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Middle East Technical University

IE 368 – Quality Planning and Control

Case Study 1 – Cotton Ltd.

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Group Number 19

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"Academic integrity is expected of all students of METU at all times, whether in the presence or absence of members of the faculty. Understanding this, I declare that I shall not give, use, or receive unauthorized aid in this study."

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Introduction

The textile industry pollutes the environment greatly with its contribution to global CO2 emissions; and more importantly, the microplastics, mainly polyester, resulting from textile production found in streams and still water around textile factories.

Cotton Ltd. operates three of these factories in different locations and uses different materials and machines. Each factory has a waste management process that measures the amount of polyester in its wastewater. Polyester is a type of plastic that can harm aquatic life and human health if it enters the water sources. The company wants to keep the amount of polyester in its wastewater within a certain range that is acceptable to an environmental organization called GrayPiece. However, sometimes the company faces problems in its factories that cause the amount of polyester to go beyond the acceptable range, which is LSL=0 piece/L and USL= 1600 pieces/L. These problems include issues with suppliers, machines, workers, and production schedules. The company wants to identify and eliminate these problems as soon as possible.

The company hired an SPC consultant to assist them with their waste management process improvement. SPC stands for statistical process control. It is a method of quality control that uses statistics and graphs to monitor how well a process is working and find what causes problems. The SPC consultant will train and coach the company's staff on how to apply SPC principles and practices to their waste management processes. The SPC consultant will also analyze the data collected from the three factories and provide feedback and recommendations on how to improve their process performance. The SPC consultant will write a report to present their findings and suggestions. The report will also explain how SPC can help the company achieve its environmental goals and reduce its waste management costs.

Cotton Ltd. operates three of these factories and is looking to fulfill its liabilities by collaborating with organizations such as GrayPiece to keep their waste management in terms of microplastics in wastewater in check. Therefore, Cotton Ltd. Measures the amount of polyester, the main plastic found in the water sediments and streams, daily. The specifications for polyester amounts regulated by the organization are LSL=0 piece/L and USL= 1600 pieces/L. This report aims to analyze the data collected from Cotton's three factories in the previous month and evaluate their performance in terms of polyester waste reduction.

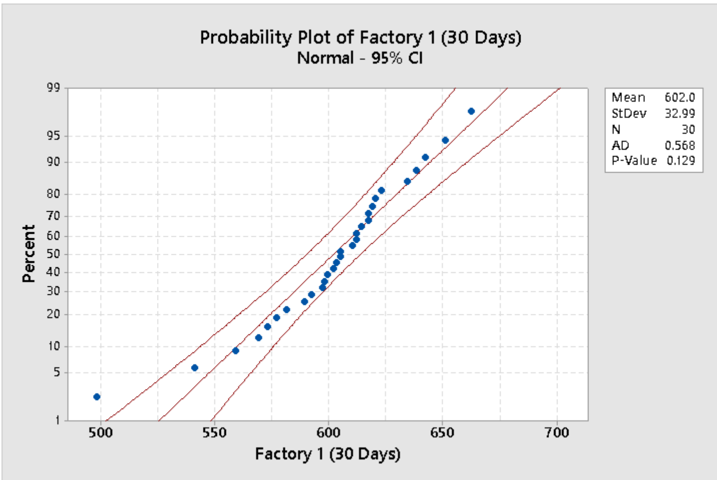
Phase I

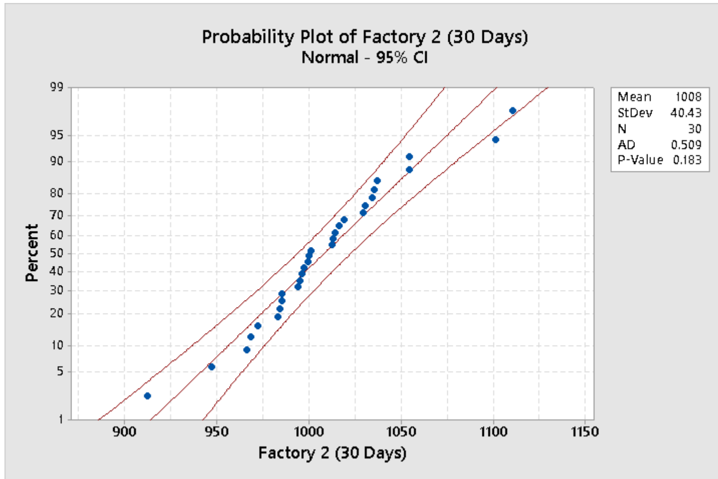
What are all possible control chart options that Cotton Ltd. can use? Construct each of these charts and observe the data. Comment on the appropriateness of using those charts comparing their advantages/disadvantages.

