

A. Sailaja¹
P.C. Basak
K.G. Viswanadhan

ANALYSIS OF ECONOMICS OF QUALITY IN MANUFACTURING INDUSTRIES

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Abstract: *In modern industries, much emphasis is given to quality as it is the most effective tool which can capture, retain and enlarge customer base. The customer satisfaction is the ultimate goal of business and no other strategy can achieve it other than attaining best quality. An improvement in quality enhances customer satisfaction, tapers manufacturing costs and of course in turn, increases productivity. But in business scenario, improving quality should be considered along with the expenses associated with it. The strategy should be to achieve high Quality in a most economic way. So identifying effective methods for the analysis of economics behind quality and reduction of costs associated with achieving quality is a serious potential management problem and should be looked in to and analysed. Economics of Quality analysis which is also termed as cost of quality or quality cost analysis has emerged as a powerful management tool for assessing the present quality level of the organisation and to identify the improvement opportunities and also supports in decision making.*

This paper presents a study on quality cost analysis of two manufacturing units and tries to analyse the interrelationships between quality cost categories using statistical methods. The secondary data collected from the financial records of two firms under manufacturing sector is used for this analysis. The Pearson product momentum correlation coefficient between different quality cost categories provides insight to the relationships between different quality cost elements and in turn helps management to set action priorities to be addressed to achieve good quality at lower cost. The regression analysis helps the management in estimation or prediction of the unknown value of one variable from the known value of the other variable.

Keywords: *Cost of Quality, COQ models, Correlation Analysis, Regression analysis*

1. Introduction

Economics of Quality has a deeper and broader sense than a technique to get the return on investment of quality efforts. It is now used in manufacturing and service industries both for controlling the costs incurred in quality activities and for identifying opportunities for organizational improvements. Quality has emerged as the central customer value and effective method to analyse the economics behind achievement and maintenance of quality is perhaps the best strategy for an industry to achieve the competitive edge. The cost incurred in quality related activities now form a quarter of resources used in companies. A study on costs incurred in quality management provides a deeper insight to various quality objectives of an organization and acts as an effective tool for performance measurement. It helps the industrialists in identification of improvement opportunities and in setting action priorities. Researches on quality costing models are significant in operational management as well as in industrial engineering field. Since the identification and estimation of costs of quality involves a better understanding of accounting theories and principles, this study is equally relevant in the finance management also.

Though quite a large number of projects are undertaken in economics of quality analysis and the academic circle has taken keen interest in quality cost researches, the effect of these studies are yet to get much appreciation from industrial world. Surveys pointed out that quality costing is yet to be accepted widely in the industries (Chopra and Garg, 2011; Kaur, 2009). Industries are not yet ready to quantify the losses incurred due to poor quality (Ramadan, 2005). Quality improvement programs are often done without the clear estimation of

expected benefits (Oliver and Qu, 1999). Though lot of theories and advices are available in literature on quality costing, published practical examples or models of proven usefulness are very scarce (Murugan and Kanapathy, 2011). As the effective economics of quality analysis can immensely benefit industries, it is necessary to implement the scientific methods of quality costing and to bring out illustrative practical examples which could guide the industrial world (Durmaz and Zengin, 2012). By the statistical analysis of quality cost data measured in a practical case study, the industrial managers will get a clear picture on the significance of each quality cost categories, their inter relationships and their behavioural patterns with the level of quality awareness in the firm (Vukcevic, 2008). This will help the industrial managers to identify the improvement opportunities, prioritise them and also to make conclusive decisions (Wang *et al.*, 2012).

In this study, quality cost analysis has been conducted in two manufacturing units with an aim to assess the inter relationship pattern between different cost categories using statistical analysis. The data collected from the financial as well as production records of the firms are used for this analysis. The Pearson Product Momentum Correlation analysis and Regression analysis are used for this study.

2. Theory of cost of quality and models

Economics of Quality is a broad term which is used to define the economics behind quality achievement strategies in manufacturing and service industries. It is also termed as Cost of Quality (COQ) or Quality Cost analysis. After the inception of the concept of Cost of Quality by Juran and Feigenbaum in 1950's, many studies were in place worldwide and the understanding of subject area has developed. Traditionally the quality costs were seen from a production oriented point of view, taking only costs of

¹ Corresponding author: A. Sailaja
email: sailajaasree@gmail.com

deviations from specification in to account. The area has become wider with the additional dimensions of the term quality. Even though there is no single definition of Cost of Quality, it is usually considered as the sum of conformance and non conformance costs (Schiffauerova and Thomson, 2006). The quality costing models developed by (Juran, 1951; Feigenbaum, 1959; Crosby, 1979) are considered as the traditional models which are still widely accepted by the quality practitioners even with their limitations that they are confined within the tangible and directly measurable costs only (Teevarapug, 2004) and are failed to address many of the cost areas. Subsequently different models have been developed for accommodating the intangible costs also (Cem Kaner, 1996; Akyol *et al.*, 2005). Further many attempts were made to overcome the drawbacks of the traditional models. The main drawbacks of the traditional models are the difficulty in grouping and categorization of cost elements (Ladder and Lee, 1995) within the frame work of classification of traditional model. Another drawback is the incapability of traditional accounting system to measure and accommodate all quality cost elements (Tsai, 1998) and tracing them to resources (Turny, 2010).

