A Review Research of Mathematical Models of Quality Cost for Manufacturing Industry.

Vinod G. Surange , S.N.Teli , Ankur M. Halankar , Dinesh S. Saroj , Siddhesh S. Rane , Datta D. Adak

Abstract--Present techno-economic scenario is marked by increasing competition in almost every sector of economy. The expectations of the customers are on the rise and manufactures have to design and produce goods in as much variety as possible to cater to the demands of the customers. Thus, there is a challenge before industries to manufacture goods of right quality and quantity and at right time and at minimum cost for their survival and growth. This demands an increase in productive efficiency of the organizations. In addition to this, the industry was also weakened by the increase in the fuel prices. The car manufacturers are relying on the creative marketing strategies for overcoming this situation. Even the companies are offering high discount rates to boost up the market. Better designs are introduced into the market too. Even the flagship models of the major manufacturers are offered in the market with heavy discounts. However, the automobile manufacturers are keeping their fingers crossed as they expect the crisis to end in the near future. As organizations strive to increase their bottom line performance in this highly competitive environment they often forget to integrate two important planning activities, strategic and quality planning. This is likely due to a lack of understanding of the cause and effect relationship between strategy, quality, productivity, profitability and competitiveness. To maximize the profits of an organization it is necessary to align the objectives and priorities of the business. The cost of poor Quality would help in analyzing the operating costs for effective and profitable business management. Paper examines the market-oriented aspects of Cost of quality using study of the relationship between unit cost and economies of scale, experience curve effects, and imputed cost of quality in a specific context. This paper proposes a new model for the COQ, which captures the value of continuous process improvement in achieving economic operation. The model given is based on Activity-Based Costing (ABC) Method. The application of computer is widely carried out in many companies. Firstly, COQ system structure is built in Computer Integrated Manufacturing Systems (CIMS) environment. Secondly, the function structure of the COQ accounting system is suggested. In the function structure the Input and Output relationship of information is shown between many sub-systems. Thirdly, the allocation method which uses two-stage procedure to assign quality resource costs is adopted when calculating COQ. Next, a model for computing the COQ of a supply chain is provided. The proposed model aims to serve as a decision making tool for engineering managers by helping with the design and quality planning of logistic routes for manufacturing plants in the design phase. Our model computes COQ in terms of internal operational decisions such as the error rate at inspection and fraction defective at manufacturing. The model can be used to design a logistic route that achieves a minimum total cost while maintaining an overall quality level and to evaluate the impact of investment in quality to increase overall profits.

Keywords*:* COQ, CIMS, ABC Method, ERP, MES.

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1   INTRODUCTION

In the era of cut throat completion, success achieved by market leaders is credited to their improvement initiatives. A common element within many of these successful companies is the use of powerful cost of poor quality concepts in connecting improvement priorities to strategic objectives, assessing the financial impact of poor quality, understanding the root causes of poor quality, selecting high payback improvement projects and managing the Improvement initiative to simultaneously deliver improved financial performance and greater customer satisfaction. Quality costs or Cost of Quality is a means to quantify the total cost of quality-related efforts and deficiencies. The "cost of quality" isn't the price of creating a quality product or service. It's the cost of NOT creating a quality product or service. Quality Costs represent the difference between the actual cost of a product or service and what the reduced cost would be if there was no possibility of substandard service, failure of products, or defects in their manufacture. Fundamentally every time work is redone, the cost of quality increases. Quality costs are a measure of the costs specifically associated with the achievement or non-achievement of product or service quality-including all product or service requirements

established by the company and its contracts with costumers &society.

More specifically quality costs are total of the cost incurred by-

(a)Investing in the prevention of nonconformance's to requirements.

(b)Appraising a product or service for
 conformance to requirements.

(c) Failing to meet requirements.

Juran defines quality as fitness for use in terms of design, conformance, availability, safety, and field use. Thus, his concept more closely incorporates the viewpoint of customer. Juran broadened the definition of quality from conformance to specification to "fitness for use". He also considered two aspects of quality. One is "freedom from deficiencies" and other is "product features".