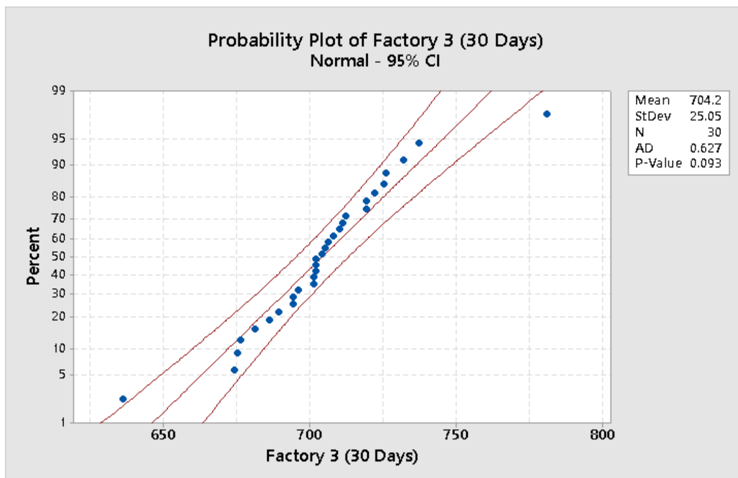
Possible control chart options:

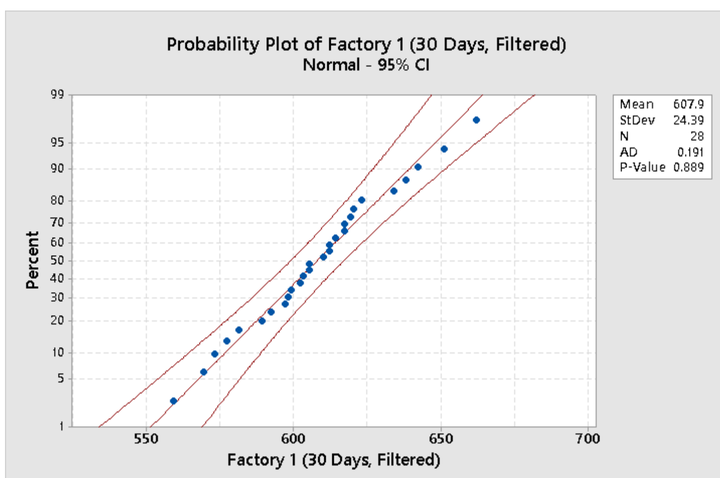
- Probability Chart

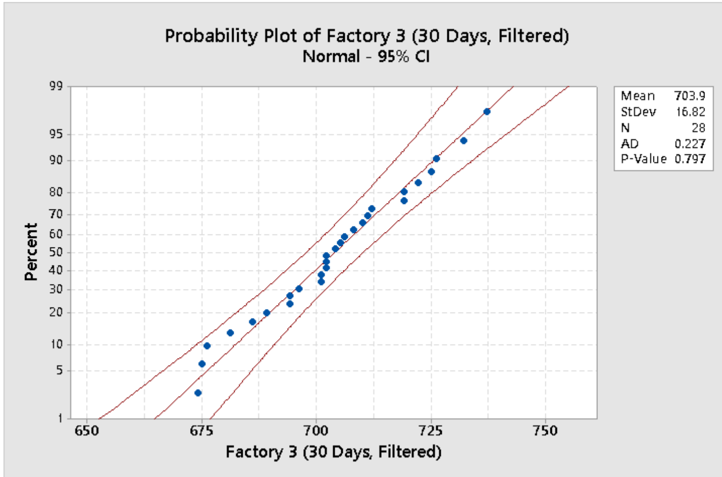
This chart helps determine whether the data follows a normal distribution or not. Compared to a histogram, this chart does not subgroup the data, making it more accurate. In addition, this chart can be combined with 95% confidence intervals to further see outlying points (if there are few) or the biasness of the data from a normal distribution (if there are many outliers).

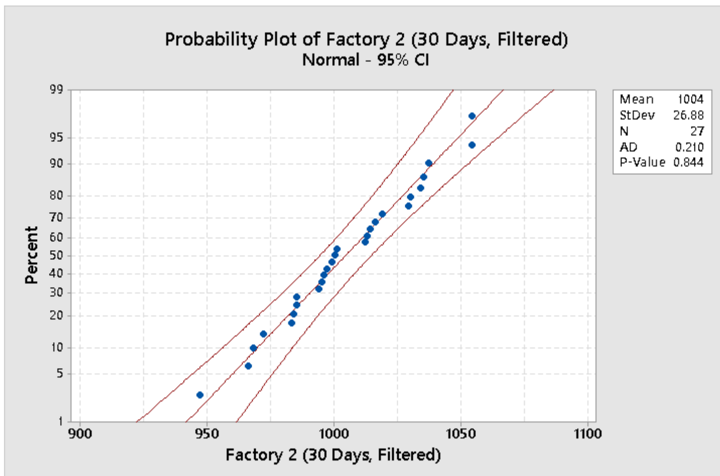



Probability Plot of Factory 2 (30 Days)
Normal - 95% CI
Percent
Factory 2 (30 Days)
900
950
1000
1050
1100
1150
1
5
10
20
30
40
50
60
70
80
90
95
99
Mean 1008
StDev 40.43
N 30
AD 0.509
P-Value 0.183


