Applying Link Relative EWMA Control Chart in Controlling the Production Quality of Laying Hens

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Abstract

The laying hens industry is one of the more promising ones in the livestock industry. Generally speaking, the two factors that determine this business's success are its ability to achieve financial profit and productivity. The number and quality of egg production must be maximized in order to meet these two success criteria. The quantity value, or total amount of production, and the quality value show how successful the egg production process was. Farmers will experience financial difficulties if there is a high output percentage of eggs but poor quality eggs do not sell in the market. The Laying Hens Training Cage in Banyuasin Regency, South Sumatra Province, was the site of the data collecting. Secondary data on egg production from weeks 35 to 45 was received in 2020 from the Laying Hens Training Cages at SMK PP N Sembawa, Palembang, and used in this study. As the result, The EWMA control chart is obtained based on the generated control chart. One observation is out of control when λ=0.3, L=3, and Z_0 = 4936.1 are used. This indicates that the laying hens production data has not been statistically controlled using the EWMA control chart. In the meantime, the laying hens production data is statistically controlled using the LR EWMA control chart, which generates no data or observations outside the control bounds for λ=0.3 and L=3, $\sigma_{\hat{X}} = 47.9$ and $\mu_{\hat{X}} = 4939.3$.

Keywords : Control Charts, EWMA, LR EWMA, Laying Hens.

1. Introduction

The laying hens industry is one of the more promising ones in the livestock industry. Generally speaking, the two factors that determine this business's success are its ability to achieve financial profit and productivity. The number and quality of egg production must be maximized in order to meet these two success criteria. The quantity value, or total amount of production, and the quality value show how successful the egg production process was. Farmers will experience financial difficulties if there is a high output percentage of eggs but poor quality eggs do not sell in the market. Conversely, in the event where the production percentage is low but the quality is high, the farmer will still suffer financial losses. Because of this, efforts must be made to identify the root cause of the drop in egg production as soon as possible so that farmers are prepared for it. Greater losses can be prevented if this is executed correctly (PT Medion Ardhika Bhakti, 2021). The accomplishment of successful laying hen production in this instance represents the success of the production business unit. until so far, this success has only been evident through the attainment of payment targets, devoid of any comprehensive statistical analysis. Statistical quality control procedures must therefore be followed to guarantee that the production process operates reliably and in compliance with specifications.

One of technique for keeping an tabs on and managing a production process's quality is statistical quality control. Statistical quality control is the practice of monitoring and regulating a process's or product's quality using statistical techniques. Statistical quality control can be used in laying hen husbandry to track and enhance egg quality and the variables affecting egg output. Utilizing control charts to track important production variables or the quality attributes of laying hen production is one method of applying statistical quality control to laying hen production.

Walter A. Shewhart invented the control chart, which became known as the Shewhart Control Chart, in 1924. One significant flaw in this Shewhart control chart is that it only utilizes data from the most recent sample, ignoring the information from earlier samples. As a result, slight changes in the process have less of an impact on the Shewhart control chart. Control charts that can identify minute changes in a process have been the subject of extensive research in recent years due to these issues. The Exponentially Weighted Moving Average (EWMA) control chart was one of the control charts suggested as a substitute for the Shewhart control chart. Compared to the Shewhart control chart, the EWMA control chart is more sensitive in identifying micro process alterations since it incorporates data from multiple samples.

Control charts have undergone numerous transformations and modifications over time, leading to ever-greater improvements. One of the methods used to achieve this is the link relative variable transformation technique, which makes the control chart more sensitive. The original process variable is changed by link relative variables such that it is relative to the mean. The relative position of an observation with relation to its mean is thus represented by the link relative.

