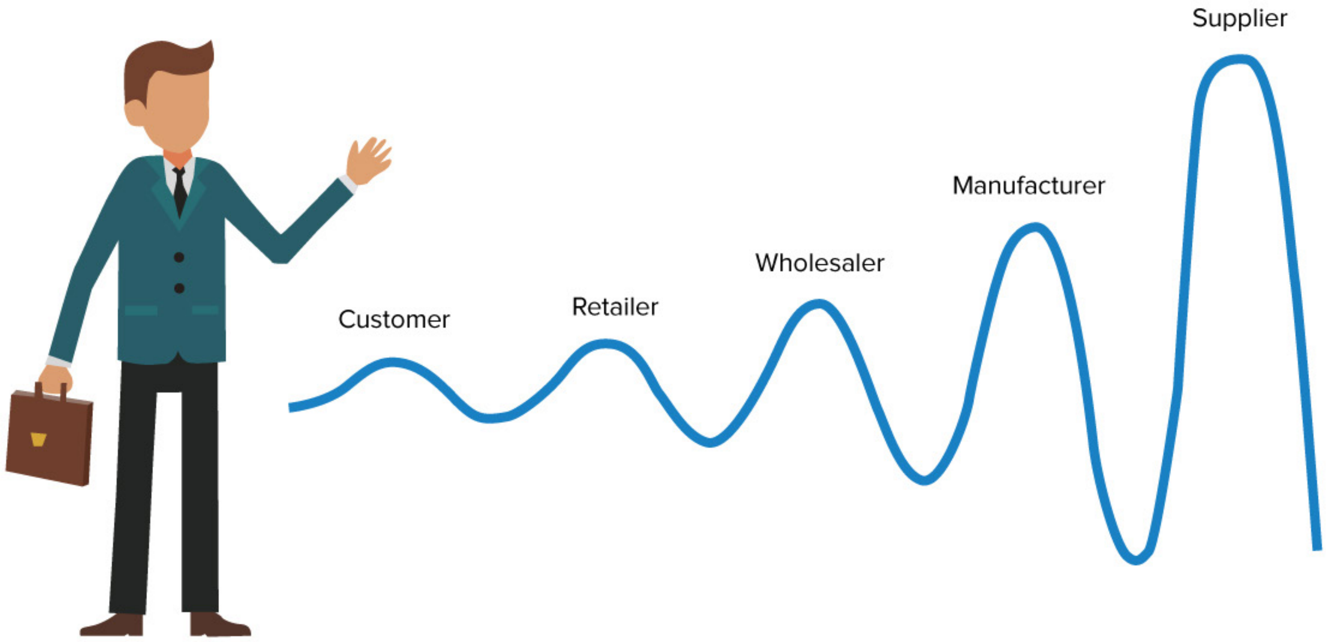
Dealing with Today's Bullwhip Effect in Supply Chain



Today's global supply chain is under stress. First the pandemic closed factories, displaced workers and crippled production worldwide – and sent economies around the world into a deep recession. Fortunately, the global demand for goods bounced back fast, fueled by the rapid development of COVID-19 vaccines, high levels of government assistance, and changed spending habits. The quick rebound in demand has left processing plants, manufacturers and businesses struggling to keep up.

The coronavirus continues to challenge areas around the world and make transportation and logistics more costly. Critical components from shipping containers to semiconductors and raw materials like rubber, lumber and steel are in short supply. Compounding all of this is a shortage of essential workers and, in some cases, outdated capital infrastructure. This is leading to deliver delays, product shortfalls and price increase.

Savvy supply chain management involves the leveraging of channel wide integration to better serve customer needs. By coordinating quality management activities, productivity and efficiencies can increase. If we implement a control technique based on a divergence system, we might be able to reduce the bullwhip effect and gain more control in a single product supply chain. Let's take a deeper look into how exactly we can reduce the bullwhip effect.

Step One – Start with Basic Statistical Process Control

Supply chains are crucial to the health of business enterprises, so we must sustain them by applying both preventative and emergency measures. With so many aspects included in supply chains, measures must be developed to indicate when supply chains are not operating efficiently and productively.