Many more dimensions of quality costs have been added by researchers like (Elridge and Balubaid, 2006) who has added knowledge management concept to Cost of Quality (Sower *et al.*, 2007) who has analysed the quality costing as a measure of quality system maturity. Quality Cost has been analysed as money invested and money lost by (Uyar, 2008; Yaccob, 2010). Giakatis *et al.* (2000), made an additional dimension of categorizing quality costs into costs and losses and analysed the association between quality and environmental costs. The manufacturing loss and design loss are analysed against this concept.

The difficulties in implementation of COQ system (Jefry, 2004, Cockins, 2006; He, 2010, Wang *et al.*, 2010), in sufficiency of

reports (Harrington, 1987; Tye *et al.*, 2011), incapability of addressing intangible costs (Modaress and Ansari, 1987; Jafar *et al.*, 2010, Shank and Govindarajan, 2005), non synergy with TQM concepts (Arvaiova *et al.*, 2009; Vaxevanidis, 2009) were addressed by many researchers in this field.

Intangible costs like loss to society and anxiety – productivity loss were analysed by (Teevaraprug, 2004). Yang (2008), has further expanded the concept by analysing the impacts of lost sales. Soo-Jin Chea (2011), emphasized the importance of cost of quality system in the present industrial situation with increase in complexity of organization, product variety and fluctuations in the market demands and explained the requirement of identification of more opportunity cost factors. Adil and Moutawakil (2012), effectively utilized the Taguchi method for ascertaining the indirect costs.

Opportunity cost models by Sandoval-Chavez and Beruvides (1998), incorporate opportunity losses into traditional quality expenses. Joseph A. DeFeo (2000), also advocates that the traditional model can be expanded to accommodate extra dimensions that are identified as the cost of inefficient resource utilization and quality design cost. Harrington's model includes the intangible and difficult to measure costs also, such as customer dissatisfaction costs, cost of lost sale, lost reputation etc. But this model does not identify the costs associated with quality improvement efforts (Jeffery, 2004).

The cost of quality measurement and analysis system supports the management in tracking the effectiveness (Modrak, 2007) of various quality improvement programs and demonstrate the quality failures to the management in monetary terms (Dian, 2010; Shank and Govindarajan, 2005). It acts as a pro-active tool in identification of causes and effects of the non conformances and in prevention of problems (Sower *et al.*, 2007; Jafar *et al.*, 2010). It supports management to identify improvement opportunities and to

set action priorities and thus leads to continuous improvement (Mohamood, 2010). It enables the firm to identify and eliminate the unnecessary costs incurred in various activities (Haryanto, 2005). COQ analysis tracks the performance over a period of time and acts as a powerful tool in decision making (Vaxevanidis *et al.*, 2009).

3. Study on quality costs

3.1. Profile of the organization under study

A Study has been conducted using data collected from the financial records of two manufacturing unit under electronic industrial sector located in South India. Unit A is manufacturing populated printed circuit assemblies and Unit B is manufacturing SIM cards for mobile applications to the telecom network. Both the Unit are having ISO 9001:2008 certifications and practicing Quality Cost analysis.

3.2. Methodology

Steps involved in this study are:

- 1) Data collection against each quality cost element using accounting reports for a period of 2 years, Compilation of data collected and calculation of quality cost.
- 2) Analysis of quality cost using statistical tools to identify the areas of improvements.
- 3) Correlation and Regression analysis to identify the interrelation ship between various quality cost categories for each unit.
- 4) Comparative analysis of the quality cost patterns for both the units and inferences.

3.3. Data collection

The expenses incurred against each quality cost elements were collected from financial records. Cost incurred against each element was quantified from these data and then total costs against Prevention (PC), Appraisal (AC) and Failure (FC) categories were tabulated on a quarterly basis for the 2 consecutive financial years 2010-11 and 2011-12.

The quality cost data collected and compiled for the 2 years for both the manufacturing units under study are given in Table 1 and 2. Sales turn over for each year and the ratio of total costs with sales turnover for each quarter, cost of conformance (CONC = Prevention + Appraisal costs) and cost of non-conformance (COC = Sum of failure costs) also tabulated.

