QUALITY CONTROL Dhrubojyoti Chanda

MINI PROJECT

CONTROL CHARTS INCLUDED: CUSUM

CUSUM V-MASK

EWMA

MOVING AVERAGE

SPC WITH SHORT RUN

SPC WITH AUTO CORRELATED DATA

**Q. SPC WITH AUTO CORRELATED DATA.**

The manager of a shipping yard wants to study the amount of cargo that is transported. The manager collects the weight of all the cargo that passes through the shipping yard each month.

1. Calculate the sample autocorrelation function. Interpret the results that you have obtained.
2. Construct an individuals control chart, using the moving range method to estimate the standard deviation. Interpret the results you have obtained.
3. Fit a first-order autoregressive model xt = x + fxt−1 +et to the temperature data. Set up an individuals control chart on the residuals from this model. Compare this chart to the individuals chart in the original data in part (a).

|  |  |
| --- | --- |
| *Weight* | The monthly weight of total shipments in thousands of pound |

( DATASET SOURCE: <https://support.minitab.com/en-us/datasets/time-series-data-sets/shipping-data/>

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Weight |  |  |  |  |  |
| 43.2 | 41 | 25.7 | 26.5 | 36.3 | 31 |
| 44.8 | 32.2 | 24.9 | 29 | 30.1 | 31.9 |
| 43.1 | 33.7 | 34 | 33.3 | 24.1 | 26.2 |
| 41.9 | 37.2 | 31.4 | 37.2 | 25.1 | 33.7 |
| 44.4 | 39.8 | 30 | 32.4 | 25.9 | 29.5 |
| 37.8 | 39 | 25.4 | 30.6 | 29.6 | 35.2 |
| 35.7 | 33.7 | 26.8 | 24 | 30.7 | 32.3 |
| 35.2 | 29.9 | 26.4 | 28.8 | 28.3 | 31.3 |
| 31.7 | 29.9 | 32.2 | 36.5 | 29.9 | 33 |
| 30.3 | 30.7 | 39.8 | 37.6 | 33.3 | 30.6 |
| 35.9 | 28.5 | 43.4 | 39.8 | 42.7 | 31.7 |
| 44.2 | 25 | 41.8 | 35.4 | 41.3 | 30.9 |
| 45.8 | 29.5 | 35.1 | 29.2 | 45.3 |  |
| 44.8 | 23.5 | 32.7 | 26.8 | 39.5 |  |
| 42.8 | 23.4 | 30.7 | 30.7 | 34.2 |  |
| 34.2 | 22.2 | 26.5 | 29.5 | 36.9 |  |
| 36.4 | 26.9 | 24.6 | 24.1 | 33.6 |  |
| 33.7 | 28.1 | 24.8 | 29.8 | 30.9 |  |
| 31.4 | 24.6 | 24.2 | 34.7 | 26.6 |  |

Sol: a) Constructing the sample auto correlation function using MINITAB. (step 1)

 FIG.1

AutocorrelationsLag ACF T LBQ1 0.749964 7.76 61.882 0.498029 3.53 89.443 0.269184 1.72 97.564 0.131431 0.82 99.525 0.092071 0.57 100.496 0.046505 0.29 100.747 0.081655 0.50 101.518 0.073495 0.45 102.159 0.126900 0.78 104.0710 0.163512 1.00 107.2811 0.155586 0.94 110.2212 0.131249 0.79 112.3413 -0.005576 -0.03 112.3414 -0.074262 -0.44 113.0315 -0.088955 -0.53 114.0416 -0.045011 -0.27 114.3017 0.005338 0.03 114.3018 0.016352 0.10 114.3319 0.062190 0.37 114.8520 0.040273 0.24 115.0621 0.023960 0.14 115.1422 -0.022013 -0.13 115.2123 -0.018943 -0.11 115.2624 0.028597 0.17 115.3725 -0.000455 -0.00 115.3726 -0.010960 -0.06 115.3927 -0.019646 -0.12 115.45

Step 2. Constructing the partial autocorrelation function using MINITAB.

