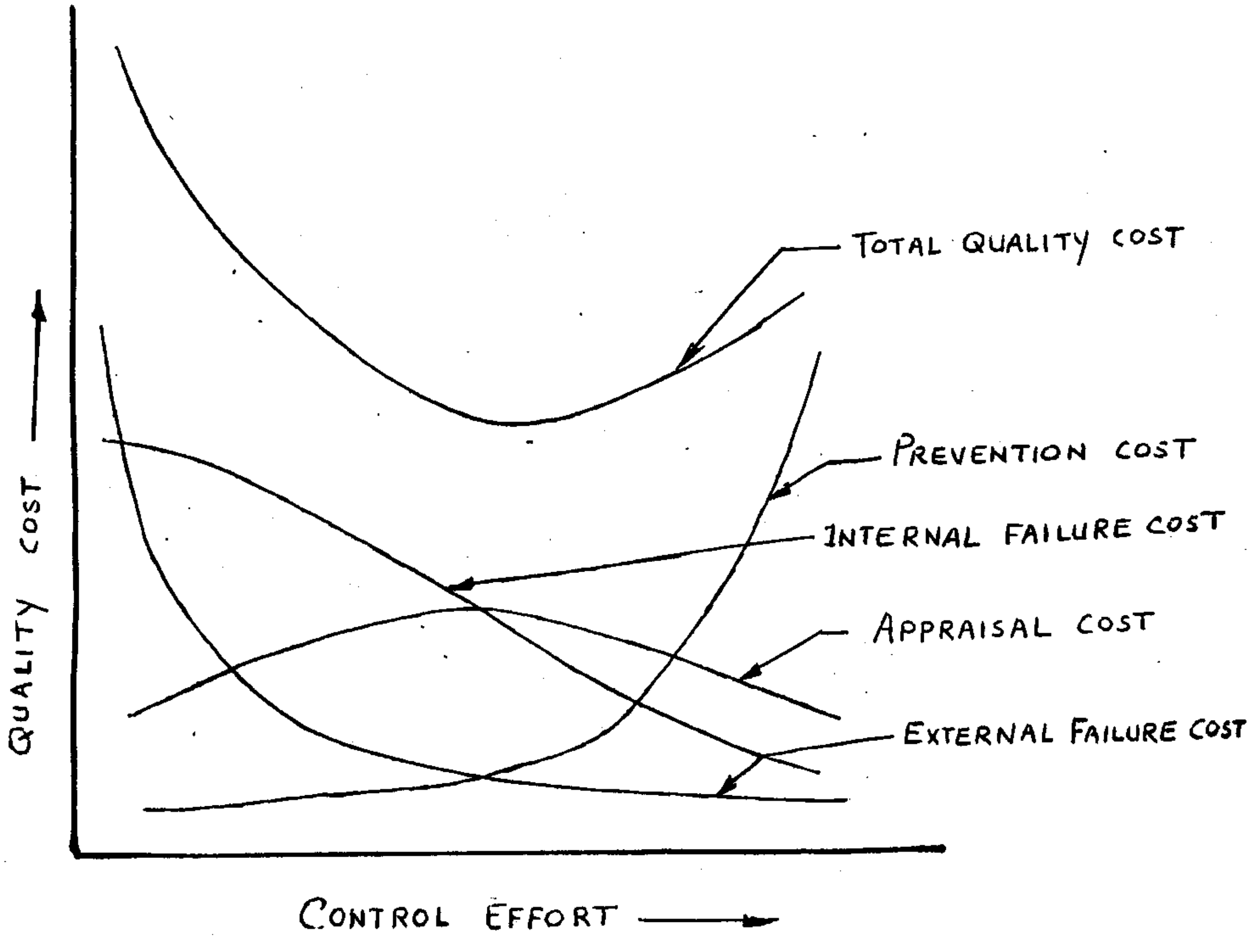
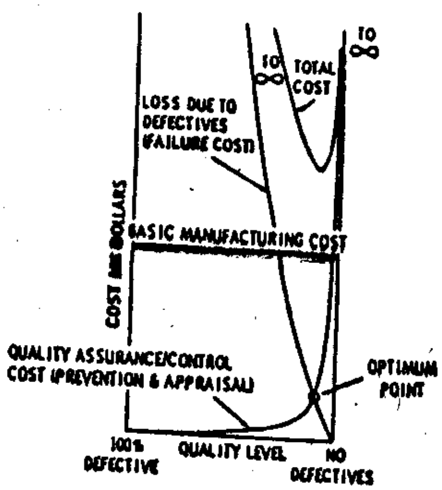


FIG 1 : QUALITY COSTS [2]

Figure 2. Quality cost changes (12)



i) prevention

ii) appraisal

iii) internal failure

iv) external failure

Figure 1 shows the hypothetical relationships of these costs to the quality effort in an organization proposed by Jura [2]. Although little else was known about these costs for a long time, the above categorization was in a way, the first necessary step towards evolving a comprehensive methodology for COQ collection, measurements and analysis.

Broadly stated, **Prevention costs** are those costs expended in an effort to prevent discrepancies, such as the costs of quality planning, supplier quality surveys, training programs etc.

Appraisal Costs are those costs expended in the evaluation of product quality and in the detection of discrepancies such as the costs of inspection, test and calibration control.

Failure Costs are those costs expended as a result of discrepancies and are usually divided into two types.

Internal failure Costs These are costs resulting from discrepancies found prior to delivery of product to the customer such as the costs of rework, scrap, and material review.

External failure These are costs resulting from discrepancies found after delivery of the product to the customer such as the costs associated with the processing of customer complaints, customer returns, field services, and warranties.

The Total quality cost is the sum of all these costs. It represents the difference between the actual cost of a product and what the reduced cost would be if there was no possibility of failure of the product nor defects in its manufacture. As described by Juran [1], it is **"the gold in the mine"** waiting to be extracted.

Figure 2 shows the expected relationship between value of quality and the quality costs:

If however a proper framework has to be created for collection of the quality costs, the above categorization per se is not sufficient. It becomes necessary to identify each type of the cost element comprising each of the above cost category. Only when these elements are identified and defined with sufficient clarity, we could incorporate them in the cost collection procedure.

