MBC 638

LIVE SESSION WEEK 8

Agenda

Topic	Time	Sunday Section	Wednesday Section
Introduction	5 min	6:30-6:35	7:30-7:35
Highlights from Week 8 Video	55 min	6:35-7:30	7:35-8:30
Breakouts	15 min	7:30-7:45	8:30-8:45
Review of Upcoming Assignments and Open Question	15 min	7:45-8:00	8:45-9:00

8.3 Control Chart Introduction and Types Available

Thoughts for the Day

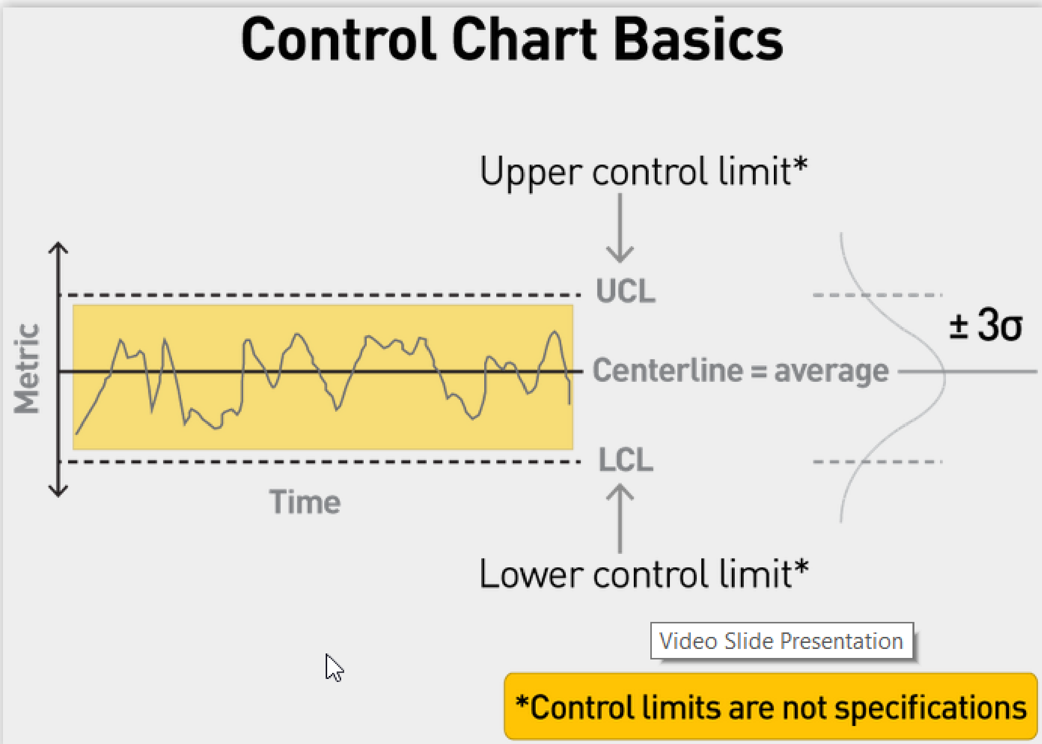
- "Just because a process is in control does not necessarily mean that it is a good process."
  —*Basic Statistics*, Kiemele, Schmidt, and Berdine
- "Our ability to assess the performance of a process we wish to improve is only as good as our ability to measure it."
  —George Group
- "If you can not measure, you can not improve."
  —Dr. Genichi Taguchi

What Is a Control Chart?

- All processes have variation.
- Control chart: common cause variation or special cause variation?
  - **Common cause:** predictable, routine, stable; noise
  - **Special cause:** unpredictable, unstable, out of control; a signal
- Control chart indicates special cause variation.
  - I.e., something needs fixing

Video Slide Presentation

8.3 Control Chart Introduction and Types Available

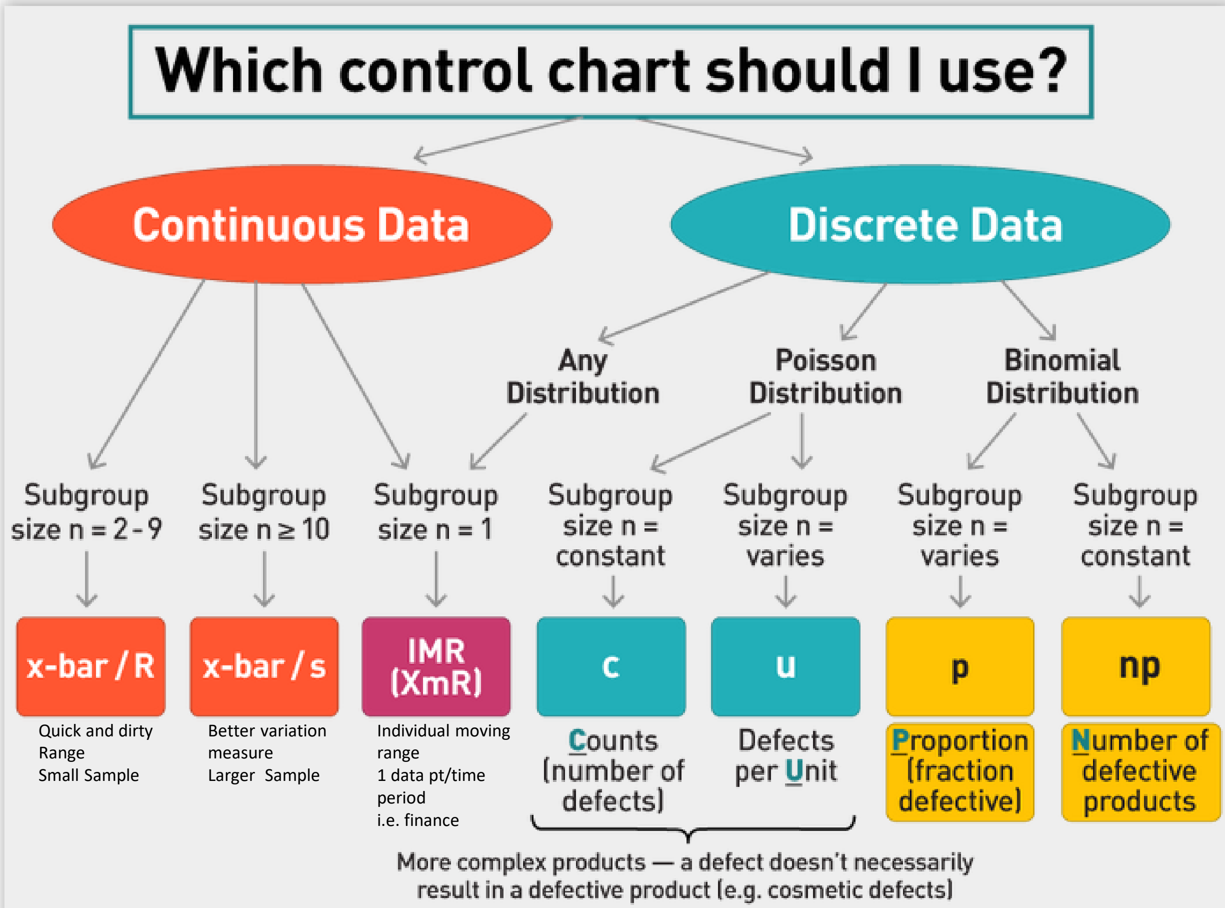


Natural Limits that happen within your process, not specifications.

