How to Use Minitab:

Gage R & R studies

Noelle M. Richard
08/27/14

Introduction

- Gage R & R studies are used to assess variation in a measurement process
- They examine Repeatability and Reproducibility
- Repeatability: variation due to the gage/equipment
  "within variation"
- Reproducibility: variation due to different operators
  "between variation"

$$\sigma^2_{total} = \sigma^2_{part} + \sigma^2_{operator} + \sigma^2_{(part)(operator)} + \sigma^2$$

$$\sigma^2_{gage} = \sigma^2_{repeat} + \sigma^2_{reproduce}$$

σ^2 $\qquad$ $\sigma^2_{operator} + \sigma^2_{(part)(operator)}$

(ANOVA method)

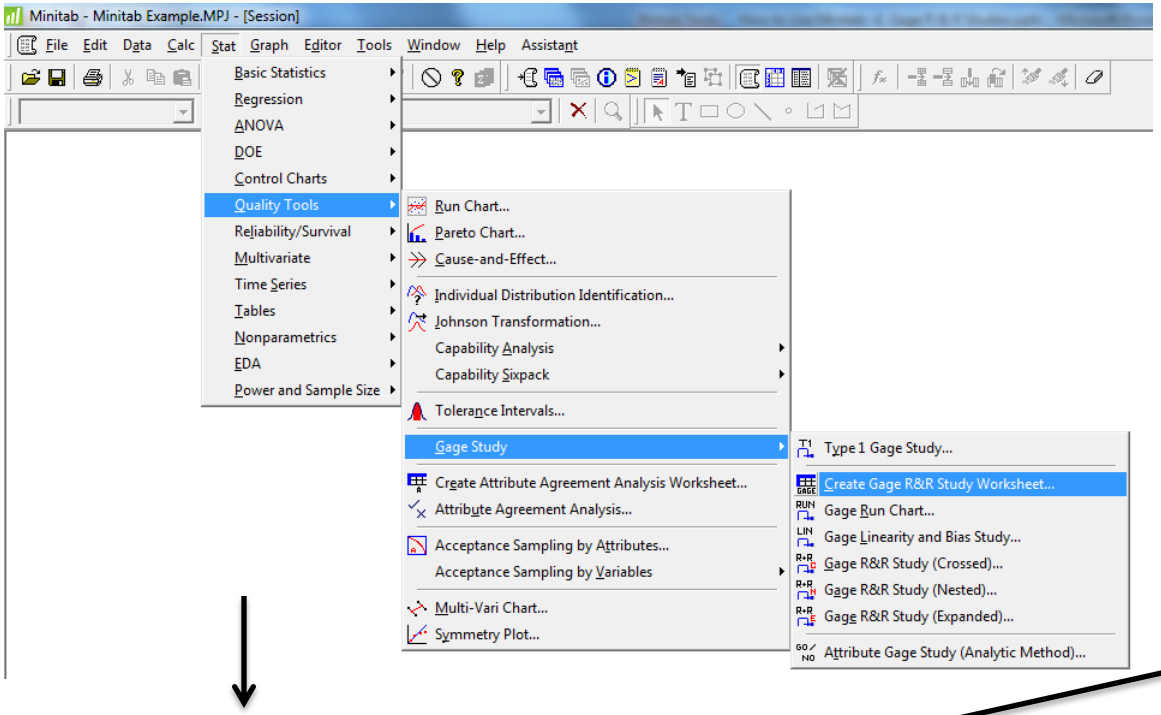
σ^2 = variance

σ = standard deviation

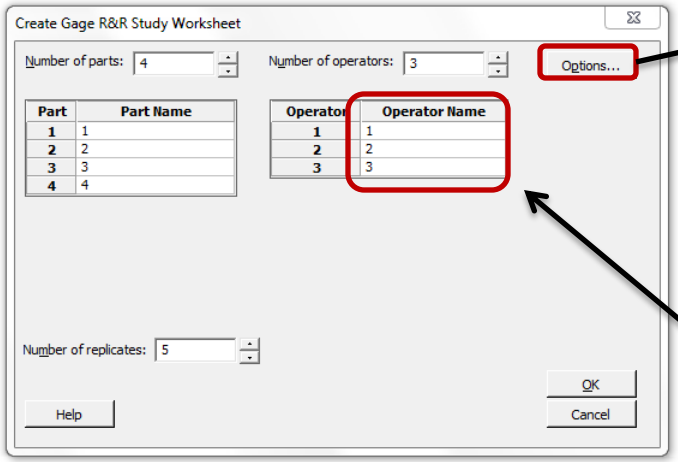
Types of Studies in Minitab