Fortunately, basic statistical quality control will indicate when risks are present in the supply chain. The faster these risks can be detected, the better as then necessary changes can be made to reduce costs, bottlenecks and inventory shortages. One commonly used and trusted statistical process control technique are control charts.

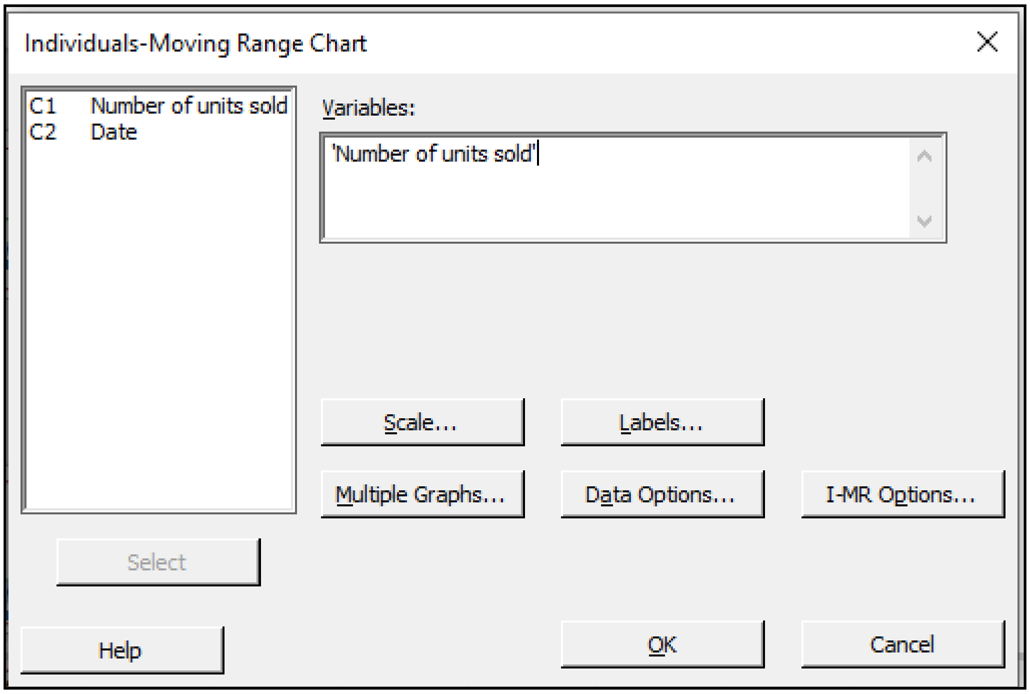
Control charts are a favored tool to monitor processes characteristics. There are many types of control charts available with the Individuals and Moving Range (I-MR) and the Mean-Range (Xbar-R) charts being two of the most popular types.

Now let's see control charts in action. For this example, we'll look at a company that wants to carefully monitor the number of units sold for one of their products. The fictional data set consists of the number units sold for the last 75 days.