Out-of-Control Signals

- One or more points outside control limits
- Also, data patterns inside control limits
  - Seven or more consecutive points above/below centerline
  - Look for patterns forming
    - E.g., consecutive points all above; all below; repeatedly alternating above and below
- Random variation desirable
  - Pattern indicates flaw in process.

8.3 Control Chart Introduction and Types Available



8.4 Control Chart Calculations: Reference

Control chart calculations

FORMULAS:

Chart	CL	UCL	LCL	Comments
$\bar{x}$ - R	$\bar{\bar{x}}$	$\bar{\bar{x}} + A_2\bar{R}$	$\bar{\bar{x}} - A_2\bar{R}$	$\hat{\sigma} = \frac{\bar{R}}{d_2}$
	$\bar{R}$	$D_4\bar{R}$	$D_3\bar{R}$	use when $n < 10$
individuals with moving range	$\bar{x}$	$\bar{x} + E_2\bar{R}$	$\bar{x} - E_2\bar{R}$	$\hat{\sigma} = \frac{\bar{R}}{d_2}$
	$\bar{R}$	$D_4\bar{R}$	$D_3\bar{R}$	use $n = 2$
$\bar{x}$ - s	$\bar{\bar{x}}$	$\bar{\bar{x}} + A_3\bar{s}$	$\bar{\bar{x}} - A_3\bar{s}$	$\hat{\sigma} = \bar{s}$
	$\bar{s}$	$B_4\bar{s}$	$B_3\bar{s}$	use when $n \geq 10$ or when n varies
np	$n\bar{p}$	$n\bar{p} + 3\sqrt{n\bar{p}(1-\bar{p})}$	$n\bar{p} - 3\sqrt{n\bar{p}(1-\bar{p})}$	n is fixed size
p	$\bar{p}$	$\bar{p} + 3\sqrt{\frac{\bar{p}(1-\bar{p})}{\bar{n}}}$	$\bar{p} - 3\sqrt{\frac{\bar{p}(1-\bar{p})}{\bar{n}}}$	use n_i instead of $\bar{n}$ if n_i's vary widely
c	$\bar{c}$	$\bar{c} + 3\sqrt{\bar{c}}$	$\bar{c} - 3\sqrt{\bar{c}}$	fixed area of observation
u	$\bar{u}$	$\bar{u} + 3\sqrt{\frac{\bar{u}}{\bar{a}}}$	$\bar{u} - 3\sqrt{\frac{\bar{u}}{\bar{a}}}$	use a_i instead of $\bar{a}$ if a_i's vary widely

Basic Statistics - Kiemele, Schmidt & Berdine

NOTATION:

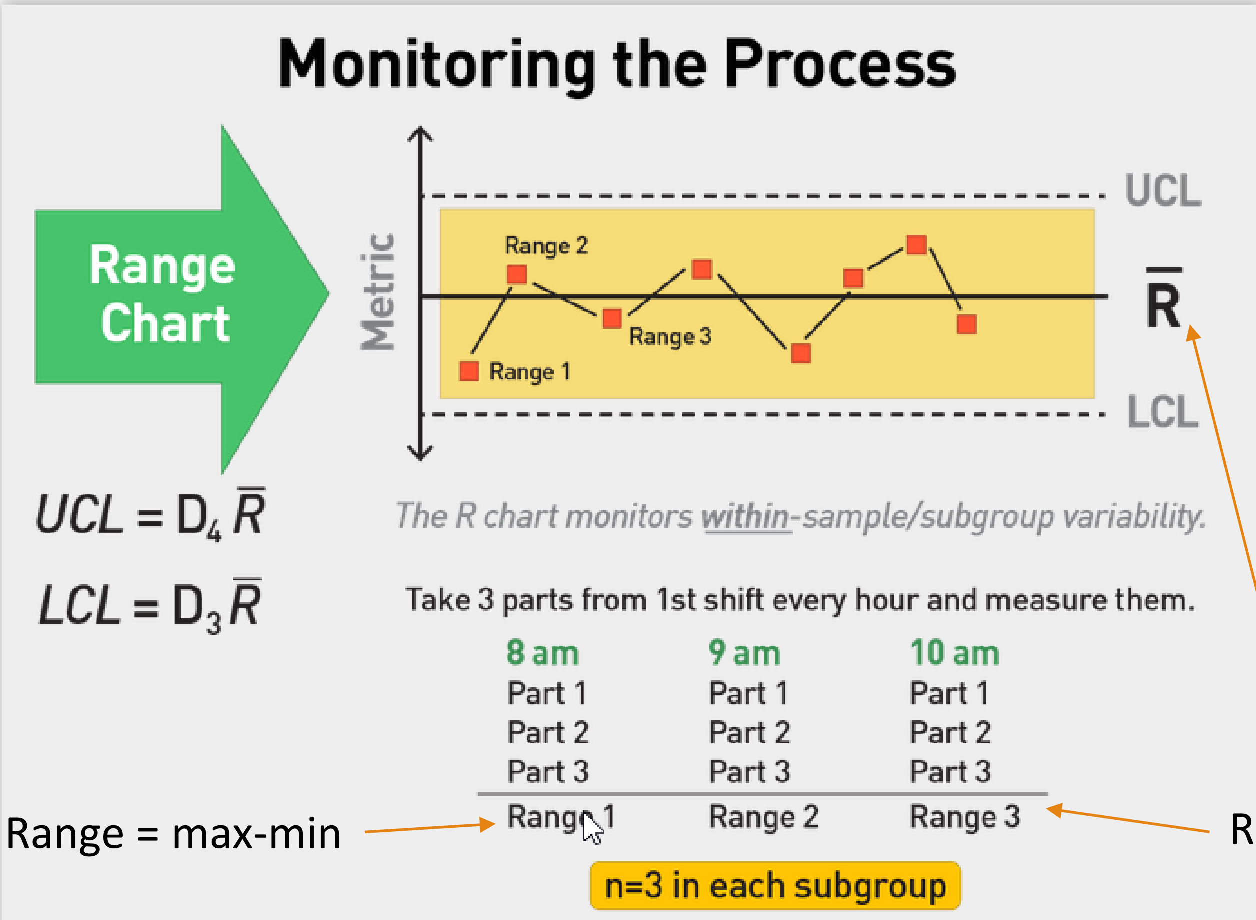
- CL = center line
- UCL = upper control limit
- LCL = lower control limit
- R = range of sample
- $\bar{R}$ = average of ranges
- $\bar{x}$ = average of readings
- $\bar{\bar{x}}$ = average of averages
- $\bar{s}$ = average of sample standard deviations
- n = sample size
- $\bar{n}$ = average sample size
- $\bar{p}$ = average proportion of defectives
- $\bar{c}$ = average count of defects
- $\bar{u}$ = average count of defects per unit area of observation
- $\bar{a}$ = average area of observation
- $\hat{\sigma}$ = estimated overall process standard deviation

