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# COST OF QUALITY ANALYSIS AND ITS CALCULATION

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***Abstract***- *According to current scenario at any place quality might be a key issue and customer desire for quality is dynamic, Quality Cost (QC) gives off an impression of being a significant issue for associations to remain or develop their market. The aim of this paper is to build up numerical expressions to evaluate QC as key execution measure at supply line though considering quality Excellency level. Utilizing PAF (Prevention Appraisal Failure) model grouping to create numerical model and its joining with significant factors in supply line substances are the key strategy during this work. In addition, our expression is tested against constant quality expense of supply line in 2 periods, first at quality immatureness then at quality matureness period. Statistical tools are utilized in data collection of these expressions and look at its conduct inside these two periods.*

## 1. INTRODUCTION

In the current market scenario so as to broaden quality, an organization should think about the costs identified together with accomplishing quality so that the target of nonstop improvement projects isn't exclusively to fulfill customer request, anyway also to attempt to it at the base worth. This will exclusively occur by bringing down the costs expected to acknowledge quality, and furthermore the decrease of those expenses is scarcely potential on the off chance that they're known and quantifiable. Accordingly, movement and news the Quality Costs (QC) should be pondered as a pivotal issue for administrators. To quantify quality costs an organization needs to agree to a system to group costs; be that as it may, there's no broad single expansive meaning of cost costs. QC is regularly comprehended in light of the fact that the aggregate of understanding and non-conformance costs, any place estimation of understanding is that the worth obtained impedance of low quality (for instance, examination and quality evaluation) and estimation of non-conformance is that the costs of low quality brought about result and fix failures (for instance, work on and returns).

Quality Costs (QC) is a deceptive term. To anyone new to it, it sounds like a term that incorporates the cost you realize to convey a quality item. Be in the straightforward manner the term would be "The costs failing to make quality items." Quality Costs (QC) is characterized as a system that enables an association to gauge how much its assets are utilized for exercises for anticipation of low quality, that entrance the nature of the association's items or administrations, and that outcome from external and internal failures. Such data allows an association to decide the potential reserve funds to be earned by executing process enhancements.

1.1 Classification of QC: QC is classified according to Figure 1


**Figure 1** QC Classifications

1.2 Quality Cost Models

Since Juran introduced the Quality Cost, a few scientists have anticipated differed approaches for movement QC. During this segment, we are going to in a nutshell audit the ways to deal with measurement of QC.

Table 1 QC Models and Cost Categories

| Generic model | Cost/activity categories |
|---|---|
| P-A-F models | Prevention + appraisal + failure |
| Crosby's model | Prevention+Appraisal+Failure+Opportunity |
| Opportunity or intangible cost models | Conformance + non-conformance<br>Conformance + non-conformance + opportunity<br>Tangibles + intangibles<br>P-A-F (failure cost includes opportunity cost) |
| Process cost models | Conformance + non-conformance |
| ABC models | Value-added + non-value-added |

In concurrence with the approaches of past scientists blessing work orders QC models into 5 separate conventional groups that are: P-A-F or Crosby's model, cost models, process/procedure cost models and ABC models. These models are condensed under Table one.

## 2. METHODOLOGY

This paper is sorted as quantitative applied analysis. During this we tend to generate mathematical expressions and justify with real production -supply line quality costs knowledge, and valuate QC predictor for equivalent supply route to attain higher quality level.
We developed mathematical expressions so as to estimate costs of quality in production-supply line. Expressions employs QC as a performance live of all individuals among supply line.

### 2.1 Development of Mathematical Expressions

These expressions speak to a supply line based on a particular product to investigate quality costs as for an each and every item. So for getting higher exactness in results we would like to limit our expressions. So that these confinements will brings down the outer pertinence of the expressions, yet because of the inward difficulties in supply line, for example interest confliction, improvement line and greater system seems inescapable. Expressions presumptions will be:

1. Component requirement remains consistent throughout the complete path from provider to end-user.
2. The expressions are applicable in the prevailing producing corporations and not for establishing new path.
3. 100% Inspections are finished double throughout the complete production cycle. 1st is once the part is receives by the producer and second when the final products are close to be shipped
4. Review errors are of error kind one and error kind two. Error kind one is that the producer risk. Error kind two is that the client risk. Error kind one during this thesis is that the selection of fine part as a faulty one and error kind two is the selection of faulty component as a fine component.

The overall QC is nothing aside from total of all the cost classes. Expression's theoretical procedure flow sheet guide is shown in Figure 2.