Fortunately, at least two such attempts are now well documented. These are due to Elridge and Dale [5] and Sullivan and Ovens [6]. Because of their importance to the COQ system we shall review each of these in depth.

2. Elements of COQ

Elridge and Dale [5] proposed a detailed list of cost elements for collection and quantification of quality costs, in a mechanical engineering company producing industrial valves. The manufacturing facilities consisted of a foundry, machine shop and assembly area. The focus of their investigation was to highlight to the senior management team the need for quality improvement and develop a basis for cost reduction projects. Their list is largely based on the categories defined in the British Standard BS 6143. Table 1 gives the details of their cost elements.

Table 1: Details of quality cost elements, Elridge & Dale [5]

Category	Cost element
Prevention	Quality Engineering Design and Development of equipment Quality planning by other functions Maintenance and calibration or production equipment Maintenance and calibration of inspection equipment Supplier assurance Quality Training Administration, audit and improvement

Appraisal	Laboratory acceptance testing Inspection and test In process inspection Set up for inspection and test Inspection and testing materials Product quality audits Review of inspection data Field (on site) performance testing Internal testing and release Evaluation of field stock Data processing
Internal failure	Scrap Rework and repair Trouble shooting Reinspect, retest Scrap and rework, fault of supplier Modification permits, concessions Downgrading
External Failure	Complaints administration Product liability Products rejected and returned Returned material repair Warranty Replacement

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Even though the cost element list proposed by Elridge and Dale is quite exhaustive, there may be some doubt regarding their classification into the four cost categories. The question we may like to ask at this stage is "In general, does the Table 1 reflect a uniformly observed practice among most or majority of the companies regarding quality cost classification? For example, do all companies classify quality audit cost as appraisal cost? What about in process control? Is it always regarded as prevention cost? Similar question can be raised in respect of many other cost elements listed in Table 1. The findings of Sullivan and Owens [6] are very pertinent in this regard.

Sullivan and Owens [6] designed a one page survey questionnaire to gather information about the way quality cost systems were organized and about top management attitudes towards the systems. The questionnaire was carried in the April 1983 issue of Quality Progress, with a mailing of 35000 copies in US & Canada. Forty of the readers returned the completed questionnaires. Thus their findings are based on analysis of these completed questionnaires. Therefore, there could rightly be questions about sample size, etc. Nevertheless, it was the first attempt to obtain some empirical data on company practices on classification of quality costs. Because of its importance, we reproduce this survey data on cost Element classification provided by Sullivan and Owens [6] in Table 2.

It is noticeable in Table 2 that in respect of classification of many cost elements, the company practices are not uniform. Particularly noteworthy are the following cost elements.

i) Quality data acquisition and analysis
ii) Administrative costs
iii) Product review
iv) Process control
v) Field evaluation and testing
vi) Quality audits
vii) Maintenance/calibration: test/inspection equipment

iii) Maintenance/calibration : production equipment

x) Trouble shooting or failure analyses

x) Downgrading

xi) Marketing error

xii) Engineering error

xiii) Factory or inspection error

xiv) Reinspect or retest

xv) Scrap and rework - fault of vendor

xvi) Discrepant Material activity

Majority of the companies classify the first eight of the above cost elements as either prevention or appraisal and the next five of the cost elements as either internal failure or external failure. The last three are classified either as appraisal or failure cost.

The cost elements where there is relatively little or no ambiguity about classification are given below, along with the corresponding cost category.

	Cost element	Cost category
i)	Quality engineering	Prevention
ii)	Quality planning by functions other than Quality	Prevention
iii)	Training to improve quality	Prevention
vi)	Inspection and Test	Appraisal
v)	Inspection and Test set up	Appraisal
vi)	Scrap	Internal failure
vii)	Rework and repair	Internal failure
viii)	Downtime	Internal failure
ix)	Complaints	External failure
x)	Product or customer service	External failure
xi)	Products rejected and returned	External failure
xii)	Warranty charges	External failure
xiii)	Recalls	External failure

xiv) Product liability | External failure

We observe that there is ambiguity regarding classification of more than half the cost elements. This is indicative of wide variance in company practices. If however we form only two broad categories namely i) Costs of prevention and appraisal ii) Costs of internal & external failure then the same data brings out considerable uniformity in company practices. In that case, we hardly notice any ambiguity at all. This finding appears to lend credence to the proposition that "quality costs should be collected and quantified on the basis of two rather than four categories". If 4-category system is still to be preferred, there is a need to resolve the ambiguities of classification, brought out earlier.

It is also important to note that a significant percentage of companies do not measure some of the cost elements. Notable amongst these are: Product review, process control, quality planning by functions other than quality, field evaluation and testing, maintenance/calibration of production equipment, down-time, downgrading product or customer service, discrepant material activity, marketing error , engineering error, factory or installation error, recalls and product liability. Either they are not considered very significant by managements or the COQ systems have not evolved to the extent of being able to capture all the relevant information.

3. COQ Indicators

Assuming that companies have some system for COQ categorization and quantification, it would be interesting to know **"how much do companies in general spend on quality? i.e. What total COQ do they incur? To what extent does COQ vary across various industries?"**

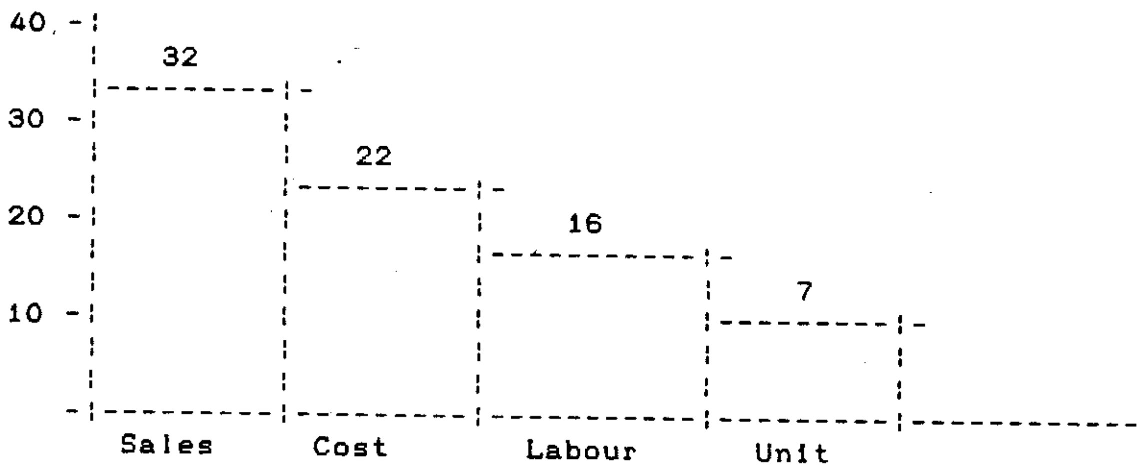
Although no hard empirical evidence was available in this regard, for a long time in the past Crosby [4], a well known quality consultant estimated the quality cost to be 15-20% of the sales. Crosby's relating the COQ to sales raises an issue regarding the indicator of quality cost. **"Do all companies relate quality cost to the sales turnover? Is the percentage of sales turnover the best indicator of quality cost ?'**

