African Journal of Business Management Vol. 6(2), pp. 670-680,18 January, 2012
Available online at http://www.academicjournals.org/AJBM
DOI: 10.5897/AJBM11.2332
ISSN 1993-8233 ©2012 Academic Journals

Full Length Research Paper

Classical model based analysis of cost of poor quality in a manufacturing organization

Hassan Ali[1]*, Wajiha Arif[2], Danial Saeed Pirzada[3] Ahsan Amir Khan[4] and Jibran Hussain[5]

[1,2,3,4]Department of Engineering Management, Center of Advanced Studies in Engineering, Islamabad, 44000, Pakistan.
[5]Department of Management Sciences, HITEC University, Taxila Cantt, Pakistan.

Accepted 24 October, 2011

In today's world of manufacturing competitiveness, quality is a prerequisite and it is no longer a differentiator. Although people in developing countries have started understanding the importance of quality in any sector but this fact is still not very much clear to decision makers that a substantial amount is lost in terms of cost of poor quality (COPQ). This is a case study focusing on COPQ in a heavy manufacturing organization of Pakistan keeping in view the literatures of economical designing of quality and quality costing. Approach of studied organization was checked out against COPQ keeping in view all kind of quality costs including prevention cost, appraisal cost, internal failure cost and external failure cost. SWOT and PAF costing analysis were performed. It was observed that statistical process control (SPC) and statistical quality control (SQC) techniques are completely being neglected and even the ISO certified departments are not implementing ISO recommendations and total quality management (TQM) guidelines in this organization. This public sector organization is still governed by the myth that quality is just a buzz word and it should just be limited to paper work far away from actual implementation. Quality is being compromised on basis of material, scrap, trainings, human resource management, product robust design, products tolerances, and Cp and product performance all leading to COPQ. This study suggests a quality cost model based upon some charting techniques devised to measure the actual and the planned activities. Furthermore a sound methodology of measuring internal and external failure cost is also provided.

Key words: Cost of poor quality, statistical process control, statistical quality control, total quality management, quality control.

INTRODUCTION

Cost of quality (COQ) is now a well known concept for many years. Dr. Joseph M Juran initiated the concept of COQ in 1951 and American Society for Quality established a Quality Cost Committee in supervision of Quality Management Division in 1961. But the credit of the popularity of COQ concept goes to Philip B Crosby who emphasized COQ in his book "Quality is Free". Now most famous quality standards like ISO 9000, AS 9000 and QS 9000 recommend the implementation of COQ models for improvement of products and services quality.

COQ always remained a confusing concept. It has never been clear that COQ is whether the cost to ensure quality or extra cost to be paid in case of poor quality. Most of the times, poor quality cost just refers to failure cost but Crosby referred both the conformance and non conformance cost which includes prevention and appraisal cost and internal and external failure cost, respectively. But in addition to these two types of cost, there are some hidden costs that are generally neglected in modeling COQ methods and these include costs due to customer incurrence, reputation loss and dissatisfaction of customer.

To run any department of a company, quality is the basic concept and has the foremost importance. Quality effects the nature of products as well as it determines the total budget to be spent on manufacturing of the product.

*Corresponding author. E-mail: mechanical.engr_hassan@yahoo.com. Tel: +923335993703. Fax: +92519268144.

All the leading companies of the world are mainly concerned with their profits while determining the quality of the product. Their main focus is to make the product as much durable as they can while spending the minimum cost.

Failures in internal, external and appraisal cost actually occur in separate and different segments and all of them are identical due to different and specific reasons. Quality costs are generally mush larger than commonly expected. Quality issues are not because of the operations being done in the factory. Other factors like human resources and maintenance also contribute heavily. The cost contribution due to other factors is avoidable and now days we fortunately have structural approaches for doing so. The department based structure of a company has its own flaws. In a departmental based structure, all departments are acting as independent units and it becomes very difficult to provide the same and consistent quality leading further in increase of cost of poor quality (COPQ).

In order to reduce COPQ, the most important thing is to set priorities for the effective use of resources and this can be done by the identification of those factors which contribute a lot in COPQ. To improve the quality, investment of resources is necessary. COPQ exercises are successful only when there is reduction in cost of errors and increase in customers. The higher authorities of company must go after COPQ with responsible approach because the managers generally call in consultants when they are in trusted with COPQ assessment. This is because they themselves do not know how to proceed or they are afraid of execution. The remedy to prevent the COPQ lays in the fact that management and the line staff should take the ownership.

