THE ECONOMICS OF QUALITY FOR TOTAL QUALITY MANAGEMENT

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ABSTRACT

A standard quality costing application model is developed for manufacturing companies and tested using a modified real life situation. The model is applied to an assembly business unit of a manufacturer of floor care products. This research was carried out with the objective of developing a model that can be used in evaluating and analyzing quality costs of a manufacturing company (using the categories of prevention, appraisal, internal and external failure) and through that, identifying potential areas of cost savings and quality improvement.

Failure costs are non-value added costs that should be eliminated and appraisal or inspection costs have a great potential for reduction and cost savings. Therefore, the methodology used in the development of this model was to focus attention on various costs associated with failures and appraisal common to manufacturing.

Besides measuring the costs of failures and appraisal the model will also aid in quantifying the root causes of failures that can be used as the basis for identifying critical costs of prevention. This is an effective approach to justify the importance of identifying prevention costs and convincing management to implement the necessary changes required in the accounting procedures to measure and monitor these costs on a regular basis.

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ABBREVIATIONS OF TERMS USED

1. COQ - Cost of quality
2. TQM - Total quality management
3. QCS - Quality costing system
4. ROQ - Return on quality
5. ABM - Activity-based management
6. COC - Cost of conformance
7. CONC - Cost of non-conformance
8. PCD - Production cost differential
9. TDLT - Total down/lost time

Chapter 1

STATEMENT OF THE PROBLEM

The Cost of Quality has been overlooked deliberately in manufacturing industries, and there is a need for critical review in this area. The Economics of Quality should be moved from the traditional outlook of quality costs - scrap and rework, to all costs incurred by the company to maintain a quality management system. This includes: cost of rework in the service departments, cost of repeated inspection, cost of preventive activities and the cost of other quality-related activities. The cost of quality (COQ) is the cost incurred by the company to carry out its quality plan to meet the quality needs of its customer. This would include the cost of all activities that 'do' and 'do not' generate value either to the company or to the customer.

Quality costing is a self assessment and a continuous improvement tool that can help companies identify non-value added activities, areas of high waste and expenditure, as well as improvement opportunities. Though, companies measure the cost of *direct* labor for rework and scrap/wastage of materials, the cost of rework in the service areas and the cost of *indirect* labor in other areas, such as Engineering, Quality Assurance and Service functions are seldom measured. Most importantly, the measure of quality costs would disclose costs incurred by the company in not '*getting things right the first time*'.

Quality costing is not just a method for cost collection, it is a quality management technique used to measure and improve quality performance that includes product quality and customer service. It is the first step a company should take toward the promotion of Total Quality Management (TQM). As stated by Bowman (1994), TQM stresses a systematic and comprehensive application of quality principles to all facets of a business. The important role that cost of quality plays in TQM necessitates that it (COQ) be constantly reviewed and revised to make it more accurate and comprehensive.

Studies in the past show that, despite the use of TQM principles and techniques, many companies have failed to realize improvements in quality and profit. For example, "Only one-third of the companies surveyed by the Boston Consulting Company credited their TQM process with having a significant impact on improving competitiveness. Nearly two-thirds of the 30 quality programs studied by McKinsey Company either were stalled or fell short of delivering real improvements" (Schaffer and Thomson, 1992). "Sixty percent of the companies surveyed by the Electronic Assembly Association failed to reduce internal defects by 10%, despite having programs in place for an average of three years. After having programs in place for an average of two and one-half years, 80% of the companies surveyed failed to reduce supplier defects by 10% or more" (Boyett, Kearney and Conn, 1992).

COQ is conducted to determine what poor quality or error(s) is/are costing the company, study the causes and effects of quality problems, implement quality improvement programs to resolve them, and monitor progress. The measurement of quality costs will help top management justify investment in quality improvement programs, prioritize improvement initiatives, assess the impact of various improvement activities and reduce quality-related costs.

The importance of establishing a formal quality costing system is to identify hidden costs that are usually considered non-quality costs that would never be identified by a traditional accounting system. Quality costing system (QCS) will uncover the limitations of a company's accounting procedures by going beyond costs and considering the impact on revenues and profits. QCS is not a profit-loss account, since the impact of quality on the company's profits is not something that can be quantified by conventional accounting procedures.

As discussed by Atkinson (1990), it is estimated in Europe that the average manufacturing company is operating with a COQ of about 15-25% of turnover. In the service sector this can be as high as 40-50% of turnover! In some parts of the public sector these costs could be even higher! Companies like IBM, Corning Glass, Unisys, Jaguar and British Telecom originally experienced COQ as high as 40% of turnover. These numbers indicate that costing quality is an extremely important activity. It has driven many companies to promote TQM in order to reduce COQ in the long term, which is achievable and possible.

1.1 Definitions

COQ has been defined in many ways. some of them [as per Omachonu (1994)] are as follows:

"Quality cost equals actual cost minus no failure cost. That is, the cost of quality is the difference between the actual cost of making and selling products and services and the cost if there are no failures during manufacture or use and no possibility of failure" (Anderson, 1991).

"Quality costs are the costs incurred because poor quality may or does exist" (Towey, 1988).

"The cost of not meeting the customer's requirements-the cost of doing things wrong" (Schroeder, 1989).

"All activities that are carried out that are not needed directly to support departmental quality objectives are considered the cost of quality" (Asher, 1988).

Based on the above definitions, COQ can be defined as *the cost of all activities concerning the effort to make sure that every product leaving the company meets the needs of the customer.*

1.2 Classification

Perigord (1990) classifies COQ into four main categories:

1.2.1 Cost of prevention

Prevention costs include the cost of all activities carried on to prevent or eliminate errors, defects and failures. Included are such activities as quality planning, supplier quality survey, training programs, production reviews, engineering analysis, maintenance, reliability and other preventive activities to ensure poor quality is not produced. Prevention also involves company policy, preparatory meetings, client satisfaction studies, study of crucial points for all services and operational procedures for trails. In short, everything that can be done before a defect, error or failure occurs.

1.2.2 Cost of appraisal

Appraisal costs include the cost of all actions taken to confirm that the product or service conforms to the user's expectations. Included are such activities as product quality evaluation and defect detection such as test and inspection. It is the cost incurred to identify poor quality after they occur, but before shipment to customers. Appraisal costs are often termed as evaluation, verification, detection, checking or even inspection.

1.2.3 Cost of internal failures

Internal failure costs include the cost all activities resulting from defects found before the delivery of the product to the customer such as rework, repair and scrap. These are costs that are documented within the company for all products, materials, and equipment that do not meet the client's requirements. It is during this phase that rejections and corrective alterations occur.

1.2.4 Cost of external failures

External failure costs include the cost of all activities resulting from defects found after the delivery of the product to the customer such as processing customer complaints, analyzing returned merchandise, field services and warranties. These are costs that are documented by the user for products and equipment that do not meet its requirements. The hidden costs of customer dissatisfaction and lost market share should also be included.

Perigord (1990) further classifies the COQ into two broad categories:

1.2.5 Cost of conformance (COC) and **cost of non-conformance** (CONC)

The cost of conformance is the sum of the costs for *prevention + appraisal*. It involves *all* costs incurred in the effort to ensure that products *conform* with the client's requirements. The cost of non-conformance is the sum of the costs for *internal failures + external failures*. It involves all costs incurred *before or during* the use due to rejection, corrective alterations, refusals of merchandise, claims, returns and reimbursements.

The *cost of quality* is therefore the sum of the costs for *conformance + non-conformance*. It includes *all* expenditures incurred to make the product *satisfy* the *client*. The COC and CONC approach for cost of quality will help focus attention on the cost of doing things right as well as the cost of doing things wrong. This is a positive and effective approach towards improvements in efficiency and quality resulting in higher profits.

Chapter 2

RESEARCH DESIGN

2.1 The research purpose

The purpose of this research is to develop a formal quality costing format for manufacturing companies. The goal is to make the concept of quality costing precise and straight forward, since there is no clear-cut method or procedure to determine the specific cost elements that should be collected and the level of depth to which this exercise should be conducted. The purpose also includes the development of a practical application model that could be used by management as the first steps toward implementing and establishing a well defined costing system.

2.2 Research objectives

The specific objectives of this research are as follows:

1. To develop a conceptual model for identifying the various quality-related activities pertaining to manufacturing settings.
2. To identify the key cost elements involved in determining the cost of quality for manufacturing companies.

3. To justify the identification and collection of the key cost elements and by that highlight the importance of maintaining a formal quality costing system.

4. To propose a method and format (application model) to aid in the collection of the key cost elements identified.

5. To test the practical capability of the application model using a modified real life situation.

2.3 Research outline

A review of previous studies on quality costs is conducted to serve as the underlying theoretical structure for this research. The literature review is used as a basis for determining different types of costs that ought to be included in the conceptual model. The conceptual model is then filtered to develop an application model that is applied to a business unit of a manufacturer of floor care products.

The quality-related costs for the business unit are reported on a monthly basis over a period of six months. These costs are related to a measurement base, which is the actual cost of production (cost input), to facilitate useful comparison. The cost trends are studied and used for the analysis of the COQ index, which is the total cost of quality divided by the measurement base. In addition to the value/cost analysis conducted to the data collected, maximizing value, minimizing cost and true prevention are the other aspects of quality costing that are discussed in detail.

2.4 Development of the application model

This section discusses the approach and methodology used in the development of the application model. Several approaches are used for categorizing and reporting quality costs. The categories of prevention, appraisal, internal and external failure are most commonly used and is the approach adopted for this study.