 FIG.2

Partial Autocorrelation Function: Weight

Partial Autocorrelations

|  |  |  |
| --- | --- | --- |
| Lag | PACF | T |
| 1 | 0.749964 | 7.76 |
| 2 | -0.147218 | -1.52 |
| 3 | -0.114229 | -1.18 |
| 4 | 0.034083 | 0.35 |
| 5 | 0.092566 | 0.96 |
| 6 | -0.087899 | -0.91 |
| 7 | 0.146770 | 1.52 |
| 8 | -0.069133 | -0.72 |
| 9 | 0.157289 | 1.63 |
| 10 | 0.015675 | 0.16 |
| 11 | -0.026583 | -0.27 |
| 12 | -0.018167 | -0.19 |
| 13 | -0.201306 | -2.08 |
| 14 | 0.045517 | 0.47 |
| 15 | 0.080363 | 0.83 |
| 16 | 0.024127 | 0.25 |
| 17 | -0.014920 | -0.15 |
| 18 | -0.010716 | -0.11 |
| 19 | 0.064049 | 0.66 |
| 20 | -0.071052 | -0.73 |
| 21 | -0.033806 | -0.35 |
| 22 | -0.042527 | -0.44 |
| 23 | 0.137168 | 1.42 |
| 24 | 0.072666 | 0.75 |
| 25 | -0.125772 | -1.30 |
| 26 | -0.040282 | -0.42 |
| 27 | 0.043166 | 0.45 |

From Fig1 and Fig 2 we can see that there is a positive correlation at lag 1. Therefore, observations that are one period apart are positively correlated with r1 = 0.749964. The partial autocorrelation function recommended an autoregressive process of order 1 (AR (1)).

B)

Individual control chart for weight:



I Chart of Weight

I Chart of Weight

Test Results for I Chart of Weight

TEST 1. One point more than 3.00 standard deviations from center line.

Test Failed at points:  1, 2, 3, 4, 5, 12, 13, 14, 15, 33, 34, 35, 49, 50, 87, 89

TEST 2. 8 points in a row on same side of center line.

Test Failed at points:  8, 18, 34, 35, 36, 37, 38, 39, 40, 85, 93

TEST 3. 6 points in a row all increasing or all decreasing.

Test Failed at points:  55

TEST 5. 2 out of 3 points more than 2 standard deviations from center line (on one side of CL).

Test Failed at points:  2, 3, 4, 5, 13, 14, 15, 25, 33, 34, 35, 39, 40, 46, 49, 50, 55, 56, 57, 58, 80, 81, 88, 89, 90

TEST 6. 4 out of 5 points more than 1 standard deviation from center line (on one side of CL).

Test Failed at points:  4, 5, 6, 7, 14, 15, 17, 33, 34, 35, 36, 37, 38, 39, 40, 57, 58, 59, 74, 82, 84, 90, 92

TEST 8. 8 points in a row more than 1 standard deviation from center line (above and below CL).

Test Failed at points:  37, 38, 39, 40

From the Above MINITAB output,

UCL = 41.64

Xbar = 32.65

LCL= 23.67

From the above data and test run, Individual’s control chart for weight is not in statistical control.

C) Fitting a first order autoregressive mode using MINITAB.

ARIMA Model: Weight

Estimates at Each Iteration

|  |  |  |  |
| --- | --- | --- | --- |
| Iteration | SSE | Parameters | |
| 0 | 3280.67 | 0.100 | 29.479 |
| 1 | 2616.08 | 0.250 | 24.559 |
| 2 | 2118.25 | 0.400 | 19.640 |
| 3 | 1787.15 | 0.550 | 14.725 |
| 4 | 1622.68 | 0.700 | 9.816 |
| 5 | 1603.22 | 0.762 | 7.803 |
| 6 | 1602.71 | 0.771 | 7.526 |
| 7 | 1602.69 | 0.773 | 7.476 |
| 8 | 1602.69 | 0.773 | 7.466 |

*Relative change in each estimate less than 0.001*

Final Estimates of Parameters

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Type | Coef | SE Coef | T-Value | P-Value |
| AR   1 | 0.7732 | 0.0622 | 12.42 | 0.000 |
| Constant | 7.466 | 0.375 | 19.92 | 0.000 |
| Mean | 32.92 | 1.65 |  |  |

Number of observations:  107

Residual Sums of Squares

|  |  |  |
| --- | --- | --- |
| DF | SS | MS |
| 105 | 1577.26 | 15.0216 |

*Back forecasts excluded*

Modified Box-Pierce (Ljung-Box) Chi-Square Statistic

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Lag | 12 | 24 | 36 | 48 |
| Chi-Square | 17.69 | 31.60 | 50.09 | 59.75 |
| DF | 10 | 22 | 34 | 46 |
| P-Value | 0.060 | 0.084 | 0.037 | 0.084 |