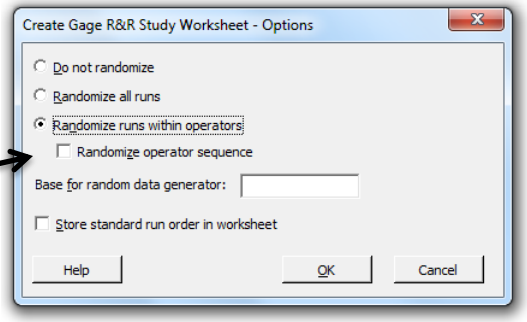
- Gage R & R Study (Crossed)
  - Best one to use, if you can
  - Each operator measures each part
  - Parts are measured more than once
  - # observations per part is the same
  - ex.) 3 operators, 4 parts, 5 observations per part total of 3x4x5 = 60 observations
- Gage R & R Study (Nested)
  - When you don't have the "balanced" design above. Most often, you use this if all operators cannot measure all parts.
  - ex. Operator 1 measures parts A and B, Operator 2 measures parts B and C.

Designing a Study



You can create a crossed (balanced) study in Minitab

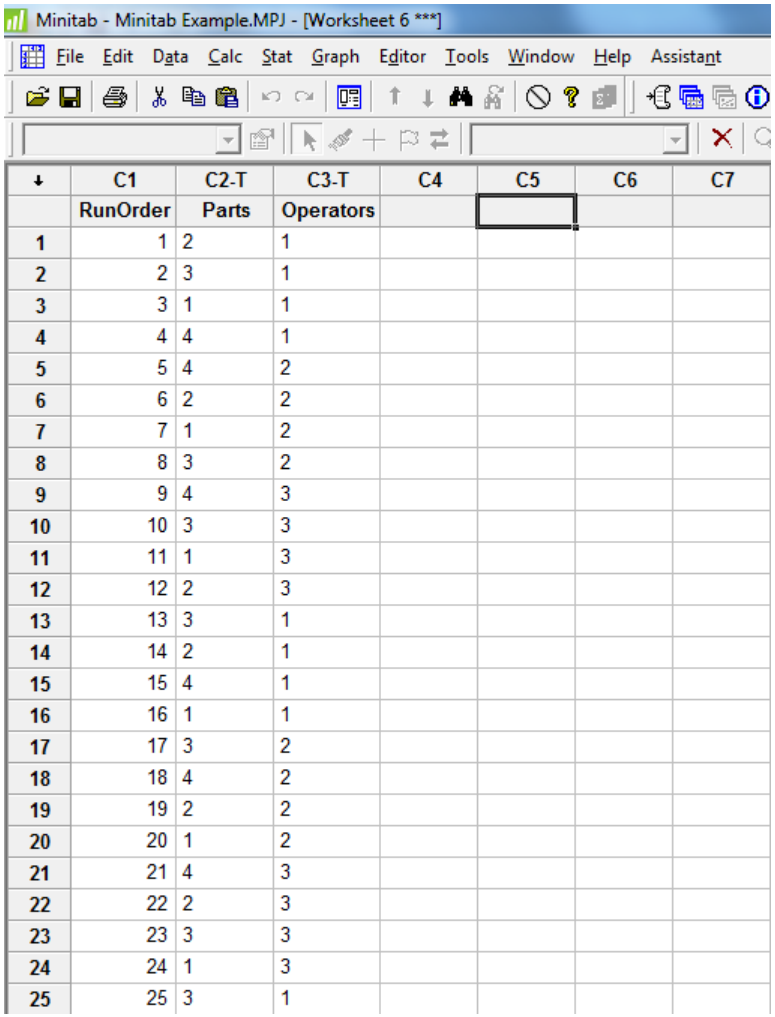




Should keep randomization if you can. If you can randomize all runs, do so.

You can change the names of parts and operators.

