Minitab

# SPC

## LESSON: Cardboard Thickness - Homework

Homework 4 NAME:_____

**Topics**: Xbar-R charts with Minitab

Solve the following problems and show your work.

**Constructing $\overline{X}$ and R charts given sample data**; i.e., μ and σ are not given – they will be estimated from the given data for the process.

A paper manufacturing company must control the thickness of cardboard sheets it produces. Random samples of size **n = 5 sheets** are selected each hour and the thickness is recorded for **k = 30 subgroups** of n = 5 sheets. Each hour, the n = 5 sample observations are placed in **Columns C1-C5 across a row**. Each row in the worksheet constitutes one hour. The **specifications** on the thickness of the cardboard sheets are **0.5 ± 0.04 mm**. [Note: Specifications ("specs") are provided by the customer – these are NOT the $\overline{X}$ control limits for the process.]

This data is in the Minitab worksheet entitled **Hmwk4DATA_CardboardThickness**.

| Hour | Obs 1 | Obs 2 | Obs 3 | Obs 4 | Obs 5 |
|---|---|---|---|---|---|
| 1 | 0.52 | 0.55 | 0.49 | 0.51 | 0.52 |
| 2 | 0.53 | 0.5 | 0.51 | 0.51 | 0.5 |
| 3 | 0.52 | 0.51 | 0.55 | 0.5 | 0.52 |
| 4 | 0.42 | 0.45 | 0.43 | 0.42 | 0.46 |
| 5 | 0.48 | 0.5 | 0.47 | 0.51 | 0.51 |
| ... | ... | ... | ... | ... | ... |

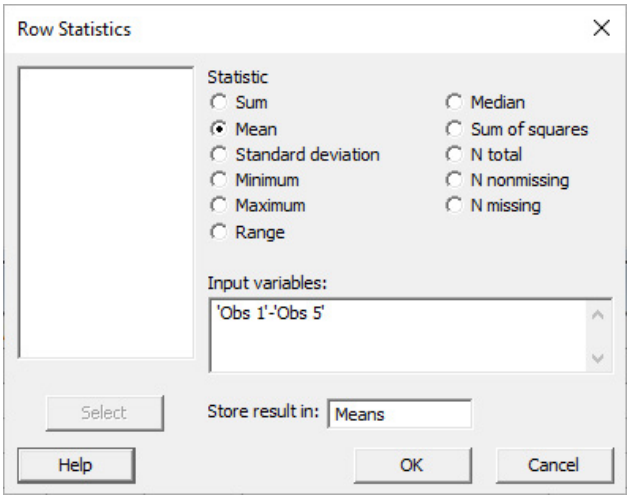
Determine the center line for the $\overline{X}$ chart "manually" in Minitab by following these instructions.

**(a)** Have Minitab determine the subgroup mean for each row of n = 5 observations.

**Minitab**

1. Choose **Calc > Row Statistics**.

2. Complete the dialog box as shown below




3. Click **OK**.

Thus, C7 contains the mean for each subgroup of size n = 5.

List the next 4 subgroup means (correct to 3 decimal places):

Hour 1: 0.518

2:

3:

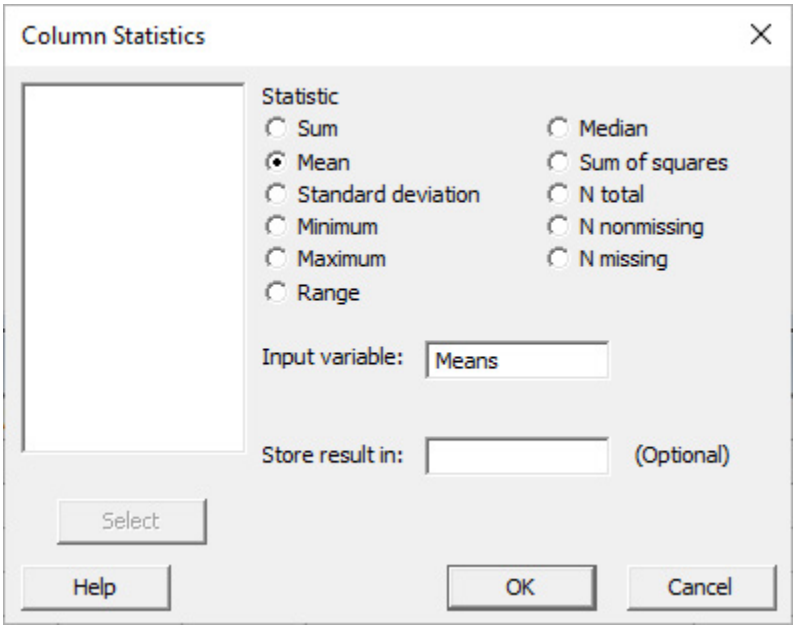
4:

5:

(b) In Minitab, determine the "mean of the means," or what we call $\overline{\overline{X}}$. The **center line** of the $\overline{X}$ chart is $\overline{\overline{X}}$.

**Minitab**

1. Choose **Calc > Column Statistics**.
2. Complete the dialog box as shown below.




3. Click **OK**.

What is the value of $\overline{\overline{X}}$?

**(c)** Using the sample means $\overline{X}_1$, $\overline{X}_2$, $X_3$,...,$\overline{X}_{30}$, write down the mathematical formula used to compute $\overline{X}$.

$\overline{X}$=

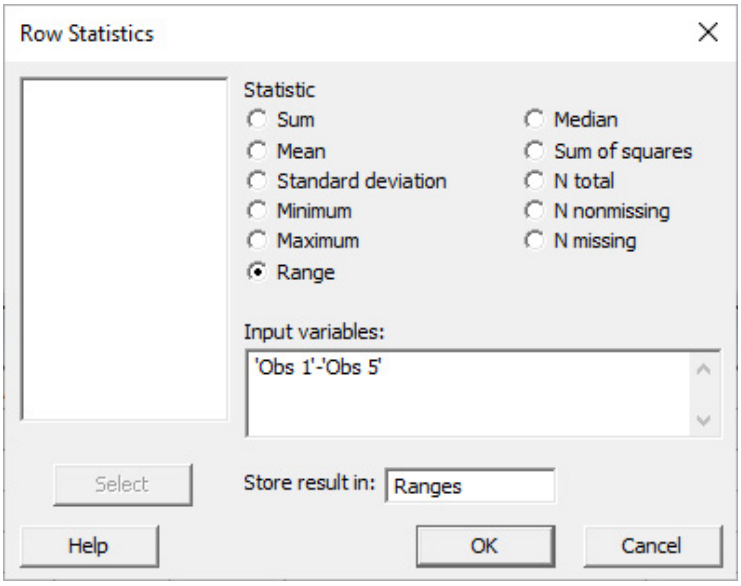
In order to compute the Lower Control Limit (LCL) and the Upper Control Limit (UCL) for the $\overline{X}$ chart, we next need to compute $\overline{R}$.

**(d)** First, determine the ranges for each row of n = 5 observations.

**Minitab**

1. Choose **Calc > Row Statistics**.

2. Complete the dialog box as shown below.




3. Click **OK**.

Thus, C8 contains the range for each subgroup of size n = 5.

List the next 4 subgroup ranges (correct to 2 decimal places):

Hour 1: 0.06

2:

3:

4:

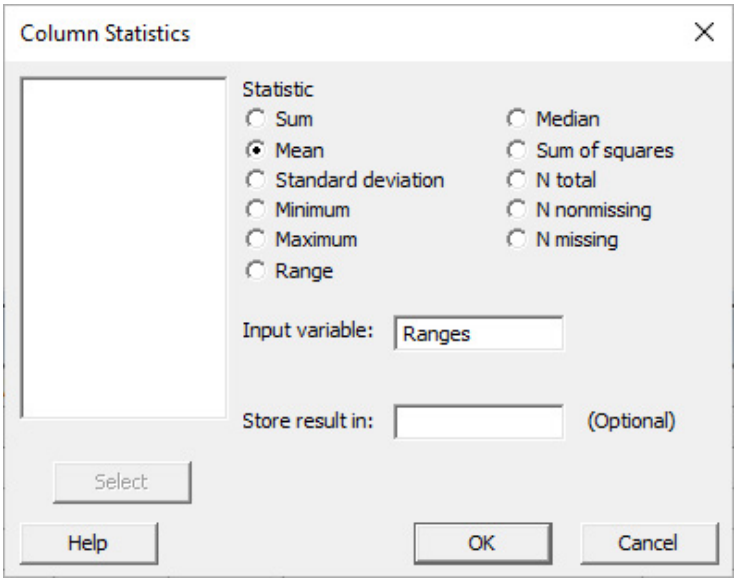
5:

**(e)** Next determine the "mean of the ranges," or what we call $\overline{R}$. The center line of the R chart is $\overline{R}$.

**Minitab**

1. Choose **Calc > Column Statistics**.

2. Complete the dialog box as shown below.




3. Click **OK**.

What is the value of $\overline{R}$?

**(f)** Using the sample ranges, R1, R2, ..., R30, write down the mathematical formula used to compute $\overline{R}$.

$\overline{R}$=

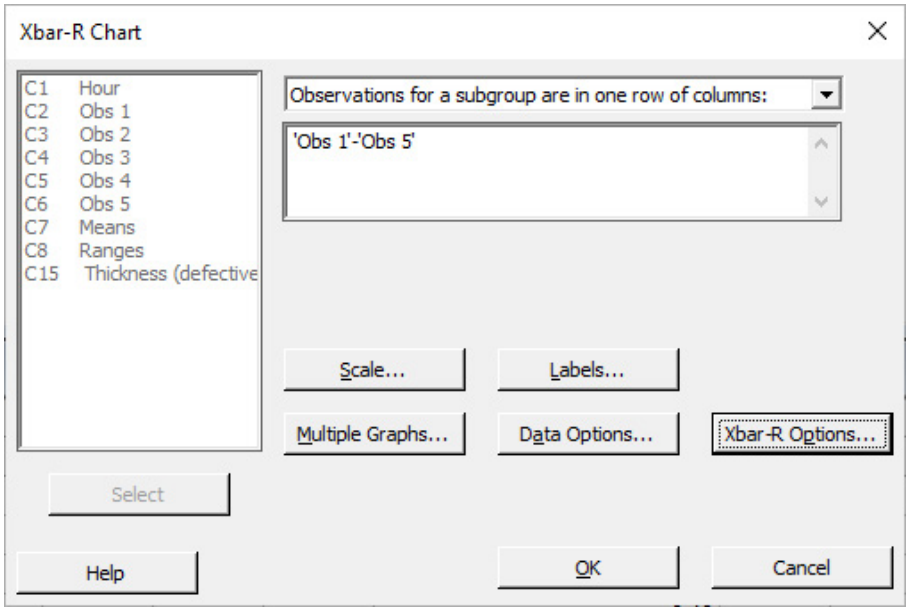
**(g)** Now that we have values for $\overline{\overline{X}}$ and R, we can compute the LCL and UCL for the $\overline{X}$ and R charts. Show your work in determining values for the LCL and UCL of the $\overline{X}$ chart. **Hint**: See the **QualityMethods_ FormulasReference_2019** resource for Chart Formulas and Control Chart constants. Recall that the subgroup size is n = 5.

**(h)** Compute the LCL and UCL for the R chart. Again, write down your calculations and determine the LCL and UCL.

**(i)** Use Minitab to construct the $\overline{X}$ and R control charts for hourly subgroups of size n = 5. The center lines and control limits should match the values you computed "by-hand."