CONSTANTS:

n	A_2	A_3	B_3	B_4	d_2	D_3	D_4	E_2
2	1.88	2.66	.00	3.27	1.13	.00	3.27	2.66
3	1.02	1.95	.00	2.57	1.69	.00	2.57	1.77
4	.73	1.63	.00	2.27	2.06	.00	2.28	1.46
5	.58	1.43	.00	2.09	2.33	.00	2.11	1.29
6	.48	1.29	.03	1.97	2.53	.00	2.00	1.18
7	.42	1.18	.12	1.88	2.70	.08	1.92	1.11
8	.37	1.10	.19	1.82	2.85	.14	1.86	1.05
9	.34	1.03	.24	1.76	2.97	.18	1.82	1.01
10	.31	.98	.28	1.72	3.08	.22	1.78	.98
11	.29	.93	.32	1.68	3.17	.26	1.74	
12	.27	.89	.35	1.65	3.26	.28	1.72	
13	.25	.85	.38	1.62	3.34	.31	1.69	
14	.24	.82	.41	1.59	3.41	.33	1.67	
15	.22	.79	.43	1.57	3.47	.35	1.65	
16	.21	.76	.45	1.55	3.53	.36	1.64	
17	.20	.74	.47	1.53	3.59	.38	1.62	
18	.19	.72	.48	1.52	3.64	.39	1.61	
19	.19	.70	.50	1.50	3.69	.40	1.60	
20	.18	.68	.51	1.49	3.74	.42	1.59	

SOURCE: A_2, A_3, B_3, B_4, d_2, D_3, D_4, E_2 reprinted with permission from *ASTM Manual on the Presentation of Data and Control Chart Analysis* (Philadelphia, PA:ASTM 1976), pp.134-36. Copyright ASTM.

8.3 Control Chart Calculations



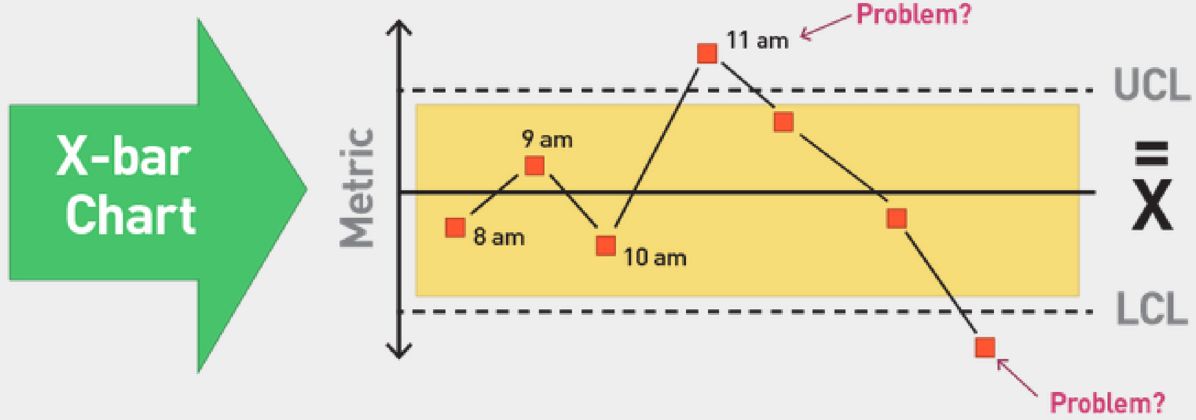
For an X bar R chart, do the R chart first – if it is not in control no point to do the X bar chart

Range = max-min

R bar = average of the ranges

8.4 Control Chart Calculations

Monitoring the Process (continued)



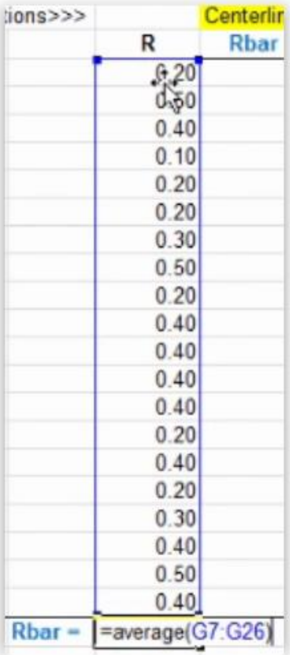
8 am	9 am	10 am
Part 1	Part 1	Part 1
Part 2	Part 2	Part 2
Part 3	Part 3	Part 3
Average 1	Average 2	Average 3

$$Limits = \bar{\bar{x}} \pm A_2\bar{R}$$

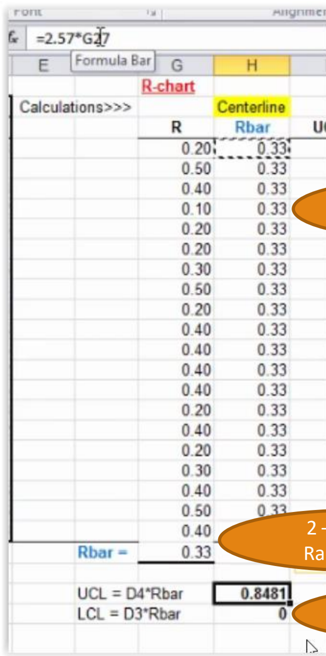
- Control charts important in preventing over- or under-reaction to problems

8.4 How to Build X-bar/R in Excel

R Chart



1 – Calc Range

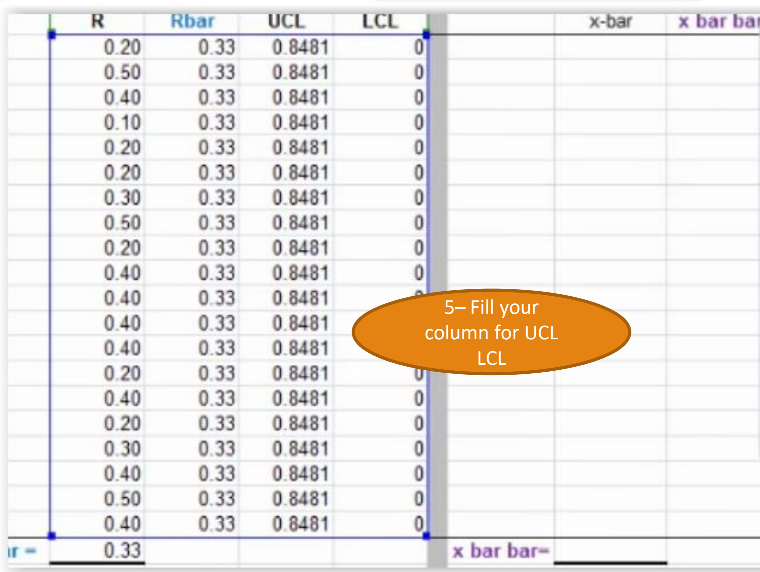


R	Rbar
0.20	0.33
0.50	0.33
0.40	0.33
0.10	0.33
0.20	0.33
0.20	0.33
0.30	0.33
0.50	0.33
0.20	0.33
0.40	0.33
0.40	0.33
0.40	0.33
0.40	0.33
0.20	0.33
0.40	0.33
0.20	0.33
0.30	0.33
0.40	0.33
0.50	0.33
0.40	