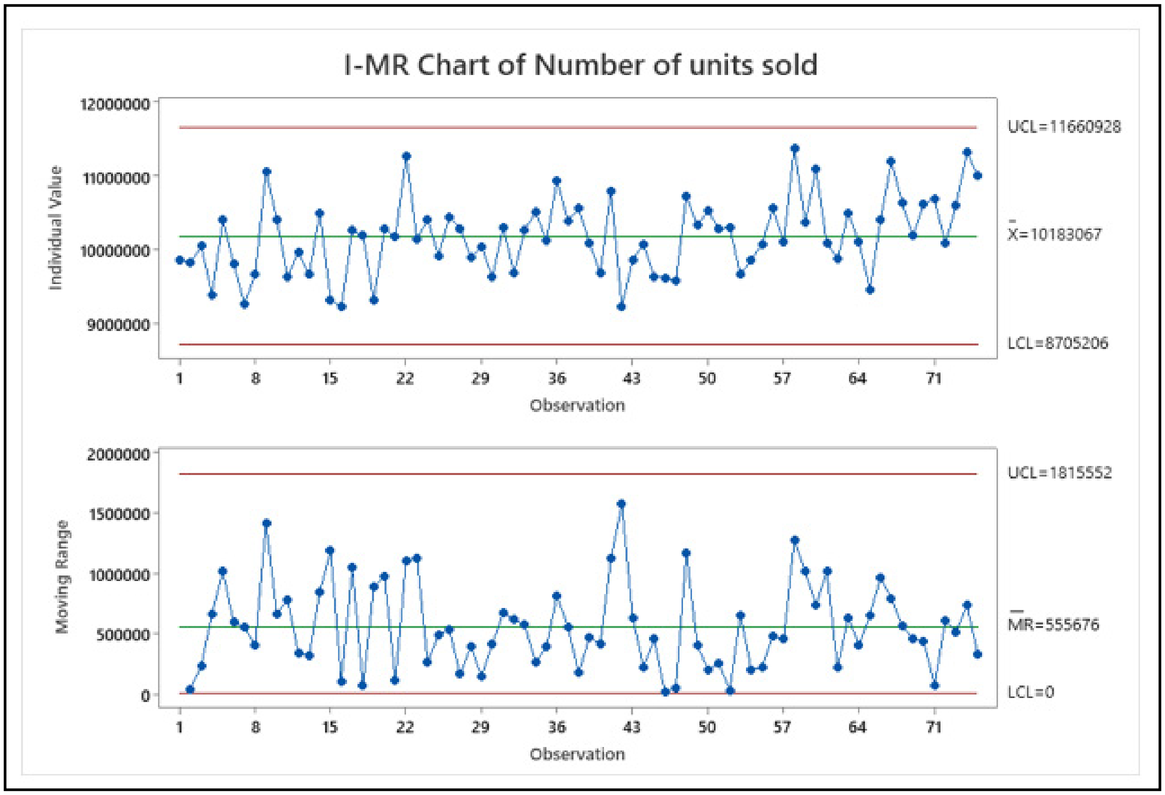
→	C1	C2-D
	Number of units sold	Date
1	9860000	1/1/2018
2	9820000	1/2/2018
3	10050000	1/3/2018
4	9390000	1/4/2018
5	10400000	1/5/2018
6	9810000	1/6/2018
7	9260000	1/7/2018
8	9660000	1/8/2018
9	11070000	1/9/2018
10	10410000	1/10/2018
11	9630000	1/11/2018
12	9970000	1/12/2018
13	9660000	1/13/2018
14	10500000	1/14/2018

Once the data set is ready in Minitab Statistical Software, we would go to Stat > Control Charts > Variable charts for Individuals > I-MR to create the control chart.

We'd complete the dialog box that appears as it is shown below and click ok.



Then we would get a control chart that looks like this:



Based on the output, we get a chart of a process that is in statistical control. This chart gives no indication of any failed test and no pattern is readily apparent. If you look closely, the later data suggests that there might be a slight increase in the process mean, but there are no points officially out of control points. If the company had used this chart – and only this chart – to monitor the supply chain, they would conclude that the mean has been stable over time.

During normal business situations, this should suffice. However, when the business climate is changing, as it is today, you must look deeper into the data to see if you can predict a change that's coming.

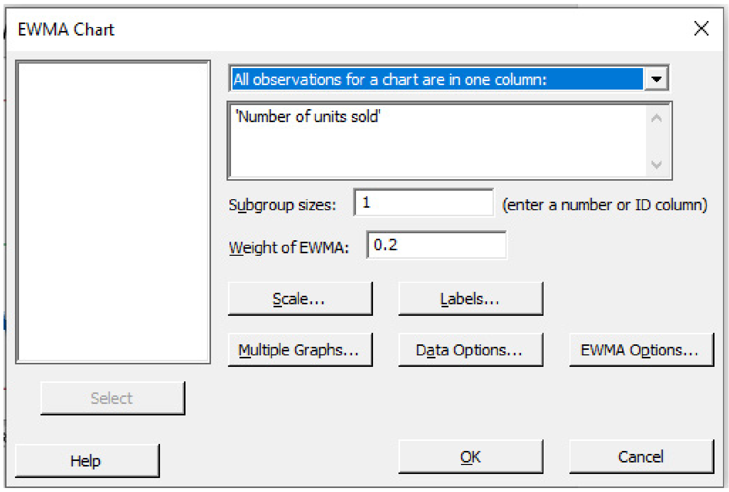
Step Two – Leverage EWMA to Avoid the Bullwhip

