Section IV. SPC Analysis

Data Collection and SPC Tools

For any analysis to begin, data needs to be collected. For this, students were given bags of Mars Chocolate M&M's, a sample size of sixty bags, and were then instructed to count how many M&M's were in the bag and how many of each color was present. The raw data collected is shown here:

M&M Bag	Red	Blue	Green	Yellow	Orange	Brown	Total
1	5	9	10	7	16	9	56
2	6	11	7	4	20	7	55
3	5	6	3	11	15	12	52
4	7	8	8	7	12	14	56
5	6	16	13	2	11	10	58
6	5	9	13	4	20	6	57
7	4	8	7	3	24	9	55
8	6	10	8	11	12	9	56
9	7	10	7	8	11	11	54
10	4	7	7	5	14	18	55
11	6	8	11	3	19	7	54
12	8	15	7	9	8	9	56
13	7	14	14	8	6	6	55
14	6	16	17	6	5	5	55
15	8	15	9	8	11	4	55
16	5	7	8	12	11	12	55
17	8	11	8	4	10	11	52
18	13	14	8	6	7	5	53
19	7	20	5	10	12	3	57
20	6	16	12	7	4	10	55
21	10	16	6	11	4	9	56
22	12	12	13	5	6	7	55
23	8	5	13	10	11	9	56
24	6	7	12	16	7	9	57
25	9	13	15	9	4	7	57

26	12	11	5	8	12	8	56
27	8	4	18	7	14	5	56
28	6	9	9	11	9	10	54
29	5	14	13	10	7	8	57
30	9	13	9	6	10	9	56
31	12	9	4	11	11	7	54
32	13	11	7	6	9	9	55
33	7	14	9	10	9	8	57
34	11	15	5	9	9	6	55
35	8	19	6	7	8	7	55
36	11	10	10	8	7	10	56
37	7	17	10	8	5	8	55
38	8	14	8	7	7	11	55
39	9	15	9	7	9	8	57
40	2	15	12	11	8	8	56
41	13	9	7	10	11	4	54
42	9	11	9	11	7	8	55
43	6	12	13	7	11	8	57
44	10	15	8	9	6	6	54
45	6	9	15	7	9	7	53
46	9	13	8	5	10	10	55
47	6	9	14	8	10	10	57
48	8	11	9	8	10	7	53
49	9	10	13	7	10	8	57
50	11	7	16	6	8	10	58
51	7	12	10	9	11	7	56
52	7	10	7	9	15	7	55
53	7	12	12	7	5	12	55
54	11	7	11	14	7	6	56
55	6	16	8	10	7	9	56
56	6	18	9	10	8	3	54
57	12	15	7	9	5	7	55
58	7	13	11	8	9	7	55
59	4	19	8	7	8	10	56
60	10	11	9	8	10	6	54

(M & M Data, 2021)

Next, the analysis had to be conducted. Though getting there is still a few steps away. Before

that, we need to decide what tools we will use to properly get the results we need. Consulting the

resources we had, it was concluded that control charts, such as X-Bar, R Chart, and P Charts, will be used for our analysis. (Control Chart, n.d.)

X-Bar and R Chart Analysis

With the raw data in our hands and the proper tools ready, it was time to conduct the first part of our analysis. Before you can make an X-Bar and R Chart, you need to organize the data properly into sample sizes. We put the sixty M&M bags into fifteen samples with four bags in each sample. The average of each sample group was calculated, along with the range. With the averages and ranges known, we could then multiply them by 0.884 grams. This table was made to showcase the information so far:

Group	#1	#2	#3	#4	Average	Range	Average	Average
1	56	55	52	56	54.75	4	48.399	3.536
2	58	57	55	56	56.5	2	49.946	1.768
3	54	55	54	56	54.75	2	48.399	1.768
4	55	55	55	55	55	0	48.62	0
5	52	53	57	55	54.25	5	47.957	4.42
6	56	55	56	57	56	2	49.504	1.768
7	57	56	56	54	55.75	3	49.283	2.652
8	57	56	54	55	55.5	3	49.062	2.625
9	57	55	55	56	55.75	2	49.283	1.768
10	55	55	57	56	55.75	2	49.283	1.768
11	54	55	57	54	55	3	48.62	2.652
12	53	55	57	53	54.5	4	48.178	3.536
13	57	58	56	55	56.5	3	49.946	2.652
14	55	56	56	54	55.25	2	48.841	1.768
15	55	55	56	54	55	2	48.62	1.768