Models of Optimum Quality Cost:

Old Model of optimum quality costs:

Previously prevention and appraisal costs were portrayed as rising asymptotically as defect-free levels were achieved as shown in fig. below.
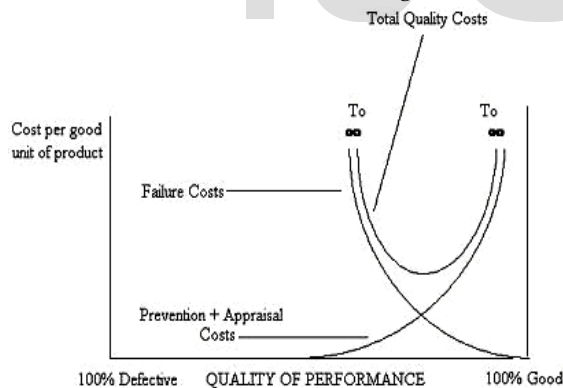

Figure1: Old Model of optimum quality costs

New model of optimum quality costs:

There is increasing evidence that the processes of improvement and new loss prevention are in themselves subject to increasing cost effectiveness. New technology has reduced inherent failure rates of materials and products, resulted in an ability to achieve perfection at finite costs.
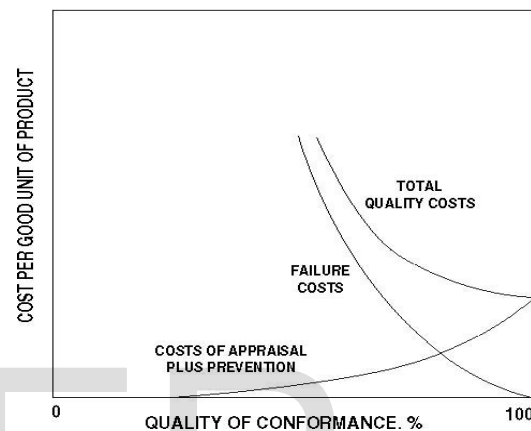

Figure2: New Model of optimum quality costs

COQ AND ABC METHOD

The main shortcoming of traditional cost accounting is to distribute overhead costs over products by using volume related allocation bases such as direct labor hours, direct labor costs, direct material costs, etc. It will not seriously distort the product cost in the conventional manufacturing environment where overheads are just a small portion of product cost. In the modern manufacturing environment, however, the overheads will grow rapidly as manufacturers increasingly promote the level of computerization and automation, and the cost distortion of traditional cost accounting will be significant. The main reason is that many overhead costs vary with product diversity, and volume-unrelated activities, not with the volume-related measures. In view of this, Cooper and Kaplan suggested using ABC to improve the accuracy of product costs. In early ABC systems, overhead cost is divided into various cost pools, where each cost pool contains