Probability Plot of Factory 3 (30 Days)
Normal - 95% CI
Percent
Factory 3 (30 Days)
650
700
750
800
1
5
10
20
30
40
50
60
70
80
90
95
99
Mean 704.2
StDev 25.05
N 30
AD 0.627
P-Value 0.093


Probability Plot of Factory 1 (30 Days, Filtered)
Normal - 95% CI
Percent
Factory 1 (30 Days, Filtered)
550
600
650
700
1
5
10
20
30
40
50
60
70
80
90
95
99
Mean 607.9
StDev 24.39
N 28
AD 0.191
P-Value 0.889





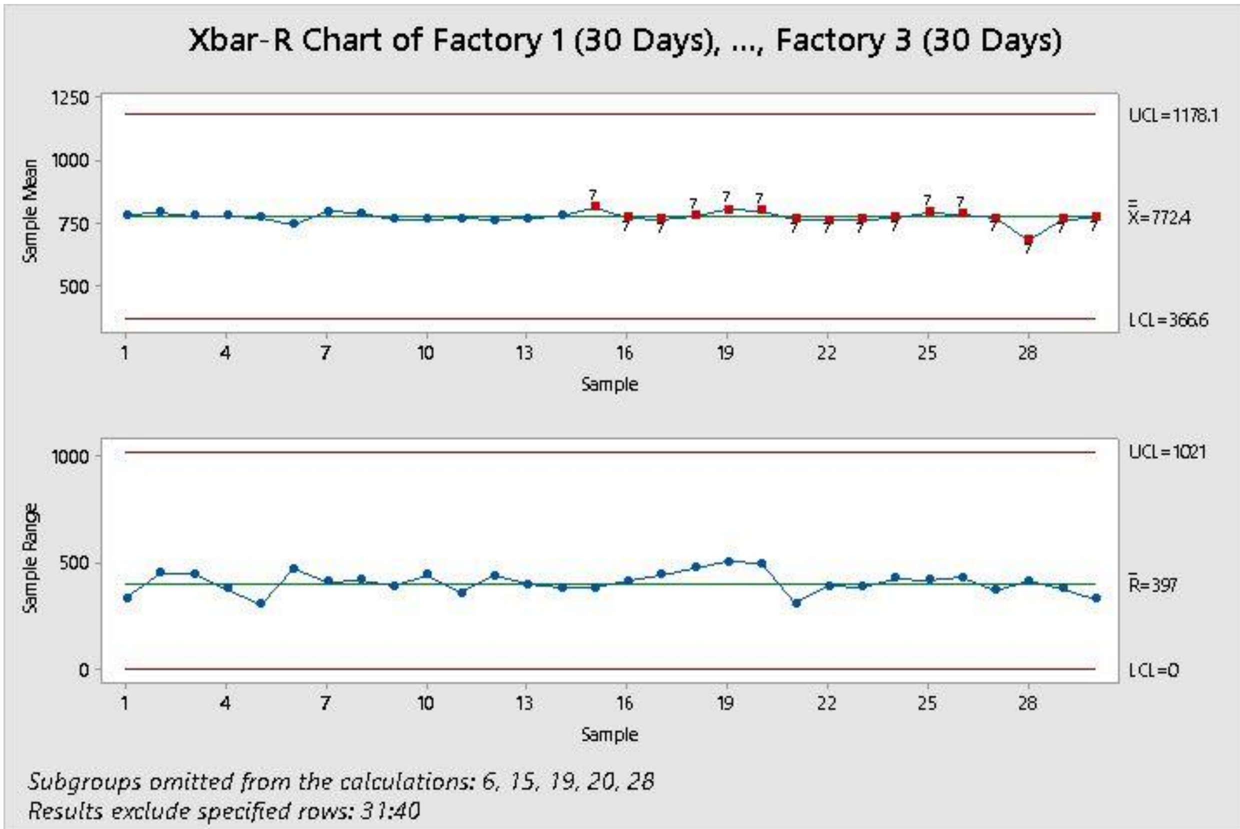
Graphs 1 through 6: The probability plot of the number of plastic pieces per liter of wastewater generated by each factory. Figures 1 to 3 offer raw, unfiltered data. Figures 4 to 6 offer filtered data that have the special cause data points removed.

Upon graphing the probability plots of each of the factories' raw, unchanged data, it can be observed that the data is normally distributed but only quite; the p-value is close to the significance level to the point where it can be assumed that one more outlier can cause this data to not be considered normal anymore. This is also reinforced by seeing several points falling outside the 95% confidence interval (corresponding to a 0.05 significance level).

Upon removing the points where special causes were detected skewing the data, it can now be observed that the data is strongly following the gaussian distribution, with a very high p-value to show for it. Thus, it is safe to assume that the data definitely follows the normal distribution.