The model was developed giving prime importance to failure costs, since these are non-value added costs and should be eliminated. The cost elements identified in the model under the categories of internal and external failure will represent the majority of failure costs for any manufacturing company. The attention was focused toward quantifying the various forms of failures and identifying their root causes. Also, equal importance was given to appraisal costs as they have a great potential for reduction and cost savings.

Much of the cost data in the prevention category is indirect, intangible, hard to quantify and normally not readily available. The time based cost element method or activity-based management can be used as a possible approach to measure and monitor these costs. However, this usually requires major changes in the accounting procedures and may be ignored or overlooked by management. Therefore, the prevention costs that are readily available are collected as well as the failure and appraisal costs. The root causes of failures identified are used as the basis for identifying the critical areas of prevention that need to be improved or included in the costing system. This is a bottom up approach of attacking failures and appraisal first and then identifying the key cost elements that need to be measured and monitored in the prevention category. This is a positive and effective approach to justify the importance of identifying these costs and convincing management to implement the changes required in the accounting system to facilitate the collection of these costs.

2.5 Factors influencing the development of the application model

The following are the factors that influenced the strategy adopted in the development of the model:

1) The data collected in the failure categories will represent most of the failure costs for any manufacturing company.

2) The focus is aimed at measuring the various costs of appraisal and failures, since they have a great potential for reduction or elimination.

3) The appraisal and failure costs are measured to a fair degree of accuracy, to identify problem areas and appropriately alter prevention costs.

4) The model will cover the different areas of appraisal and failure common to manufacturing settings with further expansion on the prevention category as required, based on the root causes of the failures identified.

5) The model can serve as the initial or first steps toward establishing a well defined costing format capable of satisfying the needs of specific users.

2.6 The scope of the research

The application model developed is used as the basis for data collection for the business unit. The business unit in question is a manufacturing assembly unit that makes floor care products. It consists of two similar assembly lines designed to produce 210 units/hour utilizing 200 (direct + indirect labor) employees over two 8 hour shifts. The product is assembled from start to finish, to include testing and packaging, in one assembly line. This line was designed and developed through the implementation of modern manufacturing concepts, such as the pull system, dock-to-dock manufacturing, on-line build, JIT, flexible manufacturing and employee empowerment. This model can be used as guidelines for manufacturing companies in developing and establishing a formal quality costing program.

Chapter 3

LITERATURE REVIEW AND CONCEPTUAL MODEL

3.1 Literature review

The costs that would be avoided if there were no quality failures and the costs associated with detection as well as prevention of these failures are the various quality-related costs. Many of these costs are overlooked or unnoticed because of the limitations in most accounting systems. This is the basic reason that has led many companies to the concept of quality costing. These costs collectively form a large hidden opportunity for profit improvement.

Quality costs include not only the cost of scrap, rework, warranties, testing, inspection, quality control and assurance, but also include the cost of design, implementation, operation and maintenance of the quality management system. The cost of dedicating resources to continuous and company-wide quality improvement and the costs associated with all forms of failures (e.g., system, product and service and all non-value added activities, and wastage) fall under quality costs as well.

Juran (1962) classifies quality costs generally into the following categories:

1. The market research costs of discovering what are the quality needs of the consumers.

2. The product research and development costs of creating a product concept which will meet these quality needs.

3. The design costs of translating the product concept into information which permits planning for manufacture.

4. The manufacturing planning needed to create a manufacturing process able to meet the quality specification (Manufacturing planning aims also to meet the cost standards, delivery standards, safety standards, etc).

5. The basic manufacturing process.

6. Inspection and test.

7. Defect prevention.

8. Quality failures.

9. Quality assurance.

As stated by Corradi (1994), there are good quality costs and bad quality costs. Unfortunately most organizations concentrate on fixing problems rather than preventing them. The efforts and costs associated with preventing problems are considered good quality costs. Prevention costs are good quality costs. Examples of prevention costs include:

- Quality planning
- Technical manual
- Design support activities
- Quality improvement

- Process definition
- Quality administrative expenses
- Supplier reviews

Appraisal costs are also included in good quality costs. Examples of appraisal costs include:

- Product quality audit
- Life testing
- Drawing checking
- Order entry review
- Review of inspection data
- Purchase order review
- Facility inspection costs
- Measurement equipment
- Field performance testing

Internal and external failure costs are bad quality costs. Examples of internal failure costs include:

- Scrap and rework
- Failure reports
- Billing-error costs
- Reinspection/retest costs
- Disposition costs
- Design corrective action
- Missing schedule
- Absenteeism
- Rework of supplier rejects
- Program debugging costs

Examples of external failure costs include:

- Verifying failure
- Analysis of returns
- Warranty expenses
- Sales and service reports

- Product recall
- Liability costs
- Loss of customer goodwill
- Returned goods
- Lost sales

Tatikonda (1996) states that, COQ data are available from a variety of sources ranging from general ledger to estimates. COQ data can be classified as hard or quantifiable (i.e., direct, visible and measurable) and soft (i.e., indirect, intangible, hard to measure and hard to quantify).

Examples of sources of hard COQ data include:

- General ledger
- Time sheets
- Scrap and rework reports
- Warranty cost reports
- Field repair cost reports
- Credit memos

Much of the COQ data is soft and requires estimates. Examples of sources of soft data include:

- Customer surveys
- Customer complaints
- Customer returns
- Market research.
- Employee surveys
- Employee time analysis
- Engineering estimates

To obtain the true impact of COQ, firms need to measure both hard and soft costs. Soft costs do not have to be 100% accurate, but must be reasonably accurate, relevant, and current. It is essential to include the best estimate (even if it is the most conservative) instead of totally ignoring it.

According to Carolfi (1996), to obtain a good measure of 'soft' costs, competitive companies use the activity-based management (ABM) as a possible solution to their quality problems. ABM is an approach that takes a proactive role in reducing costs by encouraging managers to pay more attention to managing activities and processes, rather than merely the costs. The ABM strategy identifies activities associated with poor quality and estimates costs connected with these activities. ABM identifies the costs of poor quality in 5 steps. These are: 1. Define poor quality problem, 2. Identify activities, 3. Determine operational performance measures, 4. Estimate costs, and 5. Analyze results.

The Chartered Institute of Management Accountants (1991) identifies some of the quality costs as 'lost opportunity costs' which are defined as, 'The value of a benefit sacrificed in favor of an alternative course of action' [as per Dale and Plunkett (1995)]. The following are some typical examples of lost opportunity costs as given by Dale and Plunkett (1995).

- *Losses caused by substandard product.* The revenue difference between downgraded and top grade product.
- *Unplanned substitution of material.* Substitution of higher cost material, component or product because of problems with the original. This also includes sourcing from a higher cost supplier because the lower cost supplier is experiencing

problems.

• *Lost capacity*. The capacity taken up by the production of defective material, components and products.

• *Loss of custom, goodwill, sales opportunities, revenue and profit.*

• *Cost effective maintenance of processing equipment.* The difference between the cost of effective equipment maintenance and that of repeated repairs in breakdown mode, of processing equipment, with subsequent product contamination and lost sales opportunity.

• *Utilization of sales personnel.* Sales personnel delivering product when they should be out selling.

Lost opportunities as mentioned by Collins (1995) result in lost revenues from the loss of existing customers, the loss of potential customers and the lost business growth arising from the failure to deliver products and services at required quality standards. Prominent among the lost opportunity costs is the extra inventory that results from poor quality. These cost are not measured because they are not recognized or else not believed to be quantifiable. Boucher and Muckstadt (1985) identify cost reduction in 1) inventory cycle stock, 2) inventory safety stock, 3) work-in-process, and 4) allocated costs (including expediting and checking job progress).

One critical opportunity or 'soft' cost discussed by Tatikonda (1996) is the cost of customer defection; customers switching to another brand. When a customer defects, the company loses its profit potential. One example is the Widget Company which makes and sells copying machines. Currently it sells to an average of 100,000 customers per year. Widget Company estimates average profit per customer to be $100 yearly. Based on past experience and customer satisfaction studies, Widget Company estimates:

- 70% of their customers experience no problems and 90% of them will buy again from Widget Company.
- Of the 30% that experience problems, half will report the problems of which 60% will be resolved satisfactorily.
- 80% of those who had problems resolved and 25% of those who did not have problems resolved satisfactorily will buy again from Widget Company.
- 60% of the customers that experienced a problem, but did not report it will buy again from Widget Company.

Based on this information, Widget Company's estimated the cost of lost profit per year was $1,847,500. Assuming an average loyalty of five years, the potential profit lost amounts to $9,237,500. If every dissatisfied customer were to tell ten potential customers, the expected loss (opportunity cost) could be as high as $92,375,000.

Most managers indicate that quality is their top priority, but less than one-third measure the results of quality improvement programs (Target, 1992). Companies have sophisticated techniques to measure return on investment (ROI), but only a few measure return on quality

(ROQ). World class companies use the measure of ROQ (the ratio of increase in profit to the cost of quality improvement programs) as a decision criteria to determine whether a quality improvement program is acceptable and to select the best alternative among competing quality improvement programs. For example, AT&T requires that new quality initiatives be accepted only if the project shows a potential to reduce defects by at least 30%, and a return on investment of at least 10% (Greising, 1993).

One failure cost that is of great importance to any manufacturing company is the cost of passing defective parts through the manufacturing system. Quality costs can be defined in terms of the difference in profitability between the "as is" manufacturing system and the system after proposed improvements and defect or failure rate reductions are made. These costs include lost profit, wasted materials, wasted resources and wasted time in the production of defective parts as stated by Gardner, Grant and Rolston (1995).

