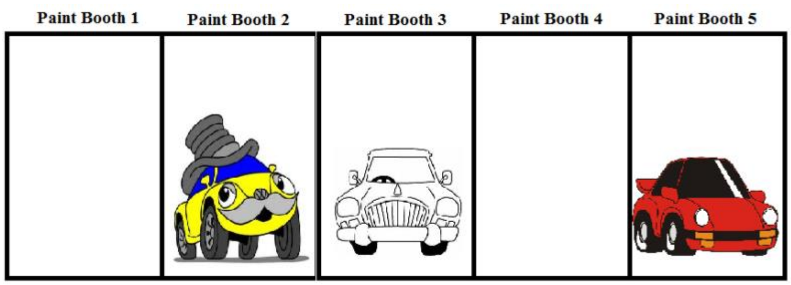
SPC

TOPICS: Rational Subgrouping, Capability Analysis

Instructions: Solve the following problems and show your work. Make sure the requested Minitab graphics and work are with the problem they go with. The data for this assignment is in the file: **Hmwk6DATA_CapabilityAnalysis**.

Problem 1. A car company was asked by its customers to create Xbar and R control charts for the metric "paint thickness." The car company has 5 different paint booths. The car company's engineering team proposed *2 different sampling plans*.



Plan 1:

- 5 cars will be randomly selected each day.
- *One car will be from each of the 5 paint booths.*
- *Paint thicknesses for the 5 cars are averaged together and the average is plotted on the Xbar chart for that day.*

The data and Xbar chart for this sampling plan are:

Day	Booth 1	Booth 2	Booth 3	Booth 4	Booth 5	Avg	Range
1	20.34	20.64	19.94	24.42	24.02	21.87	4.48
2	19.22	19.05	20.79	25.39	23.78	21.65	6.34
3	18.53	22.23	19.92	25.04	23.49	21.84	6.51
4	20.22	20.07	19.79	22.3	24.02	21.28	4.23
5	21.15	19.72	21.53	23.1	25.19	22.14	5.47
6	19.39	20.8	19.21	24.03	23.62	21.41	4.82
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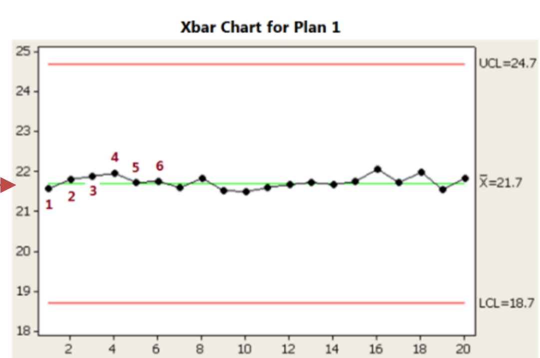


1(a) Does the **Xbar chart** indicate the *differences in paint thicknesses between the booths or the differences in paint thicknesses between the days?*

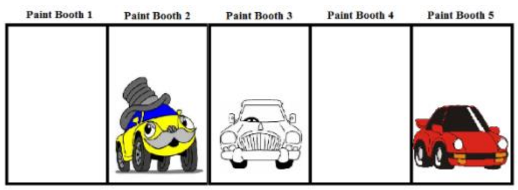
Between Booths Between Days

1(b) The **R chart** is not drawn. Would the **R chart** indicate the *differences in paint thicknesses between the booths or the differences in paint thicknesses between days?*

Between Booths Between Days

1(c) Does the **Xbar chart** appear to be "in control" considering all the Type I rules that we've talked about in class? If no, what appears to be the issue?

Problem 1 continued.



Plan 2:

- 5 cars will be randomly selected each day.
- The *5 cars will be selected from one paint booth. Paint thickness for the 5 cars are averaged and the average is plotted on the Xbar chart for that day.*
- On the following day, the *next paint booth is chosen and the 5 cars are selected from it and averaged.*

For example, 5 cars from Booth 1 are subgrouped on Monday; 5 cars from Booth 2 are subgrouped on Tuesday; 5 cars from Booth 3 are subgrouped on Wednesday, etc.

