MBC 638

LIVE SESSION WEEK 8

Agenda

Topic	Time	Thursday Section	Sunday Section
Introduction	5 min	9:00-9:05	6:30-6:35
Highlights from Week 8 Video	55 min	9:05-10:00	6:35-7:30
Breakouts	15 min	10:00-10:15	7:30-7:45
Review of Upcoming Assignments and Open Question	15 min	10:15-10:30	7:45-8:00

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

Control Chart Basics

Upper control limit*

UCL

± 3σ

Centerline = average

Metric

LCL

Time

Lower control limit*
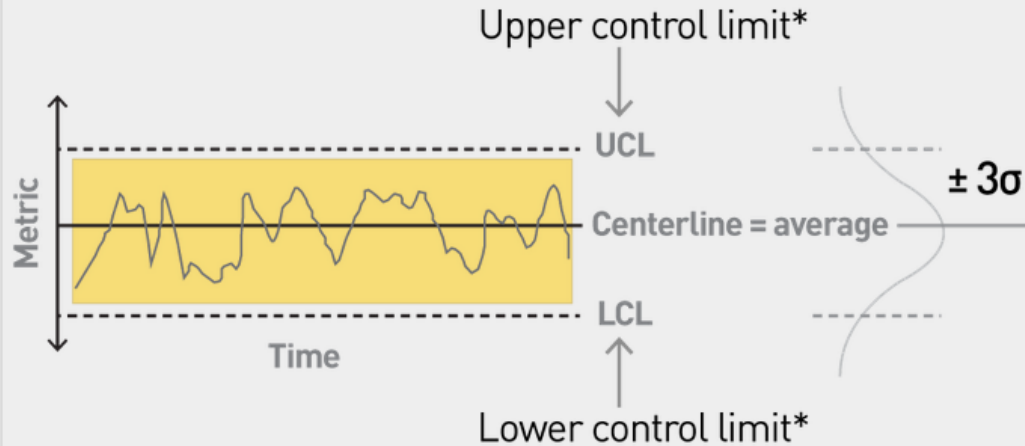
Video Slide Presentation

*Control limits are not specifications

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
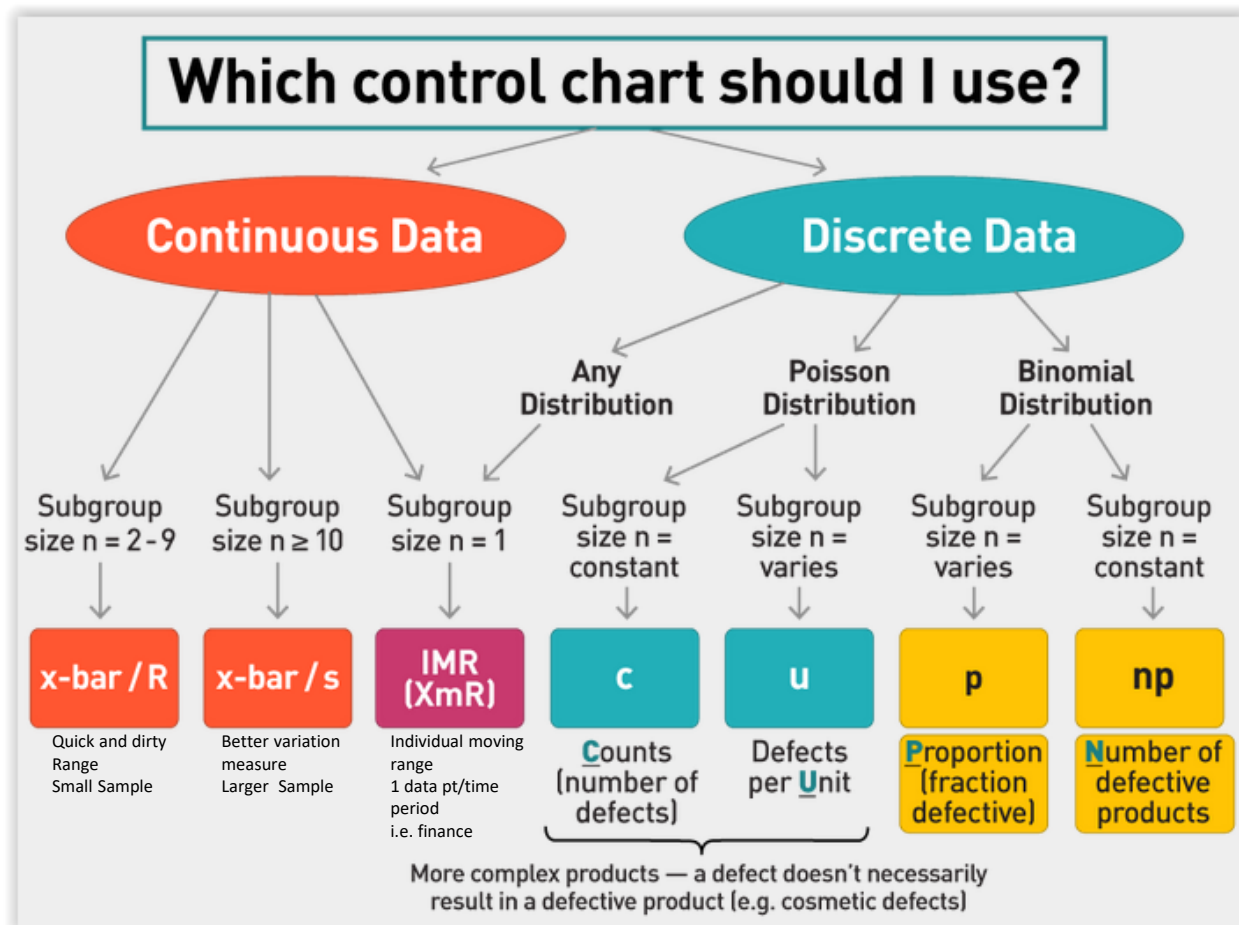
8.4 Control Chart Calculations: Reference

