Deliverable 7

Engineering of Systems I

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5/6/15

Background Information

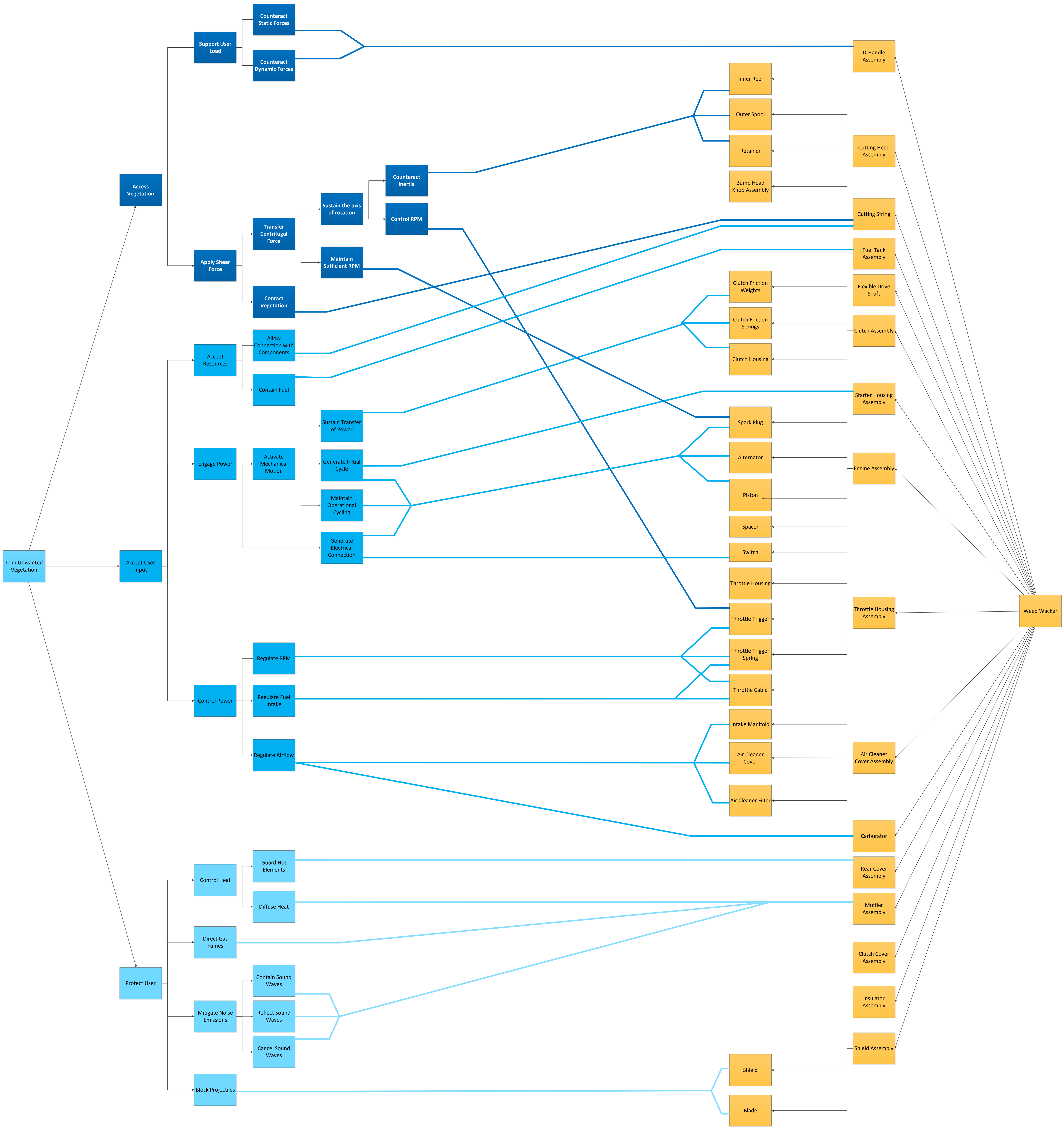
1.1.1 Customer Requirements

The customer requirements below are from the HOQ QFD 1 analysis. There weren't any updates on the number, quantity, or weight of our customer requirements, but we have developed a deeper understanding of them. These customer requirements will be applied in the Voice of Customer-based Failure Modes and Effects Analysis (VOC FMEA).

Customer Requirements	Customer Weights
A Safe Product	10%
Eco-Friendly	4%
Multi-Functional	8%
Durable Product	15%
Ergonomic	15%
Quality Performance	30%
Easy-to-Use	18%

1.1.2 Function-to-Structure Map for Weedwacker

Provided below is the Function-to-Structure Map that we came up with from deliverable 5. This maps how the functions are connected to the components in the bill of materials. This map will be applied in the Scenario-based & Function-based Failure Modes and Effects Analysis.



Trim Unwanted Vegetation
Access Vegetation
Accept User Input
Protect User
Support User Load
Apply Shear Force
Counteract Static Forces
Counteract Dynamic Forces
Transfer Centrifugal Force
Contact Vegetation
Sustain the axis of rotation
Maintain Sufficient RPM
Counteract Inertia
Control RPM
Accept Resources
Allow Connection with Components
Contain Fuel
Engage Power
Activate Mechanical Motion
Sustain Transfer of Power
Generate Initial Cycle
Maintain Operational Cycling
Generate Electrical Connection
Control Power
Regulate RPM
Regulate Fuel Intake
Regulate Airflow
Control Heat
Guard Hot Elements
Diffuse Heat
Direct Gas Fumes
Mitigate Noise Emissions
Contain Sound Waves
Reflect Sound Waves
Cancel Sound Waves
Block Projectiles
D-Handle Assembly
Inner Reel
Outer Spool
Retainer
Bump Head Knob Assembly
Cutting Head Assembly
Cutting String
Fuel Tank Assembly
Flexible Drive Shaft
Clutch Friction Weights
Clutch Friction Springs
Clutch Housing
Clutch Assembly
Starter Housing Assembly
Spark Plug
Alternator
Piston
Spacer
Engine Assembly
Switch
Throttle Housing
Throttle Trigger
Throttle Trigger Spring
Throttle Cable
Throttle Housing Assembly
Weed Wacker
Intake Manifold
Air Cleaner Cover
Air Cleaner Filter
Air Cleaner Cover Assembly
Carburator
Rear Cover Assembly
Muffler Assembly
Clutch Cover Assembly
Insulator Assembly
Shield Assembly
Shield
Blade

