IE 508: Quality Assurance
Mini-Project 1: Measurement System Analysis
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PART 1

Purpose of Gage Linearity Study

This gage linearity study was done to evaluate the accuracy of the measuring device across different distances and also how precise the operator used the device. The measuring device used in this experiment was a stopwatch app (stopwatch.onlineclock.net laptop and mouse). The flight time of a penny drop was measured. To avoid variation of operator measurement and variation in penny being released, 1 individual was tasked to drop the penny and 1 individual was tasked to measure the drop time throughout this experiment (for Part 1).

Sample Size Determination – Results and Interpretation

Table 1 summarized our team's preliminary experiment. The preliminary study was designed to drop a penny at 5 different heights (d=210 cm, 200 cm, 190 cm, 180 cm, and 170 cm) and 10 trails were completed for each height. To determine the sample size our group used the largest identified standard deviation value of 0.00637 and 0.0361 (10% of smallest average) as the margin of error value. The largest identified standard deviation and smallest average were considered to model the worst-case scenario. The sample size calculator estimated a sample size of 17, as indicated in ***Figure 1***. Reference values are summarized in **Table 2**. Time reference values for each drop height were calculated using **Equation 1**, where acceleration was 32.17 ft/s^2.

Equation 1: $t_R = \sqrt{\frac{2d}{a}}$

Distance(cm) \time (1/100s)	T1	T2	T3	T4	T5
No. of Trials	210	200	190	180	170
1	0.56	0.56	0.4	0.55	0.36
2	0.65	0.7	0.44	0.46	0.35
3	0.68	0.55	0.41	0.44	0.28
4	0.64	0.62	0.46	0.39	0.34
5	0.66	0.59	0.45	0.45	0.36
6	0.7	0.65	0.49	0.37	0.42
7	0.71	0.72	0.49	0.41	0.41

8	0.78	0.59	0.44	0.49	0.34
9	0.76	0.63	0.45	0.37	0.35
10	0.61	0.65	0.47	0.34	0.4
Average	0.675	0.626	0.45	0.427	0.361
Standard Deviation	0.06637	0.05602	0.02981	0.06378	0.04095

Table 1: Part 1 Preliminary Data Collection

Method

Parameter	Standard deviation
Distribution	Normal
Standard deviation	0.06637
Confidence level	95%
Confidence interval	Two-sided

Results

Margin of Error	Sample Size
0.0361	17

Figure 1: Sample Size for Estimation

32.17	f/s2	equals to:
980.54	cm/s2	
Time reference (1/100 seconds)	Distance (cm)	Calculated Distance
0.654	210	210
0.639	200	200
0.623	190	190
0.606	180	180
0.589	170	170