Although quality cost has become a major cost component that makes up 25-35% of the manufacturing cost (Business week, 1986) it does not appear in accounting records because traditional accounting is too outdated to accommodate it. A study conducted by Management Practices (1991) of the 20 highest scoring applicants of the Malcolm Baldridge Quality Award (MBNQA) by the General Accounting Office (GAO) indicated only five measured their cost of quality.

The list of cost elements identified by British standards institution can be used as useful starting point. The following are the guidance notes on the cost elements of prevention, appraisal and failure from BS6143: Part 2 (1990).

• Prevention costs

1. Quality Planning.

The activity of planning quality systems and translating product design and customer quality requirements into the measures that will ensure the attainment of the requisite product quality. It includes that broad array of activities that collectively create the overall plan, the inspection plan, the reliability plan and other specialized plans as appropriate. It also includes the preparation and vetting of manuals and procedures needed to communicate these plans to all concerned. Such quality planning may involve departments other than the quality organization.

2. Design development of quality measurement and test equipment.

Included are costs of designing, developing and documenting any necessary inspection, testing or proving equipment (but not capital cost of equipment in question).

3. Quality review and verification of design.

Quality organization monitoring activity during the product's design and development phase to assure the required inherent design quality. Quality organization involvement with design review activities and in verification activity during the various phases of the product development test program including design approval tests and other tests to demonstrate reliability and maintainability. This includes quality organization effort associated with that part of process control which is conducted to achieve defined quality goals.

4. Calibration and maintenance of quality measurement and test equipment.

The cost of calibration and maintenance of templates, jigs, fixtures and similar items should be included.

5. Calibration and maintenance of production equipment to evaluate quality.

The costs of calibration and maintenance of templates, jigs, fixtures and similar measurement and evaluating devices should be included but not the cost of equipment to manufacture the product.

6. Supplier assurance.

The initial assessment, subsequent audit and surveillance of suppliers to ensure they are able to meet and maintain the requisite product quality. This also includes the quality organization's reviews and control of technical data in relation to purchase orders.

7. Quality training.

Includes attending, developing, implementing, operating and maintaining formal quality training programs.

8. Quality auditing.

The activity involving the appraisal of the entire quality system of quality control or specific elements of the system used by an organization.

9. Acquisition analysis and reporting of quality data.

The analysis and processing of data for the purpose of preventing future failure.

10. Quality improvement programs.

Includes the activity of structuring and carrying out programs aimed at new levels of performance (e.g., defect prevention programs and quality motivation programs).

• Appraisal costs

1. Pre-production verification.

Cost associated with testing and measurement of pre-production for the purpose of verifying the conformance of the design to the quality requirements.

2. Receiving inspection

The inspection and testing of incoming parts, components and materials. Also included is inspection at the supplier's premises by the purchaser's staff.

3. Laboratory acceptance testing.

Costs related to tests to evaluate the quality of purchased materials (raw, semi-finished or finished), which become a part of the final product or consumed by production operations.

4. Inspection and testing.

The activity of inspection and testing first during the process of manufacture, and then as a final check to establish the quality of the finished product and its packaging. Included are product quality audits, checking by production operators and supervision and clerical support for the function. It does not include inspection and testing made necessary by initial rejection because of inadequate quality.

5. Inspection and test equipment.

The depreciation costs of equipment and associated facilities; the cost of setting up and providing for maintenance and calibration.

6. Materials consumed during inspection and testing.

Materials consumed or destroyed during the course of destructive tests.

7. Analysis and reporting of tests and inspection results.

The activity conducted prior to release of the product for transfer of ownership in order to establish whether quality requirements have been met.

8. Field performance testing.

Testing is performed in the expected user environment, which may be the purchaser's site, prior to releasing the product for customer acceptance.

9. Approvals and endorsements.

Mandatory approvals or endorsements by other authorities.

10. Stock evaluation.

Inspecting testing stocks of products and spares which may have limited shelf life.

11. Record storage.

The storage of quality control results, approval and reference standards.

• Internal failure costs

1. Scrap.

Materials, parts, components, assemblies and product end items which fail to conform to quality requirements and which cannot be economically reworked. Included is the labor and labor overhead content of scrapped items.

2. Replacement, rework and repair.

The activity of replacing or correcting defective to make them fit for use including requisite planning and the cost of the associated activities by material procurement personnel.

3. Troubleshooting or defect/failure analysis.

The costs incurred in analyzing non-conforming materials, components or products to determine causes and remedial action, whether non-conforming products are usable and to decide on their final disposition.

4. Re-inspection and re-testing.

Applied to previously failing material that has subsequently been reworked.

5. Fault of sub-contractor.

The losses incurred due to failure of purchased material to meet quality requirements and payroll costs incurred. Credits received from the sub-contractor should be deducted, but costs of idle facilities and labor resulting from product defects should not be overlooked.

6. Modifications permits and concessions.

The cost of time spent in reviewing products, designs and specification.

7. Downgrading.

Losses resulting from a price differential between normal selling price and reduced price due to non-conformance for quality reasons.

8. Downtime.

The cost of personnel and idle facilities from product defects and disrupted production schedules.

• External failure costs

1. Complaints.

The investigation of complaints and provision of compensation where the latter is attributable to defective products or installation.

2. Warranty claims.

Work to repair or replace items found to be defective by the purchaser and accepted as the supplier's liability under the terms of warranty.

3. Products rejected and returned.

The cost of dealing with returned defective components. This may involve action to either repair, replace or otherwise account for items in question. Handling charges should be included.

Note: While loss of purchaser goodwill and confidence is normally associated with external failure costs, it is difficult to quantify.

4. Concessions.

Cost of concessions are discounts made to purchasers due to non-conforming products being accepted by the purchaser.

5. Loss of sales.

Loss of profit due to cessation of existing markets as a consequence of poor quality.

3.2 Summary

The literature review indicates that there have been a number of publications that have produced lists or types of costs that ought to be included in quality costs. Based on the literature search, a conceptual model is developed (Table 1) in an attempt to develop an application model to ease the collection of these costs. The following is the conceptual model that contains the various types of costs associated with quality related activities.

Table 1: Conceptual model

Prevention costs	
1. Quality training	2. Preventive maintenance of equipment
3. Quality planning	4. Quality review and design verification
5. Supplier assurance	6. Market research
7. Quality auditing	8. Quality improvement programs
9. Quality administrative activities	10. Reporting and analysis of quality data
11. Technical manual	12. Process definition
13. Design/development of quality measurement and test equipment	
14. Calibration of quality measurement and test equipment	
Appraisal costs	
1. Inspection and testing	2. Reporting and analysis of inspection data
3. Pre-production verification	4. Laboratory acceptance testing
5. Field performance testing	6. Process control/capability measurement
7. Inventory audit	
Internal failures	
1. Scrap	2. Rework
3. Rejects	4. Reinspection and retest
5. Down/lost time	6. Downgrading
7. Design/process corrective actions	8. Billing-error
9. Troubleshooting/failure analysis	10. Excess inventory

Table 1 (continued)

External failures	
1. Returned products	2. Analysis of customer returns
3. Analysis of customer complaints	4. Product recall
5. Downgrading	6. Warranty/liability expenses
7. Lost sales	8. Lost customer good will

Chapter 4

DEFINITION, COLLECTION AND MEASUREMENT OF COST ELEMENTS

4.1 Definition

Since many quality-related activities overlap with the basic activities of manufacturing and operations, the process of defining quality cost elements is not straightforward. In areas where there is no clear distinction between what is quality-related and what is not, it is important for the people involved to use their discretion and devise their own quality cost elements to suit the situation and their industry, with an attempt not to make the cost definition exercise very elaborate and tedious.

Any activity in which the associated cost could be quality-related if it affects quality management practices or if it is concerned with the detection of possible errors or if it alters the impact on the cost of failures. The above activities are used as the criteria for the identification of quality costs.

4.2 Collection

The quality cost elements that need to be collected are determined based on the importance of the cost, its availability and the sources of cost data. The importance of cost is a key issue in the collection of costs, which is dependent on the size and potential for cost savings. The ease of cost collection is dependent upon identifying cost data sources. BS6143: Part 2 (1990) recommends the following as source documents:

a) Payroll analysis

b) Manufacturing expense reports

c) Scrap reports

d) Rework or rectification authorizations/reports

e) Travel expense claims

f) Product cost information

g) Field repair, replacement and warranty cost reports

h) Inspection and test records

I) Non-conformance report

4.3 Strategy for quality costing

The effect of quality costing strategy on the collection of these costs is a key factor. The strategy being adopted is dependent on the purpose or purposes for which the exercise is being carried on. This could range from measuring and monitoring quality costs of all departments to costing only specific departments. It is important to track and present these costs on regular basis to determine the impact of improvement activities. For many manufacturing firms, the majority of the costs are associated with the production department;

however it is important to see that the collection of costs cover all areas in the business.

The strategy used in this study was to concentrate on significant cost elements, since it is more advantageous to achieve a small reduction in a large cost than a large reduction in a small cost, depending on the degree of difficulty in deriving the cost. By establishing a formal quality cost collection system, a marked improvement could be seen in the reporting and feedback of quality-related data resulting in uncovering the inefficiencies of the management information system.

4.4 Measurement

Most companies consider the cost of material and direct labor in measuring production efficiency. The cost of indirect labor is seldom considered and this may constitute a substantial percentage of the total cost incurred. The measure of indirect labor cost largely depends on estimates of time spent by indirect workers and staff that are usually not recorded. In those cases, where indirect personnel are engaged on single activities or a narrow range of closely related activities, cost is much easier to measure. In reality, however, many people are involved in a number of diverse activities, sometimes all of which are quality related and sometimes not. For example, personnel from the quality department operate across functional boundaries, especially between inspection and prevention activities. This is also the case when the activities of the quality department merge with activities of other departments. Therefore, to achieve a fair degree of accuracy in measuring quality costs, both direct and indirect labor costs of quality related activities are important and caution must be used when measuring the cost of overlapping activities.

