

Investigation of Municipal Solid Waste Quantity in Chiang Mai Municipality with CUSUM Control Chart

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Abstract

The cumulative sum or CUSUM control chart was applied in this study as the statistical process control (SPC) instrument for surveillance of environmental state. The parameters of CUSUM control chart were pragmatically adjusted to investigate the change in municipal solid waste quantity in ChiangMai municipality of Thailand. The study result demonstrated the CUSUM control chart was obviously capable to detect changing in the amount of municipal solid waste for two periods. That was, the one-sided lower CUSUM showed the decreasing quantity of municipal solid waste at the initial year of survey. However, the one-sided upper CUSUM clearly displayed an evident signal that the number of municipal solid waste was extremely increasing from August, 2005 to August, 2006.

Keywords: Municipal solid waste, CUSUM control chart

Mathematics Subject Classification: 62-07, 62G35

INTRODUCTION

Chiang Mai is one of the developing provinces in Thailand. It is the economic and tourism center at the eastern area. Therefore, Chiang Mai has confronted to many significant social and environmental problems specifically the municipal solid waste management because this problem is normally showed an increasing trend parallel to the development of economic city, urbanization and rapid growth of population [1]. Pollution Control Department (PCD) of Thailand described municipal solid waste as any solid waste generated from community activities such as household, commercial and business establishments, fresh market, institutional facilities, construction and demolition waste excluding hazardous and infectious waste [2]. According to the

ChiangMai municipality report, there was numerous amount of municipal solid waste during the mid year of 2005 thru 2006 [3]. ChiangMai municipality then aimed to continually reduce municipal solid waste quantity in an approximate amount of 300 tons per day from 2007 to 2011.

Montgomery initially proposed a control chart as the important statistical process control (SPC) scheme for monitoring manufacturing process [4]. Control chart is a graph plotted the quality characteristic or variable against the time or the order of the sample. It is composed of three reference lines called the control limits; upper control limit (UCL.), center line (CL.) and lower control limit (LCL.). The cumulative sum or CUSUM chart is a running total of deviations from a reference value [5] so it is appropriate for detecting the small shift. Presently, the CUSUM control chart is not only limited in the manufacturing process but also appears in other fields such as [6, [7], [8] firstly indicated the excellent examples of using the CUSUM control chart for detecting marine fisheries.

Some researches, for example; [9], [10], [11], and [12], studied solid waste management and its effect to specific municipality of Thailand. However, there is few paper referred use of control chart coped with an investigation of municipal solid waste quantity. This study then purposed to (1) present the CUSUM control chart as the practical application in monitoring the change of municipal solid waste quantity of ChiangMai municipality and (2) guideline and help to caution the authorized department for planning of the optimal solid waste management.

MATERIALS AND METHODS

ChiangMai municipality supplied the number of municipal solid waste in Chiang Mai province, Thailand in the amount of 100 tons per month since January, 2000 to April 2012 [3]. Data of waste quantity in ChiangMai municipality was just gathered in a few decennial years so the parameters of in-control state, mean and standard deviation, were assumed from a preliminary study or a reference period.

Suppose a sequence of municipal solid waste quantity x_t collected at time t ; $t=1, 2, \dots, 160$ where $t=1$ meant time at January, 2000 until $t=160$ denoted time at April 2012. According to a policy of municipal solid waste management notified by ChiangMai municipality, the daily average of solid waste quantity would be continually decreased from 300 tons during 2007 to 2011 [3]. The estimates of mean and standard deviation of municipal solid waste quantity based on the reference period in eight years (2000-2006) were then computed for the in-control condition. Four steps of investigating the change of municipal solid waste quantity in Chiang Mai province were as followed.

1. The quantity of municipal solid waste was standardized with transformation technique as of Equation 1.

$$z_t = \frac{x_t - \bar{x}}{s} \quad (1)$$

Where z_t be the standardization of municipal solid waste quantity, \bar{x} and s be the estimators of mean and the standard deviation of municipal solid waste quantity,

respectively.