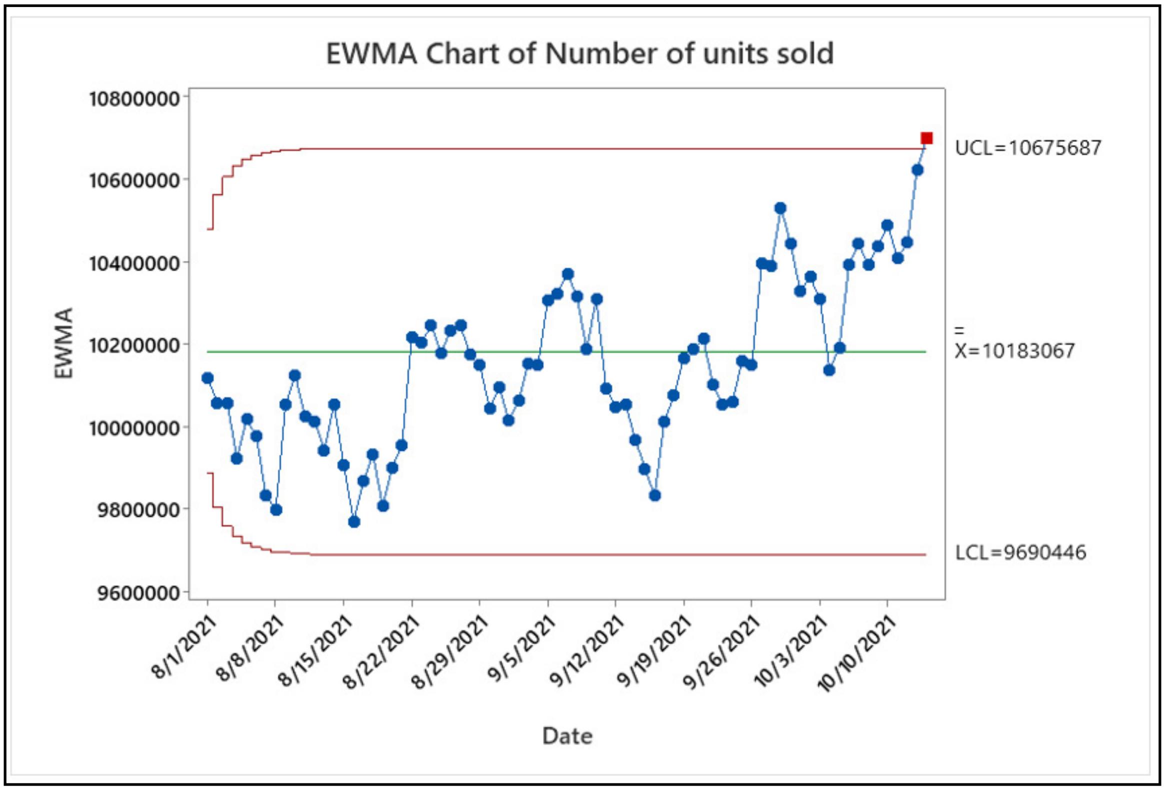
I-MR and Xbar-R control charts are effective in detecting relativity large changes in processes means, which is why they are so often used as the first line of statistical process control. Under normal business conditions, smaller shifts are not so meaningful, so these control charts suffice. However, when business climate is changing, detecting smaller shifts in processes can be critical to best prepare the supply chain.

The exponentially weighted moving average, or EWMA, unlike other controls charts available, incorporates data from all previous points in each subsequent plotted point. As a result, EWMA charts are more effective at detecting small shifts in the processes means. The rapid detection of small changes in the quality characteristic of interest and ease of computations makes the EWMA chart an attractive graph to monitor supply chain. This is especially important because in order to minimize the bullwhip effect, we need to act as fast and knowledgably as possible to implementing measures when needed.

