CLEMSON
MASTER OF BUSINESS ADMINISTRATION

Green Belt Project:

Anderson Fan Return Rate Reduction

Project Leader: Jordan Clarke

Stakeholders: TTI, Home Depot

Team members:
Arash Rashidghamat & Austin Clark

Table of Contents

Executive Summary

The first ceiling fan TTi has ever produced was recently sold into stores of our biggest customer. The fan was introduced under a new brand called Stile and as a new brand in the ceiling fan market, it is crucial that the fan appeals to customers both visually and functionally or the brand name could suffer irreparable damage. Customer sales and their continued satisfaction are crucial to maintain our firm relationship with Home Depot while developing a reputable and quality brand name. While sales are not an issue for this product, there is a 12% return rate for the Anderson fan, this sums to a $41,592 loss of revenue per year in this category. The goal is to decrease the amount of returns from %12 to ~%8 by Q2 2019 which could result to saving $12,477. In order to make this improvement, customer reviews were studied and it was found that high fan noise attributed to 24% of fan returns. This issue was further explored by examining several fan samples to locate the source. The metal ceiling fan blades were found to be the source of the problem. When the fan blades were replaced with a plastic design, noise level decreased by 8%. The resulting 8% decrease in sound level should allow TTi to see a 4% drop in returns by Q2 next year. A before and after view of the product change can be seen in the figures below.

Define Phase

Anderson Fan Project Charter

Project	*Anderson Fan Return Rate Reduction*		
Project Lead	*Jordan Clarke*	**Date**	*9/19/18*
Phone	*803-374-5444*	**Email**	*akclark@clemson.edu*

Business Case	*Techtronic Industries is the largest consumer power tools company in North America. TTi primarily supplies its largest customer, The Home Depot, with Ridgid and Ryobi products. Recently TTi sold in a new product to Home Depot, The Anderson Fan. This is the first ceiling fan TTi has produced. As a new brand in the ceiling fan market, it is crucial that the fan appeals to customers both visually and functionally. Sales are also crucial to maintain our firm relationship with Home Depot and our effort to increase our bottom line while developing a reputable and quality brand name. If these problems are not addressed, TTi risks having its ceiling fan brand become known as low quality.*
Problem Statement	*There is a 12% return rate for the Anderson fan, this sums to a $41,592 loss of revenue per year in this category.*
Project Objective	*The goal is to decrease the amount of returns from %12 to ~%8 by Q2 2019 which could result to saving $12,477.*
Primary Metric	*Reducing Return Rate is the primary metric for this project. It is being calculated and measured quarterly based on the report from customer (Home Depot) and TTI's quality department.*
Secondary Metric	*Amount of reoccurring sales to the customer, customer satisfaction. The sales are calculated on quarterly bases and are projected in sales of TTI.*
High Level Timeline	***Define:*** *September 26th* ***Measure:*** *October 10th* ***Analyze:*** *October 31st* ***Improve:*** *November 14th* ***Control:*** *December 5th*
Project Scope	*The scope will be for factory and non-factory related returns across all models (colors) of the Anderson fan*
Project Team	*Austin Clark, Arash Rashidghamat, Jordan Clarke*
Stakeholders	*TTi, The Home Depot*
Approvers	*Product Manager*
Constraints	*The time constraint might reduce the amount of data collected since the sales are reported in quarterly bases.*
Dependencies	*The project success lies upon information received from the customer (Home Depot) and their customers to determine the root cause of product returns.*
Risks	*Brand Risk, Financial Risk*

Project Schedule and Responsible Parties

	D 9/26/18	M 10/31/18	A 11/07/18	I 11/21/18	C 12/2/18
A	Dee Kivett	Dee Kivett	Dee Kivett	Dee Kivett	Dee Kivett
R	Product manager	Quality team, Analytical team		Engineering Department	Quality Team
M	Austin, Jordan, Arash	Austin, Michael	Austin, Jordan, Arash	Ronnie	
I	Product manager		Austin, Jordan, Arash	TTI	Product manager, Dee Kivett

A **Approval** of team decisions outside their charter authorities, i.e., sponsor, business leader