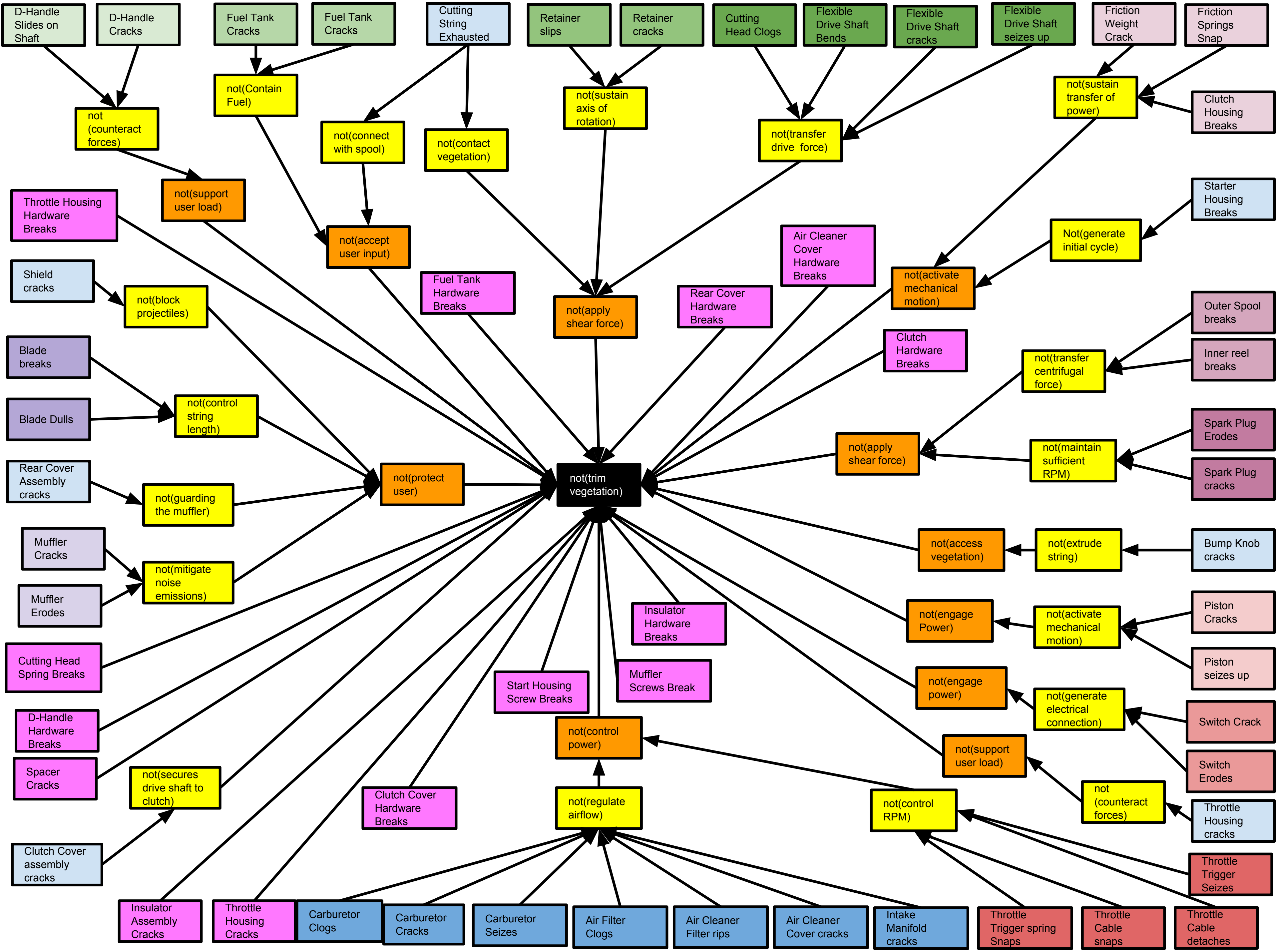
Analysis
1.2.1 Scenario and Function Based FMEA Diagram

The network diagram below was created using the methodology presented in Figure 12-6 of the FMEA ME317 document. The purpose of this diagram is to think of failures in terms of a cause and effect chain of events. Each unique pathway from the outer ring to the center is represented by a row in the FMEA diagram. The outer ring of the diagram represents a failure of a physical part. This failure event flows into the failure of a sub-function. These sub-functions continue to combine into their parent functions. They will finally congregate in the center of the diagram, our product's main function, which is the pinnacle of our function-tree.

The outer ring color scheme represents parts that are both associated with the same sub-function. Yellow is then used to indicate any sub-functions present in the second level with orange being used to identify the sub-functions of the third level. Hardware failures (Magenta) are directly connected to the center with no direct ties to a sub-function but still relevant to a total failure.