Designing a Study



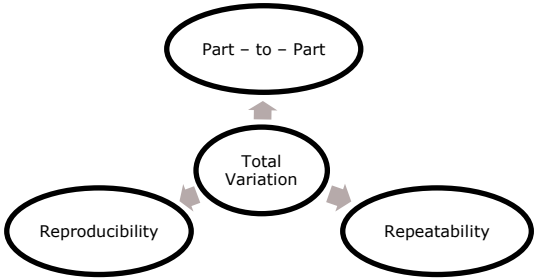
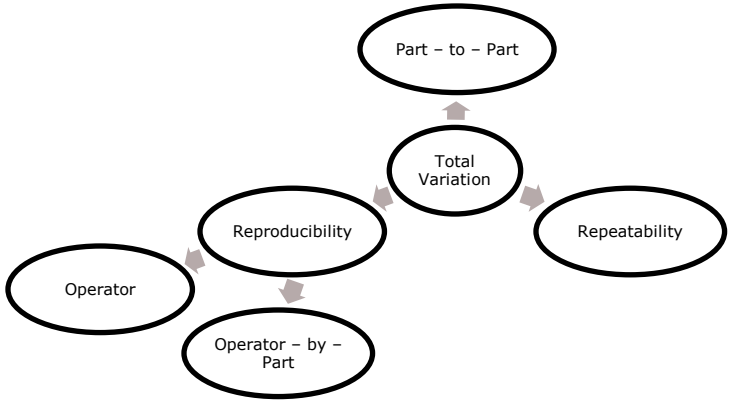
↓	C1	C2-T	C3-T	C4	C5	C6	C7
	RunOrder	Parts	Operators				
1	1	2	1				
2	2	3	1				
3	3	1	1				
4	4	4	1				
5	5	4	2				
6	6	2	2				
7	7	1	2				
8	8	3	2				
9	9	4	3				
10	10	3	3				
11	11	1	3				
12	12	2	3				
13	13	3	1				
14	14	2	1				
15	15	4	1				
16	16	1	1				
17	17	3	2				
18	18	4	2				
19	19	2	2				
20	20	1	2				
21	21	4	3				
22	22	2	3				
23	23	3	3				
24	24	1	3				
25	25	3	1				

Output: New worksheet with the design of your study

In the next column (C4) enter in your measured data, once you have it

Methods for Analyzing a Study

Two Methods for analyzing a Gage R & R Study (in Minitab)

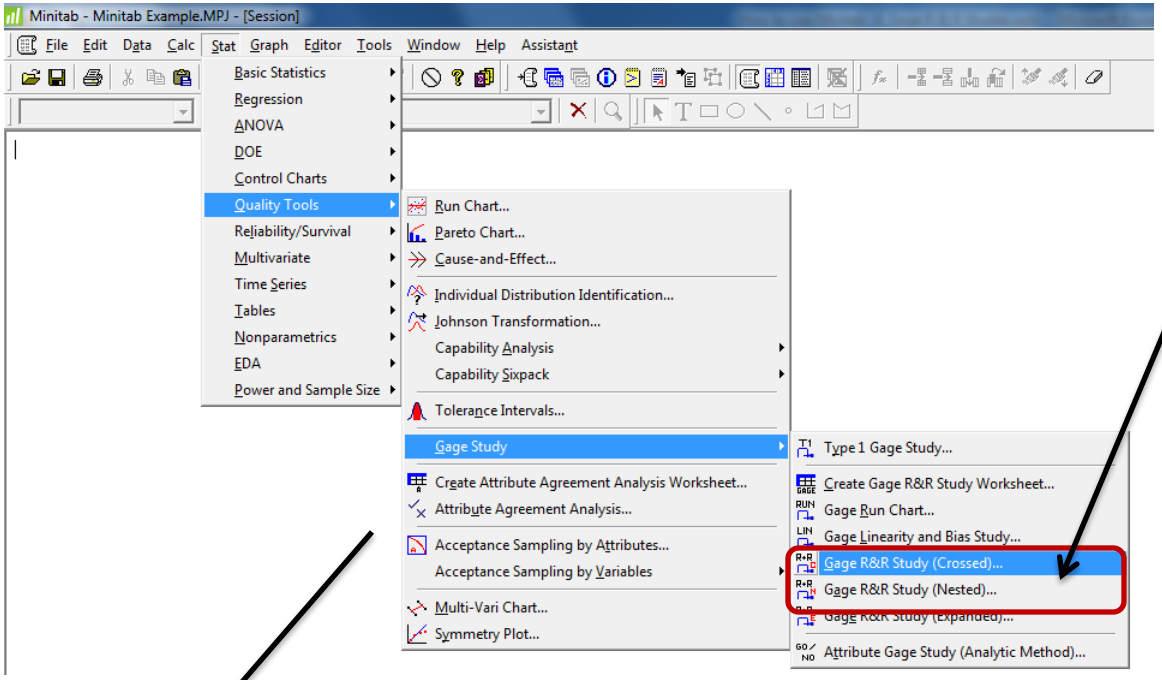
Xbar – R	ANOVA
1. Uses the average range to estimate variation	1. As the name suggests, uses an Analysis of Variance table to estimate variation
2. Breaks down the overall variation into three categories	2. Goes one step further and splits reproducibility into 2 parts
	