The formulas for X-Bar and R-Charts are as follows:

	Centerline	Control Limits		σ_x
X bar and R Charts	$CL_{\bar{X}} = \bar{\bar{X}}$	$UCL_{\bar{x}} = \bar{\bar{X}} + A_2\bar{R}$	$LCL_{\bar{x}} = \bar{\bar{X}} - A_2\bar{R}$	$\dfrac{\bar{R}}{d_2}$
	$CL_R = \bar{R}$	$UCL_R = D_4\bar{R}$	$LCL_R = D_3\bar{R}$	

(Control Chart Formulas)

The list of variables and their values:

- $\bar{\bar{X}} = 48.929$

- $\bar{R} = 2.297$

- $A_2 = 0.729$

- $D_3 = 0$

- $D_4 = 2.282$[1]
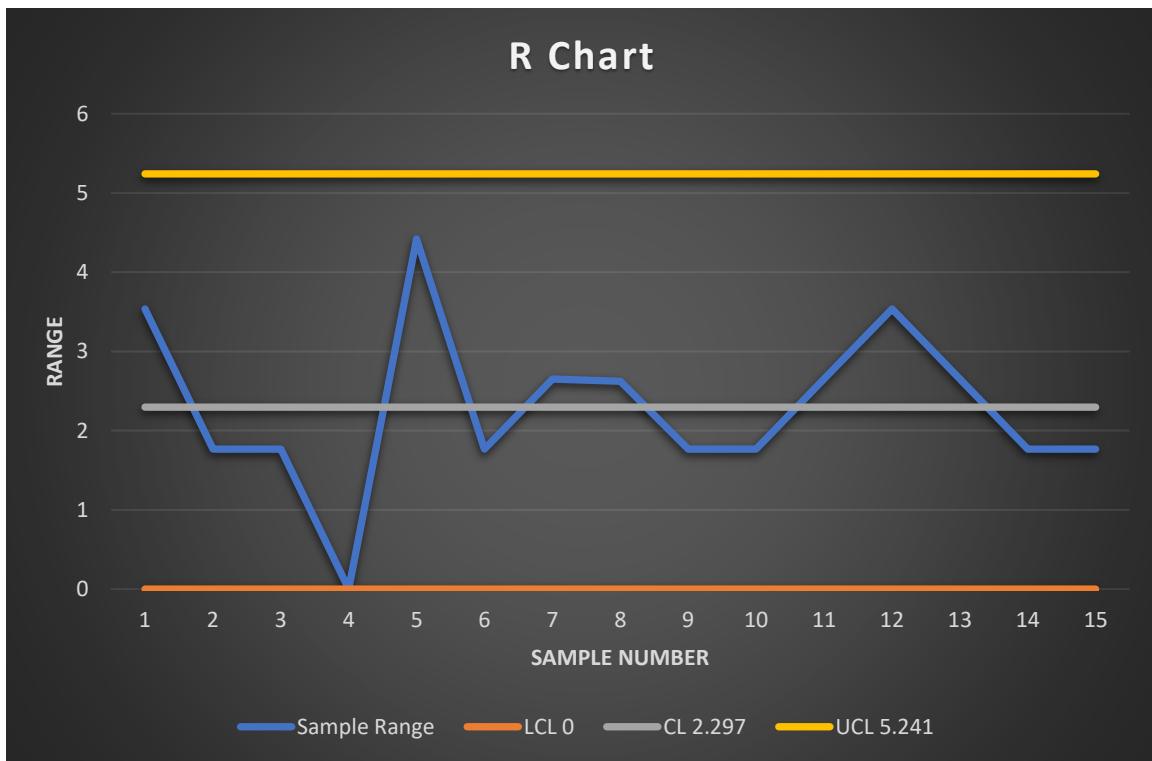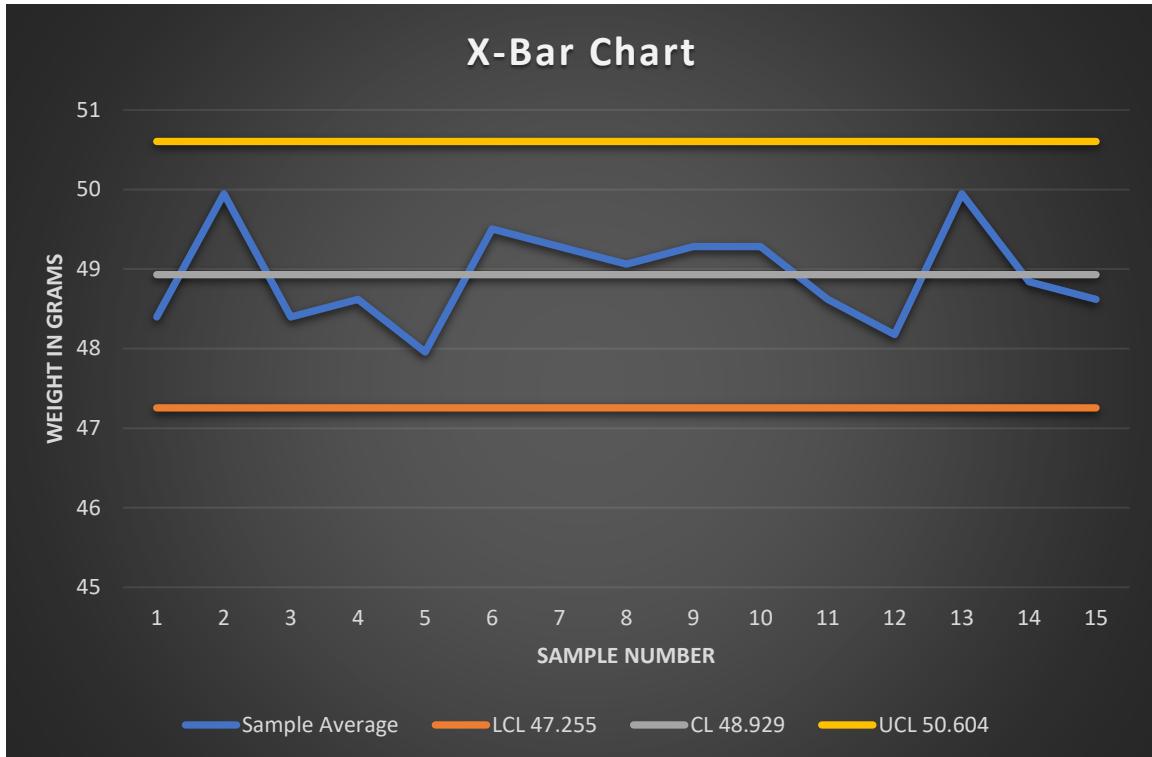
The formulas used with the values of the variables in place:

- $CL_{\bar{X}} = 48.929$

- $UCL_{\bar{X}} = 48.929 + 0.729 * 2.297 = 50.604$

- $LCL_{\bar{X}} = 48.929 - 0.729 * 2.297 = 47.255$

- $CL_R = 2.297$

- $UCL_R = 2.282 * 2.297 = 5.241$

- $LCL_R = 0 * 2.297 = 0$

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[1] $A_2, D_3, and\ D_4\ were\ all\ found\ from\ Factors\ for\ Control\ Charts$ (Henderson, 2011)

Knowing the Control Limit, Upper Control Limit, and Lower Control Limit for the X-Bar and R

Chart is the last piece of the puzzle in constructing our graphs. All the work now leads to this:

What we can conclude from this analysis is that Mars Chocolate is doing great by staying within its own limits when it comes to filling each individual bag of M&M's. Each of the sample groups stays within the Upper and Lower Limits and hovers around the Center Limit. The only thing of note here is Group #4. Each of the four bags in that group had fifty-five M&M's, meaning the range in that group would be zero.

P Chart Analysis

Now it is time to analyze the assortment of colors in each of the individual bags of M&M's. M&M's have six different main colors: Red, Blue, Green, Yellow, Orange, and Brown. When asked about the distribution of these colors, the Mars Chocolate company responded with this information:

M&M Color	Color
Red	13%
Blue	24%
Green	16%
Yellow	14%
Orange	20%
Brown	13%

(Chocolate, 2013)

