



## Combined Shewhart CUSUM charts using auxiliary variable



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### ABSTRACT

A control chart is an important statistical tool for monitoring disturbances in a statistical process, and it is widely applied in the industrial sector, the health sector and the agricultural sector, among others. The Shewhart chart and the Cumulative Sum (CUSUM) chart are traditionally used for detecting large shifts and small shifts, respectively, while the Combined Shewhart-CUSUM (CSC) monitors both small and large shifts. Using auxiliary information, we propose new CSC (MCSC) charts with more efficient estimators (the Regression-type estimator, the Ratio estimator, the Singh and Tailor estimator, the power ratio-type estimator, and the Kadilar and Cingi estimator) for estimating the location parameter. We compare the charts using average run length, standard deviation of the run length and extra quadratic loss, with other existing charts of the same purpose and found out that some of the MCSC charts outperform their existing counterparts. At last, a real-life industrial example is provided.

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### 1. Introduction

The most widely known quality control chart, the Shewhart chart, was proposed by [Shewhart \(1924\)](#). It detects shifts in a production process by signalling when a process goes beyond some particular threshold limits known as control limits. Shewhart chart makes use of the information when the process goes out of the control limits and ignores the information when the process is within the control limits, i.e. in-control. Due to this fact, the chart is sensitive for detecting large shifts (or disturbances) in a process. [Roberts \(1959\)](#) and [Page \(1954\)](#) proposed the Exponentially Weighted Moving Average (EWMA) chart and the Cumulative Sum (CUSUM) chart, respectively, which make use of the information when the process gets out-of-control and even when the process is in-control, hence, these charts are sensitive to small and moderate shifts in a process. Other modifications of these charts have been proposed to increase their efficiency in terms of time, cost, and simplicity of usage and expression.

The plotting statistic of CUSUM chart assumes normality. What if the plotting statistic is not normally distributed or its normality is altered? [Nasir, Riaz, Doo, and Abbas \(2013\)](#) answered these questions by suggesting some charts which are not normally distributed or their normality has been altered. They aimed at finding

charts that perform practically well under normal, contaminated normal, non-normal, and special cause contaminated parent cases. Based on mean, median, Hodge-Lehman, midrange and trimmed statistics, they proposed different CUSUM charts for phase II monitoring of the location parameter and computed their performance measure using the average run length (ARL) approach. [Abujiya, Lee, and Riaz \(2015\)](#) suggested the use of well-structured sampling techniques, such as the double ranked set sampling, the median-double ranked set sampling, and the double-median ranked set sampling, to significantly improve the performance of the CUSUM chart, without inflating the false alarm rate. They compared their proposed charts with some existing charts and found out that their charts perform better.

Due to the advancement in technology and industrial processes, emphasis has been made on the implementation of the CUSUM chart to existing Levy-Jennings or Shewhart control charts ([Westgard, Groth, Aronsson, & de Verdier, 1977](#)). These can be done manually using control charts or in computerized quality control systems. [Westgard et al. \(1977\)](#) applied this concept to improve quality control in clinical chemistry. A combination of the Shewhart chart and CUSUM chart was observed by [Lucas \(1982\)](#), after which some scholars improved the chart by proposing more efficient charts. Combined Shewhart-CUSUM (hereafter called "CSC") for location parameter can be optimized over the entire mean shift range by adding an extra parameter ( $w$ ), known as the exponential of the sample mean shift, to the structure of the CSC. This will improve its performance and it will not increase the

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