4. Data analysis & results

Good performance indicators like sales volume, profit, return on quality etc. are required for better analysis and judgement of any measured data and to get a clear picture of the performance status of the organisation. The sales turnover of the company was taken as the performance indicator for analysis and reporting of economics of quality in this study.

The contribution of each quality cost category to the total quality cost is calculated for all the 2 years under study for both the manufacturing units and graphically represented using pie-charts (Figure 1, 2, 3 & 4). Time trend analysis was made by plotting the quality cost variations of all the categories against each year (Figure 5 and Figure 6).

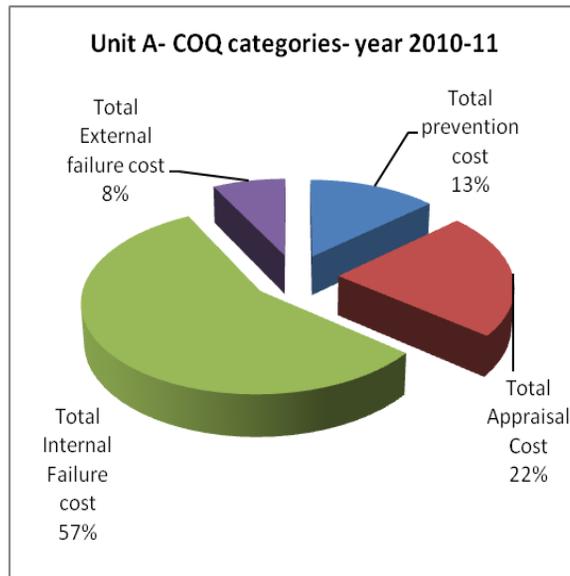


Figure 1. Percentage of COQ categories for Unit A-for the year 2010-2011

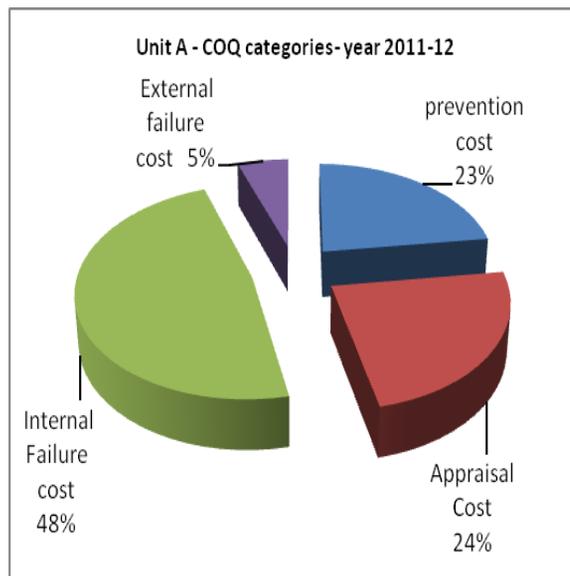


Figure 2. Percentage of COQ categories for Unit A-for the year 2011-2012

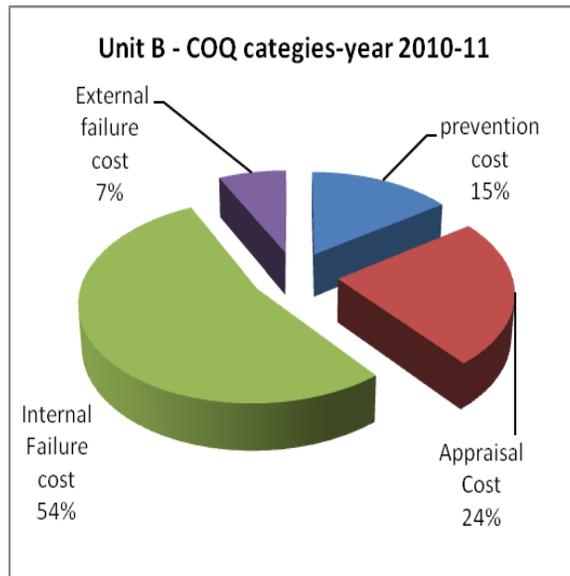


Figure 3. Percentage of COQ categories for Unit B- for the year 2010-2011

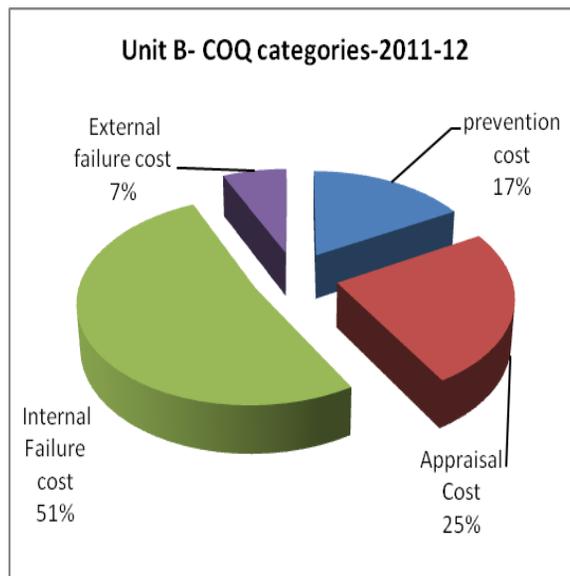


Figure 4. Percentage of COQ categories for Unit B-for the year 2011-2012

It is found that the Internal Failure Cost which comprises of all costs associated with the correction of all non conformities before the product delivery to the customer is the major contributor to the quality cost for all the 2 years under study. In the case of Unit

A, for the year 2010-11, internal failure cost is with 57% contribution, reduced to 48% for year 2011-12. On analysis, it is found that the corresponding prevention costs which are the costs incurred in proactive measures to ensure quality, are increased over these years

from 13% contribution to the total COQ to a 23 % contribution. Next major contributor is Appraisal cost, which is the costs incurred with checking the non conformities during different stages of manufacturing processes, is with 22% for year 2010-2011 and 24% for 2011-12. External failure costs, which are the costs incurred against quality failures after delivery to the customer, are the lowest contributing quality cost category and reduced from 8% to 5% along with the increase in prevention costs over the years

under study. Similar is the analysis results of quality cost categories of Unit B, where the internal failure cost with 54% contribution for the year 2010-11 reduced to 51% for 2011-12 as an impact the increase of prevention cost from 15% to 17%. In both the cases, the internal failure cost is the major quality cost category. The variations and inter dependencies of all other cost categories for unit B also shows a pattern similar to that of Unit A.