Schiffauerova and Thomson (2006) defined COQ as sum of all costs for conformance including cost to prevent poor quality and non conformance cost including cost of poor quality caused due to the failure of any service or product. Schiffauerova et al. (2006) pointed out that there is serious lack of literatures in the field of cost of quality. Schiffauerova et al. (2006) summarized different publications focusing on COQ models and categories of cost included in each model. Accordingly PAF models include the sum of prevention, appraisal and failure costs and activities while Crosby's model includes the sum of conformance and non-conformance cost. Intangible cost models or opportunity cost models includes the sum of opportunity cost and PAF costs/ conformance and non-conformance costs. It can also be categorized by the sum of tangible and intangible costs and activities. Process cost models includes the sum of conformance and non conformance costs while ABC models includes the sum value addition and non value addition costs and activities.

Schiffauerova et al. (2006) explained different types of cost in PAF model. Prevention costs are those costs which are spent as a precautionary measure to avoid any failure and to ensure the desired quality of any service or product while appraisal cost are those costs which are associated with inspection to check out the attainment of process desired quality. Failure costs include all kinds of internal and external failure cost and PAF model actually focuses on the minimization of this type of costs. Prevention and appraisal cost are spent to avoid failure cost and an increase in prevention cost will lead to decrease in appraisal cost and minimization of failure cost. As Crosby's describes the quality as conformance to requirements so the Crosby's cost model categorizes the cost as conformance and non conformance cost. Here the conformance cost means prevention and appraisal cost and non conformance cost means failure cost quantifying the cost of correction, rework and scrap. Generally PAF and Crosby's cost models are same and differ only in terminology. Opportunity or intangible cost models includes the opportunity cost in addition to PAF or conformance and non conformance costs. Due to non conformance of requirements a decrease in customer loyalty and revenues occur and estimation of loss of such profits and revenues are described as intangible costs. In the same way opportunity losses can be divided in three parts including the underuse of Cp, improper handling of materials and inappropriate service delivery. Opportunity or intangible cost models calculate the COQ as the sum of such lost profits and revenues. Such opportunity costs and quality losses can be incorporated in PAF and Crosby's models. For calculation of these losses often Taguchi's quality loss function is generally employed where accounting principles are used.

Schiffauerova et al. (2006) explained process cost model where costing of quality is done on the basis of processes and not on the quality of services and products. The total cost of conformance and non conformance of the process is defined as process cost where the conformance cost means that the production of the service and production was completed in the first attempt according to required specifications while non conformance cost means the cost incurred due to the failure in first attempt. The advantage of this model is that the COQ works on each single process and it can predict whether we need to invest more as prevention cost or to redesign the process. In total quality management (TQM) the use of process cost model is recommended.

Schiffauerova et al. (2006) summarized activity based cost (ABC) as a cost modeling methodology used for accurate costing by comparing resource cost to object cost. ABC in fact is not a cost model rather a methodology to identify, quantify and allocate cost among different products. ABC has another advantage that it helps in elimination of non value added activities. Schiffauerova et al. (2006) further highlighted that COQ parameters are very difficult to define as the COQ factors vary from industry to industry and situation to situation. Anyways an efficient and effective feedback system of metrics is required for appropriate costing of quality.

Seog et al. (1996) designed a mathematical model for estimating the production cycle time and quality costs including prevention cost, appraisal cost and both internal and external failure cost in a multistage manufacturing facility. Seog et al. (1996) classified production cycle time with reference to four different types of time including the time in which the process is under control, time up till the detection of assignable causes has been made, sampling time and time to intercept results and time for identification and correction of assignable causes. Similarly prevention cost in a multistage manufacturing facility can be classified as monitoring cost and cost for repairing and maintenance. Appraisal cost in machining area can similarly be divided in two types including inspection cost and repair and maintenance cost. Seog Ju Chang et al.'s (1996) came to the conclusion that there are some main factors which affect the quality cost more intensively and these include quality variance and policy for inspection.

Naidu (2008) came up with the idea that improvement of quality in result of reduction of variability effect can be achieved by using robust design. One of the ways to control variability is by the reduction of tolerances. Different types of cost during a product life cycle include the cost of manufacturing before sale and quality loss cost after delivery to the costumer. C_{pm} is used for balancing these two types of cost. $A + B/t^2$ equation is used for calculating manufacturing cost and it explains that tight tolerances leads to higher manufacturing cost and lose tolerances leads to lower cost while Taguchi's loss function $L(y) = K (y-T)^2$ has been used for determining quality loss in result of departing away from the target value. To obtain an optimum quality and cost relation, we need to keep a balance between these two driving parameters but the main contributor in COQ control in this optimum process design is Taguchi's loss function. But the total cost of manufacturing is still the sum of manufacturing cost and quality loss function cost of the process. So Naidu (2008) came up with the conclusion that C_p is controlled by the tolerances design and to obtain optimum tolerances there always remain two parallel methodologies where in one we just consider the manufacturing cost while in other we just consider quality loss function. Hence, a balance in both is required.