Minitab

1. Choose **Stat > Control Charts > Variables Charts for Subgroups > Xbar-R**.
2. From the drop-down menu, select Observations for a subgroup are in one row of columns.
3. Complete the dialog box as shown below.



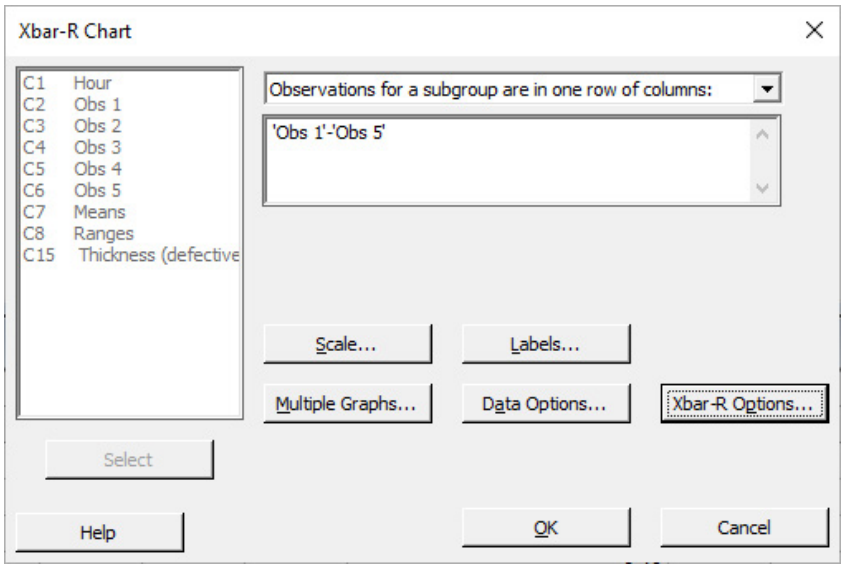

4. Click **Xbar-R Options**.
5. Click **Tests** and select **Perform all tests for special causes**.
6. Click **OK** in each dialog box.

**(j)** Is the process in control if all rules are applied? If not, **what subgroup number(s)** have violated the "out of control" rules and **which rule(s)** are violated? This information is available in the Output Window.

**(k)** Assuming special cause variation for the out-of-control points (e.g., power failure, defective material), "remove" them (Minitab has an option for this) and find the revised control limits. Record them on the following page.

### Minitab

1. Choose **Stat > Control Charts > Variables Charts for Subgroups > Xbar-R**.
2. From the drop-down menu, select **Observations for a subgroup are in one row of columns.**
3. Complete the dialog box as shown below.




4. Choose **Data Options**.
5. Choose **Specify which rows to exclude**.
6. Choose **Row numbers** and enter the subgroup numbers that should be excluded for the calculation of the control limits.
7. Check **Leave gaps for excluded points**.
8. Click **OK** in each dialog box.

**(k) (continued)** Record the **new center line and control limits** for the $\overline{X}$ and R charts as shown on the new Minitab control charts.

| | $\overline{X}$ Control Chart | R Control Chart |
|---|---|---|
| Centerline | | 0.0554 |
| Upper Control Limit | | |
| Lower Control Limit | | |

**(l)** Now that the out of control points are removed and your process is in control, what is the estimate of the process mean $\hat{\mu}$ and the process standard deviation $\hat{\sigma}$?

**(m)** "Hypothetically" what proportion of the output will be nonconforming? That is, what proportion of the cardboard thicknesses (according to their distribution with mean $\hat{\mu}$ and the process standard deviation $\hat{\sigma}$ from part (l)) is expected to be beyond the specification limits?

Recall: The **specifications** on the thickness are **0.5 ± 0.04 mm**

**(n)** What assumption(s) did you make about the thickness of cardboard sheets to do part (m) to determine this proportion?

**(o)** Check the assumption referred to in part (n) using the data with the out of control points removed. I put the single observations with the out of control points removed in column C15. What p-value accompanies this assumption? What's your decision regarding this assumption?