Control chart calculations

I - 2 Control Chart Summary — Appendix I

FORMULAS:

Chart	CL	UCL	LCL	Comments
$\bar{x}$ - R	$\bar{\bar{x}}$	$\bar{\bar{x}} + A_2\bar{R}$	$\bar{\bar{x}} - A_2\bar{R}$	$\hat{\sigma} = \dfrac{\bar{R}}{d_2}$
	$\bar{R}$	$D_4\bar{R}$	$D_3\bar{R}$	use when $n < 10$
individuals with moving range	$\bar{x}$	$\bar{x} + E_2\bar{R}$	$\bar{x} - E_2\bar{R}$	$\hat{\sigma} = \dfrac{\bar{R}}{d_2}$
	$\bar{R}$	$D_4\bar{R}$	$D_3\bar{R}$	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	$\bar{p}$	$\bar{p} + 3\sqrt{\dfrac{\bar{p}(1-\bar{p})}{\bar{n}}}$	$\bar{p} - 3\sqrt{\dfrac{\bar{p}(1-\bar{p})}{\bar{n}}}$	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	$\bar{u}$	$\bar{u} + 3\sqrt{\dfrac{\bar{u}}{\bar{a}}}$	$\bar{u} - 3\sqrt{\dfrac{\bar{u}}{\bar{a}}}$	use a_i instead of $\bar{a}$ if a_i's vary widely

Basic Statistics - Kiemele, Schmidt & Berdine

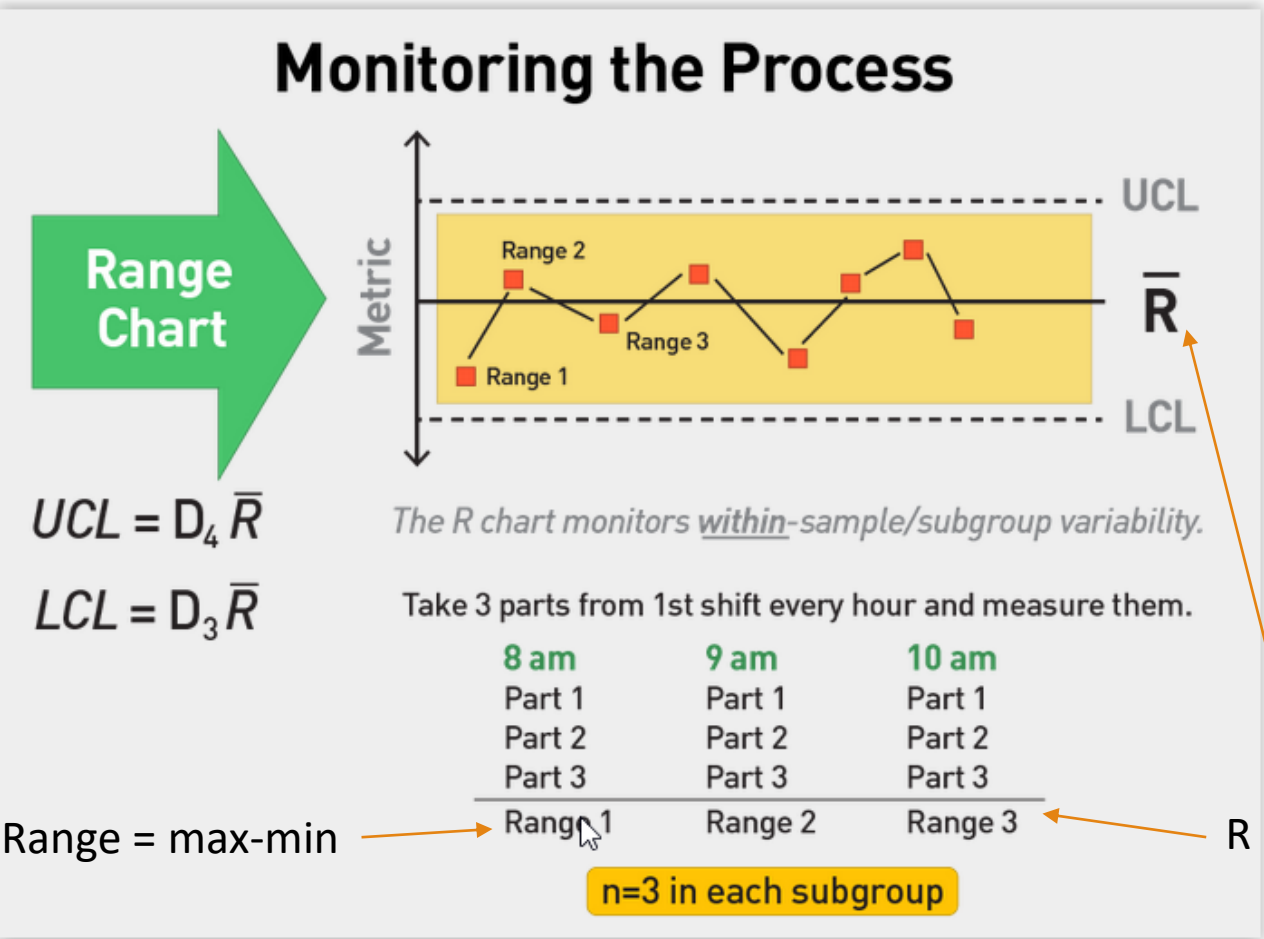### Appendix I — Control Chart Summary I - 1