the cost of a group of related activities consumed by products in approximately the same way. Each cost pool is distributed to products by using a unique factor that approximates the consumption of cost.
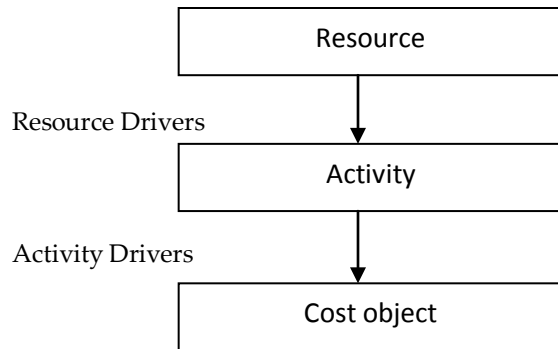
The principle is shown in Fig. 3.
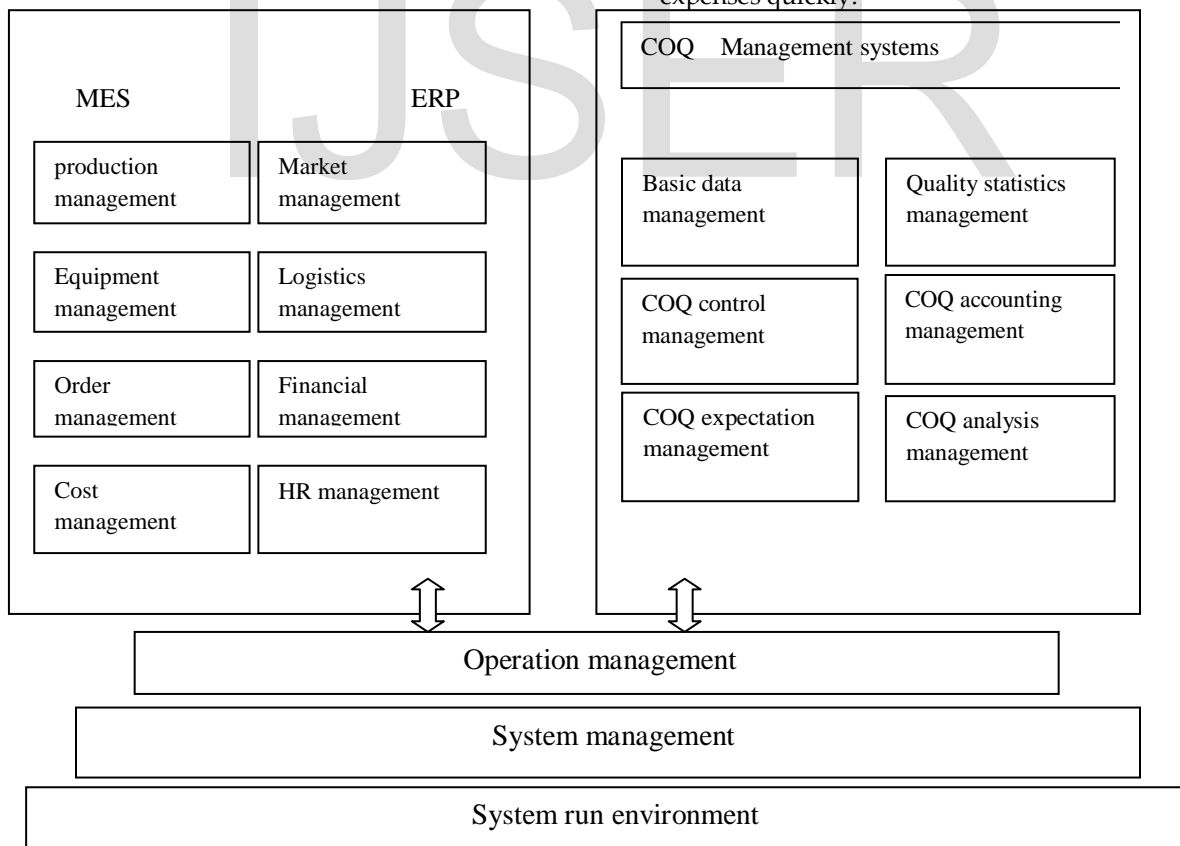

Figure3: Principle of Activity-Based Cost Method

COQ System in CIMS Environment

The information, which is required by COQ management system, is in connection with the marketing information, techniques information, logistics flow information, capital flow information in the process of operation, and even the management information between different departments and so on. COQ management system is an important part of closed-loop control in the whole enterprise CIMS. That is to say, it should be comprehensive integrated with production management system, equipment management system, orders management system, finance system, cost management system, sales management system, logistics management system, HR management system, and so on. It can collect data information generated by above-mentioned system, and collect or distribute the expenses quickly.

Fig.4: System Structure for COQ in CIMS environment

And it also can raise the computing timeliness and accuracy of the multi object of quality cost. At the same time, through the COQ analysis and control system, quality process dynamic control can be achieved. The level quality cost management is to be raised. As above described, the structure is shown in Fig. 4. System Structure for COQ in CIMS environment.

There are three important parts in the COQ management system structure. They are special business management, such as MES (Manufacturing Executive System) and ERP (Enterprise Resource Planning), operation management and system management. The business management mainly achieves special COQ function, which includes basic data management, Quality statistics management, COQ accounting management, COQ expectation management, COQ analysis management, COQ control management, and interface to other business management system. The interface module mainly includes ERP and MES system. Operational management system is to achieve the operational activities, scheduling and monitoring of different business management system as well as information communication. The main function of system management is to supervise rights management, system log management,information mechanism management, database management as well as system component services.

THE RULES OF ACCOUNTING COQ

There are some important rules in the process of accounting COQ as follow:

A. Drawing Quality Resources from Business Process

The resources are generated during the quality process, so they should be collected from design to sales or Recycle. The resources used by quality-related activities may be people, computers, equipment, material, supplies, facilities, energy,

and so on. In the CIMS environment, resources information related to quality can be got from financial management system which supports indirect resources and logistics management system which supports direct marked resources. These resources constitute the resource set, as $\{R_j\}$ $(0 \le j \le n$, n is the no. of resources).