Some of the other examples of indirect personnel costs are: purchasing and accounting personnel involved in dealing with supplier problems, production planners rescheduling rework activities and engineering personnel involved in preventive and corrective actions for failures. When calculating the cost of activities which are basically the cost of personnel multiplied by the time spent, it is important to take into consideration fringe benefits and other relevant costs in addition to salaries.

Chapter 5

APPLICATION MODEL

After deciding upon the cost elements that need to be collected and measured, reporting of costs should be done such that the information presented to the user aids in decision making. It is important to focus on areas that have the greatest potential for improvement and cost reduction rather than minor areas that may lead people involved to lose sight of the primary reason of improving quality.

Companies can use several reporting formats depending upon the user and nature of interests. Dale and Plunkett (1995), state that a standard reporting format forms a balance sheet for quality function with prevention equivalent to investment, appraisal to operating cost and failure to (negative) profit.

In this chapter a standard quality cost application model is developed to report costs under the four categories on a fixed routine (monthly basis) to provide clarity and continuity from one report to another. In the model developed, the cost of various elements is presented against the background of total cost of quality and quality costs (sub-total) by category. These costs are related to a measurement base (cost input or sales). Sales refers to the net sales of the company and cost input refers to the actual cost of production [i.e., cost of material and labor (direct and indirect) with overhead].

The cost elements classified under each of the four categories that occur frequently for most manufacturing operations are defined as separate elements, where as the elements that may not occur as frequently, as on a monthly basis, are grouped together under a common element called 'other'. The purpose of this is to standardize reporting from one month to the next.

5.1 Application model for performance appraisal and quality cost reporting

The following are illustrations of cost elements contained in the application model as seen in Table 3. A performance review format is included in the model to monitor trends and overall progress/improvement.

5.1.1 Performance review

1. Parts per million defective

To measure defect rate, world class companies use the unit of measure parts per million (ppm) instead of percentages. In this measure, 100% represents one million of these units which means 1% is equal to ten thousand ppm. The ppm unit measurement is used to enhance improvement initiatives directed toward the achievement of lower defect rates.

2. On time delivery percentage

The meaning of 'on time delivery' should be a shipment of goods reaching the customer on time. This is not always true, because some companies measure delivery performance based on shipments leaving their premises on time. For example, if a shipment is needed by the customer by 3:00 pm tomorrow and it takes 24 hours to transport it, the delivery is considered on time if it leaves the company at 3.00 pm today. In this way if a delivery leaves the company on time, but is not received on time by the customer due to transportation delay, the company will not be held responsible for it. This criteria is adopted by companies that do business only with certified trucking companies but the customer may not be willing to abide by this policy.

3. Percentage of perfect orders

A delivery or shipment is called an order. A perfect order means that a shipment delivered to the customer has no poor product quality related issues. It also includes on time delivery of the shipment and no billing discrepancies in the part of company.

4. Cost of quality

This refers to the total cost of quality incurred by the company. This is the sum of the subtotals under the four categories (i.e., prevention + appraisal + internal failures + external failures). The purpose of this measure is to study the overall COQ trend and analyze the impact of quality improvement programs on the total cost of quality.

5. Sales or cost input

As discussed earlier, sales or cost input is used as the measurement base. Sales refers to the net sales of the company and cost input refers to the actual cost of production [i.e., cost of material and labor (direct and indirect) with overhead]. The purpose of reporting either sales or cost input in this section is to relate the total cost of quality to this value.

6. COQ percentage of sales or cost input

The percentage of COQ with respect to net sales or cost input is reported in this element. This is also called as the COQ index percentage (discussed in detail in chapter 7). The purpose of this measure is to facilitate useful comparison and monitor progress of the quality management system.

5.1.2 Quality costs

1. Cost of prevention

1a) Training

This refers to the training programs conducted by the company that are aimed at improving the quality process (total quality). Training is the cost of operating and maintaining formal on-the-job training programs for employees of all levels. It is also the cost incurred in attending, developing and implementing such programs.

1b) Preventive maintenance

Preventive maintenance is the scheduled maintenance of all production, testing and inspection related equipment on a fixed routine to prevent equipment failures. This is usually done at the cost of production since equipment needs to be shut down in order to conduct maintenance activities. The cost of preventive maintenance is the sum of the cost of labor involved and the cost of downtime due to the shut down of production.

1c) Other

All product and process improvement programs aimed at improving quality are accounted for in this category. Process improvements are enhancements made to the production processes, which are usually about implementing cost-effective methods of production, increasing production rates and improving overall quality of finished products. Product improvements are enhancements made to performance of the product. In reality these improvements are sometimes about rectifying quality problems that arise during the time of production. Reporting such cases in the internal failure category would be appropriate, since these are costs of doing things over.

2. Cost of appraisal

2a) Inspection and testing

This is the cost of all inspection and testing activities such as receiving inspection, inspection and testing during the process of manufacture and final inspection of finished product. Receiving inspection is the inspection of incoming material from suppliers prior to use.

Testing is the process of examining finished or semi-finished products for required quality and safety standards. Final inspection is the final check point for finished products to ensure that they meet all needs of the customer. This will also include the cost of reporting and analysis of inspection and test data.

2b) Inventory evaluation

Audits conducted to evaluate inventory status, fall under this category. Cycle count is a physical count of inventory that is performed and recorded on a periodic basis. Adjustments are made to inventory system based on recorded cycle counts, in order to avoid inventory losses that may result in downtime of production hours.

2c) Other

Appraisal activities, such as pre-production run and laboratory/field testing are included in this class. Pre-production run refers to the pilot/trial run of a new product prior to actual production. Laboratory/field testing is the analysis of the new product to check whether it conforms to customer requirements and technical specifications.

3. Cost of internal failures

3a) Production cost differential

Production cost differential (PCD) is the opportunity cost for profit increase, identified during the time of actual production. PCD is neither the money spent nor the money lost, but is the increase in profit that could be achieved if the inefficiencies of the production system were to be eliminated. It is important for companies striving to become world class manufactures to relate their production performance to this measure. When measuring the efficiency of a system, it is more advantageous to present the inefficiency in terms of dollars, which could go toward the profit if every thing was perfect. The purpose of this measure is to create pressure and a sense of urgency/necessity for improvement.

PCD is the difference between the actual cost of production and what the cost of production would have been if the production system was 100 percent efficient, and this is calculated as follows:

Production cost differential = Actual cost of production - (Production efficiency x Actual cost of production)

As per Sink (1985), production efficiency = PEU x PPI

Production equipment utilization (PEU) = (Actual production hours ÷ Scheduled production hours) * 100.

Production performance index (PPI) = (Actual number of units produced/hour ÷ Number of units planned/hour) * 100.

3b) Goods scrapped

This is the cost of material wastage due to scrapping finished, semi-finished and raw material that fail to comply with design/technical specifications and cannot be reworked. Material damaged during the process of manufacture that are unfit for rework will also fall under this cost element. This includes the cost of labor and labor overhead content of scrapped goods.

3c) Goods reworked

These are defective products discovered in-house before, during, and after production, that are rectified and put to use. Extra inspection, sorting, re-test and other operations besides the basic production operations are all considered as rework activities. This includes the cost of labor and the cost of material consumed during rework, as well as the cost of overhead.

3d) Failure analysis

The costs incurred in analyzing non-conforming products fall under this element. This involves activities such as troubleshooting, determining root causes and implementing corrective actions. This includes the cost of labor involved with overhead and materials consumed or destroyed during the course of destructive analysis.

3e) Held rejects

The cost of scrapping or reworking rejects were accounted for in the previous two sections. There is also a cost associated with holding rejects until they are scrapped or reworked, which is calculated as follows:

Cost of holding rejects = Actual cost of production * % rejected * F%

F%: The value of 'F' is independent on the duration for which the rejects are being held. It (value) is developed based on factors such as storage costs-usage of floor space, capital costs-loss of opportunity to invest funds tied up in the form of rejects, service costs-assessments & processing of rejects in hold and risk costs-obsolescence & shrinkage (Love, 1979).

3f) Excess inventory

Most companies are frequently compelled to carry amounts of inventory in excess of the required levels. These situations commonly arise due to failures, such as engineering/design modifications, production scheduling changes and precautionary measures taken to overcome inconsistent delivery performance of the suppliers.

Cost of carrying excess inventory = Investment on the excess stock held * **F %**

F% = Same as in the case of holding rejects.

Example: As per Lambert (1975), the following (Table 2) are the list of costs associated with carrying inventory and their percentages with respect to the full manufactured cost for four companies. The percentage(F) used in the calculation of the costs pertaining to holding rejects and excess inventory will be different for different companies and usually ranges from 14-43% as stated by Love (1979).

Table 2: Inventory carrying cost components

Cost components	Company A	Company B	Company C	Company D
I Capital costs	40.000%	29.000%	25.500%	8.000%
II Service costs				
- Insurance	0.091%	0.210%	1.698%	0.058%
- Taxes	1.897%	0.460%	0.085%	1.166%
III Storage space costs				
- Recurring storage	0.738%	_	0.573%	2.893%
IV Risk costs				
- Obsolescence	⌉	⌉	⌉	⌉
- Damage	0.233%	0.398%	0.500%	2.086%
- Shrinkage				⌋
- Transshipment costs	⌋	⌋	⌋	N/A
Total carrying costs	42.959%	30.068%	28.347%	14.203%

3g) Other

This classification deals with the costs of implementing engineering/design changes and manufacturing process changes. These changes are considered as costs of failures, if implemented as corrective measures for quality problems.