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

Monitoring the Process

$UCL = D_4 \bar{R}$

$LCL = D_3 \bar{R}$

The R chart monitors *within*-sample/subgroup variability.

Take 3 parts from 1st shift every hour and measure them.

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

n=3 in each subgroup

Range = max-min

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

R bar = average of the ranges

8.4 Control Chart Calculations

Monitoring the Process (continued)
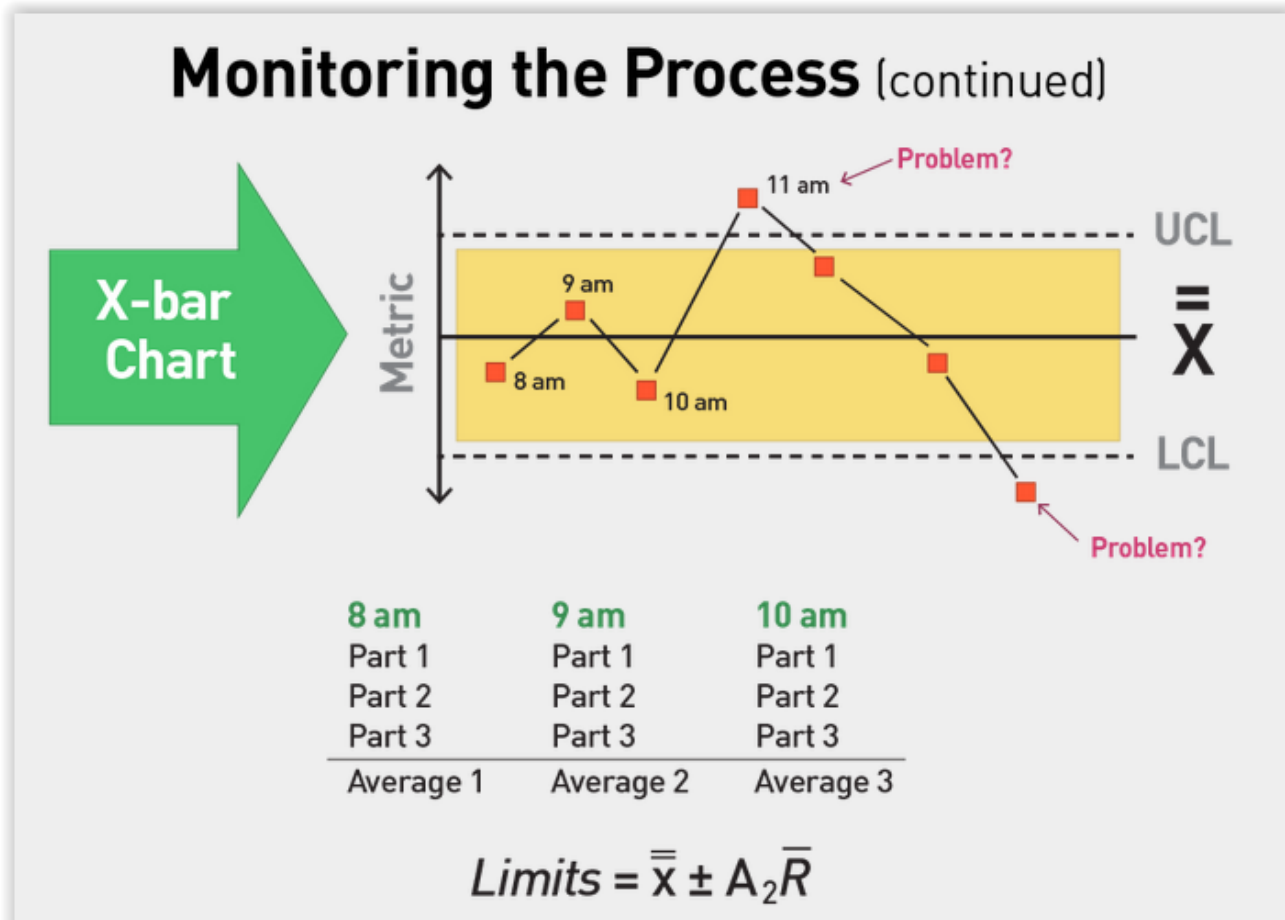
Control charts important in preventing over- or under-reaction to problems