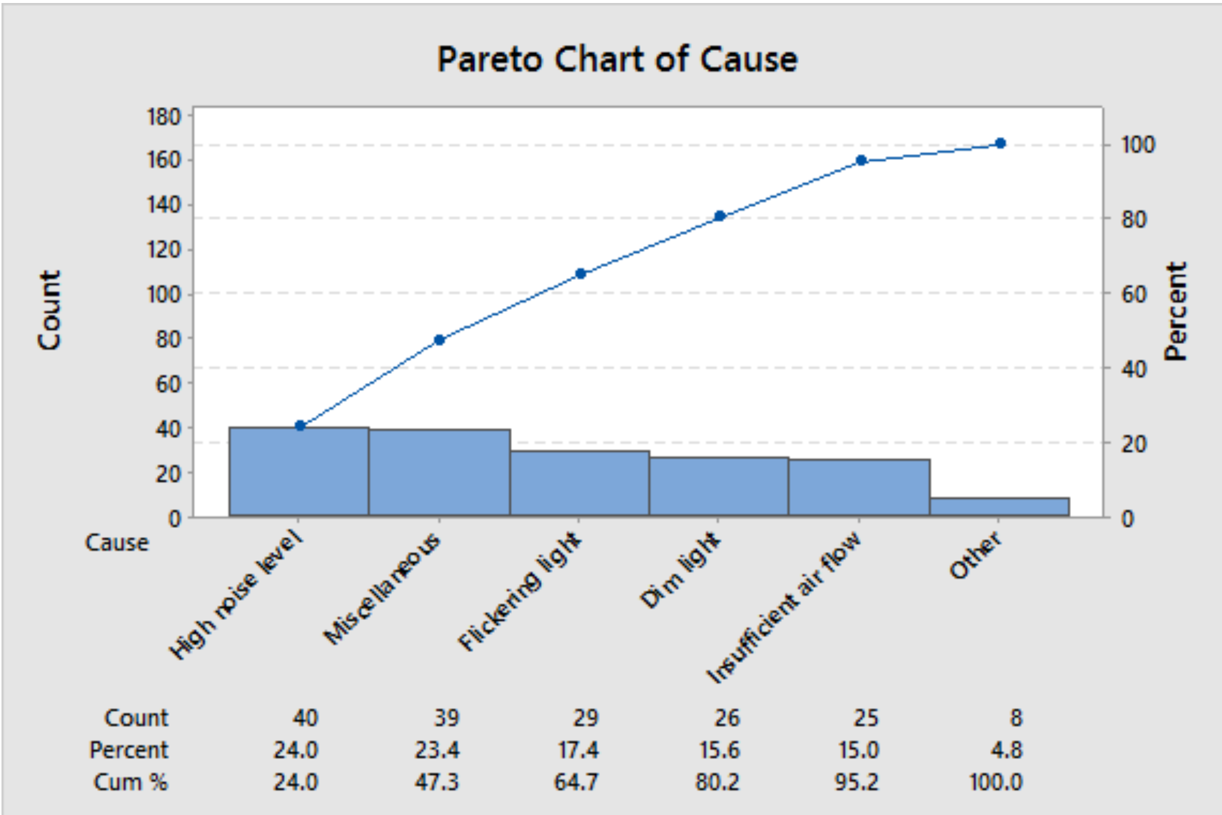
R **Resource** to the team, one whose expertise, skills, or clout may be needed on an ad hoc basis

M **Member** of team, with the authorities and boundaries of the charter

I **Interested** party, one who will need to be kept informed on

A schedule was developed including responsible parties for each phase of the project in order to keep track of project progress as well as accountability. The schedule above shows how each team member as well as company departments relate to the project and how they are involved based on classification of Approval, Resource, Member, and Interested party.

Pareto Analysis of Customer Reviews

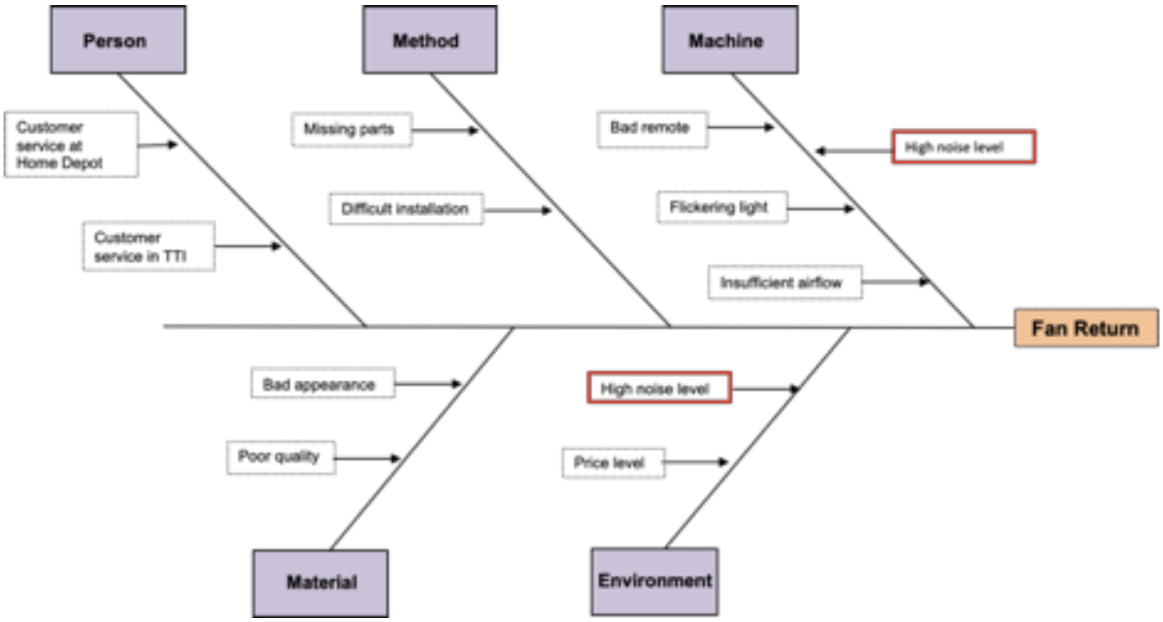


A pareto chart is a of descending bars with an ascending cumulative line at the top. It is used to visually analyze the frequency of problems in a process. An analysis of customer satisfaction and ratings on the Home Depot website was conducted. The causes of product return were categorized to better understand the causes of returning the product from customer prospective. 1, 2, and 3 star reviews were taken and broken down and categorized into 6 major issues; High noise level, miscellaneous, flickering light, dim light, insufficient air flow, and other. A Pareto chart was generated using the data extracted from the customer reviews. The Pareto chart revealed that 24% of the bad reviews were due to high noise level during product operation.