4. Cost of external failures

4a) Analysis of customer complaints.

The costs incurred in analyzing customer complaints fall under this class. This includes the cost of labor involved with overhead in investigating complaints and implementing remedial actions. The labor cost of sales, service, purchasing, and other staff who may be involved in rectifying customer complaints should also be included.

4b) Goods returned

The cost of dealing with products rejected and returned is reported under this section. This includes labor costs with overhead in handling and reworking defective products. The cost of material with overhead consumed during rework or used for replacing defective products are also included in this section.

4c) Product recall

Product recall is the recall of bad shipments delivered to customers. These are products that are found to be defective by the customer and that need to be reworked or replaced by the company. This is the return freight charges incurred by the company due to the re-call of products.

4d) Concessions

This concerns products that do not meet requirements, but are at times accepted by the customers. Cost of concessions are discounts given by the company to the customers on non-conforming products. This is the difference between the actual cost of the product and the reduced cost due to quality issues.

4e) Warranty claims

Warranty costs are claims made by customers on defective products. This is the work to either rectify or replace defective products and accepted as the company's liability under the terms of the warranty. This should also include the cost of labor with overhead involved in processing customer claims.

4f) Lost sales and customer goodwill

This is the opportunity cost of losing customers. When the company loses a customer, it loses its profit potential. There is no clear-cut method to measure this loss. The cost of lost profit due to customer defection estimated by the Widget company, as stated in chapter 3 (section 3.1), can be used as a good example or possible approach to quantify this cost.

Table 3: Application model for performance appraisal and quality cost reporting

5.1.1 PERFORMANCE REVIEW	**YTD**	**Month**
1. Parts per million defective		
2. On time delivery %		
3. % of perfect orders		
4. Cost of quality $		
5. Sales $ or Cost input $		
6. COQ % of sales or cost input		

5.1.2 QUALITY COSTS	**YTD**	**Month**	**% of total**
1. Cost of prevention	**$—**	**$—**	**—%**
1a) Training			
1b) Preventive maintenance			
1c) Other			
Subtotal			
% of Total COQ			
2. Cost of appraisal			
2a) Inspection and testing			
2b) Inventory Evaluation			
2c) Other			
Subtotal			
% of Total COQ			
3. Cost of internal failures			
3a) Production cost differential			
3b) Goods scrapped			
3c) Goods reworked			
3d) Failure analysis			
3e) Held rejects			
3f) Excess inventory			
3g) Other			
Subtotal			
% of Total COQ			
4. Cost of external failures			
4a) Analysis of customer complaints			
4b) Goods returned			
4c) Product recall			
4d) Concessions			
4e) Warranty claims			
4f) Lost sales and customer goodwill			
Subtotal			
% of Total COQ			
The total cost of quality			

Chapter 6

PRACTICAL APPLICATION OF THE MODEL

The quality costs of the business unit was collected for six straight months. The cost calculations for the first month in the prevention, appraisal and failure categories are shown below. The costs for other months are calculated in the similar fashion and consolidated into a formal reporting format as presented in the Table 4.

6.1 Quality costs for the First month

Standard costs used in the calculations are as follows:

1. Average labor cost (direct and indirect) with overhead = \$10/hour per person.
2. Average overtime labor cost with overhead = \$15/hour per person.
3. The actual cost to produce one unit is assumed to be \$50 per unit for all models of the product

The data sources used in the cost collection are as follows:

1. Production reports
2. Scrap and reject reports
4. Rework records

5. Process control reports

6. Product cost information

7. Claim and warranty reports

As discussed earlier in chapter 2, the business unit consists of two assembly lines (line 1 and line 2), running two shifts (shift 1 and shift 2) each. The lines were scheduled as follows in the first month.

Regular time hours

	Shift 1	Shift 2
Line 1	184 hours	166.5 hours
Line 2	184 hours	159 hours

Overtime hours

	Shift 1	Shift 2
Line 1	2 hours	1 hour
Line 2	0	3 hours

The business unit was scheduled for a total of 693.5 regular time hours and 6 overtime hours in the first month.

6.1.1 Preventive costs

1. Quality improvement team and cross training

The quality improvement team comprises of four trained personnel conducting statistical process control studies for a time period of one month. During this period they also trained an additional four members and then returned to their previous assignments on the assembly line. These four newly trained members would then train four more new members during the next month. The purpose of such cross training is to improve quality awareness among all employees. The cost involved is the labor cost of eight people, since the team always consists of eight people per month; four in charge and four trainees.

*Labor cost of 4 people training 4 others for 176 hours a month

(8 people x $10/hour x 176 hours)--$14,080

2. Preventive maintenance

Companies normally conduct preventive maintenance at the cost of production, which means the shut down of production equipment for maintenance. However, in this particular case the assembly line does not shut down so as not to hinder regular production hours. Preventive maintenance is achieved by allocating one person working overtime for 100 hours a month.

*Labor cost of one person for 100 hours a month

(1 person x $15/hour x 100 hours)--$1,500

6.1.2 Inspection costs.

1. Receiving inspection

Sampling inspection is conducted on incoming materials from suppliers prior to their use to ensure that they meet the design and quality requirements. This inspection consists of two people working for 176 hours every month.

*Labor cost of two inspectors for 176 hours month

(2 people x $10/hour x 176 hours)--$1,760

2. Final inspection

The final inspection is a 100% test inspection of finished products for quality and safety standards, before being packaged. This is the cost of two inspectors per assembly line per shift. For example; the cost of final inspection for line 1-shift 1 = 2 people x 10/hour x 184 hours + 2 people x 15/hour x 2 hours, for 184 regular time hours and 2 overtime hours (data obtained from section 6.1). The costs are calculated for line 1-shift 2, line 2-shift 1 and line 2-shift 2 in the similar manner and summed up to get the total cost of final inspection for the business unit in the first month.

*Labor cost of 2 inspectors for the scheduled production hours per line per shift.

[2 people x {$10/hour x (184 hours + 166.5 hours + 184 hours + 159 hours) + $15/hour x (2 hours + 1 hour + 0 + 3 hours)}]---$14,050

3. Customer acceptance evaluation

This is a random sample test of finished products in the expected user environment. One quality control person is designated for this purpose per assembly line per shift.

*Labor cost of one person for the scheduled production hours per line per shift.

[1 person x {$10/hour x (184 hours + 166.5 hours + 184 hours + 159 hours) + $15/hour x (2 hours + 1 hour + 0 + 3 hours)}]---$7,025

4. Inventory cycle count

Inventory cycle count is the physical count of inventory by cycle counters. This is done on a daily basis with the items to be counted picked randomly. The purpose of doing this on a daily basis is to identify inventory shrinkage at the earliest before it magnifies and causes loss in production. One cycle counter is dedicated for this activity for 176 hours and one for 104 hours every month.

*Labor cost of two cycle counters, with one for 176 hours and the other for 104 hours.

(1 person x $10/hour x 176 hours + 1 person x $10/hour x 104 hours)--------------$2,800

6.1.3 Internal failure costs

1. Production cost differential

$$a)\ Production\ equipment\ utilization\ (PEU) = \frac{Actual\ production\ hours}{Scheduled\ production\ hours}$$

$$= \frac{619\ hours}{699.5\ hours} * 100 = 88.5\%$$

$$b)\ Production\ performance\ index\ (PPI) = \frac{Actual\ number\ of\ units\ produced\ per\ hour}{Number\ of\ units\ planned\ per\ hour}$$

$$= \frac{190/hour}{210/hour} * 100 = 90.5\%$$

c) Production efficiency = PEU * PPI = 80%

d) Actual cost of production = The actual cost to produce one unit x Number of units produced. [Note: The actual cost to produce one unit is assumed to be $50 per unit (cost of material, all direct/indirect labor and overhead) for all models of the product. This information was extracted from the company's product cost information].

= $50 x 117,873 units = $5,893,650 (for an actual volume of 117,873 units of all models of the product, produced in the first month)

*Production cost differential = Actual cost of production - (Actual cost of production x Production efficiency)

[$5,893,650 - ($5,893,650 x 80%)]--$1,178,730

2. Scrap

Scrap refers to the material damaged in-house during the assembly process or material handling and are unfit for rework. The cost of scrapping such material cannot be charged back to the supplier as they are caused due to in-house errors. This cost of scrap was picked up from the monthly scrap reports maintained by the business unit.

*Cost of material wastage--$4,407

3. Rework and repair

Repair cost for the business unit is the cost of carrying two people per assembly line per shift, to repair the 100% test inspection fall out (i.e., the finished products that do not pass the 100% test). Rework cost is the cost of 38 extra people used during the first month for sorting rejected lots from suppliers.

*Labor cost of 2 repair persons for the scheduled production hours per line per shift and 38 people for rework (19 people used for 8 hours, 14 for 10 hours, 2 for 6 hours, 1 for 6.5 hours, 1 for 4 hours and 1 for 3 hours).

[2 x {$10/hour x (184 hours + 166.5 hours + 184 hours + 159 hours) + $15/hour x (2 hours + 1 hour + 3 hours)} + $10/hour x (19 people x 8 hours + 14 people x 10 hours + 2 people x 6 hours + 1 person x 6.5 hours + 1 person x 4 hours + 1 person x 3 hours)]-------- $17,225

4. Held rejects

A total of 4066 defective products were produced in the first month, which is 3.45% of the total number of units produced (117,873 units) that month. The number of rejects produced every month was obtained from the reject reports generated by the business unit.

*Cost of holding rejects = Cost of production x % rejected x F % (as discussed in chapter 5).

The factor 'F' is assumed to be 30% for the business unit and the same percentage is also used for excess inventory.