R Chart

	n=3	Sample	
Sample #	8 AM	Noon	4PM
Day 1	10.4	10.5	10.3
Day 2	10.3	10.6	10.1
Day 3	10.2	10.6	10.3
Day 4	10.2	10.1	10.2
Day 5	10.4	10.6	10.6
Day 6	10.2	10.3	10.1
Day 7	10.5	10.3	10.6
Day 8	10.6	10.1	10.4
Day 9	10.1	10.3	10.3
Day 10	10.5	10.2	10.6
Day 11	10.2	10.6	10.5
Day 12	10.1	10.5	10.2
Day 13	10.2	10.6	10.5
Day 14	10.1	10.2	10.3
Day 15	10.6	10.3	10.2
Day 16	10.2	10.3	10.1
Day 17	10.2	10.4	10.1
Day 18	10.2	10.4	10.6
Day 19	10.6	10.1	10.6
Day 20	10.1	10.5	10.3

tions>>>

Centerline

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

Rbar = =average(G7:G26)

R-chart

Centerline

R	Rbar	UC
=max(B7:D7)-min(B7:D7)		

1 – Calc Range

=2.57*G17

Formula Bar | G | H |

R-chart

Calculations>>>

Centerline

R	Rbar	UC
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		
Rbar =	0.33	

UCL = D4*Rbar   0.8481
LCL = D3*Rbar   0

3– Fill your column

2 – Calc Avg Range, R Bar

4– Calc UCL and LCL based on subgroup =3

R	Rbar	UCL	LCL		x-bar	x bar bar	UCL	LCL	What does this tell you about the process?
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						
r =	0.33				x bar bar=				

5– Fill your column for UCL LCL

6– Graph

8.5 How to Build X-bar/R in Excel

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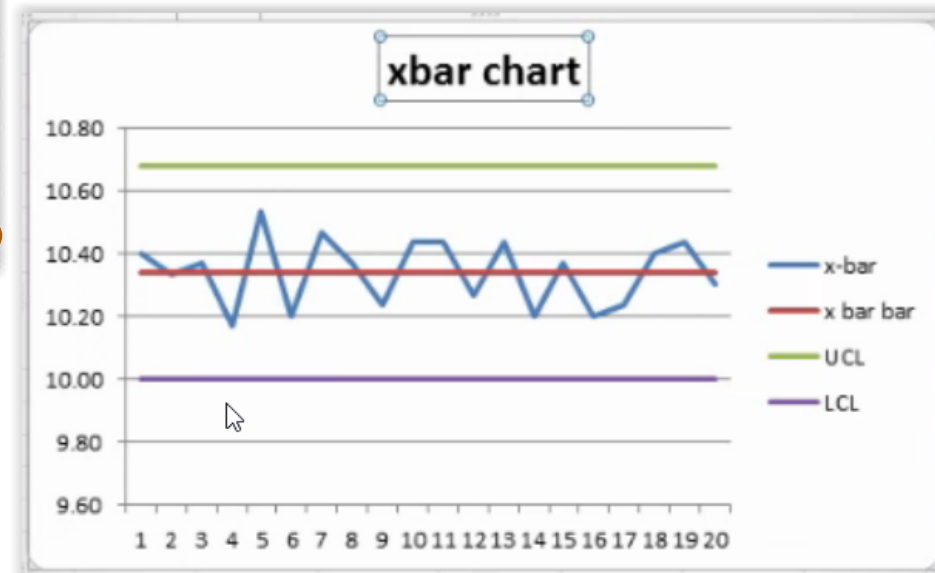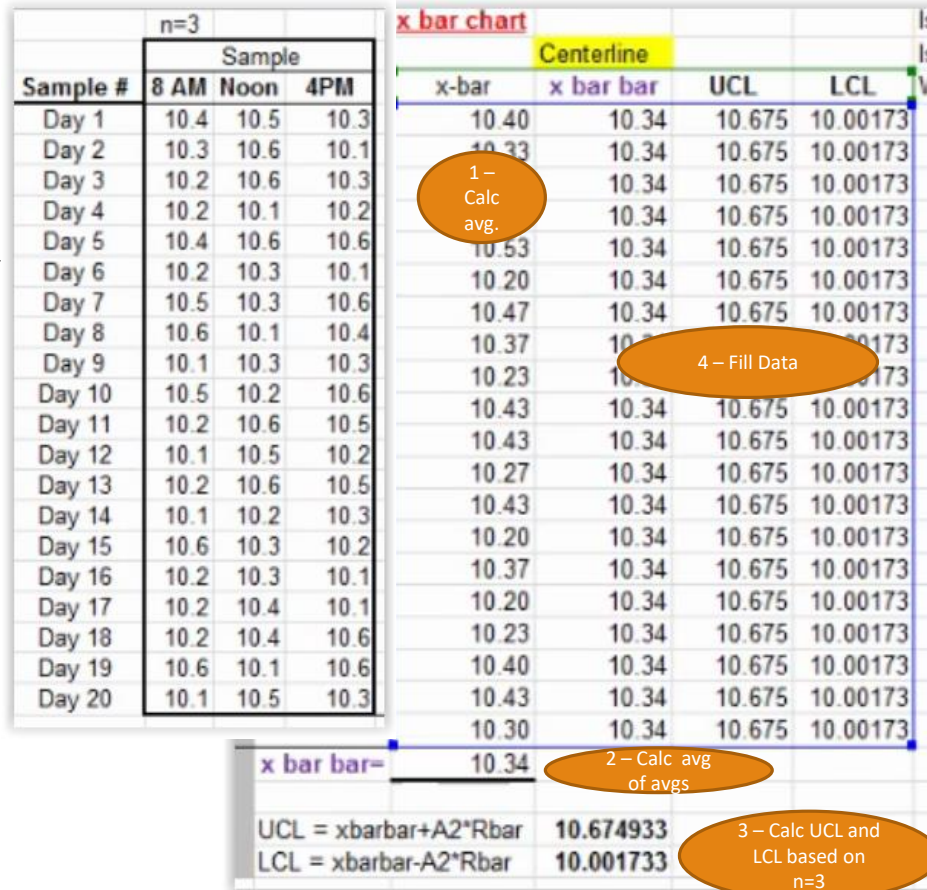
The process is consistent and stable, although that may not mean you are meeting the requirements. May be giving away more corn than you want to…

