FLORIDA POLYTECHNIC UNIVERSITY

Six Sigma: Weeks 9 & 10

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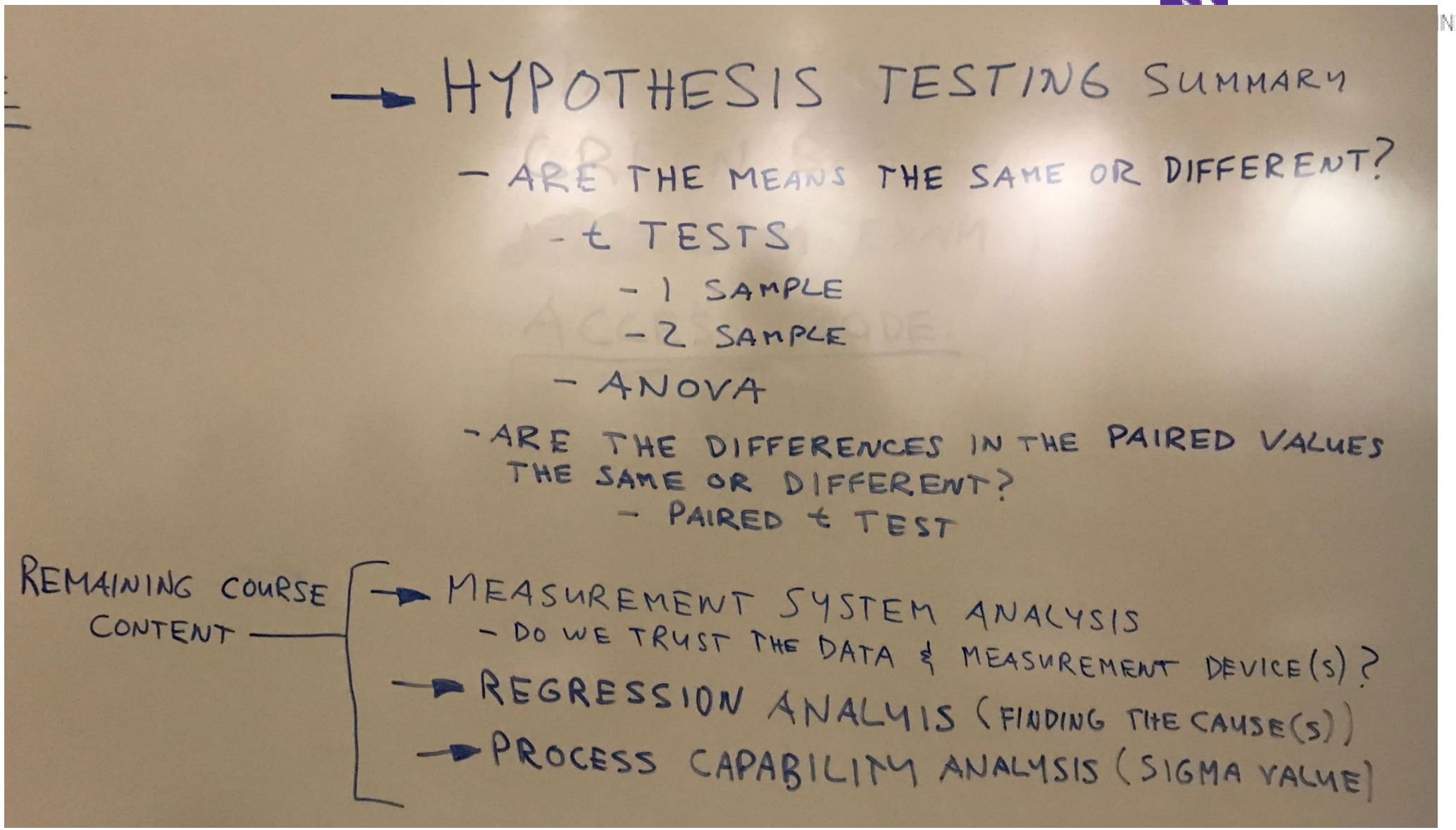
Agenda: Weeks 9 & 10