2. Research

2.1. Exponentially Weighted Moving Average (EWMA) Control Chart

Robert originally presented the Exponentially Weighted Moving Average (EWMA) control chart in 1959. The modest average shifts are found using the EWMA control chart (Montgomery, 2009). The definition of EWMA statistics is as follows:

$$Z_i = \lambda X_i + (1-\lambda) Z_{i-1} \quad (1)$$

With:

i : period or subgroup $i=1,2,3,\dots,m$
Z_i : EWMA value in relation to i
λ : weight factor (from the EWMA), with a value of $0 < \lambda < 1$
X_i : Sample to i
Z_0 : Starting point

Z_i description from equation (1) is as follows:

$$\begin{aligned} Z_i &= \lambda X_i + (1-\lambda) Z_{i-1} \\ &= \lambda X_i + (1-\lambda)[\lambda X_{i-1} + (1-\lambda) Z_{i-2}] \\ &= \lambda X_i + \lambda(1-\lambda) X_{i-1} + (1-\lambda)^2 Z_{i-2} \\ &= \lambda X_i + \lambda(1-\lambda) X_{i-1} + (1-\lambda)^2[\lambda X_{i-2} + (1-\lambda) Z_{i-3}] \\ &= \lambda X_i + \lambda(1-\lambda) X_{i-1} + \lambda(1-\lambda)^2 X_{i-2} + (1-\lambda)^3 Z_{i-3} \quad (2) \end{aligned}$$

The upper control limit (UCL), lower control limit (LCL), and center line (CL) are the three main lines on the EWMA control chart, as they are on most control charts. The line in the center line (CL) of the control chart, stands for the target value or average value of the manufacturing process. The center line of the EWMA control chart is at Z_0. If the plot point of the EWMA value is outside of the LCL or above the UCL, it is considered out of control.

The EWMA control chart is then used to establish the upper control limit (UCL) and lower control limit (LCL), with L serving as the control limit's width and displayed as follows:

$$UCL = Z_0 + L\sigma_{Z_i}$$

$$= Z_0 + L\sqrt{\frac{\lambda\sigma^2(1-(1-\lambda)^{2i})}{2-\lambda}}$$

$$= Z_0 + L\sigma\sqrt{\frac{\lambda}{2-\lambda}[1-(1-\lambda)^{2i}]} \quad (3)$$

$$LCL = Z_0 - L\sigma_{Z_i}$$

$$= Z_0 - L\sigma\sqrt{\frac{\lambda}{2-\lambda}[1-(1-\lambda)^{2i}]} \quad (4)$$

2.2. Link Relative Exponentially Weighted Moving Average (LR EWMA) Control Chart

Each data point is represented as the cumulative total of the relative differences between the actual data point and the intended mean value on a Link Relative EWMA (LR EWMA) control chart. The relative link variables can be defined as follows by taking into consideration $X_i \sim N(\mu_X, \sigma_X)$, where μ_X and σ_X are taken to be known and positive (Faisal et al., 2018):

$$Y_i = \begin{Bmatrix} \frac{X_i}{\mu_x}\ if\ X_i \geq \mu_x \\ -\frac{\mu_x}{X_i}\ if\ X_i < \mu_x \end{Bmatrix}\ where\ i = 1, 2, 3 \quad (4)$$

where sample number i is involved. Y_i depends on the process average and compares each observation to the process average, which is determined from the initial process observations. Then, Y_i can be defined as a variable whose purpose is to indicate the direction of observations with respect to the process average.

Next, by employing Y_i to define the transformation variable $\hat{X}_i$ as a target utilizing the following equation in a more focused form:

$$\hat{X}_i = a + bY_i \quad (5)$$

Where, assumed $a = \mu_X$ and $b = \sqrt{\frac{2}{\pi}}\sigma_X$

The previously stated model's mean and standard deviation are denoted by the symbols $\mu_{\hat{X}}$ and $\sigma_{\hat{X}}$, respectively. Utilizing $\sigma_{\hat{X}}$ derived from:

$$\sigma_{\hat{X}}^2 = Var(a + bY_i) \quad (6)$$

Where:

$$\sigma_{\hat{X}}^2 = E[a + bY - E(a + bY)]^2$$
$$= E\left[a + bY - \left(E(a) + E(bY)\right)\right]^2$$
$$= E[a + bY - a - E(bY)]^2$$
$$= E[bY - E(bY)]^2$$
$$= E\left[b\left(Y - E(Y)\right)\right]^2$$
$$= E\left[b^2\left(Y - E(Y)\right)^2\right]$$
$$= E(b^2)E\left(Y - E(Y)\right)^2$$
$$= b^2E\left(Y - E(Y)\right)^2$$
$$= b^2Var(Y)$$
$$= b^2\sigma_Y^2 \quad (7)$$