8.5 How to Build ImR in Excel

Moving Range Chart

ImR (or XmR) Control Chart
10 pound bag of cracked corn
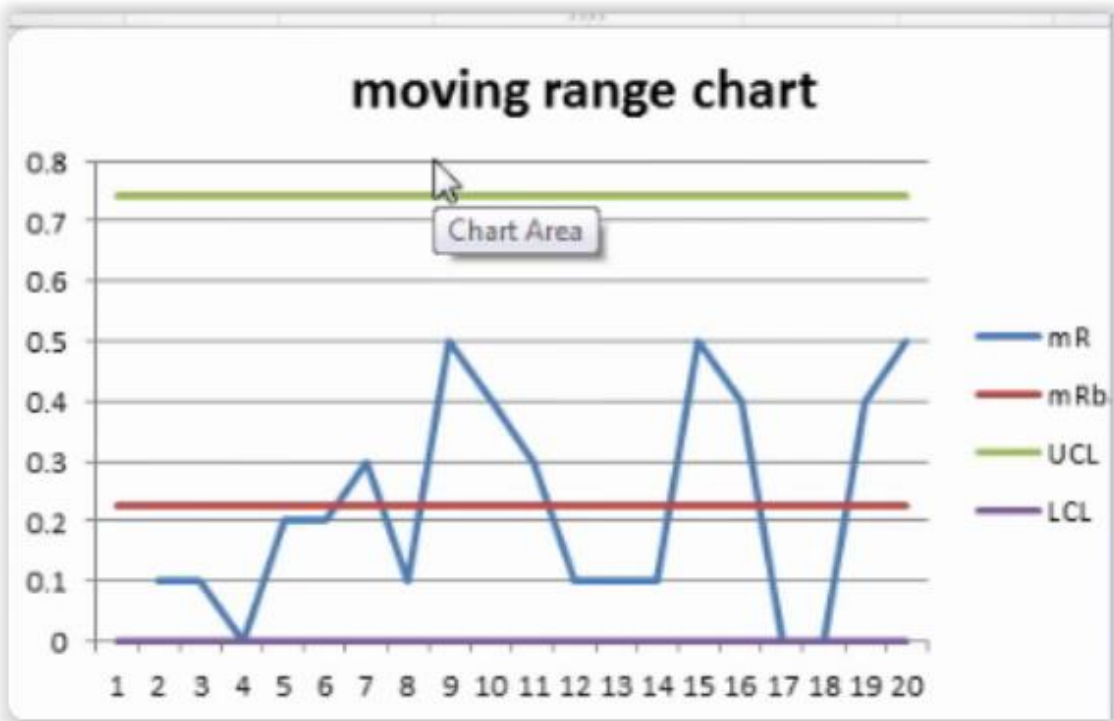
			moving Range Chart			
				Centerline		
Sample #	Data	Calculations>>>	mR	mRbar	UCL	LCL
Day 1	10.4			0.2263	0.740053	0
Day 2	10.3		0.1	0.2263	0.740053	0
Day 3	10.2		0.1	0.2263	0.740053	0
Day 4	10.2		0	0.2263	0.740053	0
Day 5	10.4		0.2	0.2263	0.740053	0
Day 6	10.2		0.2	0.2263	0.740053	0
Day 7	10.5		0.3	0.2263	0.740053	0
Day 8	10.6		0.1	0.2263	0.740053	0
Day 9	10.1		0.5	0.2263		0
Day 10	10.5		0.4	0.2263		0
Day 11	10.2		0.3	0.2263		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

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

CORREL — X ✓ fx =abs(B8-B7)

	A	B	C	D	E
		moving Rang			Cer
	n=1	Calculations>>>			
	Sample #	Data		mR	m
	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.