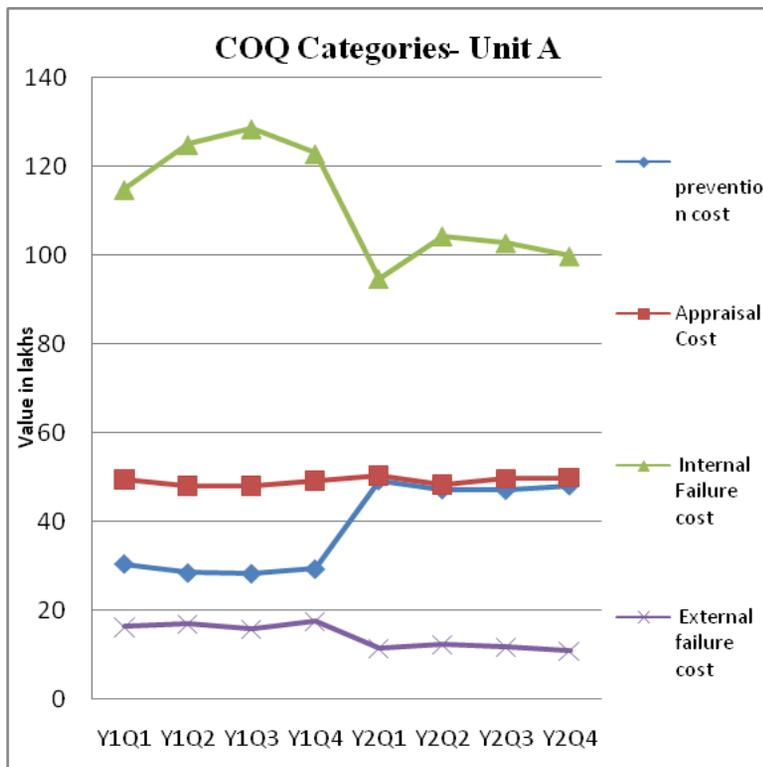


Figure 5. Quarterwise trend of COQ of unit A over time

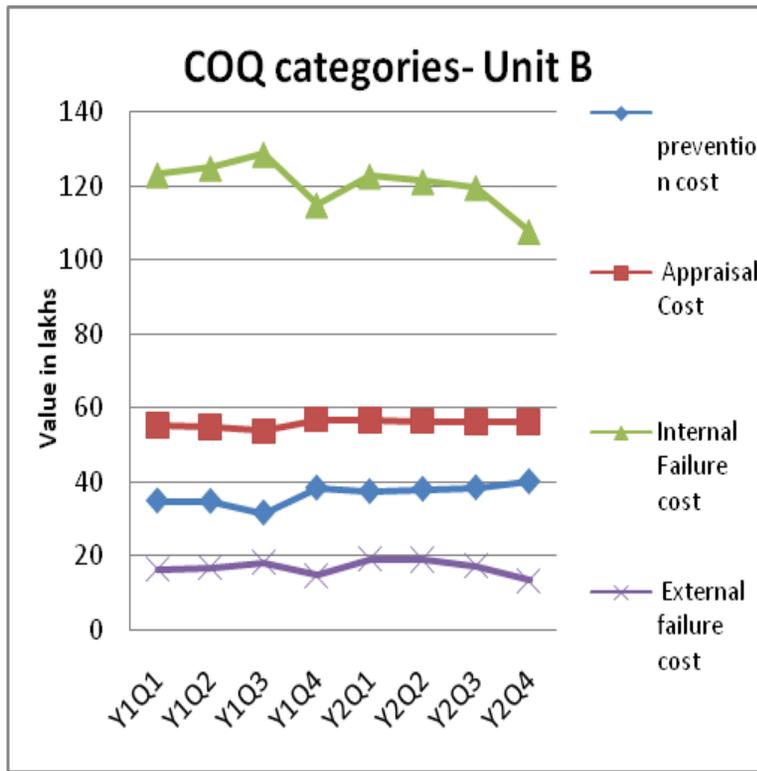


Figure 6. Quarterwise trend of COQ of unit B over time.

From the trend charts of quality cost categories over a period of 8 quarters, it is found that in both the manufacturing units, the internal failure cost found to be varying with a variation in the prevention costs and appraisal costs. Similar is the effect of variation in the prevention and appraisal costs to the external failure costs also. Appraisal costs seems to be almost stable over all the periods under study for both the units and impacts over appraisal cost is not very clear from trend charts. Dependence of other cost categories is not apparent from the trend charts.

For clear identification of the patterns of interrelationships between each of the quality cost categories, the Pearson product momentum correlation analysis used as the statistical tool. This correlation analysis of each quality cost category to the other categories is done for the data compiled for

all the 2 years under study for both the units using the data analysis tool package. Correlation analysis is done to identify the relationship between total conformance costs to total non-conformance costs also using statistical tools. Summary results of Pearson product momentum correlation analysis are as given in Table 3.

The Pearson product momentum correlation analysis reveals that the correlation between Prevention and Internal failure cost is very strong with negative correlation coefficient as -0.9589 and -0.8583 for units A and B respectively. This indicates an increase in Prevention cost follows with a decrease in the internal failure cost. The correlation between prevention and external failure costs also indicate a strong negative relationship. The correlation between appraisal and internal failure cost also is negative but comparatively weak. Similar is the