The following analysis below was created with the results found in the network diagram. Rows found in the FMEA came from the unique pathways identified in the network diagram as previously mentioned. Additional scenarios identified during the creation of the FMEA were then re-applied into the network diagram. Examples include the creation of potential causes: Blade Dulling, Switch Eroding, and Air Filter Clogging. This showed us that using a scenario-based and function-based analysis supplement one another when determining all potential Failure Modes and calculating the RPN numbers.

The FMEA showed us that airflow is a large target for failure due to the potential causes: Air Filter Clogs and Carburetor Clogs at an RPN of 224 and 147 respectively. These values are due to a high severity of 7 for both causes due to the end effect of the engine stops running which would result in a loss of primary function. The Air Filter Clogs also is a high occurrence of 9 due to the cheap quality of this component. The Carburetor Clogs has a high detection of 7 due to the complexity and quality of this component such that users are less likely to look into the carburetor early on into the trouble shooting phase of why the engine stopped running. These two potential causes ended up in the top six of the Pareto FEMA Analysis. The Functional FMEA shows the group the importance of handling these air flow based components in redesign improvements for minimizing risk.



D-Handle Slides on Shaft
D-Handle Cracks
Fuel Tank Cracks
Fuel Tank Cracks
Cutting String Exhausted
Retainer slips
Retainer cracks
Cutting Head Clogs
Flexible Drive Shaft Bends
Flexible Drive Shaft cracks
Flexible Drive Shaft seizes up
Friction Weight Crack
Friction Springs Snap
not (counteract forces)
not(Contain Fuel)
not(connect with spool)
not(contact vegetation)
not(sustain axis of rotation)
not(transfer drive force)
not(sustain transfer of power)
Clutch Housing Breaks
Throttle Housing Hardware Breaks
not(support user load)
not(accept user input)
Starter Housing Breaks
Air Cleaner Cover Hardware Breaks
Not(generate initial cycle)
Shield cracks
not(block projectiles)
Fuel Tank Hardware Breaks
not(apply shear force)
Rear Cover Hardware Breaks
not(activate mechanical motion)
Clutch Hardware Breaks
Outer Spool breaks
Blade breaks
not(transfer centrifugal force)
Inner reel breaks
Blade Dulls
not(control string length)
Spark Plug Erodes
not(apply shear force)
not(maintain sufficient RPM)
Rear Cover Assembly cracks
not(protect user)
not(trim vegetation)
Spark Plug cracks
not(guarding the muffler)
Muffler Cracks
not(access vegetation)
not(extrude string)
Bump Knob cracks
not(mitigate noise emissions)
Muffler Erodes
Insulator Hardware Breaks
not(engage Power)
not(activate mechanical motion)
Piston Cracks
Cutting Head Spring Breaks
Piston seizes up
Start Housing Screw Breaks
Muffler Screws Break
not(engage power)
not(generate electrical connection)
D-Handle Hardware Breaks
Switch Crack
not(control power)
Spacer Cracks
not(secures drive shaft to clutch)
not(support user load)
Switch Erodes
Clutch Cover Hardware Breaks
not(regulate airflow)
not(control RPM)
not (counteract forces)
Throttle Housing cracks
Clutch Cover assembly cracks
Throttle Trigger Seizes
Insulator Assembly Cracks
Throttle Housing Cracks
Carburetor Clogs
Carburetor Cracks
Carburetor Seizes
Air Filter Clogs
Air Cleaner Filter rips
Air Cleaner Cover cracks
Intake Manifold cracks
Throttle Trigger spring Snaps
Throttle Cable snaps
Throttle Cable detaches

Failure Modes & Effects Analysis

System Name: Craftsman 25-cc Curved Shaft
Major Function: Trim Unwanted Vegetation
Prepared By: EOS 1 Group 4 - Spring 2015