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

Use n=2 from the constants table

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

3 – fill your data

1 – calc avg

2– calc UCL and LCL
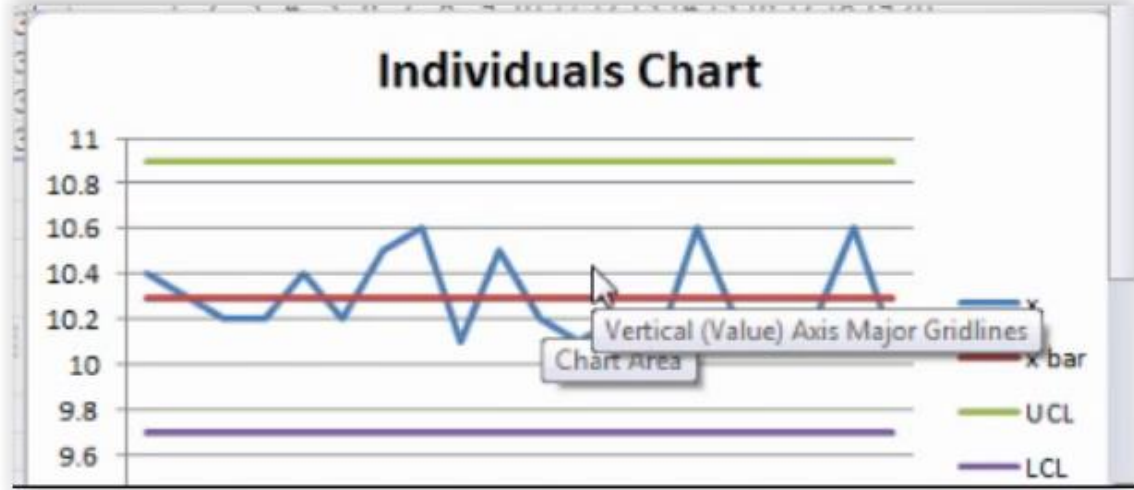
8.6 Using Control Charts as a Proactive Tool

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

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

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

2- X Bar chart

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

UCL
$\overline{R}$
LCL

Ranges should be inside, tight to R bar
Measures Repeatability

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

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

UCL
$\overline{\overline{X}}$
LCL

- 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

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

8.7 Using Control Charts as a Proactive Tool

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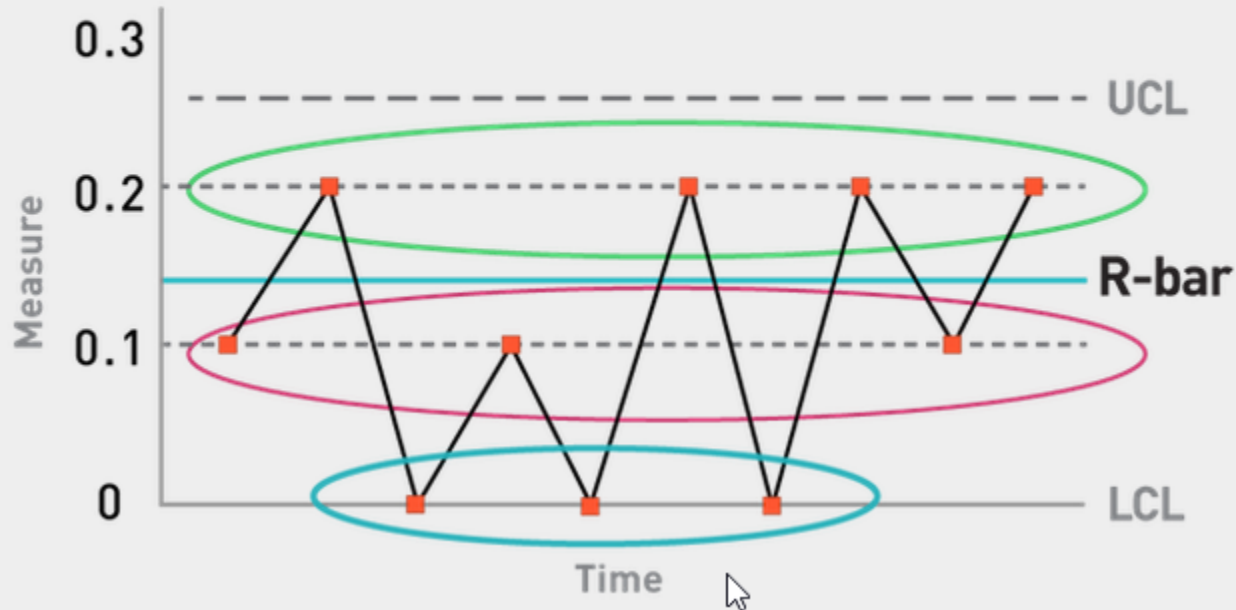
Your measurement system can't tell really tell the difference to enough detail, accuracy level may need more decimals.

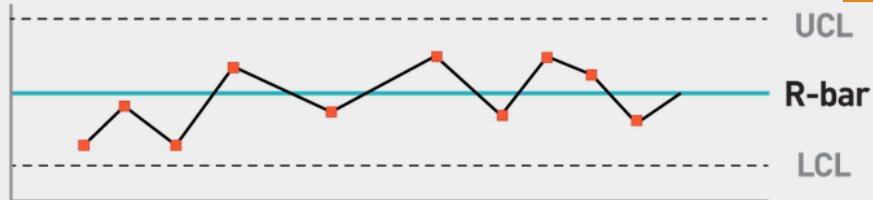You can't tell the difference between parts.