We may again refer to the survey study by Sullivan and Owens [6]. One of the questions they required the companies to respond related to the base, if any, against which the responding company indexed the quality cost. The choices provided by them were: Sales base, cost base, labour base, any other base. Figure 3 gives summary of their finding. As the figure shows, most companies index quality cost against a sales base i.e. most often gross sales or net sales. Cost bases-the second most popular category included direct material and labor cost, standard manufacturing cost, standard cost of production, manufacturing value added, cost per unit and cost of goods sold.

The firms using labour bases compared quality costs to direct labour, total labour, standard direct labour, applied direct labour, earnings on standard hours, standard hours, hourly rates and earned burden.

The unit bases included gross shipments, net shipments, units stocked, and units produced.

Figure 3 **Cost bases**
-Sullivan & Owens [6]



The survey findings seem to suggest that it is preferable to index the quality cost against multiple bases rather than a single base alone. Perhaps justifiably so. After all if COQ is to be meaningful as an indicator of company efforts in quality, indexing the cost against single base may prove to be quite inadequate. We know that various indicators like sales, different types of cost, labour inputs, etc. are influenced by a variety of factors in organization. At times the fluctuations in them are quite violent and entirely unrelated to the product or process quality. (Indexing COQ against a single base could therefore result in quite erroneous conclusions).

Just how close to reality is the figure of 15-20% of sales proposed by Crosby for quality cost? This aspect was studied in a survey by Gilmore [8]. The author selected 35 consumer product manufacturing corporations for carrying out his survey. These corporations were known to be collecting quality costs in a form both consistent with generally accepted practice and amenable to analysis and publication. 17 organizations distributed over 10 industry classifications responded. Table 3 gives the industry classifications of the units responding to the survey. Although admittedly small, the sample included organizations of different sizes and with different degrees of quality control effort (as measured by Production to Quality Control personnel ratio). Tables 4,5,6 & 7 summarize their findings. Some vital conclusions could be drawn from the data presented in these tables. These are stated below:

1) Costs incurred in prevention, appraisal and failure as percentages of total Quality Costs vary very widely across the organizations. Only 25% organizations report spending over 50% of their quality cost on prevention, whereas 38% do so for appraisal. Failure costs are over 50% of COQ in nearly 25% of the organizations.

The data presented however dbes not help very much in deducing, even empirically, a desirable level of spending on prevention and appraisal activities vis-a-vis failure costs.

ii) Going by industry classifications (Table 5) additional insight can be obtained. Firms in two industries namely, paper and fabricated metals, spend significantly higher amount on prevention activities. Firms in machinery and instrument industry, in contrast tend to incur significantly greater amount as failure cost. Excepting Non-Electrical Machinery, in general, firms spend considerable proportion on appraisal activity.

iii) Gross sales is the most popular base against which quality costs are measured. Manufacturing cost is the next most popular base. Unadjusted value added is not used as widely as the former two.

Total costs as percentage of sales vary from 1/2 to 8%. Over one half of the companies providing the data report spending less than 5% of gross sales. This is in contrast to the 15-20% figure given by Crosby. Overall average is about 5% of sales.

The manufacturing cost and value added bases show quality costs representing a much larger percentage of each. COQ as % of manufacturing cost varies from 1-12% and as % of unadjusted value added varies from 1/2 - 26%. Clearly sales and marketing personnel would find relationship of COQ to sales more meaningful whereas manufacturing management would find either manufacturing cost or value added measures more meaningful. The ranges for prevention, appraisal & failure costs are as follows:

	Range of values		
	% of Sales	**% mfg. cost**	**% value added**
Prevention Cost	0.25 - 1	0.35 - 1.7	0.04 - 1.6
Appraisal Cost	0.18 - 3	0.25 - 4.2	0.17 - 8.7
Failure Cost	0.07 - 5.1	0.10 - 7.5	0.28 -16.1

Gilmore's survey is clearly very valuable at least for three reasons: First, it brings out the wide variations across the industry in the COQ value, in relation to sales, manufacturing cost and value added. Secondly, it provides, for the first time an empirical range for the value of the COQ and its components as percentage of sales, cost and value added. The observed ratio of COQ to sales for example, is very much lower than the 15-20% suggested by Crosby. Finally, the study suggests that the companies on the whole (except in paper fabricated metals industry) are spending much less on prevention effort than they were believed to be doing.

Elridge and Dale [5] in their elaborate study to determine the quality costs also report a COQ to sales ratio of 4.7% in the first phase of their study and 5.8% during second phase. These values are much closer to Gilmore [8] results.

It may therefore be appropriate to adopt the Gilmore values as representative of the industry norm, with an average COQ to

Sales ratio of 5% rather than the 15-20% proposed earlier.

Although this value is not expected to be optimal, the optimal COQ value itself may vary across the industries, depending upon specific product and process characteristics, etc.