The data and Xbar chart for this sampling plan are:

Day	Booth	Car 1	Car 2	Car 3	Car 4	Car 5	Avg	Range
1	1	19.41	19.11	21.26	20.61	20.09	20.10	2.15
2	2	20.2	20.78	20.76	19.41	19.55	20.14	1.37
3	3	18.75	19.01	20.18	17.81	20	19.15	2.37
4	4	24.59	24.11	24.53	26	23.79	24.60	2.21
5	5	22.59	23.71	23.28	23.52	25.86	23.79	3.27
6	1	20.16	20.97	20.25	19.98	19.36	20.14	1.61
7	2	20.56	20.29	20.55	21.85	19.74	20.60	2.11
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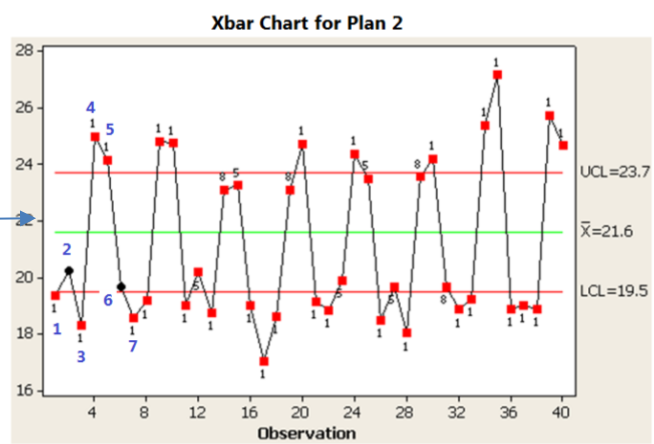


1(d) Does the **Xbar chart** indicate the *differences in paint thicknesses between the booths or the differences in paint thicknesses within a booth?*

Between Booths Between Days

1(e) The **R chart** is not drawn. Would the **R chart** indicate the *differences in paint thicknesses between the booths or the differences in paint thicknesses within a booth?*

Between Booths Between Days

1(f) Is there more variation between booths or within booths considering the data from Plan 1 and Plan 2?

Between Booths Between Days

1(g) Let's say *all* the cars that were painted in a given month are sitting in a back lot. In order to test paint thicknesses for that day, you randomly select 5 cars from the lot and measure their paint thicknesses. You average the 5 data points to put on the Xbar chart and their ranges are plotted on an R chart. What's one problem with this sampling plan?

1(h) If you are working in an industrial setting for your next job and need to come up with a subgrouping plan, will you take into consideration the appropriate way to subgroup? There is only one right answer to this question!

Problem 2. Capability Analysis Experiment. Form a team of 2, 3, or 4 members. Each team will need a tape measure or ruler and an experimental object: Pig Popper, leaping frog, flying monkey, air mail, chicken or dragon flingers, oyster crackers, hexbug, etc.

The object is to **collect some type of distance data**; e.g., distance an object lands from a target, where objects may be one of the items listed above.

(a) One team member will shoot/fling/throw the object while the other team members will measure its final distance from its target using the "tightest" possible measurement (e.g. 81.35 cm instead of 81 cm). Explain to me what data your team is collecting and how the distance is being measured (e.g. from the center of the target to (a) the center of the popped ball, or (b) the tip of the monkey's left arm, or (c) the center of frog's head, etc.). Drawings are appropriate in providing clear operational definitions.

(b) After ~10 trial runs, set lower and upper specifications for the "ideal" distance you'd like the object to land from the target. Consider these 10 original times as "burn-in" times only. List the specification limits below:

LSL: USL:

(c) Begin again and collect 30 consecutive data points. Enter the data points in a column in Minitab and name the column appropriately. Make your measurements as "tight" (or resolute) as possible. Don't just simply round your measurements to the nearest unit (recall our Normality vs. Rounding discussion!).

(d) Before conducting a capability analysis, check these necessary assumptions and **attach a copy of the appropriate graphics: 1. Process Control, 2. Normality, 3. IID.**

(e)-(g) Based on your graphics, answer the following.

(e) Are the distances "in control?" If not, what is the main issue affecting process control? (e.g., points beyond the LCL or UCL, too many points hugging the centerline, trend in the mean (e.g. team member getting "better" at activity over time), etc.)

(f) Is your team's data normally distributed? Record the p-value here for the normality test: ***p-value:***

(g) Is your team's data IID? If it is not, what lag value is significant and is it positive or negative?

(h) Regardless of whether your process met the appropriate assumptions to move forward (e.g. normality, IID data, process in control) with a Capability Analysis, do so.

Using the specification limits that you set in part (b), determine the “capability” of the team member’s distances to meet these specifications. Perform the appropriate capability analysis listed below according to the normality of your process and record the capability indices: C_p and C_{pk} (if they exist), and P_p and P_{pk}.

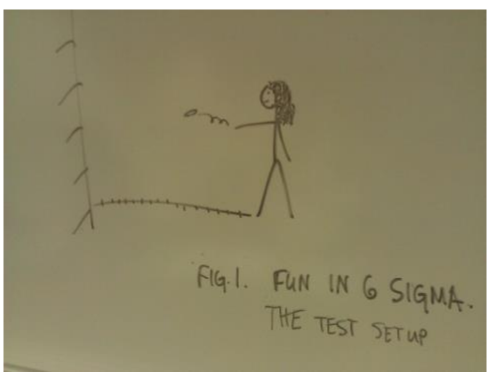
Recall: Data normally distributed: **Stat** > **Quality Tools** > **Capability Analysis** > **Normal;** your subgroup size is 1.