B. Dividing Classification of the Quality Resources

Quality cost subjects should be set up as shown in Tab.1.The first level is "quality cost", and below it, "Product Quality Element Costs"(PQEC) and "Quality Management Fee"(QMF) are set as the second level. The first one includes direct material, direct labor and manufacturing costs accordingly. That is a part of the third level. Under the "Quality Management Fee", there is "Prevention Fee", "Appraisal fee", "Internal Failure Fee", "External Failure Fee".$\{R_j\}$ should be divided into these cost subjects. One cost subject can include several resources. After dividing, $\{R_j\}$ becomes $\{R_j^i\}$ $(0 \le i \le m$, m is number of cost subject).

C. Assigning Quality Resources to Activities

In the first stage of ABC cost allocation view, resource costs of the company are traced to various quality activities by using resource drivers. And this process will be expressed as $\{R_j^i A_g\}$ $(0 \le g \le a$, a is number of activities). It means that activity $\{a_g\}$ consumes the resource $\{r_j^i\}$ .And the formula of activity cost is shown in Eq. (1).

$$C\,(a_g) = \sum_{i=1}^{m} R_j^i \, A_g R_j^i \qquad (1)$$

That is activity $\{a_g\}$ consumes m kinds of resources, $\{R_j^i\}$ is the quality resources which are classified in Tab. I.

Table. I: Quality cost subject

Quality Cost						
Product Quality Element Cost			Quality Management Fee			
Direct Material	Direct Labor	Depreciation	Appraisal	Prevention	Internal Failure	External Failure

D. Assigning Expense from Activities to Products

After finishing the first assigning period, activities cost should be diverted into cost objects. We suggest selection of the product batch as the cost object, because production organization is usually in batch in most companies. It can also help managers to control the planning and the allocation of tasks in information systems. It is proposed to calculate the COQ of batches through the cost distribution and summary. Product batches are generated in accordance with

group information, and each batch can be marked as $\{P_t\}$ ($0 \le t \le p$, p is number of products), which is the product set. In the second stage of ABC allocation, production batch consumes the activities. This period can be described as $\{A_g P_t\}$ ($0 \le g \le a$, a is number of activities). This means production P_t consumes activity a_g and the equation is as:

$$C(a_g, P_t) = C(a_g) \times \frac{A_g P_t}{\sum_{t=1}^{p} A_g P_t} \qquad (2)$$

Eq. (3) described the batch P_t consumes activity a_g cost:

$$C(a_g, P_t) = \sum_{i=1}^{m} R_j^i A_g R_j^i \times \frac{A_g P_t}{\sum_{t=1}^{p} A_g P_t} \qquad (3)$$

The final quality cost of product batch P_t is the sum of all the activities cost which is consumed by P_t , as in Eq. (4).

$$C(P_t) = \sum_{g=1}^{a} \sum_{i=1}^{m} R_j^i A_g R_j^i \times \frac{A_g P_t}{\sum_{t=1}^{p} A_g P_t} \qquad (4)$$

Accounting to the model, we can get the actual COQ and the cost subject defined as product batches is more accurate than product.

Mathematical model II

Although we compute the COQ for a specific selection of supplier, manufacturing plant, and retailer, the notation is presented in its general form, that is, the model is formulated to represent selection of one supplier among a set of suppliers; and likewise for plants and retailers.

Sets

I set of suppliers

J set of manufacturing plants

K set of retailer

Parameters for COQ computation

W number of components going through the manufacturing process and delivered to customers