Measure Phase

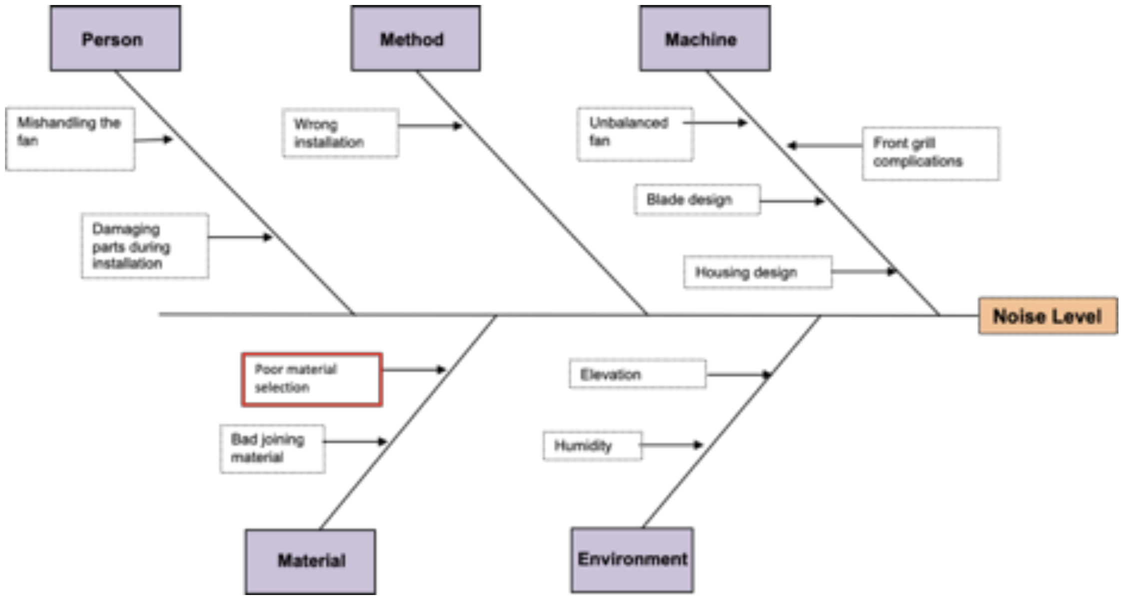
Cause and Effect Diagram

Fishbone diagram



In order to find out the root cause for fan returns a fishbone diagram was created. The categories that were investigated were person, method, machine, material and environment. Main characteristics of this fishbone diagram were reflecting the voice of customer that was extracted from customer reviews of the product accessed through online ratings. Based on this diagram and the VOC, high noise level was the most referenced issue that triggered the item return. Therefore, it had become the main focus of this project to tackle this issue.

To further focus on what causes the high noise level and tackle a specific issue, another fishbone diagram was created focusing on Xs that could lead to high noise level in the fan.

