Problem Formulation	
Scope & Boundary Definition	Dan
System Identification (eg. system block diagram, PLC, FU)	Dan
Hazard Identification	Aaron
Stakeholder Analysis	Esten
Citation of Relevant regulations & ISOs	Esten
Impacts Assessment	
FMECA (S/O/D definition? RPN cut-off?)	Noah
FTA	Ashley
ETA	Aaron
LIFE-CYCLE BASED ANALYSIS (eco-audit at least)	Kedar
Evaluation & Mitigation	
Re-calculated FMECA	Noah
Critical evaluation (options appraisal & decision-making)	Ashley
Selected mitigations - BATNEEC	Dan
Is residual mitigated risk ALARP	Noah
References included?	

Delivering an Integrated Management Solution (Lawn mower)

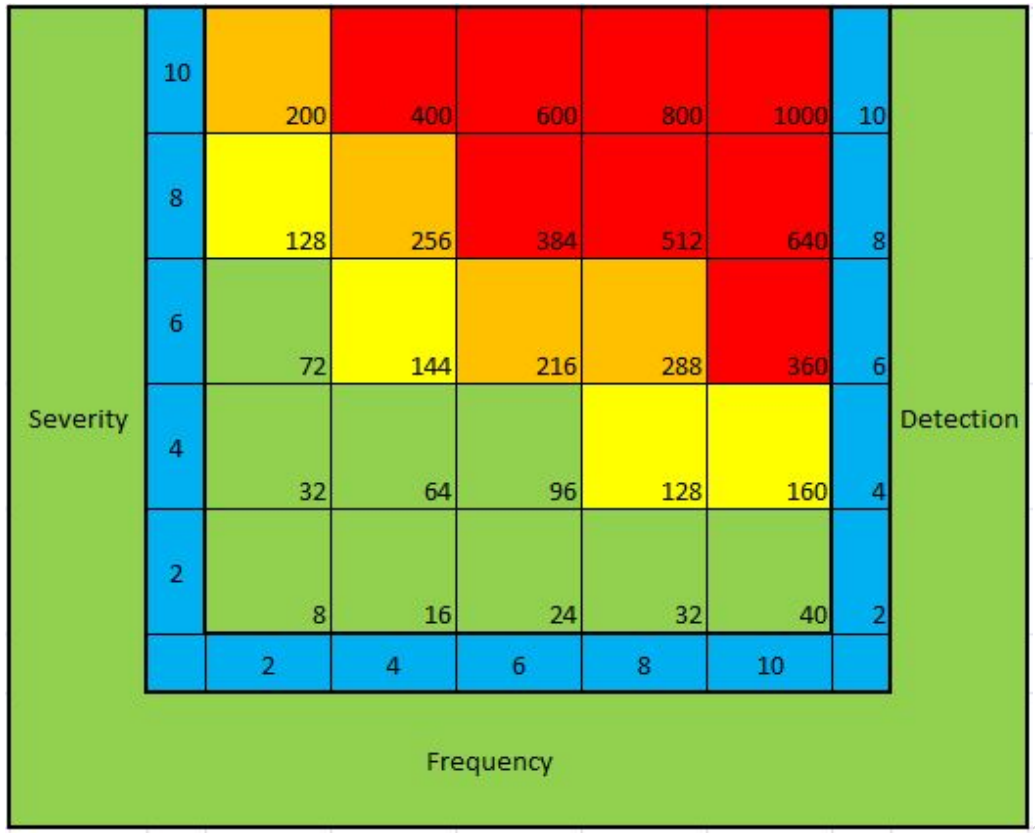
ME3619 Assignment 2022

Scope & Boundary Definition

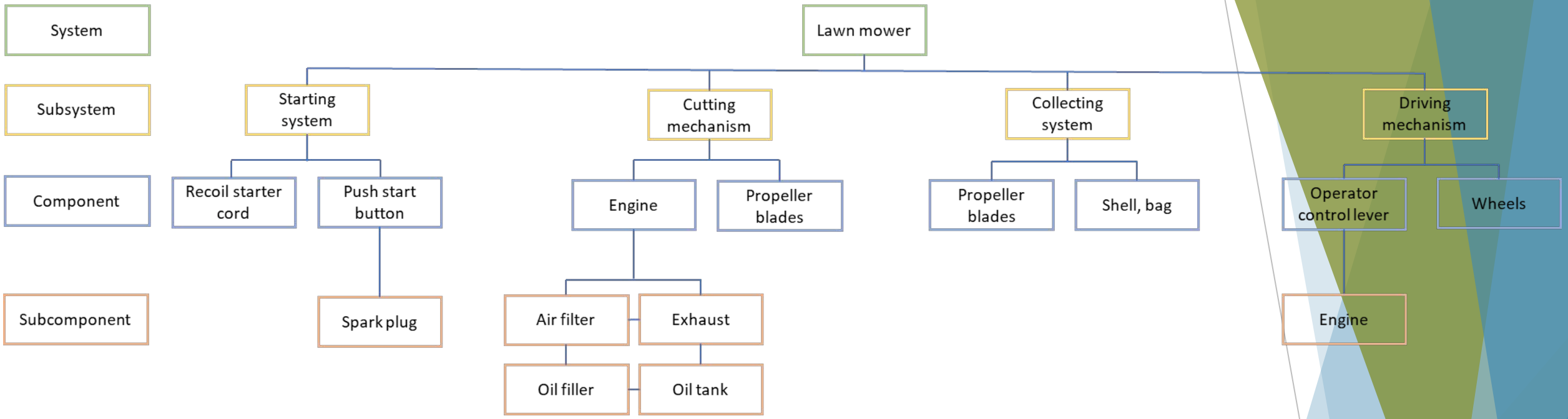
- To identify, prioritise, analyse and mitigate H&S, environmental and socio-economic risks of a Hyundai HYM430SPER Lawnmower life cycle.
- Apply analytical and relevant assessments to evaluate issues for current factors to improve product life cycle, sustainability, economical and ethical objectives while reducing the products expenditure and risks.
- Conclusion to comply with appropriate ISO standards and legislations.

Scope & Boundary Definition

- Remain within RPN range of 0-180 class. Mitigate as many RPN values over 100 to <100.



