Performance Evaluation of an EWMA p Chart Based on Improved Square Root Transformation to detect Small Shift Process Variation

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Abstract. A control chart was used to detect whether the unexpected variation due to special causes was happening. Generally, Shewhart control chart was used, while this chart was not a good one to control the process with small variation. EWMA p chart was one of the alternatives used to monitor small shifts in the process mean. Traditionally, attribute Shewhart p chart has been developed for charting the binomial data or using the normal approximation when percent defective was low and sample size was small. In 100% inspection, these assumptions were not valid. For this reason, EWMA p control chart was modified by improving square root transformation. In this research, the implementation of the modified EWMA p control chart based on Improved square root transformation (ISRT p EWMA chart) was studied. This chart was used to monitor the actual production process where the process has shifted. The research found that. The ISRT p EWMA chart detects the shift twice, while Shewhart p chart does not detect any shift. The research also found that at λ = 0.25, the shift is detected 2 times, at λ = 0.5, the shift is detected once while at λ = 0.75, no shift is detected. The larger the value of the λ parameter, the worse the ISRT p EWMA control chart performed.

Keywords: Shewhart Control Chart, EWMA p Chart, Small Shift, Square Root Transformation

1. Introduction

Statistical Process Control (SPC) is applied for inspecting production or service processes. Typically, it was carried out by control charts. Shewhart developed a control chart for monitoring the defective of a manufacturing process called p chart in early 20th century. The general idea of a control chart consists of signalling an alarm if a specified control limits was exceeded. An alarm will lead to stopping the process in order to prevent from excessive defective unit and restore the process back [3]. Shewhart control charts is characterized by taking only the most recent sample into account. Therefore, Shewhart control charts perform very well to detect a large change in the process parameters but it is not a good one when it used for small shift [4][6]. Nowadays the Shewhart control chart can also be used to attain a sustained continuous quality improvement [6]. The further development of the control chart fundamentals has progressed rapidly. Numerous enhancements of the p chart exist to monitor other process parameters. One of them was developed from Shewhart concept where it takes the previous samples into account. This idea leads to a better performance to detect a small change in the process parameters. Exponential weighted moving average (EWMA) chart and cumulative sum (CUSUM) chart are approaches that considers not only the last sample but it also considers the information about the process contained in the rest of the samples. The CUSUM chart was developed by Page [4]. It is an...
alternative type of control chart used to monitor small shifts in the process mean which uses the cumulative sum of deviations from a target. The CUSUM chart plots the cumulative sum of deviations from the target for individual measurements or subgroup means. CUSUM charts improved the ability to detect small shifts (i.e. less than 1.5σ) by charting a statistic that incorporates current and previous data values from the process [4]. CUSUM charts, while not as simple to operate as Shewhart charts, it shown to be more efficient in detecting small shifts in the mean of a process [1]. The EWMA chart is also an alternative to the Shewhart chart in detecting small shifts in the mean process. It introduced by Roberts [7] and was originally called a geometric moving average chart. The name was changed to reflect the fact that exponential smoothing serves as the basis of EWMA charts. Specifically, EWMA was also used on individual observations. It was assumed that observation of the process is normally distributed with mean μ and variance σ².

Most research proved that the EWMA charts, performed better in detecting the small shift in the manufacturing process compared to Shewhart chart [5][6][7][9] while EWMA chart was more effective than CUCUM chart [2]. EWMA chart is preferable because it is easier to use [7]. EWMA chart is developed for variable and attribute data. Study on EWMA chart for variable was easily found. In this paper the research will focus on EWMA chart for attribute data. EWMA p chart for attribute was introduced by Page [4]. Generally, the traditional EWMA p chart has been developed for charting attribute data characterized by binomial data. This chart can also be developed using the normal approximation with condition as low defect level and the small to moderate sample size where np < 5 [8]. In situation where the process is monitored under 100% inspection, these assumptions was not valid. Although the defect level was small, but the sample size was large so that normal assumption is not matched. For this reason, EWMA p chart for detecting a change is modified by improving square root transformation. The application of the modified EWMA p chart based on Improved square root transformation namely ISRT p EWMA is studied. A comparative study of the performance of ISRT p EWMA and the performance of Shewhart p chart is analysed.