- Continue to build our Six Sigma tool set
  - Hypothesis testing: Paired t-test – review examples – LS text pages 528; LSSM text page 167
  - Measurement System Analysis (MSA)
    - Video: https://www.youtube.com/watch?time_continue=18&v=qdosHXCsCxY
    - Quick story about MSA at Rockwell Automation
      - Failed sensor during product functional testing
    - Gage Repeatability and Reproducibility Studies
      - Continuous data: LS text pg. 365; LSSM text pg. 62
    - Attribute Agreement Analysis
      - Attribute data: LS text pg. 357; LSSM text pg. 66

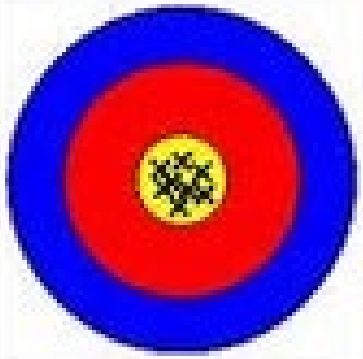
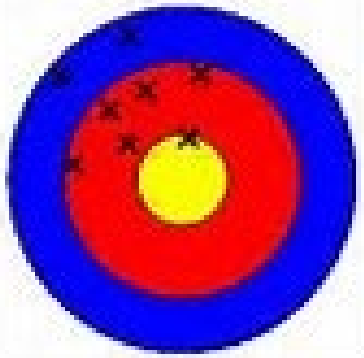
Our Six Sigma Journey So Far



Measurement System Analysis

- Goals of GR&R analysis are:
  - Identify and quantify dominant causes of measurement variation
  - Compare variation of measurement system with variation of the measured object
- If lack of *repeatability* is large compared to lack of reproducibility, it is likely that
  - The gauge needs maintenance
  - The gauge can be redesigned
  - There is excessive within-part variation
- If lack of *reproducibility* is large compared to lack of repeatability, it is likely that
  - Operators need to be better trained
  - Instructions on use of gauge may not be clear
  - There is a need to have a fixture to help operators

Measurement System Analysis

Image from wellesley.edu	Accurate	Inaccurate (systematic error)
Precise		
Imprecise (reproducibility error)		

Measurement System Analysis – LSSM Text

- GR&R studies quantify the precision errors of a measurement system to determine its acceptability
  - A GR&R study measures precision error by taking one part and measuring it several times, with different people
  - Given that the part is not changing in size, any variation in the results must represent the *repeatability* of the gauge and the *reproducibility* of measurements by different people
  - A GR&R study repeats this approach on several different parts to assess results
- Acceptable levels of GR&R variation
  - Acceptability of GR&R variation is assessed on ratio (expressed as percentage) of GR&R variation compared to process (part-to-part) variation and customer tolerance. (See page 62).

GR&R Acceptability Criteria	Unacceptable	Marginal	Good	Excellent
GR&R as percentage of the Total Variation = GR&R / Total Variation x 100%	>30%	<30%	<20%	<10%
GR&R as percentage of the Tolerance = GR&R / Tolerance x 100%	>30%	<30%	<20%	<10%

Gage R&R (ANOVA) Report for Measurement

Gage name:
Date of study:

Reported by:
Tolerance:
Misc:

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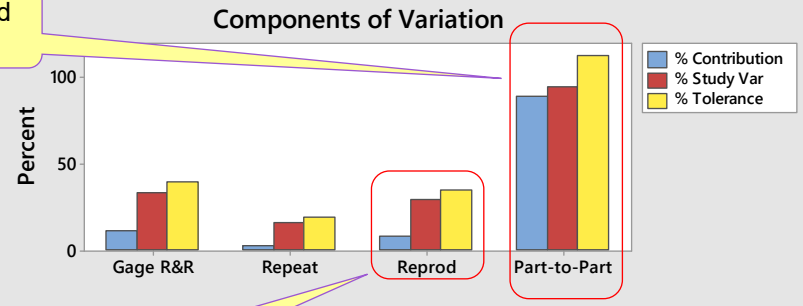
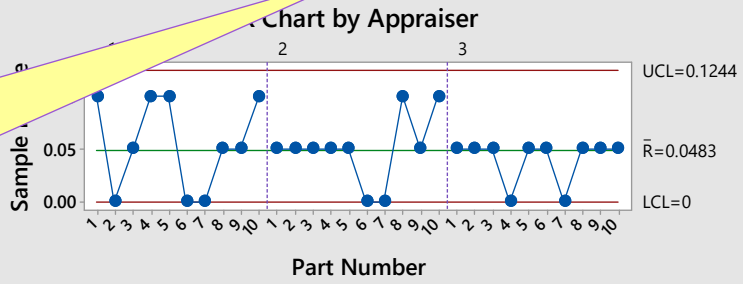
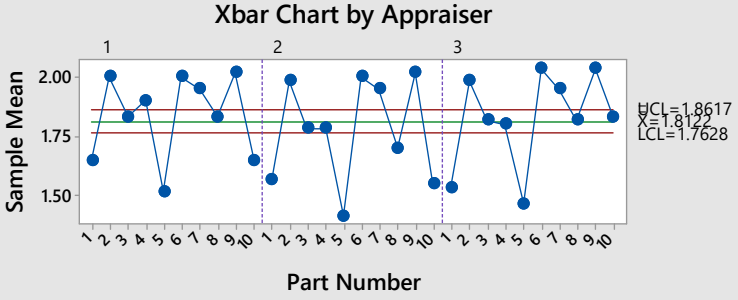
Part to part group should be highest percent