System Block diagram



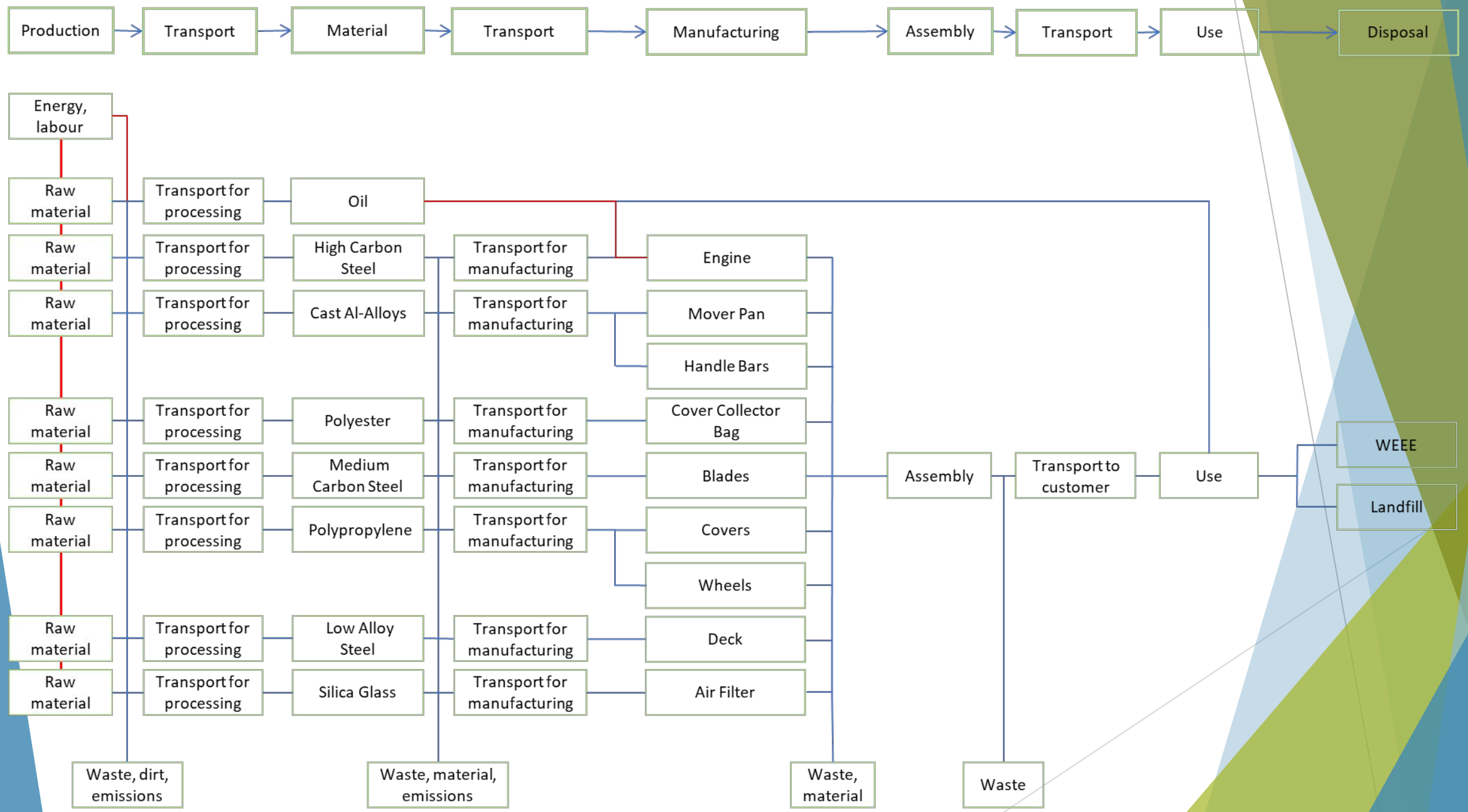
Starting system – to start the motor the recoil starter cord is pulled with enough force to start the pistons rotating inside the engine with enough momentum to keep running independently with combustion. The push start button is held at the same time to initiate the spark plug which will continue the combustion process.

Cutting system – the main engine rotates the propeller blades fast enough to cut the grass. The engine has other important systems connected such as the air filter which keeps the air supplied to the engine clean from dust and debris and grass. The exhaust pipes lead the gases after the combustion reaction out of the engine and into the atmosphere. The oil filler is the lubricant for the engine and the oil tank holds the fuel for the engine.

Collecting system – the propeller blades which rotate have a spoon like shape at the end to allow the cut grass to be collected and thrown outwards, the shell inside the mower has a path that directs the grass into a bag.

Driving mechanism – the operator has a lever by the mower handle that is constantly held down keep the engine running, also as a safety feature so that the mower is always under control by an operator. The mower is self driven that can be started by another lever by the handle and is controlled by the engine.

Product Life Cycle



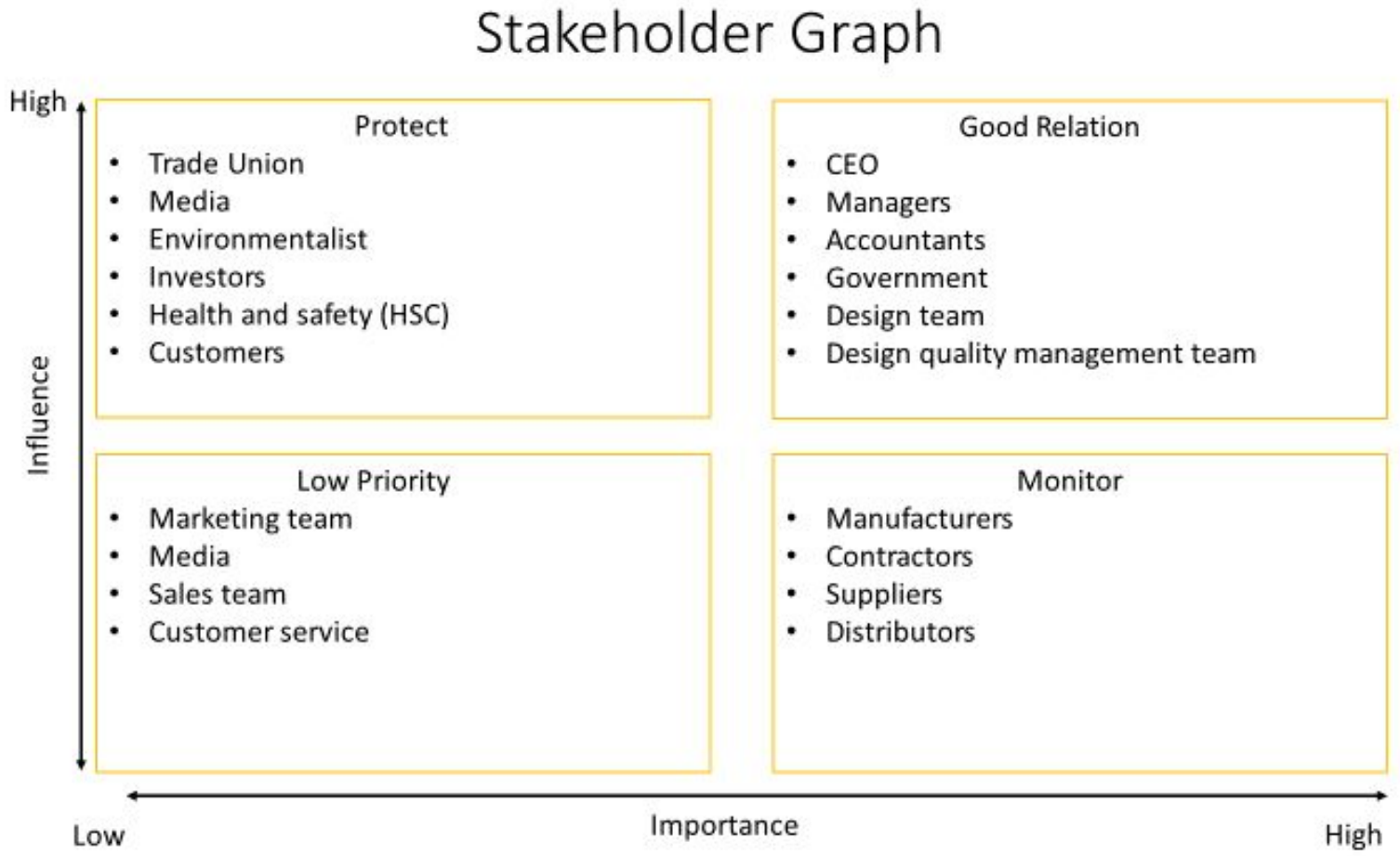
Hazard Identification [11]

No.	Type or Group	Example of Hazards	
		Origin	Potential Consequences
1	**Mechanical Hazards**	Acceleration Cutting parts Machine mobility Moving elements Rotating elements Kinetic Energy	Being run over Cutting or severing Drawing-in or trapping Impact Shearing Stabbing or puncture
2	**Electrical Hazards**	Electrostatic phenomena Live parts Overload Parts which have become live under fault conditions short-circuit	Burn Electrocution Fire Shock
3	**Thermal Hazards**	Explosion Flame Objects or materials with a high temperature	Burn Discomfort Injuries by the radiation of heat sources
4	**Noise Hazards**	Gas leaking at high speed Moving parts Scraping Surfaces Unbalanced rotating parts Worn parts	Discomfort Loss of awareness Stress Tiredness Hearing damage

Hazard Identification [11]