The objective of the research is how to monitor a small shift process variation using ISRT p EWMA chart and whether ISRT p EWMA chart performed better to detect small shift of process variation compare to Shewhart p chart?

The performance of ISRT p EWMA chart will be studied under the assumptions that monitoring process is done on production line of shoes assembly at PT. Primarindo Asia Infrastruktur Tbk. during March-May 2019. The shift of the process mean is less than 2σ. Parameter L and λ is set at best recommended value from previous research and no extra cost when using the ISRT p EWMA chart.

2. Methods

To evaluate the performance of the ISRT p EWMA chart, the chart will be used to monitor on the actual production process of shoes assembly at PT Primarindo Asia Infrastruktur Tbk where all product is 100% inspected. The average process is assumed to be shifting. Usually it was monitored using Shewhart p chart. As a result, when the process was actually shifting, the shift was undetected, and the process continues to run without any action to prevent from excessive defective unit. Therefore, defective unit cannot be reduced. An alternative control chart is needed to replace Shewhart p chart. The ISRT p EWMA chart was chosen to monitor the process under 100% inspection where normality assumption was not fulfilled (np < 5) due to large sample size.

The performance of ISRT p EWMA chart was evaluated using the following step:

First Step. Estimate the μ and σ of the population:

1. Set initial observation

Parameter was estimated through initial observation during March 2019. The detail observation presented in Table 1. Total 13,817 unit production was inspected during March resulting 535 unit defective or $\bar{p} = \frac{\sum p_i}{m} = \frac{535}{13817} = 0.0387$
2. Set parameter $\lambda$ and $L$ for ISRT $p$ EWMA chart.
$\lambda$ is the weight of past information where $0 < \lambda < 1$, while $L$ is coefficient of control limit of ISRT $p$ EWMA. From previous research, these parameters were set at $\lambda = 0.25$ and $L = 0.2998$.

3. Convert the initial observation data into the $Z$ Value.
The ISRT $p$ EWMA chart will plot the value of the weighted moving average ($Z_i$). For this purpose, each data observation was converted into $Z_i$ value using equation (1).

$$ Z_i = \lambda \bar{p}_i + (1 - \lambda) Z_{i-1} $$

Substitute $Z_0 = \bar{p} = 0.0387$ using parameter $\lambda = 0.25$ and $L = 0.2998$ into equation (1) resulting $Z_1 = (0.25 \times 0.020) + (1 - 0.25) \times 0.0387 = 0.0343$ and $Z_2 = (0.25 \times 0.052) + (1 - 0.25) \times 0.0343 = 0.0389$

Recalculate $Z_i$ for all of the observation and the overall value of $Z_i$ is presented in the 5th column of Table 1.

4. Set up trial control limit UCL and LCL of ISRT $p$ EWMA chart using equation (2) and (3)

$$ UCL_{ISRT\ p\ EWMA} = Z_0 + L \left[ \frac{\lambda}{2 - \lambda} \left( \frac{1}{2} \sqrt{\frac{1 - p}{n}} - \frac{1}{6} \frac{1 - p}{n \sqrt{p}} \right) \right] $$

$$ LCL_{ISRT\ p\ EWMA} = Z_0 - L \left[ \frac{\lambda}{2 - \lambda} \left( \frac{1}{2} \sqrt{\frac{1 - p}{n}} - \frac{3}{8} \frac{1 - p}{n \sqrt{p}} \right) \right] $$