correlation between appraisal and external failure costs. However there exists a strong negative correlation between conformance cost and non conformance costs for both the manufacturing units. The between prevention and appraisal cost shows a positive correlation which indicates increase in appraisal cost along with prevention costs. Similar is the case of relationship between internal failure costs and external failure costs.

Another statistical tool used for analysis is the regression analysis which is used to explore and model the relationship between the quality cost categories and to assess the statistical significance of the estimated relationships, that is, the degree of confidence that the true relationship is close to the estimated relationship. Table 4 and 5 shows the results of regression analysis for manufacturing units A and B respectively.

Figure 7, 8 and 9 shows the graphical

representations of regression trend line analysis between Prevention costs to Internal failure costs, Prevention costs to external failure costs and cost of conformance to cost of non conformance for Unit A and Figures 10,11 & 12 represents the same for UnitB.

It is apparent from the above data and graphs, that for Unit A , the Prevention and Internal failure costs are having strong and statistically significant negative relationship at 95% confidence level. Similar is the relation ship with Prevention to external failure cost and cost of conformance to cost of non conformance. Where as the relation of prevention cost to appraisal cost category is significant positive at 95% confidence level.

The data of regression analysis and regression trend line graphs of manufacturing unit B also gives the similar relation ship patterns.

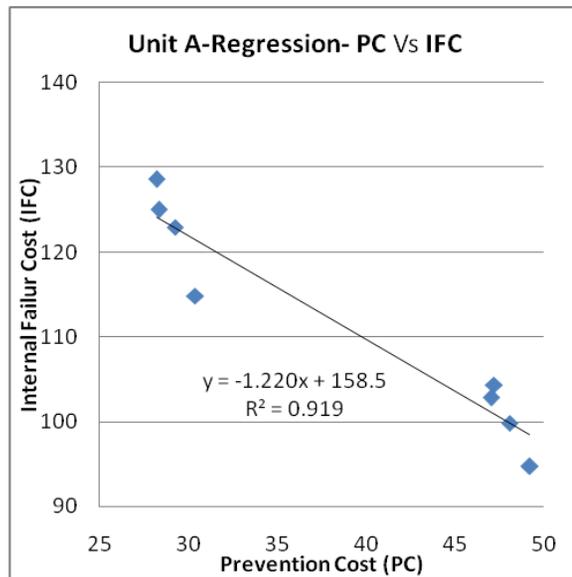


Figure 7. Regression analysis between prevention & Internal failure costs of Unit A