No.	Type or Group	Example of Hazards	
		Origin	Potential Consequences
5	**Vibration**	Misalignment of parts Mobile equipment Scraping surfaces Unbalanced rotating parts Vibrating equipment Worn parts	Discomfort Low-back morbidity Trauma of the spine Raynaud's phenomenon Carpal tunnel syndrome
6	**Material/substance hazards**	Combustible Explosive Flammable Fluid Fume Gas Oxidiser	Breathing difficulties Explosion Fire
7	**Ergonomic hazards**	Access Design, location, or identification of control devices Effort Posture Repetitive activity	Discomfort Loss of balance leading to injury
8	**Hazards associated with the environment in which the machine is used**	Pollution Temperature	Burn Burning petrol which affects the climate

Stakeholder Analysis



Stakeholder Engagement

Stakeholder Engagement						
Category	**Customers and distributers**	**Employees**	**Suppliers**	**Local Communities**	**Government**	**Shareholers and investors**
Roles of stakeholders	• The distributers deliver the products as well as services to the customers. • Customers make decisions on making a purchase depending on the quality of the product.	• Employees handle development of products, production and sales. · The competency of the employees is the competencies of the company.	• The parts or material to Hyundai is provided by the supplier which enables the company to produce quality products. •Their quality competitiveness impacts the company's quality.	• Local communities as in, the residents in the vicinity of the business or the global citizen, Hyundai strives for their sustainable development.	• The government enact rules and regulation that are related to the company which influence the activities of the business.	•Shareholders and investors provide capital and finance to the business which helps in the growth of the company whilst implementing

Citation of Relevant regulations & ISOs

Regulations	Relation	Description	Citation
EN ISO 3744:1995	**Acoustics**- Determines sound power levels of sources of noise using sound pressure.	This ISO ensures it gives detailed information on the particular surface as a differently shaped measurement surface will yield different estimates of sound power levels.	EN ISO 3744:1995 - Acoustics - Determination of sound power levels of noise sources using sound (iteh.ai)
EN ISO 11094:1991	**Acoustics**- Test code for measuring airborne noise given off by power lawn mowers.	This ISO specifies methods for the measurement of sound pressure levels at prescribed microphone positions in machines' vicinity. (How far the noise can travel)	ISO - ISO 11094:1991 - Acoustics — Test code for the measurement of airborne noise emitted by power lawn mowers, lawn tractors, lawn and garden tractors, professional mowers, and lawn and garden tractors with mowing attachments
EN ISO 5395-1:2013-09	Garden equipment- Requirements of safety for combustion powered lawnmowers-Part 1: Terminology and common tests.	This specifies common test methods used to verify combustion engine safety requirements for cylinder/ rotary lawnmowers which includes pedestrian controlled and ride on types lawnmowers.	ISO - ISO 5395-1:2013 - Garden equipment — Safety requirements for combustion-engine-powered lawnmowers — Part 1: Terminology and common tests
EN ISO 14982:2009	Agricultural and forestry machinery - Electromagnetic compatibility - Test methods and acceptance criteria	This specifies test methods and criteria for acceptance to evaluate electromagnetic compatibility of tractors and mobile inclusive of hand held agricultural, landscaping, forestry and gardening machinery.	EN ISO 14982:2009 standard - CE Marking assistant (ce-marking.help)

FMECA

Key points to note from the FMECA:

- Initial RPR(Risk Priority Rating) is categorized using Red, Yellow and Black fonts to identify the areas in most need of mitigating.

- These areas surpass the failure risk threshold to which the team deems as tolerable therefore a focus on these areas for improvements needs to be carried out.

FMECA with re-evaluation of Risks

Name // Part Number (if applica	Potential failure modes	Causes (failure mechanisms)	Effects	Risk Priority Rating (Initial)			
				Severity	Frequency	Detection	RPN
Exhaust	Rust build-up weakening the strength/integrity of the exhaust.	Prolonged exposure to moisture and air.	If material becomes too weak holes can form allowing the fumes to be directed to internal parts	5	5	8	200
	Detachment of exhaust causing vibration to occur to mower.	Bolts and screws holding it in place with time can loosen or pop out of place.	Rattling of the exhaust can cause resonance to other parts causing damage to itself and the mower.	3	4	7	84
	Back-pressure too great from closed exhaust exit.	Grass / dust and debris build-up from general use without maintenance.	Clogged exhaust would re-direct hot fumes back into engine damaging internal parts.	7	5	5	175
Spark Plug	Gap between spark and ignition is too large resulting in failed start of engine.	A shift of engine/spark plug position from a collision.	Failure to ignite fuel.	3	4	6	72
	Failed spark.	Dirty connection between positive and negative terminals.	Failure to ignite fuel.	2	4	4	32
Oil Filler	Becomes unable to close.	Loss of Sealing Cap.	Oil Spillage onto mower and loss of engine lubrication causing engine to cease.	4	4	7	112
Electric Push Button Start	Water spillage causing a short-circuit.	Prolonged exposure to rain or moisture.	Moisture can intervene with the electrical circuit.	7	3	7	147
	Sticky button not fully inserting or retracting.	Spillage from external sticky substances such as mud or fizzy drinks.	Excess friction causing in-out motion of button to malfunction.	1	4	8	32
Air Filter	Air does not pass through into the mower.	Clogged up air filter from dust making the filter impermeable to air.	Engine over-heating, poor suction for grass collection.	4	6	4	96
Grass collector	Collector attachment-to-body clips can break	Over-filling collector applying too great of a moment on clips.	Failure to collect grass without proper attachment of the collector.	6	6	5	180
	Hole puncture into 45l grass collector.	Sharp plants/rocks enter the collector causing it to rip.	Grass will fall out the mower leaving mess on lawn.	2	5	4	40
	Structural clips for metal bars can break off.	Improper storage crushing the part.	Without metal bars, the collector will collapse on itself.	5	5	3	75
Wheels	Dries out and cracks.	Mower left outside in hot weather too often.	Mower becomes prone to getting stuck.	5	2	4	40
	Break off bearings.	Use of mower on gravel/rough surfaces weakening bond between wheel and axle.	Mower fails to roll on wheel and gets stuck.	6	4	4	96
139V Engine // 1137030	Engine rattling/knocking.	Excess carbon build-up can accumulate in combustion chamber from poor maintenance/cleaning.	Toxic fumes are released into the atmosphere.	7	4	6	168
	Engine ceasing then stalling.	Over-heating of engine due to air filter failing.	Air filter contributes to the cooling of motor so additional heat would be added to the system.	7	4	4	112
	Smoke being generated.	Carburettor malfunction.	Spoils balance between fuel and air within the motor releasing toxic fumes.	7	5	4	140
		Burning oil due to not having enough to lubricate motor.	Toxic fumes are released into the atmosphere.	3	5	3	45
	Engine stalls	Moisture in Engine affecting fuel combustion.	Moisture can intervene with the combustion reaction.	3	3	6	54
Upper Handle // 1137005	Handle collapses on itself.	Too much compressive pressure applied to handle.	Buckling of the material.	7	3	5	105
		Bolts and screws holding it straight come undone.	Buckling at the joint.	3	6	3	54
Operator presence control	Handle for operator pops off from hinges.	Handle forced in opposite direction.	Spontaneous continuation of motor after the user has disengaged with the motor may be allowed to happen if there is no handle.	5	6	3	90
	Mower no longer recognises engagement of operator despite functioning handle.	Failure of electrical connection due to moisture or broken internal circuit.	Spontaneous continuation of motor after the user has disengaged with the motor would be allowed without proper connection.	3	3	3	81
Blade // 1138028	Goes blunt.	Wear and tear.	Poor cutting of grass.	1	8	3	24
	Rust	Prolonged exposure to moisture and air.	Weakened blade material making it prone to breaking.	3	6	3	54
	Falls off	Improper fixing to the body, loosening fixing bolt.	Blade breaches body of safety.	3	4	6	216

FMECA-improvements (Re-calculated)

Key points to note from the FMECA:

- Initial RPR(Risk Priority Rating) is categorized using Red, Yellow and Black fonts to identify the areas in most need of mitigating but with these improvements, theoretically, these values dramatically decrease making a more reliable and safe product.