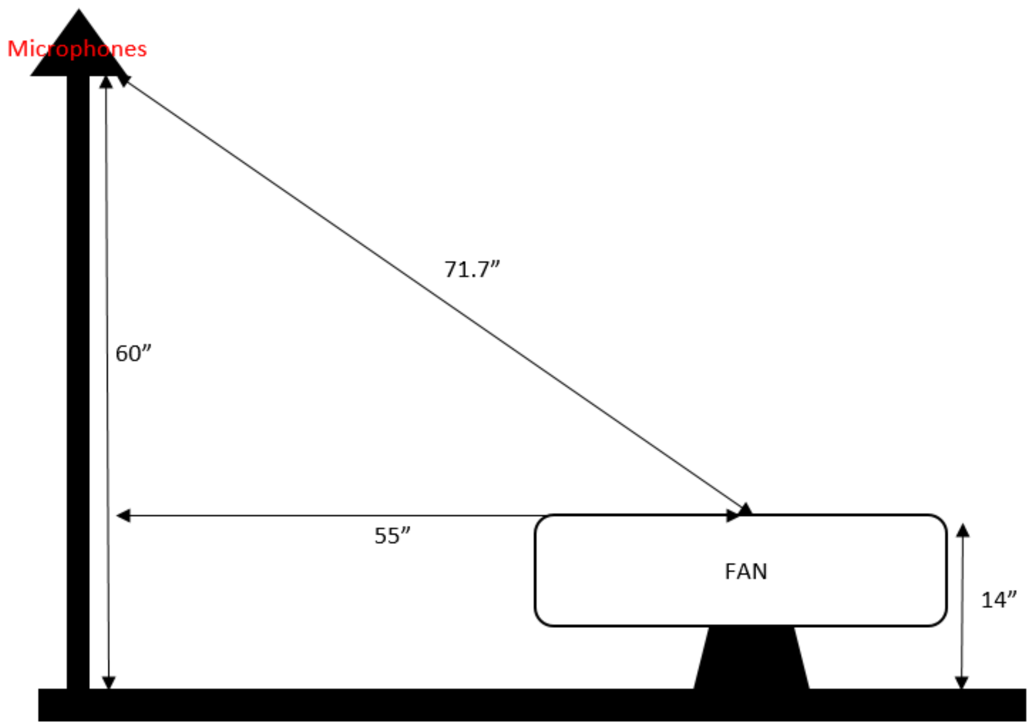


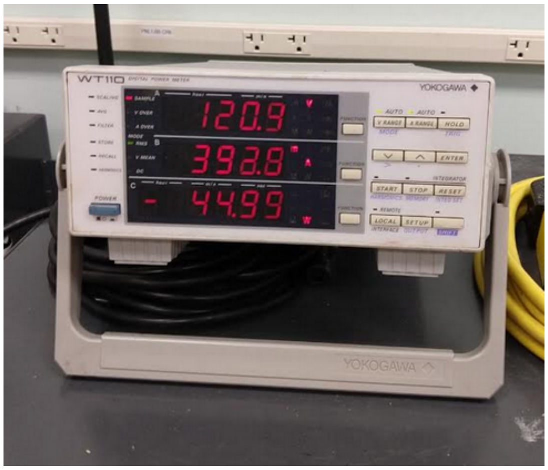
By doing some research it was discovered that many small fan designs are using lighter materials for fan blade, mostly plastic derivatives, rather than metallic compositions. Heavier blade requires more force from engine to rotate and inadvertently causes higher noise levels. So, it was decided to pursue and investigate the possibility of using an alternative material for fan blade and study the effects on the noise level.

The fishbone diagram above was created to identify, organize, and display the potential causes of our fan returns in a graphical way. The five main categories selected for potential causes of returns are Person, Method, Machine, Material, and Environment. It can be seen from the Pareto chart in the previous section that high noise level of the fan is the highest impact cause. High noise level of the fan is the metric (x) we will be focusing on.

Measurement Setup

The test setup for noise level measurement consisted of 3 microphones on a 60 inch tall microphone stand in an array 55 inches away from the center of the fan that was placed 14 inches off the ground with the air flow directed upwards. A diagram of the setup can be seen below. A power supply of 120VAC was supplied to each fan at high speed to eliminate variance in fan speed.



