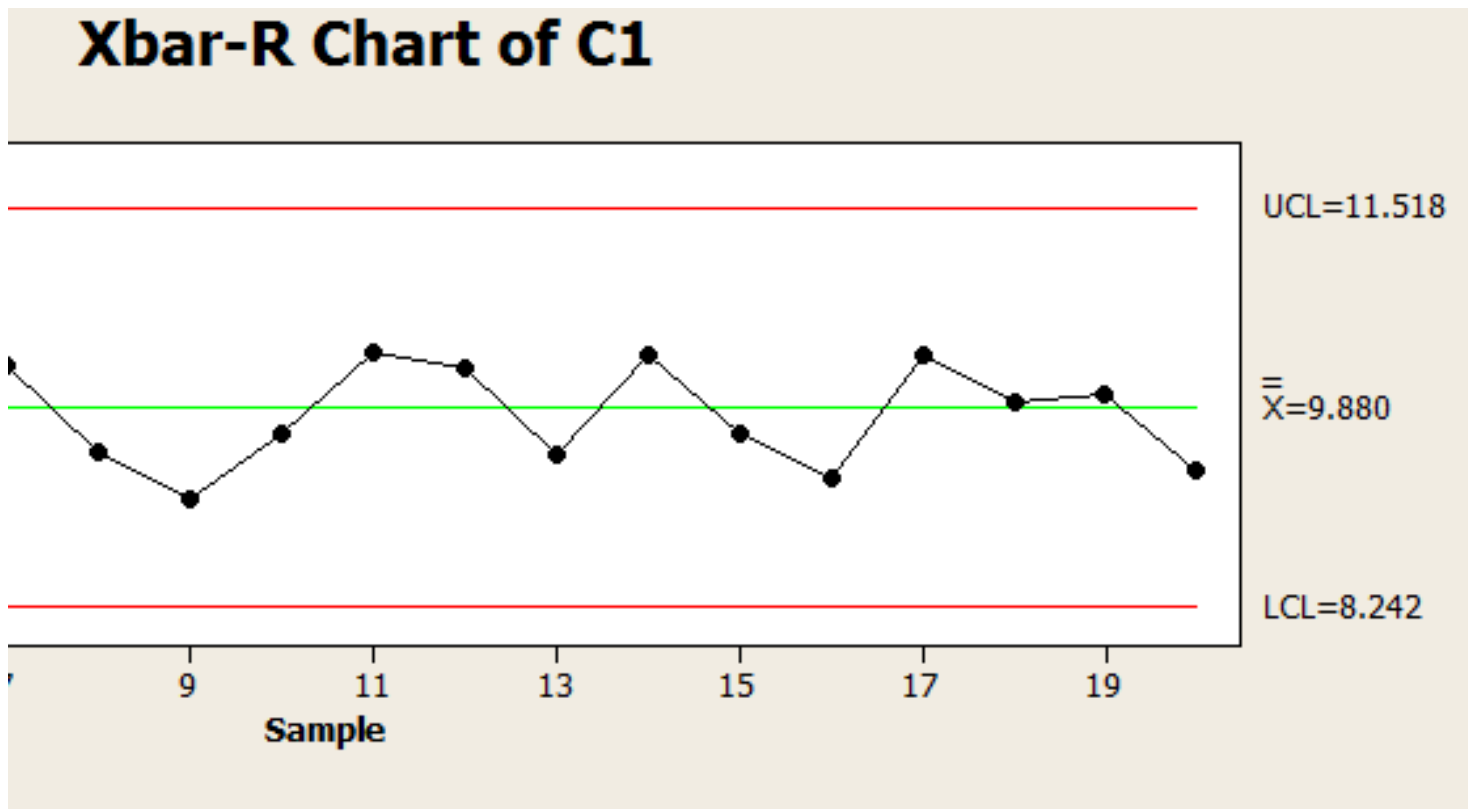


What tests apply to MR and Range charts?