- There is still a degree of risk within the grass collector, exhaust and electric button, but it is severely reduced after the improvements.

- Any further mitigation would require pros and cons analysis or physical testing of parts to practically test each failure mode.

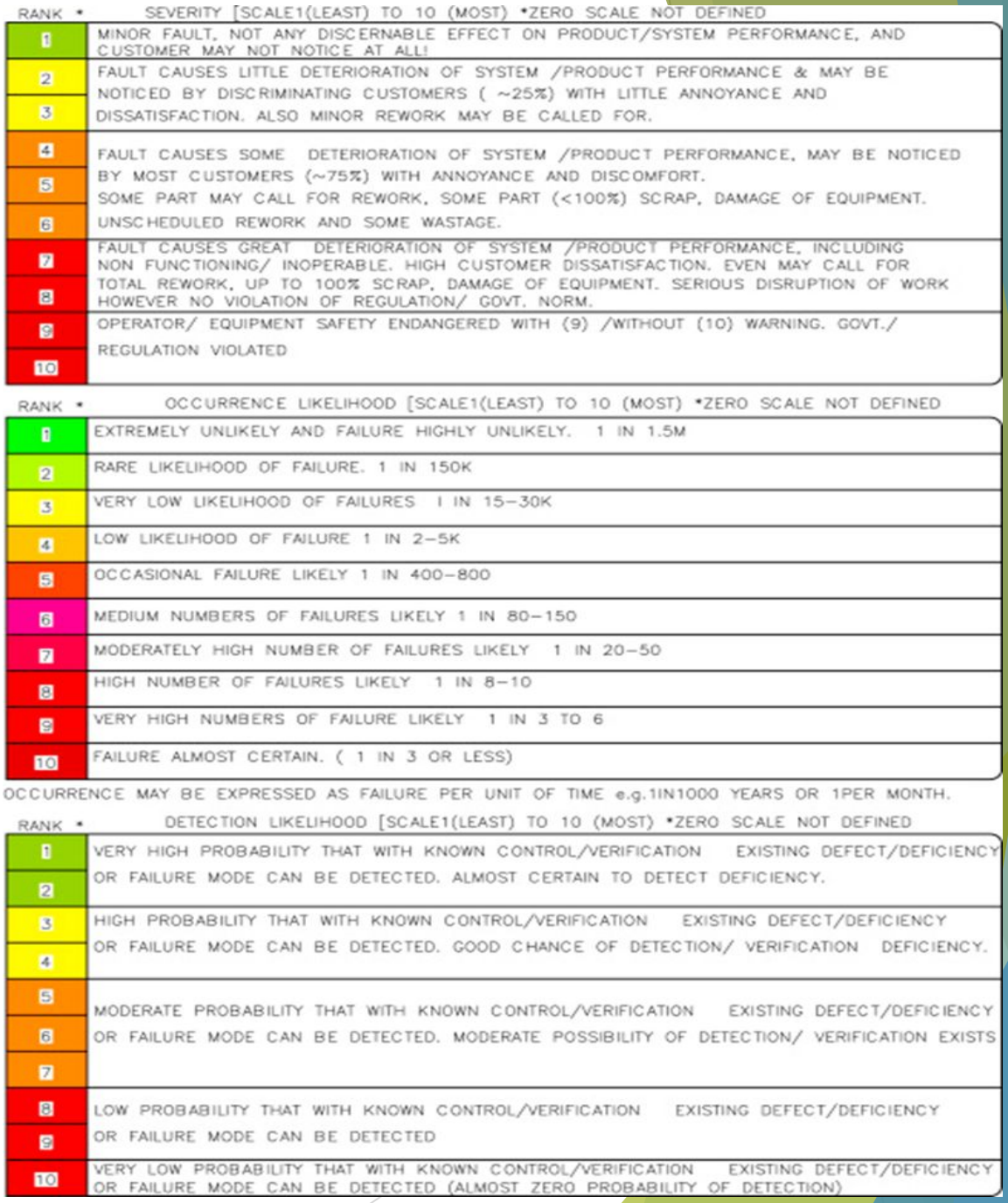
FMECA with re-evaluation of Risks									
Name // Part Number (if applica	Risk Priority Rating (Initial)				Recommended Improvement	Risk Priority Rating (Revised			
	Severity	Frequency	Detection	RPN		Severity	Frequency	Detection	RPN
Exhaust	5	5	8	200	Stainless steel should be used or use a corrosion protection spray.	5	2	8	80
	3	4	7	84	Use washers between bolts and screws to dampen vibration and secure a tight fit.	3	2	7	42
	7	5	5	175	A safety feature to detect low air flow inside the exhaust would prevent further damage.	6	5	1	30
Spark Plug	3	4	6	72	Secure spark plug to a stirdy part of the mower.	3	2	6	36
	2	4	4	32	Put a protective cover over it to mitigate	2	2	4	16
Oil Filler	4	4	7	112	Have the lid be attached to the mower.	4	1	5	20
Electric Push Button Start	7	3	7	147	A button with a soft plastic cover to protect it from fluids.	7	2	5	70
	1	4	8	32	A button with a soft plastic cover to protect it from fluids.	1	2	6	12
Air Filter	4	6	4	96	Larger diameter air intake.	4	2	4	32
Grass collector	6	6	5	180	Use a more robust material to hold the weight of grass over plastic.	6	3	4	72
	2	5	4	40	Have product come with an exchangeable collection bag.	1	2	4	8
	5	5	3	75	Use a more robust material to hold the metal clips in place.	5	2	3	30
Wheels	5	2	4	40	Use a softer type of plastic.	5	1	4	20
	6	4	4	96	Use a tougher type of axle for the inner wheel.	6	2	4	48
139V Engine // 1137030	7	4	6	168	Fitting a cleaning brush for regular cleaning.	7	2	4	56
	7	4	4	112	Include air vents into design of mower body to ensure air flow is always present.	5	2	4	40
	7	5	4	140	Increase volume of carburator for air to circulate within the motor.	5	3	2	30
	3	5	3	45	Fit a catalytic converter or system to notify user of incomplete combustion.	2	3	1	6
	3	3	6	54	Seal all water entry points in motor.	3	1	6	18
Upper Handle // 1137005	7	3	5	105	Strengthening the segments of handle.	7	1	5	35
	3	6	3	54	Rubber washers to ensure a tight interlocking of each handle segment.	3	4	3	36
Operator presence control	5	6	3	90	Use a more robust hinge.	5	4	3	60
	9	3	3	81	Sealed electrical unit to protect feature from the elements.	9	1	3	27
Blade // 1138028	1	8	3	24	Harden the steel used for less maintenance.	1	4	3	12
	3	6	3	54	Stainless steel should be used or use a corrosion protection spray.	3	3	3	27
	9	4	6	216	Use big diameter bolts with washers.	9	1	6	54

Justification of Severity, Frequency and Detection.

The severity before and after improvements only goes down if the design of the lawn mower itself changes or there is a safety feature implemented as an attachment. Otherwise, the severity of the failure stays the same.

The frequency of the failure should be reduced with all mitigations unless the only mitigation is a detection device which although won't reduce the likelihood of the part failing, it will aid the user to spot the issue before any additional harm is caused.

The detection score represents the ease of detection before failure occurs, so if a part can not be seen before it fails, that would be a 7-9 score, whereas if the problem has a delayed or exposed failure trigger, then that would be easier to spot and hence easier to mitigate before the failure of the part.