Therefore, the following plot data are present in the suggested LR EWMA control chart:

$$Z_i = \lambda\hat{X}_i + (1-\lambda)Z_{i-1} \quad (8)$$

When the following definitions apply to $Z_0 = \mu_{\hat{X}}$ and the control limits:

$$UCL = \mu_{\hat{X}} + L\sigma_{\hat{X}}\sqrt{\frac{\lambda}{2-\lambda}[1-(1-\lambda)^{2i}]} \quad (9)$$

$$LCL = \mu_{\hat{X}} - L\sigma_{\hat{X}}\sqrt{\frac{\lambda}{2-\lambda}[1-(1-\lambda)^{2i}]} \quad (10)$$

3. Study on Case

3.1. Data Sources and Research Variables

The Laying Hens Training Cage in Banyuasin Regency, South Sumatra Province, was the site of the data collecting. Secondary data on egg production from weeks 35 to 45 was received in 2020 from the Laying Hens Training Cages at SMK PP N Sembawa, Palembang, and used in this study. The production of eggs by each chicken or variable x, is the one employed in this study with days expressed in units. Data on egg production for weeks 35 through 45 are as follows:

Table. 1. Data on egg production for weeks 35 through 45

No.	Week	Quantity of Egg Production	No.	Week	Quantity of Egg Production
1	35	4961	40	40	4932
2	35	4946	41	40	4928
3	35	4924	42	40	4983
4	35	4974	43	41	4991
5	35	4976	44	41	4887
6	35	4850	45	41	4918
7	35	4877	46	41	4907
8	36	4805	47	41	4880
9	36	5045	48	41	4879
10	36	4920	49	41	4922
11	36	4910	50	42	4974
12	36	4913	51	42	4960
13	36	4955	52	42	4998
14	36	4943	53	42	4928
15	37	4845	54	42	4963
16	37	4962	55	42	5028
17	37	4952	56	42	4958
18	37	4834	57	43	4933
19	37	4944	58	43	4965
20	37	5028	59	43	4961
21	37	4957	60	43	4952
22	38	4996	61	43	4876
23	38	4988	62	43	4931
24	38	4912	63	43	4941
25	38	4955	64	44	4952
26	38	4950	65	44	4950
27	38	4975	66	44	4880
28	38	4978	67	44	4965
29	39	4901	68	44	5037
30	39	4780	69	44	4969

31	39	4857	70	44	5121
32	39	4867	71	45	4832
33	39	4827	72	45	4990
34	39	4921	73	45	5012
35	39	4921	74	45	4929
36	40	4794	75	45	5058
37	40	4888	76	45	4999
38	40	4873	77	45	4956
39	40	4932			

3.2. Analysis Step

The following steps were taken in response to the research objectives:

1. Create an EWMA control chart using the data on chicken egg production from weeks 35 to 45 by following these steps:
   a. Ascertain the value of the weighting constant λ, which 0 < λ< 1.
   b. Determines Z_i the plot points.
   c. Control Limit Calculation (UCL and LCL)
2. Create an EWMA control chart using the data on chicken egg production from weeks 35 to 45 by following these steps:
   a. Determines Y_i Values.
   b. Ascertain the value $a = \mu_0$ and $b = 0.8 \times \sigma$.
   c. Determines $\hat{X}_i = a + bY_i$ values.
   d. Ascertain the value of the weighting constant λ, which 0 < λ< 1.
   e. Determine the plot point Z_i using the data in $\hat{X}_i$.
   f. Control Limit Calculation (UCL and LCL)

4. Result

4.1. Exponentially Weighted Moving Average (EWMA) Control Chart

Determining the starting value of EWMA Z_0 is the first step in creating an EWMA control chart. The average value can be used to determine Z_0 beginning value on the EWMA control chart, just like it can with CUSUM. $\mu_0 = Z_0 = 4936.1$ is the target value, which can be defined as the beginning value of EWMA. The creation of an EWMA control chart requires the use of λ and L. Plot points from the EWMA are found using the λ value, also known as the EWMA weight factor, while the EWMA's boundaries are found using the L value. The CL value, which is $CL = \mu_0 = 4936.1$, is fixed. Each set of data will have a distinct LCL and UCL.