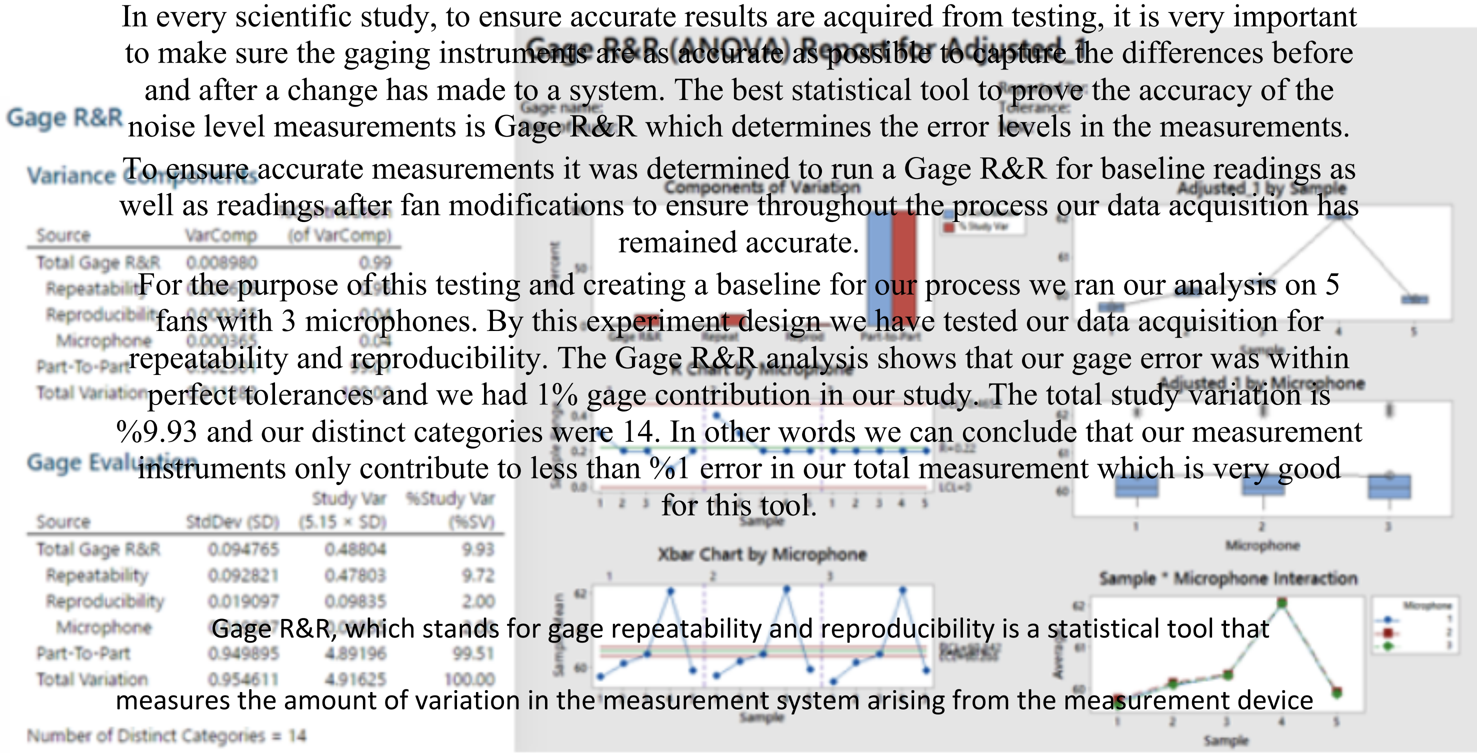


Gage R&R

Gage R&R

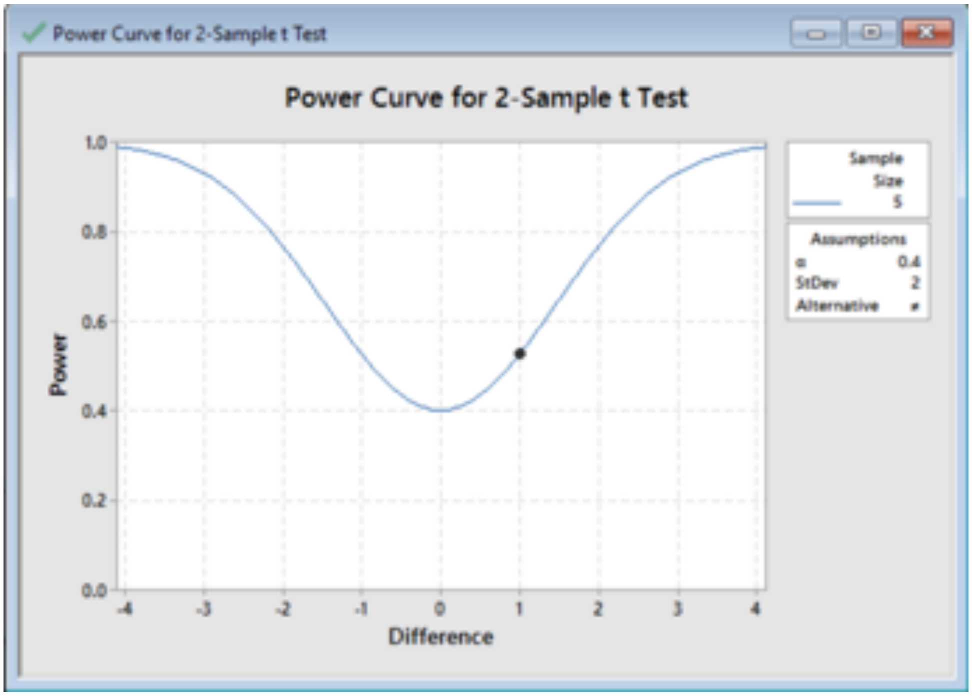
In every scientific study, to ensure accurate results are acquired from testing, it is very important to make sure the gaging instruments are as accurate as possible to capture the differences before and after a change has made to a system. The best statistical tool to prove the accuracy of the noise level measurements is Gage R&R which determines the error levels in the measurements. To ensure accurate measurements it was determined to run a Gage R&R for baseline readings as well as readings after fan modifications to ensure throughout the process our data acquisition has remained accurate.

For the purpose of this testing and creating a baseline for our process we ran our analysis on 5 fans with 3 microphones. By this experiment design we have tested our data acquisition for repeatability and reproducibility. The Gage R&R analysis shows that our gage error was within perfect tolerances and we had 1% gage contribution in our study. The total study variation is %9.93 and our distinct categories were 14. In other words we can conclude that our measurement instruments only contribute to less than %1 error in our total measurement which is very good for this tool.



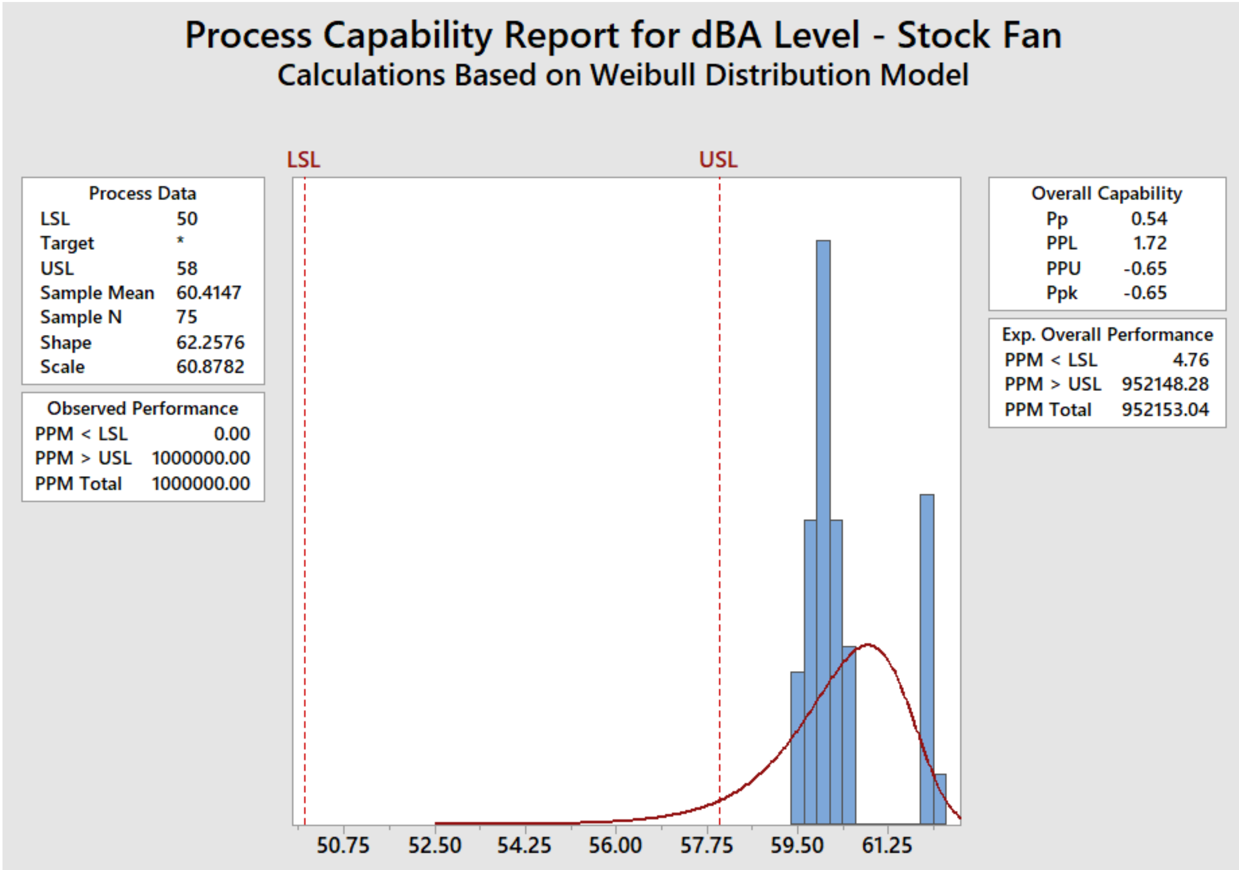
Gage R&R, which stands for gage repeatability and reproducibility is a statistical tool that measures the amount of variation in the measurement system arising from the measurement device and the people taking the measurement. Repeatability evaluates whether the same appraiser can obtain the same value multiple times when measuring the same object using the same equipment under the same environment. Reproducibility evaluates whether different appraisers can obtain the same value measuring the same object interpedently. The Gage R&R only addresses the precision of the measurement system. For the purpose of this testing and creating a baseline for our process we ran our analysis on 5 fans with 3 microphones. The Gage R&R analysis shows that our gage error was within perfect tolerances and we had 1% gage contribution in our study. The total study variation is 9.93% and our distinct categories were 14.