- $\bar{X} - R$ Chart

These control charts enable one to observe any sudden shift in the output. Since the data points are aggregated into subgroup, the number of false alarms are reduced. A disadvantage is that if a point is deemed to be an outlier and a special cause, then it can only be known that at least one of the points in that subgroup are affected, not how many.

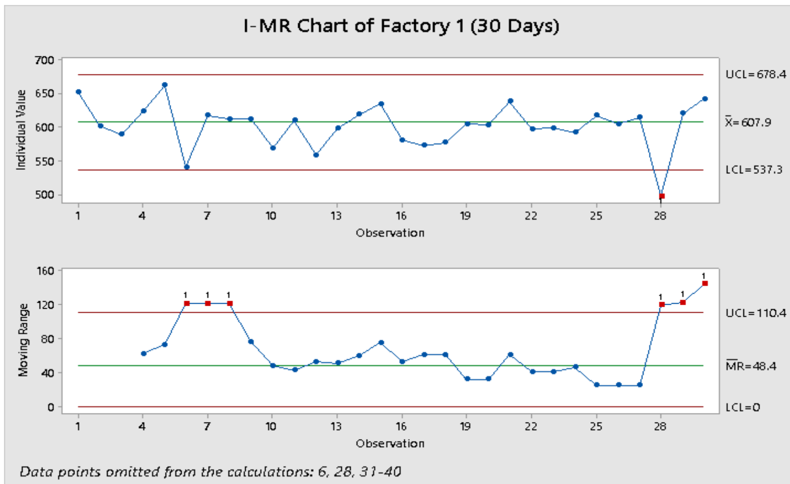


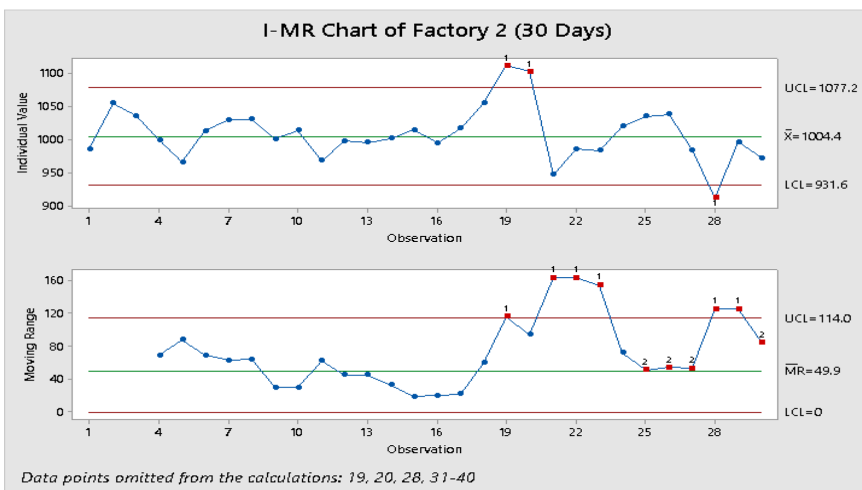
Graph 7: $\bar{X} - R$ chart of the number of plastic pieces per liter of wastewater for Cotton Ltd.

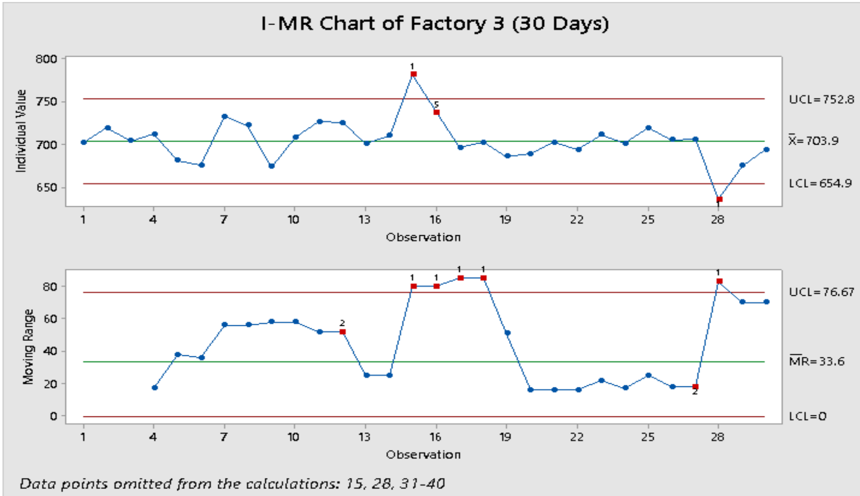
These $\bar{X}$ chart represent the $\bar{X}$ and R chart of Cotton Ltd.'s Çorlu, Gebze and Bursa factories' polyester amount in their wastewater. This chart represents all three factories' plastic amounts in their wastewater to observe the organization's complete wastewater pollution condition. The first chart, which consists of the first 30 days of plastic pollution data, has a couple of waves around the center line in $\bar{X}$ chart and R chart.