Substitute $Z_0 = 0.0387$ and $n=572$ for the first data using parameter $L = 2.998$ and $\lambda = 0.25$ into equation (2) and (3) resulting UCL and LCL for ISRT $p$ EWMA as follow:

$$ UCL_{ISRT\ p\ EWMA} = 0.0387 + 2.998 \left[ \frac{0.25}{2-0.25} \left( \frac{1}{2} \sqrt{\frac{1-0.0387}{572}} - \frac{1}{6} \frac{1-0.0387}{572 \sqrt{0.0387}} \right) \right] = 0.0466 $$

$$ UCL_{ISRT\ p\ EWMA} = 0.0387 + 2.998 \left[ \frac{0.25}{2-0.25} \left( \frac{1}{2} \sqrt{\frac{1-0.0387}{572}} - \frac{3}{8} \frac{1-0.0387}{572 \sqrt{0.0387}} \right) \right] = 0.0311 $$

The control limit of ISRT $p$ EWMA chart for each initial observation was displayed in Table 1.

5. Decide whether the parameter and trial control limit represent the incontrol situation so that the ISRT $p$ EWMA chart can be used as a bias estimate of mean and variance and used it to monitor the production process. Table 1 indicated that the process was in control so that the parameter can be used to monitor the production process for April. The parameters of ISRT $p$ EWMA chart were $\mu = 0.0387$, $\sigma = 0.0016$, $Z_0 = 0.0385$, and the control limits were $UCL_{ISRT\ p\ EWMA} = 0.0476$ and $LCL_{ISRT\ p\ EWMA} = 0.0303$.

6. To evaluate the performance of the ISRT $p$ EWMA chart, the same observation data was then controlled using Shewhart $p$ chart. The above step is done for the same observation data in Table 1. Each initial observation data was then compiled with control limits UCL and LCL of Shewhart $p$ chart which were calculated using equation (4) and (5) at $\bar{p} = 0.0387$ as follow:

$$ UCL_{p\ chart} = \bar{p} + 3 \sqrt{\frac{\bar{p}(1-\bar{p})}{n_i}} $$

$$ LCL_{p\ chart} = \bar{p} - 3 \sqrt{\frac{\bar{p}(1-\bar{p})}{n_i}} $$

7. Substitute $\bar{p} = 0.0387$ and $n=575$ for 1st observation into equation (4) and (5) resulted the following $UCL_{p\ chart}$ and $LCL_{p\ chart}$:

$$ UCL_{p\ chart} = 0.0387 + 3 \sqrt{\frac{0.0387(1-0.0387)}{575}} = 0.0629 $$

$$ LCL_{p\ chart} = 0.0387 - 3 \sqrt{\frac{0.0387(1-0.0387)}{575}} = 0.0146 $$

Recalculate all observation data in Table 1 resulted the $UCL_{p\ chart}$ and $LCL_{p\ chart}$ as presented in 9th and 10th column of Table 1.
Table 1. Initial observation to estimate parameter of ISRT p EWMA Chart and Shewhart p Chart.