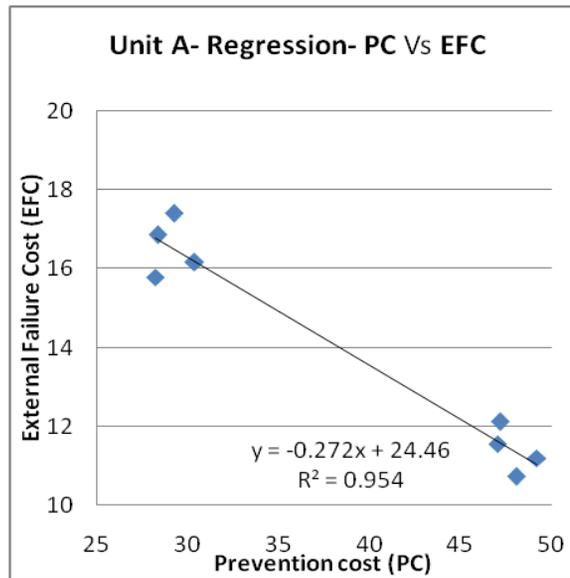


Figure 8. Regression analysis between prevention & External failure cost of Unit A

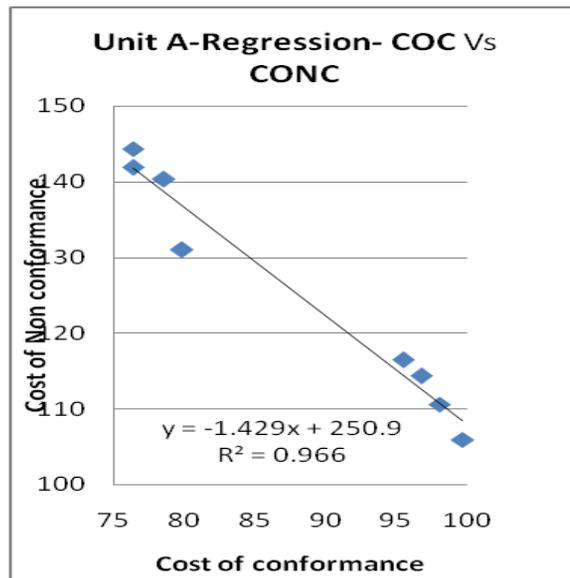


Figure 9. Regression analysis between Cost of conformance to cost of non-conformance of Unit A

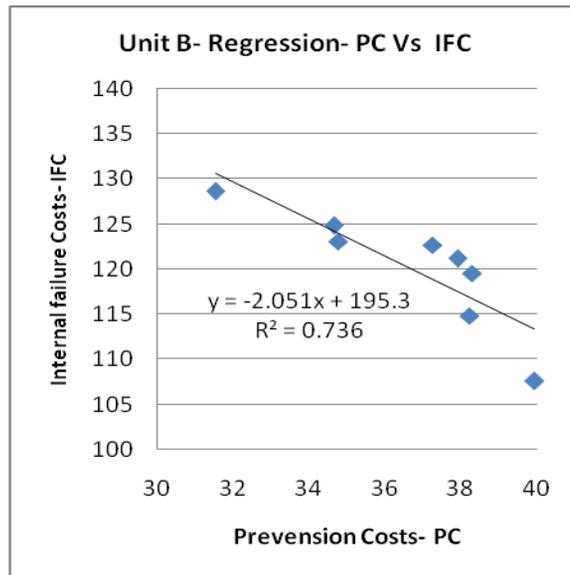


Figure 10. Regression analysis between prevention & Internal failure costs of Unit B

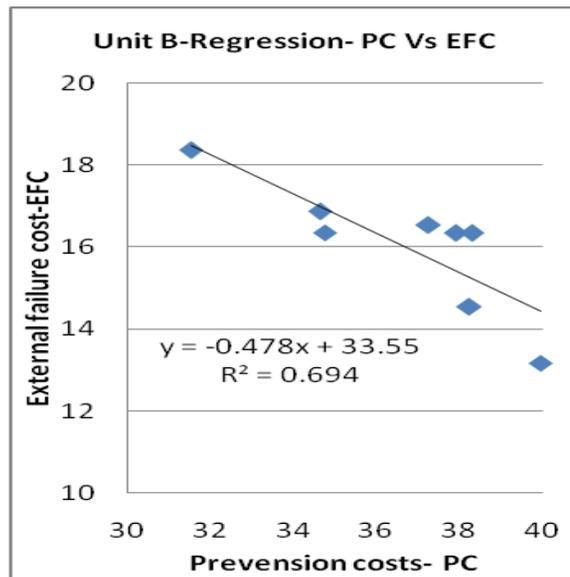


Figure 11. Regression analysis between prevention & External failure cost of Unit B.