3. Sometimes, can produce biased estimates.	3. Much better method, because it produces unbiased estimates.
4. Because of (2) and (3), not the best method.	4. ANOVA more accurate, so I suggest using this one all the time.
Click HERE for more information.	Click HERE for more information.

What is Bias? The difference between the expected value and the actual (true) value.

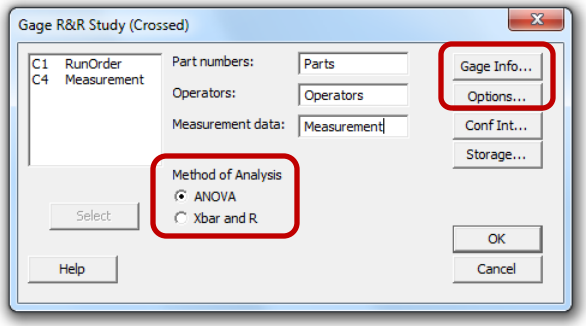
Many people look to use estimates that have zero bias because expected = actual. These are called unbiased. There is a trade-off between bias and variation, however. As bias goes down, variance often goes up (and vice versa).

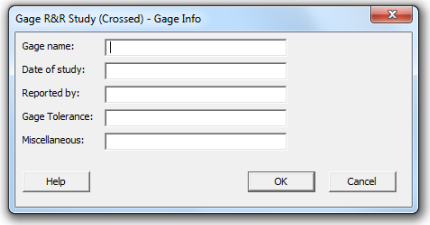
Analyzing Gage R & R Study

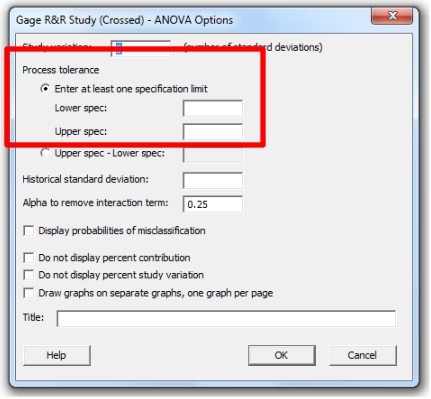
Remember, *crossed* is the "balanced" study, and *nested* is when all operators cannot measure all parts



By entering in specification limits, you will output a column of %Tolerance. The %Tolerance compares the estimates of variation with the allowable spread of variation.







For Crossed studies, have the option of using either ANOVA or Xbar – R

Analyzing Gage R & R Study- Output

Gage R&R Study - ANOVA Method
Gage R&R for Height

Gage name: Tencor P-6
Misc: LSL = 1.6 USL = 2.4 Target = 2

Two-Way ANOVA Table With Interaction

Source	DF	SS	MS	F	P
Part	9	0.0562044	0.0062449	321.822	0.000
Operator	2	0.0002798	0.0001399	7.210	0.005
Part * Operator	18	0.0003493	0.0000194	0.960	0.515
Repeatability	60	0.0012127	0.0000202		
Total	89	0.0580462			

Alpha to remove interaction term = 0.25

Two-Way ANOVA Table Without Interaction

Source	DF	SS	MS	F	P
Part	9	0.0562044	0.0062449	311.856	0.000
Operator	2	0.0002798	0.0001399	6.987	0.002
Repeatability	78	0.0015620	0.0000200		
Total	89	0.0580462			

