COST OF QUALITY- A SYSTEM DYNAMICS APPROACH

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Abstract: The aim of the using the technique of cost of quality is to reduce non-conformance costs i.e internal failure cost & external failure cost by investing in conformance costs i.e. prevention cost & appraisal cost. The prevention activities are undertaken to identify & rectify the root cause of defect. System dynamics has been used to study the effect of investment in the prevention & appraisal activities w.r.t. time. This will help to calculate the time required for the return on the investment and the change in the total cost of quality over a period of time. This will enable the management of the organization to understand how the prevention & appraisal activities affect the failure costs. It has been found that Prevention is better investment as compared to appraisal. When compared over a period of time internal failure cost and external failure cost reduce with the increase in prevention cost.

1. Cost of Quality

Quality of a product is an important and critical factor for remaining competitive. As every quality related activity comes with a cost so measuring and reporting Cost of Quality (CoQ) is important. The purpose of measuring CoQ is not only to reduce cost but also to ensure that cost incurred on the quality activities is of right kind (Omar, 2009). The concept Cost of Quality is part of standardization of procedures available in the form of ISO and QS standards. These standards define quality costs as measures of quality management and quality improvement tool. The tool of cost of quality provides justification for any corrective action in the quality management program (Desai, 2008). Quality cost is the cost incurred by any organization to apply quality management system in the areas of design, implementation, operation and maintenance (Dale and Plunkett, 1999). The measurement of these costs helps in expressing the quality related activities in terms of money.

2. Introduction to system dynamics:

System dynamics is used to get the feedback regarding the effects of the variables within the closed loop. All the variables internal and external to the system influence each other's behavior.

System dynamics will help to predict the effects of the variables over a period of time. Thus system dynamics deals with the complex systems. It involves computer based simulation of the real life system to see the effect of the decision making policies on the behavior of the system. Causal loop diagrams are the used to represent cause- effect relation among the various elements of the system forming feedback loops. Casual loop diagrams are used as a tool, which helps the user to conceptualize the real life problem in terms of feedback loops. A casual loop diagram is also known as influence diagram. In a causal loop diagram, the direction of influence is indicated by arrows and the type of influence is indicated by the plus or minus signs. The variable at the tail of the arrow is known as casual variable and the variable at head as affected variable. A casual loop diagram is a circular chain of casual & affected variables. "All other things being equal, if a change in one variable generates a change in the same direction in the second variable, relative to its prior value, the relationships between the two variables are referred to as positive and if the change in the second variable takes place in the opposite direction, the relationship is negative (Kiani, B. 2009). The use of available software helps to simulate a system dynamic model for different situation. This helps to test certain conditions and gives information regarding the change in the system for set of conditions over the period of time. This helps the organization in decision making (Daniel and Bengt, 2005). Effect of technology on lean manufacturing has been shown by the use of system dynamic model. It helps to select the most viable policy for the perceived results (Hasan et al., 2013).

3. System dynamics model of costs of quality:

Dynamic modeling of quality costs in the manufacturing environment is dealt with in this chapter. System dynamics modeling is used to study the relationship between different categories of quality costs. The aim of the using the technique of quality costing is to reduce non-conformance costs i.e internal failure cost & external failure cost by investing in conformance costs i.e. prevention cost & appraisal cost (Omar, 2009). The prevention activities are undertaken to identify & rectify the root cause of defect (Keogh, 2003).. The appraisal is a defect detection activity. Both activities are necessary to reduce the defects in the product or services thus leading to better productivity and increased profits (Hou, 2011). It has been found that prevention is better investment as compared to appraisal (Opperman et al., 2001). System dynamics is used to study the effect of investment in the prevention & appraisal activities w.r.t. time. This will help to calculate the time required for the return on the investment and the change in the total cost of quality over a period of time. This will enable the management of the organization to understand how the prevention & appraisal activities affect the failure costs. Thus it will help in decision making regarding investment in the improvement initiatives. With the models available for calculation of CoQ it is difficult to predict the behavior of the non-conformance costs with the changes in the prevention & appraisal costs over a period of time.