The 5 fans were randomly selected from the company's stock to minimize the risk of biased sampling. Although having more samples would have provided higher confidence level in our data, the limitation was imposed by cost of sampling and limited budget. Based on the 5 fans acquired, and using Minitab it was determined that this number of samples means we can detect 1 unit of change (1desibel) with %51 chance and error tolerance of %40 and standard deviation of 2.



Process Capability

Process capability measures how well the process performs to meet a given outcome. This analysis helps us to better understand the performance of the process with respect to meeting customer specifications and identify process improvement opportunities. The metrics used in this tool to determine capability vary but the main indicies are capability of the process with k factor adjustment (Cpk) and performance of the process with k factor adjustment (Ppk). The Cpk and Ppk both take variation and average of the process into consideration for their calculations. Generally a Ppk and Cpk greater than 1.0 are fairly capable processes but the greater your Ppk and Cpk that better.



To determine process capability for the fan at high speeds, the data was checked for normality. Our data had a non-normal distribution so the process capability for non-normal data was performed.The test results show that the measurements taken of the fan on high speed are all above our set acceptable limit of noise. It can be inferred from the graph that our process is precise but not accurate and it should be shifted within the spec limits. It can also be seen in the chart that our Ppk is much below 1.0 thus an extremely uncapable process.

Failure Modes and Effects Analysis

A failure modes and effects analysis (FMEA) document was created to further determine the main failure modes which could possibly lead to customer returning the products. This document is essentially a list of all of the components of the fan and ways in which they can fail. Each line is given a ranking of severity (how severe the issue), occurance (how often this issue could occure), and detction (how easy it is to detect the issue). These numbers are multiplied and each potential issue is given a score. For our document, a score over 150 is unacceptable and would need to be addressed before moving on with the product. Several members of the TTi team were involved in developing the document. The top 5 causes were determined to be:

1. The diffuser fan shroud broken/deformed due to impact (Customer drops fan during installation).
2. Receiver PCBA abnormal (remote lost or broken).
3. Housing appearance degraded due to UV damage. (Fan installed outside)
4. Gaps created in the housing due to vibration (Mechanical failure-Fan off centered in production).
5. Misinformation due to labeling on the product being damaged (Incorrect labeling in production).

This document was very useful in identifying potential issues and reasons for fan returns. This helps in pinpointing a critical X to be tested and deployed in the next phases of the project. The FMEA can be seen in the following pages.

Verification and Elimination in Analyze

Possible X's to be verified:

- Noise Level
- Flickering Light

Possible X's to be eliminated:

- Insufficient air flow
- Bad remote
- Missing parts
- Dim light

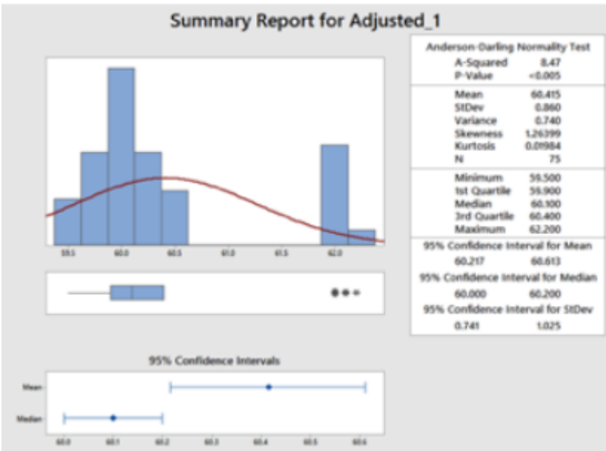
Analyze Phase

Sampling Strategy

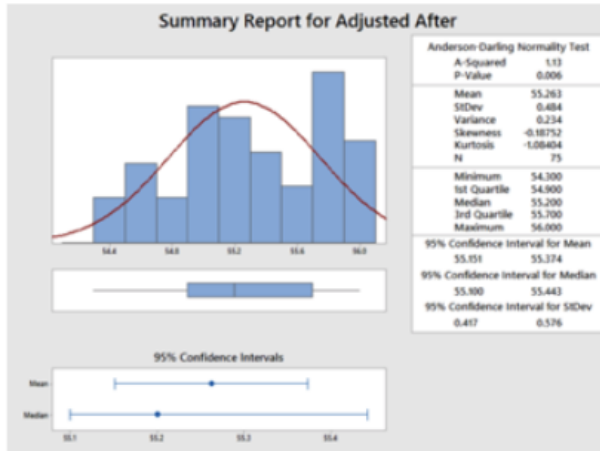
For the purpose of this project a large number of samples were deemed too costly and time consuming to test. A simple random sampling strategy was established to collect data from a subset of the population. 5 random fans were pulled from the warehouse shelves with no bias to the selection. This technique should minimize variation between the samples used for testing. The sample size was chosen to be 5 due to cost and time constraints. With this small sample size there is a higher risk that the statistics will not reflect the true population parameter. For the project historical data is limited because it is a new to market product. If more information were available for the population a suggested sample sized could be calculated using Minitab.

Normality Test

Measurements before Fan change



Measurements after Fan change



Normality test are used to determine if a data-set is well modeled by a normal distribution and to compute how likely it is for a random variable underlying the data set to be normally distributed. In descriptive statistics terms, it measures a goodness of fit of a normal model to the data. The Normality test was ran on the sound measurements of stock fan and improved fan. The normality test basically compares to scenarios which are called hypothesis. Null hypothesis is that the data is normal and the alternative hypothesis is that the data is not normnal. The P value as the critical metric determines which hypothesis is correct. As shown above in the chart since the p-values for the stock and improved fan data were less than the alpha level (0.05), we reject the null and claim that the data is not normal.

Mann-Whitney Test

The most important objective of this study is to reduce the return rate of the fans by reducing the noise level. To quantify this objective it is important to compare the noise levels after the engineering modifications are made to the fans. In order to make such comparison, different statistical tools could be implemented. The first step to find the right tool is to test the acquired data for Normality. The Normality test basically determines if the data are going to fit under the bell curve or not and depending on Normal or non-normal data, different tools must be used.

After running the normality test on both data sets for before and after modification it was determined that the data is not normally distributed.

Mann-Whitney: Improved Fan, Stock Fan

Method

η_1: median of Improved Fan
η_2: median of Stock Fan
Difference: $\eta_1 - \eta_2$

Descriptive Statistics

Sample	N	Median
Improved Fan	75	55.2
Stock Fan	75	60.1

Estimation for Difference

Difference	CI for Difference	Achieved Confidence
-4.9	(-5.1, -4.7)	95.02%

Test

Null hypothesis $H_0: \eta_1 - \eta_2 = 0$
Alternative hypothesis $H_1: \eta_1 - \eta_2 \neq 0$

Method	W-Value	P-Value
Not adjusted for ties	2850.00	0.000
Adjusted for ties	2850.00	0.000

To find out if there is a statistical difference between the noise levels before and after implementing the new fan blade design and since the data was not normal, the Man-Whitney test was used to determine if there is any significance between after making the fan blade design change. Two hypothesis are usually being tested by using Mann-Whitney test. Null hypothesis is that there are no statistical difference between the median value of the previous and new data sets or alternative hypothesis that determines there is a difference between the two data sets. P value is the deciding factor in determining the result of the test. Since the P value is less than 0.05, we reject the null hypothesis and conclude that there is a statistical significance after making the fan blade modification. The median values (The chart segment titled Descriptive Statistics) show that the noise level has been lowered by 4.9 dBA.

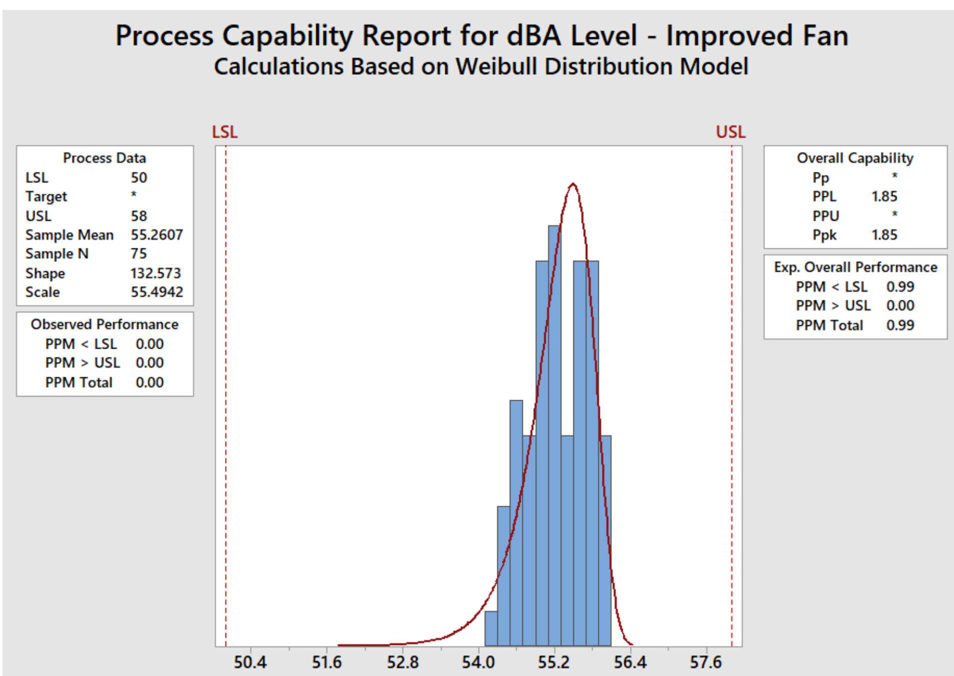
The fan noise level is a verified critical X that will be tested and deployed in the Improve phase. In order to tackle this critical X we will be changing the fan blade design and re-testing the fans for any measurable noise reduction.