- Much confusion
- Run tests, 2 out of 3, 4 out of 5, 8 in a row do not apply to MR and R charts
- Run tests do not apply to charts with non-symmetrical limits
- Most software corrects for this
- 95% of WECO experience with X-bar and R charts
- I always refer to WECO SQC Handbook at www.contesolutions.com CQE Resources

Xbar & R control chart created from random data from a process with mean of 10 and std dev of 1.0 using Minitab default



Xbar-R Chart - Options

Parameters | Estimate | S Limits | Tests | Stages | Box-Cox | Display | Storage

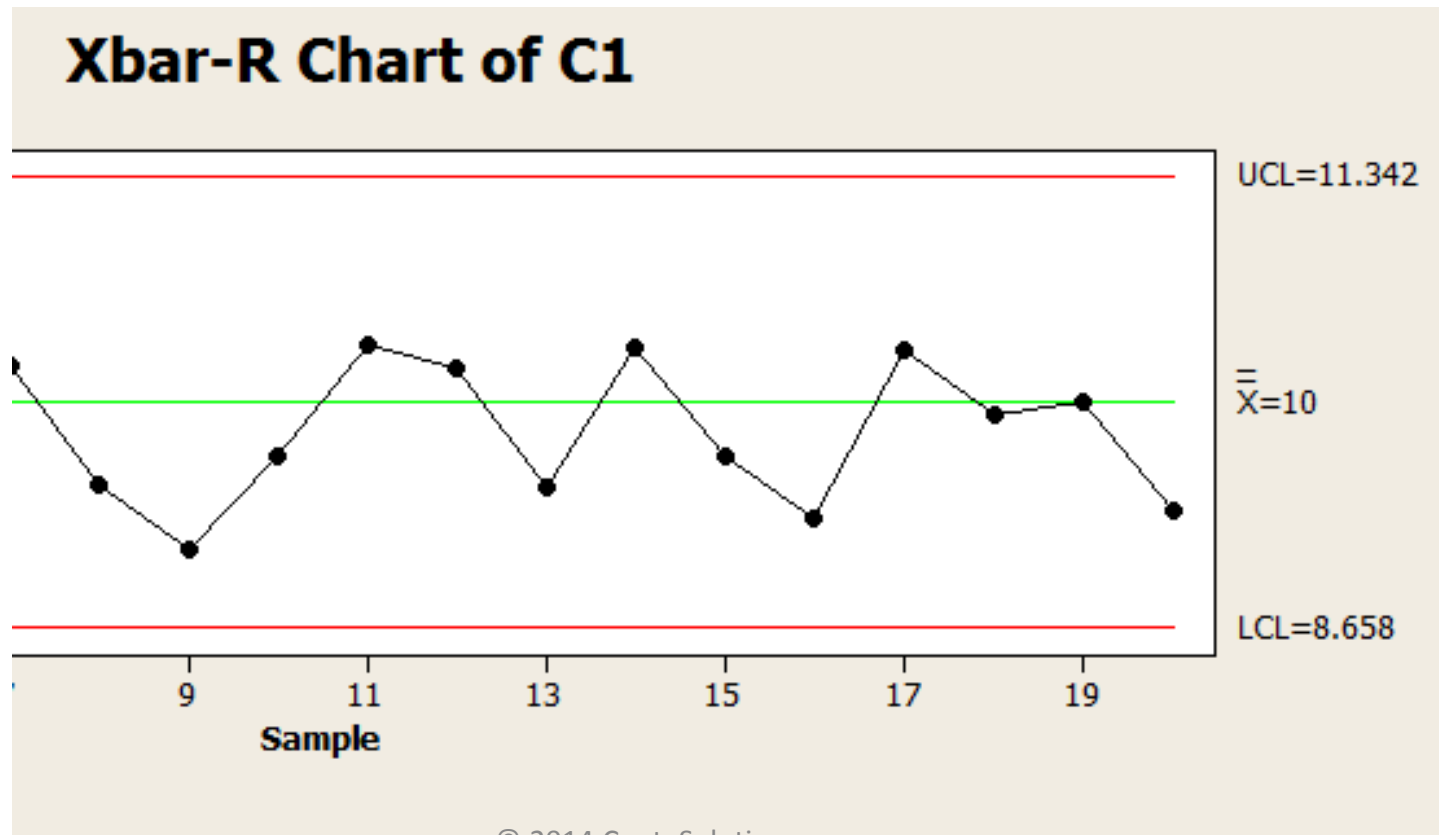
To specify the values for one or both parameters, enter them here. Minitab uses these values instead of estimating them from the data.