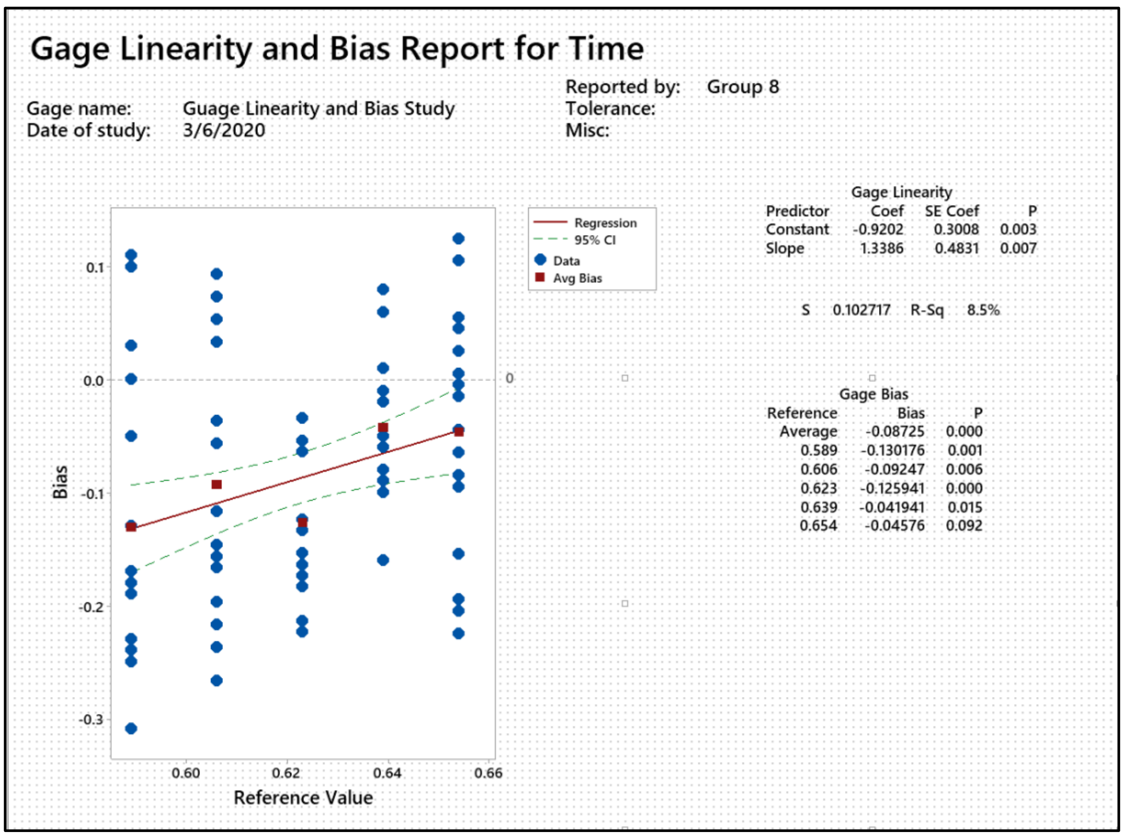
Table 2: Part 1 Reference Values

Gage linearity Study – Interpretation and results

This section references ***Graph 1***. First, our group used the bias versus reference value plot to assess the average bias throughout the drop distance range. The slope of the plotted line indicates that bias changes across the drop distance range.

Second, our group assessed the p-value for slope and constant. A p-value below 0.05 indicates that there is bias for all reference values, since the bias and reference value do not equal 0. This is illustrated by the blue data points not falling near the horizontal line. The p-value for slope is less than 0.05, meaning that our measuring system does not have the same bias for all reference values. The linearity problem is illustrated by the slope line.

Next, our team accessed the bias p-values for each reference value. Bias values for reference values range from -0.041941 to -0.130176, with p-values ranging from 0.000 to 0.092. A negative bias is present for all reference values, indicating that the gage measures less than the reference value. In addition, the R-Squared value of 8.5% means that a small proportion of the variation, in the bias, is explained by the relationship between the biases and the reference values. ***Table 3*** summarizes the data collection, using a sample size of 17 for 10 trials.



Graph 1: Gage Linearity and Bias Report for Sample Size 17

Distance(cm) \time (1/100s)	T1	T2	T3	T4	T5
No. of Trials	210	200	190	180	170
1	0.56	0.56	0.4	0.55	0.36
2	0.65	0.7	0.44	0.46	0.35
3	0.68	0.55	0.41	0.44	0.28
4	0.64	0.62	0.46	0.39	0.34
5	0.66	0.59	0.45	0.45	0.36
6	0.7	0.65	0.49	0.37	0.42
7	0.71	0.72	0.49	0.41	0.41
8	0.78	0.59	0.44	0.49	0.34
9	0.76	0.63	0.45	0.37	0.35
10	0.61	0.65	0.47	0.34	0.4
11	0.45	0.55	0.57	0.57	0.54
12	0.46	0.54	0.57	0.55	0.46
13	0.5	0.54	0.5	0.66	0.59
14	0.59	0.58	0.59	0.64	0.62
15	0.57	0.55	0.57	0.7	0.7
16	0.43	0.48	0.59	0.66	0.69
17	0.59	0.65	0.56	0.68	0.59
Average	0.675	0.626	0.45	0.427	0.361
Std Dev	0.06637	0.05602	0.02981	0.06378	0.04095

Table 3: Part 1 Actual Data Collection

The current measurement system is not acceptable. As mentioned in the previous problem, the bias for all reference values are significant since they do not equal 0, and the measurement system does not have the same bias. Other concerning interpretations from ***Graph 1*** are that:

(1) the slope line is not close to the horizontal line and
(2) the horizontal line does not fall within the 95% confidence interval (green lines).

Therefore, our team concluded that the measuring system is not acceptable. Possible factors that may have contributed to the bias in the measuring system is (1) how the penny may have been dropped (different orientation or angle) and the response time from starting/ending the stop watch. Our team recommends using a youtube countdown video (“3,2,1, GO”) to have one person drop the penny at “GO” and the operator start the timer at “GO.” In addition, a standardized dropping method should be selected and followed throughout the entire experiment.

As we concluded earlier that this measurement system was unacceptable, in order to correct it we dropped the penny from each of the height and video recorded the same. Wilson positioned his fingers as illustrated in **Figure 2**. This was done to reduce variability in the angle or orientation of the penny drop. A countdown “3,2,1, GO " was used for each penny drop from the different heights. Wilson released the penny at “GO.” Once the video was recorded for all the trials, Pritish watched the video recorded and used the stopwatch on an online platform “stopwatch.onlineclock.net” to record the time when Wilson said “GO”, until hearing the sound of the penny dropping on the ground. The preliminary data collection for the second experiment (prior to sample size calculation) is summarized in **Table 4**.