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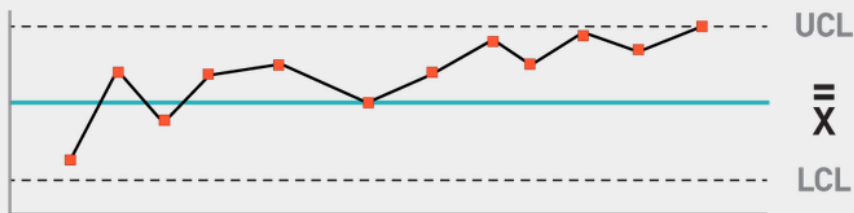
Subgroup Size (n)	Minimum Number of Levels
2	4
3–5	5
6	6

8.7 Using Control Charts as a Proactive Tool

Trends

Range Chart

UCL
R-bar
LCL

X-bar Chart

UCL
$\bar{\bar{X}}$
LCL

Is your machine wearing out over time?

Rational Subgrouping

By day, by operator(person)

X-bar Chart

Measure

0.4
0.3
0.2
0.1

UCL
$\bar{\bar{X}}$
LCL

Operator 1   Operator 2   Operator 3   Operator 4
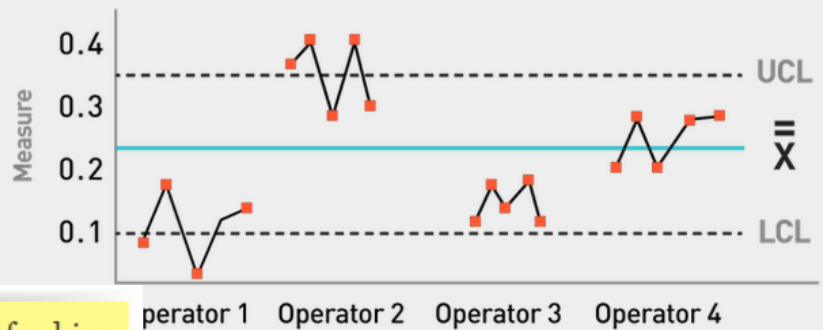
- Group by operator, shift, day of week, etc., to spot clusters, look for bias

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

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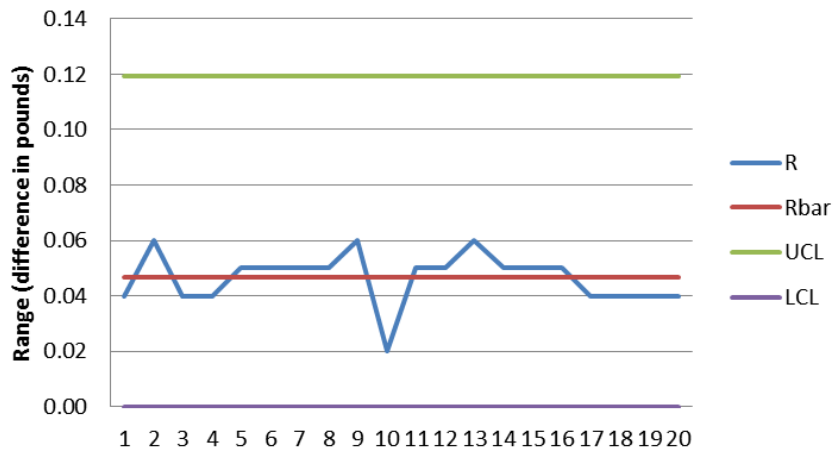
Yes, it is in control – tight to the R bar
Means your multiple measurements of
The same "part" yield close to the same
value

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

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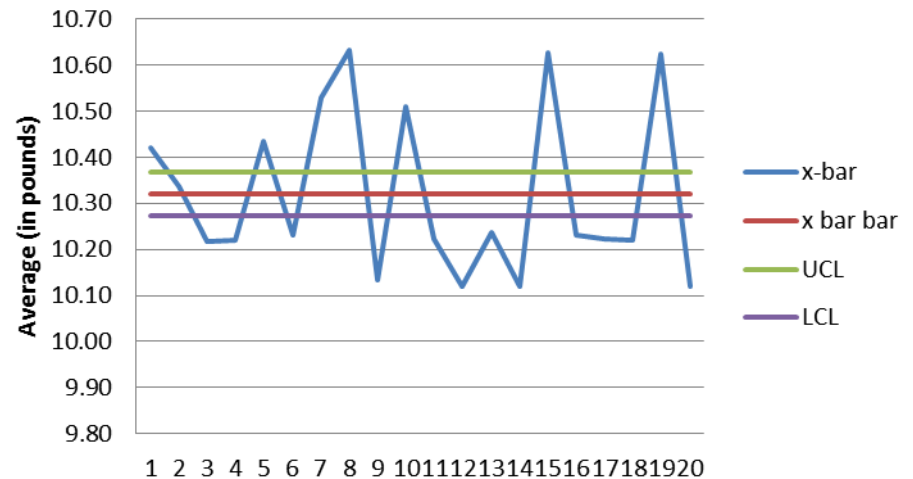
50%+ of the data points are out of control, this is good – it means your measurement system can tell the difference between the parts

Yes, the measurement system is good.