Mean: 10

Standard deviation: 1.0

Help OK Cancel

Xbar & R control chart created from random data from a process with mean of 10 and std dev of 1.0 using Minitab parameter setting



SPC Questions

- When you have included in Minitab the historical mean and standard deviation, was this from the previous data taken? **yes**
- At what point do you take the mean and standard deviation from the data you currently track? **When that is the only data you have from a stable process**
- Can you create the control chart in Minitab based on the mean and standard deviation from your current data? **Yes, it is the default**
- How would you answer the question when somebody would ask you, “the chart shows an out of control condition but we are still within the specification limits, so why worry about it when the part is still good?”
- **First, let us assume that we are talking about a X-bar and R chart. The “thing” that is plotted is a statistic not a data point. The x-bar is the average of a sample of data (a sample mean). It has a different standard deviation than the raw data. The R is the range of sample data and the control limits on the range are 3-sigma limits on the range statistic.**

SPC and Minitab

- The software is educational
- Look at SPC as data collection, calculation, plot, and decision loop
- Your project versus real life
 - Assumption about a defined, repeatable, and stable process
 - Control limits were computed on the current data

SPC

- Identify repeatable, stable process
- Write SPC Instructions
- Create charts
- Collect data, cal/plot point, decision, loop
- Decision 1 – take no action
- Decision 2 – take action including collect more data, stop process, call engineer

SPC Instructions

- Where in process
- Frequency of data collection
- Size of data collection
- Method of calculating points to be plotted
- How to plot
- How to make decision (WE four rules?)
- What actions to take including collect more data, stop process, call engineer

SPC Chart Types

- Variable data
 - Sample size 1, 2 to 10, 10 to 25
 - I \bar{X} mR, \bar{x} -bar and R, \bar{x} -bar and s
 - Classic is \bar{x} -bar and R (n=5)
 - Minitab Demo
 - X-bar and R
 - X-bar and s

Manual calculation of x-bar and R

- 45
- 48
- 49
- 46
- 50
- Total = 238
- $238 + 238 = 476$, divide by 10 = 47.6 for x-bar
- Range = $50 - 45 = 5$

X-bar and R chart with n=5

- If the process mean is 10 and the standard deviation of the process is 1.0 what would be the control limits on x-bar?
- ± 3 times the standard deviation of the x-bar
- $\sigma_{x\text{-bar}} = \frac{\sigma_x}{\sqrt{n}}$
- $\sigma_{x\text{-bar}} = \frac{1.0}{\sqrt{5}} = 0.4472$
- $3 \times 0.4472 = 1.34$
- $10 \pm 1.34 = 8.66$ and 11.34

Range (R) and standard deviation (s)

$$\sigma = \frac{R}{d_2}$$

Sigma known or unknown?

- If sigma was stated as 1.0 and I had enough data to say with 95% confidence that sigma was somewhere between 0.96 and 1.04 would sigma be known or unknown to be 1.0?
- Minimum sample size needed 849

Calc/Random data/normal

Normal Distribution ✖

Number of rows of data to generate:

Store in column(s):

Mean:

Standard deviation:

Select

Help

OK

Cancel

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	Work						
↓	C1	C2	C3	C4	C5	C6	C7
1	8.7802	9.3526	11.1758	8.5161	9.5531		
2	9.1974	10.7168	11.3696	10.6298	11.5620		
3	10.5286	10.1171	10.2176	9.7994	8.7488		
4	10.8505	9.2006	11.1228	9.4086	10.6691		
5	8.5873	10.2097	11.0911	10.1628	10.8652		
6	9.3539	10.2226	12.3455	11.9362	10.4250		
7	9.7928	8.8973	10.4967	9.2886	9.7668		
8	10.5510	9.7656	10.8501	11.3841	11.5592		
9	9.4537	9.3129	10.5672	7.9932	9.0785		
10	8.6940	11.0433	10.7263	9.7054	7.8737		
11	11.4225	9.3873	10.6271	8.0100	10.9763		
12	11.6484	10.2519	9.1927	8.0015	10.5542		
13	11.5296	10.8976	12.0213	9.9096	9.1412		
14	8.3625	12.0758	9.9713	11.3991	10.0709		
15	10.4837	8.7645	9.4971	12.0935	9.7276		
16	10.3364	9.8532	11.3716	12.0361	9.2243		
17	9.5366	10.4487	10.6180	11.3065	10.1164		
18	10.2917	10.7243	10.6965	10.8972	10.0149		

Calc/Row Statistics/Range

Row Statistics [Close]