Interestingly Elridge and Dale [5] study resulted in the following values of various categories of quality cost:

i)	Prevention Cost to Total Cost	: 3.5%
ii)	Appraisal Cost to Total Cost	: 14.8%
iii)	Internal failure Cost to Total Cost	: 69.4%
iv)	External failure Cost to Total Cost	: 13.3%

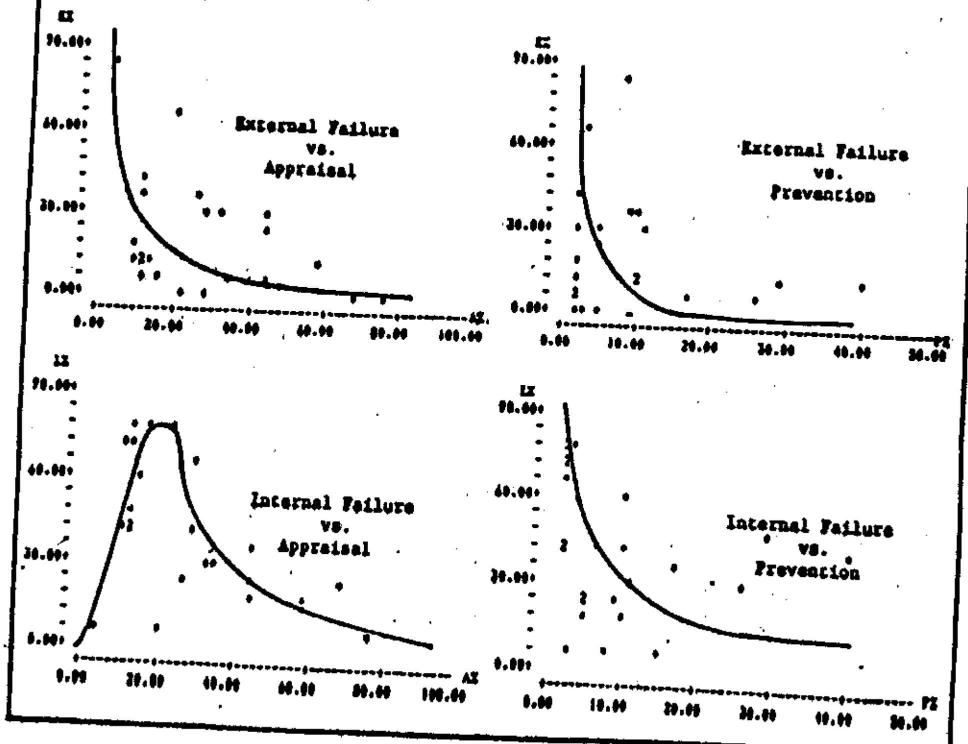
Obviously this particular company studied by Elridge & Dale spends very little on prevention and appraisal, resulting in relatively much higher failure cost.

4. Relationship between Prevention, Appraisal and failure Costs

It has been theoretically proposed in the past that there exists an optimum prevention and appraisal effort for an organization. While economic sampling plans do address the issue of optimal sampling inspection effort, based on limited consideration of inspection cost and cost of deflectives, very little is known about how an overall optimal quality policy could be determined, that takes into account the various cost elements of the prevention, appraisal, internal and external failure categories.

A first step towards working out such a policy is to be able to determine the relationships between the various cost categories. If such relationships could be quantified it would enable a study of how total COQ varies with changes in individual cost categories. This in turn could help determination of optimal quality policy. Krishnamoorthi [10] and Chauvel & Andre [11] focus their investigations on determination of these cost

Figure 4 Quality cost relationships (10)



relationships.

Krishnamoorthi [10] uses the regression approach to determine the relationships amongst quality costs. He considers the prevention, appraisal, internal failure and external failure costs as random variables, jointly distributed, taking different values in different cost systems.

The random variables represent the components expressed as per-cent of total quality costs. For his study, Krishnamoorthi used data from 23 quality systems, from different types of industry and from systems in different stages of improvement. Some had failure cost as high as 96% of total costs, others accounted for only 32% of total costs. There were also a few data points that had failure costs of about 50% of the total.

Figure 4 is reproduced from Krishnamoorthi's study. It shows graphs of external failure and internal failure against input variables i.e. prevention and appraisal. These graphs were used to develop regression models.

In this study, prevention and appraisal are used as independent variables. It is however known that they are themselves related. Similarly Internal and External failure costs are also related. This creates problem of multi-collinearity and hence the study results suffer from this problem. However, two useful relationships have been derived from the regression analysis. These are :

$$E = \frac{5.9}{P} + \frac{298}{A}$$

$$I = \frac{121}{P} + 0.213A$$

E = External failure Cost (% of COQ)
I = Internal failure Cost (% of COQ)
P = Prevention Cost (% of COQ)
A = Appraisal Cost (% of COQ)

For example, if P = 2 and A = 13
I = 53 and E = 22.

If it is desired to reduce I by 50% i.e. I = 26, then we write

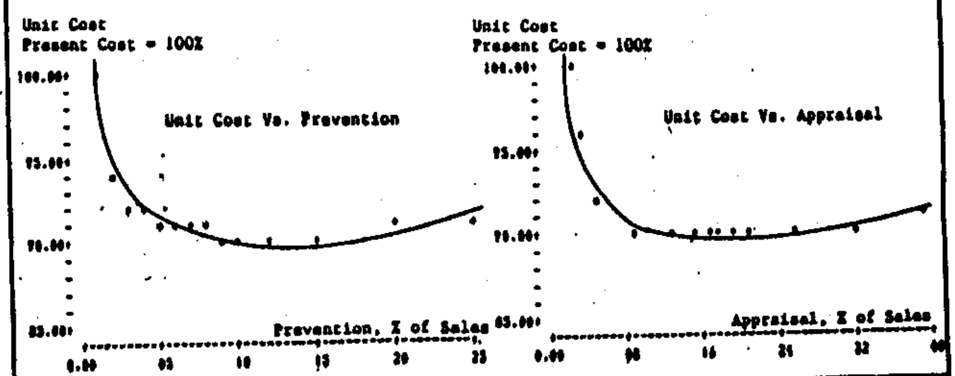
$$26 = \frac{121}{P} + (0.213)(13)$$

and P = 5.2.

The above relationships show that the external failure cost is inversely related to both prevention and appraisal in an assymtotic manner. This implies that initial efforts in prevention and appraisal will yield much greater reductions in external failure cost compared to the later efforts and in fact, increases of effort beyond ascertain level will result in greater total cost of quality, due to lower marginal cost reductions of external failure. We also observe that the coefficient of 1/P is smaller. This means E decreases faster with increase in prevention than with an increase in appraisal cost. However, most of the decrease in E has to come from A rather than P. So if external failure has to be reduced, even though a rupee of prevention produces more reduction in external failure, prevention can do only so much and appraisal must be increased to reduce most of the external failure. At least this is what companies are evidently doing.