The value of Z_i can be determined by utilizing the following equation with λ=0.3 and L=3:

$$Z_i = \lambda X_i + (1-\lambda)Z_{i-1}$$

$$Z_1 = \lambda X_1 + (1-\lambda)Z_0$$
$$= 0.3 \times 4961 + (1-0.3) \times 4963.1$$
$$= 4943.57$$

$$Z_2 = \lambda X_2 + (1-\lambda)Z_1$$
$$= 0.3 \times 4946 + (1-0.3) \times 4943.57$$
$$= 4944.31$$

$$Z_3 = \lambda X_3 + (1-\lambda)Z_2$$
$$= 0.3 \times 4924 + (1-0.3) \times 4944.31$$
$$= 4938.22$$

$$Z_4 = \lambda X_4 + (1-\lambda)Z_3$$

$$= 0.3 \times 4974 + (1 - 0.3) \times 4938.22$$
$$= 4948.95$$
$$Z_5 = \lambda X_5 + (1 - \lambda) Z_4$$
$$= 0.3 \times 4976 + (1 - 0.3) \times 4948.95$$
$$= 4957.07$$
$$\vdots$$
$$Z_{77} = \lambda X_{77} + (1 - \lambda) Z_{76}$$
$$= 0.3 \times 4956 + (1 - 0.3) \times 4995.07$$
$$= 4983.35$$

This computation is done for every Z_i up to Z_{77}. Table 2 displays the overall Z_i value calculation findings. The Z_i value will be obtained, and the EWMA control chart will be used to calculate the control limit value. The equation (3) can be used to calculate UCL.

When i = 1,

$$UCL = Z_0 + L\sigma \sqrt{\frac{\lambda}{2-\lambda}\left[1-(1-\lambda)^{2i}\right]}$$
$$= 4936.1 + 3 \times 61.3 \sqrt{\frac{0.3}{2-0.3}\left[1-(1-0.3)^{2\times 1}\right]}$$
$$= 4991.27$$

Using the same computational technique, the UCL value for $i = 2,3,\cdots,77$ is determined and shown in Table 2. Next, equation (4) is used in the calculation to obtain the LCL value.

When i = 1,

$$LCL = Z_0 - L\sigma \sqrt{\frac{\lambda}{2-\lambda}\left[1-(1-\lambda)^{2i}\right]}$$
$$= 4936.1 - 3 \times 61.3 \sqrt{\frac{0.3}{2-0.3}\left[1-(1-0.3)^{2\times 1}\right]}$$
$$= 4880.93$$

Using the same computational technique, the UCL value for $i = 2,3,\cdots,77$ is determined and shown in Table 2 as follows:

Table. 2. EWMA Plot Values for Control Chart

n	Xi	Zi	UCL	LCL	n	Xi	Zi	UCL	LCL
1	4961	4943.58	4991.28	4880.95	40	4932	4902.28	5013.37	4858.87
2	4946	4944.31	5003.46	4868.78	41	4928	4909.99	5013.37	4858.87
3	4924	4938.22	5008.68	4863.55	42	4983	4931.90	5013.37	4858.87
4	4974	4948.95	5011.11	4861.13	43	4991	4949.63	5013.37	4858.87
5	4976	4957.07	5012.27	4859.97	44	4887	4930.84	5013.37	4858.87
6	4850	4924.95	5012.83	4859.40	45	4918	4926.99	5013.37	4858.87
7	4877	4910.56	5013.10	4859.13	46	4907	4920.99	5013.37	4858.87
8	4805	4878.89	5013.24	4859.00	47	4880	4908.69	5013.37	4858.87
9	5045	4928.73	5013.30	4858.93	48	4879	4899.79	5013.37	4858.87
10	4920	4926.11	5013.34	4858.90	49	4922	4906.45	5013.37	4858.87
11	4910	4921.28	5013.35	4858.88	50	4974	4926.71	5013.37	4858.87
12	4913	4918.79	5013.36	4858.87	51	4960	4936.70	5013.37	4858.87