FMEA Number: 1
Page: 1
Date: 5/6/2015

Function or Requirement	Potential Failure Modes	Potential Causes of Failure	Occurrence	Local Effects	End Effects on Product, User, Other Systems	Severity	Detection Method/ Current Controls	Detection	RPN	Actions Recommended to Reduce RPN	Responsibility and Target Completion Date
SUPPORT USER LOAD											
Counteract Forces	Not counteract forces	D-Handle Slides on Shaft	6	No Stability	Potential user injury	6	Visual Inspection	3	108	Actions to reduce the severity of the failure mode in terms of its impact on the user, performance, and other systems	
		D-Handle Cracks	3	No Stability	Potential user injury	7	Visual Inspection	2	42	Actions to reduce the severity of the failure mode in terms of its impact on the user, performance, and other systems	
		Throttle Housing Cracks	4	Vibration Pain	Potential user injury	7	Visual Inspection	2	56	Actions to reduce the severity of the failure mode in terms of its impact on the user, performance, and other systems	
ACCEPT USER INPUT											
Contain Fuel	Not contain fuel	Fuel Tank Cracks	2	No Fuel	No Energy source	10	Visual Inspection	2	40	Design solutions to eliminate the failure mode or reduce likelihood, including: functional redundancies and error proofing the assembly, installation and usage.	
		Fuel Tank Empties	10	No Fuel	No Energy source	8	Visual Inspection	1	80	Providing diagnostics to easily identify the failure mode or cause during manufacturing or operation	
Connect with Spool	Not connect with spool	Cutting String Exhausted	10	No String	Vegetation not trimmed	8	Replace the String	1	80	Establish periodic maintenance or check-ups to enhance availability and safety	
APPLY SHEAR FORCE											
Contact Vegetation	Not contact vegetation	Cutting String Exhausted	10	No String	Vegetation not trimmed	8	Replace the String	1	80	Establish periodic maintenance or check-ups to enhance availability and safety	
Sustain Axis of Rotation	Not sustain axis of rotation	Retainer Slips	2	Cutting Head Slides	Potential user injury	10	None	2	40	Actions to reduce the severity of the failure mode in terms of its impact on the user, performance, and other systems	
		Retainer cracks	1	Cutting Head Slides	Potential user injury	10	None	2	20	Actions to reduce the severity of the failure mode in terms of its impact on the user, performance, and other systems	
Transfer Drive Force	Not transfer drive force	Cutting Head Clogs	7	No Shear Force Applied	Vegetation not trimmed	7	Visual/Auditory Inspection	1	49	Establish periodic maintenance or check-ups to enhance availability and safety	
		Flexible Drive Shaft Cracks	1	No Shear Force Applied	Vegetation not trimmed	10	Visual Inspection	1	10	Test to provide more information data to assess likelihood and severity	
		Flexible Drive Shaft Seizes Up	2	No Shear Force Applied	Vegetation not trimmed	8	Testing	2	32	Test to provide more information data to assess likelihood and severity	
		Flexible Drive Shaft Bends	3	No Shear Force Applied	Vegetation not trimmed	8	Visual Inspection	1	24	Test to provide more information data to assess likelihood and severity	
Transfer Centrifugal Force	Not transfer centrifugal force	Outer Spool Breaks	4	No Shear Force Applied	Vegetation not trimmed	10	Visual Inspection	3	120	Design solutions to eliminate the failure mode or reduce likelihood, including: functional redundancies and error proofing the assembly, installation and usage.	
		Inner Reel Breaks	2	No Shear Force Applied	Vegetation not trimmed	7	Manual Inspection	3	42	Design solutions to eliminate the failure mode or reduce likelihood, including: functional redundancies and error proofing the assembly, installation and usage.	
Maintain Sufficient RPM	Not maintain sufficient RPM	Spark Plug Erodes	9	Engine Shuts Off	Vegetation not trimmed	8	Manual Inspection	5	360	Establish periodic maintenance or check-ups to enhance availability and safety	
		Spark Plug Cracks	3	Engine Shuts Off	Vegetation not trimmed	8	Manual Inspection	5	120	Providing diagnostics to easily identify the failure mode or cause during manufacturing or operation	
ACTIVATE MECHANICAL MOTION											
Sustain Transfer of Power	Not sustain transfer of power	Friction Weight Cracks	1	Cutting Head Stops	Vegetation not trimmed	7	Testing	10	70	Test to provide more information data to assess likelihood and severity	
		Friction Spring Snaps	2	Cutting Head Stops	Vegetation not trimmed	7	Visual Inspection	10	140	Test to provide more information data to assess likelihood and severity	
		Clutch Housing Breaks	2	Cutting Head Stops	Vegetation not trimmed	8	Visual Inspection	8	128	Developing means of detecting causes of failure modes during manufacturing including: inspection, testing, and error proofing.	
Generate Initial Cycle	Not generate initial cycle	Starter Housing Breaks	4	Weedwhacker doesn't start	Vegetation not trimmed	8	Visual Inspection	1	32	Developing means of detecting causes of failure modes during manufacturing including: inspection, testing, and error proofing.	
ACCESS VEGETATION											
Extrude String	Not extrude string	Bump Knob Cracks	5	Bump knob does not work	No string extrusion	7	Visual Inspection	3	105	Developing means of detecting causes of failure modes during manufacturing including: inspection, testing, and error proofing.	
ENGAGE POWER											
Activate Mechanical Motion	Not activate mechanical motion	Piston Cracks	1	Engine Dies	Vegetation not trimmed	10	Testing	6	60	Test to provide more information data to assess likelihood and severity	
		Piston Seizes up	2	Engine Dies	Vegetation not trimmed	8	Testing	6	96	Test to provide more information data to assess likelihood and severity	
Generate Electrical Connection	Not generate electrical connection	Switch Cracks	2	Engine Dies	Vegetation not trimmed	4	Visual Inspection	2	16	Design solutions to eliminate the failure mode or reduce likelihood, including: functional redundancies and error proofing the assembly, installation and usage.	
		Switch Erodes	2	Weedwacker won't start	Vegetation not trimmed	8	Visual Inspection	4	64	Providing diagnostics to easily identify the failure mode or cause during manufacturing or operation	
CONTROL POWER											
Control RPM	Not control RPM	Throttle Trigger Seizes	3	Loss of control over power	Decreased functionality	6	Manual Inspection	1	18	Design solutions to eliminate the failure mode or reduce likelihood, including: functional redundancies and error proofing the assembly, installation and usage.	
		Throttle Cable Detaches	5	No Control Over Power	Vegetation not trimmed	8	Visual Inspection	2	80	Design solutions to eliminate the failure mode or reduce likelihood, including: functional redundancies and error proofing the assembly, installation and usage.	
		Throttle Cable Snaps	2	No Control Over Power	Vegetation not trimmed	8	Visual Inspection	2	32	Developing means of detecting causes of failure modes during manufacturing including: inspection, testing, and error proofing.	
		Throttle Trigger Spring Snaps	3	Reduced Control Over Power	Vegetation is no longer trimmed	6	Visual Inspection	2	36	Developing means of detecting causes of failure modes during manufacturing including: inspection, testing, and error proofing.	
Regulate Airflow	Not regulate airflow	Intake Manifold Cracks	3	Increased Airflow	Engine Stops Running	6	Visual Inspection	4	72	Developing means of detecting causes of failure modes during manufacturing including: inspection, testing, and error proofing.	
		Air Cleaner Cover Cracks	3	Increased Airflow	Engine Stops Running	5	Visual Inspection	4	60	Developing means of detecting causes of failure modes during manufacturing including: inspection, testing, and error proofing.	
		Air Cleaner Filter Rips	5	Reduced Clean Air	Engine Stops Running	5	Visual Inspection	4	100	Developing means of detecting causes of failure modes during manufacturing including: inspection, testing, and error proofing.	
		Air Filter Clogs	8	Reduced Clean Air	Engine Stops Running	7	Visual Inspection	4	224	Establish periodic maintenance or check-ups to enhance availability and safety	
		Carburetor Seizes	2	No Airflow	Engine Stops Running	7	Testing	5	70	Test to provide more information data to assess likelihood and severity	
		Carburetor Cracks	1	Reduced Airflow	Engine Stops Running	7	Visual Inspection	7	49	Test to provide more information data to assess likelihood and severity	
		Carburetor Clogs	3	Reduced Airflow	Engine Stops Running	7	Testing	7	147	Test to provide more information data to assess likelihood and severity	
Secure Drive Shaft to Clutch	Not secure drive shaft to clutch	Clutch Cover Assembly Cracks	3	Drive Shaft and Engine get loose	Potential User Injury	4	Visual Inspection	1	12	Actions to reduce the severity of the failure mode in terms of its impact on the user, performance, and other systems	
Trim Vegetation	Not trim vegetation	Insulator Assembly Cracks	2	Reduced Airflow	Engine Stops Running	6	Visual Inspection	2	24	Developing means of detecting causes of failure modes during manufacturing including: inspection, testing, and error proofing.	
		Spacer Cracks	1	Internal Vibration	Shortened product life	5	Visual Inspection	10	50	Developing means of detecting causes of failure modes during manufacturing including: inspection, testing, and error proofing.	
		D-Handle Hardware Strips	2	D-Handle is unstable	Potential User Injury	5	Manual Inspection	1	10	Providing diagnostics to easily identify the failure mode or cause during manufacturing or operation	
		Cutting Head Spring Breaks	4	Bump Head Knob loosens	String not extruded	6	Manual Inspection	6	144	Developing means of detecting causes of failure modes during manufacturing including: inspection, testing, and error proofing.	
PROTECT USER											
Mitigate Noise Emissions	Not mitigate noise emissions	Muffler Cracks	3	Noise Decibals Increase	Potential User Injury	4	Testing	2	24	Actions to reduce the severity of the failure mode in terms of its impact on the user, performance, and other systems	
		Muffler Erodes	6	Noise Decibals Increase	Potential User Injury	4	Testing	2	48	Actions to reduce the severity of the failure mode in terms of its impact on the user, performance, and other systems	
Guard the Muffler	Not guard the muffler	Rear Cover Assembly Cracks	3	Hot Metal is exposed	Potential User Injury	4	Visual Inspection	2	24	Actions to reduce the severity of the failure mode in terms of its impact on the user, performance, and other systems	
Control String Length	Not control string length	Blade Breaks	2	String Hits the sheild	Potential User Injury	4	Visual Inspection	2	16	Actions to reduce the severity of the failure mode in terms of its impact on the user, performance, and other systems	
		Blade Dulls	8	String Slides across the blade	Potential User Injury	3	Manual Inspection	2	48	Establish periodic maintenance or check-ups to enhance availability and safety	
Block Projectiles	Not block projectiles	Shield Cracks	5	Vegetation flows through the cracks	Potential User Injury	4	Visual Inspection	1	20	Actions to reduce the severity of the failure mode in terms of its impact on the user, performance, and other systems	
	Becomes a projectile	Shield Snaps Off	2	No Protection	Potential User Injury	10	Visual/Auditory Inspection	1	20	Design solutions to eliminate the failure mode or reduce likelihood, including: functional redundancies and error proofing the assembly, installation and usage.	