The internal failure cost gets reduced much more by an increas

Figure 5. Changes in unit cost with changes in quality costs [10]



in prevention than the external failure cost. Interestingly, an increase in appraisal leads to increase in the internal failure cost, though only slightly. Krishnamoorthi [10] feels that these models are reasonably reliable and could be used to see quantum changes rather than predicting exact value of changes.

We should however remember that while the Krishnamoorthi equations do help to quantify the nature of cost relationships, the specific coefficients which have been derived are based on the data set used. It might at least be necessary to reestimate these coefficients, depending on the data set pertaining to the quality systems being studied.

The equations could be stated in their general form as follows:

$$E = \frac{K1}{P} + \frac{K2}{A}$$

$$I = \frac{K3}{P} + K4\ A$$

Here K1, K2, K3 and K4 are constants which have to be determined for the quality system under consideration.

Krishnamoorthi used the cost equations derived earlier to simulate a production system with given production volume, cost of production, and a given breakdown of the four quality costs. The study was intended to examine the behaviour of the unit cost with variations in prevention and appraisal. Figure 5 gives the graph of the results obtained. It can be seen that there are optimal prevention and appraisal levels at which the unit cost is a minimum.

The results of this study go a long way in quantifying the quality cost relationships. The major problem that is still unresolved is the quantification of relationship between prevention and appraisal, if indeed there exists such a well defined relationship. If this could be achieved, the problem of determining optimum quality policy would be much closer to solution.

Another study which helps gain further insights into quality cost relationships is reported by Chauvel and Andre [11]. They highlight the results obtained through a **"quality diagnosis"** of small and medium French firms (PME - Petites et Moyennes Enterprises). They selected 54 diagnoses completed between September 1982 and July 1983. Table 8 gives the classification of the firms in the sample. A major strength of this study is that the quality cost is measured as percentage to sales.

Table 8 : <u>Classification of the firms in the sample Chauvel and Andre [11]</u>

<u>In terms of activity</u>

26% in the construction material sector
20% in buildings and public works activities
18% in mechanical activities
11% in carpentry
9% in the chemicals sector
16% in others : medical devices, cosmetics, electricity. electronics, food products and services.

<u>In terms of sales*</u>

44% less than 25 million francs
48% between 25 million and 100 million francs
8% from 100 million to 400 million francs.

Figure 6 [11]

Reducing Quality Cost:
The Effect of Prevention

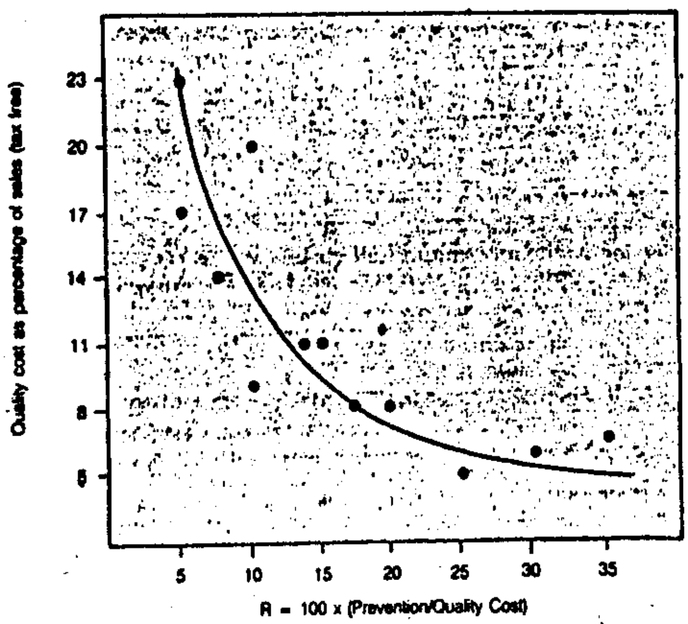


Figure 7.(11)