3– Fill your column

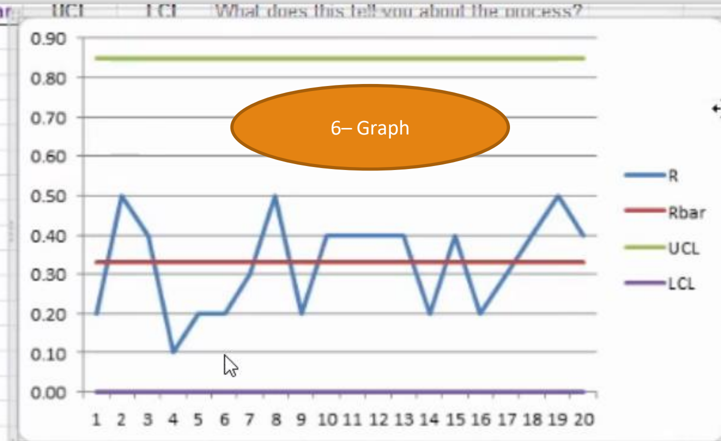
2 – Calc Avg Range, R Bar

4– Calc UCL and LCL based on subgroup =3



R	Rbar	UCL	LCL
0.20	0.33	0.8481	0
0.50	0.33	0.8481	0
0.40	0.33	0.8481	0
0.10	0.33	0.8481	0
0.20	0.33	0.8481	0
0.20	0.33	0.8481	0
0.30	0.33	0.8481	0
0.50	0.33	0.8481	0
0.20	0.33	0.8481	0
0.40	0.33	0.8481	0
0.40	0.33	0.8481	0
0.40	0.33	0.8481	0
0.40	0.33	0.8481	0
0.20	0.33	0.8481	0
0.40	0.33	0.8481	0
0.20	0.33	0.8481	0
0.30	0.33	0.8481	0
0.40	0.33	0.8481	0
0.50	0.33	0.8481	0
0.40	0.33	0.8481	0
0.33			

5– Fill your column for UCL LCL



6– Graph

8.5 How to Build X-bar/R in Excel

X Bar Chart

n=3

x bar chart

Sample #	Sample: 8 AM	Sample: Noon	Sample: 4PM	x-bar	Centerline: x bar bar	UCL	LCL
Day 1	10.4	10.5	10.3	10.40	10.34	10.675	10.00173
Day 2	10.3	10.6	10.1	10.33	10.34	10.675	10.00173
Day 3	10.2	10.6	10.3	[illegible]	10.34	10.675	10.00173
Day 4	10.2	10.1	10.2	[illegible]	10.34	10.675	10.00173
Day 5	10.4	10.6	10.6	10.53	10.34	10.675	10.00173
Day 6	10.2	10.3	10.1	10.20	10.34	10.675	10.00173
Day 7	10.5	10.3	10.6	10.47	10.34	10.675	10.00173
Day 8	10.6	10.1	10.4	10.37	[illegible]	[illegible]	[illegible]
Day 9	10.1	10.3	10.3	10.23	[illegible]	[illegible]	[illegible]
Day 10	10.5	10.2	10.6	10.43	10.34	10.675	10.00173
Day 11	10.2	10.6	10.5	10.43	10.34	10.675	10.00173
Day 12	10.1	10.5	10.2	10.27	10.34	10.675	10.00173
Day 13	10.2	10.6	10.5	10.43	10.34	10.675	10.00173
Day 14	10.1	10.2	10.3	10.20	10.34	10.675	10.00173
Day 15	10.6	10.3	10.2	10.37	10.34	10.675	10.00173
Day 16	10.2	10.3	10.1	10.20	10.34	10.675	10.00173
Day 17	10.2	10.4	10.1	10.23	10.34	10.675	10.00173
Day 18	10.2	10.4	10.6	10.40	10.34	10.675	10.00173
Day 19	10.6	10.1	10.6	10.43	10.34	10.675	10.00173
Day 20	10.1	10.5	10.3	10.30	10.34	10.675	10.00173

1 – Calc avg.

4 – Fill Data

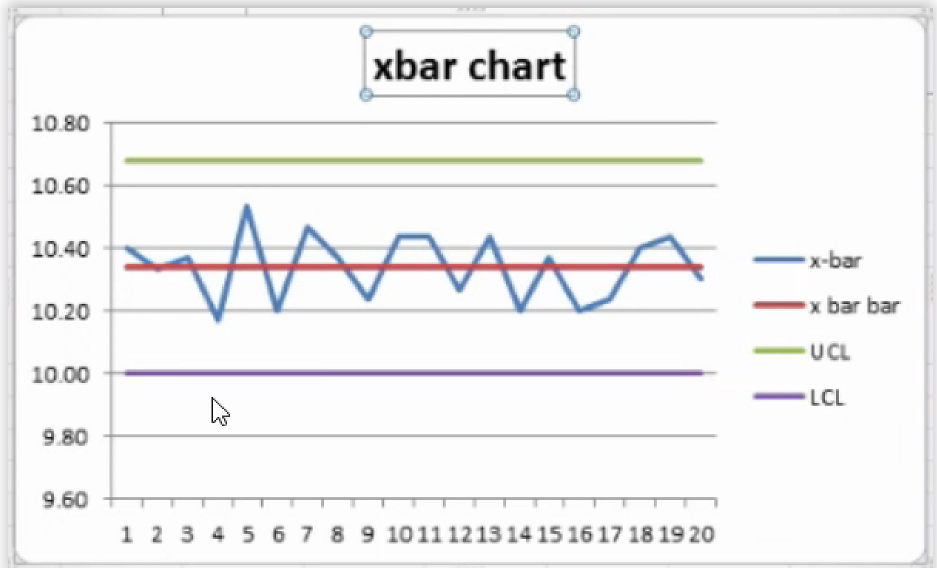
x bar bar= 10.34

2 – Calc avg of avgs

UCL = xbarbar+A2*Rbar 10.674933

LCL = xbarbar-A2*Rbar 10.001733

3 – Calc UCL and LCL based on n=3



The process is consistent and stable, although that may not mean you are meeting the requirements. May be giving away more corn than you want to…

