

Apply CUSUM Control Chart To Monitor Amount of Municipal Solid Waste In Bangkok

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Abstract

The purpose of this study was to apply CUSUM control chart as a simple instrument for monitoring the shift of municipal solid waste amount in Bangkok by tuning CUSUM parameters. The study results indicated the one-sided upper CUSUM significantly showed a tendency of increasing municipal solid waste amount since 2000 to 2004. Then, it was sharply decreasing in 2005 and converging to the average of municipal solid waste amount in the succeeding year.

Keywords: Municipal solid waste, CUSUM control chart

Mathematics Subject Classification: 62-07, 62G35

Introduction

Control chart is one of the efficiency statistical process control (SPC) tools for investigating process shift. The cumulative sum (CUSUM) control chart discovered by Page [1] is universally utilized in detecting small shift because both of positive and negative deviations of CUSUM test statistic are equally important performed. That's why CUSUM control chart is not only favorably applied in manufacturing process but also in diverse fields. Nevertheless, the examples of CUSUM applications were initially limited only in marine fisheries such as [2], [3], [4], [5].

Bangkok is the capital and the most popular city of Thailand. It occupies 1,568.7 square kilometres (605.7 sq mi) and has a population of over 8 million, or 12.6

percent of the country's population [6]. Bangkok is also then the hub of all civilization like business, economic, tourism, education, etc. Because of such rapid growth, Bangkok has been confronting many critical problems particularly the environment as considering from a daily large number of municipal solid waste produced. To effectively solve this problem, the Pollution Control Department declared the average of municipal solid waste amount of Bangkok would be 8,300 tons per day [7]. The demolition system of municipal solid waste is rather expensive so a control chart is an alternative technique applied for investigating the change of municipal solid waste.

This study then objected to propose the CUSUM control chart as the pragmatic illustration in monitoring the shift of municipal solid waste in Bangkok by adjusting the CUSUM parameters as a suggestion of [8]. Moreover, the authorized organization could use these results for directing and planning the efficient municipal solid waste disposal system in Bangkok.

Materials and Methods

The daily amount of municipal solid waste in Bangkok was measured in the unit of tons per year by Pollution Control Department, Ministry of Natural Resources and Environment since 1993 to 2010 [9]. Due to the report of [7] notified the average amount of municipal solid waste in Bangkok was approximately 8,300 tons per day, the reference period to define two parameters, mean and standard deviation, for the in-control state was 1993-1999. Let x_i be the daily amount of municipal solid waste at year i ; $i = 1993, 1994, \dots, 2010$. Regarding as this reference period, the in-control mean (\bar{x}) was approximately 8,300 tons while the in-control standard deviation (s) need to estimate. The procedure of monitoring municipal solid waste amount was following these three steps; (1) Calculating the standardization of municipal solid waste amount (z_i) as $z_i = \frac{x_i - \bar{x}}{s}$. (2) Determining two values of CUSUM test statistic (S_i^+ and S_i^-). S_i^+ is the positive deviation (or the one-sided upper CUSUM) computed by $S_i^+ = \max[0, S_{i-1}^+ + z_i - k]$ and S_i^- is the negative deviation (or the one-sided lower CUSUM) counted on $S_i^- = \min[0, S_{i-1}^- + z_i + k]$ where k be the reference value or allowance parameter of CUSUM. The beginning values of S_i^+ and S_i^- are generally set to zero ($S_i^+ = S_i^- = 0$). (3) Plotting S_i^+ and S_i^- into the CUSUM control chart contained the control limits, $UCL./LCL. = \pm h$ and $CL. = 0$ where h be the decision interval parameter of CUSUM. Petitgas respectively recommended using $k = 1.3$ and $h = \pm 1$ in the practice situation [8]. Whenever S_i^+ or S_i^- are plotted

within the control limits (upper and lower), the process is indicated in the in-control situation. Otherwise, it is notified as the out-of-control condition.