Ys_i fraction defective at selected supplier i

Yr_k fraction defective at selected retailer k

Dem customer demand

Af Fixed cost for prevention activities

Av Variable cost for prevention activities

Bf Fixed cost of inspection at the end of the manufacturing process

Bv Variable cost of inspection at the end of the manufacturing process

Cf Fixed cost for internal failure cost

Cs Loss incurred due to failure of purchased components from supplier to meet quality requirement.
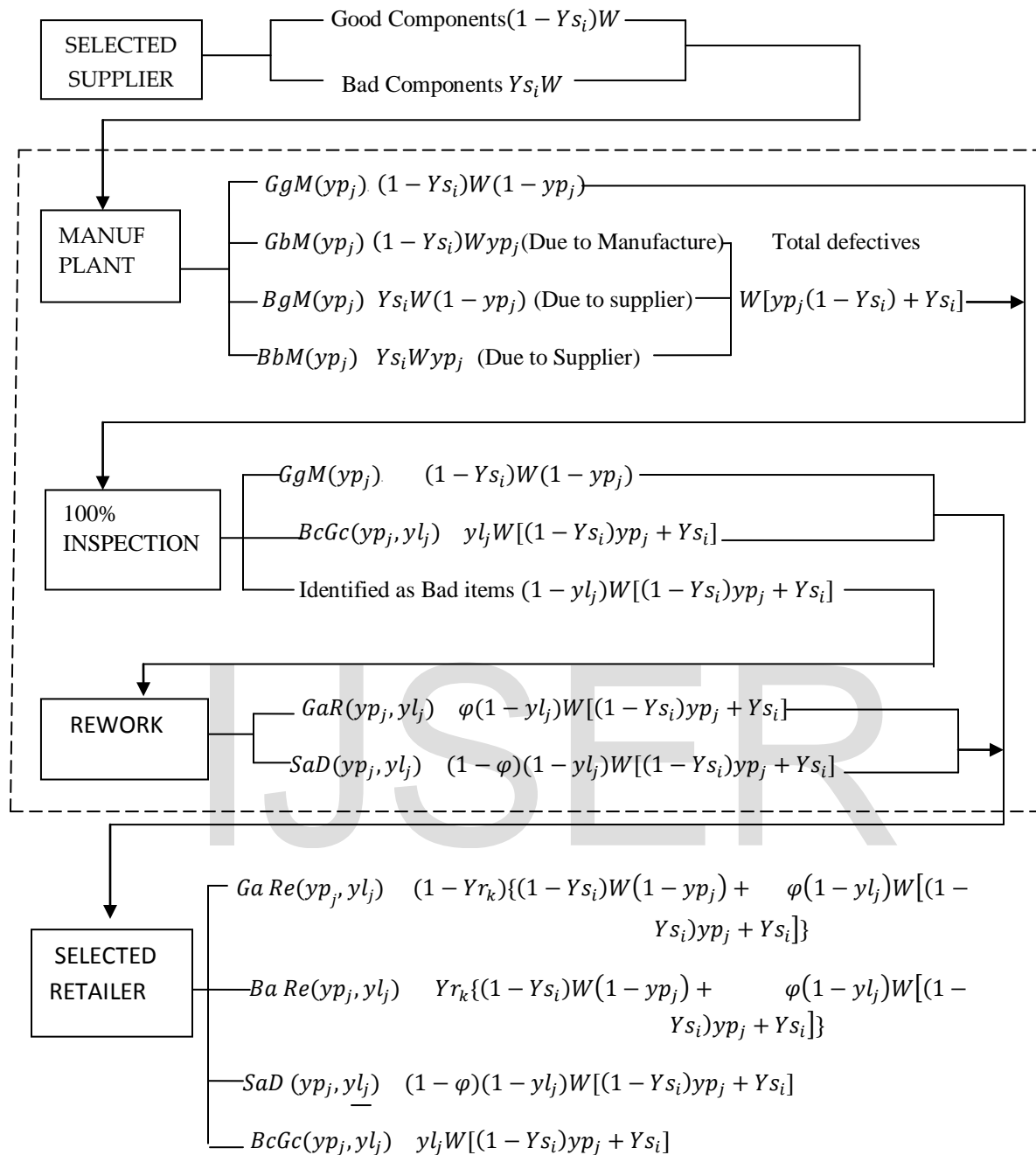
Serial supply chain with a manufacturing plant and inspection after manufacturing.

Cm Direct manufacturing cost per processed item that goes to rework

Cr Rework cost per item

Φ rework rate at the manufacturing plant j

C_{EF} cost per defective item related to repair or replace the product.

k   coefficient of the Taguchi loss function. k represents the cost of working at the specification limit divided by the width of the specification.

P_1 price per sold item paid by retailer k to manufacturing plant j.

P_2 price per 'sold as defective' item paid by retailer k to manufacturing plant j.

Expressions

$GgM(yp_j)= (1 − Ys_i)W(1 − yp_j)$ represents good components with a successful manufacturing

$GbM(yp_j) = (1 − Ys_i)Wyp_j$ represent good component with a failed manufacture. These defective products are due to the manufacturing.