These are the assumed to be observed percentages. If you were to randomly open a bag of M&M's, this would be on average what you would expect to receive. To begin creating the P Charts for each color, we need to define new variables and plug them into new equations.
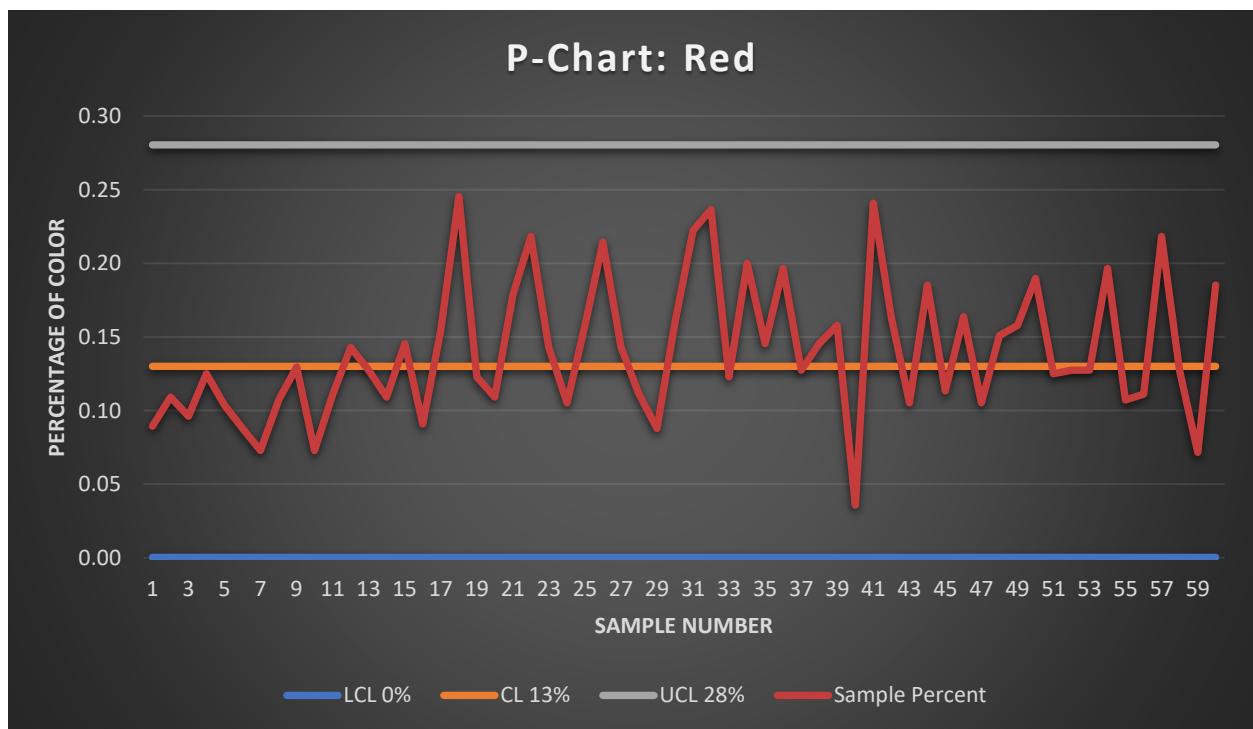
The new set of variables and their values are:
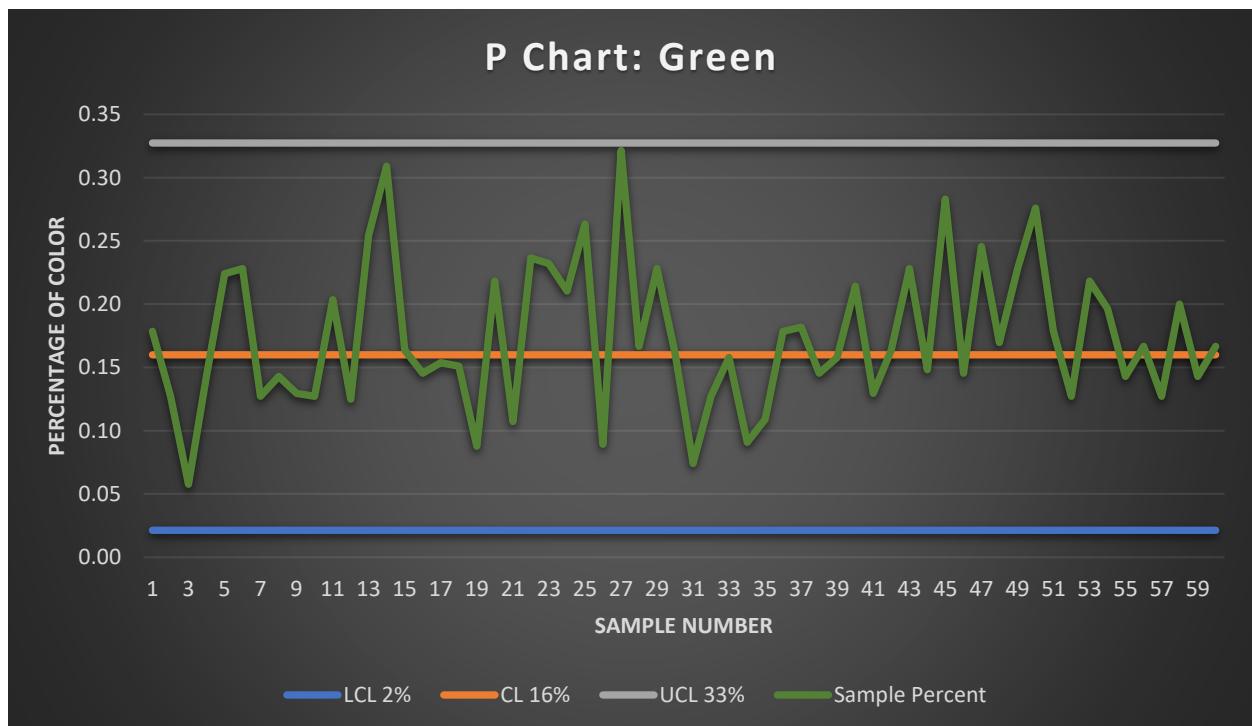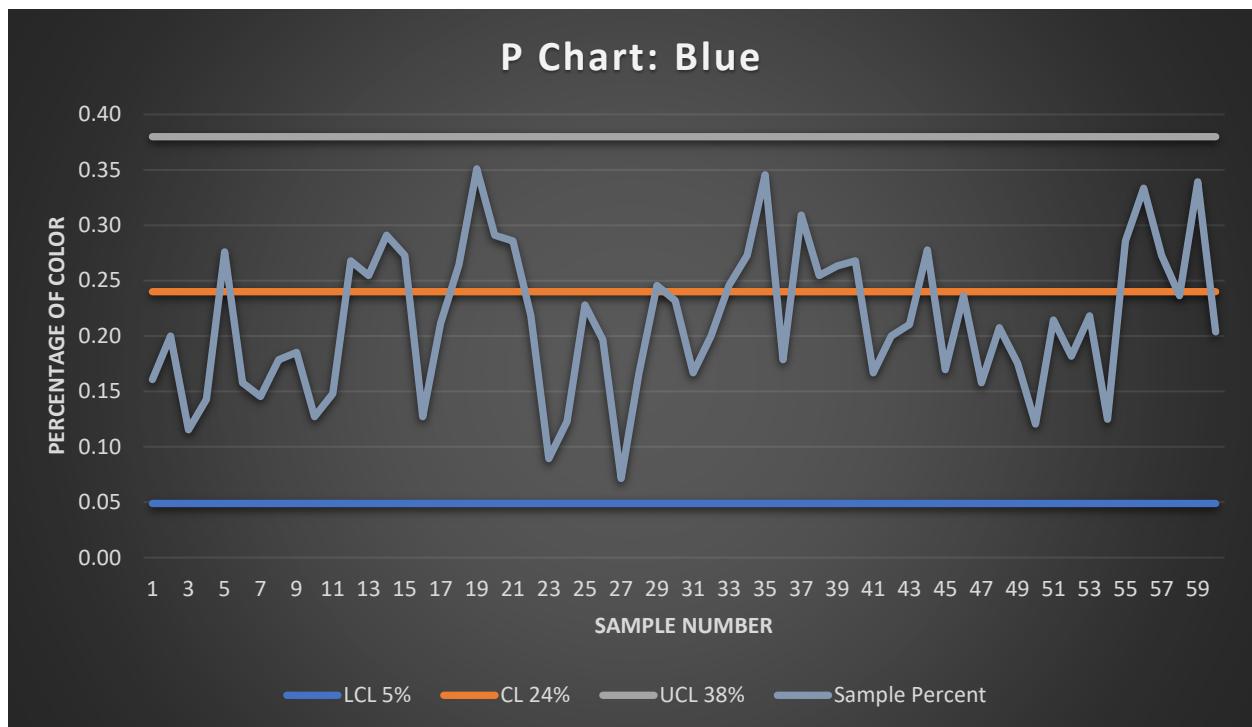
- $n = 3321$