Sample Size for Estimation

Method

Parameter	Standard deviation
Distribution	Normal
Standard deviation	0.113
Confidence level	95%
Confidence interval	Two-sided

Results

Margin of Error	Sample Size
0.058	18

Figure 2: Corrected Sample Size for Estimation

Distance/Time	T1	T2	T3	T4	T5
No. of Trials	210.00	200.00	190.00	180.00	170.00
1	0.786	0.621	0.574	0.527	0.580
2	0.894	0.700	0.462	0.709	0.557
3	0.888	0.818	0.811	0.676	0.660
4	0.859	0.548	0.677	0.518	0.613

5	0.668	0.567	0.787	0.620	0.530
6	0.628	0.677	0.629	0.588	0.485
7	0.847	0.755	0.524	0.590	0.628
8	0.778	0.683	0.526	0.523	0.621
9	0.724	0.612	0.683	0.668	0.663
10	0.811	0.614	0.630	0.618	0.448
Average	0.788	0.660	0.630	0.604	0.579
Std Dev	0.091	0.084	0.113	0.068	0.073

Table 4: Part 2 Preliminary Data Collection

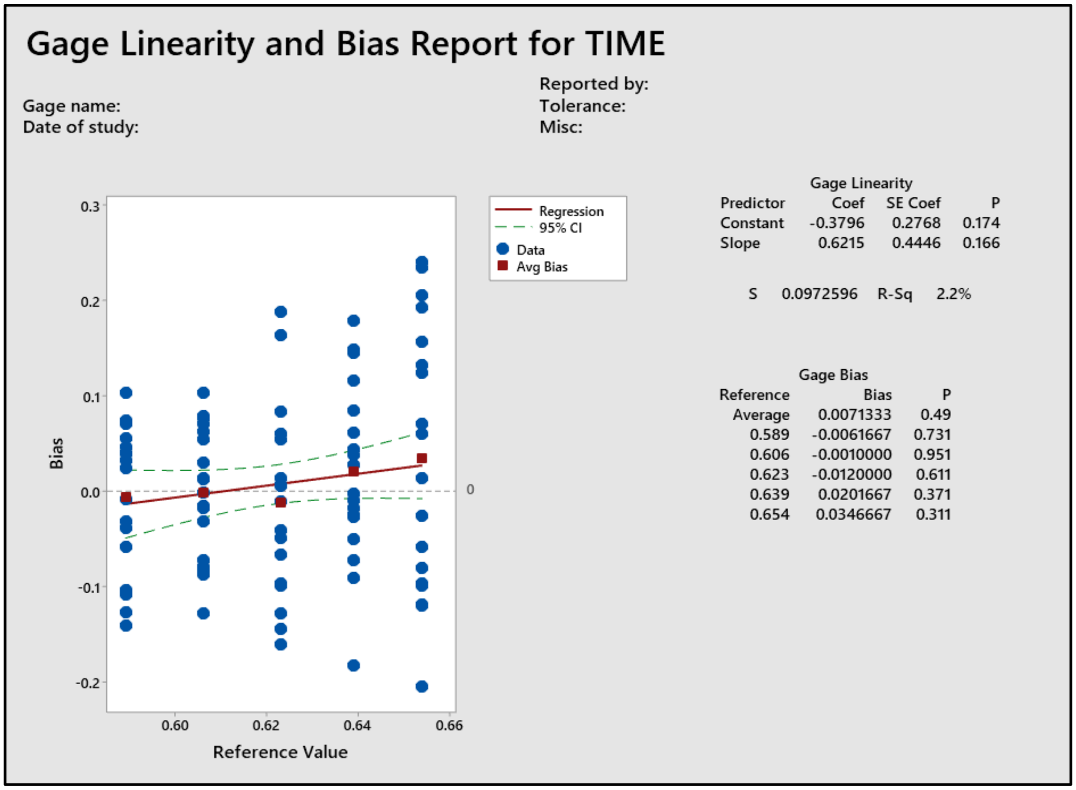
As per the question, we had to collect 10 samples of the flight time for each of the distances 170,180,190,200,210 cm respectively. The average and standard deviation of the flight time of these 10 observations were calculated and are summarized in ***Table 4***. Our group used Minitab for the sample size determination by using the largest identified standard deviation value of 0.113 and a margin of error value of 0.0570 (10% of the average of the total flight time for the shortest distance 170 cm). The largest identified standard deviation of 0.113 and 10% of the flight time of the smallest distance 0.058 were considered to model the worst-case scenario for the sample size determination. The sample size estimate indicates that we had to collect 18 observations to estimate a parameter within the margin of error (the worst-case scenario). Initially we had 10 observations and collected 8 additional samples. The data collected is summarized in ***Table 5***.