1.2.2 VOC FMEA

The VOC FMEA analysis found below began with the implementation of customer requirements. The functions under each requirement were determined from the experience of the user within the surrounding environment. These functions were also based on meeting customer requirements.The focus of our failure modes were based on events that would cause customer dissatisfaction. From there we determined every failure mode that resulted in the violation of customer requirements. We brainstormed the different possible causes for the failures, keeping in mind that it could be environmental, component interface, or customer usage related. From there we determined the values needed for the RPN calculations.

The VOC FMEA differed from the Functional FMEA in that the Functional FMEA focused on how the product can fail in performing its tasks while the VOC FMEA focused on how the product can fail at meeting the customer requirements. Each method provided additional failure modes that were not accounted for by the other. This suggests that focusing on both methods proves to be more effective than just focusing on one or the other. If either is left out, a critical failure mode could be missed and ultimately cause user injury or an unsuccessful product. However, if there is only time to perform one method, the Functional FMEA is recommended since more failure modes were detected compared to the VOC FMEA. The function-to-structure map proved to be a useful tool for the Functional FMEA as it helped to visually see and detect each failure mode. While the VOC FMEA gives us a good baseline for identifying those important failures that affect customer satisfaction, many of these can also be found in the Functional one. The functional FMEA gives us a vast understanding of the complete system and a very comprehensive analysis of many functional failures that may occur.

Failure Modes & Effects Analysis

System Name: Craftsman 25-cc Curved Shaft Weedwacker
Major Function: Trim Unwanted Vegetation
Prepared By: EOS 1 Group 4 - Spring 2015