However, there are no outlying points observed in the first 30 days after omitting the special cause points that have been determined beforehand. The only point that has deviated is Day 28 where all factories had worked two shifts instead of three, due to a national holiday. It is worth noting that despite many special causes given in the system, no point was raised as a false alarm. For example, day 28, which was a half-holiday for all factories, was not detected by the system as an outlier/non-conforming point.

- $I - MR$ Chart







Figures 8 through 10: $I - MR$ charts of the number of pieces of plastic per liter of wastewater from all factories. MR length = 4

Note: the MR length has been chosen as 4 due to the relatively large sample of 30. In addition, changing the length has not had much effect on the value of $\overline{MR}$, overall.

Considering the data points falling within the 3-sigma control limits - excluding the data points that have been assigned to special causes - the process seems to be under control. It is also worth noting that the UCL is vastly smaller than the USL, indicating that Cotton Ltd. is well within the imposed waste-emission limits.

Select the most appropriate chart(s) and estimate the mean and standard deviation for the measures of polyester amounts in wastewater samples.

It seems that $I - MR$ charts have given the most reasonable values, as well as detected all the special cause points. So, it will be used:

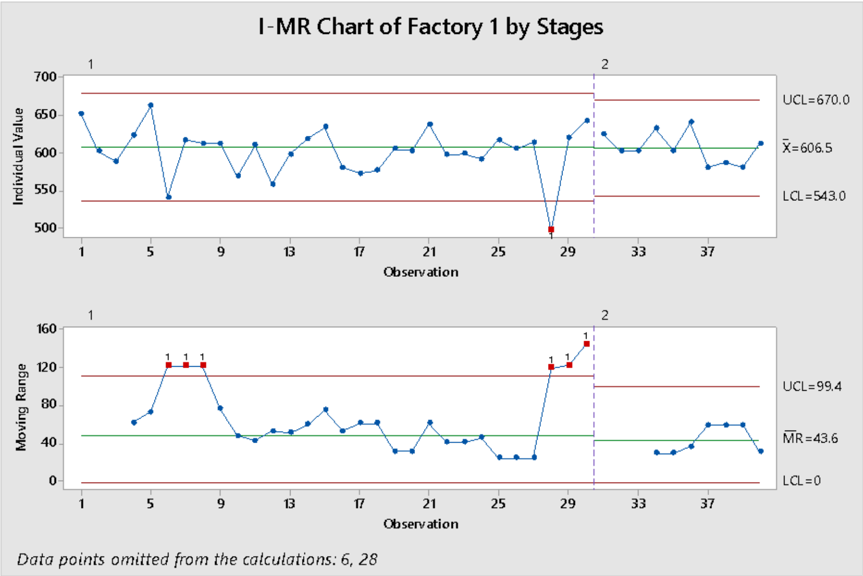
Let μ_k and σ_k be the estimated mean and standard deviation of factory k.

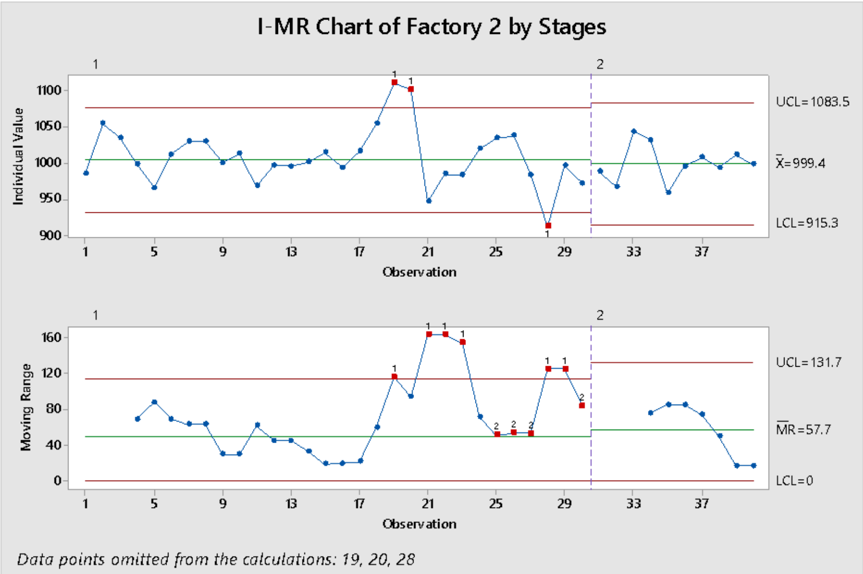
$\mu_1 = 607.9 \approx 608\ pieces/lt$ $\quad$ $\mu_2 \approx 1004\ pieces/lt$ $\quad$ $\mu_3 \approx 704\ pieces/lt$

