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Measurement System Analysis

1. A steel producer wants to ensure that the thickness of steel being produced from the rolling process can be properly sustained within specification. A Gage Repeatability and Reproducibility (GR&R) study for the measurement system (gage) has been completed on 10 samples of steel. Three different appraisers each measured the 10 steel samples three times each, for a total of 90 measurements.
- I. Complete the Gage R&R study on the measurement data from the attached Minitab worksheet.

Gage R&R

Variance Components

| Source | VarComp | %Contribution (of VarComp) |
|-----------------------|-----------|-------------------------------|
| Total Gage R&R | 0.0026852 | 8.06 |
| Repeatability | 0.0016944 | 5.09 |
| Reproducibility | 0.0009907 | 2.97 |
| Appraiser | 0.0002263 | 0.68 |
| Appraiser*Part Number | 0.0007644 | 2.30 |
| Part-To-Part | 0.0306214 | 91.94 |
| Total Variation | 0.0333066 | 100.00 |

Process tolerance = 1.2

Gage Evaluation

| Source | StdDev (SD) | Study Var (6 × SD) | %Study Var (%SV) | %Tolerance (SV/Toler) |
|-----------------------|-------------|-----------------------|---------------------|--------------------------|
| Total Gage R&R | 0.051819 | 0.31091 | 28.39 | 25.91 |
| Repeatability | 0.041164 | 0.24698 | 22.56 | 20.58 |
| Reproducibility | 0.031476 | 0.18886 | 17.25 | 15.74 |
| Appraiser | 0.015045 | 0.09027 | 8.24 | 7.52 |
| Appraiser*Part Number | 0.027648 | 0.16589 | 15.15 | 13.82 |
| Part-To-Part | 0.174990 | 1.04994 | 95.88 | 87.49 |
| Total Variation | 0.182501 | 1.09501 | 100.00 | 91.25 |

Number of Distinct Categories = 4

Two-Way ANOVA Table With Interaction

| Source | DF | SS | MS | F | P |
|-------------------------|----|---------|----------|---------|-------|
| Part Number | 9 | 2.51622 | 0.279580 | 70.1115 | 0.000 |
| Appraiser | 2 | 0.02156 | 0.010778 | 2.7028 | 0.094 |
| Part Number * Appraiser | 18 | 0.07178 | 0.003988 | 2.3534 | 0.007 |
| Repeatability | 60 | 0.10167 | 0.001694 | | |
| Total | 89 | 2.71122 | | | |

α to remove interaction term = 0.05

Probabilities of Misclassification

Joint Probability

| Description | Probability |
|---|-------------|
| A randomly selected part is bad but accepted | 0.000 |
| A randomly selected part is good but rejected | 0.001 |