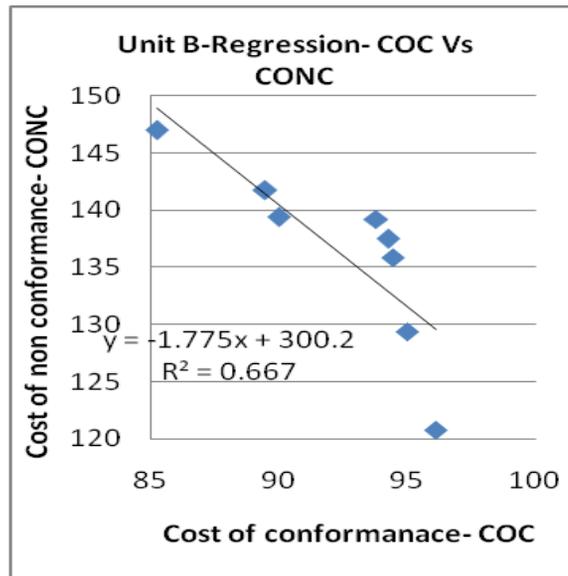


Figure 12. Regression analysis between Cost of conformance to cost of non-conformance of Unit A

4.1. Discussions

This study conducted among two manufacturing units under electronic manufacturing sector reveals the statistical interrelationship patterns between various quality cost categories. This also provides an insight to the major quality cost categories which is to be analysed further for cost reduction to achieve more productivity and profit for the firms under study.

Prevention cost found to be low which indicates the inadequacy of quality improvement programs, training and quality planning, which is slightly improved in the subsequent year, with a resultant increase in the prevention costs and decrease in the failure costs. Increase in Prevention and Appraisal costs gets reflected in Failure costs as identified from the analysis between cost of conformance and cost of non conformance also.

External Failure costs are less compared to internal failure costs. This is an indication of end product quality and less expenditure on field complaints and warranty supports. But this is achieved by spending more on

Appraisal costs as the analysis shows. This gives a picture that the firm is aiming at the customer satisfaction, but on the cost of its profitability.

The case study shows that the total quality cost in the Unit A is in the higher side than that of Unit B, and is exceeding 10% of the sales turnover in some of the quarters under analysis. Analysis reveals the lack of sufficient prevention activities and quality planning and higher internal failure costs in the firm during this period. Total quality cost shows reduction with the increase the prevention and appraisal costs.

The Pearson product momentum correlation analysis reveals the strong negative correlation between Prevention to Internal failure cost as well as cost of conformance to cost of non conformance. The regression analysis also confirms the strong and significant negative linear relationship between these two sets of quality cost categories with higher degree of confidence interval.

The existence of a strong negative correlation between appraisal cost and internal failure costs also confirmed with the

regression analysis as it results a strong linear negative regression model which is significant at 95% confidence interval. The existence of positive correlation between prevention and appraisal costs as well as between internal failure costs and external failure costs also confirmed further with the results of regression analysis. The interrelation ship patterns are found similar in both the units.

5. Limitations and future scope of study

The study focuses only on direct and visible costs which are easy to track and measure. No attempt is made to trace the hidden elements of quality costs. The intangible costs like cost of lost sales, loss due to customer dissatisfaction, cost associated with lost opportunities etc. were not considered in this Cost of Quality assessments. The study can be extended with the incorporation of these cost elements.

From this study it is identified that a strong negative correlation exists between cost incurred in the vendor qualification and education and the total cost of quality. The

analysis of interrelationship patterns can be extended with the inclusion of correlation and regression analysis of raw material quality with total quality costs.

6. Conclusion

This study provides an insight to the Cost of Quality practices prevailing in two manufacturing units under electronic industry in India. Detailed study on quality cost model used by this firm was made. The most critical quality cost categories were identified and the controlling factors were also analysed in detail. Using the Pearson product momentum correlation analysis and regression analysis, the interrelation ship patterns between different quality cost categories were identified and linear regression model has been identified for the inter relationships of most important quality cost categories . This provides an insight to the action priorities to control costs incurred in attaining quality and gaining profitability. Further this case study analyses the draw backs and limitations of the system in practice and also suggests future scope of the study.