C1
C2
C3
C4
C5

Statistic

Sum Median

Mean Sum of squares

Standard deviation N total

Minimum N nonmissing

Maximum N missing

Range

Input variables:

C1 C2 C3 C4 C5

Select **Store result in:** c7

Help **OK** **Cancel**

C7 Range

Worksheet 1								
↓	C1	C2	C3	C4	C5	C6	C7	C8
1	8.7802	9.3526	11.1758	8.5161	9.5531		2.65972	
2	9.1974	10.7168	11.3696	10.6298	11.5620		2.36459	
3	10.5286	10.1171	10.2176	9.7994	8.7488		1.77979	
4	10.8505	9.2006	11.1228	9.4086	10.6691		1.92229	
5	8.5873	10.2097	11.0911	10.1628	10.8652		2.50386	
6	9.3539	10.2226	12.3455	11.9362	10.4250		2.99164	
7	9.7928	8.8973	10.4967	9.2886	9.7668		1.59934	
8	10.5510	9.7656	10.8501	11.3841	11.5592		1.79361	
9	9.4537	9.3129	10.5672	7.9932	9.0785		2.57406	
10	8.6940	11.0433	10.7263	9.7054	7.8737		3.16956	
11	11.4225	9.3873	10.6271	8.0100	10.9763		3.41248	
12	11.6484	10.2519	9.1927	8.0015	10.5542		3.64695	
13	11.5296	10.8976	12.0213	9.9096	9.1412		2.88004	
14	8.3625	12.0758	9.9713	11.3991	10.0709		3.71335	
15	10.4837	8.7645	9.4971	12.0935	9.7276		3.32900	
16	10.3364	9.8532	11.3716	12.0361	9.2243		2.81184	
17	9.5366	10.4487	10.6180	11.3065	10.1164		1.76992	
18	10.2917	10.7243	10.6965	10.8972	10.0149		0.88229	