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13	4955	4929.65	5013.36	4858.87	52	4998	4955.09	5013.37	4858.87
14	4943	4933.66	5013.36	4858.87	53	4928	4946.96	5013.37	4858.87
15	4845	4907.06	5013.37	4858.87	54	4963	4951.77	5013.37	4858.87
16	4962	4923.54	5013.37	4858.87	55	5028	4974.64	5013.37	4858.87
17	4952	4932.08	5013.37	4858.87	56	4958	4969.65	5013.37	4858.87
18	4834	4902.66	5013.37	4858.87	57	4933	4958.65	5013.37	4858.87
19	4944	4915.06	5013.37	4858.87	58	4965	4960.56	5013.37	4858.87
20	5028	4948.94	5013.37	4858.87	59	4961	4960.69	5013.37	4858.87
21	4957	4951.36	5013.37	4858.87	60	4952	4958.08	5013.37	4858.87
22	4996	4964.75	5013.37	4858.87	61	4876	4933.46	5013.37	4858.87
23	4988	4971.73	5013.37	4858.87	62	4931	4932.72	5013.37	4858.87
24	4912	4953.81	5013.37	4858.87	63	4941	4935.20	5013.37	4858.87
25	4955	4954.17	5013.37	4858.87	64	4952	4940.24	5013.37	4858.87
26	4950	4952.92	5013.37	4858.87	65	4950	4943.17	5013.37	4858.87
27	4975	4959.54	5013.37	4858.87	66	4880	4924.22	5013.37	4858.87
28	4978	4965.08	5013.37	4858.87	67	4965	4936.45	5013.37	4858.87
29	4901	4945.86	5013.37	4858.87	68	5037	4966.62	5013.37	4858.87
30	4780	4896.10	5013.37	4858.87	69	4969	4967.33	5013.37	4858.87
31	4857	4884.37	5013.37	4858.87	70	5121	5013.43	5013.37	4858.87
32	4867	4879.16	5013.37	4858.87	71	4832	4959.00	5013.37	4858.87
33	4827	4863.51	5013.37	4858.87	72	4990	4968.30	5013.37	4858.87
34	4921	4880.76	5013.37	4858.87	73	5012	4981.41	5013.37	4858.87
35	4921	4892.83	5013.37	4858.87	74	4929	4965.69	5013.37	4858.87
36	4794	4863.18	5013.37	4858.87	75	5058	4993.38	5013.37	4858.87
37	4888	4870.63	5013.37	4858.87	76	4999	4995.07	5013.37	4858.87
38	4873	4871.34	5013.37	4858.87	77	4956	4983.35	5013.37	4858.87
39	4932	4889.54	5013.37	4858.87					

The laying hens production data's EWMA control chart is then shown as follows:

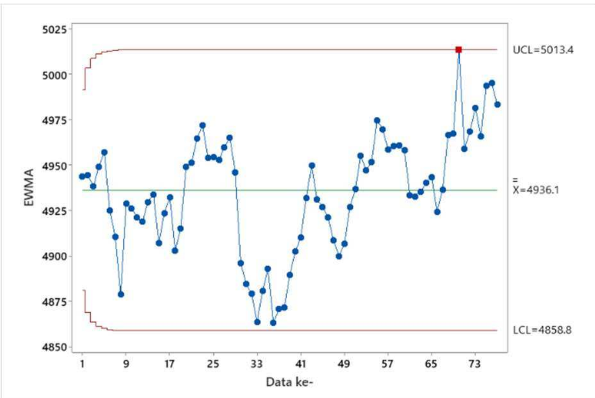

Fig. 1. EWMA Control Chart

UCL= 5013.4 and LCL= 4858.8 were produced by controlling the average process with the EWMA control chart and a weighting of 0.3. Figure 1 has all the information. The control chart can be read as an EWMA control chart with a weighting of 0.3 that is not yet statistically controlled because it reveals that 1 observation is out of the control.