Now, Constructing the Individual’s control chart for residual values given below:

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Weight | Residuals |  | Weight | Residuals |  | Weight | Residuals |
| 43.2 | 4.135553 |  | 26.9 | 2.269436 |  | 26.8 | -3.24296 |
| 44.8 | 3.932255 |  | 28.1 | -0.1646 |  | 30.7 | 2.51272 |
| 43.1 | 0.995137 |  | 24.6 | -4.59244 |  | 29.5 | -1.70276 |
| 41.9 | 1.109575 |  | 25.7 | -0.78624 |  | 24.1 | -6.17492 |
| 44.4 | 4.537414 |  | 24.9 | -2.43676 |  | 29.8 | 3.700358 |
| 37.8 | -3.99558 |  | 34 | 7.281799 |  | 34.7 | 4.193123 |
| 35.7 | -0.99247 |  | 31.4 | -2.35431 |  | 36.3 | 2.004448 |
| 35.2 | 0.131249 |  | 30 | -1.744 |  | 30.1 | -5.43267 |
| 31.7 | -2.98215 |  | 25.4 | -5.26152 |  | 24.1 | -6.63884 |
| 30.3 | -1.67596 |  | 26.8 | -0.3048 |  | 25.1 | -0.99964 |
| 35.9 | 5.006524 |  | 26.4 | -1.78728 |  | 25.9 | -0.97284 |
| 44.2 | 8.976609 |  | 32.2 | 4.322 |  | 29.6 | 2.1086 |
| 45.8 | 4.159056 |  | 39.8 | 7.437445 |  | 30.7 | 0.347763 |
| 44.8 | 1.921938 |  | 43.4 | 5.161132 |  | 28.3 | -2.90276 |
| 42.8 | 0.695137 |  | 41.8 | 0.777616 |  | 29.9 | 0.552922 |
| 34.2 | -6.35846 |  | 35.1 | -4.68527 |  | 33.3 | 2.715803 |
| 36.4 | 2.491047 |  | 32.7 | -1.90483 |  | 42.7 | 9.486926 |
| 33.7 | -1.90999 |  | 30.7 | -2.04915 |  | 41.3 | 0.818855 |
| 31.4 | -2.12235 |  | 26.5 | -4.70276 |  | 45.3 | 5.901334 |
| 41 | 9.256005 |  | 24.6 | -3.35532 |  | 39.5 | -2.99146 |
| 32.2 | -6.96671 |  | 24.8 | -1.68624 |  | 34.2 | -3.80691 |
| 33.7 | 1.337445 |  | 24.2 | -2.44088 |  | 36.9 | 2.991047 |
| 37.2 | 3.677647 |  | 26.5 | 0.323038 |  | 33.6 | -2.39659 |
| 39.8 | 3.57145 |  | 29 | 1.04468 |  | 30.9 | -2.54503 |
| 39 | 0.761132 |  | 33.3 | 3.411682 |  | 26.6 | -4.7574 |
| 33.7 | -3.92031 |  | 37.2 | 3.986926 |  | 31 | 2.96736 |
| 29.9 | -3.62235 |  | 32.4 | -3.82855 |  | 31.9 | 0.465284 |
| 29.9 | -0.6842 |  | 30.6 | -1.91719 |  | 26.2 | -5.93059 |
| 30.7 | 0.115803 |  | 24 | -7.12544 |  | 33.7 | 5.97664 |
| 28.5 | -2.70276 |  | 28.8 | 2.777678 |  | 29.5 | -4.02235 |
| 25 | -4.50172 |  | 36.5 | 6.766322 |  | 35.2 | 4.925083 |
| 29.5 | 2.704479 |  | 37.6 | 1.912689 |  | 32.3 | -2.38215 |
| 23.5 | -6.77492 |  | 39.8 | 3.26217 |  | 31.3 | -1.13987 |
| 23.4 | -2.23572 |  | 35.4 | -2.83887 |  | 33 | 1.333325 |
| 22.2 | -3.3584 |  | 29.2 | -5.63679 |  | 30.6 | -2.38111 |
|  |  |  |  |  |  | 31.7 | 0.574564 |
|  |  |  |  |  |  | 30.9 | -1.07596 |

FIG.4

**According to FIG.4 The Individual’s control chart for residuals is in statistical control.**

**Q.** **SPC WITH SHORT RUN**

A manufacturer uses short runs to create small batches of metal parts. The quality manager measures parts from three runs to assess the stability of the stamping process.