Mean value of range, n= 5

Descriptive Statistics: C7

Variable	N	N*	Mean
C7	1000000	0	2.3264

Variable	Q3	Maximum
C7	2.8770	7.4975

Control Chart Constants

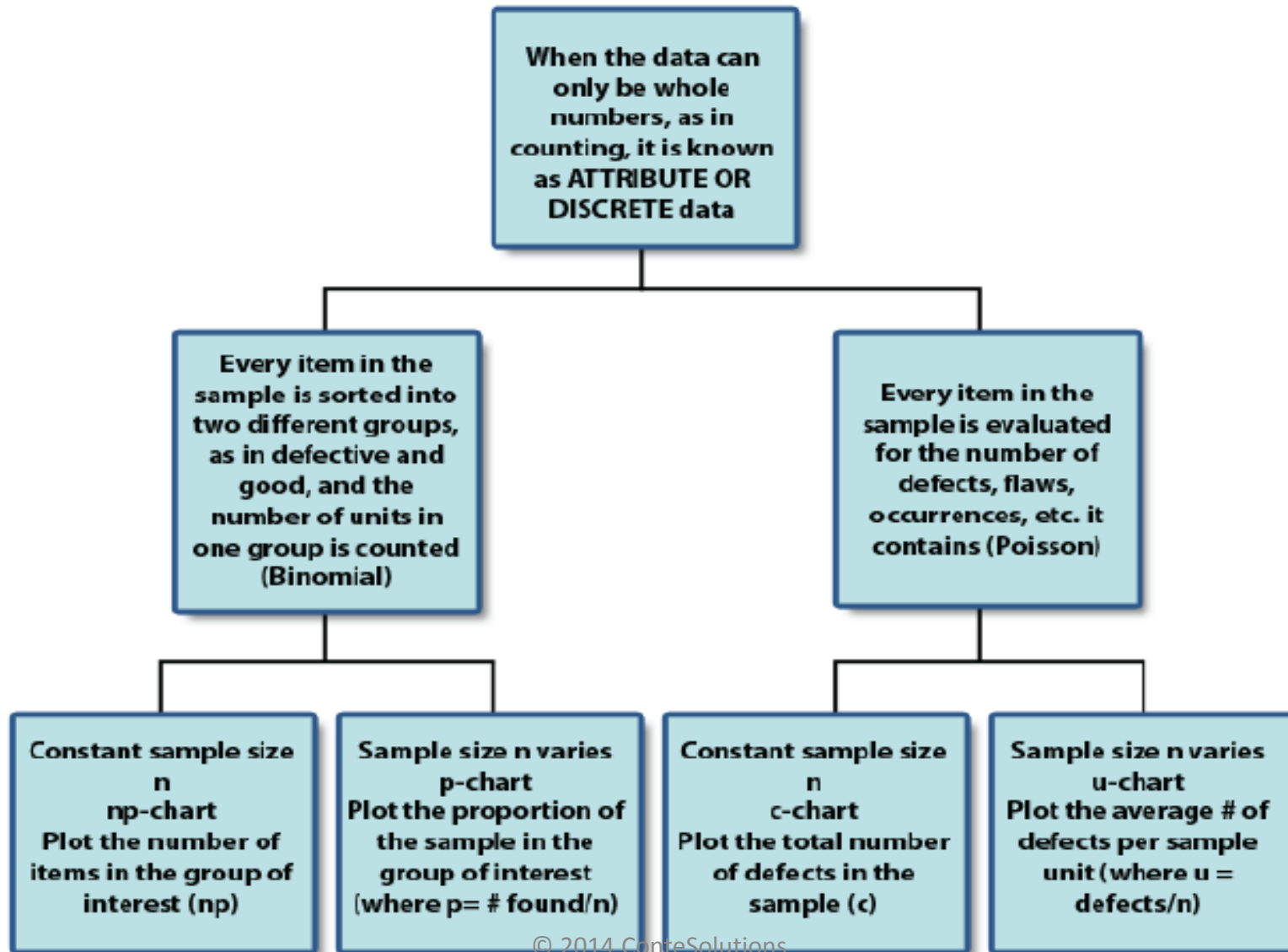
\bar{X} and R Control Charts

n	A ₂	D ₃	D ₄	d ₂
1	2.660	-	-	-
2	1.880	0	3.267	1.128
3	1.023	0	2.574	1.693
4	0.729	0	2.282	2.059
5	0.577	0	2.114	2.326
6	0.483	0	2.004	2.534
7	0.419	0.076	1.924	2.704
8	0.373	0.136	1.864	2.847
9	0.337	0.184	1.816	2.970
10	0.308	0.223	1.777	3.078
11	0.285	0.256	1.744	3.173
12	0.266	0.283	1.717	3.258

\bar{X} and S Control Charts

n	A ₃	B ₃	B ₄	C ₄
10	0.975	0.284	1.716	0.9727
11	0.927	0.321	1.679	0.9754
12	0.886	0.354	1.646	0.9776
13	0.850	0.382	1.618	0.9794
14	0.817	0.406	1.594	0.9810
15	0.789	0.428	1.572	0.9823
16	0.763	0.448	1.552	0.9835
17	0.739	0.466	1.534	0.9845
18	0.718	0.482	1.518	0.9854
19	0.698	0.497	1.503	0.9862
20	0.680	0.510	1.490	0.9869
21	0.663	0.523	1.477	0.9876
22	0.647	0.534	1.466	0.9882
23	0.633	0.545	1.455	0.9887
24	0.619	0.555	1.445	0.9892
25	0.606	0.565	1.435	0.9896

SPC Attribute Chart Types, Page 357 VU SSBB Online Textbook

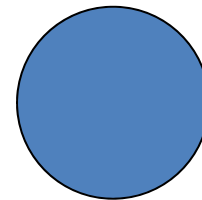
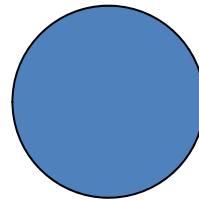
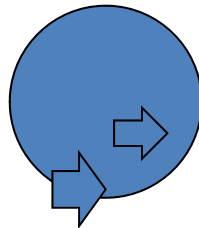
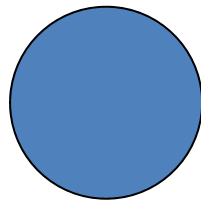
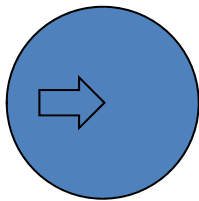


SPC Attribute Chart Types

- Discrete data
 - Concept of defects and defectives
 - Defects are Countable and a unit may have more than one
 - Defective units are units with one or more defects
 - Concept of fixed sample size and a sample size that may vary from time to time
 - p, np, c, and u charts