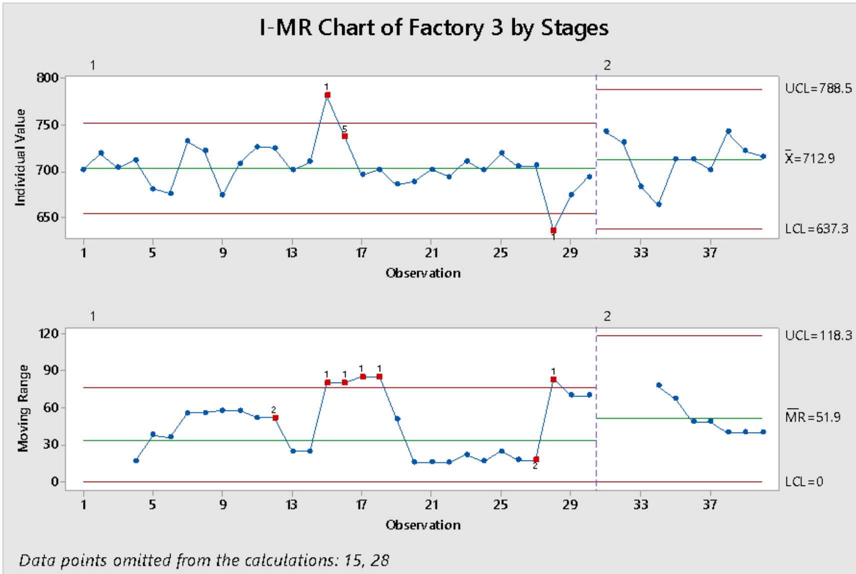
$\sigma_1 = \frac{\overline{MR}}{d_2} = \frac{48.4}{2.059} = 23.51$ $\quad$ $\sigma_2 = \frac{49.9}{2.059} = 24.24$ $\quad$ $\sigma_3 = \frac{33.6}{2.059} = 16.3$

Phase II

Comment on what you observe on the chart(s) based on the newly collected data. As a consultant, comment also on how Cotton Ltd. should continue monitoring and improving the process.



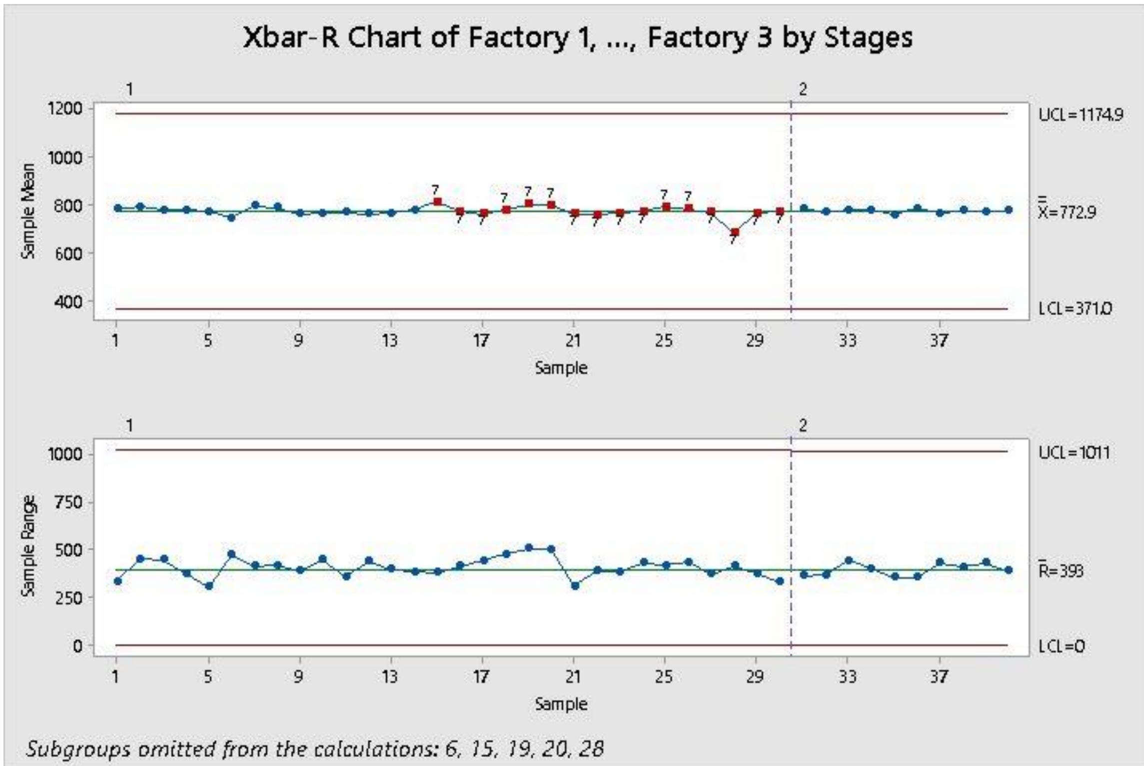




Figures 11 through 13: $I - MR$ charts of plastic pieces per liter of wastewater of each factory, divided by stages 1 and 2. MR length = 4

Interestingly, it seems that in the 10 days between days 31 and 40, no red flags had been raised, indicating that the processes have been under control. There also does not seem to be a very obvious pattern, except for some consistently decreasing points in the MR of factories 2 and 3 around days 35-40. However, the sample is too small to tell if the decreasing points are actually part of a pattern.