Gage R&R

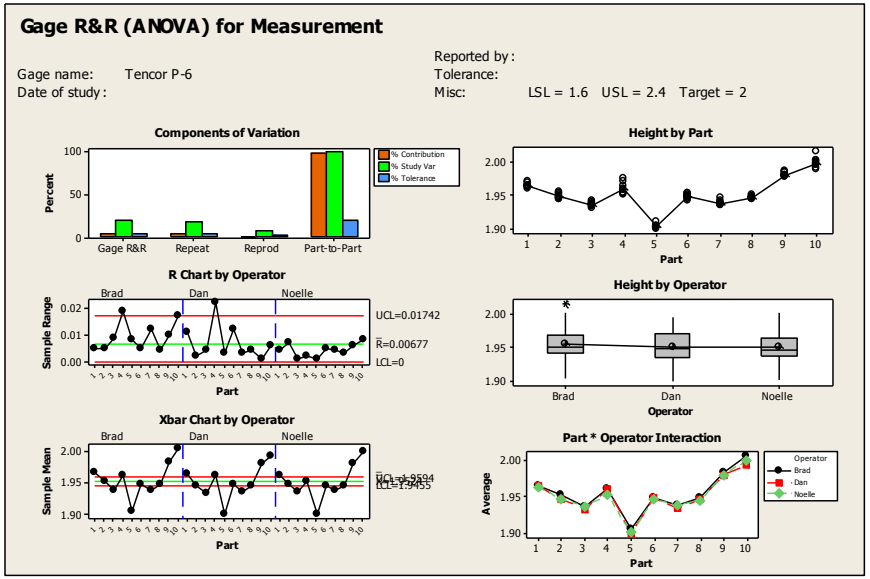
Source	VarComp	%Contribution (of VarComp)
Total Gage R&R	0.0000240	3.36
Repeatability	0.0000200	2.80
Reproducibility	0.0000040	0.56
Operator	0.0000040	0.56
Part-To-Part	0.0006917	96.64
Total Variation	0.0007157	100.00

Shows how the variation is split up

Process tolerance = 0.8

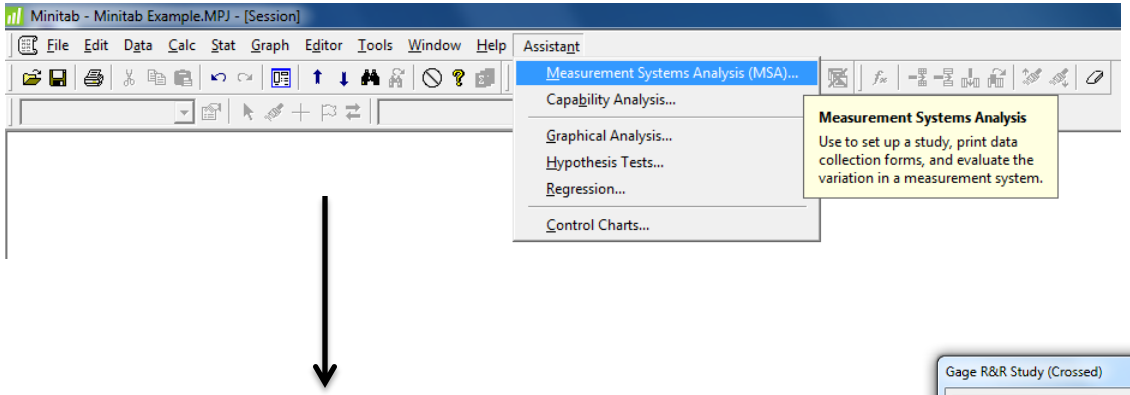
Source	StdDev (SD)	Study Var (6 * SD)	%Study Var (%SV)	%Tolerance (SV/Toler)
Total Gage R&R	0.0049012	0.029407	18.32	3.68
Repeatability	0.0044749	0.026850	16.73	3.36
Reproducibility	0.0019991	0.011994	7.47	1.50
Operator	0.0019991	0.011994	7.47	1.50
Part-To-Part	0.0262994	0.157796	98.31	19.72
Total Variation	0.0267522	0.160513	100.00	20.06