Let's take a look at the same example as before but use the EWMA chart instead. An engineer would decide to use it, to ensure if there is even a small change detected. This might help predict that a bullwhip is ahead and allow the supply chain to prepare in advance.

To create an EWMA in Minitab, go to Stat > Control Charts > Time-Weighted Charts > EWMA. Complete the dialog box as it is showing below. Then click ok.





As you can see, this chart has a clear upward trend after October 3rd and the last point is out-of-control (marked in red). This shift in mean at this point should be investigated, as the mean number of units sold is increasing and the company might need to implement measures in order to meet customer demand.

With insight that demand is increasing, the company aims to prepare to ramp up manufacturing quickly.

Step Three – Take Action and Ramp Up Manufacturing

With the EWMA chart revealing that demand is about to increase, a company might decide to add more production lines to meet growing demand. Naturally, the first place to look is within the same factory that produces the product.

Given current events, let's use an example of something that requires resin, like paint. In this case, the company manufactures the paint on two lines and fortunately has a third line that they can prepare to expand their manufacturing capacity.

Before starting to use the third line, their engineers want to make sure of two things:

1. That the paint produced has resin content of at least 60%
2. That the third line average is the same as the other two lines

The ultimate goal is to have all three lines producing quality product with 60% resin content that are similar on average. To achieve this, one of the company statisticians suggests doing a one-way analysis of variance (ANOVA) on the alcohol content of the product.

The one-way or one factor ANOVA is one of the most popular methods in statistics. It is used to determine if factor level means are statistically different from one another. This method is a generalization of the 2 independent sample t test. But unlike the t test, one-way ANOVA allows you to test more than 2 means while safeguarding the overall error rate.

Looking back at our example, we'll call the 2 active production lines, Line 1 and Line 2. The company wants to know if the third line, Line 3, produces products that are similar on average to the products produced on Line 1 and Line 2. After a power and sample size analysis, they decided to measure 25 cans of paint from each line for a total of 75 cans of paint. The data was put into a Minitab worksheet.

The one-way ANOVA for our scenario tests the following hypothesis:

H_0: PopulationMeanLine1 = PopulationMeanLine2 = PopulationMeanLine3

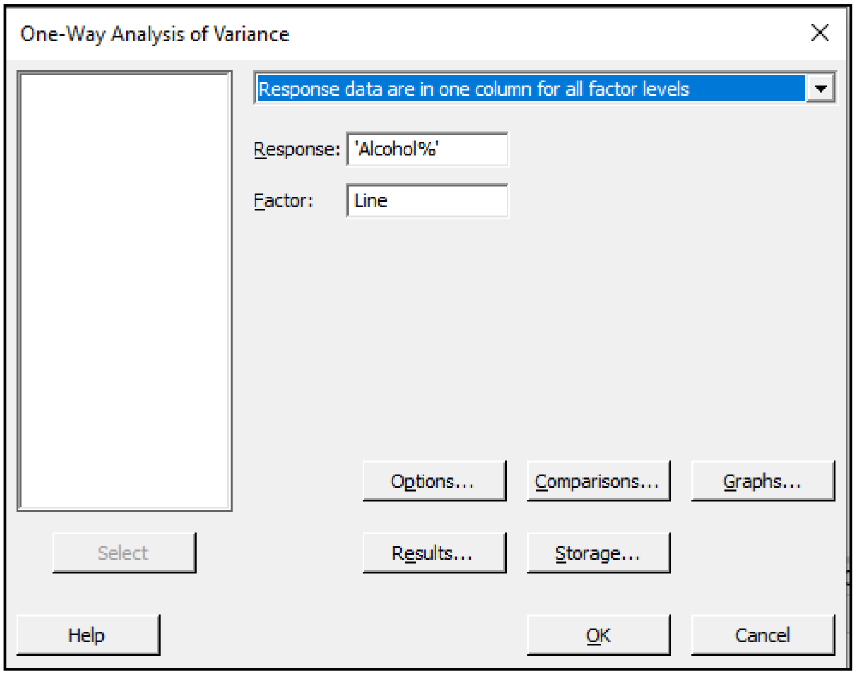
The above represents the null hypothesis.