($5,893,650 x 3.45% x 30%)--$60,999

5. Held excess inventory

The business unit was designed and set up to maintain a safety stock of five days worth of inventory at all times. The inventory level held at the end of the first month was six days worth of inventory, which means a day's worth of inventory was carried in excess. The dollar value of inventory at the end of the month was $1,312,000, which was obtained from the monthly inventory status reports.

*Cost of holding excess inventory = $ value of the excess inventory held x 30%.

[($1,312,000 ÷ 6 days) x 30%]--$65,600

6.1.4 External failure costs

1. Analysis of customer returns/complaints

This is the cost of labor involved in the analysis of customer complaints. It was estimated that eight hours was spent by one person in the first month for this purpose.

*Labor cost of 1 person for 8 hours

(1 person x $10/hour x 8 hours)--$80

2. Return freight

Return freight is the transportation charges incurred by the business unit due to the recall of rejected shipments from the customers. The return freight charges show as zero, since no shipments were rejected and returned during the first month.

*Cost of return freight---$0

3. Claims

This refers to the claims on poor quality products by the customers. This information was obtained from the company's accounting/warranty records.

*Cost of claims---$320

Table 4: The quality costs for six straight months

QUALITY COSTS	First	Second	Third	Fourth	Fifth	Sixth
Preventive costs						
Quality teams & cross training	$14,080	$14,080	$14,080	$14,080	$14,080	$14,080
Preventive maintenance	$1,500	$1,500	$1,500	$1,500	$1,500	$1,500
Sub-total	***$15,580***	***$15,580***	***$15,580***	***$15,580***	***$15,580***	***$15,580***
Inspection costs						
Incoming inspection	$1,760	$1,760	$1,760	$1,760	$1,760	$1,760
Final inspection	$14,050	$15,200	$12,980	$14,480	$14,215	$11,277
Customer acceptance evaluation	$7.025	$7,600	$6,490	$7,240	$7,107	$5638
Inventory cycle count	$2,800	$2,800	$2,800	$2,800	$2,800	$2.800
Sub-total	***$25,635***	***$27,360***	***$24,030***	***$26,280***	***$25,882***	***$21,475***
Internal failure costs						
Production cost differential	$1,178,730	$1,269,870	$1,181,621	$1,172,393	$1,320,014	$1,032,322
Scrap	$4,407	$5,233	$4,409	$3,120	$3,515	$3621
Rework and repair	$17,225	$15,770	$13,700	$14,560	$14,375	$11,237
Held rejects	$60,999	$53,697	$31,352	$44,144	$22,457	$32,477
Held excess inventory	$65,600	$147,342	$293,175	$91,050	$178,885	$24,772
Sub-total	***$1,326,961***	***1,491,912***	***$1,524,257***	***$1,325,267***	***$1,539,246***	***$1,104,429***
External failure costs						
Customer return analysis	$80	$160	$60	$60	$440	$120
Return freight	$0	$0	$0	$0	$0	$0
Claims	$320	$820	$1,398	$1277	$1,322	$121
Sub-total	***$400***	***$980***	***$1,458***	***$1337***	***$1,762***	***$241***
The total cost of quality	***$1,368,576***	***$1,535,832***	***$1,565,325***	***$1,368,464***	***$1,582,470***	***$1,141,725***

Chapter 7

QUALITY COST ANALYSIS

7.1 The cost of quality, index

$$COQ\ index, \% = \frac{The\ total\ cost\ of\ quality}{Measurement\ base} * 100$$

[As per Campanella and Corcoran (1983)]

The commonly used measurement bases are net sales and cost input. In the analysis of quality costs for the business unit the actual cost of production (cost-input) that includes the cost of material and labor (direct and indirect) as well as overhead, is used as the base for the index.

$$Index, \%\ for\ the\ first\ month = \frac{COQ}{Cost\text{ - }input} * 100 = \frac{\$1,368,576}{\$5,893,650} * 100 = 23.2\%$$

7.2 The total cost of quality trend

The COQ for the six months measured in the previous chapter is presented graphically in Figure 1, to get an overall picture of the total cost trends. From Table 5, it is noted that COQ of the business unit ranges between 20-30% of the cost-input.

Table 5: The index, percentages for the six months

Month	First	Second	Third	Fourth	Fifth	Sixth
COQ index %	23.2%	25.4%	29.8%	22.2%	27.7%	25%

7.3 Quality cost trend, by category

The different cost categories are shown as the percentages of the total cost of quality for each month in Table 6. As noted from its contents, the majority of the quality costs are in the internal failure categories, for all months. Since internal failures are the problem areas a closer analysis is conducted on its sub-categories.

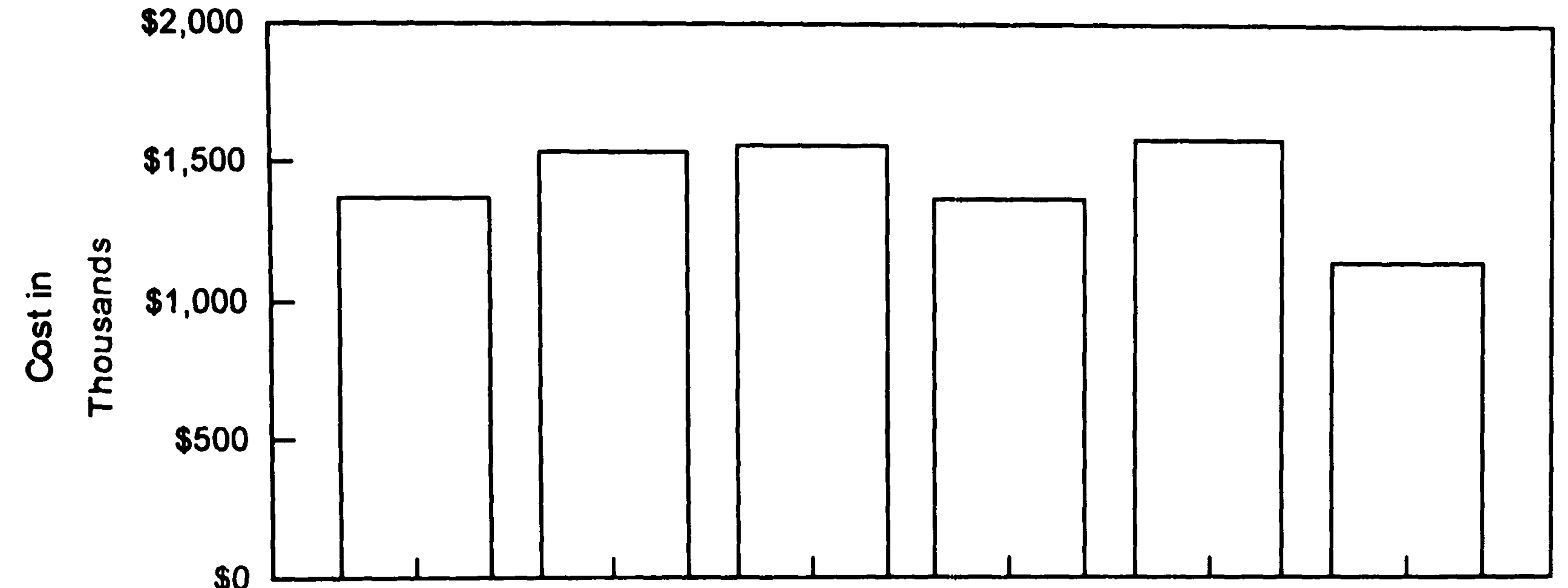
Table 6: Cost category percentages, of COQ

Cost category	**First**	**Second**	**Third**	**Fourth**	**Fifth**	**Sixth**
Preventive	1.1%	1.0%	1.0%	1.1%	1.0%	1.4%
Inspection	1.9%	1.8%	1.5%	1.9%	1.6%	1.9%
Internal failures	**96.9%**	**97.2%**	**97.4%**	**96.8%**	**97.3%**	**96.7%**
External failures	0.03%	0.06%	0.09%	0.09%	0.11%	0.02%

7.4 Internal Failure cost, sub-categories

The percentages of the different sub-categories with respect to the total cost of internal

The total cost of quality trend



Month	1st	2nd	3rd	4th	5th	6th
COQ	$1,368,576	$1,535,832	$1,565,325	$1,368,464	$1,582,470	$1,141,725

Fig 1

failures are shown in Table 7. Since, a very high percentage of the costs incurred are concentrated in the production cost differential, the focus is directed toward the different areas within this cost element.

Table 7: Internal failure sub-category percentages

Sub-categories	First	Second	Third	Fourth	Fifth	Sixth
PCD	**88.8%**	**85.1%**	**77.5%**	**88.5%**	**85.8%**	**93.5%**
Scrap	0.3%	0.4%	0.3%	0.2%	0.2%	0.3%
Rework and repair	1.3%	1.1%	0.9%	1.1%	0.9%	1.0%
Held rejects	4.6%	3.6%	2.1%	3.3%	1.5%	2.9%
Excess inventory	4.9%	9.9%	19.2%	6.9%	11.6%	2.2%

7.5 Production cost differential

Production cost differential, as discussed in chapter 5 is an opportunity cost. The magnitude of this element identifies a great opportunity for cost savings. The prime causes of PCD are in-efficiencies such as, downtime and lost time. These are usually caused by equipment breakdown, engineering changes, quality issues, lack of material, accidents, absenteeism and lack of motivation amongst the employees.

The broad categories of the different causes that contribute to the PCD (the causes for downtime and lost time), the down/lost time under these categories and their respective opportunity costs for the first month are given in Table 8. The total down/lost time for each month and the opportunity costs under the different categories are calculated as shown in example (7.5.1) and (7.5.2).