4. Proposed methodology

The system dynamics models have been developed by for quality cost system (Burgess 1998, Kiani, B. 2009). A quality cost study is one of the tools of TQM and is used to gauge the level of performance of a quality system. It indicates whether good quality is produced at the right price. If not, it indicates the areas of improvement. To study the effect of the components of quality cost, it is necessary to know relationship between prevention, appraisal, internal failure & external failure costs. A quality control manager is interested to know the level of increase in the appraisal costs necessary to decrease the external failure costs by some amounts and the time required for the same. This kind of information will act as cost-benefit analysis and help quality control manager to justify investments in quality (Chopra and Garg,2011). Tools such as Pareto, histogram, correlation coefficients have been used for studying COQ system, but these tools do not take into consideration the dynamic relationship between the various cost factors. Prevention, appraisal, internal and external failure costs affect each another, and change in the investment in one component can change the other cost factors. In order to determine the optimal investment level for prevention & appraisal costs and analyze their effect for achieving a desired quality level at appropriate price a dynamics approach is required. Causal loop diagrams have been used as a dynamic instrument in order to determine the relation between variables and to analyze the effect of variation in the cost factors on a given time scale.

5. Identification of elements:

The elements and sub-elements of cost of quality for which the system dynamic model is to be developed were identified on the basis of the literature review, interaction with the industry personnel and brain storming. A survey was conducted in the Indian engineering industry to measure the cost of the prevention, appraisal, internal failure and external failure. The costs of the various sub elements of the quality costs were also calculated. It has been observed that the relationship among the various elements of CoQ calculated using the statistical teqniques like regression, Pearson’s correlation coefficient; tukey’s test is compatible with the previous research results available in the literature. The proposed system dynamics model will help to simulate the behavior of the elements of quality costs.

6. MODEL FOR COST OF QUALITY

The Fig.1.1 shows the model developed for the calculation of total cost of quality using vensim software.

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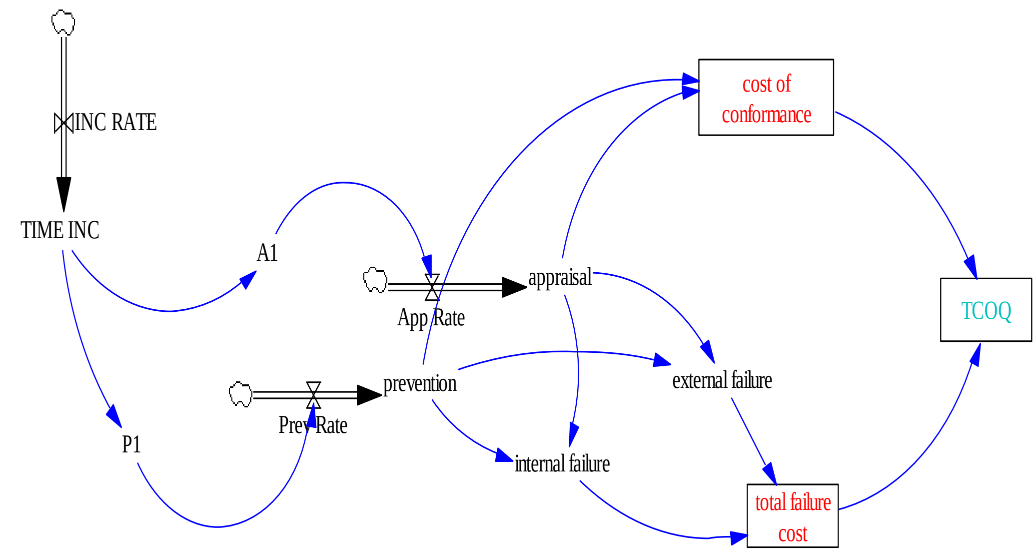

Fig. 1.1 Model for Total Cost of Quality

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7. RESULTS AND DISCUSSION

This section discusses the variation in the total cost of quality (TCOQ) over a period of 200 months. The relation between the prevention cost & appraisal cost and failure cost determining variation in the TCOQ have been calculated using observations taken from industry.