RANK *	SEVERITY [SCALE1(LEAST) TO 10 (MOST) *ZERO SCALE NOT DEFINED
1	MINOR FAULT, NOT ANY DISCERNABLE EFFECT ON PRODUCT/SYSTEM PERFORMANCE, AND CUSTOMER MAY NOT NOTICE AT ALL!
2	FAULT CAUSES LITTLE DETERIORATION OF SYSTEM /PRODUCT PERFORMANCE & MAY BE NOTICED BY DISCRIMINATING CUSTOMERS (~25%) WITH LITTLE ANNOYANCE AND DISSATISFACTION. ALSO MINOR REWORK MAY BE CALLED FOR.
3	
4	FAULT CAUSES SOME DETERIORATION OF SYSTEM /PRODUCT PERFORMANCE, MAY BE NOTICED BY MOST CUSTOMERS (~75%) WITH ANNOYANCE AND DISCOMFORT. SOME PART MAY CALL FOR REWORK, SOME PART (<100%) SCRAP, DAMAGE OF EQUIPMENT. UNSCHEDULED REWORK AND SOME WASTAGE.
5	
6	
7	FAULT CAUSES GREAT DETERIORATION OF SYSTEM /PRODUCT PERFORMANCE, INCLUDING NON FUNCTIONING/ INOPERABLE. HIGH CUSTOMER DISSATISFACTION. EVEN MAY CALL FOR TOTAL REWORK, UP TO 100% SCRAP, DAMAGE OF EQUIPMENT. SERIOUS DISRUPTION OF WORK HOWEVER NO VIOLATION OF REGULATION/ GOVT. NORM.
8	
9	OPERATOR/ EQUIPMENT SAFETY ENDANGERED WITH (9) /WITHOUT (10) WARNING. GOVT./ REGULATION VIOLATED
10	

RANK *	OCCURRENCE LIKELIHOOD [SCALE1(LEAST) TO 10 (MOST) *ZERO SCALE NOT DEFINED
1	EXTREMELY UNLIKELY AND FAILURE HIGHLY UNLIKELY. 1 IN 1.5M
2	RARE LIKELIHOOD OF FAILURE. 1 IN 150K
3	VERY LOW LIKELIHOOD OF FAILURES 1 IN 15–30K
4	LOW LIKELIHOOD OF FAILURE 1 IN 2–5K
5	OCCASIONAL FAILURE LIKELY 1 IN 400–800
6	MEDIUM NUMBERS OF FAILURES LIKELY 1 IN 80–150
7	MODERATELY HIGH NUMBER OF FAILURES LIKELY 1 IN 20–50
8	HIGH NUMBER OF FAILURES LIKELY 1 IN 8–10
9	VERY HIGH NUMBERS OF FAILURE LIKELY 1 IN 3 TO 6
10	FAILURE ALMOST CERTAIN. (1 IN 3 OR LESS)

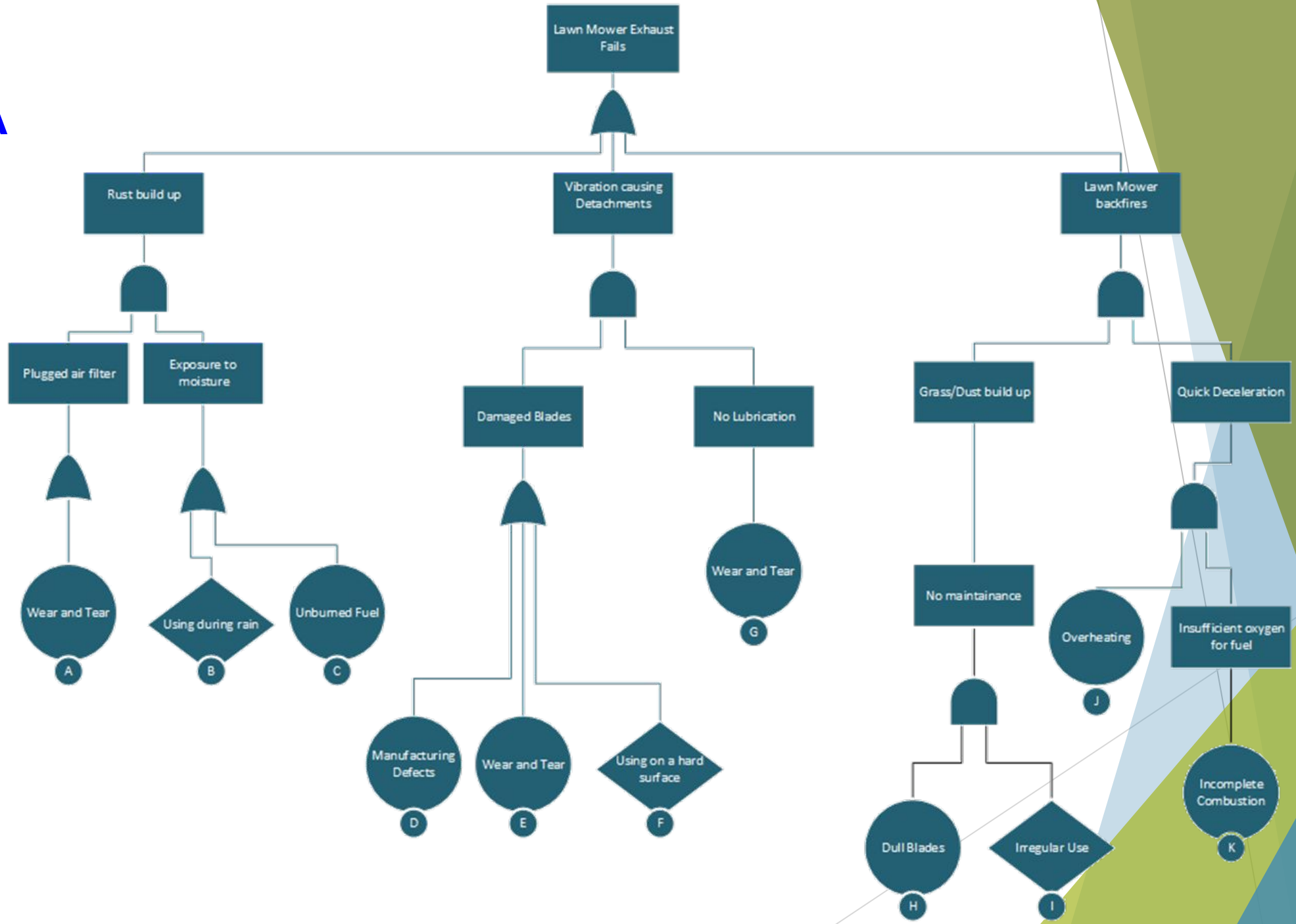
OCCURRENCE MAY BE EXPRESSED AS FAILURE PER UNIT OF TIME e.g.1IN1000 YEARS OR 1PER MONTH.

RANK *	DETECTION LIKELIHOOD [SCALE1(LEAST) TO 10 (MOST) *ZERO SCALE NOT DEFINED
1	VERY HIGH PROBABILITY THAT WITH KNOWN CONTROL/VERIFICATION EXISTING DEFECT/DEFICIENCY OR FAILURE MODE CAN BE DETECTED. ALMOST CERTAIN TO DETECT DEFICIENCY.
2	
3	HIGH PROBABILITY THAT WITH KNOWN CONTROL/VERIFICATION EXISTING DEFECT/DEFICIENCY OR FAILURE MODE CAN BE DETECTED. GOOD CHANCE OF DETECTION/ VERIFICATION DEFICIENCY.
4	
5	MODERATE PROBABILITY THAT WITH KNOWN CONTROL/VERIFICATION EXISTING DEFECT/DEFICIENCY OR FAILURE MODE CAN BE DETECTED. MODERATE POSSIBILITY OF DETECTION/ VERIFICATION EXISTS
6	
7	
8	LOW PROBABILITY THAT WITH KNOWN CONTROL/VERIFICATION EXISTING DEFECT/DEFICIENCY OR FAILURE MODE CAN BE DETECTED
9	
10	VERY LOW PROBABILITY THAT WITH KNOWN CONTROL/VERIFICATION EXISTING DEFECT/DEFICIENCY OR FAILURE MODE CAN BE DETECTED (ALMOST ZERO PROBABILITY OF DETECTION)

Reference:

Kent, R., 2022. *Design quality management*.