4.2. Link Relative Exponentially Weighted Moving Average (LR EWMA) Control Chart

The data is initially modified to obtain the values before figuring out the necessary parameter values $a = \mu_x = 4939.3$, $b = \sqrt{\frac{2}{\pi}}\sigma_x = 0.8 \times 47.9 = 38.32$ and $\hat{X}_i = 4939.3 + 38.32\, Y_i$. The $\hat{X}_i$ value will be used to determine plot points and control limits on the LR EWMA control chart when it has been determined. The value of $\hat{X}_i$ can be found as shown in the table below:

Table. 3. $\hat{X}_i$ and Y_i Values

i	X_i	Y_i	$\hat{X}_i$	i	X_i	Y_i	$\hat{X}_i$
1	4961	1.010	4985.402	40	4946	1.002	4887.038
2	4946	1.006	4985.253	41	4924	1.009	4886.998
3	4924	1.016	4886.958	42	4974	1.008	4985.620
4	4974	1.036	4985.531	43	4976	-1.008	4985.700
5	4976	1.024	4985.551	44	4850	1.001	4886.586
6	4850	1.016	4886.208	45	4877	1.000	4886.899
7	4877	1.022	4886.485	46	4805	1.005	4886.788
8	4805	1.005	4885.741	47	5045	1.006	4886.515
9	5045	1.023	4986.236	48	4920	-1.010	4886.505
10	4920	1.011	4886.919	49	4910	-1.035	4886.939
11	4910	1.022	4886.818	50	4913	-1.019	4985.531
12	4913	1.012	4886.848	51	4955	-1.017	4985.392
13	4955	1.008	4985.342	52	4943	-1.025	4985.769
14	4943	1.015	4985.223	53	4845	-1.006	4886.998
15	4845	1.001	4886.157	54	4962	-1.006	4985.422
16	4962	1.019	4985.412	55	4952	-1.032	4986.067
17	4952	1.010	4985.312	56	4834	-1.013	4985.372
18	4834	1.007	4886.043	57	4944	-1.016	4887.048
19	4944	1.000	4985.233	58	5028	-1.004	4985.442
20	5028	1.002	4986.067	59	4957	-1.004	4985.402
21	4957	-1.001	4985.362	60	4996	-1.004	4985.312
22	4996	-1.005	4985.750	61	4988	1.007	4886.475
23	4988	1.005	4985.670	62	4912	1.008	4887.028
24	4912	1.005	4886.838	63	4955	-1.013	4985.203
25	4955	-1.021	4985.342	64	4950	-1.006	4985.312
26	4950	-1.015	4985.293	65	4975	-1.009	4985.293

27	4975	-1.030	4985.541	66	4978	-1.014	4886.515
28	4978	1.019	4985.571	67	4901	-1.014	4985.442
29	4901	-1.006	4886.728	68	4780	-1.006	4986.157
30	4780	-1.008	4885.478	69	4857	1.005	4985.481
31	4857	-1.007	4886.280	70	4867	1.002	4986.991
32	4867	1.001	4886.383	71	4827	1.010	4886.023
33	4827	-1.001	4885.971	72	4921	-1.004	4985.690
34	4921	-1.022	4886.929	73	4921	1.003	4985.908
35	4921	1.003	4886.929	74	4794	1.016	4887.008
36	4794	1.000	4885.625	75	4888	1.002	4986.365
37	4888	-1.024	4886.596	76	4873	-1.003	4985.779
38	4873	-1.001	4886.444	77	4932	1.003	4985.352
39	4932	1.016	4887.038				

Next, using λ = 0.3 and L = 3, the value of Z_i will be computed using the following equation to generate an LR EWMA control chart:

$$Z_i = \lambda\hat{X}_i + (1-\lambda)Z_{i-1}$$

$$Z_1 = \lambda\hat{X}_1 + (1-\lambda)Z_0$$
$$= 0.3 \times 4985.4 + (1-0.3) \times 4939.3$$
$$= 4953.13$$

We perform the same procedure for Z_2 through Z_{77}. Table 3 displays the overall Z_i value calculation findings. Following the Z_i value's determination, the control limit value will be computed using the EWMA control chart's values of $\sigma_{\hat{X}} = 47.9$ and $\mu_{\hat{X}} = 4939.3$. The following equation can be used to determine UCL.