Mayer and Nusswald (2001) explained the importance of manufacturing process for conformance to the desired standards and specifications and the approximation of work can be measured by C_p. C_p is one of the influencing factor in order to determine the amount of rework and scrap. If $C_p = 1$ than it means that 99.73% products are according to the required conformance. If the product is not according to desired specifications than it will fall in the category of rework and scrap. Rework substantially increase manufacturing cost as well as lead times resulting in the increase of COPQ. WIP will also be disturbed when the product come back for the rework.

Various ways to increase C_p includes the variance of parameters of process such as machine feed and speed, new devices installation such as tools, dies and fixtures, advance machine use such as shifting from conventional lathe to CNC lathe and change of methodology such as die casting to investment casting. All these processes cost money thus increasing COQ and reducing COPQ. Mayer et al. (2001) further explains that cost of process and cost of inspection increases as the process variation decreases because of the fact that higher capable process requires more inspection and more advanced processes and equipments. So for sticking to conformance of specifications COQ should increase which will result in the decrease of COPQ.

Gunasekaran and Sarhadi (1997) explained that higher range of products leads to deviation from the exact information about the cost. So accurate information about the manufacturing cost and value addition activities cost is very necessary for accurate cost modeling. For this process the ABC modeling is best designed according to which the total cost of any process is equal to the sum of the cost of raw material and the cost of all value added activities. In this way ABC model also helps in the elimination of activities which do not add any value in the process and ultimately COQ as well as COPQ decreases. So ABC method also helps in optimum designing of the processes as well. This type of cost modeling methodology is best suited for advanced manufacturing systems such as FMS, JIT and CIM. Similarly Spedding and Sun (1999) gave a simulation model based upon discrete events for ABC of any manufacturing system. Zbayraka et al. (2003) also worked on ABC system for any manufacturing system based upon push and pull environment. The system was modeled for the manufacturing companies who work on either MRP or JIT. ABC helps out in decision making system so it is more than just a mere pricing system. Chan and Spedding (2003) also pointed out that a mix of TQM and ABC is very good in any manufacturing system because of the reason that TQM helps in good optimization of process while ABC helps in costing as well as decision making.

Tsou (2007) pointed out that one of the assumptions of EOQ model that inventory and production line is defect free make it a weak case to be implemented in real life industry. Tsou (2007) combined the traditional EOQ model with Taguchi's COPQ and evaluated the effect of inclusion of later with the EOQ model. Tsou (2007) proved that annual profits are decreased due to involvement of poor quality and Taguchi's COPQ in traditional EOQ model. So as a result EOQ in this revised model increases leading to increase in COPQ. Ho and Chang (2011) corrected some numerical mistakes made by Tsou in his research work on Taguchi's loss function. Freiesleben (2008) suggested an economical function for quality loss composed of single profit factors and explained that how the profits of a company can be disturbed by the level of defects. Kazaza et al. (2004) in their research work explained the classical view of quality

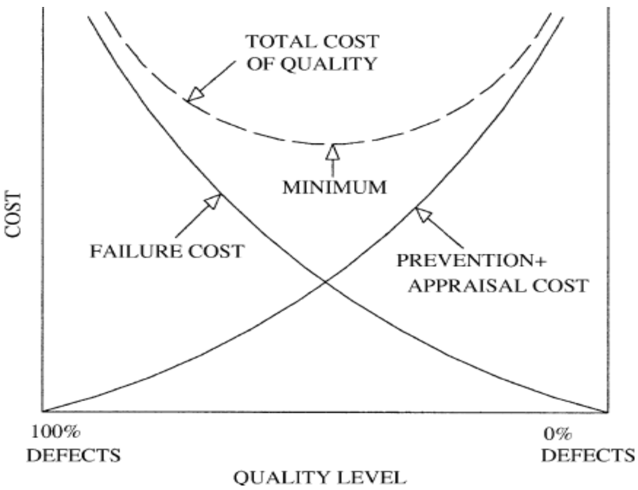

Figure 1. Classical quality level versus cost curve.

level versus cost curve which is an adaption from Kane and Brown. Kazaza et al. (2004) explained that an increase in prevention and appraisal cost leads to reduction in defects and an increase in defects leads to higher failure cost. But the total COQ is not dependent upon a single parameter rather it is a compromise between failure cost, prevention and appraisal cost and quality level. Figure 1 explains that the minimum cost of quality occurs at the point where the curve for failure cost intersects with the curve of prevention and appraisal cost but the quality level is not maximum at this point. So to further increase the quality we have to add in prevention and appraisal cost. So, higher quality means a greater investment in prevention activities and inspection and setup activities.