#### 2.1.1 Input Parameters:

| | |
|---|---|
| QC | Quality Cost/Cost of Quality |
| $T_P$ | Total no. of product produced |
| QL | Total quality level achieved |
| D | Total demand |
| $A_P$ | Cost of production per item |
| $A_R$ | Cost of Rework per item |
| ξ | Rework rate |

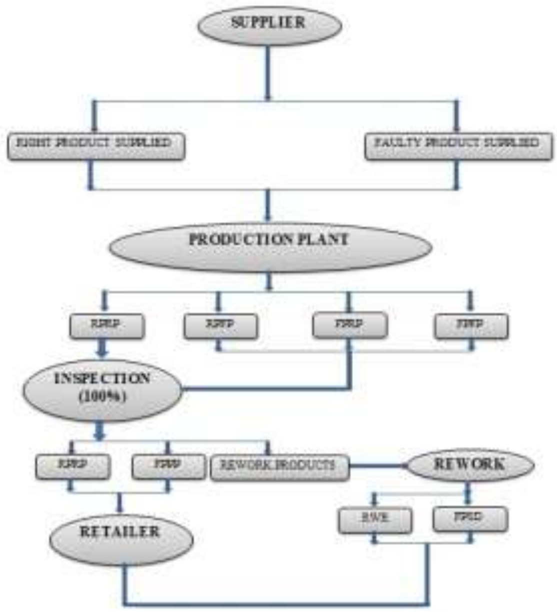


**Figure 2 Process flow chart of Supply Line using QC**

| | |
|---|---|
| $SP_R$ | Revenue received by selling quality products |
| $SP_F$ | Revenue received by selling faulty products |
| $PC_f$ | Fixed prevention cost |
| $PC_v$ | Variable prevention cost |
| $AC_f$ | Fixed appraisal cost |
| $AC_v$ | Variable appraisal cost |
| $IF_f$ | Fixed internal failure cost |
| $A_{EF}$ | Cost of return or replacement per item in external failure |
| $L_S$ | Loss due to faulty product supplied by supplier |
| H | Taguchi's Loss function |
| $F_s$ | Fraction of faulty products at supplier level |
| $F_r$ | Fraction of faulty products at retailer level |
| $F_P$ | Fraction of faulty products at production level |
| F | Overall percentage of faulty products |
| $F_{REL}$ | Relative value of quality characteristics |
| $I_E$ | Inspection error rate |

Various expressions are used in developing Quality Cost model i.e. to find out no. of products under various categories and these are given as under:

1. **Right Product under Right Production (RPRP):**

$$RPRP = (1-F_S)*T_P*(1-F_P)$$

2. **Right Product under Faulty Production (RPFP) i.e. defect caused by producer:**

$$RPFP = (1-F_S)*T_P*F_P$$

3. **Faulty Product under Right Production (FPRP) i.e. defect caused by supplier:**

$$FPRP = F_S*T_P*(1-F_P)$$

4. **Faulty Product under Faulty Production (FPFP) i.e. defect caused by both producer and supplier**:

$$FPFP = F_S*T_P*F_P$$

5. **Right Products after Rework (RPR):**

$$RPR = \xi*[\{(1-I_E)*T_P\}*\{(1-F_S)F_P+F_S\}$$

6. **Faulty Products Sold at a Discount (FPSD):**

$$FPSD = (1-\xi)*(1-I_E)*T_P*\{(1-F_S)*F_P+F_S\}$$

7. **Faulty Products at Production Process (FPPP):**

$$FPPP = I_E*T_P*\{(1-F_S)*F_P+F_S\}$$

8. **Right Products by Retailer to End User (RPRE):**

$$RPRE = (1-F_R)*[\{(1-F_S)*T_P*(1-F_P)\} +[\xi*(1-I_E)*T_P*\{(1-F_S)*F_P+F_S\}]]$$

9. **Faulty Products by Retailer to End User (FPRE):**

$$FPRE = F_R[\{(1-F_S)*T_P*(1-F_P)\} +[\xi*(1-I_E)*T_P\{(1-F_S)*F_P+F_S\}]]$$

### 2.1.2 Quality Cost Function (QCF)

PAF model is used to categorize QC components in these expressions and these are divided into 3 categories:

1. Internal and external failure
2. Prevention and
3. Appraisal

### 2.1.2.1 Prevention Cost *(PC)*:

Prevention costs are the cost related to all the operations performed to prevent quality dissatisfaction and is measured as the sum of fixed prevention cost and variable prevention cost:

$$PC = PC_f+[PC_v*\{(1-F_S)*T_P*(1-F_P)\}]$$

Here; $\{(1-F_S)*T_P*(1-F_P)\}$ represents right products under right production (RPRP).