2. The two CUSUM test statistics were calculated. The one-sided upper CUSUM deviation was the first positive statistic derived from Equation 2.

$$S_t^+ = \max[0, S_{t-1}^+ + z_t - k] \quad (2)$$

The one-sided lower CUSUM deviation was the other negative statistic defined as of Equation 3.

$$S_t^- = \min[0, S_{t-1}^- + z_t + k] \quad (3)$$

Where k be the referenced or allowed parameter of CUSUM control chart. While the starting value was generally specified as $S_t^+ = S_t^- = 0$.

3. The control limits of CUSUM control chart were constructed as of Equation 4 with the decision limit h called the decision interval.

$$UCL. = +h$$

$$CL = 0 \quad (4)$$

$$LCL. = -h$$

4. The CUSUM control chart of municipal solid waste quantity in ChiangMai municipality was displayed by plotting both of positive statistic, S_t^+ , and negative statistic, S_t^- .

As a recommendation of [13], two parameters of CUSUM control chart, k and h , were set up equal to 1.3 and ± 1 , respectively. The process would be stated in the out-of-control condition if any S_t^+ fell beyond the upper control limit (UCL.) or S_t^- located below the lower control limit (LCL.).

RESULTS

Once the mean and standard deviation for in-control state of municipal solid waste quantity were estimated, the standardization of municipal solid waste quantity, z_t , was computed following Equation 1. Then, the two statistics, S_t^+ and S_t^- , were derived by replacing z_t and k in Equation 2 and 3, respectively. Finally, the CUSUM chart contained the control limits set up followed Equation 4 was pictured in Figure 1 after plotting S_t^+ and S_t^- .

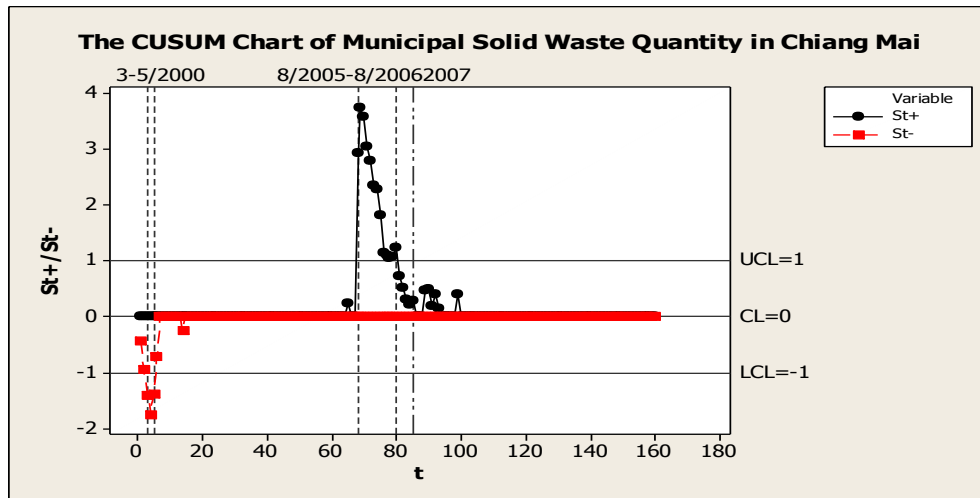


Figure 1: The CUSUM Chart of Municipal Solid Waste Quantity in Chiang Mai

The CUSUM chart illustrated the S_t^- located below the lower control limit in March, April and May of 2000 (3-5/2000). Contrarily, the S_t^+ fell beyond the upper control limit from August, 2005 to August, 2006 (8/2005-8/2006).

DISCUSSION

The CUSUM control chart is suitably utilized in detecting small shift because both of the positive and negative deviations are equally important considered. Therefore, the CUSUM technique is also helpful in environmental application. For this study, it showed the decrease of municipal solid waste quantity in 2000 due to it was just the beginning time before Chiang Mai province became the urban society. In addition, it exhibited the increase of municipal solid waste quantity from August, 2005 to August, 2006 since Chiang Mai province extremely grew up and developed to the center of economic growth and industrialization at that time while the amount of municipal solid waste was uninterruptedly confined closed to 300 tons a day after 2007 under the policy regulation of ChiangMai municipality. These results were in agreement of ChiangMai municipality report [3].

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