| No | N   | Np | p    | Control Limit for ISRT p EWMA | Control Limit for p Chart |
|----|-----|----|------|--------------------------------|---------------------------|
|    |     |    |      | Zi   | UCL | LCL | CL    | UCL | LCL | CL  |
| 1  | 575 | 12 | 0.020 | 0.0343 | 0.0466 | 0.0311 | 0.0385 | 0.0629 | 0.0146 | 0.0387 |
| 2  | 512 | 27 | 0.052 | 0.0389 | 0.0471 | 0.0308 | 0.0385 | 0.0643 | 0.0131 | 0.0387 |
| 3  | 309 | 10 | 0.032 | 0.0372 | 0.0493 | 0.0291 | 0.0385 | 0.0716 | 0.0058 | 0.0387 |
| 4  | 381 | 13 | 0.034 | 0.0365 | 0.0483 | 0.0298 | 0.0385 | 0.0684 | 0.0091 | 0.0387 |
| 5  | 454 | 15 | 0.033 | 0.0356 | 0.0476 | 0.0304 | 0.0385 | 0.0659 | 0.0116 | 0.0387 |
| 6  | 314 | 17 | 0.054 | 0.0402 | 0.0492 | 0.0292 | 0.0385 | 0.0714 | 0.0061 | 0.0387 |
| 7  | 487 | 18 | 0.037 | 0.0394 | 0.0473 | 0.0306 | 0.0385 | 0.0649 | 0.0125 | 0.0387 |
| 8  | 423 | 16 | 0.037 | 0.0390 | 0.0479 | 0.0301 | 0.0385 | 0.0669 | 0.0106 | 0.0387 |
| 9  | 476 | 24 | 0.050 | 0.0419 | 0.0474 | 0.0305 | 0.0385 | 0.0652 | 0.0122 | 0.0387 |
| 10 | 601 | 24 | 0.039 | 0.0414 | 0.0465 | 0.0312 | 0.0385 | 0.0623 | 0.0151 | 0.0387 |
| 11 | 596 | 20 | 0.033 | 0.0394 | 0.0465 | 0.0312 | 0.0385 | 0.0624 | 0.0150 | 0.0387 |
| 12 | 412 | 14 | 0.034 | 0.0381 | 0.0480 | 0.0301 | 0.0385 | 0.0672 | 0.0102 | 0.0387 |
| 13 | 434 | 14 | 0.032 | 0.0366 | 0.0478 | 0.0302 | 0.0385 | 0.0665 | 0.0109 | 0.0387 |
| 14 | 478 | 15 | 0.031 | 0.0353 | 0.0474 | 0.0305 | 0.0385 | 0.0652 | 0.0122 | 0.0387 |
| 15 | 372 | 19 | 0.051 | 0.0392 | 0.0484 | 0.0297 | 0.0385 | 0.0687 | 0.0087 | 0.0387 |
| 16 | 495 | 16 | 0.032 | 0.0375 | 0.0472 | 0.0306 | 0.0385 | 0.0647 | 0.0127 | 0.0387 |
| 17 | 367 | 12 | 0.032 | 0.0363 | 0.0485 | 0.0297 | 0.0385 | 0.0689 | 0.0085 | 0.0387 |
| 18 | 551 | 21 | 0.038 | 0.0368 | 0.0468 | 0.0310 | 0.0385 | 0.0634 | 0.0141 | 0.0387 |
| 19 | 611 | 30 | 0.049 | 0.0398 | 0.0464 | 0.0313 | 0.0385 | 0.0621 | 0.0153 | 0.0387 |
| 20 | 430 | 23 | 0.053 | 0.0433 | 0.0478 | 0.0302 | 0.0385 | 0.0666 | 0.0108 | 0.0387 |
| 21 | 521 | 18 | 0.034 | 0.0411 | 0.0470 | 0.0308 | 0.0385 | 0.0641 | 0.0134 | 0.0387 |
| 22 | 320 | 10 | 0.031 | 0.0386 | 0.0491 | 0.0292 | 0.0385 | 0.0711 | 0.0064 | 0.0387 |
| 23 | 510 | 21 | 0.041 | 0.0393 | 0.0471 | 0.0307 | 0.0385 | 0.0643 | 0.0131 | 0.0387 |
| 24 | 552 | 27 | 0.048 | 0.0417 | 0.0468 | 0.0310 | 0.0385 | 0.0634 | 0.0141 | 0.0387 |
| 25 | 377 | 12 | 0.031 | 0.0392 | 0.0484 | 0.0298 | 0.0385 | 0.0685 | 0.0089 | 0.0387 |
| 26 | 490 | 16 | 0.032 | 0.0376 | 0.0473 | 0.0306 | 0.0385 | 0.0649 | 0.0126 | 0.0387 |
| 27 | 322 | 10 | 0.031 | 0.0359 | 0.0491 | 0.0292 | 0.0385 | 0.0710 | 0.0065 | 0.0387 |
| 28 | 414 | 17 | 0.041 | 0.0372 | 0.0480 | 0.0301 | 0.0385 | 0.0672 | 0.0103 | 0.0387 |
| 29 | 577 | 26 | 0.045 | 0.0392 | 0.0466 | 0.0311 | 0.0385 | 0.0628 | 0.0146 | 0.0387 |
| 30 | 456 | 18 | 0.039 | 0.0393 | 0.0476 | 0.0304 | 0.0385 | 0.0658 | 0.0116 | 0.0387 |

| Total | 13817 | 535 | -  | 1.1558 | -  | -  | -  | -  | -  | -  |
| Mean  | 0.0387 | -  | -  | -  | -  | -  | -  | -  | -  | -  |