### 2.1.2.2 Appraisal Cost *(AC)*:

Appraisal costs are the costs of conformance regarding quality requirements. For example; quality audits, cost of test equipment, inspection costs etc. Appraisal cost is measured as the sum of both fixed and variable appraisal cost. Fixed cost consists of instrument costs, labour work in maintaining quality level and inspection cost etc. Variable cost depends on the accuracy of inspection. Appraisal cost is given by:

$$AC = AC_f+\{AC_v*(1-I_E)*T_P\}$$

Here; $[(1-I_E)*T_P]$ is the quantity of the products which are defective because of inspection error after 100% inspection.

### 2.1.2.3 Internal Failure Cost (IFC):

Internal failure cost is the cost of products which are not confirming the targeted quality level before reaching in the hand of end user. In internal failure cost 100% inspection is done and right product is selected as right & faulty product as faulty and also the faulty product selected as right product because of inspection error.

Followings are the components of internal failure cost:

i. Cost of rework ($A_R$) i.e. faulty product selected as faulty goes for rework.
ii. Fixed cost for internal failure ($IF_f$) i.e. cost of labour work for corrective action, tool rework etc.
iii. Direct production cost ($A_P$).
iv. Purchasing cost i.e. capital loss due to inadequate quality purchase. Finally the internal failure cost is given by:

$$IFC = [IF_f+\{(A_P+A_R)*\xi*(1-I_E)*RPFP\} +\{(L_S+A_M+A_R)*\xi*(1-I_E)*(FPRP+FPFP)\} +\{(SP_R-SP_F)*FPSD\}]$$

### 2.1.2.4 External Failure Cost (EFC):

External failure cost is the cost associated with defective product reached in the hand of end users. Followings are the components of external failure cost:

i. Faulty products returned by customer either for return or replacement i.e. $\{A_{EF}*(FPRE+FPPP)\}$.
ii. Taguchi Loss function.

External Failure Cost can be calculated as:

$$EFC = \{A_{EF}*(FPRE+FPPP)\}+h(F_{rel})^2$$

Here; $F_{rel}$ is the difference between the measured amount of quality character and required amount of quality character and is known as relative quality character.

Taguchi loss function is given as:

$$\text{Loss at any point 'x' i.e. } L(x) = h*(F-t)^2$$

Here; 'F' is the measured cost of quality characteristics and is given as overall percentage of faulty products and measured as:

$$F = \frac{FPRE+FPPP+FPSD}{D} * 100\%$$

't' is the target value of quality characteristics and is measured as:

$$t = \{(F_R+F_S(1-\xi)(1-F_R)\}*100\%$$

*'h'* is the coefficient for taguchi loss function and is given as:

$$h = \frac{Specification\ Limit}{Specification\ Width}$$

### 2.1.2.5 Total Quality Cost Function (QC):

Total quality cost is the sum of prevention, appraisal, internal failure, and external failure cost and is expressed as:

$$QC = AC+PC+IFC+EFC$$

### 2.1.2.6 Overall Quality Level (QL):

Overall quality level is the level of quality achieved by an organization and is expressed as:

a. In terms of production:

$$QL = \frac{Actual\ Quantity\ of\ Right\ Products\ Produced}{Total\ Quantity\ of\ products\ Produced} * 100\%$$

b. In terms of customer satisfaction:

$$QL = \frac{Actual\ Quantity\ of\ Right\ Products\ Reaches\ to\ end\ users}{Total\ Demand} * 100\%$$

## 3. TRENDS OF DATA COLLECTED

Here in our paper we have gathered 18 samples obtained from production line in two slots. First slot is of 8 points and another is of 10 points respectively for respective month. Data are represented in percentage of overall revenue received by selling of components.

