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# Designing repetitive screening procedures with imperfect inspections: An empirical Bayes approach

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ABSTRACT

A batch of expensive items, such as IC chips, is often inspected multiple times in a sequential manner to further discover more conforming items. After several rounds of screening, we need to estimate the number of conforming items that still remain in the batch. We propose in this paper an empirical Bayes estimation method and compare its performance with that of the traditional maximum likelihood method. In the repetitive screening procedure, another important decision problem is when to stop the screening process and salvage the remaining items. We propose various types of stopping rules and illustrate their procedures with a simulated inspection data. Finally, we explore various extensions to our empirical Bayes estimation method in multiple inspection plans.



## 1. Introduction

In statistical quality control, "acceptance sampling" is an effective tool that improves and assures the quality of the items in a batch (Schilling and Neubauer 2012). A sample of items is picked at random from the batch and, on the basis of information that is yielded by the sample, we make a decision regarding the disposition of the remaining items in the batch.

In some situations, however, *all* the items in the batch are subjected to a series of rigorous tests, and only the items that pass the test successfully are taken out of the batch. Some authors call it "100% inspection" (Duffuaa, Al-Turki, & Kolus, 2009) or "100% attribute sampling" (Dhavale, 1987). Because no real sampling takes place in such a case, we use the term "screening" throughout the paper (Tang & Tang, 1994).

During a round of screening, not every conforming item is identified due to inevitable inspection errors. That is why some expensive items are screened more than once in a sequential manner. This "repetitive screening" is also known as a sequential defect removal sampling (Bonnett & Woodward, 1994), a repetitive testing (Greenberg & Stokes, 1995), a repeat inspection (Duffuaa & Khan, 2005; Elshafei, Khan, & Duffuaa, 2006), or a sequential review (Rallis & Lansdowne, 2001).

Consider, for example, the semiconductor industry (Greenberg & Stokes, 1995). The fabrication of an integrated circuit (IC) or "chip" is accomplished by depositing a series of film layers upon a silicon wafer, which forms the foundation of the chip. A single wafer may hold hundreds of chips, each of which will go on to power such electronic devices as MP3 players, cell phones, personal computers, and more. At the final stage, packaged chips are subjected to a functionality test, where hundreds of different input patterns are used to ensure that each chip works in accordance with manufacturing specifications.

It is possible for a non-defective chip to fail the screening procedure. (e.g., the electrical leads on the packaged device may be contaminated with a small amount of dust or not lined up perfectly with the test head.) Due to the stringency of the test design, however, it is not likely for any defective chips to pass the functionality test successfully. Because the market value of a chip is much higher than the cost of its functionality test, it is cost-effective to re-test any chips that have failed the functionality test.

In such a situation, an important managerial decision is how to estimate the number of non-defective chips still remaining in the batch after a given number of screening cycles (Chun, 2006). Conversely, we also want to determine the number of screening cycles that produce the maximum profit or the minimum cost (Chun, 2009). In this paper, we first propose a Bayesian method for estimating the total number of confirming items in a batch, and then we deal with the problem of when to stop the screening procedure.

One of the difficulties in Bayesian analysis is how to determine the "prior distribution" of the total number of conforming items in a batch and estimate its parameter values. In the paper, we use the so-called "empirical Bayes" estimation, where the parameter of a binomial prior distribution is estimated from the inspection data. Based on the empirical Bayesian estimate of the number of

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