$BgM(yp_j) = Ys_iW(1 − yp_j)$ represents bad components with a successful manufacture. These defective products are due to the supplier

$BbM(yp_j) = Ys_iWyp_j$ represents bad components with a failed manufacture. These defective products are due to the supplier

$GaR(yp_j, yl_j) = φ(1 − yl_j)W[(1 − Ys_i)yp_j + Ys_i]$ function that returns the number of good products after successful rework

$SaD(yp_j, yl_j) = (1 − φ)(1 − yl_j)W[(1 − Ys_i)yp_j + Ys_i]$ function that returns the number of defective products which will be sold at a reduced price

$BcGc(yp_j, yl_j) = yl_jW[(1 − Ys_i)yp_j + Ys_i]$ function that returns the number of bad products after entering the manufacturing process

$$Ga\,Re(yp_j, yl_j) = (1 − Yr_k)\{(1 − Ys_i)W(1 − yp_j) + φ(1 − yl_j)W[(1 − Ys_i)yp_j + Ys_i]\}$$

$BgM(yp_j) = Ys_iW(1 − yp_j)$ represents   bad components with a successful manufacture. These defective products are due to the supplier

$BbM(yp_j) = Ys_iWyp_j$ represents bad components with a failed manufacture. These defective products are due to the supplier

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$BcGc(yp_j, yl_j) = yl_jW[(1 − Ys_i)yp_j + Ys_i]$ function that returns the number of bad products after entering the manufacturing process

$$Ga\,Re(yp_j, yl_j) = (1 − Yr_k)\{(1 − Ys_i)W(1 − yp_j) + φ(1 − yl_j)W[(1 − Ys_i)yp_j + Ys_i]\}$$

function that returns the number of good products after the retailer that are delivered to the final customer

$Ba\,Re(yp_j, yl_j) = Yr_k\{(1 − Ys_i)W(1 − yp_j) + φ(1 − yl_j)W[(1 − Ys_i)yp_j + Ys_i]\}$ function that returns the number of bad products after the retailer that are delivered to the final customer

$y(yp_j, yl_j)$ overall percentage of defective products

$QL(yp_j, yl_j)$ overall quality level achieved by the supply chain

$COQ(yp_j, yl_j)$ total cost of quality given by the sum of the costs of internal and external failure, prevention, and appraisal

Decision variables

yp_j fraction defective at the manufacturing plant j

yl_j inspection error rate at the manufacturing plant j

Prevention cost

The prevention cost (CP) is related to all activities related to the prevention of poor quality. In this model, prevention cost is linked to the production of good products after the manufacturing process as shown in Eq. (1):

$$C_p = A_f + A_v(1 − Ys_i)W(1 − yp_j)$$

where A_f is a fixed cost and A_v is a variable cost for prevention activities. The reasoning is that by increasing good components with successful manufacture, the overall quality level will improve and such items will not incur rework costs.). Ys_i means that supplier selection is part of the prevention activities (other supplier related costs could be supplier reviews and purchasing prevention costs). Ys_i is a constant in the model since the company has already picked a specific supplier which meets the company's requirements.

Appraisal cost

A 100% inspection is performed at the end of the manufacturing process to verify conformance. The appraisal costs (CA) are modeled by a fixed cost (cost of maintenance of a measurement system; that is, measurement equipment expenses, inspection labor, laboratory support, review of test, and inspection data) and a variable cost per item that is classified accurately (performance of the evaluation). Thus, the appraisal cost increases when inspection is more accurate. The appraisal cost is given by Eq. (2):

$$C_A = B_f + B_v(1 - yI_j)W$$

where B_f is a fixed cost and B_v is a variable cost. W represents the number of items to be inspected (all the components going through the system are inspected).

Internal failure cost

The internal failure cost comprises the costs arising from inadequate quality discovered before the transfer of ownership from manufacturing plant to retailer. After inspection, the products are classified as good products, bad products identified as bad, and bad products not identified as bad (due to error rate at inspection). The 'bad products identified as bad' enter a rework process but the source of the non-conformance could be the supplier, manufacturing or both. Campanella classified the internal failure costs as: due to product/service design, purchasing, and operations (product or service). Therefore, the internal failure cost has four terms as shown in Eq. The first term is a fixed cost (Cf) for corrective activities. Some of the costs that can be included are: labour for correction of non-conformance, remedial engineering, and shop down time, among others. The second term is the operations failure cost computed as the sum of the direct manufacturing cost per processed item (Cm) and a rework cost per item (Cr) times the identified good components with an unsuccessful manufacture, that is, $\emptyset(1 - yI_j)GbM(yp_j)$. We assume that components can be recovered or disassembled. The third term is the purchasing failure cost computed as the sum

of: (1) losses incurred due to failure of purchased components to meet quality requirements (Cs) such as: purchased material replacement and payroll costs, (2) direct manufacture cost per processed item (Cm), and (3) rework cost per item (Cr), multiplying by the items identified as defective due to bad components $\emptyset(1 - yI_j)BgM(yp_j)$ as well as the items identified as defective because of bad components and unsuccessful manufacture $\emptyset(1 - yI_j)BbM(yp_j)$. There are units that cannot be reworked or that management may decide not to restore. The two alternatives for those parts are to scrap them or to attempt to sell the unit 'as is'. Supposing there is a market for those items, a fourth term is added to the internal cost expression as the profit foregone by selling a defective product 'as is'. The cost is computed as the difference between P1 profit for good product and P2 profit for defective unit times the items sold as defective or discounted products as shown in Eq.