**Table 2 Statistical Data of Complete Sample**

| | *QL* | *Prevention Cost Percentage* | *Appraisal Cost Percentage* | *Internal Failure Cost Percentage* | *External Failure Cost Percentage* | *Total Quality Cost Percentage* |
|---|---|---|---|---|---|---|
| **Mean** | 0.85 | 0.068 | 0.050 | 0.068 | 0.015 | 0.019 |
| **Median** | 0.73 | 0.069 | 0.052 | 0.061 | 0.016 | 0.19 |
| **Standard Deviation** | 0.0728 | 0.010 | 0.00078 | 0.0071 | 0.0004 | 0.0083 |
| **Sample Variance** | 0.0042 | 0.00010 | 0.05302 | 0.060931 | 0.018921 | 0.057763 |
| **Range** | 0.32 | 0.038 | 0.038 | 0.037 | 0.018 | 0.048 |
| **Minimum** | 0.55 | 0.036 | 0.031 | 0.049 | 0.010 | 0.19 |
| **Maximum** | 0.80 | 0.067 | 0.074 | 0.085 | 0.024 | 0.20 |
| **Count** | 18 | 18 | 18 | 18 | 18 | 18 |

**Table 3 Statistical Data of First Sample**

| | *QL* | *Prevention Cost Percentage* | *Appraisal Cost Percentage* | *Internal Failure Cost Percentage* | *External Failure Cost Percentage* | *Total Quality Cost Percentage* |
|---|---|---|---|---|---|---|
| **Mean** | 0.66 | 0.055 | 0.048 | 0.074 | 0.025 | 0.212 |
| **Median** | 0.67 | 0.058 | 0.050 | 0.073 | 0.024 | 0.223 |
| **Standard Deviation** | 0.07 | 0.010 | 0.0097 | .0075 | 0.0038 | 0.012 |
| **Sample Variance** | 0.006 | 0.00011 | 0.06625 | 0.03685 | 0.01284 | 0.0001 |
| **Range** | 0.26 | 0.035 | 0.038 | 0.028 | 0.013 | 0.035 |
| **Minimum** | 0.58 | 0.037 | 00.032 | 0.061 | 0.019 | 0.188 |
| **Maximum** | 00.78 | 0.072 | 0.067 | 0.084 | 0.036 | 0.235 |
| **Count** | 08 | 08 | 08 | 08 | 08 | 08 |

**Table 4 Statistical Data of Second Sample**

| | *QL* | *Prevention Cost Percentage* | *Appraisal Cost Percentage* | *Internal Failure Cost Percentage* | *External Failure Cost Percentage* | *Total Quality Cost Percentage* |
|---|---|---|---|---|---|---|
| **Mean** | 0.75 | 0.072 | 0.052 | 0.059 | 0.0162 | 0.208 |
| **Median** | 0.78 | 0.078 | 0.056 | 0.060 | 0.0163 | 0.206 |
| **Standard Deviation** | 0.0273 | 0.0028 | 0.0051 | .0041 | 0.0014 | 0.008 |
| **Sample Variance** | 0.00069 | 0.02820 | 0.01950 | 0.011362 | 0.014412 | 0.046279 |
| **Range** | 0.1123 | 0.0075 | 0.0223 | 0.016 | 0.006 | 0.036 |
| **Minimum** | 0.701 | 0.068 | 0.046 | 0.050 | 0.012 | 0.192 |
| **Maximum** | 0.850 | 0.075 | 0.0708 | 0.067 | 0.019 | 0.228 |
| **Count** | 10 | 10 | 10 | 10 | 10 | 10 |

## 4. RESULTS:

**Analysis 1:**

In Juran's trade off behavior, quality costs knowledge ought to have these two aspects:

1. Increment in conformance cost can result in the decrementing trend in nonconformance cost.
2. Economic QC point should exist, i.e. for a particular quality level QC is lowest.

**Analysis 2:**

Another analysis is that the 2nd group of samples is either behaving likes continuous improvements models or not. This model ought to have conjointly subsequent aspects:

1. Decrement in nonconformance costs is obtained in controlling or perhaps lowering the quantity of corresponding cost.
2. Economic QC point absent and hence the lowest QC is obtained at where perfection is achieved.

Result for Analysis 1

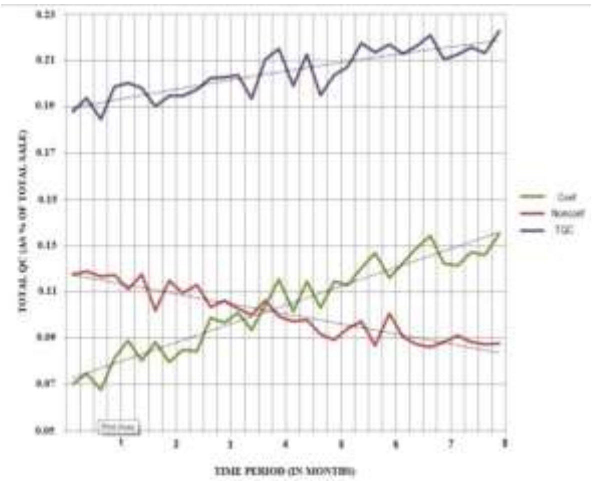

**Figure 3 Trend of QC for First Sample**

For verifying the trend for initial sample, a plot of QC against time is needed. In the above diagram QC expenses as a fraction of total revenue for 8 months.