Compares variation to specification limits

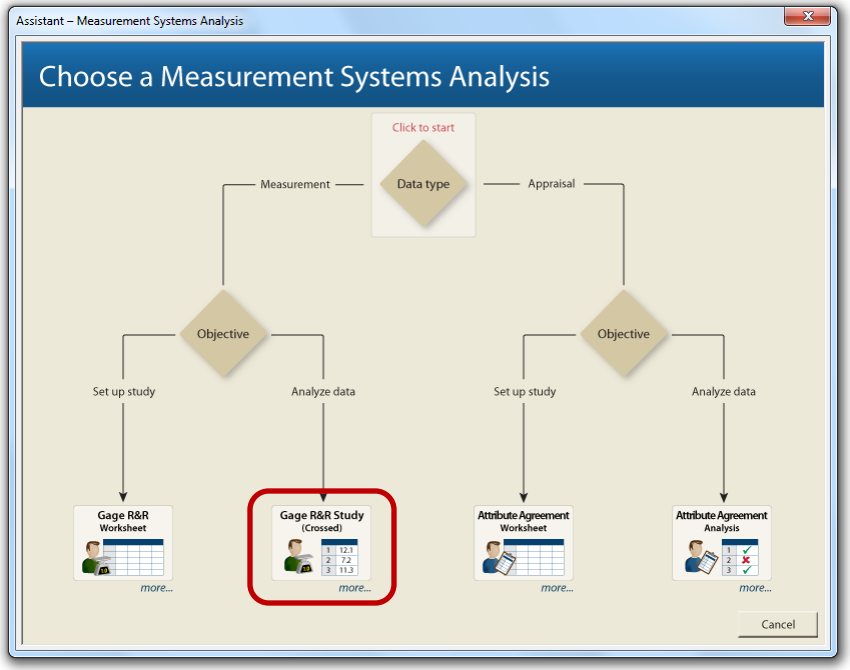


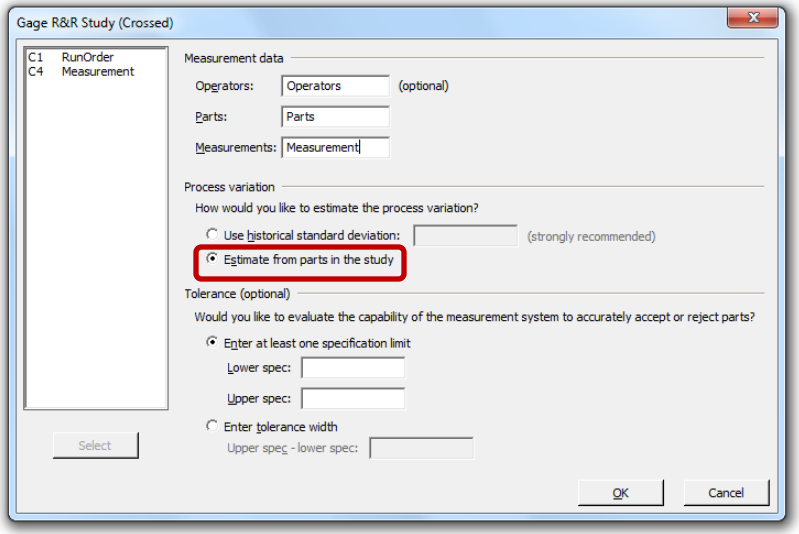
Sometimes, the interaction term (part)x(operator) may not be significant. If so, it will not influence reproducibility. Minitab will remove the interaction term from the calculations, to make things simpler, if the term is insignificant.