Also, control limits generally have widened instead of narrowed done, perhaps indicating that the previous control limits were too wide. Or it could be that a shift has occurred but went undetected due to the relatively small sample size.



Figures 14: $\bar{X} - R$ chart of plastic pieces per liter of wastewater for all factories

After finishing Phase I, the rest of the days of observation shows that the quality engineers have improved the processes in all factories. It is understood from both of $\bar{X} - R$ charts that the fluctuations of each day's data has least variance and also control limits of both $\bar{X} - R$ charts get narrowed. As a result, Cotton Ltd. has improved processes for plastic waste in their wastewater.

After removing the special cause points from the chart to prevent any bias, the above charts were generated. To observe the monitoring processes after the first 30 days and to try to detect any problems in the system, the chart has been split by stages: days 1 to 30 and days 31 to 40. The staging also helps in reducing the control limits to further refine the processes.

What can you tell about the capability of the waste management process to conform to the specifications?

When taking the average of the outputs of the factories through an $I - MR - R$ chart:

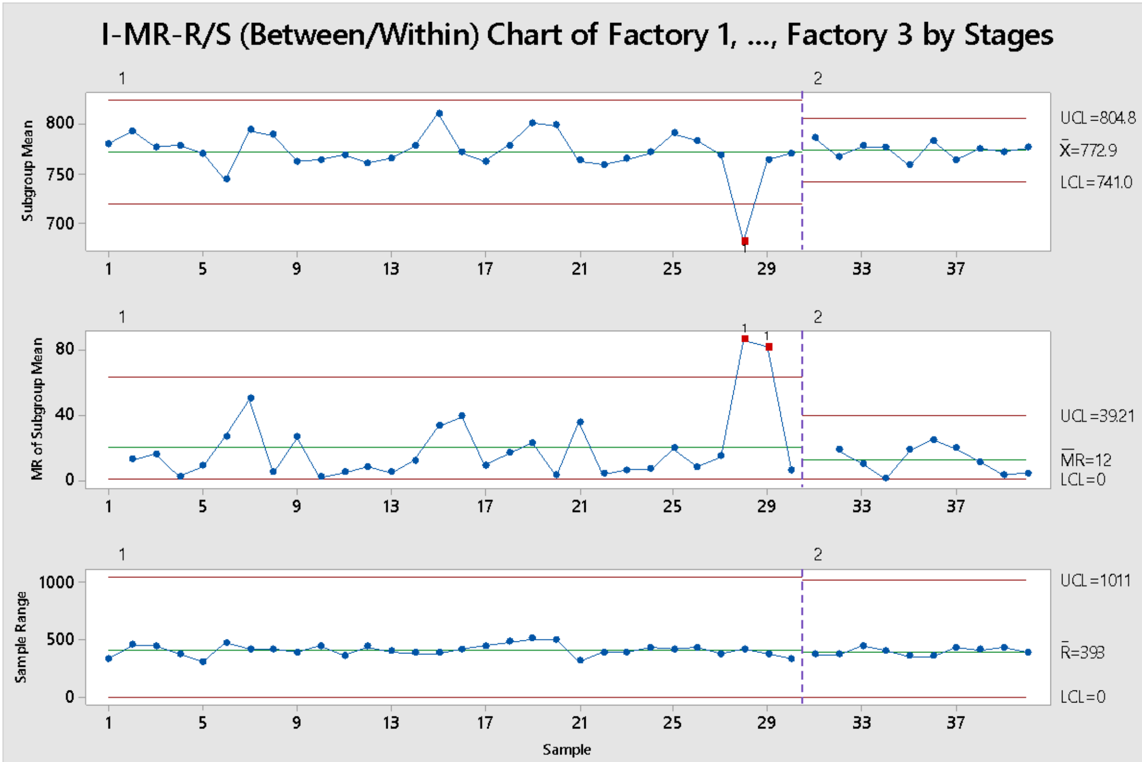


Figure 15: I − MR − R chart of the plastic pieces per liter of waster aggregated over all factories. MR length = 4, Subgroup sample size = 3

Process Capability Ratio is how much system takes up specification limits of the process. It is crucial to have a process ratio to conform specification limits of process and it allows to control process.

- $C_p = \frac{USL - LSL}{6\sigma} = \frac{1600-0}{6\sigma}$

  But, $\hat{\sigma} = \frac{\bar{R}}{d_2}$

- $R = 393$ and d_2 value for $n = 3$ is 1.693
- $\widehat{C_p} = \frac{1600-0}{6*(\frac{397}{1.693})} = 1.137$
- $\hat{P} = \left(\frac{1}{C_p}\right)(100\%) = \frac{1}{1.137}(100\%) = 87.935\%$

That is, the process uses up about 88% of the specification band. Moreover, C_p is greater than 1 so we can clearly state that, the process produces relatively few nonconforming units.