FMEA Number: 2
Page: 2
Date: 5/6/2015

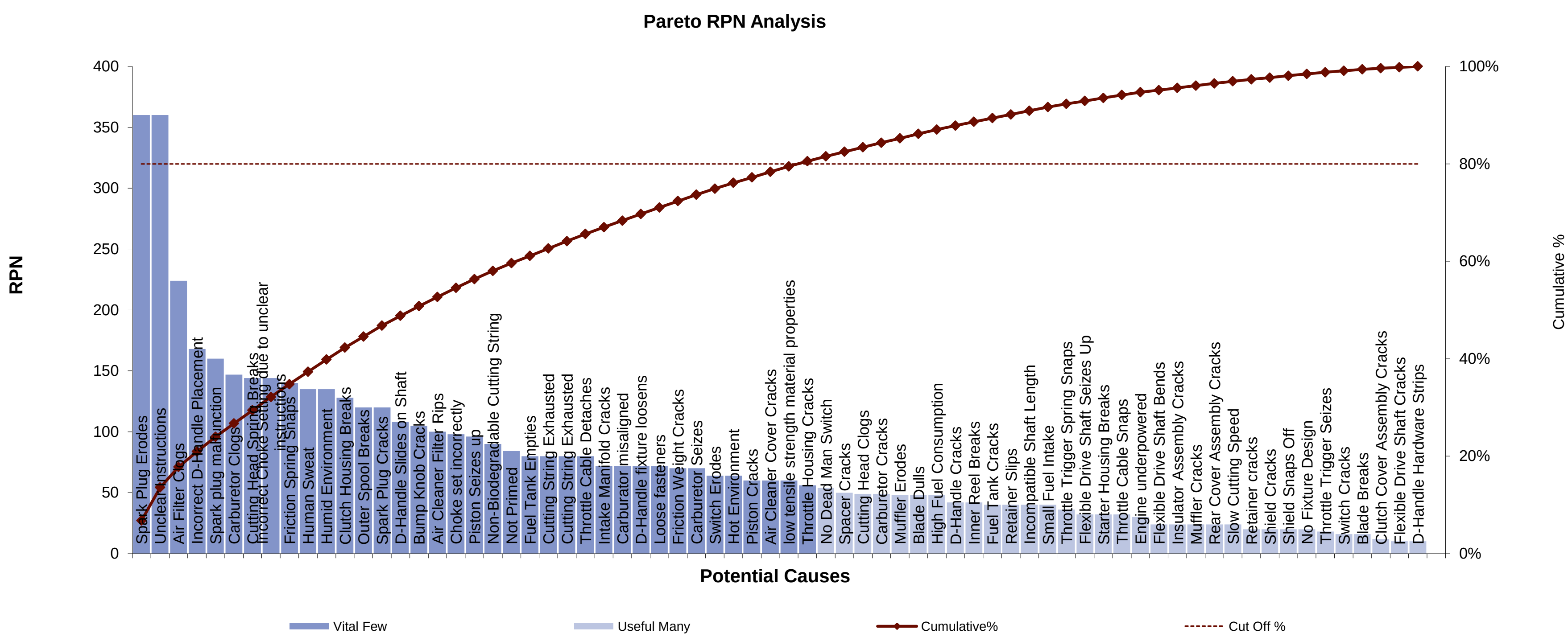
Function or Requirement	Potential Failure Modes	Potential Causes of Failure	Occurrence	Local Effects	End Effects on Product, User, Other Systems	Severity	Detection Method/ Current Controls	Detection	RPN	Actions Recommended to Reduce RPN	Responsibility and Target Completion Date
A SAFE PRODUCT											
Tight Grip Handles	Slippery when wet	Human Sweat	9	Decreased control	Inefficient vegetation trimming	5	Manual Inspection	3	135	Design solutions to eliminate the failure mode or reduce likelihood, including: functional redundancies and error proofing the assembly, installation and usage.	
	Slippery when wet	Humid Environment	9	Decreased control	Inefficient vegetation trimming	5	Manual Inspection	3	135	Design solutions to eliminate the failure mode or reduce likelihood, including: functional redundancies and error proofing the assembly, installation and usage.	
Automatic Shut Off	Throttle Trigger gets stuck	No Dead Man Switch	6	Won't turn off	Potential User Injury	9	Manual Inspection	1	54	Design solutions to eliminate the failure mode or reduce likelihood, including: functional redundancies and error proofing the assembly, installation and usage.	
ECO-FRIENDLY											
Low Fuel Odor	Sub-optimal Fuel:Air Ratio	Incorrect Choke Setting due to unclear instructions	4	Increased Emmisions	Inefficient Running of the Motor	6	Odor Detection	6	144	Test to provide more information data to assess likelihood and severity	
	Sub-optimal Fuel:Air Ratio	Carburator misaligned	2	Increased Emmisions	Inefficient Running of the Motor	6	Odor Detection	6	72	Establish periodic maintenance or check-ups to enhance availability and safety	
	Sub-optimal Gas:Oil Ratio	Unclear Instructions	6	Increased Emmisions	Ruining the Engine	10	Odor Detection	6	360	Design solutions to eliminate the failure mode or reduce likelihood, including: functional redundancies and error proofing the assembly, installation and usage.	
Decomposible String	String litter	Non-Biodegradable Cutting String	10	Harmful material released	Environmental Damage	3	Visual Inspection	3	90	Design solutions to eliminate the failure mode or reduce likelihood, including: functional redundancies and error proofing the assembly, installation and usage.	
MULTI-FUCNTIONAL											
Capable of Having Attachments	No Attachment Ability	No Fixture Design	10	Decreased functionality	More Tools needed for the Job	2	Manal Inspection	1	20	Design solutions to eliminate the failure mode or reduce likelihood, including: functional redundancies and error proofing the assembly, installation and usage.	
DURABLE PRODUCT											
Heat Control	Engine overheats	Hot Environment	4	Engine Shuts Down	Incomplete Job	8	Auditory/Manual Inspection	2	64	Establish periodic maintenance or check-ups to enhance availability and safety	
Long-Lasting String	String Breaks often	low tensile strength material properties	6	Frequent String Changeover	Annoyed User	5	Manual/Visual Inspection	2	60	Test to provide more information data to assess likelihood and severity	
Stable Control	Loss of Control	D-Handle fixture loosens	6	No Stability	Potential user injury	6		2	72	Establish periodic maintenance or check-ups to enhance availability and safety	
ERGONOMIC											
Comfortable to Hold	High levels of vibration	Loose fasteners	6	Decreased control	Inefficient vegetation trimming	6	Manual Inspection	2	72	Establish periodic maintenance or check-ups to enhance availability and safety	
Balanced Weight	Unbalanced weight distribution	Incorrect D-Handle Placement	7	Decreased control	Inefficient vegetation trimming	6	Manual Inspection	4	168	Establish periodic maintenance or check-ups to enhance availability and safety	
Easy Vegetation Access	Exerting Muscles to Cut Grass	Incompatible Shaft Length	8	Muscle fatigue	Potential User Injury	5	Visual Inspection	1	40	Actions to reduce the severity of the failure mode in terms of its impact on the user, performance, and other systems	
QUALITY PERFORMANCE											
Cuts Grass Immediately	Cuts Grass after multiple attempts	Slow Cutting Speed	4	Increased time of cutting	User Frustration	6	Visual Inspection	1	24	Providing diagnostics to easily identify the failure mode or cause during manufacturing or operation	
Continually Runs	Engine dies frequently during use	Engine underpowered	5	Engine Struggles to Operate	User Fatigue	6	Physical/Auditory Inspection	1	30	Providing diagnostics to easily identify the failure mode or cause during manufacturing or operation	
	Run out of Fuel	High Fuel Consumption	8	Engine Shuts Off	Vegetation not Trimmed	6	Visual Inspection	1	48	Providing diagnostics to easily identify the failure mode or cause during manufacturing or operation	
EASY-TO-USE											
Start with one swift pull	Starts after multiple pulls	Not Primed	7	Engine Struggles to Start	User Fatigue	6	Manual Inspection	2	84	Developing means of detecting causes of failure modes during manufacturing including: inspection, testing, and error proofing.	
	Starts after multiple pulls	Choke set incorrectly	7	Engine Struggles to Start	User Fatigue	7	Visual Inspection	2	98	Developing means of detecting causes of failure modes during manufacturing including: inspection, testing, and error proofing.	
	Doesn't Start after many pulls	Spark plug malfunction	4	Engine Shuts Off	Vegetation not Trimmed	8	Mechanical Inspection	5	160	Establish periodic maintenance or check-ups to enhance availability and safety	
Simple Fill Up	Spilled Fuel	Small Fuel Intake	8	Flammable Liquid on the User	Potential User Injury	5	Visual Detection	1	40	Developing means of detecting causes of failure modes during manufacturing including: inspection, testing, and error proofing.	