Reducing Quality Cost: Prevention Plus Appraisal

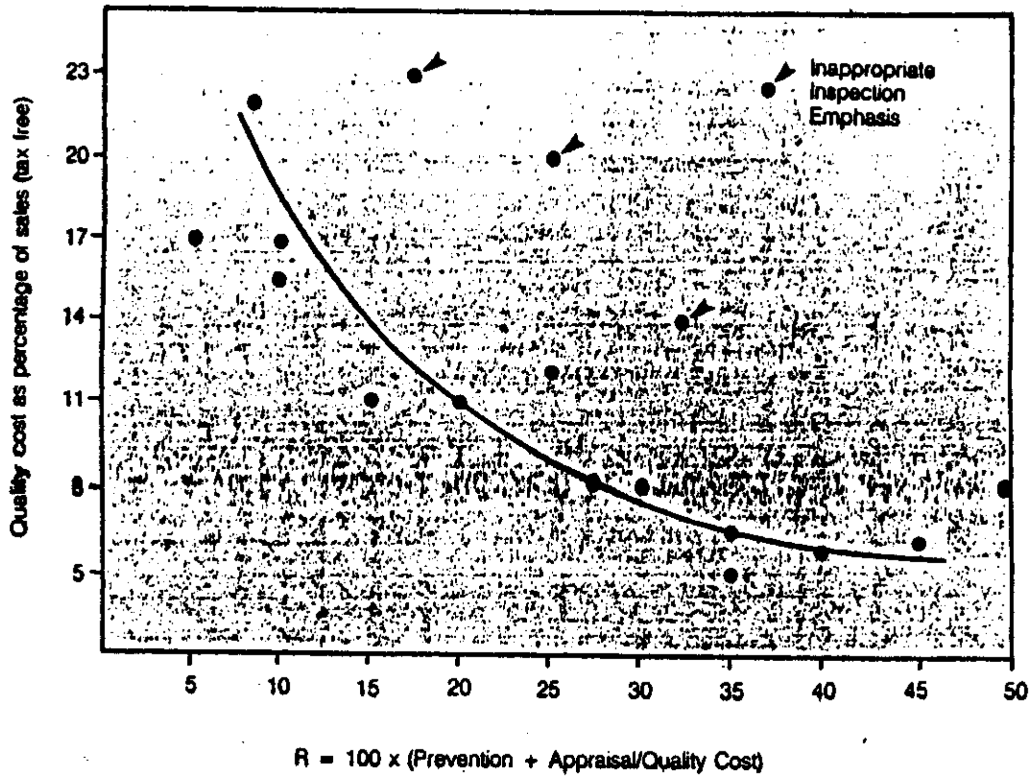
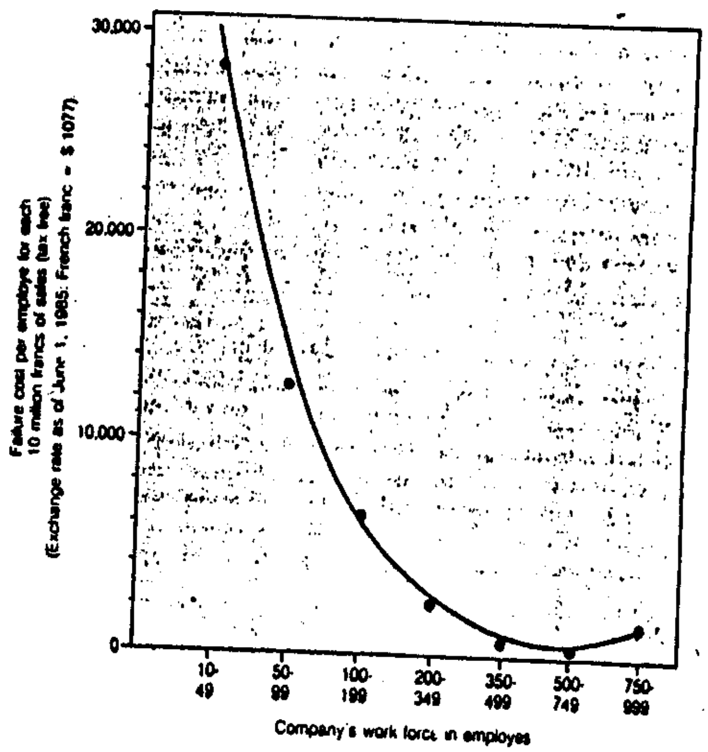


Figure 8. (11)
Failure Cost: Effect of Company Size (Number of Employes)



*Exchange rate : 1 french franc = approx. Rs.3.5.

In terms of work force

81% having fewer than 200 employees
19% having 200-800 employees

Figures 6, 7 & 8 give graphs of the results obtained from the study. The major conclusions are:

i) As prevention efforts increase, the total COQ, measured as percentage to sales decreases in an asymtotic manner.

ii) When appraisal costs are added to the prevention cost, even though the total COQ (as % of sales) decreases with increase in % of P & A to COQ, the decrease is not as sharp as with prevention cost alone. This situation was due to heavy inspection systems used by the firms.

iii) Appraisal or inspection efforts, without appropriate investment in prevention may lead to a feeling of false security and may generate unnecessary costs.

iv) Quality cost as % to sales decreases dramatically with increase in the size of the firms (measured by the size of the workforce). This is perhaps due to the fact that larger companies are better organized, and probably have either a product engineering department or quality department. Secondly, the cost of errors is spread over a large sales amount.

v) Whatever the size of the company, prevention effort directly contributes to reducing quality cost.

An important contribution of the Chauvel & Andre study [11] is the empirical relationships they have derived between (i) total COQ and prevention cost (ii) total COQ and Prevention & Appraisal cost. The clearly asymptotic nature of the former may enable us to formulate an analytical model for total COQ as function of prevention cost. The following model would appear to define this relationship reasonably accurately.

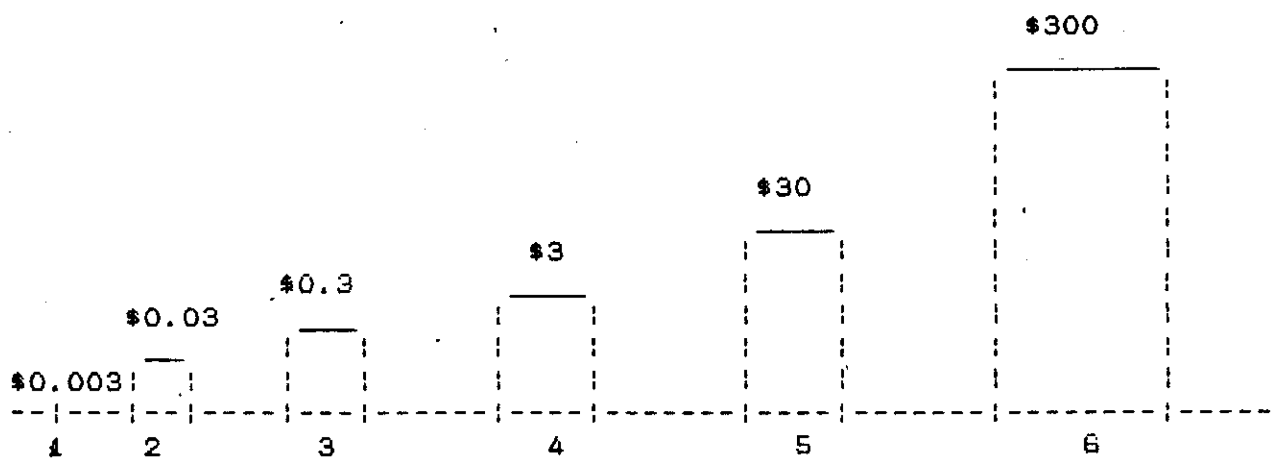
$$X = \frac{K}{Y}$$

where X = [Total COQ/Sales] X 100
Y = [Prevention Cost/Total COQ] X 100
K = Constant.

To define the relationship between Total COQ and Prevention & Appraisal cost, the flatter nature of the curve makes it more difficult to conjecture an analytical model. However, Chauvel & Andre Study shows that the total COQ continuously decreases for the values of P & A costs (as % of COQ) considered by them i.e. up to 45%. The nature of the curve for larger values of P & A is not known. We could infer that the proportion of P & A to COQ costs will have to be at least 50%, in an optimal quality policy.