Distance/Time	T1	T2	T3	T4	T5
No. of Trials	210.00	200.00	190.00	180.00	170.00
1	0.786	0.621	0.574	0.527	0.580
2	0.894	0.700	0.462	0.709	0.557
3	0.888	0.818	0.811	0.676	0.660
4	0.859	0.548	0.677	0.518	0.613
5	0.668	0.567	0.787	0.620	0.530
6	0.628	0.677	0.629	0.588	0.485
7	0.847	0.755	0.524	0.590	0.628
8	0.778	0.683	0.526	0.523	0.621
9	0.724	0.612	0.683	0.668	0.663
10	0.811	0.614	0.630	0.618	0.448

11	0.714	0.456	0.582	0.574	0.462
12	0.534	0.723	0.495	0.605	0.613
13	0.555	0.666	0.556	0.682	0.635
14	0.573	0.589	0.637	0.66	0.55
15	0.449	0.629	0.706	0.478	0.629
16	0.596	0.636	0.479	0.533	0.481
17	0.557	0.784	0.612	0.636	0.644
18	0.535	0.787	0.628	0.685	0.692
Average	0.689	0.659	0.611	0.605	0.583
Std Dev	0.141	0.084	0.113	0.068	0.073

Table 5: Part 1 Corrected Data Collection (Recorded)

Figure 3: Standard Penny Drop Method (Recorded Experiment, Dropped by Wilson)



Graph 2: Gage Linearity and Bias Report for Sample Size 18

This section references ***Graph 2***. First, our group used the bias versus reference value plot to assess the average bias throughout the drop distance range. The slope of the plotted line is relatively close to the horizontal line, which indicates some improvement from the previous experiment.

Second, our group assessed the p-value for the slope and constant. From ***Graph 2.*** We can see that the p-value of the slope is 0.166 and that for the constant is 0.174, both the p-values are above the 0.05 significance value so we reject the null hypothesis. Other important considerations is that:

1) The slope line is close to the horizontal line

2)The horizontal line does fall within the 95% confidence interval (green lines). We can infer from this that the bias for all the reference values is nearly close to 0. We can conclude the Gage Linearity for the measurement system is achieved.

Part 2:

Purpose of Gage Linearity Study

The purpose of the gage repeatability and reproducibility is to evaluate the variation in each operator's measurement, when each observation is different. Our team initially considered a nested design (referred to as experiment 1). For experiment 1, one individual was selected to drop the helicopters throughout the experiment. ***Figure 4*** illustrates the standard method used to drop each helicopter. The experiment consisted of 10 helicopters and 4 operators. Each helicopter was dropped three times. Each operator measured the flight times of each observation using a stopwatch app (stopwatch.onlineclock.net). Initially our team completed a nested design for experiment 1 because each observation (flight) is destroyed and the exact observation can not be repeated. However, from this study our team obtained a Total Gage R&R %Contribution of 70. There we decided to create a cross design experiment which designed the proceeding questions for part 2.

This experiment is discussed in problems 1 to 3, and improved in problem 4.

The purpose of the crossed designed experiment (referred to experiment 2) was to evaluate the variation in each operator's measurement when every operator measured every part (same observations. For experiment 2, one person dropped each helicopter (10 in total) three times. This was recorded using an iPhone. Each operator viewed the video recording and measured the time using the stopwatch app. These guidelines were created to serve as standards throughout the experiment and reduce the effect of possible nuisance variables in our experimental design. A total of 120 observations were obtained in this experiment (4 operators, 10 parts, helicopters dropped three times). However, to analyze the results, the average of the 3 measurements for each part by each operator was completed and considered as 1 data point. Therefore, this experiment was analyzed using 40 points.

A major distinction of experiment 2 to the the improvement (in problem 4) is that we did not use a countdown when the helicopter was released. This was corrected in experiment 3, in problem 4.

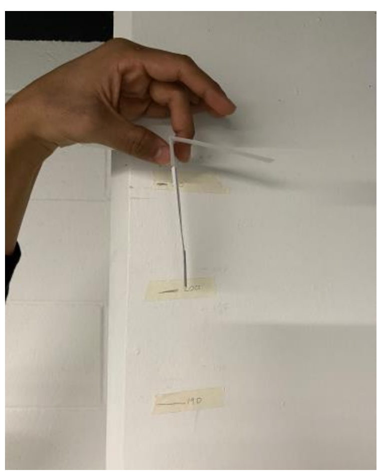


Figure 4: Helicopter Drop from 200cm (Recorded Experiment)

ORIGINAL GAGE:

The crossed gage R&R study was performed on the helicopter experiment and the following results of variability estimates, measurements and graphs of these measurements were validated.