7.5.1 Example-The total down/lost time, for the first month

Downtime for the first month = 80.5 hrs.

The planned line rate was 210/hr, but for the first month the actual rate was 190/hr producing 117,873 units in 619 hours.

Therefore, the time lost due to low efficiency of the production process (i.e., low efficiency in the part of the operators or equipment or both)

= 619 hrs - (117,873 units ÷ 210/hr) = 57.7 hrs

The total down/lost time (TDLT) = 80.5 hrs + 57.7 hrs = 138.6 hrs.

7.5.2 Example - Opportunity cost of equipment downtime, for the first month

Production cost differential for the first month = $1,178,730.

Equipment downtime for the first month = 6.8 hours.

(i.e., downtime due to the breakdown of production related equipment)

Equipment downtime as % of TDLT = (6.8 hours ÷ 138.6 hours) x 100 = 4.91%

Therefore, opportunity cost of equipment downtime:

= $1,178,730 x 4.91% = $57,875.64 = $57,876

(Note: The costs are rounded off to the nearest dollar).

The opportunity costs for the PCD categories, for the six months are presented in table 9 and the cost trends are studied in section 7.6.

Table 8: The PCD, categories and their opportunity costs for the first month

Production cost differential, categories	**Down/lost time**	**As a % of TDLT**	**Opportunity cost**
1. Equipment (Production and test equipment breakdown)	6.8 hrs	4.91 %	$57,876
2. Engineering (Corrective actions; engineering deviations/design changes)	0 hrs	0 %	$0
3. Material handling (In-house material handling delays/errors)	2.3 hrs	1.66 %	$19,567
4. Outside, supplier quality (Rework of poor quality products and lack of material due to outside suppliers)	23.2 hrs	16.74 %	$197,319
5. In-house, supplier quality (Rework and lack of material due to in-house suppliers)	5.5 hrs	3.97 %	$46,796

Table 8 (continued)

Production cost differential, categories	**Down/lost time**	**As a % of TDLT**	**Opportunity cost**
6. Change-overs (Stoppage in production due to model and line rate change-overs)	3.9 hrs	2.81 %	$33,122
7. Lack of people (Shortage of operators due to absenteeism)	3.0 hrs	2.16 %	$25,461
8. Inventory losses (Shrinkage in inventory due material transaction errors)	1.5 hrs	1.08 %	$12,730
9. Planning (Production planning and scheduling errors)	12.9 hrs	9.31 %	$109,739
10. Safety (Accidents and safety incidents)	0 hrs	0 %	$0
11. Low-efficiency (Low process efficiency; operator or equipment or both)	57.7 hrs	41.63 %	$490,705
12. Process failures (Quality issues due to production process failures; assembly)	19.1 hrs	13.78 %	$162,429
13. Other	2.7 hrs	1.95 %	$22,985

7.6 The prime causes of PCD.

The following are the top nine or significant root causes of PCD (opportunity costs) based on totals under the different categories for six months identified from Table 9. The top six causes for each month are also identified and presented in Table 10.

1. Low-efficiency: Production efficiency, as discussed in chapter 5 pertains to two elements. 1) The percentage of actual production hours with respect to the scheduled production hours. 2) The percentage of actual line rate with respect to the planned line rate. Low-efficiency pertains to the opportunity cost of the time lost by not keeping up to the planned or required line rate. The reason for this is identified as low-efficiency in the part of the operators or equipment or both.

2. Outside,supplier quality: This refers to the production downtime due to material not being delivered by suppliers as scheduled or due to poor quality of material from suppliers. The in-coming materials from suppliers are inspected (lot sampling) prior to use and the lots that do not pass this inspection are rejected and shipped back to the suppliers. Sometimes, these rejected lots are sorted during production and put to use. Though, the cost of such rework activities are usually charged back to the suppliers, this would slow down the pace of production considerably and may affect the quality of finished products, since sorting is not 100% efficient.

3. Process failures: Process failures pertain to the downtime due to production process failures (assembly errors). This includes meetings conducted to resolve quality issues and rework of non-conforming products as a result from assembly failures.

4. Equipment: This is a lost opportunity cost identified due to production coming to a stand still as result of equipment breakdown. The valuable production hours lost, is normally considered to be the representation of equipment idle time and wastage of labor. In reality, it is also represents the cost of carrying the inventory that could have been used up, holding rejects for a longer period of time, overtime scheduled to meet demands and other factors that have an impact on the cost of production.

5. In-house, supplier quality: The failures caused by in-house suppliers fall under this category. This refers to the delays in production as a result of material not being delivered on time and rework activities conducted on poor quality products.

6. Planning: These are failures or disrupted production schedules caused by planners or schedulers. This refers to the stoppage in production due to lack of material as a result from planning and scheduling errors.

7. Material handling: The downtime caused by inefficient material handling is reported under this section. This refers to the delays in supplying the assembly line with material required for production and receiving incoming material from suppliers.

8. Change-overs: Change-overs pertain to the set-up time. This is the production time spent on setting up or making the necessary modifications to the process in switching from one model of the product to another.

9. Inventory losses: Inventory losses are shrinkage in inventory levels. This category refers to the downtime of production hours due to material shortages as a result from material transaction errors.

Table 9: The PCD, opportunity costs for the six months

PCD, categories	First	Second	Third	Fourth	Fifth	Sixth	Total
1. Equipment	$57,876	$62,605	$156,682	$152,880	$173,581	$178,282	$781,906
2. Engineering	$0	$0	$0	$27,551	$31,284	$0	$58,835
3. Material handling	$19,567	$4,952	$38,403	$143,735	$31,284	$30,557	$268,498
4. Outside, supplier quality	$197,319	$458,169	$209,737	$325,104	$242,618	$289,669	$1,722,616
5. In-house, supplier quality	$46,796	$106,288	$10,635	$66,826	$32,076	$77,527	$340,148
6. Change-overs	$33,122	$49,525	$90,630	$33,413	$5,676	$18,995	$231,361
7. Lack of people	$25,461	$1,651	$14,652	$0	$12,012	$6,607	$60,383
8. Inventory losses	$12,730	$0	$0	$6,683	$10,428	$147,725	$177,566
9. Planning	$109,739	$26,413	$73,379	$49,241	$33,792	$30,557	$323,121
10. Safety	$0	$0	$2,481	$2,462	$16,104	$0	$21,047
11. Low efficiency	$490,705	$373,341	$321,519	$298,374	$568,002	$63,591	$2,115,532
12. Process failures	$162,429	$177,909	$259,484	$62,723	$110,089	$108,809	$881,441
13. Other	$22,985	$9,016	$4,018	$3,400	$53,065	$80,005	$172,489

Table 10: The top six root causes of PCD, for each month

First month	Second month	Third month
1 Low-efficiency	1 Outside, supplier quality	1 Low-efficiency
2 Outside, supplier quality	2 Low-efficiency	2 Process failures
3 Process failures	3 Process failures	3 Outside, supplier quality
4 Planning	4 In-house, supplier quality	4 Equipment
5 Equipment	5 Equipment	5 Change-overs
6 In-house, supplier quality	6 Change-overs	6 Planning
Fourth month	**Fifth month**	**Sixth month**
1 Outside, supplier quality	1 Low-efficiency	1 Outside, supplier quality
2 Low-efficiency	2 Outside, supplier quality	2 Equipment
3 Equipment	3 Equipment	3 Inventory losses
4 Material handling	4 Process failures	4 Process failures
5 In-house, supplier quality	5 Other	5 Other
6 Process failures	6 Planning	6 In-house, supplier quality

Chapter 8

VALUE/COST ANALYSIS

8.1 Cost of quality and value of quality

This value/cost analysis is about obtaining the right balance between the cost of quality and value of quality. The cost of quality is relatively easier to quantify than the value of quality since value would include customer satisfaction that is not easy to measure. The economics of quality is basically a question of value (to which pricing and market shares are related) and costs (which measure the efficiency with which the company generates value and, together with value, determine the company's business results), (Conti 1993).

The value of a quality management system or even specific quality improvement programs is the ability to satisfy customers and contribute to the company's profits. The right mix between the cost of conformance (prevention and appraisal) and cost of non-conformance (internal and external failures) is the optimum point as shown in Figure 2 (Juran, 1962). It is at this point the total cost of quality is at the minimum. To identify and attain the optimal mix, is easier said than done. The objective of any value and cost analysis is to bring the total cost of quality to minimum and maintain the required quality standards. This is the most economical means of generating value.

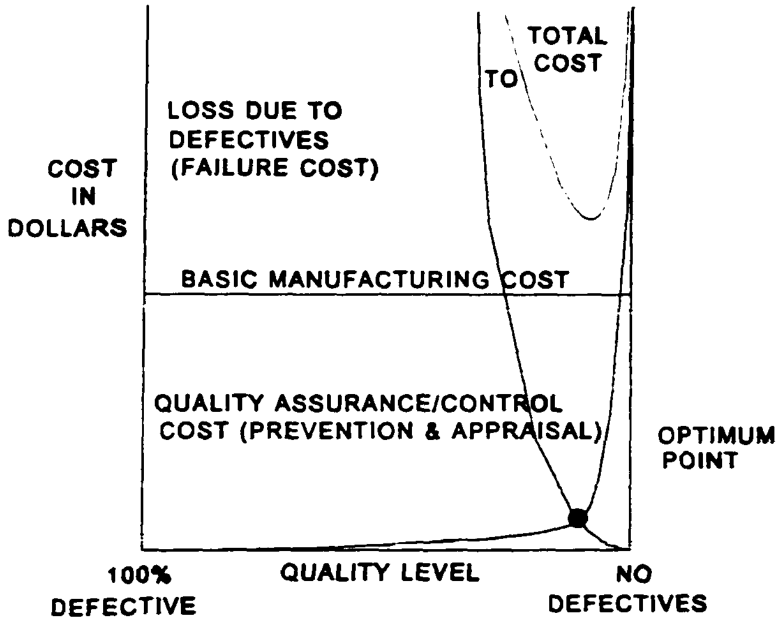


Figure 2: The cost of quality vs value of quality

A self-assessment criteria is developed for manufacturing companies using the COQ index percentages (discussed in chapter 7). The manufacturing units can be classified into following four groups based on the percentages of cost of quality to the cost-input or sales.