Pursglove and Dale (1995) mentioned that the COQ models do not convey a real COQ picture due to the fact that most of internal failure costs are not included in COQ model for calculation. Similarly machine downtime is also not calculated because this cost is insignificant but it actually contributes to COQ. Similarly all the external COQ are not included in calculation due to insignificance. So, all types of cost due to dynamic nature of processes are not included in COQ model which limit the effectiveness of most COQ models.

Alaa et al., (1996) mentioned that up till 1980's traditional accounting systems were being used in order to measure the performance of any manufacturing system but in today's world of manufacturing competitiveness such systems are tendered useless. Alaa et al. (1996) presented such a system which combined three most important parameters in any organization including factory shop floor, process improvement team and management. This integrated system helps in real time information. If such systems are utilized for performance measurement than it leads to better quality and resulting lower COPQ. Ali et al. (2010) explained the increasing the number of stations for the control of quality increase the processing time of the problem solution. Ali G. Shetwa et al. (2010) developed system based upon biological algorithms and simulation so that such systems can handle the complexity of greater extent. It also suggests further research in this field as well as the use of parallel computing and dividing the problem in individual in dependent parts.

Berte et al. (1997) mentioned out that 20 to 40% of the sales revenues of US companies were spent as COQ. Berte et al. (1997) further explained that COQ method cannot be benchmarked. It is because of the fact that variability of COQ parameters is so huge from system to system that it becomes practically impossible to use one measuring system at multiple facilities. So the development of COQ models for every single facility is highly recommended. Koc (2007) compared the impact of ISO 9000 QMS by benchmarking ISO 9000 certified and non certified manufacturing SMEs. It explains the implementation of systematic approach towards QMS as implied in ISO 9000 leads to better quality and decrease in COPQ. This will further increase the customer loyalty.

Jayaram et al. (1999) explained the role of human resource management in controlling manufacturing performance which ultimately results in quality. Jayaram et al. (1999) proposed that human resource management can be grouped in five parameters, four out of which are cost, time, quality and flexibility. These four parameters are those which are used to specify the manufacturing competitiveness of any organization. So quality of human resource management can be translated into the quality of the product or service in any organization.

METHODOLOGY

The methodology of this research work is based on the observation of manufacturing process of one of the components shown in 'Figure 2' of a complete product. BOM and processes break down of the XYZ (name of the component) was obtained and then this component was analyzed with the help of PAF cost analysis and SWOT analysis. Then a quality cost model is proposed for implementation in X. Activities breakdown structure for the manufacturing of XYZ includes billet cutting on circular saw, ultrasonic inspection of each billet, rough diameter turning and facing of both sides on turret lathe machine, copy turning of external profile on copy turning lathe machine, cutting of job into three segments of 120° on a band saw machine, finis hing of sides of cut piece on duplex milling machine, welding of three segments on a spot welding machine, finished internal threading on CNC machine on both sides, external finish profile on CNC machine, milling slot on three segments and hard anodizing.

SWOT ANALYSIS OF X

Before going for the quality costing analysis a SWOT analysis of the facility is performed to recognize the strengths, weaknesses, opportunities and threats to the

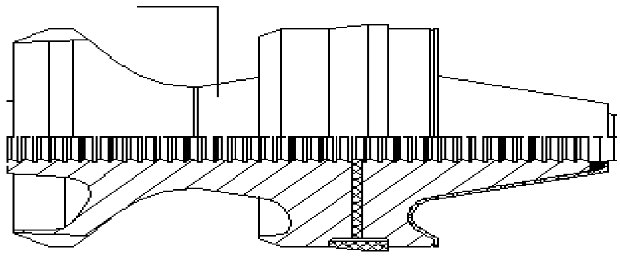

Figure 2. Discussed component.

Table 1. SWOT analysis of X.

Strengths	**Weaknesses**
Excellent production facilities.	Unavailability of statistical process control techniques.
State of art technology.	Unavailability of statistical quality control techniques.
No competitor fear.	Untrained quality staff.
Focused customers	No ownership of rejections.
Developed production processes.	Unavailability of QMS.
Focused suppliers and vendors	
Opportunities	**Threats**
Deployment of trained quality staff.	Power crisis in the country.
Gain a niche in the market due to manufacturing competitiveness.	Decrease in customer loyalty due to external failure.
Increased number of exports due to an opportunity of increase in customers market in other countries.	Decrease in customer's satisfaction due to unavailability of QMS.
Availability of potential and trusted suppliers.	Bureaucratic control and slow managerial process.

facility. Based on this SWOT analysis a PAF costing analysis will be performed. Table 1 represents the SWOT analysis of the studied organization.

PAF costing analysis of X

Based on SWOT analysis some failures which can be encountered in the production of XYZ are enlisted in Table 2.