The above discussions should make it sufficiently clear that the earlier a defect is prevented or detected, the more would be the saving. For example, according to an estimate by General Electric [13, 14], error costs rise by an order of magnitude each time a product or components moves a step further along the production chain. An error that costs $0.003 if found at the supplier level costs as much as $300 - 100,000 times more, if left undiscovered until the product is in the field. Figure 9 gives GE's estimates of the error cost , for a particular product as it progresses through the various stages of the production line.

Fig 9 : Escalation in Cost of Errors down the production line -Robert Cole [13, 14].



(figure not to scale)

1 - Supplier inspection cost
2 - Incoming inspection Component Cost
3 - Fabrication inspection Cost
4 - Subproduct test Cost
5 - Final product test Cost

6 - Product Service Cost

5. Quality Costs and Profitability

"Does minimum quality cost imply maximum profit?"

Not always. This is because profitability of a product is determined by a number of other factors such as level of competition, volume of production, the life cycle stage of the product etc. For instance, when a product is in its growth phase, its profitability is usually higher than when it reaches the maturity phase, even though quality costs are probably less in the maturity phase compared to the product's growth phase. Many cases can be cited to illustrate this point. For instance, Hitoshi Kume [12] cites the case of video tape recorder division and the television division - of a Japanese electronics Company. The data is given in Table 9 below.

Table 9 : **Profit and failure cost : A comparison of the VTR and TV (in millions of dollars) -Hitoshi Kume [12]**

	VTR Division	TV Division
Sales Volume, MILLION	\$540	\$365
Failure Cost (Ratio to Sales)	\$17.6 (3.3%)	\$2.4 (0.7%)
Profit (ratio to Sales)	\$53.6 (10%)	\$20.8 (5.7%)

The other important points Kume makes about quality cost and its influence on firm's profitability are:

i) Minimum quality cost does not necessarily mean minimum product cost, since the product comprises of various other elements. How these elements are managed determine the total product cost, and therefore product profitability.

ii) Losses due to failure cannot be calculated only by failure cost alone. Opportunity loss (for ex. by way of lost market share, both present and future) must be also included. Non-consideration of this may yield erroneous results on profitability.

iii) The cost of marketing research should be included in the prevention cost.

iv) A product's profitability is determined, by its "superiority -i.e. quality of its design and technology of manufacture. This aspect cannot be easily evaluated by mere quantification of quality cost.

v) The important thing about prevention and appraisal cost is not their total but the way the money is used in these activities i.e. quality of these efforts.

6. Setting up a quality cost program

The foregoing studies focussed on examination, in detail, of the various issues connected with quality costs. In summary these include: i)the quality cost elements and their categories ii) the company practices on quality cost classification iii) appropriate indicators of quality cost iv) company expenditures on quality v) relationship among quality cost components and their effect on total cost of quality as well as on unit product cost, and vi) effect of quality cost on profitability.

It is however obvious that if an organization would like to launch a systematic program for quality improvement, it will first need to develop and implement a suitable quality costing system. How is such a program started? We discuss below a few key steps in setting up a quality costing system.

i) Determine the need for such a system and follow it up with a presentation to management, to obtain support and commitment. One way is to establish a simple trial program -where only major cost are gathered, and readily available data are included. Some of the costs may even be estimated. Usually, results of a trial run will be spectacular enough to make management take notice, and become convinced.

ii) Determine the specific quality costs to be collected. The costs elements and the major cost categories defined earlier in the paper may be used for this purpose.

iii) Develop a method for collecting the costs. This should be the responsibility of the cost controller. Either the existing cost accounting system could be modified to enable collection of quality costs or, if necessary, the present system may be supplemented by separate forms designed specially for the quality cost program. It is preferable to code the various cost elements so that the costs of preventions, appraisal, internal and external failures are easily distinguished and sorted. The Controller will then provide all the collected quality costs to the Quality management, for analysis and corrective actions. Training programs for concerned personnel, on the proposed quality system would be quite useful.

iv) Summarize the quality cost elements. This may be done by company, by division, by facility, by department, or by shop. They may also be summarized by type of program, or by total of all programs. This is predicated on the individual needs of the firm. In summarizing the quality costs, these should be indexed against appropriate bases: for example, sales, manufacturing cost, value added, labour input. The values of these indices must be analyzed, so as to work towards optimum quality effort.

It may be useful to plot the indices which will enable monitoring of the cost on a continuing basis and set goals for future.

It will also be necessary to study how changes in one cost category affect other categories and the total quality cost. Increases of failure cost should be specially investigated, so as to determine what kind of prevention activities could reverse the trend.

The level of detail which will be included in quality cost report will generally vary from firm to firm and will reflect the nature of management commitment to the quality improvement process, as well as with the reviewing authority.

v) Use the quality cost system to justify and support improvement in each major area of product activity. For this reason Quality costs should be reviewed for each major product line, manufacturing area or cost center. This will facilitate moving towards an optimal quality program at a minimum quality cost.

The system can also be used a budgeting tool.

vi) Conduct periodic audit of the quality cost program to determine if the system functions as originally designed and to see if it is still conceptually adequate. Such audit will therefore go a long way in maintaining and improving the accuracy of the system.

7) **Conclusions**

In summary, some important conclusions drawn from our study are as under:

i) The four important quality cost categories are:

prevention, appraisal, internal failure and external failure. Each category comprises of a large number of cost elements. The Company practices are not uniform with regard to classification of over 50% of the cost elements. Similarly, a number of the cost elements are not measured by a significant proportion of the companies.

ii) Percentage to sales is the most widely used index of total cost of quality (COQ). Other indices include percentage cost, value added and labour input. The COQ, measured as % to sales varies from 1/2-8% across companies, with an average of around 5%. Measured as % of manufacturing cost and % of value added, the COQ varies from 1-12% and 1/2-26% respectively.

iii) Costs incurred in prevention, appraisal and failure as percentages of total COQ vary widely across organizations. Expressed as % of sales, they range from 0.25-1%, 0.18-3% and 0.08-5.1% respectively. As % of manufacturing cost they range from 0.35-1.7%, 0.25-4.2% and 0.10-7.5% respectively. As % of value added, they are 0.04-1.6%, 0.17-8.7% and 0.28-16.1% respectively.

iv) Two equations, developed from regression analysis, may be used to predict the effect on failure cost of changes in prevention and appraisal effort. These relationships are:

The symbols have been explained in the text of the paper. A not of caution however! It may be necessary reestimate the regression of coefficients, for the particular quality system being studied. External failure cost (as % of COQ) reduces with increase of both prevention and appraisal, but major reduction has to come from the latter. The internal failure cost reduces with increase of prevention, and increases marginally with increase of appraisal.