Two-Way ANOVA Table With Interaction

Source	DF	SS	MS	F	P
Parts	9	1.44797	0.160885	11.5590	0.000
Operators	3	0.17988	0.059960	4.3079	0.013
Parts * Operators	27	0.37580	0.013919	6.3534	0.000
Repeatability	80	0.17526	0.002191		
Total	119	2.17891			

α to remove interaction term = 0.05

Gage R&R

Variance Components

Source	VarComp	%Contribution (of VarComp)
Total Gage R&R	0.0076348	38.40
Repeatability	0.0021907	11.02
Reproducibility	0.0054440	27.38
Operators	0.0015347	7.72
Operators*Parts	0.0039093	19.66
Part-To-Part	0.0122472	61.60
Total Variation	0.0198820	100.00

Figure 4: ANOVA Results from Experiment 2

Gage Evaluation

Source	StdDev (SD)	Study Var (6 × SD)	%Study Var (%SV)	%Tolerance (SV/Toler)
Total Gage R&R	0.087377	0.524263	61.97	52.43
Repeatability	0.046805	0.280832	33.19	28.08
Reproducibility	0.073784	0.442702	52.33	44.27
Operators	0.039176	0.235054	27.78	23.51
Operators*Parts	0.062524	0.375146	44.34	37.51
Part-To-Part	0.110667	0.664002	78.49	66.40
Total Variation	0.141003	0.846020	100.00	84.60

Number of Distinct Categories = 1

Figure 5: Gage Evaluation from Experiment 2

- ANOVA Analysis:

Our group analysed and interpreted the results to understand and identify the source of variability in the experiment based on the observations of the ANOVA table in crossed gage R&R. We can see that the P value of Total Gage R&R (0.00), Repeatability (0.013), Reproducibility (0.00) is less than 0.05 which means that they are all statistically significant.

- Measurement Error:

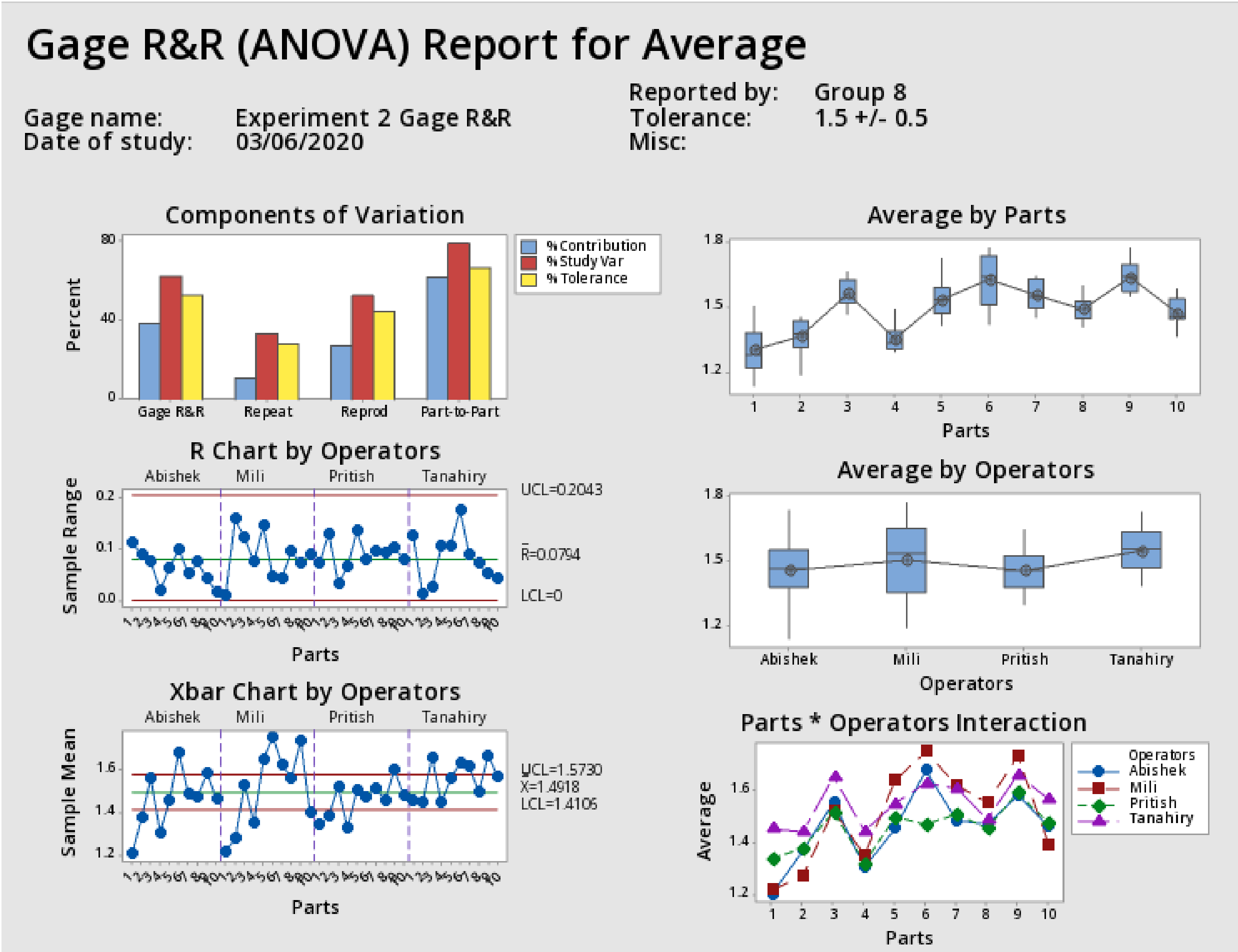
Our group later assessed the variation due to measurement error of each of the sources by using the variance components 'VarComp' and the %Contribution.The variance components accounts to the total amount of variation of each source of the different measurement error and the part-part difference contributes to the total variability.