Goals of quality cost model for X

The goals of proposed quality cost model are explained in Figure 3. The purpose of this proposed model is to reduce the internal and external failure cost. It means that this model is intended to minimize and eliminate the failure cost including cost of lost costumer in X, lost warranty cost, costumer complaint administration cost, extra shipping cost, product replacement cost, extra material cost, RFR cost, rework cost, scrap cost, repair station cost, increased labor cost, increased overhead cost and increased equipment cost. This can be done by spending extra amount in trainings, inspection, and quality function deployment auditing and market research.

Proposed quality cost model for X

Actual cost breakdown structure for X

The costs incurred in X can be divided into seven different types of cost including labor cost, equipment cost, material cost, cost of subsidiaries, overheads cost, risk costs and profit costs. These costs can further be classified as:

1. Direct cost = labor cost + equipment cost + material cost + cost of subsidiaries of X
2. Markup cost = risk cost + profit cost
3. Manufacturing cost = direct cost + overhead cost
4. Product cost = manufacturing cost + markup cost

Activity based cost of poor quality in X

A charting process is devised for measuring the COPQ. These charts are based on losses incurred due to unutilized time of manpower and equipment, underuse of facility as compared to planned rate and cost of rework

Table 2. PAF cost analysis of X.

Prevention	**Appraisal**
Education and training of X employees.	Internal audit cost in X.
Quality function deployment cost in X	External audit cost in X.
Quality administrative cost in X	Controlling EOQ cost for the control of inventory in X.
Market research cost for development in X	Suppliers and vendors evaluation reports cost.
Preventive maintenance and field testing cost for products manufactured in X.	Inspection activities cost in X.
	Incoming inspection cost
Internal failure	**External failure**
RFR cost in X.	Cost of lost customer in X.
Rework cost in X.	Lost warranty cost.
Scrap cost in X.	Customer complaint administration cost in X.
Repair stations cost in X.	Extra shipping cost incurred by X.
Increased labor cost in X.	Product replacement cost.
Increased overhead cost in X.	Extra material cost incurred by X.
Increased equipment cost.	

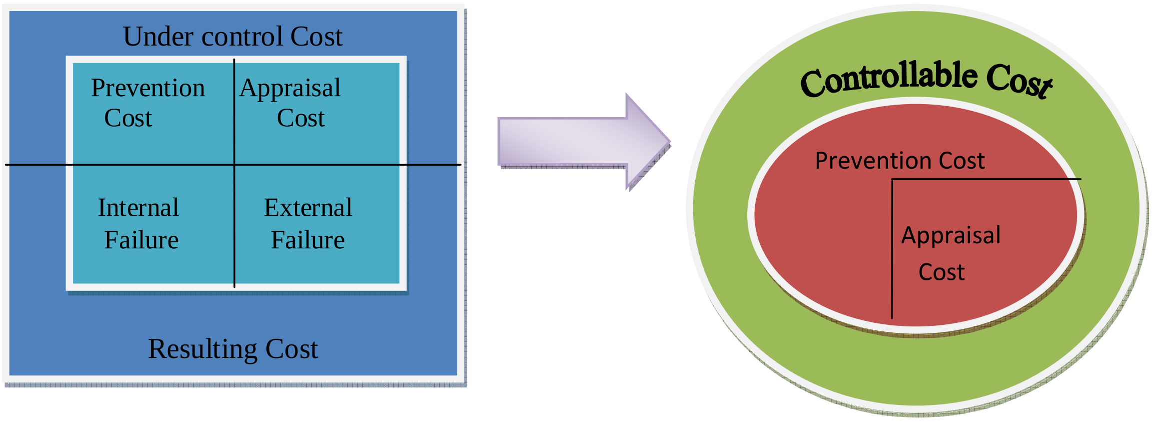

Figure 3. Goals of proposed model.

and unapproved work. Devised charts explain the following:

1. Each day analysis of planned and actual production rate and its weekly report.
2. Monetary value of actual and planned weekly production with respect to Table 3. Reasons of delays are also mentioned.
3. Table 5 shows actually weekly loss resulting in COPQ.

Measuring failure cost

Following procedure is to be adopted for measuring of failure cost.

1. List all the failures encountered both in internal and external environment.
2. List all the activities necessary to do in order to correct failure.
3. Measure the cost of each activity.
4. Multiply it with the each frequency of failure. It will give the total cost of failure in a year.
5. Sum all the costs.

Some of the failures, preventive activities, cost of activities and sum of cost in manufacturing of 100 XYZs annually are given in Table 6.

Measuring preventive/ appraisal cost

Following procedure is adopted for measurement of prevention and appraisal cost.

Table 3. Planned/ actual production vs. time in days.