When i = 1,

$$UCL = \mu_{\hat{X}} + L\sigma_{\hat{X}}\sqrt{\frac{\lambda}{2-\lambda}[1-(1-\lambda)^{2i}]}$$
$$= 4939.3 + 3 \times 49.7\sqrt{\frac{0.3}{2-0.3}[1-(1-0.3)^{2\times 1}]}$$
$$= 4984.03$$

Using the same computational technique, the UCL value for i = $2,3,\cdots,77$ is determined and shown in Table 4. Next, calculation to obtain the LCL value.

When i = 1,

$$LCL = \mu_{\hat{X}} - L\sigma_{\hat{X}}\sqrt{\frac{\lambda}{2-\lambda}[1-(1-\lambda)^{2i}]}$$
$$= 4939.3 - 3 \times 49.7\sqrt{\frac{0.3}{2-0.3}[1-(1-0.3)^{2\times 1}]}$$
$$= 4894.57$$

Using the same computational technique, the UCL value for i = $2,3,\cdots,77$ is determined and shown in Table 4 as follows:

Table. 4. LR EWMA Plot Values for Control Chart

n	$\hat{X}_i$	Zi	UCL	LCL	n	$\hat{X}_i$	Zi	UCL	LCL
1	4985.40	4953.13	4984.05	4894.54	40	4887.04	1466.11	5001.96	4876.63
2	4985.25	1530.38	4993.93	4884.67	41	4887.00	1466.10	5001.96	4876.63
3	4886.96	1466.09	4998.16	4880.43	42	4985.62	1495.69	5001.96	4876.63