$$C_{IF} = Cf + (Cm + Cr)\emptyset(1 - yI_j)GbM(yp_j) + (Cs + Cm + Cr)\emptyset(1 - yI_j)\left(BgM(yp_j) + BbM(yp_j)\right) + (P1 - P2)SaD(yp_j, yI_j).$$

Finally, defective items that are not discovered by appraisal will be discovered by customers incurring in external failure costs discussed in the following section.

External failure cost

The expression for external failure costs and opportunity costs is given by Eq.

$$C_{EF} = C_{EF}[BaRe(yp_j, yI_j) + BcGC(yp_j, yI_j)] + k(y_{rel})^2.$$

The total external cost (C_{EF}) is given by two terms. The first term models the cost related to customer returns which involve the action to either repair or replace the defective item. We assume that all defective products are returned by customers. The second term is based on the Taguchi loss function concept. The Taguchi loss function is part of the compendium of methods proposed by Albright and Roth to measure hidden costs. Although the Taguchi loss function was first applied in manufacturing processes where the objective is to

model losses in terms of the deviation between the actual value of a quality characteristic and a target value, the Taguchi loss function has also been used for non-manufacturing applications. The loss constant coefficient k, depends on the cost at the specification limits and the width of the specification.

$$L(y) = k(y)^2$$

The quality characteristic y, is the overall percentage defective for a given demand as shown in Eq. (6). It is worth noting that even though clients accepted such products 'as is' products sold as defective are also included for the overall percentage defective computation.

$$y = \frac{\left[\left(BaRe(yp_j, yI_j) + BcGC(yp_j, yI_j)\right) + SaD(yp_j, yI_j)\right]}{Dem} * 100\%$$

The retailer has a fraction defective (Yr_k) which means that retailer can turn good products into defective items. From Eq. it can be seen that for a perfect inspection and manufacturing process, the target value for the Taguchi function is $Lb = [Yr_k + Ys_i(1 - \emptyset)(1 - Yr_k)] * 100\%$ and the upper specification limit is set at $Ub = 100$ to indicate the allowable deviation

from target value. Notice that y=100 is the worst case, that is, when the process has 100% of defective products. In order to compute the loss for the supply chain, a relative value of the quality characteristic (y_{rel}) is obtained by subtracting the target value or lower bound from the current overall percentage defective as shown in Eq.

$$y_{rel} = y - Lb.$$

To sum up, the total external failure cost (C_{EF}) is given by Eq. and it comprises the cost of processing customer returns, and losses due to defective items. The losses incurred due to defective products are: loss of sales, complaints from customers, warranty claims, loss of market and purchaser goodwill, concessions, and product liability, among others.

Deriving a quality cost function and overall quality level

The total quality cost (COQ) is computed by summing the PAF cost categories as shown in Eq.

$$COQ(yp_j, yI_j) = C_A + C_P + C_{IF} + C_{EF}.$$

The overall quality level achieved is given by Eq. It is worth noting that

$GaRe(yp_j, yI_j) + BaRe(yp_j, yI_j) + SaD(yp_j, yI_j) + BcGC(yp_j, yI_j)$ is equal to the customer demand (Dem) in the model presented.

$$QL = GaRe(yp_j, yI_j)/GaRe(yp_j, yI_j) + BaRe(yp_j, yI_j) + SaD(yp_j, yI_j) + BcGC(yp_j, yI_j).$$

The proposed model can generate COQ curves that resemble both the original and the revised Juran's model. The behavior of Juran's original model is observed when supplier fraction defective is high and when the cost of implementing prevention activities to improve quality level surpasses the cost of appraisal activities. On the other hand, the behavior of Juran's revised model is observed when working at low fraction defective at supplier and retailer, high rework rate, and when having a cost structure where the cost of prevention activities is similar or at most twelve times the cost of appraisal activities. On the surface, the prevention and appraisal variable costs have no direct connection. However, we found that when the variable prevention cost is similar to the variable appraisal cost, the model suggests investing in prevention activities rather than in appraisal activities.