Defects and defectives

- Defect



- Defective is a unit of product with one or more defects
- $p = 2/5 = 0.40$
- $c = 3$
- $u = 3/5 = 0.60$
- $np = 5 \times 2/5 = 2.0$

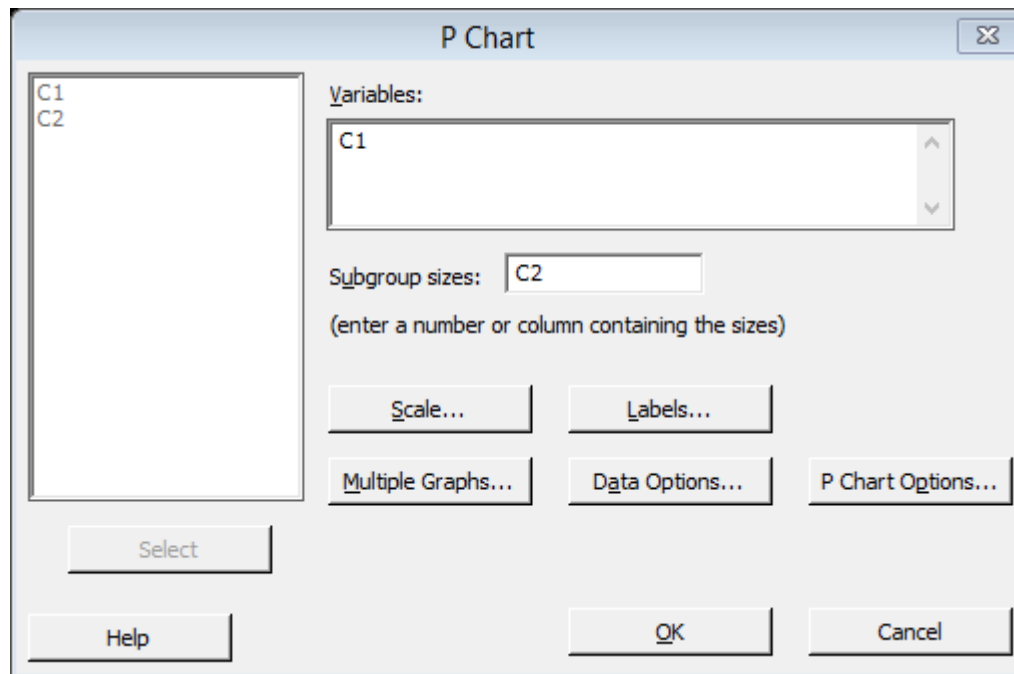
Attribute Control Charts

Chart Type	Centerline	Control Limits	Estimate of Sigma
p	$\bar{p} = \frac{\sum p}{k}$	$UCL_p = \bar{p} + 3\sqrt{\frac{\bar{p}(1-\bar{p})}{n}}$ $LCL_p = \bar{p} - 3\sqrt{\frac{\bar{p}(1-\bar{p})}{n}}$	$\sqrt{\frac{\bar{p}(1-\bar{p})}{n}}$
np	$n\bar{p} = \frac{\sum np}{k}$	$UCL_{np} = n\bar{p} + 3\sqrt{n\bar{p}(1-n\bar{p})}$ $LCL_{np} = n\bar{p} - 3\sqrt{n\bar{p}(1-n\bar{p})}$	$\sqrt{n\bar{p}(1-n\bar{p})}$
c	$\bar{c} = \frac{\sum c}{k}$	$UCL_c = \bar{c} + 3\sqrt{\bar{c}}$ $LCL_c = \bar{c} - 3\sqrt{\bar{c}}$	$\sqrt{\bar{c}}$
u	$\bar{u} = \frac{\sum u}{k}$	$UCL_u = \bar{u} + 3\sqrt{\frac{\bar{u}}{n}}$ $LCL_u = \bar{u} - 3\sqrt{\frac{\bar{u}}{n}}$	$\sqrt{\frac{\bar{u}}{n}}$