Table 1 indicated that the Shewhart p chart was in control, so that the parameters of Shewhart p control Chart were $\overline{p} = 0.0387$, UCL$_{Shewhart p} = 0.0629$ and LCL$_{Shewhart p} = 0.146$ and the chart can be used to monitor the production process for April.
Table 2. Process Monitoring on April using ISRT p EWMA Chart and Shewhart p Chart.

| i^{th} | N  | Np | p     | Control Limit for ISRT EWMA p ISRT | Control Limit for p Chart |
|-------|----|----|-------|-------------------------------------|---------------------------|
|       |    |    |       | Z_i | UCL_i | LCL_i | CL_i | UCL_i | LCL | CL_i |                      |
| 1     | 482| 14 | 0.0290| 0.0361 | 0.0473 | 0.0306 | 0.0385 | 0.0651 | 0.0123 | 0.0387 |                      |
| 2     | 402| 19 | 0.0473| 0.0389 | 0.0481 | 0.0300 | 0.0385 | 0.0676 | 0.0098 | 0.0387 |                      |
| 3     | 525| 16 | 0.0305| 0.0368 | 0.0470 | 0.0308 | 0.0385 | 0.0640 | 0.0134 | 0.0387 |                      |
| 4     | 507| 25 | 0.0493| 0.0399 | 0.0471 | 0.0307 | 0.0385 | 0.0644 | 0.0130 | 0.0387 |                      |
| 5     | 490| 16 | 0.0327| 0.0381 | 0.0473 | 0.0306 | 0.0385 | 0.0648 | 0.0126 | 0.0387 |                      |
| 6     | 493| 24 | 0.0487| 0.0408 | 0.0473 | 0.0306 | 0.0385 | 0.0648 | 0.0126 | 0.0387 |                      |
| 7     | 523| 13 | 0.0249| 0.0368 | 0.0470 | 0.0308 | 0.0385 | 0.0640 | 0.0134 | 0.0387 |                      |
| 8     | 531| 15 | 0.0282| 0.0346 | 0.0470 | 0.0309 | 0.0385 | 0.0638 | 0.0136 | 0.0387 |                      |
| 9     | 511| 22 | 0.0431| 0.0367 | 0.0471 | 0.0307 | 0.0385 | 0.0643 | 0.0131 | 0.0387 |                      |
| 10    | 521| 15 | 0.0288| 0.0348 | 0.0470 | 0.0308 | 0.0385 | 0.0641 | 0.0133 | 0.0387 |                      |
| 11    | 475| 23 | 0.0484| 0.0382 | 0.0474 | 0.0305 | 0.0385 | 0.0652 | 0.0122 | 0.0387 |                      |
| 12    | 443| 23 | 0.0519| 0.0416 | 0.0477 | 0.0303 | 0.0385 | 0.0662 | 0.0112 | 0.0387 |                      |