- $p = 0.130, 0.240, 0.160, 0.140, 0.200,$ and 0.130

- $\bar{n} = 55.350$

- $\bar{p} = 0.140, 0.214, 0.174, 0.145, 0.178,$ and 0.148
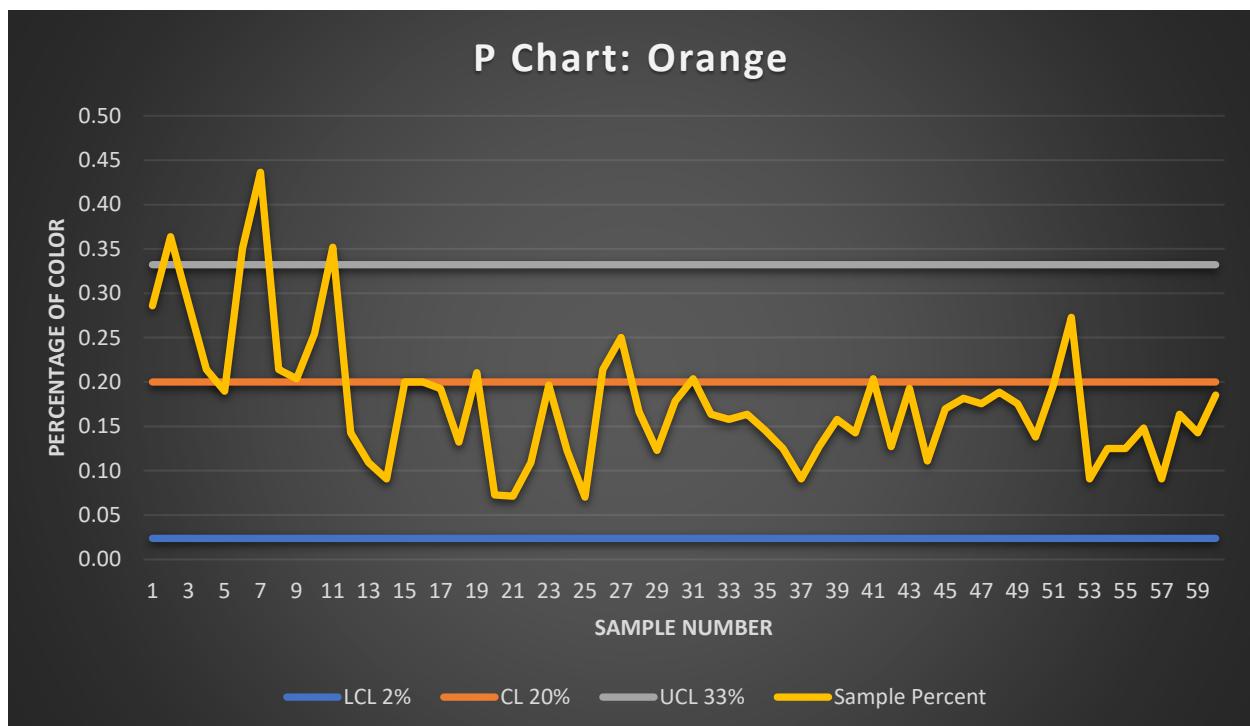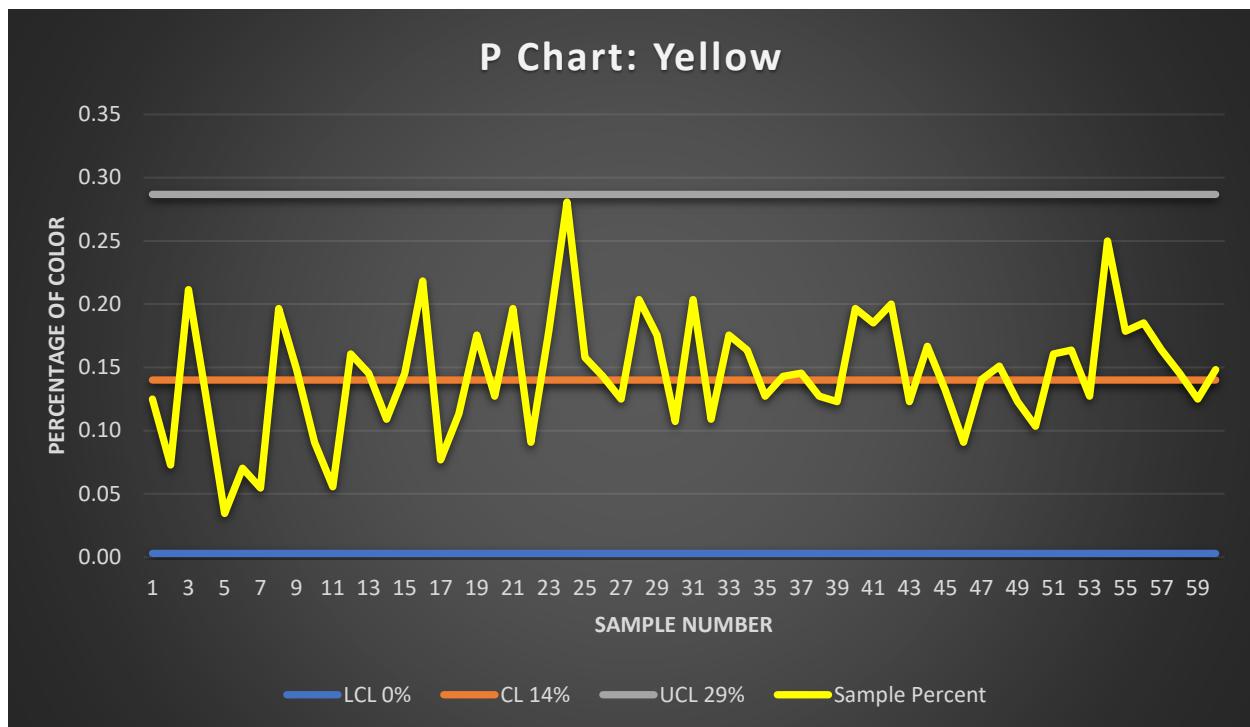