The variance component gives us the variation in the source of measurement error. Total Gage R&R accounts for the sum of the Repeatability and Reproducibility components. We can observe that the Repeatability contributes for 11.02% of the total variation and the Reproducibility contributes for 27.30% The Total Gage R&R contributes to 38.4% of the total variation in the measurement systems. We observe that Part-to-Part variation contributes to 61.6% of the total variation of the measurement system. Our group identifies that our measurement system is unacceptable since the Total Gage R&R accounts for nearly 38.4%. Since the value is way above the range our group identifies this measurement system to be unacceptable. For a good measurement system, the variation from Part-to-Part should contribute the most, which we obtained in our results. We realised that the high %Contribution in Repeatability was due to the difference in timings recorded by the operators during their independent 3 trials for each helicopter drop.

In the %StudyVar we compare the measurement system variation the total variation in the system, also this gives us a better understanding of improving the measurement system. We can observe that the %StudyVar of the Total Gage R&R is about 61.97%, which accounts for most of the measurement system variability. Since the Gage Evaluation table tells us the source of variation and its relative importance. The variation due to the Total Gage R&R is the strongest contributor of the overall variation accounting for about 61.97%. This makes our group not accept the measurement system.

We can also see that the tolerance percentage is equal to 52.43%, a value which is high and clearly indicates that the measurement systems are out of specifications.

Based on the ANOVA table, Variance components and Gage Evaluation reports, our team identifies this measurement system to be unacceptable as it was observed that the %Contribution (38.4%) and %StudyVar (61.97%) for the Total Gage R&R was very high.



Graph 3: R&R ANOVA Report for Experiment 2

It is evident from the 'Components of Variation' graph that the Part-to-Part variation dominates the Gage R&R variation, which is the desired output. Ideally, for a good Gage R&R, the yellow bar for Gage R&R should be high and Part-to-Part variation should be the highest.

The average by parts graph indicates the average response for each part joined by a line. The boxes correspond to total variation among all the recorded responses for each part. Ideally, the box should be as flat as possible indicating minimum variation in recorded response. It is evident that the average flight time of Part 1 is significantly lower than the flight time for Part 6.

The R-chart by operators represents the average response of range of each operator for each part. In other words, it gives the average of highest and lowest response of each part for each operator. The Y-axis indicates the range of our responses. The UCL and LCL values show that the process is under control. We can observe that there is room for improvement in our operator performances.

The adjacent box plot represents the amount of variation in performance of each operator for each part. It is a useful tool to analyze the performance of our operators. A higher graph indicates that the operator should improve his/her precision.

The Xbar chart takes the average of all the responses of each operator by parts. Similar to the R-chart, it is used to evaluate operator performance.

The part*operator interaction graph is similar to the Xbar chart. It plots the average responses for each part and plots in one over the another. Ideally, all the plots should overlap each other. Any deviation from overlap suggests a glitch in operator performance.

The measurement system for the first gage R&R is not acceptable, as we can see that the total variation is high with almost a 38.40%, with 11.02% variation in repeatability and 27.38% variation in reproducibility. This means that the measurement techniques or methods have not been correctly established and standardized. Additionally, the graph "Parts * Operators Interaction" indicate to us that there is a high reproducibility because the average between each operator and each part is different and they are not near each other.

Directly measuring the time for each helicopter part and obtaining the average is not the most effective measuring technique, this is why we re-dropped all the helicopters and recorded each trial. Also by recording the helicopter drops we can get a standardized measure as we are more focused and directed to the problem.

Before re-analyzing the recorded video, we need to set up the necessary procedures so every operator can have the same setups and techniques for measuring, also it is necessary that every operator makes some warm up measurements so they get used to the stopwatch equipment and they don't get any variation when pressing the button.

As a general process we can develop the following standardized document:

STANDARDIZED MEASUREMENT TECHNIQUES

1. Select the most suitable tool to measure the drop times. If you don't have a stopwatch you can use the following:
    - Smartphone with stopwatch app, the disadvantage is that you will have less exact values and more variation between measurements with the same operator or part, since the button from the stopwatch is a touchpad, it causes a time delay between the pressed button and effective time.
    - Computer with internet to access a stopwatch website with a computer mouse. A computer mouse has similar physical properties as a standard stopwatch, both of them have a button that when pressed automatically records the time with less process time
    - The most suitable choice if we don't have a stopwatch is a computer with a mouse, but if we don't have neither of them, use as a last resort a smartphone with a stopwatch app. The precision of the stopwatch will depend on how much time you want to measure, if it is a small period of time, we require a stopwatch with higher accuracy and precision (it needs to display milliseconds as well).