| 13    | 396| 18 | 0.0455| 0.0426 | 0.0482 | 0.0299 | 0.0385 | 0.0678 | 0.0096 | 0.0387 |                      |
| 14    | 374| 22 | 0.0588| 0.0466 | 0.0484 | 0.0297 | 0.0385 | 0.0686 | 0.0088 | 0.0387 |                      |
| 15    | 563| 14 | 0.0249| 0.0412 | 0.0467 | 0.0310 | 0.0385 | 0.0631 | 0.0143 | 0.0387 |                      |
| 16    | 545| 21 | 0.0385| 0.0405 | 0.0469 | 0.0309 | 0.0385 | 0.0635 | 0.0139 | 0.0387 |                      |
| 17    | 559| 11 | 0.0197| 0.0353 | 0.0468 | 0.0310 | 0.0385 | 0.0632 | 0.0142 | 0.0387 |                      |
| 18    | 424| 24 | 0.0566| 0.0406 | 0.0479 | 0.0301 | 0.0385 | 0.0668 | 0.0106 | 0.0387 |                      |
| 19    | 382| 14 | 0.0366| 0.0396 | 0.0483 | 0.0298 | 0.0385 | 0.0683 | 0.0091 | 0.0387 |                      |
| 20    | 363| 18 | 0.0496| 0.0421 | 0.0486 | 0.0296 | 0.0385 | 0.0691 | 0.0083 | 0.0387 |                      |
| 21    | 499| 17 | 0.0341| 0.0401 | 0.0472 | 0.0307 | 0.0385 | 0.0646 | 0.0128 | 0.0387 |                      |
| 22    | 298| 16 | 0.0537| 0.0435 | 0.0495 | 0.0289 | 0.0385 | 0.0722 | 0.0052 | 0.0387 |                      |
| 23    | 400| 17 | 0.0425| 0.0433 | 0.0481 | 0.0299 | 0.0385 | 0.0676 | 0.0098 | 0.0387 |                      |
| 24    | 380| 24 | 0.0632| 0.0482 | 0.0484 | 0.0298 | 0.0385 | 0.0684 | 0.0090 | 0.0387 |                      |
| 25    | 551| 29 | 0.0526| 0.0493 | 0.0468 | 0.0310 | 0.0385 | 0.0634 | 0.0140 | 0.0387 |                      |
| 26    | 441| 11 | 0.0249| 0.0432 | 0.0477 | 0.0303 | 0.0385 | 0.0663 | 0.0111 | 0.0387 |                      |
| 27    | 487| 11 | 0.0226| 0.0381 | 0.0473 | 0.0306 | 0.0385 | 0.0649 | 0.0125 | 0.0387 |                      |
| 28    | 512| 15 | 0.0293| 0.0359 | 0.0471 | 0.0307 | 0.0385 | 0.0643 | 0.0131 | 0.0387 |                      |
| 29    | 498| 26 | 0.0522| 0.0400 | 0.0472 | 0.0307 | 0.0385 | 0.0646 | 0.0128 | 0.0387 |                      |
| 30    | 336| 17 | 0.0506| 0.0426 | 0.0489 | 0.0294 | 0.0385 | 0.0703 | 0.0071 | 0.0387 |                      |