0 - 10 % : **World class manufacturing**

10 - 20 % : **Substantial improvement required**

20 - 30 % : **Great deal of improvement required**

Above 30 % : Far from world class and major changes required

This criteria is proposed as an alternative for the task of quantifying the optimal point. As mentioned by Bowman (1994), instead of having to deal with the vague task of finding an appropriate balance between costs of providing good quality and the resulting quality level, management should be presented with a more precise goal of minimizing the overall cost of quality. According to Crosby (1979), if one considered all the consequences of poor quality as well as the costs of quality improvement efforts, one would realize that quality pays for itself many times over. He estimates direct increases in profitability of 5 to 10 percent of sales are possible through quality improvement.

8.2 True prevention

An increase in the cost of prevention should result in a larger decrease in the cost of failure, thereby reducing the total quality cost. When this no longer happens, prevention costs have been "saturated," and no further dollars should be invested in prevention until conditions change or a breakthrough is achieved [(Campanella and Corcoran 1983) as per Juran (1964)]. It is at this point, the *saturation point,* that further costs of prevention become larger than the savings afforded [(Campanella and Corcoran 1983) as per Campanella (1975)].

To successfully monitor results of improvement initiatives or investments, it is advisable to make a note of the day or month when they are actually being implemented, since there is a time delay between 'implementation' and 'result' for most quality improvement programs. This would also help in knowing when the saturation point for these programs have been reached.

There are two types of prevention as stated by Perigord (1990):

1. Anticipatory prevention, that is, prevention implemented during the design, research or even development. Although it obviously pertains to products, it also involves processes and procedures. It is carried out by means of group efforts, and also by simulation on models.

2. Active prevention, or the elimination of errors or failures at the earliest possible point in the production process, which requires detection of defects as early as possible.

8.3 Maximize value and minimize cost

Maximization of value is usually directed towards process, the key to value. Process quality is the process ability to generate the required value for the customer/user and doing it at the minimum cost. The equation for process quality (Conti 1993):

Process quality = output quality/process cost

= added value for the user/process cost

Process quality and product quality does not mean one and the same. Process quality is the 'source' and product quality is the 'result'. The two aspects of process quality are added value and process costs that are not related at all times. A high percentage of the process cost is related to activities that do not generate value to the customer. The term 'value' is interpreted in two ways, ***"value to the company"*** and ***"value to the customer"***. The distinguishment between the two interpretations of value is explained using Figure 3 (Conti 1993).

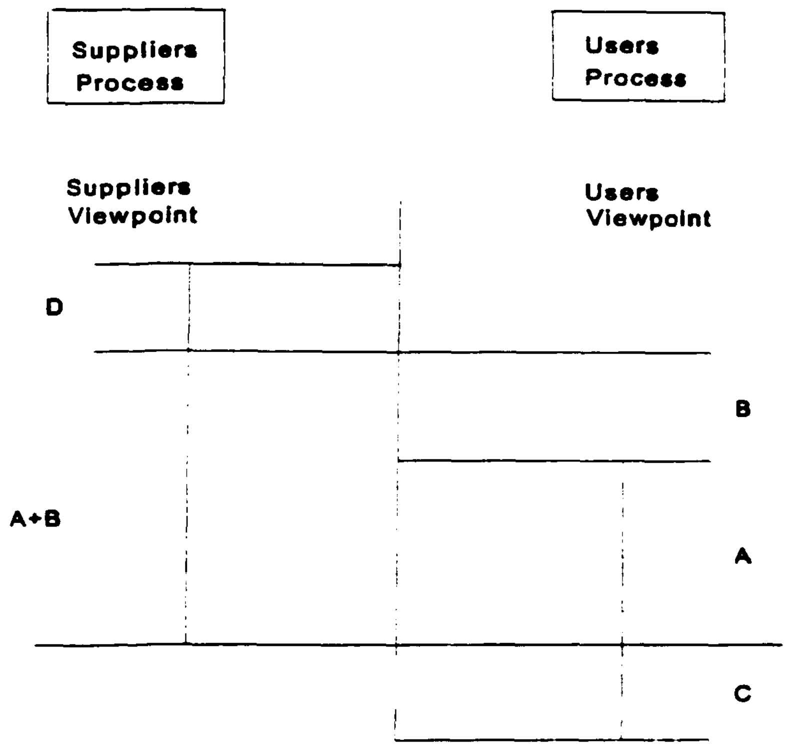


Figure 3: The suppliers and the user's viewpoints of process added value.

From the supplier's viewpoint: D is activity wasted owing to internal process defectiveness; A and B are activities that generate value. From the user's viewpoint: A is value recognized by the user; B is non-value for the user; C is value expected by the user and not provided by the supplier. Costs correspond to A+B+D; added value corresponds to A; value expected but not provided (shortcomings in quality) corresponds to C. Therefore, all activities that do not generate value either to the company or to the customer need to be eliminated and 'True value' is the value generated to the customer.

8.4 Concluding remarks of the value and cost analysis, pertaining to the business unit

1. As seen in chapter 6, considering the size of the PCD in comparison to the other cost elements, it is obvious that a great deal of cost savings can be accomplished in this area. Though, there are other areas that could be identified for improvement, it is this area that has the most wastage and non-value added activities.

2. Based on the analysis of PCD root causes conducted in chapter 7, it would be worthwhile to collect and monitor the costs of preventive/improvement measures in the following areas besides the costs of training and maintenance so as to alter these costs (spend more money) to reduce the cost of failures.

1. Process improvement
2. Supplier quality assurance
3. Planning and scheduling
4. Material handling
5. Inventory accuracy

3. The cost of prevention, which is the cost of cross training and preventive maintenance, is the same for all months. On the other hand the cost of quality index has a fluctuating trend in the range between 20 - 30% of the cost-input as discussed in chapter 7. This is a typical case [as stated by Campanella and Corcoran (1983) as per Juran (1964)] in which the prevention costs/programs probably have either reached a saturation point or they need to be

altered to have greater impact on the failure costs.

4. Receiving inspection, 100% test and final inspection are some of the many ways of making sure that defective products do not get to the customer. Thereby, satisfy customers and minimize external failure costs for the business unit. Repeated inspection will reduce external failures, but on the other hand tend to increase internal failures, since more defects are found in-house. Therefore, inspection will not improve competitive quality (to gain the competitive edge over competitors), prevention is the only alternative.

5. Excess inventory and repeated inspection are examples of costs that are value added to the business unit, but add very little value to the customer. Excess inventory is mostly carried to be *safe than sorry* (to overcome some system inefficiencies). Some inspections are necessary while the rest have a great potential for elimination. By implementing concepts of active and anticipatory prevention, a more stable process can be developed and some activities that are non-value added in the customer's view point can be eliminated. Thereby, generating the same value or greater value in more economical way. The cost of permanently carrying two repair persons as a part of the production workforce is another example of activities that add value in the company's view point but add no value in the customer's view point.

6. In value/cost discussions the question that would most definitely arise is, *How much value should be transferred with no charge or with an additional charge to the customer*? If market

shares is of a greater importance than profits, then the answer to this question is, ***transfer greater value at the same charge.***

Chapter 9

CONCLUSION

9.1 Major conclusions of the research

1. The existing theory and literature of 'COQ' were filtered to develop a methodology that can be used to operationalize the collection of quality costs for manufacturing settings. The framework is practically sound and was successfully tested for its practical application.

2. Quality costs are necessary feedback to a number of important management decisions in all areas of the business. The methodology developed can be used by managers to determine quality costs specifically geared to their company.

3. The cost of quality is one of the key issues in implementing Total Quality Management and monitoring progress of the quality process. The model will serve as the first steps toward implementing a well defined quality costing system for companies undertaking TQM.

4. The application model developed is capable of quantifying various forms of failures and inspection as well as root causes of failures. By that, identifying critical areas of prevention based on the needs of specific users.

5. The model will aid in identifying areas of high expenditure and non-value added activities. By that, identifying improvement opportunities to maximize value and minimize cost.

6. Besides measuring direct and indirect or intangible costs of failures, the opportunity costs of failures such as down/lost time, carrying excess inventory and holding rejects can be measured using the model. It is important to measure these costs as they may constitute a substantial percentage of the total cost of quality incurred by a manufacturing company.

7. The majority of failures for any manufacturing company can be identified during the time of actual production. Therefore, including PCD in the measurement of COQ is important, to improve the overall performance of the business.

9.2 Suggestions for future research

This research presents a substantial break-through in the measurement of quality costs for manufacturing companies. Nevertheless, it has its limitations presenting scope for further research. The following are some of the possible directions of future research.

1. To develop a methodology to quantify the different areas of prevention pertaining to manufacturing.

2. To explore into the areas of quality planning, product design/development, supplier surveillance and market research using Activity Based Management as a possible approach.

2. To study the area of customer service and measure costs associated with lost sales and loss of customer goodwill.

3. To develop quality costing model for service/non-manufacturing situations using Time-based cost element method.

4. To develop a method to identify the optimal mix between the cost of quality and value of quality.

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