8.5 How to Build ImR in Excel

ImR (or XmR) Control Chart
10 pound bag of cracked corn

	n=1	Calculations>>>	moving Range Chart	Centerline		
Sample #	**Data**		**mR**	**mRbar**	**UCL**	**LCL**
Day 1	10.4			0.2263	0.740053	0
Day 2	10.3		0.1	0.2263	0.740053	0
Day 3	10.2		0.1	0.2263	0.740053	0
Day 4	10.2		0	0.2263	0.740053	0
Day 5	10.4		0.2	0.2263	0.740053	0
Day 6	10.2		0.2	0.2263	0.740053	0
Day 7	10.5		0.3	0.2263	0.740053	0
Day 8	10.6		0.1	0.2263	0.740053	0
Day 9	10.1		0.5	0.226		0
Day 10	10.5		0.4	0.22		0
Day 11	10.2		0.3	0.226		0
Day 12	10.1		0.1	0.2263	0.740053	0
Day 13	10.2		0.1	0.2263	0.740053	0
Day 14	10.1		0.1	0.2263	0.740053	0
Day 15	10.6		0.5	0.2263	0.740053	0
Day 16	10.2		0.4	0.2263	0.740053	0
Day 17	10.2		0	0.2263	0.740053	0
Day 18	10.2		0	0.2263	0.740053	0
Day 19	10.6		0.4	0.2263	0.740053	0
Day 20	10.1		0.5	0.2263	0.740053	0
		mRbar =	0.226316			

3 – calc UCL and LCL

1 – calc mR, see below

4 – Fill your data

2 – avg mR

UCL = D4*mRbar	0.740053
LCL = D3*mRbar	0

Use n=2 from the constants table

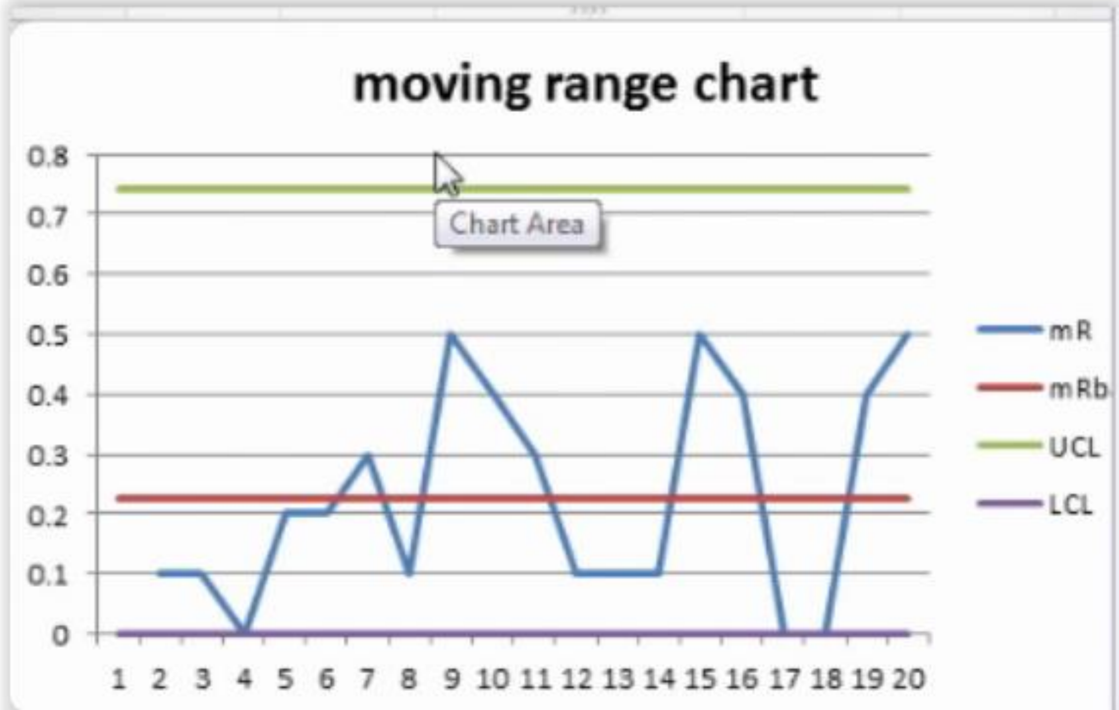
CORREL =abs(B8-B7)

A	B	C	D	E
ImR (or XmR) Control Chart				
10 pound bag of cracked corn				
				moving Rang
	n=1	Calculations>>>		Cer
Sample #	**Data**			**mR**
Day 1	4			
Day 2	10.3			=abs(B8-B7)
Day 3	10.2			

Absolute difference

Absolute value of difference between day 2 and day 1 value.

Moving Range Chart



8.6 How to Build ImR in Excel

Individuals X Chart

Individual Chart

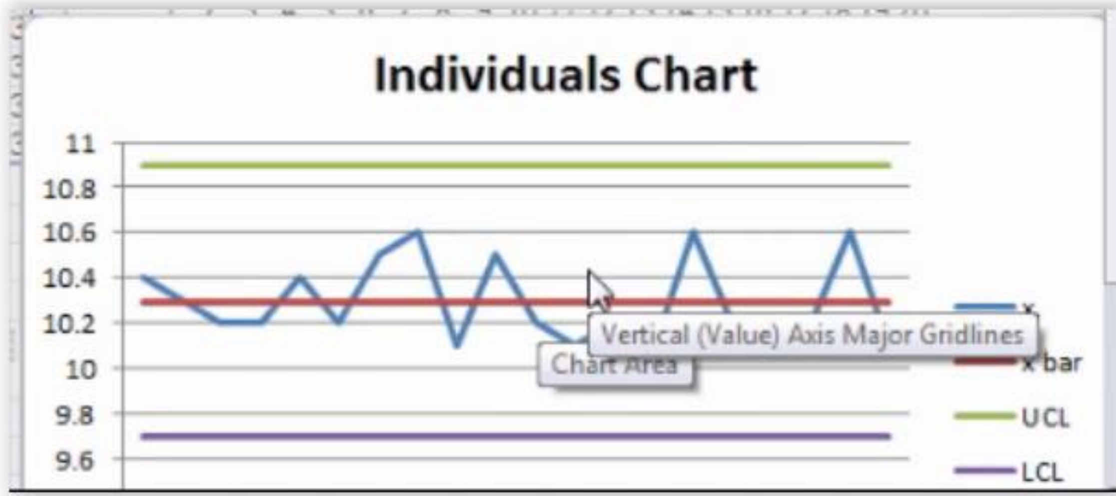
		Centerline x bar	UCL	LCL
	10.4	10.30	10.897	9.693
	10.3	10.30	10.897	9.693
	10.2	10.30	10.897	9.693
	10.2	10.30	10.897	9.693
	10.4	10.30	10.897	9.693
	10.2	10.30	10.897	9.693
	10.5	10.30	10.897	9.693
	10.6	10.30	10.897	9.693
	10.1	10.30	10.897	9.693
	10.5	10.30	10.897	9.693
	10.2	10.30	10.897	9.693
	10.1	10.30	10.897	9.693
	10.2	10.30	10.897	9.693
	10.1	10.30	10.897	9.693
	10.6	10.30	10.897	9.693
	10.2	10.30	10.897	9.693
	10.2	10.30	10.897	9.693
	10.2	10.30	10.897	9.693
	10.6	10.30	10.897	9.693
	10.1	10.30	10.897	9.693
x bar=	10.30			
UCL = xbar+E2*mRbar		10.897		
LCL = xbar -E2*mRbar		9.693		