2. Establish the right measurement conditions: Coordinate with your teammates which one will collect the data, which one will measure the time and which one will drop the helicopter. The one who drops the helicopter should not be replaced as we want to see
3. Establish a drop technique: a single dropping form should be replicated and performed by the operator during the whole measurement time.
4. Practice until you are sure that the measured values have low variation, for example if you have the following measurements.

First setup run:

1.23	1.36	1.54	1.02	1.52	1.19	we can observe less variation
0.52	range is low between the lowest and biggest value					

Second setup run:

1.88	2.44	3.69	3.01	2.04	1.99	we observe more variation
1.81	range is high between the lowest and biggest value					

Ideally the best measurement data is the one where there is less variation between the highest and lowest values.

We may encounter situations in which we will require multiple measurement points, in that case it is recommended to establish an additional milestone to reduce the values variation. An initial milestone we can suggest to apply is that everyone starts when given an specific signal or uses a visual object to identify when the measurement will start and when it will end.

The most common signal in our mini project was when the operator who was in charge of dropping the helicopter said the word “Go”, this signal notified the operator who was measuring the time.

5. If there is another operator who will start measuring be sure that the measurement tool is the same for every operator. There are many factors between tools that may affect the measurement which can contribute to the overall variability system.

Two-Way ANOVA Table With Interaction

Source	DF	SS	MS	F	P
Parts	9	1.65789	0.184210	31.5608	0.000
Operators	3	0.09936	0.033121	5.6746	0.004
Parts * Operators	27	0.15759	0.005837	2.8168	0.000
Repeatability	80	0.16577	0.002072		
Total	119	2.08061			

α to remove interaction term = 0.05

Gage R&R

Variance Components

Source	VarComp	%Contribution (of VarComp)
Total Gage R&R	0.0042364	22.18
Repeatability	0.0020721	10.85
Reproducibility	0.0021643	11.33
Operators	0.0009095	4.76
Operators*Parts	0.0012549	6.57
Part-To-Part	0.0148645	77.82
Total Variation	0.0191009	100.00

Process tolerance = 1

Figure 5: ANOVA Results from Experiment 3

Gage Evaluation

Source	StdDev (SD)	Study Var (6 × SD)	%Study Var (%SV)	%Tolerance (SV/Toler)
Total Gage R&R	0.065088	0.390528	47.09	39.05
Repeatability	0.045520	0.273122	32.94	27.31
Reproducibility	0.046522	0.279135	33.66	27.91
Operators	0.030158	0.180946	21.82	18.09
Operators*Parts	0.035424	0.212544	25.63	21.25
Part-To-Part	0.121920	0.731519	88.22	73.15
Total Variation	0.138206	0.829236	100.00	82.92

Number of Distinct Categories = 2

Figure 6: ANOVA Results from Experiment 3

As the measurement system was unacceptable, we recorded the video of the flight time of all the helicopters. The 4 operators watched the video of these and recorded the time for each flight time for the helicopters. The crossed gage R&R study was performed on the helicopter experiment and the following results of variability estimates, measurements and graphs of these were measurements were validated.

- **ANOVA Analysis:**

Our group analysed and interpreted the results to understand and identify the source of variability in the experiment based on the observations of the ANOVA table in crossed gage R&R. We can see that the P value of Total Gage R&R (0.00), Repeatability (0.004), Reproducibility (0.00) is less than 0.05 which means that they are all statistically significant.