The trend shown here is linear i.e. QC is growing with time. Also, decrement in nonconformance costs can be achieved by increment of conformance costs. Hence primary condition of model is satisfied. Now for satisfying 2nd criteria there should be no optimum QC point and also some native points are present. For example here for the month three to four are the relative optimum QC points. Hence 2nd condition is also satisfied. So Juran's model is satisfied.

Result for Analysis 2

Now in 2nd sample also both criteria of continuous improvement are to be satisfied. According to the figure 3 trend shows that the overall quality costs are perpetually lowering hence nonconformance costs are also lowered. Hence the initial condition is satisfied.

Now the absence of optimum QC point in gathered data in 2nd sample, hence, another criterion is also satisfied. As a result samples behavior shows continuous improvement.

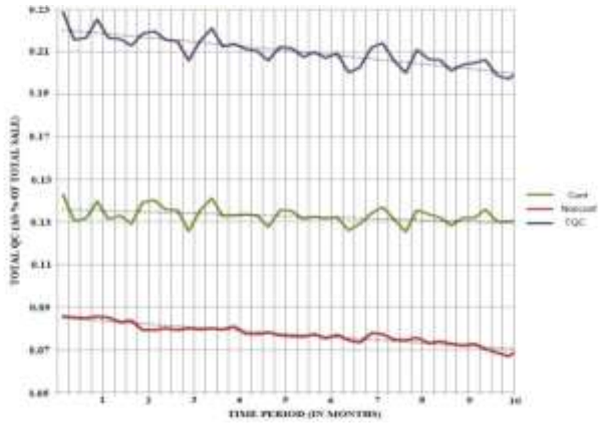

**Figure 4 Trend of QC for Second Sample**

Overall Result

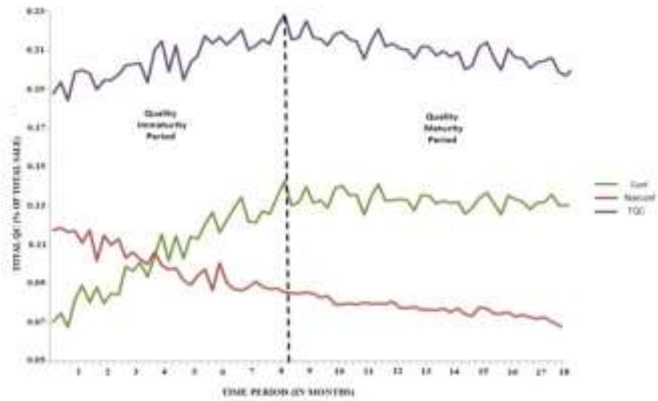

**Figure 5 Trend of QC for Complete Sample**

According to above diagram, 2 types of behavior is shown by the data collected for 18 samples. Here in diagram total QC is represented as percentage of overall revenue obtained by selling of items within the supply line. In the above diagram the cost of highest QC is seen in point no. 8 and it is taken as separation between two samples. Here in 1st sample i.e. up to 8 follows Juran's model and from 9 to 18 follows continuous improvement model. Here these two intervals are known as quality matureness and immatureness intervals respectively.

## 5. CONCLUSION

QC classification under PAF model has been utilized to develop mathematical expressions for total QC. Based upon idea of our results the QL shows increment once the QC increases in quality matureness span and, also, increase in level of quality aren't basically leads by greater quality costs in quality matureness span. Prevention costs shows two completely different behavior in two groups of data i.e. in quality matureness and immatureness respectively. In case of appraisal costs the errors in inspection at producer and supplier level in quality immatureness affects appraisal cost. However it is not significant in in matureness span.

Hence appraisal cost depends on errors in inspection at producer stage in matureness span and goes on decreasing continuously by the effect of continuous improvement. And at last, based on data analysis IFC is predominant predictor of total IFC. On the other hand we can say that IFC can be taken as IFC variable costs.

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