Use n=2 from the constants table

1 – calc avg

2– calc UCL and LCL

3 – fill your data



8.6 Using Control Charts as a Proactive Tool

Evaluating Measurement Systems

- Use control charts to check for issues with measuring device
  - E.g., calipers, ruler, machine, person, gauge, scale

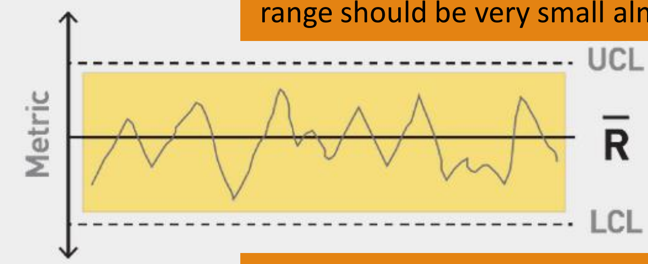
One part from first shift, every hour; measure that part three times

8 a.m.	9 a.m.	10 a.m.
Part 1	Part 2	Part 3
Part 1	Part 2	Part 3
Part 1	Part 2	Part 3
Range 1	Range 2	Range 3

Should be tiny

1- R chart

Measuring same part 3 times so range should be very small almost 0



Ranges should be inside, tight to R bar
Measures Repeatability

- $UCL = D_4\bar{R}$, $LCL = D_3\bar{R}$
- Ideally, a very small range

8 a.m.	9 a.m.	10 a.m.
Part 1	Part 2	Part 3
Part 1	Part 2	Part 3
Part 1	Part 2	Part 3
Avg 1	Avg 2	Avg 3

- Limits = $\bar{\bar{x}} \pm A_2\bar{R}$
- Tight range chart → small $\bar{R}$

Measuring the same part multiple times different than, what we did before.

2- X Bar chart

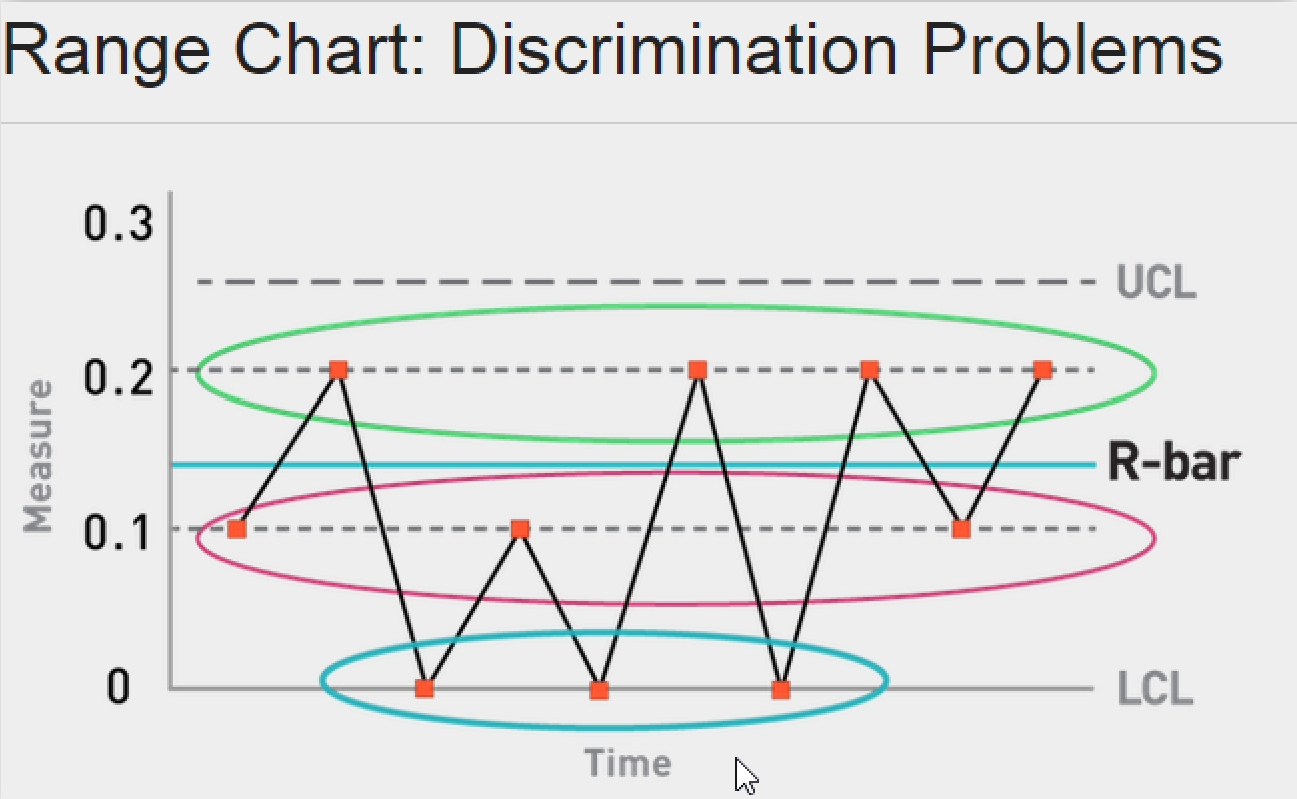
Measurement System Example: Average Chart

Should be outside the limits, we can tell the difference between parts because UCL/LCL are very close to X bar bar

Measurement system can tell the difference between parts, based on the very small range.

- Unconventional use of control charts
- Narrower range values; creates tighter x-bar chart limits
- 50% or more of points out of control: good
  - Measuring device distinguishes between good part and bad part