Total: 13911 550 - 1,2062 - - - - - 0,3470 -
Mean: - 0,0395 - 0,0402 - - - - -

2^nd Step: Process monitoring using ISRT p EWMA chart
The ISRT p EWMA chart is now ready to monitor the production process on April at PT Primarindo Asia Infrastruktur Tbk using the above parameter. All the unit produced on April was inspected and the number of defective units found was presented in Table 2. Using equation (1) and (2) each data during April was converted to Z value and UCL/LCL for ISRT p EWMA chart was calculated. The plot of the data into the ISRT p EWMA chart presented in Figure 1.
Every single data in table 2 was plotted on ISRT p EWMA chart. Overall monitoring result using ISRT p EWMA chart was displayed in Figure 1.

To study the performance of ISRT p EWMA chart, the Shewhart p chart was also developed for the same data observation and the UCL/LCL for Shewhart p chart also presented in Table 2. The plotted data on Shewhart p Chart and the overall monitoring result was presented in Figure 2.

3. Result and Discussion

The study resulted that the ISRT p EWMA performed better than traditional Shewhart p chart. Using ISRT p EWMA chart, the shift was detected twice at 18th and 25th observation. Meanwhile, the shift was not detected when traditional Shewhart p chart is used to control the process. In the case of PT Primarindo Asia Infrastruktur Tbk, the Shewhart p chart failed to detect the shift while the process actually has shifted. As a result, the process run in the out of control condition, and automatically produced defectives units. That is the reason why the fraction defective at PT. Primarindo Asia Infrastruktur Tbk was excessive. On the other hand, when ISRT p EWMA chart was used, the shift was
detected and the process was restored so that defectives unit could be avoided. Therefore, the fraction defective of the process could be reduced. The result was obtained at a specified parameter L and λ. As a preliminary investigation, in this paper the effect of λ was analysed. To see the effect of λ parameters, the same procedure for the same observation data presented in Table 1 was repeated at λ = 0.25, λ = 0.5 and λ = 0.75. The summary results presented in Figure 3a for λ = 0.25, Figure 3b for λ = 0.5 and Figure 3c for λ = 0.75.

**Figure 3a. Performance of ISRT p EWMA chart for λ = 0.25.**

**Figure 3b. Performance of ISRT p EWMA chart for λ = 0.5.**

**Figure 3c. Performance of ISRT p EWMA chart for λ = 0.75.**

Figure 3a, 3b, and 3c explained that at λ = 0.25 the shift was detected twice at 18th and 25th observation, while at λ = 0.5 the shift was detected only once at 18th observation and at λ = 0.75 the ISRT p EWMA chart could not detect the shift while actually the process has shifted. It means that the greater the value of λ, the worse the performance of ISRT p EWMA chart to detect small shift.
Time limitation leaving L parameter could not be investigated. To get a comprehensive result, it is recommended for further research:

1. Instead of parameter λ, the effect of L parameter should also be investigated.
2. For accurate result, the performance of ISRT p EWMA chart should be measured in term of Average Run Length (ARL).
3. To get a comprehensive result, the ISRT p EWMA chart must be compared against Shewhart p chart as well as p EWMA chart.

4. Conclusion
This paper investigates the performance of ISRT p EWMA chart on detecting small shift variation with the following conclusion:

1. The ISRT p EWMA chart detected small shift better than Shewhart p chart. The ISRT p EWMA chart detected the shift twice, while Shewhart p chart did not not detect any shift.
2. The value of λ parameter has a significant effect on the performance of ISRT p EWMA chart. The larger the value of λ parameter, the worse the performance of the ISRT p EWMA chart. At λ = 0.25, the shift was detected twice, at λ = 0.5, the shift was detected once while at λ = 0.75, the shift was not detected.
3. For further research, the performance of the ISRT p EWMA chart, should not only be compared with Shewhart p chart, but also with p EWMA chart as well, in term of Average Run Length for different value of L parameter.

5. References
[1] Abbas A, Riaz M and Arden M 2010 Enhancing the Performance of Cusum Scale Chart. Computers and Industrial Engineering, 63, pp 400-409.
[2] Grant E and Leavenworth R 1996 Statistical Quality Control (7th Edition). (Singapore: McGraw Hill)
[3] Erna TH 2018 Modified Exponentially Weighted Moving Average (EWMA) Control Chart on Autocorrelation Data Journal of Physic:Conf. Ser. 979012097.
[4] Knoth S and Steinmetz S 2013 EWMA p charts under sampling by variables. International Journal of Production Research 51(13).
[5] Lucas J and Saccucci M 1990 Exponentially Weighted Moving Average Control Schemes. Properties and Enhancements Technometrics, 32(1), pp 1-12.
[6] Montgomery D C 2012 Introduction To statistical quality control. (USA: John Wiley & Son), pp 120-121.
[7] Robert S W 1959 Control Chart test based on Geometric Moving Average. Technometric, 1, pp 239 – 250.
[8] Sukparungsee S 2014 EWMA p Chart Based on Improved Square Root Transformation, International Journal of Mathematical, Computational, Physical, Electrical and Computer Engineering 8(7).
[9] Vera D C et all 2004 Comparative study of the performance of the CuSum and EWMA control charts Computer & Industrial Engineering 46(4), pp 707-72