Day	Production (parts)		Activity 1 (h)		Activity 2 (h)		Activity 3 (h)	
	Planned	Actual	Planned	Actual	Planned	Actual	Planned	Actual
Monday								
Tuesday								
Wednesday								
Thursday								
Friday								
Saturday								
Total	Total P	Total A						
Loss factor = 1 – (total A/total P) * 100								

Table 4. Cost value of production per week.

Factor	Actual	Planned	Difference	Reason
Production (parts)	Total A	Total P	Total P – Total A	
Price/ unit	P			
Weekly income/ losses	Total A * P	Total P * P	(Total P – Total A) * P	
Loss factor = (total P – total A) * 100 / total A				

Table 5. Weekly COPQ.

Item	Loss/ week	Loss factor	Modified losses	% of losses	Remarks
Labor cost		S			
Equipment cost		S			
Material lost		1.00			
Quality lost		1.00			
Overheads	(Total P – Total A) * Total P	0.5			
Total lost going week					
Lost cost /week income					
Modified loss per week = loss factor * actual cost per week					

Table 6. Failure cost calculation for per hundred XYZs manufacturing.

Environment	Failure	Corrective activity	Cost of activity (Rs)	Frequency	Total annual cost (Rs)
Internal	Improper cutting	Re-cutting	5000	10	50000
Internal	Improper finishing	Rework on machine	5000	10	50000
Internal	Improper slots marking	New material	30000	5	150000
Internal	Wrong inspection	Re-inspection	10000	15	150000
External	Improper dimension	New product	50000	3	150000
External	Rejection by assembly	New product	50000	5	250000
Internal external	Others	Different	1000	50	50000

Total annual failure cost of all activities = Rs. 850000.
Total cost of manufacturing 100 XYZs = Rs. 50000 * 100 = 5000000.
Total cost of manufacturing 100 XYZs = Rs. 50000 * 100 = 5000000.
So the amount for corrective action is seventeen percent of the total cost.

1. List all the preventive measures and appraisal measures. Measure the cost of each activity.
2. Multiply with the frequency of each activity.
3. Sum all the costs.

Listed in Table 7 are some of the preventive and appraisal factors which are suggested to be taken in X. As XYZ manufacturing is only two percent of total work done in X so we consider one percent of appraisal and preventive cost as the share in XYZ manufacturing.

Estimating total cost of quality

The failure cost is maximum when there is no preventive and appraisal cost spent according to the goal of cost of quality model. So we increase preventive and appraisal cost from zero to Rs. 750000 and decrease failure cost from Rs. 850000 to 0. Results are shown in Table 8 and Figure 4.

DISCUSSION

The process of production and quality control is carried out in such sequence by X.

1. X receives 'Extract (Rs.)' for the manufacturing of products from the A.
2. On the authority of extract 'Indents' are initiated by MC and forwarded to purchase department.
3. 'Indents' contains specification of materials, inspection authority, quantity and source through which material is purchased such as local or foreign vendor on the basis of BOM.
4. Materials purchased from foreign vendor are provisionally inspected by B deputed in China for inspection of raw material and is received in X on clearance of inspection carried out by B.
5. When material receive in X then SD submits an "inspection note (I-Note)" to inspection agency whichever is mentioned in indent/contract. There are 03 inspection agencies which are working in X.
6. After acceptance of material the material is kept by SD and record of store and material control is updated regarding availability of material.
7. Production control department issues 'warrant' to the production shop on the basis of received 'extract, for the manufacturing of components, sub assemblies and final assemblies. On the 'warrant' following provisions are given to production shop:

(a) Amount of material which could be drawn per component and total number of components to be produced.
(b) 5% excess material is authorized for accommodation of rejection of component during line or final inspection.
(c) Amount of scrap to be returned to the store department after machining the component from raw material.
(d) Authorized labor hours for the production of said 'warrant' quantity.

8. Production shop prepares 'demand note' on the basis of issued warrant and get this 'demand note' released from MC in view of the availability of requisite material in store and then on provision of this released 'demand note', material is issued from store and comes in production shop.
9. During manufacturing of components, gauges are available at machines for inspection of operator and patrolling inspector.
10. After going through all process operations a component is completed. This component is submitted to quality control department after in house checking of production department.
11. Quality control department inspect component on the basis of 'gauge schedule' which mention the size of the inspected by the quality control department.
12. After inspection components along with a report on 'view card' is returned to production department mentioning the fate of component:

(a) Passed
(b) RFR
(c) Rejected

13. Then components are stamped by quality control department.
14. Accepted components are submitted next day to the C on 'I –Note'. Again as per 'gauge schedule' C inspects the components already passed by quality control department and give a copy of 'I-Note' mentioning same parameters.
15. These finally inspected components are dispatched by production department to the next production shop for further assembly processes.
16. Going through all of these 300% inspection of each component, sub assembly and final assembly a product in term of production is completed.
17. As per 'proof schedule', specific number of components is selected by C for proofing. If the components qualify proofing criteria then lot of products is sentenced as 'Serviceable' and same is dispatched to I.
18. If the components could not qualify in proofing criteria than lot is sentenced as 'Re-proof' which means double than the original quantity of products will be proofed.
19. Now again products qualify proofing then lot is declared to be passed otherwise 'Rejected'.
20. Products lot is rejected by C which is involved right from the inspection of raw materials to individual components, sub assemblies and to final assembly.