8.7 Using Control Charts as a Proactive Tool



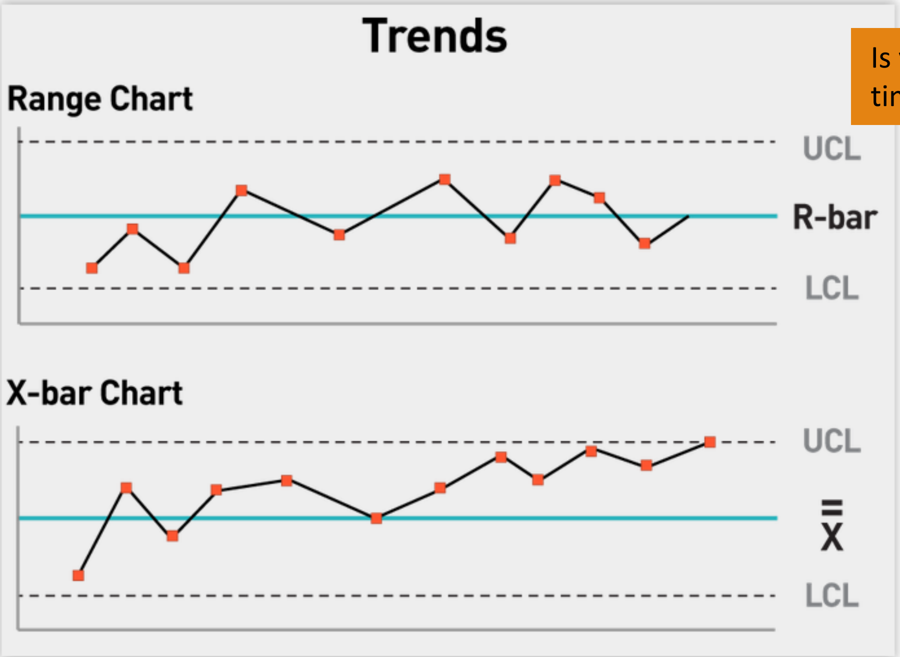
Your measurement system can't tell really tell the difference to enough detail, accuracy level may need more decimals.

You can't tell the difference between parts.

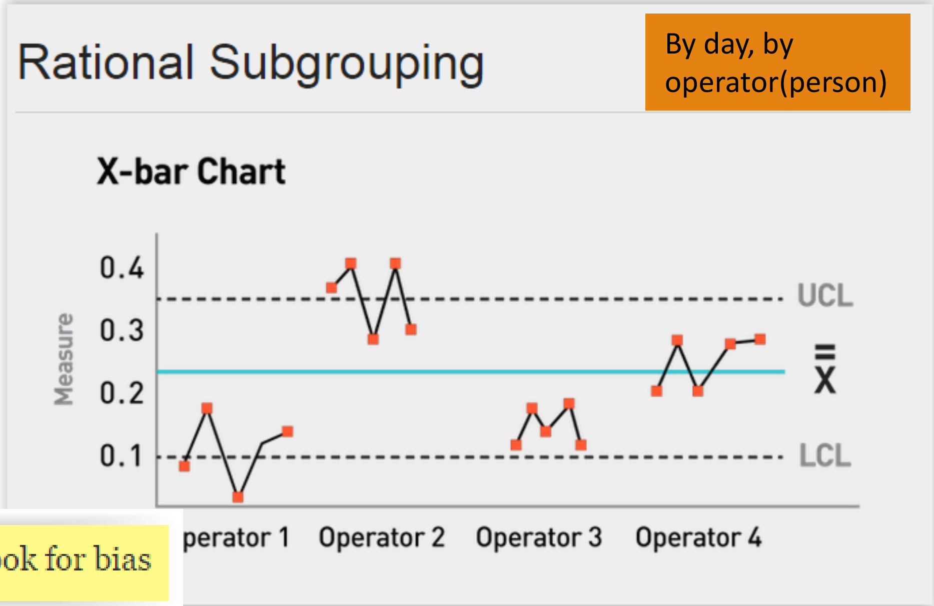
Subgroup Size

Subgroup Size (n)	Minimum Number of Levels
2	4
3–5	5
6	6

8.7 Using Control Charts as a Proactive Tool



Is your machine wearing out over time?



By day, by operator(person)

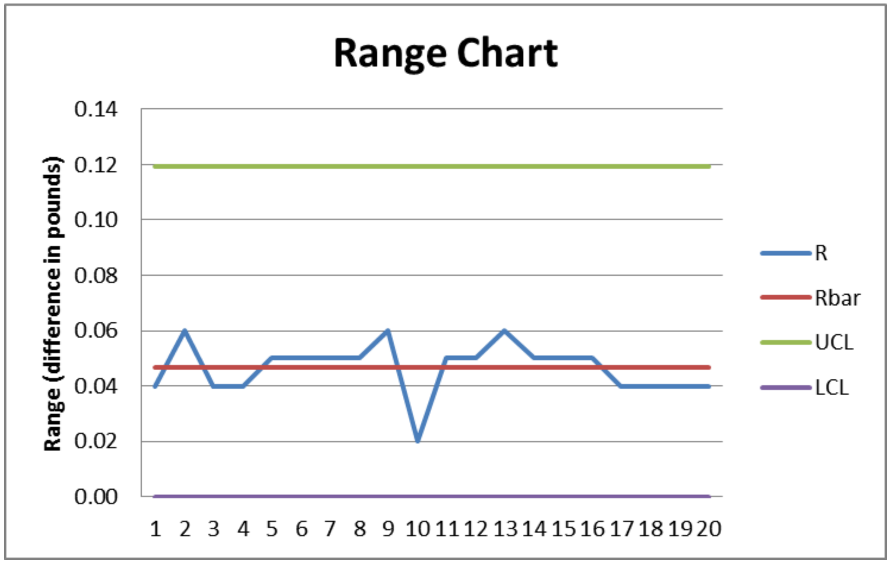
- Group by operator, shift, day of week, etc., to spot clusters, look for bias

8.7 Using Control Charts as a Proactive Tool

Things to Remember

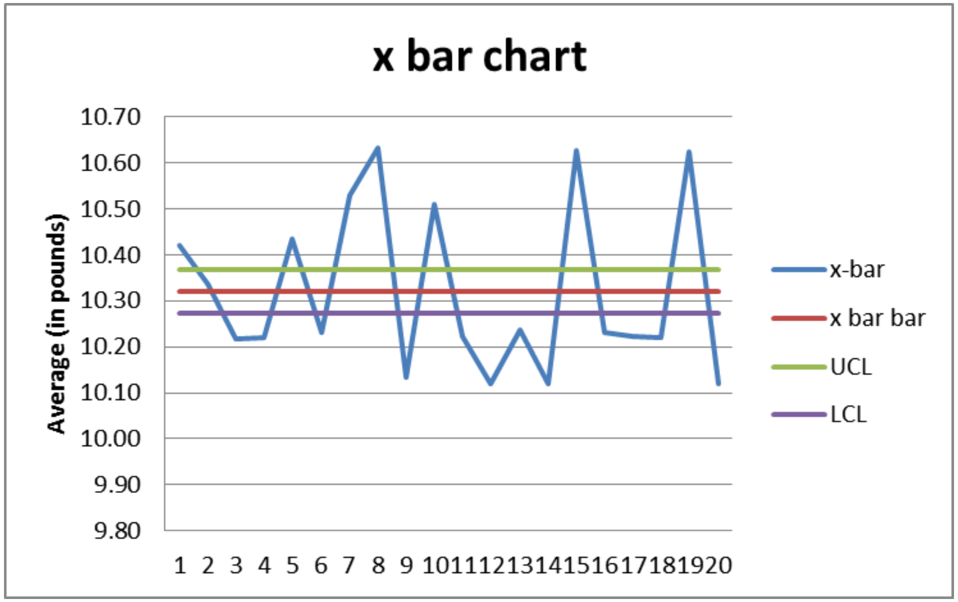
- All data occurs in time and has time-order.
- Continuous data: focus on range chart (moving range or s-chart) first; the x-bar chart relies on that result.
- Variable or discrete data control charts: use only one chart.
- Control charts enable separation of random variation (noise) from assignable variation (signal).
- "Control" does not mean "under *my* control" or in spec; it means that through past experience we can predict future outcomes.
- Focus on the process rather than the products.
    - If the process is consistent and in control, you know what to expect of the finished product.