FTA



Cut Sets

1.A,B.

2.A,C.

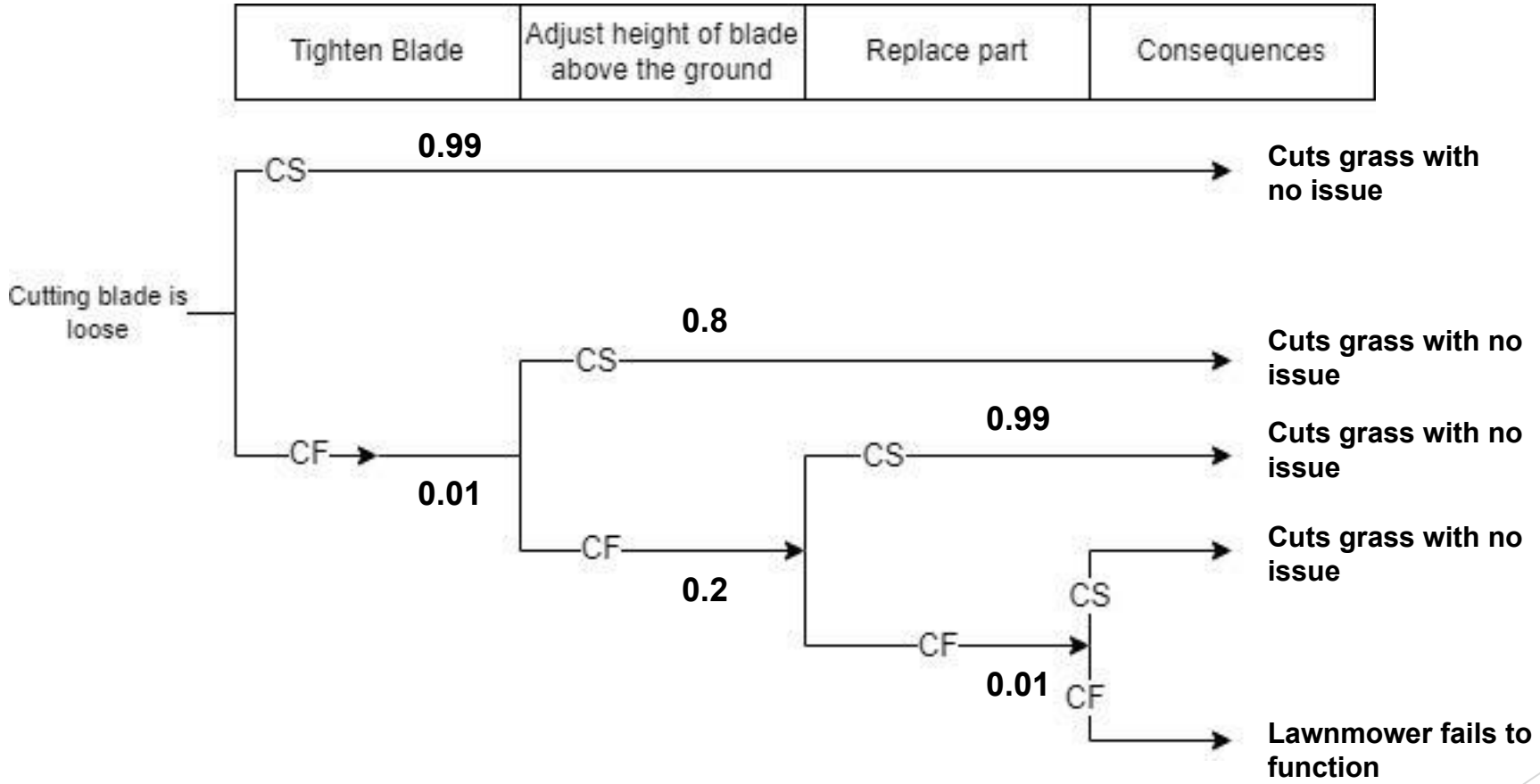
3.D,G.

4.E,G.

5.F,G.

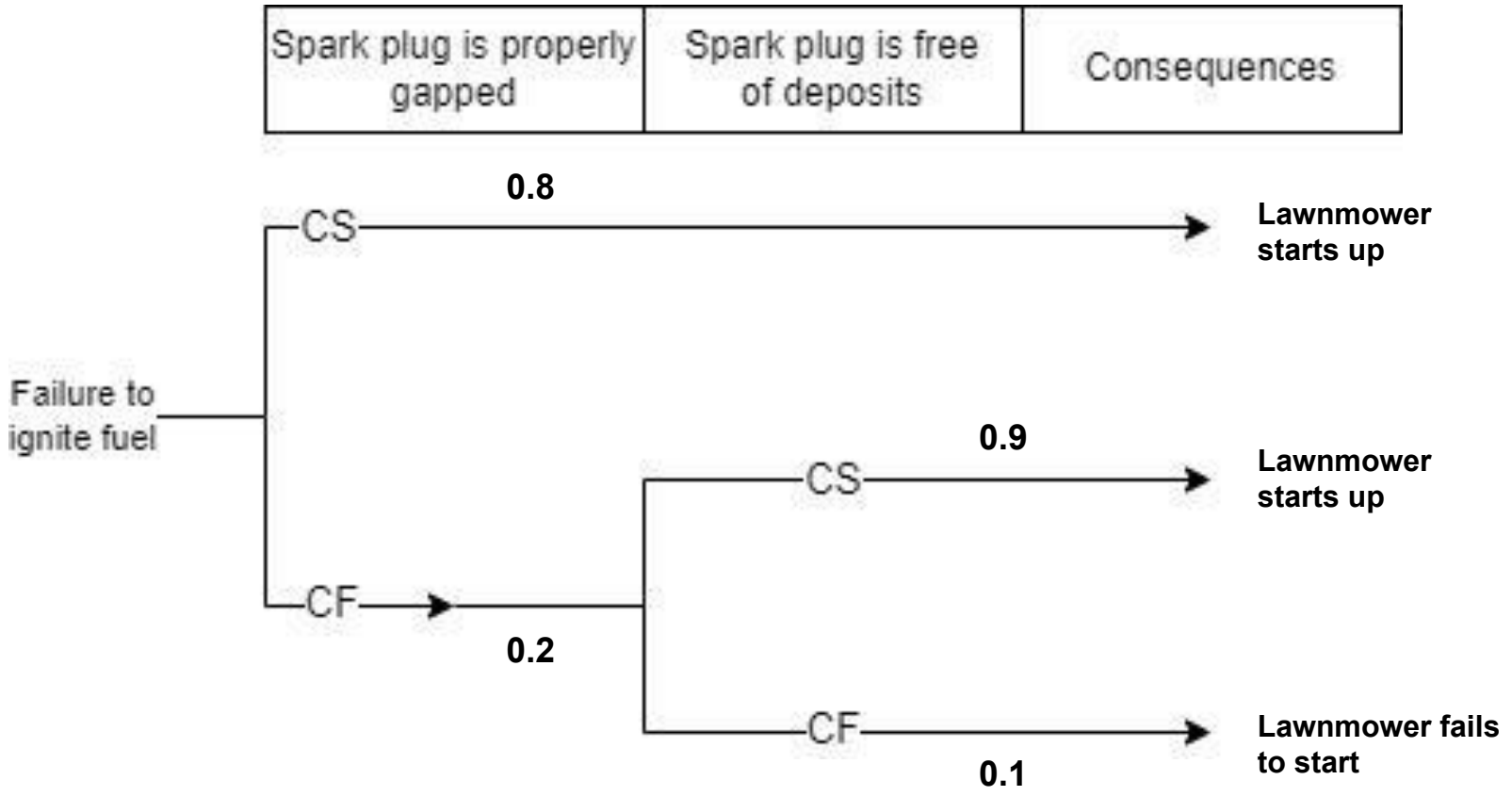
6.H,I,J,K.

