Computers & Industrial Engineering 80 (2015) 254–260

Contents lists available at ScienceDirect

Computers & Industrial Engineering

journal homepage: www.elsevier.com/locate/caie

Impact of inspection errors on the formulation of a multi-objective optimization process targeting model under inspection sampling plan ☆

S.O. Duffuaa *, A. El-Ga'aly

Department of Systems Engineering, King Fahd University of Petroleum & Minerals, Dhahran 31261, Saudi Arabia

ARTICLE INFO

Article history:
Received 9 May 2013
Received in revised form 23 July 2014
Accepted 28 July 2014
Available online 25 August 2014

Keywords:
Process targeting
Multi-objectives
Inspection errors
Measurement errors

ABSTRACT

The literature on inspection systems has demonstrated that such systems are error prone. Such systems exhibit type I and type II errors. Type I error is classifying a conforming item as non-conforming while type II error is classifying a non-conforming item as conforming. The errors may arise from the measurement system or the inspectors. It is essential to assess the impact of the inspection errors on the optimal parameters and objective functions of process targeting models. The purpose of this paper is to assess the impact of the inspection errors on the optimal parameters and objectives functions values of Duffuaa and El-Ga'aly multi-objectives optimization model recently developed for process targeting (2013a). In order to accomplish the objectives of the paper, Duffuaa and El-Ga'aly multi-objective optimization model is extended by introducing the measurement errors in the inspection system and penalties to mitigate the effect of the errors. The results of the extended model is compared with the previous model and employed to studying the impact of the errors on the values of objective function and the optimal process parameters in a multi-objectives environment. The results indicated that inspection errors have significant impact on the profit and uniformity objectives.

1. Introduction

The process targeting problem is an active area of research since Springer (1951) proposed his initial model for the can filling problem. Researchers have extended Springer model in several directions. The extension include optimizing the parameters of several processes in series, studying the impact of inspection errors and integrating process targeting models with other related areas. Recently Duffuaa and El-Ga'aly (2013b) extended the process parameters optimization by developing a multi-objective optimization model. The objectives considered are maximization of income, profit and product uniformity to increase customer satisfaction. The purpose of this paper is to develop a multi-objectives optimization model for the process targeting problem using error-prone lot-by-lot inspection as a means of product control. The motivation for this model is that in many situations, organization may consider more than one objective to achieve simultaneously. An organization may require maximization of income, profit and customer satisfaction. Customer satisfaction will be achieved through ensuring product quality by minimizing product variation from a target using Taguchi quadratic loss function, Taguchi, Elsayed, and Hsiang (1989). Maximizing income may be required to pay organization's financial commitments while maximizing profit is important to increase return on investment for the shareholders.

An industry example where this model is applicable is the canning filling problem. This problem has motivated many of the researchers in the area of process targeting. In this problem the quality characteristic of interest is the volume of liquid in a can. Depending on whether the volume meets the primary market specification limit, the secondary market specification or not meet both, the decision will be made where to sell the can or rework it. The cans are produced in lots and lot-by-lot acceptance sampling is used as a means for accepting the product, selling it in a secondary market or reworking the whole lot.

In the next section the literature review demonstrates that the topics of process targeting and inspection errors are of relevant and current research interest. The recent model of Duffuaa and El-Ga'aly (2013a) is developed assuming the inspection process is error free. This may not be true since inspection systems are subject to inherent variability due to many factors, such as variation in testing material, measuring instruments and inspectors. This variability causes errors of misclassifications of the products quality. The motivation behind the extension made in this paper stems

☆ This manuscript was processed by Area Editor Min Xie.

* Corresponding author.
E-mail address: duffuaa@kfupm.edu.sa (S.O. Duffuaa).

http://dx.doi.org/10.1016/j.cie.2014.07.025

from the fact that errors in measurement system can cause considerable financial losses due to product misclassification. This paper addresses the impact of the inspection measurement errors in a multi-objective process targeting environment. This paper extends the work in the literature of Duffuaa and El-Ga'aly (2013a) by developing a more realistic multi-objective optimization model that integrates measurement errors in the inspection system. In addition such a model provides the mean to study the impact of inspection errors on targeting models' optimal parameters.

The rest of the paper is organized as follows: Section 2 presents the literature review followed by problem statement in Section 3. The model is developed in Section 4 and Section 5 provides the results and analysis. Section 6 concludes the paper.

2. Literature review

The initial process targeting model has been developed by Springer (1951) to determine the optimum process target mean for a canning process, that minimizes the total expected production cost. This model has been modified and extended under several assumption and conditions.

Some models developed using the specification limits and process variability to determine the optimum target. Hunter and Kartha (1977) developed a model with only one specification limit where the conforming items are sold in a primary market and non-conforming ones are sold in a secondary market. Bisgaard, Hunter, and Pallensen (1984) modified the Hunter and Kartha (1977) non-conforming items are sold in secondary markets at a price proportional to their quality characteristic. Golhar (1987) modified the model of Bisgaard et al. (1984) assuming that, non-conforming items are reprocessed. Boucher and Jafari (1991) extended the model of Hunter and Kartha (1977) using single sampling plan.