8.8 Test Your Knowledge: Measurement System



Is your Range chart in control?	
Is your measurement system good?	

Yes, it is in control – tight to the R bar
Means your multiple measurements of
The same "part" yield close to the same
value



50%+ of the data points are out of control, this is good – it means your measurement system can tell the difference between the parts

Yes, the measurement system is good.

Agenda

Topic	Time	Sunday Section	Wednesday Section
Introduction	5 min	6:30-6:35	7:30-7:35
Highlights from Week 8 Video	55 min	6:35-7:30	7:35-8:30
Breakouts	15 min	7:30-7:45	8:30-8:45
Review of Upcoming Assignments and Open Question	15 min	7:45-8:00	8:45-9:00

Review of Upcoming Assignments: Wednesday Section

1. Homework #5, due Saturday, March 11th, Midnight EST in Learning Management System – Questions from the Understanding Variation Book Problems 1-10 pg 114-116- **You will upload 1 excel file**.

2. Optional Learning Opportunity:9.10 Relate Time Series to Your Project

3. Projects….Should be in Improve moving towards Control stage– any questions on the Rubrics?

4. Homework #6 3/18

5. Data Collection Paper due 3/25

6. Story Board due 3/27

7. Final Exam due 3/29

- Password: AnalysisExam3
- Time limit: 90 mins
- No partial credit despite directions

	March 2017						
	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
Week #8	5	6	7	8	9	10	11
				Live Class #8			***Homework #5 Due:*** 1. Problems 1-10 pg 114-116 in Understanding Variation
Week #9	12	13	14	15	16	17	18
				Live Class #9			***Homework #6 Due:*** 1. Time Series Problem posted in Excel
Week #10	19	20	21	22	23	24	25
				Live Class #10			***Data collection and Analysis Paper DUE***
	26	27	28	29	30	31	1
		Project Storyboard DUE		***Final Exam DUE***			

Homework #5

WHAT SHOULD YOU DO NOW?

Statistics has never been a spectator sport. Process behavior charts are no exception. You should see if you can compute the limits and construct an *XmR* chart.

1. The U.S. Trade Deficits for the last half of 1988 are shown in Figure 6.7. Use the data of Figure 6.7, and the blank form in Figure 6.8 to plot the time series graph for the U.S. Trade Deficits for the last half of 1988.

	Jul	Aug	Sep	Oct	Nov	Dec
1988	10.5	11.2	9.2	10.1	10.4	10.5

Figure 6.7: Monthly U.S. Trade Deficits, 1988 ($ billions)

2. Use the data in Figure 6.7 to compute the monthly moving ranges. Note that moving ranges are defined to be positive values, and are found by computing the differences between successive values. Write these values in the space provided in Figure 6.8, and plot the running record of the moving ranges.
3. Compute the average trade deficit for the last half of 1988.
4. Compute the Average Moving Range.
5. Compute the Natural Process Limits for the *X*-chart using the formulas on page 60 or on page 137.
6. Compute the Upper Range Limit using the formula on page 60 or on page 137.

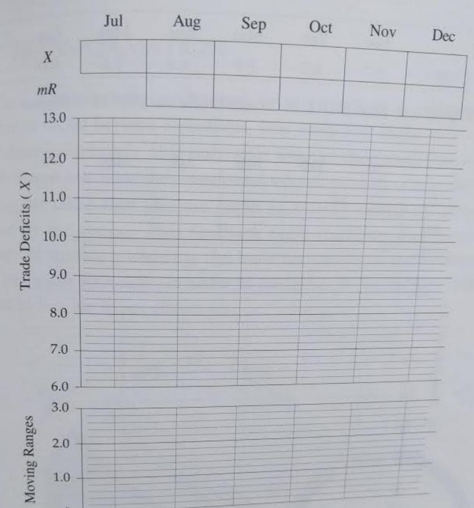


Figure 6.8: Form for *XmR* Chart

7. Plot the *limits* from Figure 6.8 on Figure 6.10.
8. The U.S. Trade Deficits for the first half of 1989 are shown on the next page in Figure 6.9. Plot these values and their moving ranges on the form given in Figure 6.10.

	Jan	Feb	Mar	Apr	May	Jun
1989	8.7	8.7	7.0	6.8	9.6	9.0

Figure 6.9: Monthly U.S. Trade Deficits, 1989 ($ billions)

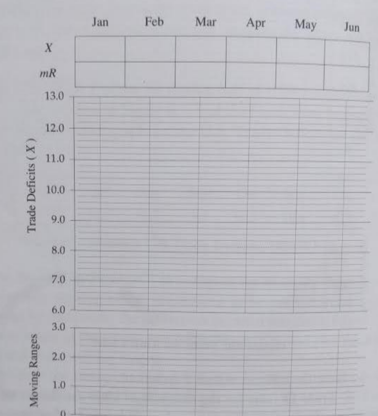


Figure 6.10: Form for *XmR* Chart

There are two indications of shifts in Figure 6.10. The first shift was favorable, and the second was unfavorable.

9. When is this favorable shift *detected*?
10. When might this favorable shift have begun?
11. When is the unfavorable shift detected?

Paper

Data Collection & Analysis Paper – Feedback –

Content Requirements	Possible Points	Points Earned	Comments
A) Is it a cohesive **1500 -1700** word paper opening with the business process and **problem statement?**	2.0		
B) Was the **success measure** clearly identified, operationally defined and baseline identified? (Was the data identified as continuous or discrete, includes SQL?)	3.0		
C) Was the **data measurement plan or data stratification tree** included?	1.0		
D) Was the **data collection method** identified?	1.0		
E) Was there rationale for the **sample size** taken? Use of the formula? Is there any reference to **measurement error** and how to minimize?	2.0		
F) Are **4-5 tools** and techniques clearly identified? Are the tools linked/ pertinent to the data analysis?	4.0		
G) Does the data analysis clearly tie to the problem **conclusion**? Is the "discovery" clear to the reader?	2.0		
Total possible 15 points			

Storyboard

Storyboard – Feedback –

Content Requirements	Possible Points	Points Earned	Comments
A) Is the storyboard presented in 1 or 2 PowerPoint slides?	1.0		
B) Follows DMAIC?	1.0		
C) Are tools/graphs/charts used and clearly visible? Do they support findings and conclusions?	1.0		
D) Are arrows, call-out boxes, etc. used to summarize, highlight questions and key learnings?	1.0		
E) Are expected results clear? And next steps noted?	1.0		
Other comments:			
Total possible 5 points	5		