Agenda

Topic	Time	Thursday Section	Sunday Section
Introduction	5 min	9:00-9:05	6:30-6:35
Highlights from Week 8 Video	55 min	9:05-10:00	6:35-7:30
Breakouts	15 min	10:00-10:15	7:30-7:45
Review of Upcoming Assignments and Open Question	15 min	10:15-10:30	7:45-8:00

Review of Upcoming Assignments: Thursday Section

1. Homework #5, due Sunday, November 25th, Midnight EST in Learning Management System(2U) – Questions from the Understanding Variation Book Problems 1-10 pg. 114-116- **You will upload 1 file with your name in the name of the file and your answers clearly marked**. If you do not answer all parts of all questions you will lose points.

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

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

4. Homework #6 12/2

5. Process Improvement Project due 12/10

6. Final Exam 12/13

Week #8	18	19	20	21	22	23	24
	Homework #4 Due: 1. **CH 4** Learning Curve **Reminder:** Start reading Understanding Variation	_Live Class #8 RESCHEDULE 9PM EST_ ★			Live Class #8 **RESCHEDULE**		
Week #9	25	26	27	28	29	30	1
	Homework #5 Due: 1. Problems 1-10 pg 114-116 in Understanding Variation				Live Class #9		
December 2018							
	Sunday	**Monday**	**Tuesday**	**Wednesday**	**Thursday**	**Friday**	**Saturday**
Week #10	2	3	4	5	6	7	8
	Homework #6 Due: 1. Time Series Problem posted in Excel				Live Class #10		
Week #11	9	10	11	12	13	14	15
		Process Improvement Project DUE			Live Class #11: **FINAL EXAM**		

Review of Upcoming Assignments: Sunday Section

1. Homework #5, due Wednesday, November 28th , Midnight EST in Learning Management System(2U) – Questions from the Understanding Variation Book Problems 1-10 pg. 114-116- **You will upload 1 file with your name in the name of the file and your answers clearly marked**. If you do not answer all parts of all questions you will lose points.

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

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

4. Homework #6 12/5

5. Process Improvement Project due 12/13

6. Final Exam 12/16

December 2018	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
Week #8	25 Live Class #8 ⭐	26	27	28 *Homework #5 Due:* 1. Problems 1-10 pg 114-116 in Understanding Variation	29	30	1
Week #9	2 Live Class #9	3	4	5 *Homework #6 Due:* 1. Time Series Problem posted in Excel	6	7	8
Week #10	9 Live Class #10	10	11	12	13 *Process Improvement Project DUE*	14	15
Week #11	16 Live Class #11: FINAL EXAM	17	18	19	20	21	22

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.
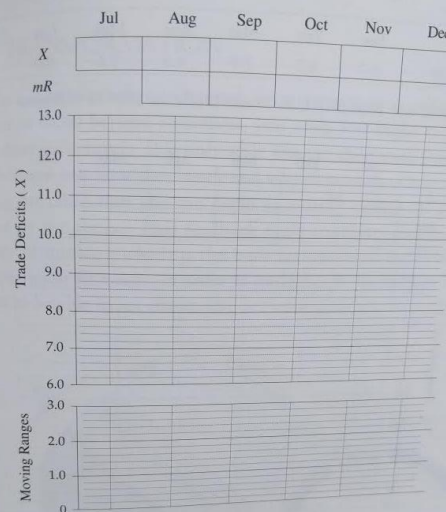
Six / Look What You've Been Missing

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.

Understanding Variation / Managing Chaos

	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)
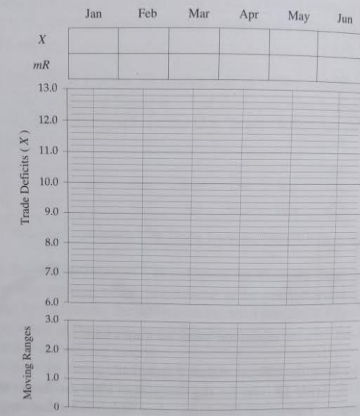

Figure 6.10: Form for XmR Chart

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?

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Project Rubric

Process Improvement Project – Feedback –			
Content Requirements	**Possible Points**	**Points Earned**	**Comments**
Project			
A) An executive summary is provided in the storyboard format including: Is the storyboard presented in 1 PowerPoint slide? Follows DMAIC? Are tools/graphs/charts used and clearly visible? Do they support findings and conclusions Are arrows, call-out boxes, etc. used to summarize, highlight questions and key learnings? Are expected results clear? And next steps noted?	5		
B)Is it a cohesive presentation opening with the business process and problem statement? The back-up slides (5-15) detail and support the storyboard content.	2		
C) Was the success measure clearly identified, operationally defined and baseline identified? (Was the data identified as continuous or discrete, includes SQL?)	3		
D) Was the data measurement plan or data stratification tree included?	1		
E) Was the data collection method identified?	1		
F) Was there rationale for the sample size taken? Use of the formula? Is there any reference to measurement error and how to minimize?	1		
G) Are at least 5 different tools and techniques clearly identified? Are the tools linked/ pertinent to the data analysis?	5		
H) Does the data analysis clearly tie to the problem conclusion? Is the "discovery" clear to the reader?	2		
Total possible 100 points	20	0.00	