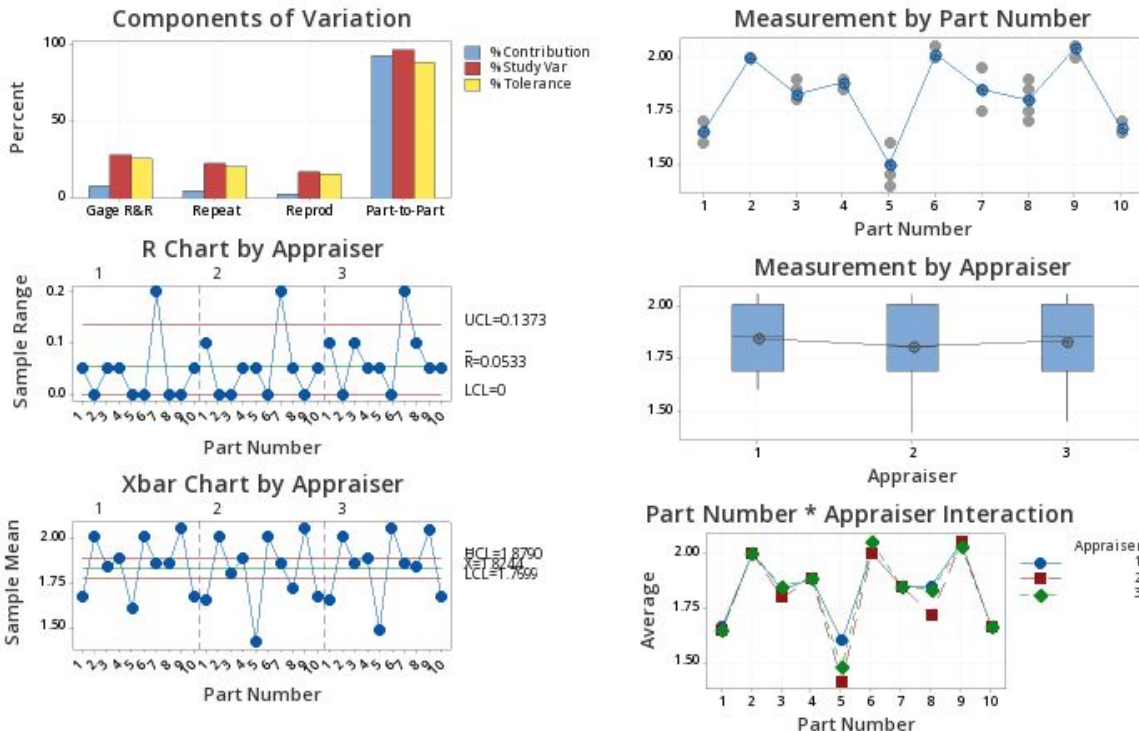
Conditional Probability

| Description | Probability |
|--|-------------|
| A part from a group of bad products is accepted | 0.253 |
| A part from a group of good products is rejected | 0.001 |

Gage R&R (ANOVA) Report for Measurement

Gage name:
Date of study:

Reported by:
Tolerance:
Misc:



- II. Provide a brief assessment of the measurement system for the steel rolling process.
 - The part-to-part component is the largest component of variation which is acceptable. However, the total Gage R&R value is high at 28%. While this is acceptable, it is not optimal. We can look at the Measurement by Part Number and find that variation is highest with parts 5, 7, and 8. By bringing that variation down, the overall variation should also decrease.
2. Three taste-testing appraisers are asked to decide the acceptability of samples of Smuckers Uncrustables sandwiches, each several different times. Results are used to assess the reproducibility as well as the repeatability of the manufacturing process to ensure good tasting sandwiches.
- I. Complete the Attribute Agreement Analysis on the measurement data from the attached Minitab worksheet.

Within Appraisers

Assessment Agreement

| Appraiser # | Inspected # | Matched | Percent | 95% CI |
|-------------|-------------|---------|------------------------|--------|
| 1 | 30 | 26 | 86.67 (69.28, 96.24) | |
| 2 | 30 | 30 | 100.00 (90.50, 100.00) | |
| 3 | 30 | 29 | 96.67 (82.78, 99.92) | |

Matched: Appraiser agrees with him/herself across trials.

Fleiss' Kappa Statistics

| Appraiser | Response | Kappa | SE Kappa | Z | P(vs > 0) |
|-----------|----------|---------|----------|---------|-----------|
| 1 | Accept | 0.82187 | 0.105409 | 7.79695 | 0.0000 |
| | Reject | 0.82187 | 0.105409 | 7.79695 | 0.0000 |
| 2 | Accept | 1.00000 | 0.105409 | 9.48683 | 0.0000 |
| | Reject | 1.00000 | 0.105409 | 9.48683 | 0.0000 |
| 3 | Accept | 0.95445 | 0.105409 | 9.05474 | 0.0000 |
| | Reject | 0.95445 | 0.105409 | 9.05474 | 0.0000 |

Each Appraiser vs Standard

Assessment Agreement

| Appraiser # | Inspected # | Matched | Percent | 95% CI |
|-------------|-------------|---------|----------------------|--------|
| 1 | 30 | 22 | 73.33 (54.11, 87.72) | |
| 2 | 30 | 28 | 93.33 (77.93, 99.18) | |
| 3 | 30 | 25 | 83.33 (65.28, 94.36) | |

Matched: Appraiser's assessment across trials agrees with the known standard.