Results

After obtaining the estimate of in-control standard deviation, both of S_i^+ and S_i^- were determined by substituting z_i and k in step 1 and 2, respectively. The CUSUM control chart was illustrated as of Figure 1 by plotting S_i^+ and S_i^- into the chart included the three reference lines; $UCL./LCL. = \pm 1$ and $CL. = 0$.

Figure 1 showed all S_i^- uninterruptedly maintained along the center line. However, the two points of S_i^+ in 2003 and 2004 were plotted above the upper control limit. It could be then stated the process was out-of control.

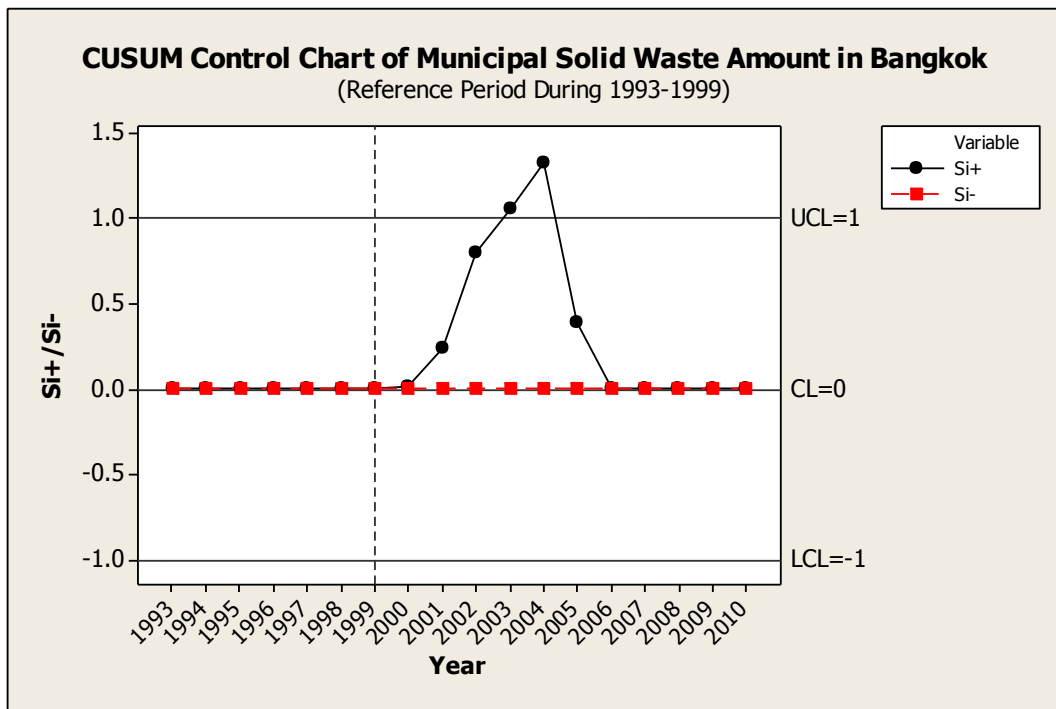


Figure 1: CUSUM Control Chart of Municipal Solid Waste Amount in Bangkok

Discussion

The CUSUM control chart was a beneficial application for detecting the change of municipal solid waste amount as seeing of an increasing signal of S_i^+ since 2001 to 2004. Also, both of S_i^+ in 2003 and 2004 were higher than the average. Subsequently,

S_i^+ was sharply decreasing in 2005 and continually converging to the average during 2006-2010. As of these findings, it was in agreement of Pollution Control Department's report. It informed that Bangkok had faced the serious problem of municipal solid waste disposal system because of the speedy urbanization during the last 10 years ago. In addition, the important campaign was proclaimed during 2007-2012 named 3Rs (Reduce, Reuse and Recycle) to control the amount of municipal solid waste in Bangkok not exceeding the average (8,300 tons). Therefore, the municipal solid waste amount was later significantly decreasing also it was then continually staying around the average at final.

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