1.2.3 Pareto Chart & Discussion

The Pareto Analysis of the RPN values for each potential cause is found below. The potential causes Spark Plug Erodes and Unclear Instructions stand out as the highest risks for functional failure at 360 RPN each. The Air Filter Clogging was the next highest risk at a RPN of 224. There were 34 other components that contributed to the top 80.53% of the potential causes of failure.

Most of the components that resulted in the higher RPNs were expected due to the frequency of the occurrence and the severity as outlined in the Functional and VOC FMEA Tables. For example, the spark plug eroding will almost certainly occur over time so it was given an occurrence rating of 9. This failure was also given a relatively high severity rating, at 8, because if the spark plug becomes eroded then the weed whacker will have issues starting. Aside from the issues involving the spark plug, the potential cause with the third highest RPN was the air filter. This is something that we would not have initially thought to have been so significant, but after analyzing its severity, occurrence, and difficulty detecting we learn that it is quite important. When weed whacking there is a large amount of particulate in the air. As the motor takes in air it will also pull these particles in. The air filter will prevent any debris from entering the cylinder, but as material builds up in the filter the motor will begin to have trouble running and it will eventually cease to operate. The reason this is so significant is that it is not visible to the user. It is hidden in a black case that most operators may not think of checking at first. The detection of the potential causes had the lowest contribution since most of the failures were easily noticeable by the user and those that weren't had little chance of occurring.

The Pareto Analysis also showed us that just over half of the potential causes account for 80.53% as opposed to the traditional 20%. This means that our product has many components across many subsystems that affect the overall operation of the product, each with a relatively equal importance in relation to the overall function of the product. Out of these 37 potential causes, Unclear Instructions, Incorrect D-Handle Placement, Choke Set Incorrectly, and Fuel Tank Empties are low hanging fruit for us to come up with redesign improvements to reduce overall risk with the functionality of our product.


Pareto RPN Analysis
RPN
400
350
300
250
200
150
100
50
0
100%
80%
60%
40%
20%
0%
Cumulative %
Potential Causes
Spark Plug Erodes
Unclear Instructions
Air Filter Clogs
Incorrect D-Handle Placement
Spark plug malfunction
Carburetor Clogs
Cutting Head Spring Breaks
Incorrect Choke Setting due to unclear instructions
Friction Spring Snaps
Human Sweat
Humid Environment
Clutch Housing Breaks
Outer Spool Breaks
Spark Plug Cracks
D-Handle Slides on Shaft
Bump Knob Cracks
Air Cleaner Filter Rips
Choke set incorrectly
Piston Seizes up
Non-Biodegradable Cutting String
Not Primed
Fuel Tank Empties
Cutting String Exhausted
Cutting String Exhausted
Throttle Cable Detaches
Intake Manifold Cracks
Carburator misaligned
D-Handle fixture loosens
Loose fasteners
Friction Weight Cracks
Carburetor Seizes
Switch Erodes
Hot Environment
Piston Cracks
Air Cleaner Cover Cracks
low tensile strength material properties
Throttle Housing Cracks
No Dead Man Switch
Spacer Cracks
Cutting Head Clogs
Carburetor Cracks
Muffler Erodes
Blade Dulls
High Fuel Consumption
D-Handle Cracks
Inner Reel Breaks
Fuel Tank Cracks
Retainer Slips
Incompatible Shaft Length
Small Fuel Intake
Throttle Trigger Spring Snaps
Flexible Drive Shaft Seizes Up
Starter Housing Breaks
Throttle Cable Snaps
Engine underpowered
Flexible Drive Shaft Bends
Insulator Assembly Cracks
Muffler Cracks
Rear Cover Assembly Cracks
Slow Cutting Speed
Retainer cracks
Shield Cracks
Shield Snaps Off
No Fixture Design
Throttle Trigger Seizes
Switch Cracks
Blade Breaks
Clutch Cover Assembly Cracks
Flexible Drive Shaft Cracks
D-Handle Hardware Strips
Vital Few
Useful Many
Cumulative%
Cut Off %