Assessment Disagreement

| Appraiser | # Reject / Accept Percent | # Accept / Reject Percent | # Mixed | Percent |
|-----------|------------------------------|------------------------------|---------|---------|
| 1 | 3 15.00 | 1 10.00 | 4 | 13.33 |
| 2 | 2 10.00 | 0 0.00 | 0 | 0.00 |
| 3 | 3 15.00 | 1 10.00 | 1 | 3.33 |

Reject / Accept: Assessments across trials = Reject / standard = Accept.
Accept / Reject: Assessments across trials = Accept / standard = Reject.
Mixed: Assessments across trials are not identical.

Fleiss' Kappa Statistics

| Appraiser | Response | Kappa | SE Kappa | Z | P(vs > 0) |
|-----------|----------|----------|----------|---------|-----------|
| 1 | Accept | 0.562222 | 0.105409 | 5.33371 | 0.0000 |
| | Reject | 0.562222 | 0.105409 | 5.33371 | 0.0000 |
| 2 | Accept | 0.856459 | 0.105409 | 8.12509 | 0.0000 |
| | Reject | 0.856459 | 0.105409 | 8.12509 | 0.0000 |
| 3 | Accept | 0.669289 | 0.105409 | 6.34943 | 0.0000 |
| | Reject | 0.669289 | 0.105409 | 6.34943 | 0.0000 |

Between Appraisers

Assessment Agreement

| # Inspected | # Matched | Percent | 95% CI |
|-------------|-----------|----------------------|--------|
| 30 | 20 | 66.67 (47.19, 82.71) | |

Matched: All appraisers' assessments agree with each other.

Fleiss' Kappa Statistics

| Response | Kappa | SE Kappa | Z | P(vs > 0) |
|----------|----------|-----------|---------|-----------|
| Accept | 0.698341 | 0.0304290 | 22.9498 | 0.0000 |
| Reject | 0.698341 | 0.0304290 | 22.9498 | 0.0000 |

All Appraisers vs Standard

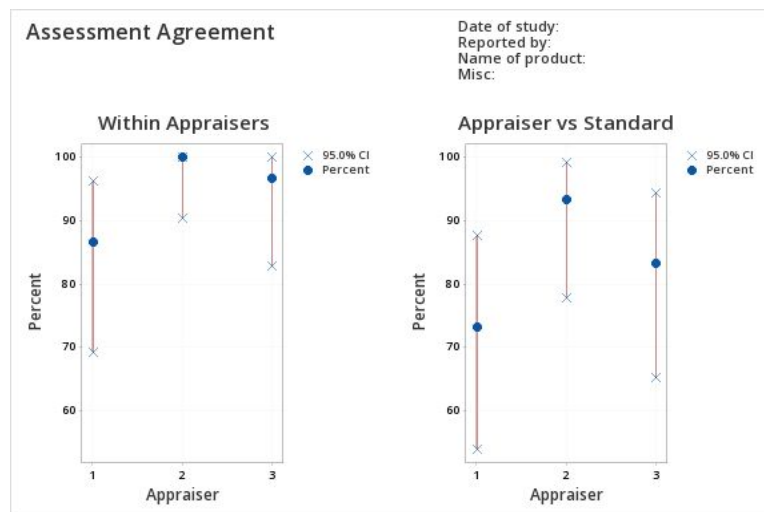
Assessment Agreement

| # Inspected | # Matched | Percent | 95% CI |
|-------------|-----------|----------------------|--------|
| 30 | 19 | 63.33 (43.86, 80.07) | |

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

Fleiss' Kappa Statistics

| Response | Kappa | SE Kappa | Z | P(vs > 0) |
|----------|----------|-----------|---------|-----------|
| Accept | 0.695990 | 0.0608581 | 11.4363 | 0.0000 |
| Reject | 0.695990 | 0.0608581 | 11.4363 | 0.0000 |



- II. Provide a brief assessment of the measurement system for the samples of Smuckers Uncrustables.

- Appraiser 2 was the most consistent with themselves at 100% consistency with Appraiser 1 the worst at 86.67%. All three appraisers rejected some parts that the expert would have accepted, but only appraiser 2 did not accept a part that the expert would have rejected while both 1 and 3 did. The overall consistency between the three appraisers was bad with only a 66.67% agreement rate between themselves and a 63.33% agreement with the expert.
- On a quick side note, how are they rating the Uncrustables? Do they each take a bite of the same one or each have one from the same batch? Is this like wine-tasting where they spit after each bite? I have so many questions.