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Determining the optimal target for a process with multiple markets and variable holding costs☆

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Abstract

The determination of the quality target for a manufacturing process represents an intricate and fiscally vital decision. This study examines methods for process target optimization in industries where several grades of consumer specifications (and hence several quality-grades of products) may be sold within the same market. In such situations, manufacturers may hold goods that have been rejected by one customer to sell the same goods to another consumer in the same market at a later date. The expected profit function for such firms must consider the holding costs as well as the profits associated with this sales strategy. This study provides a conceptual and mathematical overview of such situations. A method for identifying the optimal process target that reflects holding costs is presented and illustrated in the context of the steel galvanization industry. © 2000 Elsevier Science B.V. All rights reserved.

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1. Introduction

The determination of the optimal target, or set point, for a manufacturing process has a tremendous impact on both a manufacturer's customer satisfaction and on the fiscal bottom line. Although the quality characteristics of the finished product may satisfy consumer expectations when the process target is set high, the raw material and production costs necessary to maintain such high quality levels may prove prohibitively expensive [1]. Conversely, while the manufacturer may avoid excessive production costs by setting lower process targets, the finished product's quality characteristics may not meet the customer's specifications. Depending on the industry and the market, such unacceptable products may be reworked for later sale (e.g., an overfilled or underfilled can of fruit may be emptied and refilled), sold in a secondary market at a lower price, discarded, or, in some cases "held" for later sale to another customer in the primary market. Each of these methods of disposing of unacceptable products carries its own relative costs and benefits. Therefore, setting the optimal process target (OPT) is an integral and financially significant aspect in the design of any manufacturing process.

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Nomenclature

A_1	selling prices to the original in the primary market
A_2	selling prices to the nonoriginal consumers in the primary market
A_3	selling price in the secondary market
c	quality-specific production cost (cost of maintaining specific quality characteristic for one unit of finished product)
$E[P(x); u]$	expected value of profit as a function of the process target when holding cost is fixed
$E[P(x,t); u]$	expected value of profit as a function of the process target when holding cost is normally distributed
$f(x)$	probability density function (pdf) of the random variable x which is normally distributed.
$F(x)$	cumulative distribution function (CDF) of the random variable x which is normally distributed
L_1	customer's lower limit specification
L_2	plant tolerance limit specification
$P(x)$	profit function when holding cost is fixed
$P(x, t)$	profit function when holding cost is normally distributed
R	basic production cost (cost of producing one unit of finished product independent of the specific quality characteristic)
S	holding cost. Two cases are considered: (1) a fixed cost and (2) a normal random variable
t	holding time
t_u	average holding time
t_σ	standard deviation of holding time
u	process mean
u^*	optimal process target
x	quality characteristic of the one unit of finished product (i.e., this study assumes that x is normally distributed with mean u and standard deviation σ)

Greek letters

α_0	fixed cost for the holding of the product
α_1	holding cost per unit of time
σ	process standard deviation
$\phi(x)$	pdf of the random variable x which is standard normally distributed
$\Psi(x)$	CDF of the random variable x which is standard normally distributed

Methods for determining an appropriate process target have been studied under a variety of economic and industrial circumstances. Springer [2] concentrated on the economic dimension of the problem, determining the optimal target under the assumption of a process with a net income function with upper and lower specification limits. Bettes [3] took the optimal target and upper specification limit into account simultaneously. Hunter and Kartha [4] proposed an approach which employed a single (lower) specification limit and assumed no reworking of substandard output; instead, their approach assumed the sale of rejected products in a secondary market at a fixed price. Although there is no explicit solution for Hunter and Kartha's [4] assumed conditions, Nelson [5] offered an approximated solution for their technique. Bisgard et al. [6] modified the assumptions of Hunter and Kartha's study in their consideration of the "canning problem" by assuming that an underfilled canned product would be sold at a rate which is proportional to the product's content.

Carlsson [7] applied Hunter and Kartha's [4] findings to an investigation of the steel beam industry. Carlsson's method divides the producer's basic costs into a fixed component and a variable component, then incorporates an additional premium into the income function when the output displays high quality and a deduction when the products exhibit inferior quality. Golhar [8] investigated the canning problem in circumstances in which rejected canned products are emptied and refilled for sale in