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The investment model in preventive maintenance in multi-level production systems

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Abstract

In this research, cost/benefit models for investments made in quality improvements are developed to measure the impact of quality programs and to predict the return of an investment in these programs in a multi-level assembly system. Using these models, the decision makers can decide whether and how much to invest in quality improvement projects. The relationship between the investment and return on investment can be developed based on the tangible variables. The investment model in preventive maintenance is developed in a multi-level assembly system. The investment in preventive maintenance is to reduce the variance and the deviation of the mean from the target value of the quality characteristic, and hence to reduce the proportion of defectives and also to increase reliability. The proportion of defectives can be linked to manufacturing cost, inventory cost, and profit loss. The reliability is linked to warranty cost. The total costs in this investment model include manufacturing cost, setup cost, holding cost, profit loss, and warranty cost.

Keywords: Batch quantity; Investment in quality improvement; Variance; Mean; Defective proportion; Reliability; Multi-level system

1. Introduction

The development of cost/benefit models for investments in quality improvement is crucial because it can help the manufacturers in evaluating the effectiveness of the amount of investment they spend and selecting optimal investment opportunities. The investment in quality improvement should not be based on faith, and should be analyzed by the ‘‘quantified’’ measures of quality. Therefore, what is needed is a way of measuring the impact of quality programs and a mechanism for predicting the return of an investment in these programs.

Investment models are used to evaluate the effect of investment in prevention and appraisal activities on the resulting internal and external failure costs and to predict the return of the investment (Gupta and Campbell, 1995). Goyal and Gunasekaran (1990), Chen (1996), Lee et al. (1997), and Deleveaux (1997) developed investment models in quality improvement. Porteus (1986a, b), Trevino et al. (1993), and Leschke and Weiss (1997) presented the investment models in setup reduction. Hwang et al. (1993), Hong et al. (1993), Hong and Hayya (1995), Gunasekaran (1995), and Hong (1997) developed the investment models in quality and setup improvement. Ben-Daya

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Nomenclature

The two-tuple notation (i_h,j) indicates the jth stage of component/subassembly i_h at level h. The following notations are used at stage (i_h,j) to develop the investment model.

$X(i_h,j)$ quality characteristic
$\mu(i_h,j)$ mean of quality characteristic
$\sigma^2(i_h,j)$ variance of quality characteristic
$x_0(i_h, j)$ target value of quality characteristic
$C(i_h, j)$ manufacturing cost per unit
$S(i_h, j)$ setup cost per batch
$V(i_h, j)$ sales value
$p(i_h, j)$ proportion of defectives
$d(i_h, j)$ demand rate
$\mathrm{PO}(i_h, j)$ production rate
$F(i_h, j)$ production quantity required for one unit of final product
$\omega(i_h, j)$ replenishment time
$y(i_h, j)$ maximum inventory level
$\mathrm{PL}(i_h, j)$ profit loss per batch
$\mathrm{LSL}(i_h, j)$ lower specification limit
$\mathrm{USL}(i_h, j)$ upper specification limit
$\mathrm{Cpm}(i_h, j)$ process capability index
$R(t/X(i_h, j))$ reliability function
$\xi(i_h, j)$ shape parameter of characteristic
$B(i_h, j)$ new scale parameter of characteristic
Other notations will be introduced in the text.

(1999) considered the effect of imperfect quality on lot-sizing decisions and inspection errors. Salameh and Jaber (2000) studied the model for economic production quantity of the items with imperfect quality. Sheu and Chen (2004) developed a lot-sizing model for the determination of the level of preventive maintenance for an imperfect process control. Zequeira et al. (2004) presented a model to determine the optimal length of production periods between maintenance actions and the optimal buffer inventory during preventive maintenance. Hoque and Goyal (2005) presented a cost model of setup, transportation, and inventory with respect to setup and transportation times in multi-stage production systems. Lee (2005a–c) developed the model to increase the service level and reduce the defectives in imperfect production systems with imperfect products' quality and imperfect supplied quantity. Lee (2006) presented the investment model with respect to repetitive inspections and measurement equipment in imperfect production systems. Papachristos and Konstantaras (2006) considered the timing of withdrawing the imperfect quality items from stock in economic ordering quantity models. Eroglu and Ozdemir (2007) studied an economic order quantity model by considering defective items and shortages backordered. Sana et al. (2007) derived a flexible inventory model of imperfect quality items with a reduced selling price. Lee et al. (1997) studied the problem of selecting the optimum production batch size in multi-stage manufacturing facilities with scrap and determining the optimal amount of investment. They analyzed the effect of investment for quality improvement on proportion of rejection, and the effect of proportion of rejection on processing cost, setup cost, holding cost, and profit loss. The purpose of the investment was to reduce the variance of the quality characteristic and hence the proportion of defectives. Taguchi's loss function was simplified so that it included the variance and the deviation of the mean from the target value as well as the proportion of defectives in the expression. The model assumed known demand, which must be satisfied completely, scrap at each stage, and profit loss due to scrap. Using this model, the optimal values of the production quantity and the proportion of defective products for minimizing the total cost were obtained. The optimal investment was then obtained using the relationship between the investment and the proportion of defectives. Deleveaux (1997) extended the investment model in a multi-stage system into a multi-component multi-stage system with imperfect processes to develop the lot-size models as a function of quality level, and the cycle time model as a function of lot size. A conditional bi-variate Weibull distribution for reliability was developed that incorporated the impact of variance and mean setting on time to failure.

In this research, the investment model will be extended to a multi-level multi-stage system. The investment in preventive maintenance is to reduce the variance and the deviation of the mean from the target value of the quality characteristic, and hence to reduce the proportion of defectives and also to increase reliability. The proportion of defectives can be linked to manufacturing cost, inventory cost, and profit loss, which is the loss in profit due to the defective units. The reliability is linked to the