ETA [12]



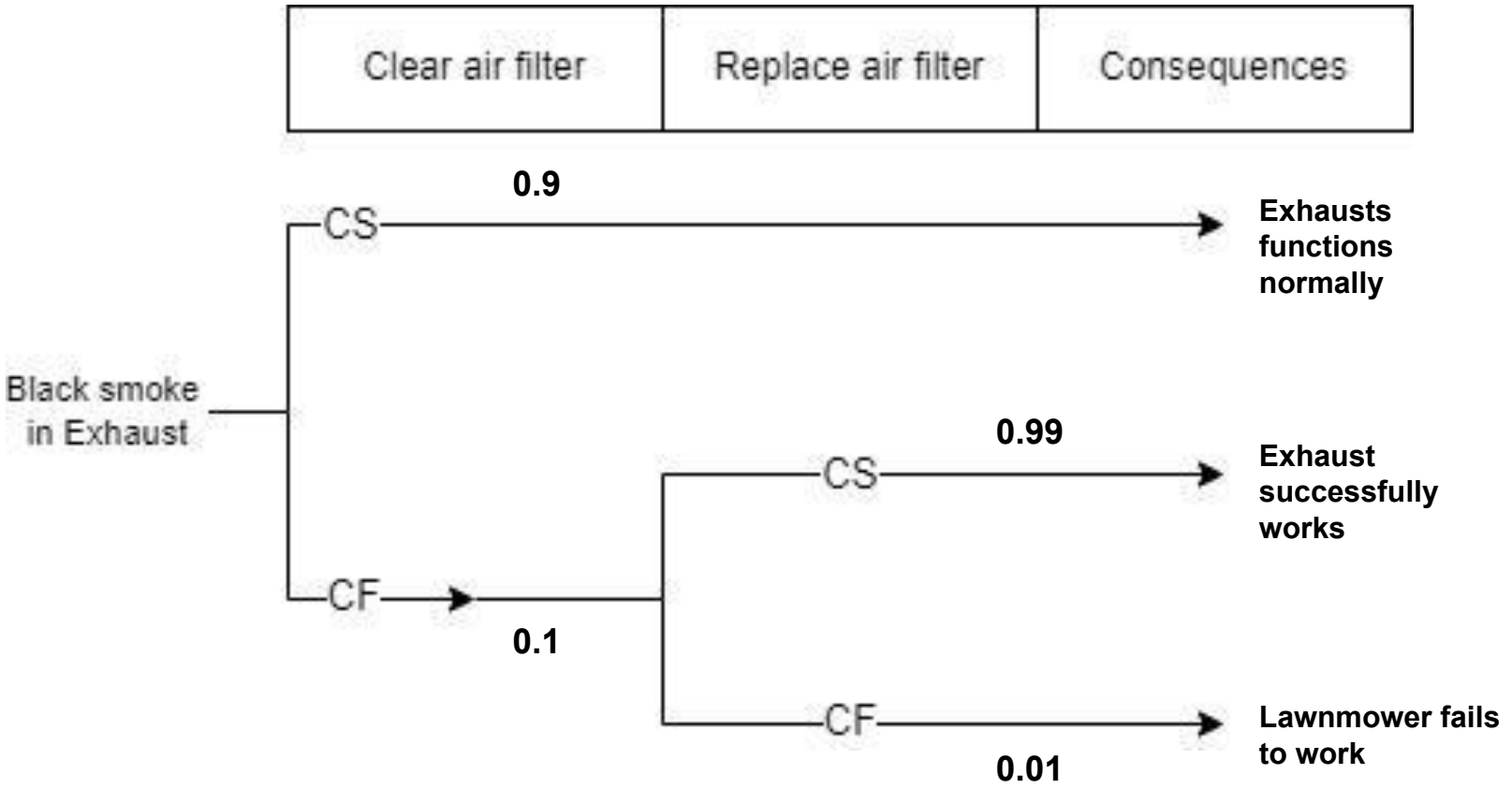
CS
Component Success
CF
Component Failure

ETA [12]



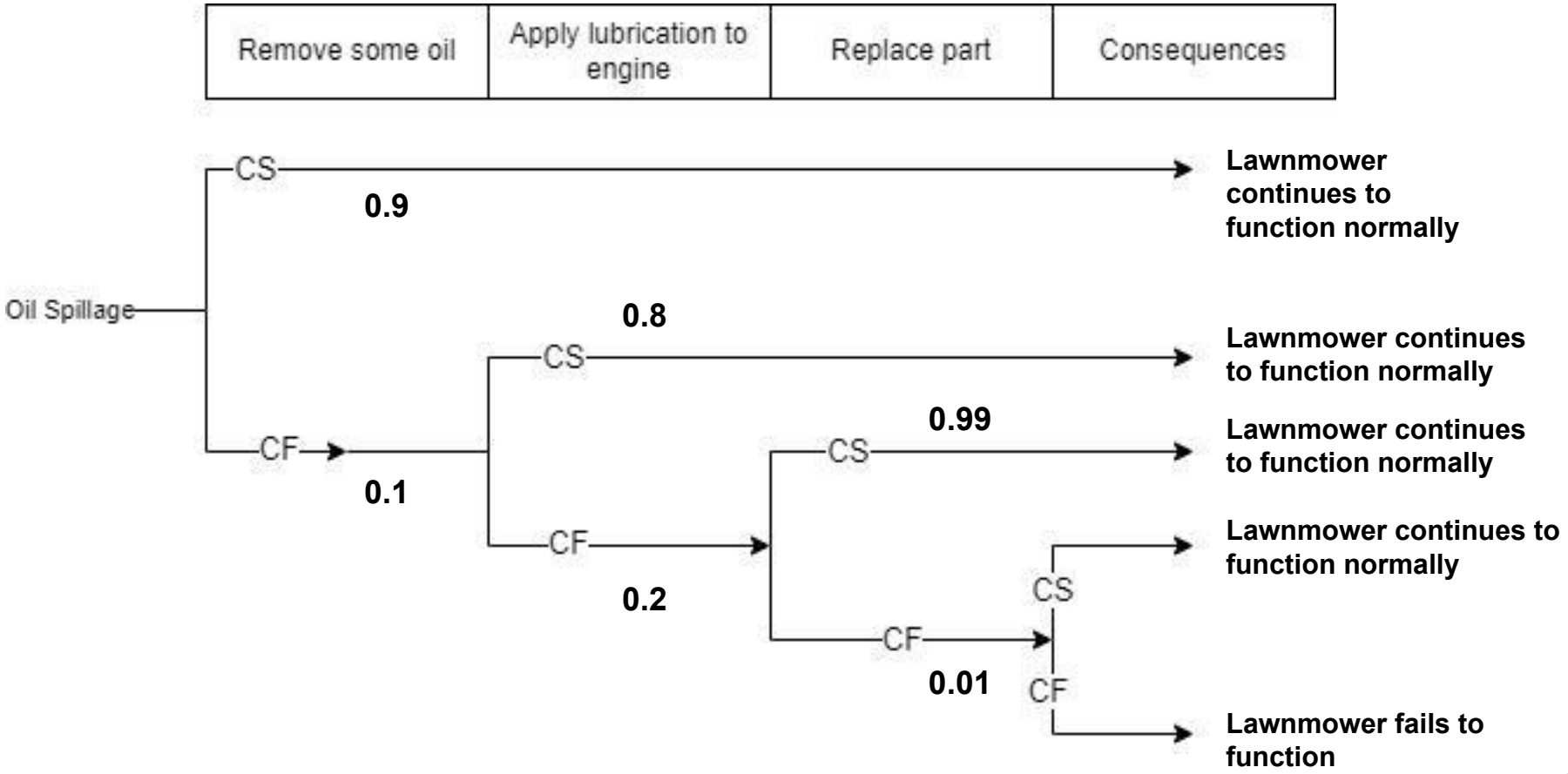
CS
Component Success
CF
Component Failure