H_1: PopulationMeanLine1 ≠ PopulationMeanLine2 ≠ PopulationMeanLine3

The decision for the test will be to either reject or fail to reject the null hypothesis. If we reject the null hypothesis, then we can say that at least one of the lines is different on average (we will then have to do a multiple comparison analysis to find out which line(s) are different). If we fail to reject, we will assume that lines are statistically different on average.

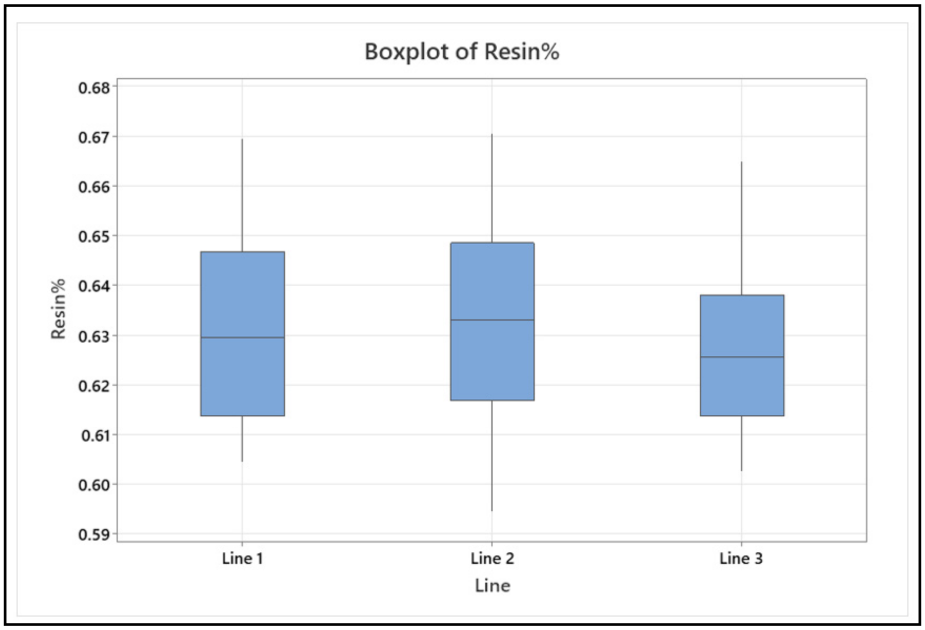
To run a one-way ANOVA in Minitab, go to: STAT > ANOVA > One Way ANOVA. Complete the dialog box as it is showing below. Click Graphs and select Boxplots. Then click OK twice.

↓	C1-T	C2
	Line	Alcohol%
1	Line 2	0.6550
2	Line 2	0.6410
3	Line 2	0.6280
4	Line 2	0.6215
5	Line 2	0.6310
6	Line 2	0.6420
7	Line 2	0.6475
8	Line 2	0.6345
9	Line 2	0.6265
10	Line 2	0.6120
11	Line 2	0.6160
12	Line 2	0.6145
13	Line 2	0.6255
14	Line 2	0.6330
15	Line 2	0.6045
16	Line 2	0.5945
17	Line 2	0.6495
18	Line 2	0.6175



The output of the analysis is below. The box plot shows that the means are not that different across the lines. Also, the mean for each line is above the target mean of .6, which shows that each line produces bottles with at least a 60% amount of alcohol.

The p-value in the ANOVA table is p = 0.733. Using an alpha of 0.05, we can conclude using a 95% confidence interval, that there is not enough evidence to say that the average strength for the lines are different. In other words, because there is no evidence to conclude the lines are different, the company cannot reject the null hypothesis and assumes that the averages from all three lines are similar. As a fantastic result, the company can use the third manufacturing line to produce additional cans of paint!



Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Line	2	0.000221	0.000111	0.31	0.733
Error	72	0.025538	0.000355		
Total	74	0.025759			

Conclusion

Whether you're in the early part of your data analysis and statistical process control journey or looking for more advanced methods, Minitab can help analyze your data quickly and efficiently so you can take data-driven actions easily and effectively.

If you're already using control charts, perhaps now is the time to explore the EWMA control chart to identify changes quicker. Then, you can further leverage data analysis to help you ramp up production of the products most in demand.