Analyzing Crossed Gage R & R Study



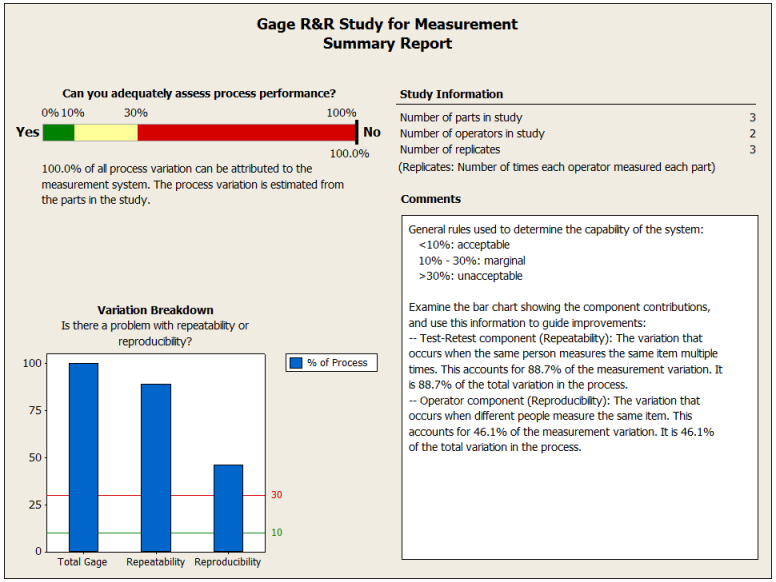
Can also use Minitab's Assistant feature (for crossed only).

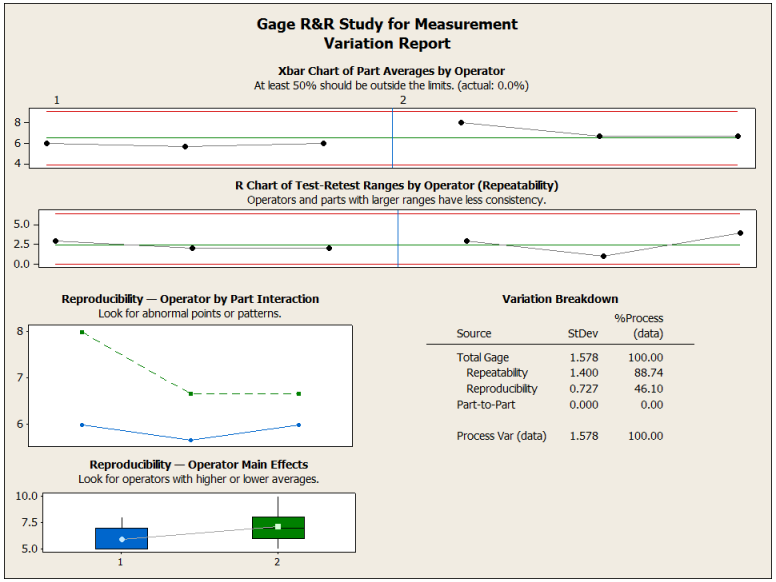


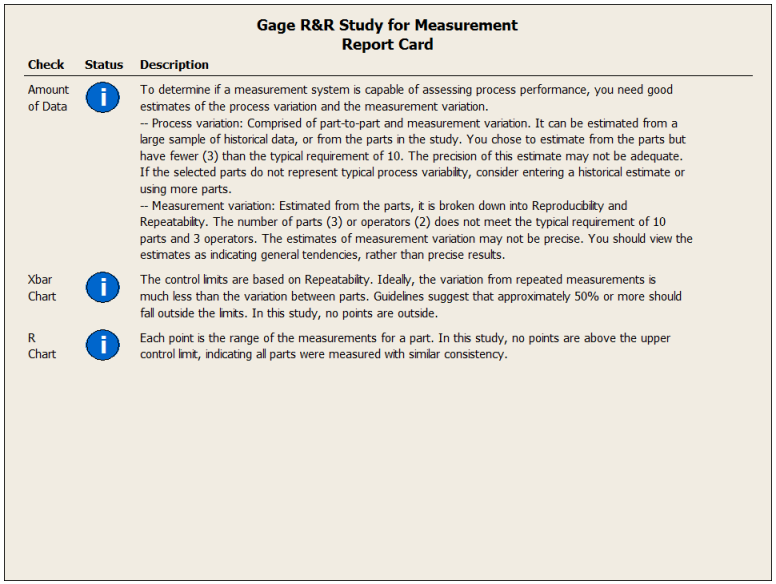


Unless you already know the process standard deviation, you must estimate it.

OUTPUT- ASSISTANT







References

- Khan, R. M. (2013). *Problem solving and data analysis using minitab: A clear and easy guide to six sigma methodology* (1st ed.). West Sussex, United Kingdom: Wiley.

- Minitab's Help Section