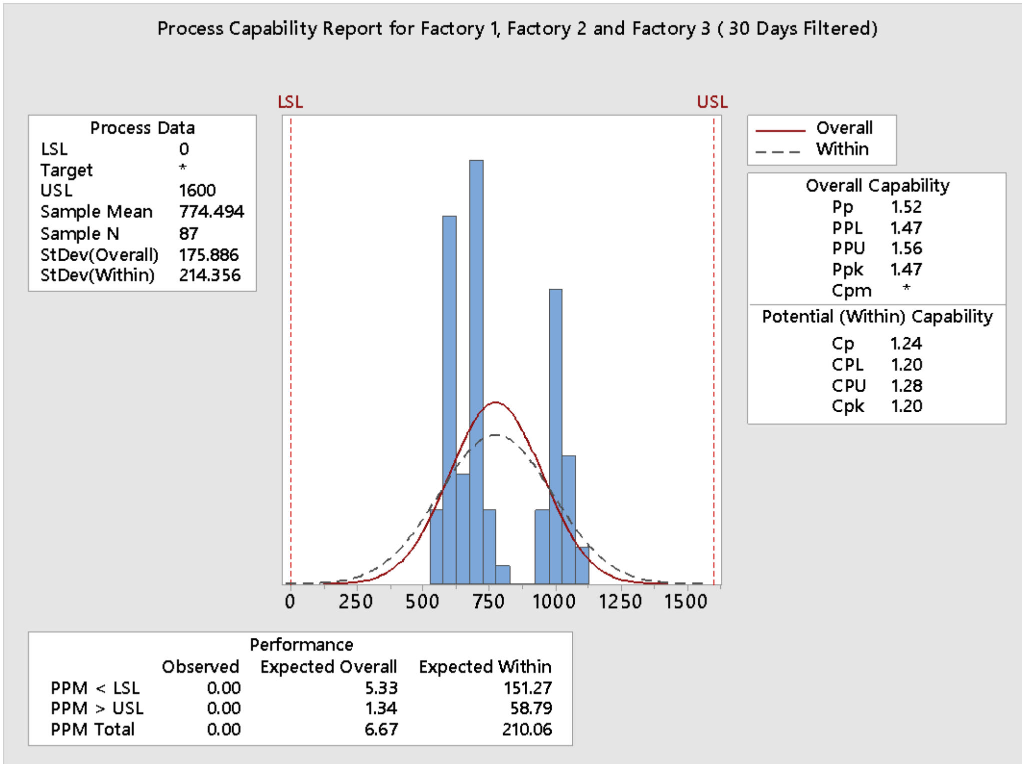


Figure 16: Process Capability Chart of the Organization's Factories, subgrouped by factories

The values of the standard deviation between hand calculated and Minitab's values are slightly different. In hand calculation, the σ has been estimated with $\bar{R}$ and the statistical constant, d_2. However, Minitab uses the real variance which is calculated by formula shown below:

$$\hat{\sigma}_{total} = \sqrt{\sigma^2_{between} + \sigma^2_{within}}$$

The difference between C_p values occurs because Minitab standard deviation calculation is 175.886 and because of that C_p is 1.24 and in hand calculation, estimator of standart deviation with $\bar{R}/d_2$ is equal to 234.49. However, for both of the results the process is barely capable when it is between 1.0 to 1.33.

What can be done to improve the process quality?

There are a lot of different factors that can affect the quality process in the factory. There are a couple of special causes that occurred in Cotton Ltd.'s factories. The first one is about the dirtiness of machines. To improve process quality and get rid of this kind of special cause, adding sensors may prove to be beneficial. The second special cause is about suppliers. The company should state a new contract with the supplier which includes new clauses to prevent factories out of raw material shortage. The last factor concerns workers. A worker could start just in that week or work for a long time. There should be training sessions for new workers which includes all the information about processes and EHS issues to keep machines, factories, and workers safe. For the usual workers, there should be training sessions to ensure they follow the rules of EHS and machines working processes. These improvements will reduce special causes and ensure quality.

Conclusion

Under the assumption that the obtained data is normally distributed, and under the assumption that the factories can be grouped into subgroups, the process is capable according to Kiran (2017).

As described before, the $I - MR$ charts have proved to be more beneficial since they have detected special cause points successfully and thus can help Cotton Ltd. to detect any further special causes that may have gone undetected otherwise.

Also, it was noticed that the control limits have generally expanded in phase II of the study. This could be due to a multitude of factors, one of which could be that the data in phase I could have been too narrow and may have resulted in a lot of false alarms later on, had the control limits not widened up.

In addition, it can be concluded the organization is complying with the specification limits imposed, and that the auditing company, GrayPiece should conclude that as well.

References

Kiran, D., R. (2017). Process Capability Index. *Science Direct.* https://www.sciencedirect.com/topics/engineering/process-capability-index#:~:text=When%20the%20process%20capability%20index,the%20process%20is%20not%20capable