Improve Phase

The fan blade design was studied and it was found that the current metal design was a major contributing source of noise. A plastic design was 3D printed and installed on our samples and tested for noise reduction. The raw data showed roughly a 5dBA decrease. This data was analyzed further to ensure that our process was still reliable.

Product Improvement (Capability)

Process capability measures how well the process performs to meet a given specified outcome. The process capability test was re-run in order to show the shift in the improved fan data. The data remained a similar distribution but shifted within the upper and lower limits. The process is now capable based on customer requirements.



Product Improvement (Gage R&R)

After implementing the fan design change, we had to test for noise levels again to see if we had any significant changes in our data acquisition. The Gage R&R study shows on the borderline of acceptable by %8.89 contribution percentage and total Gage R&R study variation of %29.82. The higher level of error in our measurement system after implementing fan modifications could be attributed to the fact that the new fan installation was handled by hand and the fan blade was produced with 3D printing rather than industry standard of mold injection.

Gage R&R

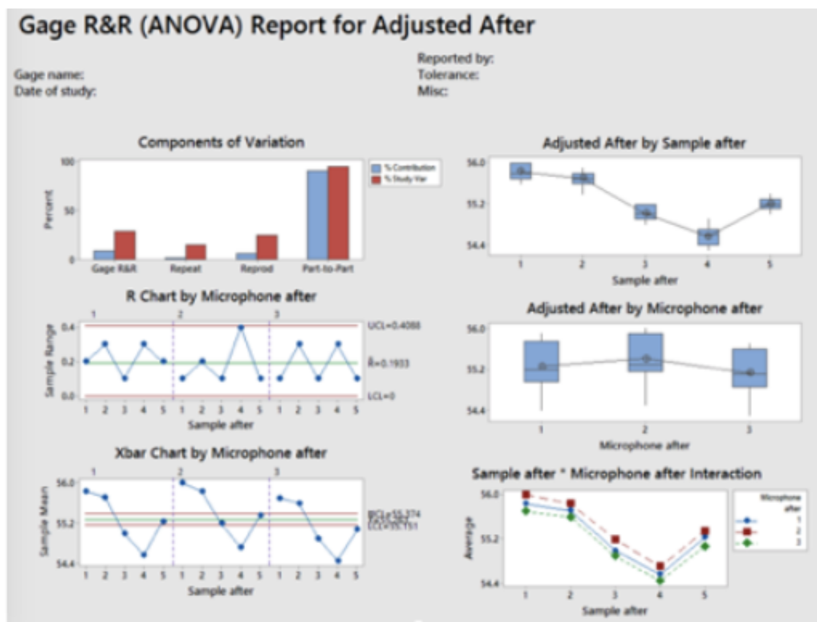
Variance Components

Source	VarComp	%Contribution (of VarComp)
Total Gage R&R	0.025790	8.89
Repeatability	0.006992	2.41
Reproducibility	0.018798	6.48
Microphone a	0.018798	6.48
Part-To-Part	0.264303	91.11
Total Variation	0.290093	100.00

Gage Evaluation

Source	StdDev (SD)	Study Var (5.15 × SD)	%Study Var (%SV)
Total Gage R&R	0.160592	0.82705	29.82
Repeatability	0.083619	0.43064	15.53
Reproducibility	0.137105	0.70609	25.46
Microphone a	0.137105	0.70609	25.46
Part-To-Part	0.514104	2.64763	95.45
Total Variation	0.538602	2.77380	100.00

Number of Distinct Categories = 4



Executive summary of improvement results.

After the improved fan blade design was implemented noise level for the fan decreased from and average of 60dBA to 55dBA, roughly an 8% decrease. The only change made to the Anderson fan was the replacement of the metal fan blades to plastic blades. This change lowered the sound level of the fan significantly and is a major improvement to the current fan design. The data and analysis show that our measurement process is reliable in repeatability and reproducibility and that our design change shifted noise level of our fan well within the customer requirements.

Control Phase

- Control Plan Including Response Plan (Arash)

Control plan by definition ensures that any 6Sigma project implementation is sustained through different documentation or training. Some of the core benefits of Control Phase is to ensure the well communicated roll out plan for a new process or change in an existing process. It also controls a standard communication to notify all involved parties and personnel and informs them of the changes that has been initiated.

For this particular project, based on the finding of material selection importance, a training plan and communication plan is necessary to ensure the new engineers and current design engineers are trained properly to utilize and test different materials for new products before just implementing them without proper preliminary investigation. A communication plan ensures that all the new and current design engineers are communicated with importance of material selection. A training plan from Technical Leader as a recorded online course and test would ensure engineers are aware of such material.