Other models used Taguchi et al. (1989) quadratic loss function to ensure the product uniformity. Chen and Chou (2002) used Taguchi quadratic loss function for a one sided specification limit, to evaluate the quality cost for a production process with poor capability. Hong, Kown, Lee, and Cho (2006) considered product with the larger the better (L-Type) quality characteristic.

Products with multiple quality characteristics are considered in some models also. Elsayed and Chen (1993) determined optimum levels of process parameters for products with multiple characteristics. Teeravaraprug and Cho (2002) extended Taguchi single variable loss function to a multivariate quality loss function. Duffuaa, Al-Turki, and Kolus (2009) developed a profit maximization model to determine the optimum target means for a product with two quality characteristics produced by two processes in series.

The optimal process target value was determined along with other production and quality decisions in many papers. Chen and Chung (1996) developed a model to obtaining the optimum production run length and target level. Hong, Elsayed, and Lee (1999) considered the situation where there are several markets with different cost/price structures. Rahim and Tuffaha (2004) modified Chen and Chung's (1996) method using Taguchi loss function to determine the optimal process target value and production run.

Cao and Subramaniam (2013) proposed an integrated quantity and quality model for manufacturing systems with sampling plans. The model is based on a Markovian approach and used to study various measures. The model is of general nature but does not address the impact of inspection errors. Wang and Tsai (2012) proposed a model to determine the optimal production lot size and inspection policy for unreliable production process. Sadjadi, Yazdian, and Shahanaghi (2012) developed a profit maximization model to jointly determine the lot size, price and marketing decisions for an imperfect production system. All of the above paper, although they consider imperfect processes, none has considered the impact of inspection errors namely type I and type II errors.

The effect of inspection error on the optimum target value setting has been investigated in a number of models. Hong and Elsayed (1999) studied the effect of inspection errors on the optimal target mean for the case of a two-class screening process. Duffuaa and Siddiqui (2003) proposed a process targeting model for three-class screening under inspection error. The formulating of the process targeting problem under sampling plans with inspection error consider by quite a few models. Hassen and Manaspiti (1982) studied the effect of inspection errors on single-product multi-component multi-stage production system. They considered both lot-by-lot and continuous inspection. Maghsoodloo (1987) investigated the effects of inspection error on performance measures of single and double sampling by attributes. Ferrell and Chhoker (2002) developed a process targeting model where the inspection errors included as is the mitigate the consequences by extending resources. Duffuaa and khan (2005) studied the impact of inspection errors on the performance measures for an inspection plan used for the quality control of critical multi-characteristic components. Wang (2007) extended the inspection/disposition model to consider two types of inspection errors in order to facilitate the adaptation of this economic inspection/disposition model to real world applications.

Wang, Dohi, and Tsai (2010) presented a model to determine the optimal purchase lot size under the existence of inspection errors that minimize total cost per item including the order cost, material purchase cost, set up cost, inventory holding cost and quality related cost. Tsai and Wang (2011) reformulated and corrected the flaws in the model of Wang et al. (2009). Both models determine optimal inspection, deposition and rework. However Wang et al. (2009) assumed the process shift has a memory less property. Yu, Yu, and Wu (2009) developed a model to deal with a mixed policy between precise inspection and CSP-1 with inspection errors (types I and II) and return cost and the used the concept of renewal theory to obtain long-term profit. Yoo, Kim, and Park (2009) proposed a profit-maximizing economic production quantity model that incorporates both imperfect production quality and two-type imperfect inspection. Chen and Chang (2010) modified two previous quality models to incorporate the quality loss and inspection error in these models. Wang et al. (2010) developed an integrated model that deals with the acquisition of input materials, material inspection and production planning, where type I and type II inspection errors are allowed, and the unit acquisition cost is dependent on the average quality level. Khan, Jaber, and Bonney (2011) developed a model to obtain the optimal production/order quantity that takes care of imperfect processes where inspector may commit errors while screening. Lin, Chen, and Chen (2011) developed an integrated model of production lot-sizing, maintenance and quality for considering the possibilities of inspection errors, preventive maintenance (PM) errors and minimal repairs for an imperfect production system with increasing hazard rates.

Berrade, Cavalcante, and Scarf (2012) presented an inspection replacement policy model for a protection system where the inspection process s subject to the two types of errors. Lin et al. (2011) developed an integrated model of production lot-sizing, maintenance and quality for considering the possibilities of inspection errors, preventive maintenance (PM) errors and minimal repairs for an imperfect production system with increasing hazard rates. In addition, they studied the effects of inspection errors and PM errors on the minimum total cost of the optimal inspection interval, inspection frequency and production quantity. Taheri-Tolgari, Mirzazadeh, and Jolai (2012) represented a discounted cash-flow approach for an inventory model for imperfect items under inflationary conditions with considering inspection errors.