5) The total COQ decreases with increase in prevention effort in an asymptotic manner. The total COQ decreases with increase of prevention & appraisal effort together (upto the range of effort for which data was available i.e. P & A Cost/COQ<50%). The decrease is however much more gradual than for prevention alone.

The COQ (as % of sales) decreases sharply with increase of company size (measured by the size of work force).

6) Minimum quality cost does not always imply minimum product cost or maximum profit. The latter depends on other factors such as competitive situation, life cycle stage of the product, "superiority of product design, etc. Quality cost should take into account cost of market research and opportunity loss due to poor quality.

7) Organizations, serious about quality improvement program should develop and implement a quality cost system which will serve as the basis to determine the directors for quality improvement.

8) Finally, it is not so much the amount of money that is spent on prevention and appraisal that is important. Rather the way in which it is spent i.e it is the quality of the prevention and appraisal efforts that is of far greater consequence than their quantity, per se.

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Table 2: **Cost Elements in Quality cost Categories -Survey by Sullivan and Owens [6]**

Cost Elements	No. of Companies using each category						
	P	A	IF	EF	F	NM	TOTAL
Quality data acquisition and analysis	23	18	8	5	2	6	62
Administrative Costs	24	12	6	4	1	11	58
Product review	18	6	1	1	0	17	43
Process Control	12	18	2	1	0	18	51
Quality Engineering	28	9	3	2	2	10	54
Quality planning by functions other than Quality	14	2	1	1	0	24	42
Training to improve quality	28	0	1	0	0	13	42
Inspection and Test	1	35	5	1	1	3	46
Field evaluation and Testing	7	11	1	3	0	20	42
Inspection and test set-up	5	28	4	1	0	10	48
Quality Audits	23	15	1	2	0	8	49
Maintenance/Calibration: test/insp. equipment	15	19	3	0	0	8	45
Maintenance/Calibration:	11	12	2	0	0	18	43
Scrap	0	3	36	4	3	1	47
Rework and repair	1	3	35	6	5	3	53
Downtime	1	0	11	1	1	27	41
Trouble shooting or failure analysis	5	3	15	11	4	11	49
Reinspect or Retest	1	11	20	3	3	9	47
Scrap and rework-fault of vendor	0	7	21	5	3	10	46
Downgrading	0	0	8	5	0	30	43

Cost Elements	No. of Companies using each category						
	P	A	IF	EF	F	NM	TOTAL
Complaints	3	2	2	23	1	13	44
Product or Customer Service	1	0	2	23	1	21	48
Products rejected and returned	1	3	4	29	5	5	47
Returned material repair	0	4	4	27	3	9	47
Discrepant material activity	2	5	17	5	2	14	45
Warranty Charges	1	2	1	28	2	11	45
Marketing error	0	0	5	11	0	28	44
Engineering error	1	1	10	10	1	25	48
Faculty or installation error	0	0	8	14	1	23	46
Recalls	0	0	0	19	1	22	42
Product liability	2	0	1	19	2	22	46

P-Prevention A-appraisal IF-internal failure

EF-external failure F-failure NM-not measured

Table 3: **Respondents to Gilmore Survey [8]**

Standard Industrial Code	Industry	No. of business units
20	Food and kindred Products	2
22	Textile Mill Products	1
25	Furniture and Fixtures	1
26	Paper and Allied Products	3
28	Chemicals and Allied Products	3
34	Fabricated metal products, Except ordinance machinery and Transportation equipment	2
35	Machinery, except Electrical	1
36	Electrical machinery equipment and supplies	2
38	Measuring, analysis and controlling instruments	1
39	Miscellaneous manufacturing industries	1

Table 4: **Expenditure on Prevention, Appraisal, and Failure activity (% of total COQ and % of Respondents) -Gilmore [8]**

Prevention		Appraisal		Failure	
Cost (%)	Respondents (%)	Cost (%)	Respondents (%)	Cost (%)	Respondents (%)
<5	38	<20	12	<5	38
5-9.9	25	21-50	50	5-50	38
10-50	12	>50	38	>50	24
<50	25				
	100		100		100

Table 5: **Total Quality Cost allocation by Industry -Gilmore [8]**

SIC	26	28	34	35	36	38
Quality Activity (% of Total Quality Cost	N = 2 %	N = 2 %	N = 2 %	N = 1 %	N = 1 %	N = 1 %
Prevention	40	22	48	8	16	3
Appraisal	48	60	28	13	45	34
Failure	7	20	16	79	40	62

Table 6: **Total Quality Cost OQ) as a % of Selected bases -Gilmore**

Industry (SIC Code	% of Manufacturing Cost	% of Gross Sales	% of unadjusted Value Added
	COQ	COQ	COQ
20	*	0.45	*
26	1	1	1
28	7	2	8
34	11	3.3	0.5
35	7.4	5.3	18.6
36	*	6.5	*
38	12	8.2	25.6

Table 7: **Prevention, Appraisal and Failure cost as % of Selected bases [8]**

Industry (SIC Code)	% Manufacturing Cost			% of Gross Sales			% of unadjusted Value Added		
	P	A	F	P	A	F	P	A	F
20	*	*	*	*	*	*	*	*	*
26	0.35	0.25	0.10	0.25	0.18	0.07	1.35	0.95	0.40
28	1.7	4.2	1.2	0.5	1.3	0.4	*	*	*
34	0.9	3.7	6.2	0.3	1.1	1.9	0.04	0.17	0.20
35	0.6	1.0	5.9	0.5	0.7	4.2	1.6	2.4	14.6
36	*	*	*	1	3	2.5	*	*	*
38	0.4	4.1	7.5	0.3	2.8	5.1	0.8	8.7	16.1