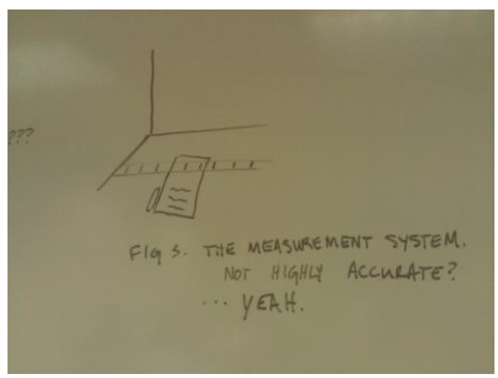
Recall: Data not normally distributed: **Stat** > **Quality Tools** > **Capability Analysis** > **Normal;** your subgroup size is 1; Select **Transform** and choose the **Box-Cox transformation**.

$C_p =$ $C_{pk} =$ $P_p =$ $P_{pk} =$

Note: If your data is not normal and a transformation doesn’t work, let me know and we’ll try something else.

Problem 3. Coin Toss Exercise: This is an exercise in which team member Mr. Potato head flipped a coin near a classroom wall to get as close to it as possible. The distance (in cm) from the wall to the center of the coin is collected for his 30 tosses. Data for Mr. Potato Head is in the Minitab worksheet: **HmwkSet6_CapabilityAnalysisDATA.**





(a) Yes or No. Construct an I-MR chart to determine if his coin tosses are in control. Turn on all tests for Type I Error. Is his data in control based on the I-MR chart?

Yes **No**

(b) True or False. Before performing a capability analysis on process data, it is necessary to make sure the data is in control first.

True **False**

(c) Yes or No. Check normality for Potato Head’s process. Based on the p-value of the normality test, can you assume his data is normally distributed?

Yes **No**

(d) Yes or No. Check for dependency in Pareto Head’s tosses. Is there dependency in his coin tosses?

Yes **No**

(e) Perform a Box-Cox Transformation on Potato Head's data to transform it into normally distributed data. Store the transformed data in another column in Minitab. What transformation (e.g., ln(X), X2, $\sqrt{X}$, etc.) are you applying to the data?

Stat > **Control Charts** > **Box-Cox Transformation**

(f) **Yes or No.** Run a normality test on the transformed data. Is the transformed data normally distributed according to the normality test's p-value?

Yes **No**

(g) Perform a capability analysis on Potato Head's data with lower and upper specifications set at 1 and 15 cm. Report the Cp and Cpk values. Make sure to apply the appropriate transformation as determined in part (e).

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Stat > **Quality Tools** > **Capability Analysis** > **Normal;** your subgroup size is 1; Select **Transform** and choose the **Box-Cox transformation**

Cp = Cpk =

(h) Given the Cp value from part (g), which is larger – Voice of Customer (specification spread) or Voice of Process (process spread)?

VOC VOP

(i) Use Minitab's distribution identification abilities to write down just one distribution that "fits" Potato Head's ORIGINAL data (not transformed data!), where "fits" means the distribution's *p*-value is at least greater than 0.05. Make sure the chosen distribution is NOT a transformation (e.g., Box-Cox or Johnson transformation). Report the distribution's scale, threshold, spread, etc. parameter values as well.

Stat > **Quality Tools** > **Individual Distribution Identification**

Distribution: Parameter values (such as scale, spread, threshold):

(j) Perform a Capability Analysis using the distribution you reported from part (i). The instructions for doing this are in the Lesson 16 notes.

Stat > **Quality Tools** > **Capability Analysis** > **Non-normal**, and select the distribution you want from the drop down menu list. Report the Pp and Ppk values.

Pp = Ppk =

(k) Use the distribution from part (i) to determine the proportion of his throws that would land between 5 and 10 cm. You can use either of the following methods:

- Write out the expression you are integrating below and then evaluate it, or
- Use Minitab's Probability Distribution Plot to fit the desired distribution function with parameters reported from part (i). Sketch a graph below of the distribution and shade the area corresponding to the appropriate probability.

(l) Use the *transformed data* to determine the proportion of his throws that would land between 5 and 10 cm. Recall that the transformed data does follow a normal distribution and that the values 5 and 10 have not been transformed. Determine the proportion correct to at least 2 decimal places.

Show your Minitab work (or sketch the graph and shade the proportion) to support your answer.