Conclusions:

An interdependent relationship between the selected supplier and the optimal quality level as well as between the selected retailer and the optimal quality level achieved by the logistic route is observed in the numerical examples. Therefore, quality costs are an aid to identify the economic impact that supplier and retailer fraction defective have on the logistic route. Quality costs show the relevance of making good selections among available suppliers and retailers. Conformance

costs, usually divided into prevention and appraisal activities, play an important role in the definition of the optimal COQ point. The proposed model seeks to utilize prevention activities and make use of appraisal activities only when necessary or when the cost of prevention activities exceeds appraisal costs by a great amount. Internal failure cost plays a relevant role in the behavior of the COQ curves and selection of optimal values for decision variables since the defective parts found through inspection are either reworked or sold 'as is'. As a result, a positive relationship between appraisal and internal failure costs emerged in the proposed model.

In conclusion, the major contribution of this research lies in developing a formal framework for computing the quality cost across a single-product three-echelon serial supply chain model and providing useful managerial insights. The proposed methodology provides an aid for engineering managers who want to translate quality into monetary terms, and moreover, into internal operational decisions such as error rate at the inspection and fraction defective at manufacturing. This will facilitate the evaluation of supplier and retailer selection and provide a better understanding of the interdependencies among defective rates at each stage of the supply chain. The results show that computing quality costs and determining the optimal COQ point when generating a new logistic route will reduce costs

while maintaining the best possible quality level. Computing COQ for a supply chain is the first step in integrating it into the decision process because it allows exploring the interrelationships among business entities. Independent COQ curves based on fraction defective at each business unit are not the best way to integrate quality costs since the integration should be addressed from a systems viewpoint. We can only conclude that more research needs to be conducted and that including quality costs in supply chain modeling can provide significant benefits. The model developed provides a way to manage cost of quality across a single-product three-echelon serial supply chain.

References:

[1] Mark De Feo Juran Institute of Research on "Cost of Poor Quality"- August-2005 Juran.

[2] Xiaobing Liu, Fajing Cui, Qiunan Meng, Ruilin Pan "Research on the Model of Quality Cost in CIMS Environment"- 2008 ISOB&IM ,SOMDUOT, DUTDalian, China.

[3] Chin-Chung Wu , Zhuoning Chen , Geo-Ry Tang "Component tolerance design for minimum quality loss and manufacturing cost - Computers in Industry", Elsevier.

[4] J.S. Oakland, "Total Quality Management", 2nd ed., Butter worth-Heinemann Ltd, Oxford, p:186-210, 1993.

[5] M.Gupta, K. Gallo, "Activity-based costing management and its Implications for operations management," Technovation, vol.23, p:131-138, 2003.

[6] M.Singer, "Empirical validation of an activity-based optimization system," Int. J. Production Economics,vol.113 p:335–345,2008.

[7] A. Ramudhin, C. Alzaman, A. Bulgak, Incorporating the "cost of quality in supply chain design", J. Quality Maintenance Eng. 14 (1) (2008) 71–86.

[8] B. Beamon, "Supply chain design and analysis: models and methods", Int. J. Product. Econ. 55 (3) (1998) 281–294.

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- *Vinod G.Surange, Asst.Professor ,Mech.Engg.Dept. SCOE, Kharghar Maharashtra, India[P.G.Student- SCOE, Kharghar, Maharashtra, India] PH-8976130221. E-mail: vinod.surange@gmail.com*

- *S.N.Teli, Associate Professor & HOD -Mech. Engg. Dept., SCOE, Kharghar, Maharashtra, India.E-mail: shivanandteli@yahoo.com*

- *Ankur M. Halankar B.E. Student,Mech.Engg. SCOE, Kharghar, Maharashtra, India.E-mail: ankurhalankar121@gmail.com*

- *Dinesh S. Saroj B.E. Student,Mech.Engg. SCOE, Kharghar, Maharashtra, India.E-mail: dinu_saroj@yahoo.com*

- *Siddhesh S. Rane B.E. Student,Mech.Engg. SCOE, Kharghar, Maharashtra, India.E-mail: siddheshsudhakarrane@gmail.com*

- *Datta D. Adak B.E. Student,Mech.Engg. SCOE, Kharghar, Maharashtra, India.E-mail: dattaadak@gmail.com*

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