Appendix:

Table 1. Year wise – Quarterly Quality Cost data for Unit A (Values in Lakhs)

Categories	Y1Q1	Y1Q2	Y1Q3	Y1Q4	Y2Q1	Y2Q2	Y2Q3	Y2Q4
Prevention Cost	30.38	28.35	28.20	29.24	49.22	47.19	47.04	48.08
Appraisal Cost	49.47	48.02	48.16	49.32	50.476	48.311	49.735	49.991
Internal Failure Cost	114.84	124.99	128.57	122.95	94.71	104.37	102.79	99.83
External Failure Cost	16.16	16.86	15.79	17.41	11.2	12.11	11.56	10.736
Total COQ	210.85	218.22	220.71	218.92	205.606	211.98	211.13	208.64
Sales Turnover	2136.00	2197.00	2185.00	2082.00	2566.0	2527.0	2618.0	2635.0

% COQ	9.87	9.93	10.10	10.51	8.0%	8.4%	8.1%	7.9%
Cost of Conformance	79.85	76.37	76.36	78.56	99.696	95.501	96.775	98.071
Cost of Non Conformance	131.00	141.85	144.36	140.36	105.91	116.48	114.35	110.57

Table 2. Year wise- Quarterly Quality Cost data for Unit B (Values in Lakhs)

Categories	Y1Q1	Y1Q2	Y1Q3	Y1Q4	Y2Q1	Y2Q2	Y2Q3	Y2Q4
prevention cost	34.77	34.65	31.53	38.24	37.26	37.91	38.30	39.95
Appraisal Cost	55.22	54.82	53.71	56.75	56.55	56.36	56.14	56.17
Internal Failure cost	123.06	124.85	128.63	114.84	122.68	121.16	119.54	107.60
External failure cost	16.353	16.86	18.36	14.54	16.53	16.34	16.34	13.17
Total COQ	229.403	231.18	232.23	224.37	233.02	231.77	230.32	216.89
Production value	3867	3678	3568	3987	3867.00	3678.00	3568.00	3987.00
% COQ	5.93%	6.29%	6.51%	5.63%	6.03%	6.30%	6.46%	5.44%
Cost of Conformance	89.99	89.47	85.24	94.99	93.81	94.27	94.44	96.12
Cost of Non Conformance	139.413	141.71	146.99	129.38	139.21	137.50	135.88	120.77

Table 3. Pearson Product Momentum Correlation Analysis between various cost categories.

	Unit A	Unit B
Correlation coefficient between Prevention & Appraisal cost	0.5782	0.9127
Correlation coefficient between Prevention & Internal Failure cost	-0.9589	-0.8583
Correlation coefficient between Prevention & External Failure cost	-0.9772	-0.8357
Correlation coefficient between Appraisal & Internal Failure cost	-0.7308	-0.65957

Correlation coefficient between Appraisal & External Failure cost	-0.5541	-0.67187
Correlation coefficient between Internal failure Cost & External failure cost	0.9252	0.9820
Correlation coefficient between Cost of Conformance & Non Conformance cost	-0.98301	-0.81704

Table 4. Regression analysis between major cost categories: Unit A

	Correlation Cofft.	Intercept	Slope	Regression model	Statistical Significance	Best fit
PC & IFC	0.95893	158.5853	-1.22077	$y = -1.22x + 158.58$	0.00017	92%
PC & EFC	0.97717	24.4607	-0.27254	$y = -0.2725x + 24.46$	0.00003	95%
PC & AC	0.57819	47.1641	0.05251	$y = 0.05251 x + 47.16$	0.13327	33%
COC & CONC	0.98301	250.9328	-1.42988	$y = -1.429 x + 250.93$	0.00001	97%

Table 5. Regression analysis between major cost categories: Unit B

	Correlation Cofft.	Intercept	Slope	Regression model	Statistical Significance.	Best fit
PC & IFC	0.858327	195.3115	-2.05096	$y = -2.051 x + 195.31$	0.006375	74%
PC & EFC	0.83357	33.55574	-0.47829	$y = -0.4782 x + 33.55$	0.010134	69%
PC & AC	0.91275	42.89588	0.350477	$y = 0.3504 x + 42.895$	0.001554	83%
COC & CONC	0.817044	300.2507	-1.77584	$y = -1.775 x + 300.25$	0.013286	67%

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A. Sailaja

School of Management
Studies
Indira Gandhi National Open
University,
India
sailjaasree@gmail.com

K.G. Viswanadhan

NSS College of Engineering,
Center for Quality
India
kgv1964@yahoo.co.in

P.C. Basak

Indira Gandhi National Open
University,
India
pcbask@ignou.ac.in