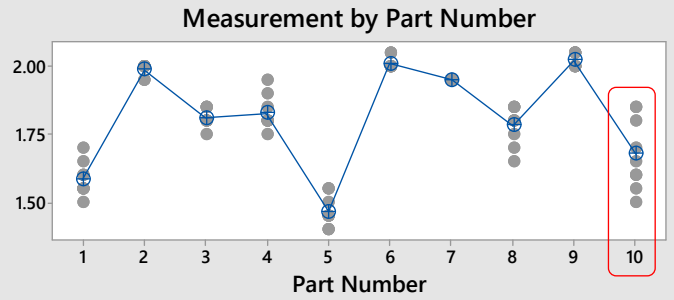
Reproducibility is largest component of GR&R, indicating improvements should focus on reducing differences between appraisers first

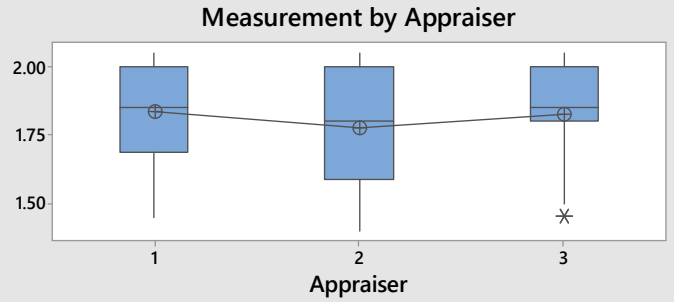
Part 10 had most variable results

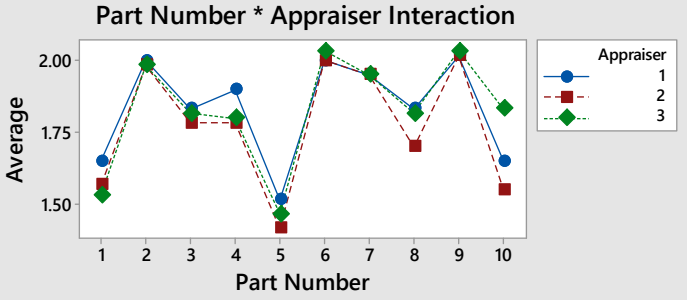












Measurement System Analysis – LSSM Text

- How to do a GR&R study – Continuous data
  - A common standard is to use 10 parts, measured by 3 different people, 3 times each, for a total of 90 samples (example from LSSM text – page 63)
  - ***Example:*** A project is looking at controlling the thickness of steel from a rolling process. A GR&R study for the measurement *gage* has been completed on 10 pieces of steel, using 3 different appraisers.

Two-Way ANOVA Table With Interaction

Source	DF	SS	MS	F	P
Part Number	9	2.92322	0.324802	36.5530	0.000
Appraiser	2	0.06339	0.031694	3.5669	0.050
Part Number * Appraiser	18	0.15994	0.008886	8.8858	0.000
Repeatability	60	0.06000	0.001000		
Total	89	3.20656			

α to remove interaction term = 0.05

ANOVA table: assess which sources of variation are statistically significant. Appraiser ***does*** affect the result, and there is an interaction between Part Number and Appraiser.