- **Measurement Error:**

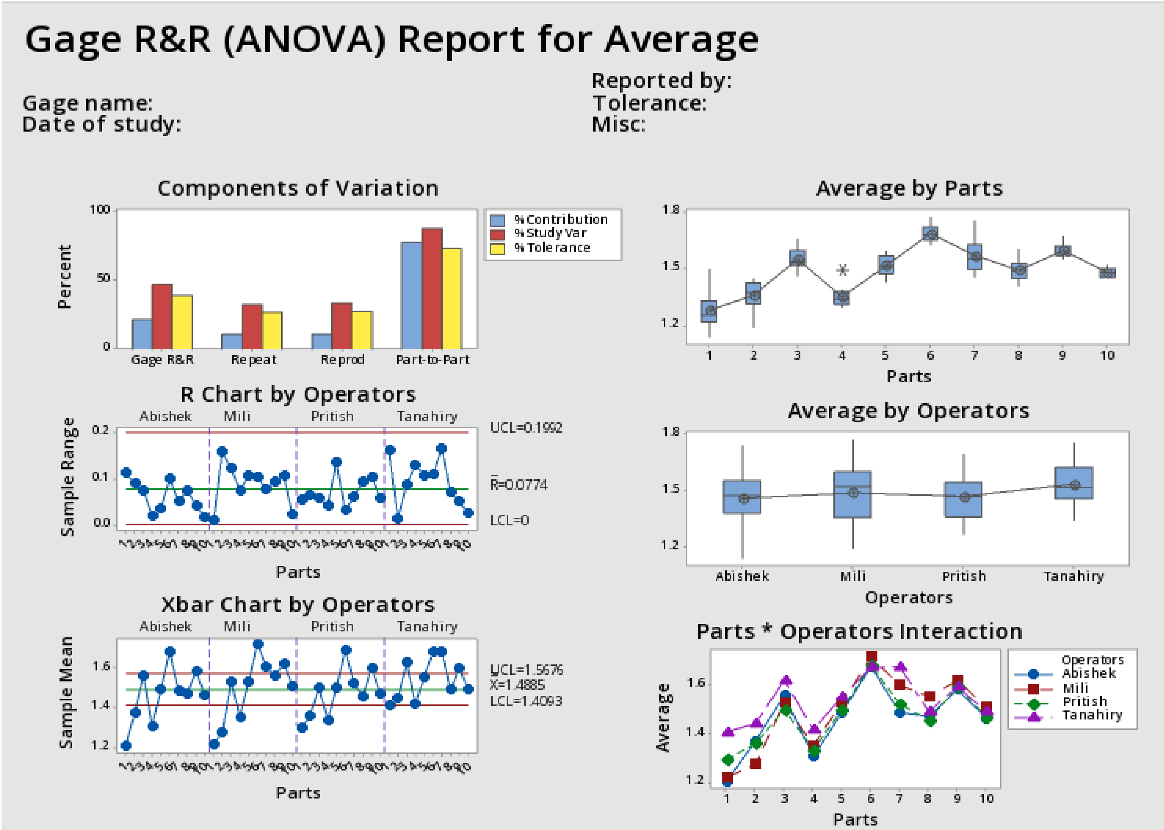
Our group later assessed the variation due to measurement error of each of the sources by using the variance components 'VarComp' and the %Contribution. The variance components accounts to the total amount of variation of each source of the different measurement error and the part-part difference contributes to the total variability.

In the variance components the Total Gage R&R accounts for the sum of the Repeatability and Reproducibility components. We can observe that the Repeatability contributes for 10.85% of the total variation and the Reproducibility contributes for 11.33% which is less than what we got earlier. The Total Gage R&R contributes to 22.12% of the total variation in the measurement systems. We observe that Part-to-Part variation contributes to 77.82% of the total variation of the measurement system. Since the value is near to the specified range our group identifies this measurement system to be partially acceptable. For a good measurement system, the variation from Part-to-Part should contribute the most. We realised that the high %Contribution in Repeatability was due to the difference in timings recorded by the operators during their independent 3 trials for each helicopter drop.

In the %StudyVar we compare the measurement system variation the total variation in the system, also this gives us a better understanding of improving the measurement system. We can observe that the %StudyVar of the Total Gage R&R is about 47.09%, which accounts for most of the measurement system variability. Since the Gage Evaluation table tells us the source of variation and its relative importance. The variation due to the Total Gage R&R is the strongest contributor of the overall variation accounting for about 47.09%. This makes our group not accept the measurement system.

A tolerance column has been added to the gage analysis (based on the given tolerance in the problem 1.5 +/- 0.5) as it may be more important than the %Study Var column, this is because the %Tolerance is more specific to the helicopter parts and its spec limits such as length or width. One of the main reasons an operator was assigned with the task of making the 10 helicopters was to reduce the variability of the specification in length and width.

As we can see in the Gage Evaluation, the Tolerance percentage is 39.05%, higher than 30%, this can give us a better insight about the helicopter parts, even though it is a high percentage, the tolerance tells us that the measurement tool. It is telling us that the measurement tool is not as precise as it its intended, since we are measuring small quantities of time, we need a higher precision tool that every operator can handle with ease. .



Graph 4: R&R ANOVA Report for Experiment 3

The Part-to-Part variation dominates the Gage R&R variation, which is the desirable output.

The average by parts graph indicates the average response for each part joined by a line. The boxes correspond to total variation among all the recorded responses for each part. Ideally, the box should be as flat as possible indicating minimum variation in recorded response. The average flight time for parts 1,2 is lower than the flight time of other parts.

The R chart by operators suggests that there is slight variance in time recording performance of the operators. Similarly, the adjacent box plot helps visualize the variation.

The Xbar chart takes the average of all the responses of each operator by parts. Similar to the R-chart, it is used to evaluate operator performance.
The part*operator interaction graph is similar to the Xbar chart. It plots the average responses for each part and plots in one over the another. Ideally, all the plots should overlap each other. Any deviation from overlap suggests a glitch in operator performance. In our case, we observe that there is variation in recorded flight times of part 1 and 7.

Finally, we have to consider even though the measurement system is not acceptable it is not because due to the measuring technique of the operators within each part but rather other factors that are applied and they require a higher precision tool to measure and reduce the variation results.