7.1 Case I - Prevention cost and appraisal costs are increased at rate of 0.3 % per month.

The cost of conformance increases until both prevention and appraisal reaches their maximum level. The total failure cost decreases for with the increase in the prevention and appraisal costs achieve their highest level. The total cost of quality (TCOQ) decreases from level of 160 to 150 as shown in the Fig.7.2 till the prevention cost and appraisal cost are increased which is as per the models available/studies conducted so far. It indicates that an organization is able to reduce its total cost of quality if investment in the prevention and appraisal is increased over a period of time. This results in reduction of internal and external failure costs.

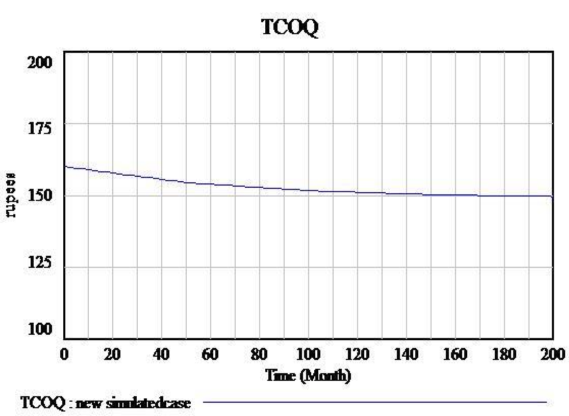

Fig. 7.1 Prevention cost and appraisal costs are increased at rate of 0.3 % per month.

7.2 Case II - Prevention cost increased at rate 0.4 % per month and appraisal cost is increased at rate of 0.1 % per month.

With increase in the allocation of investment in prevention activities the decrease in the total cost of quality is more as compared to Case-I. The total cost of quality (TCOQ) decreases from level of 160 to level of 145 as shown in the Fig.7.3. This indicates that increasing investment in prevention results in reducing failure cost and thus total cost of quality.

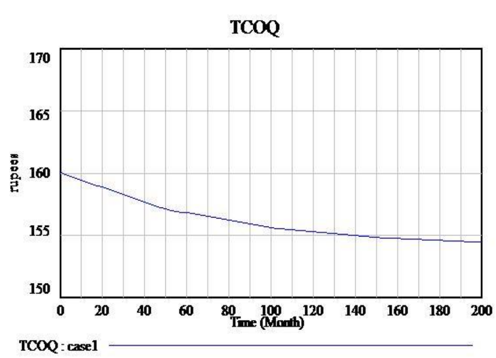

Fig. 7.2 Prevention cost increased at rate 0.4 % per month and appraisal cost is increased at rate of 0.1 % per month.

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7.3 Case III - Prevention cost increased at rate 0.1 % per month and appraisal cost is increased at rate of 0.4 % per month.

This case deals with allocating more investment to appraisal activities. The total cost of quality (TCOQ) decreases from level of 160 to level of 149 as shown in the Fig.7.4. Indicating that increasing investment in appraisal activities is less effective in reducing failure cost as compared to prevention activities. Resulting in the less reduction in the TCOQ compared to the case when prevention cost is higher. Indicating prevention is better investment as it prevents the defect to occur while appraisal detects the defect.

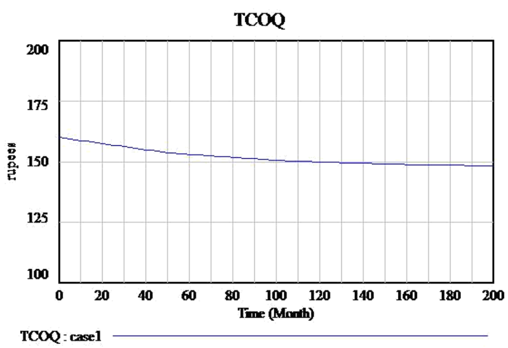

Fig 7.3 Prevention cost increased at rate 0.1 % per month and appraisal cost is increased at rate of 0.4 % per month.

7.4 Case IV- Prevention cost increased at rate 0.5 % per month and appraisal cost is kept constant.

The comparison of case IV & case V represented in Fig. 7.5 and Fig.7.6 indicates that if investment in prevention activity is sufficient than the investment in appraisal activity can be kept to a minimum. In case IV, the investment in prevention is very high and TCOQ decreases to a level 146 in 200 months as compared to 156 in Case V.