| **Worksheet column** | **Description** |
| --- | --- |
| *Stamp Data* | The measurement of the sample part |
| *Run* | The run identifier (part indicator) |

Data set source: <https://support.minitab.com/en-us/datasets/control-charts-data-sets/stamped-parts-data/>

(data set has been modified with reference to the above mentioned)

|  |  |  |  |
| --- | --- | --- | --- |
| Stamp Data | Run | Nominal | Difference |
| 301.24 | Run A | 300 | 1.24 |
| 300.2 | Run A | 300 | 0.2 |
| 301.6043 | Run A | 300 | 1.604302 |
| 299 | Run A | 300 | -1 |
| 298.8243 | Run A | 300 | -1.17568 |
| 302.724 | Run A | 300 | 2.724 |
| 300.281 | Run A | 300 | 0.281 |
| 298.204 | Run A | 300 | -1.796 |
| 505.282 | Run B | 500 | 5.282 |
| 506.8792 | Run B | 500 | 6.879212 |
| 506.1887 | Run B | 500 | 6.18872 |
| 501.21 | Run B | 500 | 1.21 |
| 498.402 | Run B | 500 | -1.598 |
| 495.1696 | Run B | 500 | -4.8304 |
| 506.8514 | Run B | 500 | 6.851392 |
| 492.201 | Run B | 500 | -7.799 |
| 400.5483 | Run C | 400 | 0.548342 |
| 403.1932 | Run C | 400 | 3.193177 |
| 392.7898 | Run C | 400 | -7.21021 |
| 399.5377 | Run C | 400 | -0.4623 |
| 379.192 | Run C | 400 | -20.808 |
| 417.812 | Run C | 400 | 17.812 |
| 393.4572 | Run C | 400 | -6.54284 |
| 401.0513 | Run C | 400 | 1.051314 |

( Above chart also include include the nominal values for 3 different Run’s (Run A, Run B and Run C)

Difference = Stamp data value – Nominal Value

Now, Short run SPC focuses on the process rather than the product.

Since, we are looking at individual items. Therefore, we are using I-MR (Individual- Moving range) chart (in MINITAB)

 FIG1

I-MR Chart of Difference

I-MR Chart of Difference

Test Results for I Chart of Difference

TEST 1. One point more than 3.00 standard deviations from center line.

Test Failed at points:  21

Test Results for MR Chart of Difference

TEST 1. One point more than 3.00 standard deviations from center line.

Test Failed at points:  22

**From the above FIG1 and the test results we can say that I-MR chart for stamp data is not in statistical control.**

**Q. MOVING AVERAGE CHART**

A quality engineer from a plastic manufacturing company would like to make sure his batch process stays in control. The engineer measures the concentration of pigment of each batch for all 35 batches.

1. Plot a moving average chart for the above pigment data.
2. Is the process in control?

| **Worksheet column** | **Description** |
| --- | --- |
| *Batch* | The batch identifier. This column contains the subgroup sizes. |
| *Pigment* | The concentration of pigment in the batch. |

Dataset Source: <https://support.minitab.com/en-us/datasets/control-charts-data-sets/pigment-concentration-data/>

|  |  |  |  |
| --- | --- | --- | --- |
| Batch | Pigment | Batch | Pigment |
| 1 | 9.687765 | 21 | 9.907706 |
| 2 | 9.376966 | 22 | 8.306911 |
| 3 | 10.82535 | 23 | 10.49958 |
| 4 | 9.636838 | 24 | 9.616519 |
| 5 | 10.40494 | 25 | 9.542704 |
| 6 | 9.210302 | 26 | 14.10974 |
| 7 | 10.74506 | 27 | 10.28421 |
| 8 | 10.35469 | 28 | 11.2402 |
| 9 | 10.0961 | 29 | 10.874 |
| 10 | 9.625592 | 30 | 12.73937 |
| 11 | 10.31464 | 31 | 11.28508 |
| 12 | 10.40391 | 32 | 10.869 |
| 13 | 11.01761 | 33 | 11.32265 |
| 14 | 9.852254 | 34 | 10.865 |
| 15 | 9.748416 | 35 | 10.99261 |
| 16 | 10.7151 |  |  |
| 17 | 9.781192 |  |  |
| 18 | 10.04083 |  |  |
| 19 | 9.485814 |  |  |
| 20 | 8.715005 |  |  |



**The Moving Average Chart of Pigment shows that the process is in statistical control.**