Life Cycle Design for Service

2.1.1 Identification of Service Modes

Identify Service Modes

A Failure Mode that requires frequent repair or service, or outright replacement of the product/process

Service Mode	Potential Causes	FMEA Source	Frequency of Occurrence	Who Performs Service?	Service Tasks
Not Regulate Airflow	Air Filter Clogged	Functional	8	Do-It-Your User	Replace the Air Filter
Not Contain Fuel	Fuel Tank Empties	Functional	10	Anyone	Refill the Fuel Tank
Not Contact Vegetation	Cutting String Exhausted	Functional	10	Anyone	Refill Cutting String
Not Maintain Sufficient RPM	Spark Plug Erodes	Functional	8	Do-It-Your User	Replace the Spark Plug
Mitigate Noise Emissions	Muffler Erodes	Functional	4	Highly Trained Technician	Replace Muffler
Control String Length	Blades Dulls	Functional	10	Anyone	Sharpen/Replace Blade
Engine Overheats	Hot Environment	VOC	3	Highly Trained Technician	Repair/Replace
Loss of Control	D-Handle Loosens	VOC	5	Anyone	Tighten Hardware
High Levels of Vibration	Loose Fasteners	VOC	6	Anyone	Tighten Hardware

2.1.2 Discuss Service Modes

There were 9 service modes that we selected for our product. The reasons that we chose these service modes were because they had high frequency of occurrence and/or they were failures that we understood their service tasks. Based on the service modes we identified, we realized that many of them had a very high frequency of occurrence. This prompted us to think of ways to either reduce/eliminate the occurrence or to make service easier. The first design improvement that we brainstormed which directly related to our service mode was to make the fuel tank opening larger in order to make fueling up easier. Currently, it requires significant control to fill the fuel tank without spillage. Another one was a quick change string cartridge to make refilling the string quick and easy for the user. A third design improvement was to make it easier to access and change the spark plug. Currently, the plastic casing around the spark plug makes it difficult to reach with a socket. If the plastic casing dipped down so that even a wrench could get to it the task of changing it would become much easier. All three of these improvements deal with areas that anyone is able to service so improving them would benefit the most people involved with the product.

3. Design Improvements

As a group, we brainstormed 11 design improvements and determined their functional benefit, convenience benefit and the disadvantages associated with them. From there, each member of the group ranked the improvements in the order of importance. We then averaged the rankings that the group assigned to determine which improvements the group found most important based on the benefits it added. The group kept in mind the disadvantages of implementing the improvement as their individual rankings were assigned. As seen in the chart below, the improvement that was chosen was to add a telescopic drive shaft.

Design Improvements

Rank	Potential Improvement	Functional Benefit	Convenience Benefit	Disadvantages
1	Telescopic Drive Shaft	Adjustability for different users		Expensive component, adds more weight, complex component
2	Stature Ruler System	Easy adjustability guide for users		Additional manufacturing step, doesn't address all factors involved
3	Quick Change String Cartridge	Reduces Changeover Time	Less Irriation	Need to dispose of cartridges, more expensive to change string
4	Anti-Vibration Handles	Protects the user from injury	More comfortable to use	More expensive and adds more weight
5	Larger Shield	More protection from projectiles		More expensive and adds more weight
6	Quick-to-Move & Adjustable D-Handle	Better grip and handling of tool	Quick and Easy Adjustments	Complex component, more expensive and heavier
7	Adjustable Weight Distribution	Adjustability for different users		Additional weigth needed, additional attachements needed to allow for adjustment
8	Adjustable Cutting Head	Simplfies cutting at akward angles	Bend the product, not the user	More expensive, adds more weight and complex component
9	Larger Fuel Tank Opening	Easier to fill the fuel tank	Reduced Flamable Fuel Spillage	Larger fuel cap needed, Fuel tank adjustments required
10	Larger Cutting Head	Cut more vegetation at once		More powerful engine needed, adds more weight, more expensive part
11	Washable Filter		Economical Component, Purchase Once	More expensive part

Figure 1: Mechanism for telescopic shaft

Source: http://www.weasler.com/product/ptodriveshafts

The design change involves adding a telescopic drive shaft that can be adjusted to the user's preference. The goal for this improvement is to allow users of various stature to adjust the weight distribution and balance of the weedwhacker by adjusting both the shaft length and D-handle. This would allow for more comfortable use of the product as it would mitigate any unnecessary strain or extra energy expenditure that comes with balancing the product.

This improvement, a relatively minor mechanical change, is something that will have a positive effect on the user during their operation of the product. There were a couple disadvantages to the change that were considered. This change will add manufacturing cost to the product but should still be under $100, which was our goal. A small amount of weight will also be added to the product, but this will not affect the overall performance. This fits the goal of our product to remain in the lower cost market while addressing the major customer requirements of keeping the product ergonomic and easy-to-use.