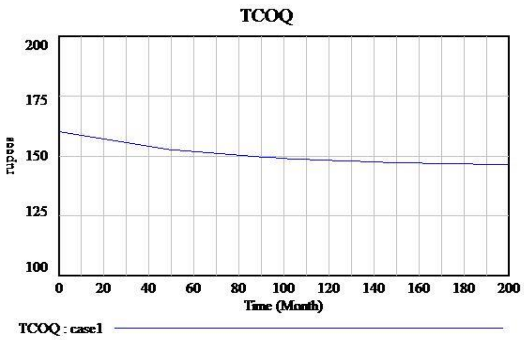

Fig.7.4 Prevention cost increased at rate 0.5 % per month and appraisal cost is kept constant.

7.5 Case V - Appraisal cost increased at rate 0.5 % per month and prevention cost is kept constant.

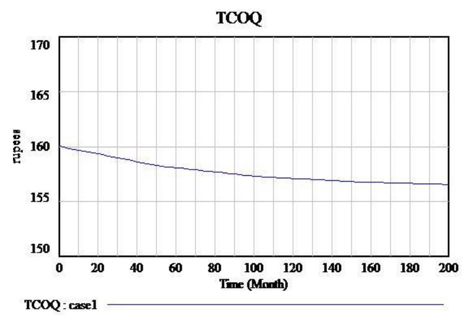

Fig.7.5 Appraisal cost increased at rate 0.5 % per month and prevention cost is kept constant.

7.6 Case VI - Prevention cost decreased at rate 0.3 % per month and appraisal cost is increased at rate of 0.3 % per month.

If prevention cost is decreased at 0.3% and appraisal cost is increased at 0.3% , the cost of failure cost decreases . The total cost of quality decreases from a level of

160 to a level of 153.

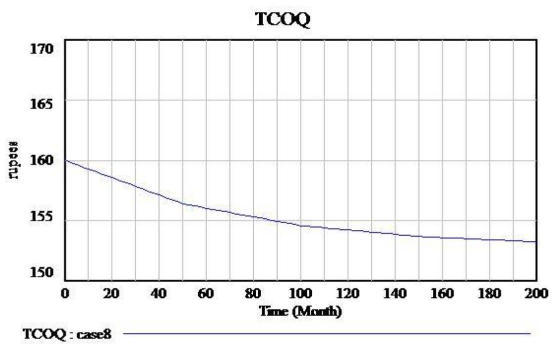

Fig.7.6 Prevention cost decreased at rate 0.3 % per month and appraisal cost is increased at rate of 0.3 % per month.

7.7 Case VII - Prevention cost increased at rate 0.3 % per month and appraisal cost is decreased at rate of 0.3 % per month.

In this case, the total cost of quality decreases from a level of 160 to a level of 146. On comparing case VI where the decrease is from a level of 160 to a level of 153, it is established that increase in the prevention cost and decrease in the appraisal cost over a period of time reduces the failure cost thus decreasing total cost of quality.

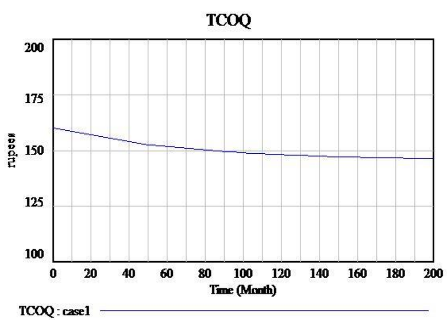

Fig. 7.7 Prevention cost increased at rate 0.3 % per month and appraisal cost is decreased at rate of 0.3 % per month.

7.8 Conclusion

Prevention is better investment as compared to appraisal. When compared over a period of time internal failure cost and external failure cost reduce with the increase in prevention cost. The industry spends a major portion of total cost of quality on appraisal activities. For reducing the spending on appraisal activities industry personnel needs training. Support of top management and skilled manpower is required to understand the importance of shifting from defect detection to defect prevention. There is built in system in the industry of spending more on appraisal activities which needs to be changed. This change can only be brought in a phased manner. Since the spending on appraisal activities gives quicker results in the form of defect detection, industry tends to spend more on appraisal. On the other hand a prevention activity involves removal of root cause of the defect and is visible only after a time gap.

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