Gage Evaluation

Source	StdDev (SD)	Study Var (6 × SD)	%Study Var (%SV)	%Tolerance (SV/Toler)
Total Gage R&R	0.066249	0.39749	33.34	39.75
Repeatability	0.031623	0.18974	15.91	18.97
Reproducibility	0.058214	0.34928	29.29	34.93
Appraiser	0.027573	0.16544	13.88	16.5
Appraiser*Part Number	0.051270	0.30762	25.80	30.76
Part-To-Part	0.187355	1.12413	94.28	112.41
Total Variation	0.198723	1.19234	100.00	119.23

Total GR&R is high at 33.3% of total variation. Improvements for measurement system needed.

Reproducibility factors contributed twice the variation that Repeatability factors contributed.

Measurement System Analysis – LSSM Text

- **Attribute Agreement Analysis**
  - Principles of Gage R&R can be applied to attribute data as well
  - The objective for an attribute MSA (Attribute Agreement Analysis) is for it to reach the correct decision every time
- What are we trying to determine?
  - With Attribute Agreement Analysis, results are used to:
    - assess *reproducibility* – how well appraisers agree with each other
    - assess *repeatability* – how consistently appraisers agree with themselves
  - *Within Appraisers:* shows repeatability of the each appraiser with herself/himself as a percentage
  - *Between Appraisers:* shows reproducibility of all appraisers with each other as a percentage
  - *Each Appraiser vs. Standard:* shows repeatability of each appraiser with a standard or expert response as percentage
  - *All Appraisers vs. Standard:* shows reproducibility of all appraisers with a standard or expert response as percentage
- Attribute Agreement Analysis – Video
  - https://www.youtube.com/watch?time_continue=8&v=SPPJGSkmFSk

Measurement System Analysis – LSSM Text

- GR&R study – Attribute data
  - Key differences of Attribute Agreement Analysis and GR&R studies are:
    - More data required – attribute data has less resolution. At least 20 parts should be assessed 3 times by each appraiser
    - Ensure selection of parts includes some borderline products or services that really challenge measurement system capability

- ***Example:*** 30 parts are appraised by 3 appraisers. Each appraiser does 3 trials of the parts. The appraisers either accept or reject the part for each trial. There is also a "correct answer" provided in the data (expert decision).

Within Appraisers

Assessment Agreement

Appraiser	# Inspected	# Matched	Percent	95% CI
Tom	30	27	90.00	(73.47, 97.89)
Dick	30	30	100.00	(90.50, 100.00)
Harry	30	29	96.67	(82.78, 99.92)

 # Matched: Appraiser agrees with him/herself across trials.

Appraisers were consistent (repeatability) within themselves

Measurement System Analysis – LSSM Text

- GR&R study – Attribute data
  - Key differences of Attribute GR&R studies are:
    - More data required – attribute data has less resolution. At least 20 parts should be assessed 3 times by each appraiser
    - Ensure selection of parts includes some borderline products or services that really challenge measurement system capability
  - With attribute GR&R, results are used to:
    - assess *reproducibility* – how well appraisers agree with each other
    - assess *repeatability* – how consistently appraisers agree with themselves
  - ***Example:*** 30 parts are appraised by 3 appraisers. Each appraiser does 2 trials of the parts. The appraisers either accept or reject the part for each trial. There is also a "correct answer" provided in the data (expert decision).

Each Appraiser vs Standard Assessment Disagreement

Appraiser	# Reject / Accept	Percent	# Accept / Reject	Percent	# Mixed	Percent
Tom	3	14.29	0	0.00	3	10.00
Dick	1	4.76	0	0.00	0	0.00
Harry	1	4.76	0	0.00	1	3.33

Appraisers rejected part, but experts accepted part

No appraisers decided that a part was acceptable when experts said it was a reject

Between Appraisers Assessment Agreement

# Inspected	# Matched	Percent	95% CI
30	25	83.33	(65.28, 94.36)

Matched: All appraisers' assessments agree with each other.