The new set of UCL and LCL formulas along with a filled-out example:
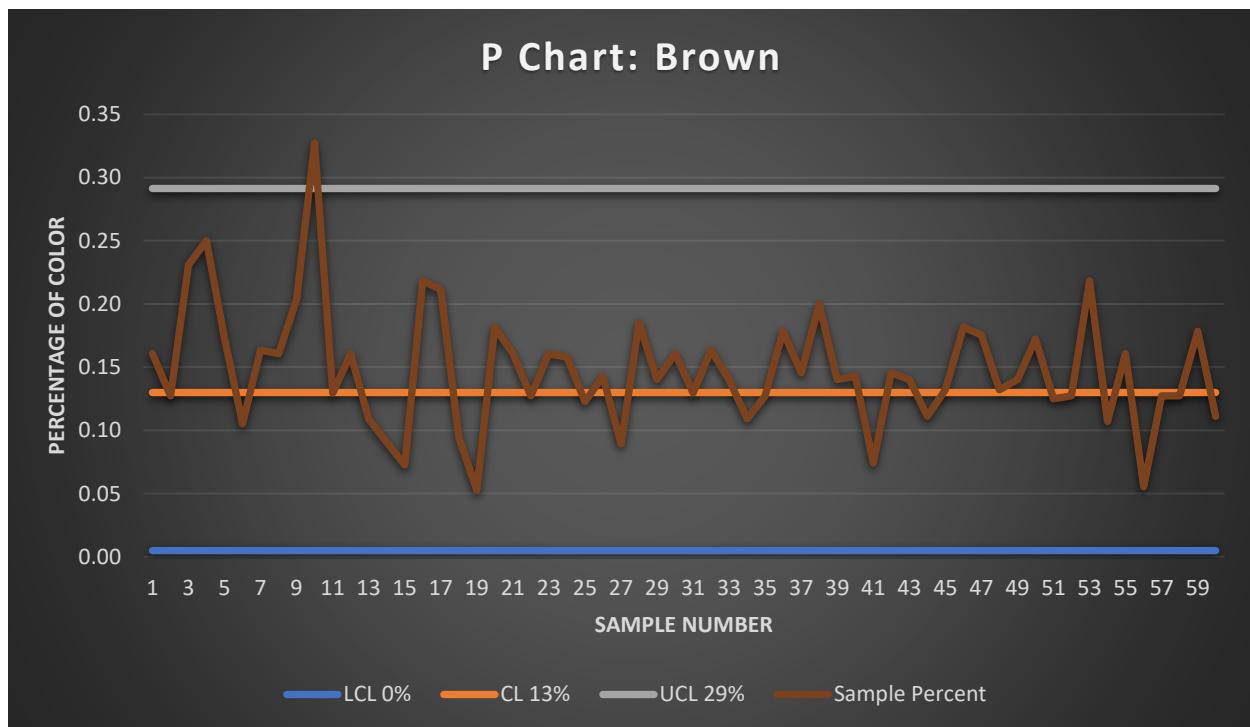
- $UCLp = \bar{p} + 3\sqrt{\dfrac{\bar{p}(1-\bar{p})}{\bar{n}}} \rightarrow 0.140 + 3\sqrt{\dfrac{0.140(1-0.140)}{55.350}}$