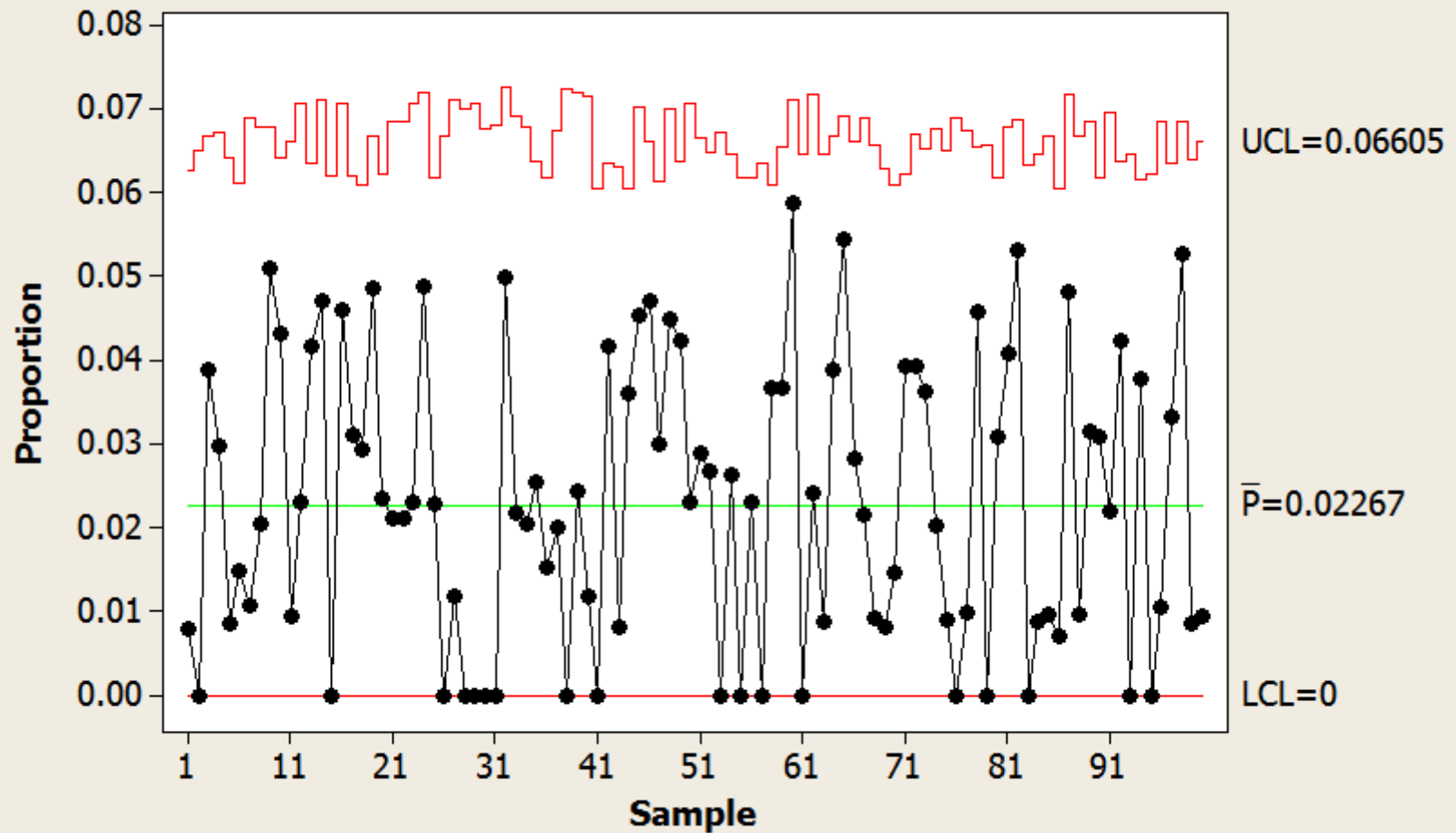
SPC Charts for Attributes

- Minitab Demo
- p chart with varying sample size

↓	C1	C2	C3	C4
1	1	125		
2	0	111		
3	4	103		
4	3	101		
5	1	116		
6	2	135		
7	1	93		
8	2	98		
9	5	98		
10	5	116		



P Chart of C1



Tests performed with unequal sample sizes

P Chart - Options



Parameters

Estimate

S Limits

Tests

Stages

Display

Storage

Display control limits at

These multiples of the standard deviation:

Place bounds on control limits

Lower standard deviation limit bound:

Upper standard deviation limit bound:

When subgroup sizes are unequal, calculate control limits

Using actual sizes of the subgroups

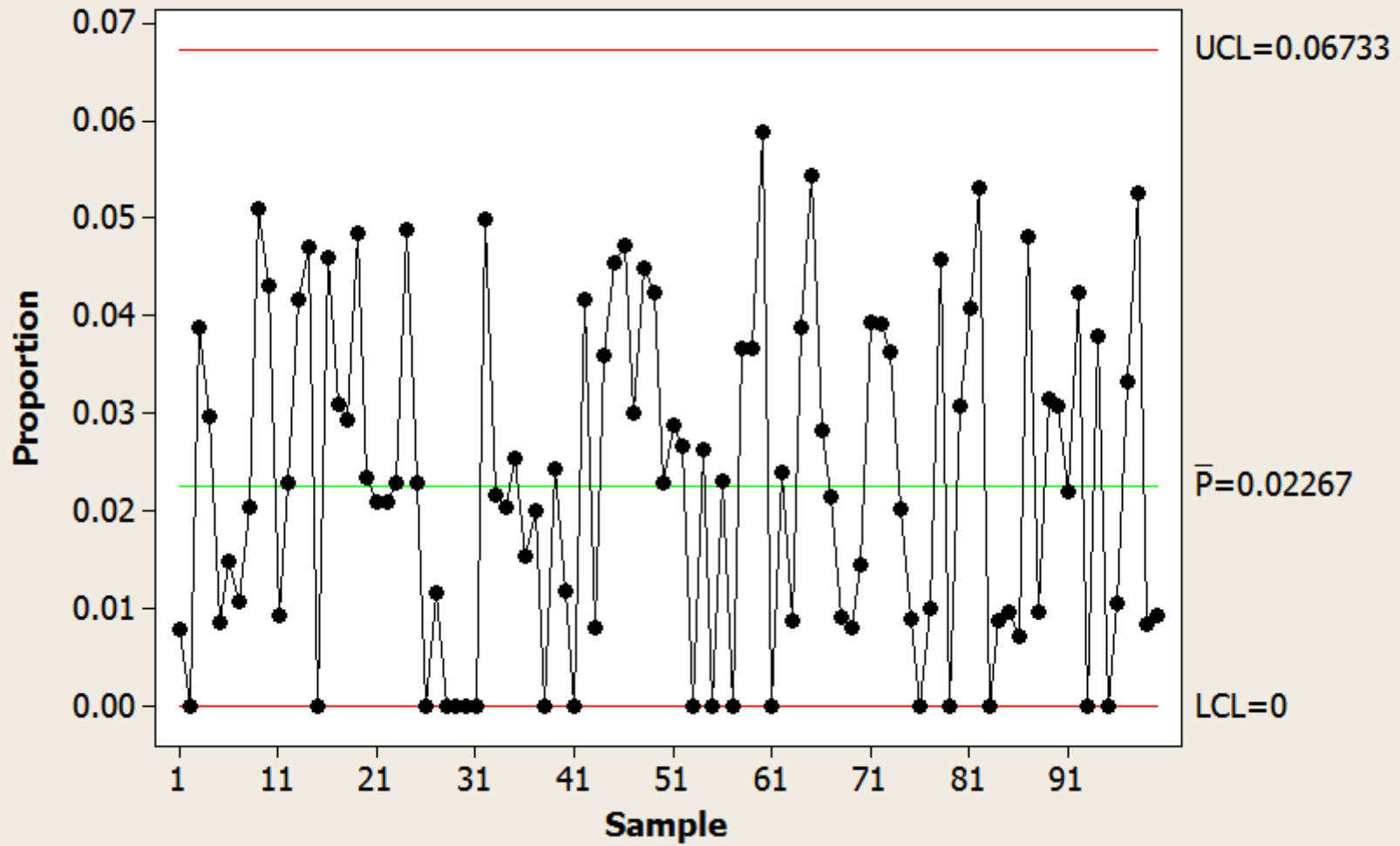
Assuming all subgroups have size:

Help

OK

Cancel

P Chart of C1



P Chart - Options



Parameters

Estimate

S Limits

Tests

Stages

Display

Storage

Perform selected tests for special causes

K

1 point $>$ K standard deviations from center line

3

K points in a row on same side of center line

9

K points in a row, all increasing or all decreasing

6

K points in a row, alternating up and down

14

Help

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OK

Cancel

Specification Limits

- Control Charts are about the expectations of the process
- Nowhere in this discussion was any mention of specification limits
- The control chart has statistics about the process mean and the process variation
- Comparison of the process and the specifications will occur when we discuss Process Capability