Complete agreement (reproducibility) between appraisers on 25/30 parts (83%)

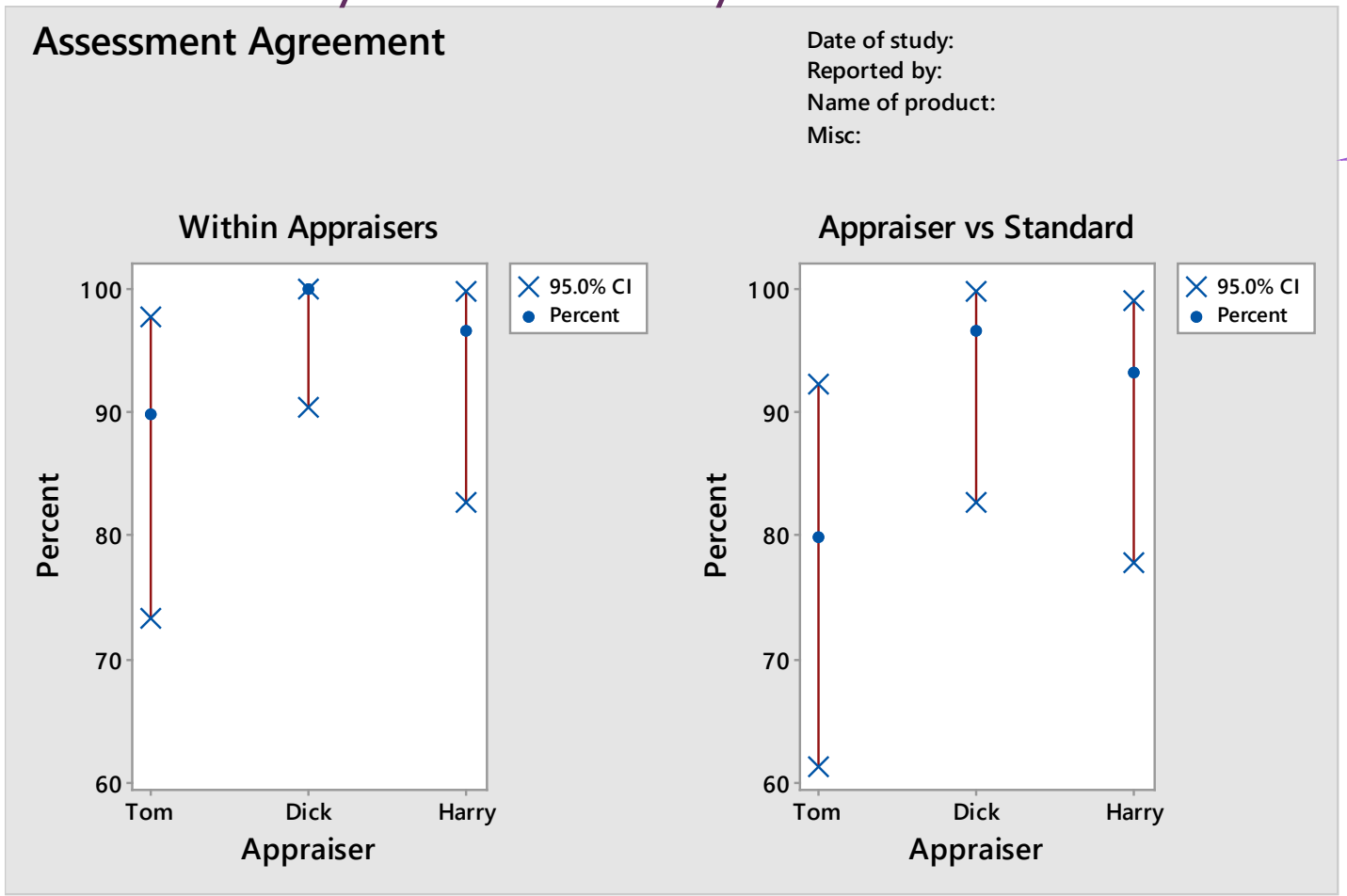
All Appraisers vs Standard

# Inspected	# Matched	Percent	95% CI
30	24	80.00	(61.43, 92.29)

Matched: All appraisers' assessments agree with the known standard.

Complete agreement between appraisers and the standard on 24/30 parts (80%)

Measurement System Analysis – LSSM Text



Within appraisers shows repeatability of appraisers as a percentage score

Tom reached the same decision on 90% of parts, but confidence interval is 73%-97%

Dick reached same decision on 100% of parts, but confidence interval indicates his true performance could be between 90-100%

Tom only agreed with expert decision on 80% of parts

Dick agreed with expert for 97% of parts

Harry agreed with 28/30 parts (93%)

Low ***within*** appraiser scores indicates need to help appraisers reach consistent decisions.

Low ***appraiser vs. standard*** scores indicates need to provide better operational definitions on acceptability criteria of product/service