- $LCLp = \bar{p} - 3\sqrt{\dfrac{\bar{p}(1-\bar{p})}{\bar{n}}} \rightarrow 0.140 - 3\sqrt{\dfrac{0.140(1-0.140)}{55.350}}$ $\hspace{2cm}$ (McNeese, 2005)

Using these UCL and LCL formulas, and the CL Mars Chocolate provided, we can now put together each color's P Chart:

P-Chart: Red

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P Chart: Blue

P Chart: Green

P Chart: Yellow

P Chart: Orange

P Chart: Brown

Legend: LCL 0% — CL 13% — UCL 29% — Sample Percent

What we can gather from each P Chart, is that for most of the sixty bags examined, almost all of them nicely fit in-between the Upper and Lower Limits. Red M&M's mostly seem to trend high above the Center Limit. They get close to the Upper Limit but never pass it. On the Blue P Chart, it seems to be the opposite, mostly below the Center Limit. Though some bags edge near the Upper Limit, like with Bag #19 having 35% Blue M&M's. Green M&M's followed the same general trend as Red, being mostly above the Center Limit. Bags #14 and #27 barely reached the Upper Limit having 31% and 32% Green M&M's respectively. Yellow had the same results, Bag #24 had 28% Yellow M&M's. Other than that, one outlier, it stayed right around the Center Limit. The Orange color was the first to pass the Upper Limit, and it did so four times. Bags #2, #6, #7, and #11 were all above. Brown only had one bag reach above the Upper Limit, that being Bag #10. As it would seem, only five out of the sixty bags examined went past the upper threshold. That is only 8.3% of bags. In conclusion, Mars Chocolate seems to have it handled in terms of the color ratios present in a bag of M&M's.

Bibliography

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