Table 7. Preventive/appraisal cost calculation for X.

Type of activity	Activity	Cost of activity/year (Rs)
Preventive	Education	3000000
Preventive	Workshops	2500000
Preventive	QFD	10000000
Preventive	Market research	5000000
Preventive	Maintenance	10000000
Preventive	Testing	500000
Appraisal	Internal audit	5000000
Appraisal	External audit	500000
Appraisal	SQC application	1000000

Total appraisal/ preventive cost = Rs. 37500000.
Let 2 percent of this contributes in XYZs = Rs. 750000.

Table 8. Supposed data for the estimation of COQ in X.

S/No.	Failure cost (Rs.)	Preventive/ appraisal cost (Rs.)	Total COQ (Rs.)
1	750000	0	750000
2	700000	30000	730000
3	650000	50000	700000
4	600000	80000	680000
5	550000	100000	650000
6	500000	130000	630000
7	450000	150000	600000
8	400000	180000	580000
9	350000	250000	600000
10	300000	320000	620000
11	250000	380000	630000
12	225000	450000	675000
13	200000	500000	700000
14	150000	570000	730000
15	100000	640000	740000
16	500000	695000	745000
17	0	750000	750000

OBSERVATIONS

1. Quality control department comes under the umbrella of same controlling officer which is responsible for completion of production target.
2. Component rejected by QC and I are only taken into account on document while these reflects no evidence regarding rejection during production stages.
3. Moreover there is only limitation of final rejection of 5% on 'warrant' but there is no limitation that how much components are declared as 'RFR' by QC and I and how much machine and labor resources have been consumed in rectification of components.
4. As component duly passed by 100% inspection of QC department are only submitted to I for inspection then there should be no change of 'RFR' or 'rejection' by I but in reality there is always some components are being declared "RFR" and some line are being rejected.
5. Rejection of QC passed component by I is taken seriously by top management, hence production department always remains in touch with I and in case of rejection the same is being declared as 'RFR' by requesting **I** for the sake of their job.
6. Practice in rogue is that workers of production side request to top management for their posting in QC department reasons being:

(a) I am heart patient and could not work in production…………
(b) I am disable ……………….accident
(c) I am studying part time…………

7. Moreover workers, staff and officers having good

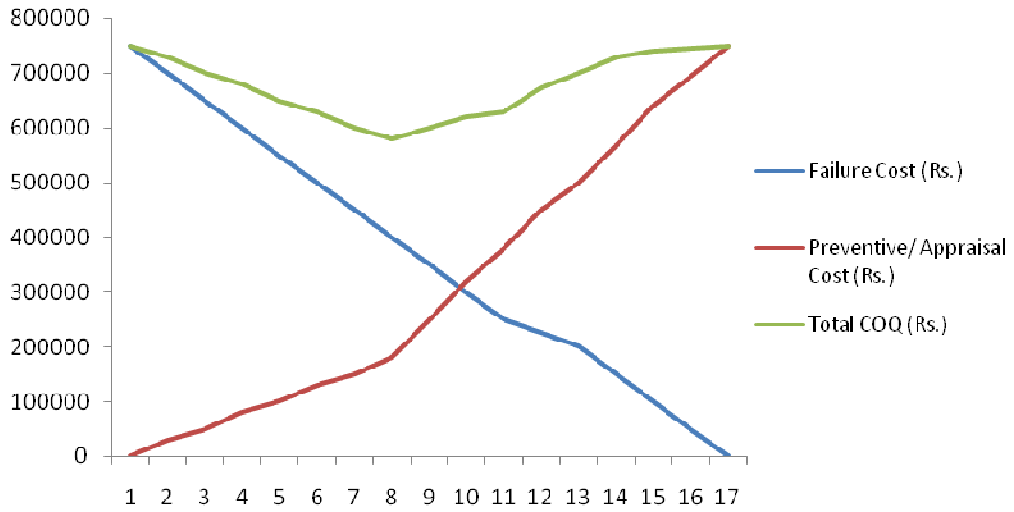

Figure 4. Supposed COQ model curve based upon classical view.

performance is always kept by the production side and spared workers, staff officers is of no use of production. These spared workers, staff and officer are posted in 'MC', 'PC', 'purchase', 'SD' and 'QC and QA departments.