n	$\widehat{X}_i$	Zi	UCL	LCL	n	$\widehat{X}_i$	Zi	UCL	LCL
4	4985.53	1495.66	5000.13	4878.46	43	4985.70	1495.71	5001.96	4876.63
5	4985.55	1495.67	5001.07	4877.52	44	4886.59	1465.98	5001.96	4876.63
6	4886.21	1465.86	5001.53	4877.06	45	4886.90	1466.07	5001.96	4876.63
7	4886.48	1465.95	5001.75	4876.84	46	4886.79	1466.04	5001.96	4876.63
8	4885.74	1465.72	5001.86	4876.73	47	4886.52	1465.95	5001.96	4876.63
9	4986.24	1495.87	5001.91	4876.68	48	4886.51	1465.95	5001.96	4876.63
10	4886.92	1466.08	5001.94	4876.65	49	4886.94	1466.08	5001.96	4876.63
11	4886.82	1466.05	5001.95	4876.64	50	4985.53	1495.66	5001.96	4876.63
12	4886.85	1466.05	5001.96	4876.64	51	4985.39	1495.62	5001.96	4876.63
13	4985.34	1495.60	5001.96	4876.63	52	4985.77	1495.73	5001.96	4876.63
14	4985.22	1495.57	5001.96	4876.63	53	4887.00	1466.10	5001.96	4876.63
15	4886.16	1465.85	5001.96	4876.63	54	4985.42	1495.63	5001.96	4876.63
16	4985.41	1495.62	5001.96	4876.63	55	4986.07	1495.82	5001.96	4876.63
17	4985.31	1495.59	5001.96	4876.63	56	4985.37	1495.61	5001.96	4876.63
18	4886.04	1465.81	5001.96	4876.63	57	4887.05	1466.11	5001.96	4876.63
19	4985.23	1495.57	5001.96	4876.63	58	4985.44	1495.63	5001.96	4876.63
20	4986.07	1495.82	5001.96	4876.63	59	4985.40	1495.62	5001.96	4876.63
21	4985.36	1495.61	5001.96	4876.63	60	4985.31	1495.59	5001.96	4876.63
22	4985.75	1495.72	5001.96	4876.63	61	4886.47	1465.94	5001.96	4876.63
23	4985.67	1495.70	5001.96	4876.63	62	4887.03	1466.11	5001.96	4876.63
24	4886.84	1466.05	5001.96	4876.63	63	4985.20	1495.56	5001.96	4876.63
25	4985.34	1495.60	5001.96	4876.63	64	4985.31	1495.59	5001.96	4876.63
26	4985.29	1495.59	5001.96	4876.63	65	4985.29	1495.59	5001.96	4876.63
27	4985.54	1495.66	5001.96	4876.63	66	4886.52	1465.95	5001.96	4876.63
28	4985.57	1495.67	5001.96	4876.63	67	4985.44	1495.63	5001.96	4876.63
29	4886.73	1466.02	5001.96	4876.63	68	4986.16	1495.85	5001.96	4876.63
30	4885.48	1465.64	5001.96	4876.63	69	4985.48	1495.64	5001.96	4876.63
31	4886.28	1465.88	5001.96	4876.63	70	4986.99	1496.10	5001.96	4876.63
32	4886.38	1465.91	5001.96	4876.63	71	4886.02	1465.81	5001.96	4876.63
33	4885.97	1465.79	5001.96	4876.63	72	4985.69	1495.71	5001.96	4876.63
34	4886.93	1466.08	5001.96	4876.63	73	4985.91	1495.77	5001.96	4876.63
35	4886.93	1466.08	5001.96	4876.63	74	4887.01	1466.10	5001.96	4876.63
36	4885.63	1465.69	5001.96	4876.63	75	4986.37	1495.91	5001.96	4876.63
37	4886.60	1465.98	5001.96	4876.63	76	4985.78	1495.73	5001.96	4876.63
38	4886.44	1465.93	5001.96	4876.63	77	4985.35	1495.61	5001.96	4876.63
39	4887.04	1466.11	5001.96	4876.63					

The laying hens production data's EWMA control chart is then shown as follows:

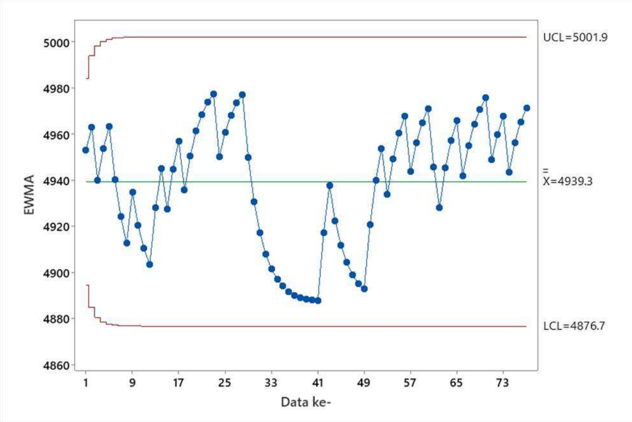

Fig. 2. LR EWMA Control Chart

Figure 8 displays the use of the LR EWMA control chart with a weighting of 0.3 to regulate the average phase I production process for laying hens. The values of UCL = 5001.9 and LCL = 4876.7, with a maximum LR EWMA value of 4977.2 and a minimum LR EWMA value of 4887.7, are shown in this figure. In order to consider the process statistically controlled, the control chart must demonstrate that no data exceeds the control limits.

5. Conclusions

The EWMA control chart is obtained based on the generated control chart. One observation is out of control when λ=0.3, L=3, and Z_0 = 4936.1 are used. This indicates that the laying hens production data has not been statistically controlled using the EWMA control chart. In the meantime, the laying hens production data is statistically controlled using the LR EWMA control chart, which generates no data or observations outside the control bounds for λ=0.3 and L=3, $\sigma_{\hat{X}} = 47.9$ and $\mu_{\hat{X}} = 4939.3$.

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