8. No training is being imparted to the persons of QC department. In case of rejection of components, subassembly and final assembly by I (already passed by QC), responsibility lies only on production. This responsibility is not being shared by QC dept.

Conclusion

The use of the proposed model is highly recommended to be utilized in the facility for checking out the difference between planned and actual production and losses. Furthermore, the use of SQC charts should be utilized for implementation in case of tolerances allocation design. X is lagging behind in quality and there is a strong need of some QMS.

RECOMMENDATIONS

The following is recommended in result of this research:

1. This research should be carried forward for creating a mathematical model and simulation based techniques of COPQ.
2. A QMS should be induced in X and the inspectors should be from independent bodies so that the quality of the product can be optimized.
3. SPC and SQC techniques should be implemented for processes optimization.
4. Staff should be trained in this field.

Abbreviations: COQ, Cost of quality; **COPQ,** cost of poor quality; **SQC,** statistical quality control; **AS 9000,** aerospace basic quality system; **RFR,** rejection for rectification; **TQM,** total quality management; **QMS,** quality management system; **ABC,** activity based cost; **C_p,** process capability; **WIP,** work in progress; **JIT,** just in time; **EOQ,** economic order quantity; **MRP,** material requirement planning; **X,** studied public organization; **A,** fund issuance department; **B,** inspector of internal customer; **C,** department of internal customer; **I,** internal customer; **MC,** material control department; **SD,** store department; **QS 9000,** automotive basic quality system; **PAF,** prevention appraisal failure model; **C_{pm},** process capability index; **FMS,** flexible manufacturing system; **CIM,** computer integrated manufacturing; **BOM,** bill of material.

REFERENCES

Alaa MG, James SN, Thomas JC (1996). An Integrated Dynamic Performance Measurement System for Improving Manufacturing Competitiveness. Int. J. Prod. Econ., 48: 207-225.
Ali GS, Valentin IV, Benny T (2010). Allocation of Quality Control Stations in Multi Stage Manufacturing Systems. Comput. Ind. Eng., 60: 473-484.
Bert LM, David EN (1997). Quality Pays_In Every Business. Transfus. Sci, 18(4): 589-596.
Chan KK, Spedding TA (2003). An Integrated Multidimensional Process Improvement Methodology for Manufacturing Systems. Comput. Ind. Eng., 44: 673-693.
Freiesleben J (2008). A Proposal for an Economic Quality Loss Function. Int. J. Prod. Econ., 113: 1012-1024.
Gunasekaran A, Sarhadi M (1998). Implementation of Activity-Based Costing in Manufacturing. Int. J. Prod. Econ., 56(57): 231-242.
Jayaram J, Dorge C, Vickery SK (1991). The Impact of Human Resource Management Practices on Manufacturing Performance. J. Oper. Manage., 18: 1-20.
Kazaza A, Talat B M, Serdar U (2005). Cost-Based Analysis of Quality in Developing Countries: A Case Study of Building Projects. Build. Environ., 40: 1356-1365.
Koc T (2007). The Impact of ISO 9000 Quality Management Systems on Manufacturing. J. Materials Process. Technol., 186: 207-213.
Mayer M, Nusswald M (2001). Improving Manufacturing Costs and Lead Times with Quality-Oriented Operating Curves. J. Materials Process.

Technol., 119: 83-89.
Naidu NVR (2008). Mathematical Model for Quality Cost Optimization. Robot. Comput. Integr. Manuf., 24: 811-815
Ozbayrak M, Akgun M, Turker AK (2003). Activity-Based Cost Elimination in a Push/Pull Advanced Manufacturing Systems. Int. J. Prod. Econ., 87: 49-65.
Pursglove AB, Dale BG (1995). Developing a Quality Costing system: Key Features and Outcomes. Omega, Int. J. Manage Sci., 23(5): 567-575.
Schiffauerova A, Thomson V (2006). A Review of Research on Cost of Quality Models and Best Practices. Int. J. Qual. Reliab. Manage., 23(4): 1-23.
Seog Ju Chang, Park, Young Hyun, Eui H Park (1996). Quality Costs in Multi Stage Manufacturing Systems. Comput. Ind. Eng., 31(½): 115-118.
Spedding TA, Sun GQ (1999). Application of Discrete Event Simulation to the Activity Based Costing of Manufacturing Systems. Int. J. Prod. Econ., 58: 289-301.
Tsou JC (2007). Economic Order Quantity Model and Taguchi's Cost of Poor Quality. Appl. Math. Model., 31: 283-291.