ETA [12]



CS
Component Success
CF
Component Failure

ETA [12]



CS
Component Success
CF
Component Failure

LIFE-CYCLE BASED ANALYSIS

Ansys
GRANTA EDUPACK

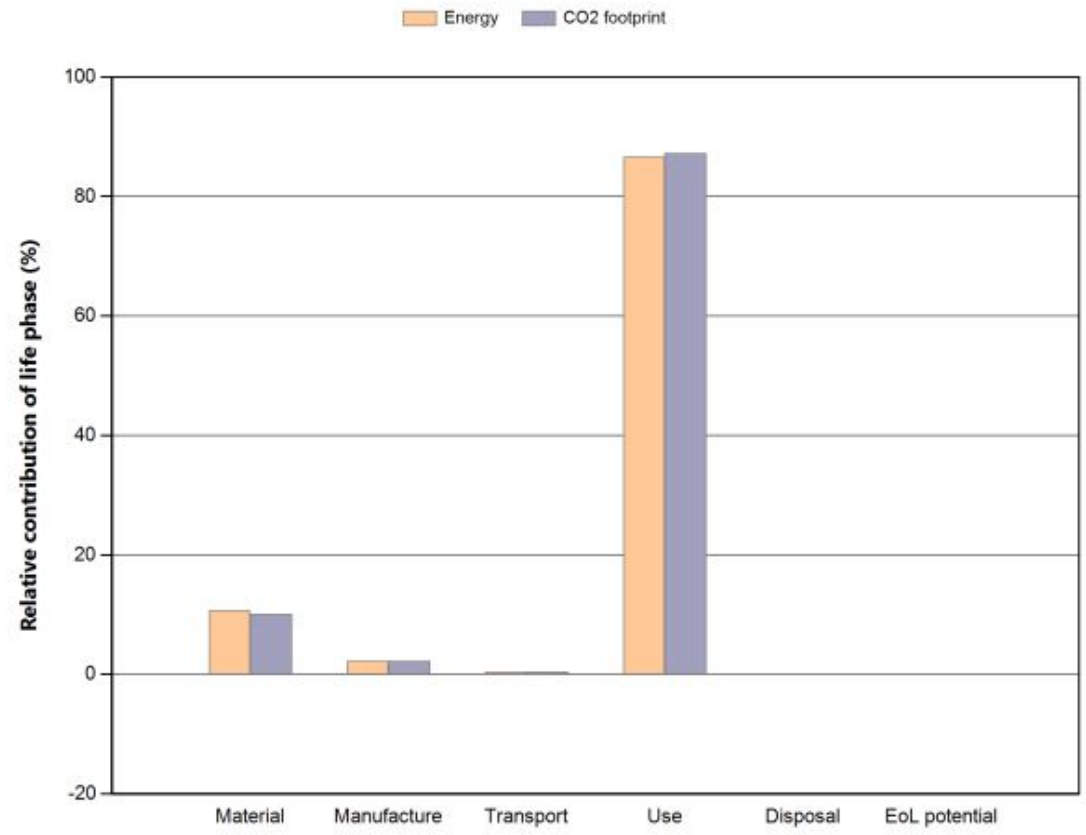
Eco Audit Report

Product name: Hyundai Lawn Mower HYM430SPER

Country of use: United Kingdom

Product life (years): 10

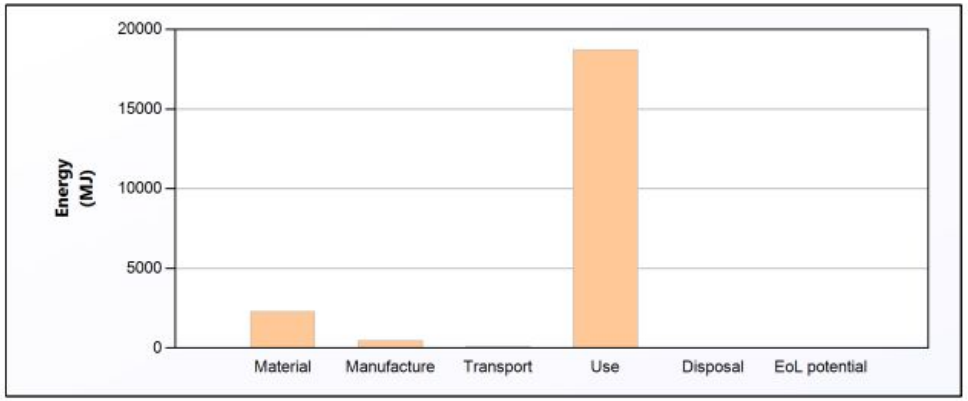
Summary:



Phase	Energy (MJ)	Energy (%)	CO2 footprint (kg)	CO2 footprint (%)
Material	2.3e+03	10.7	155	10.1
Manufacture	473	2.2	34.7	2.2
Transport	96.8	0.4	6.97	0.5
Use	1.87e+04	86.7	1.35e+03	87.2
Disposal	7.98	0.0	0.558	0.0
Total (for first life)	**2.16e+04**	**100**	**1.55e+03**	**100**
End of life potential	0		0	

Energy Analysis

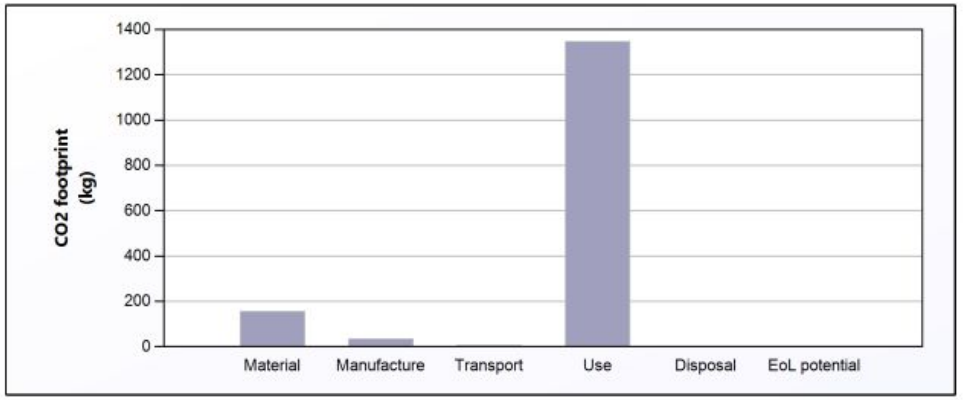
Summary



	Energy (MJ/year)
Equivalent annual environmental burden (averaged over 10 year product life):	2.16e+03

CO2 Footprint Analysis

Summary



	CO2 (kg/year)
Equivalent annual environmental burden (averaged over 10 year product life):	155

LIFE-CYCLE BASED ANALYSIS - CONTINUED

Material:

Summary

Component	Material	Recycled content* (%)	Part mass (kg)	Qty.	Total mass (kg)	Energy (MJ)	%	CO2 footprint (kg)	%
Handle bars	Cast Al-alloys	Virgin (0%)	0.96	1	0.96	1.8e+02	8.0	12	7.7
Cover collector bag	Polyester (UP)	Virgin (0%)	0.3	1	0.3	21	0.9	0.76	0.5
Mover pan	Cast Al-alloys	Virgin (0%)	5	1	5	9.6e+02	41.8	62	39.8
Engine	High carbon steel	Virgin (0%)	28	1	28	9.1e+02	39.4	66	42.7
Blades	Medium carbon steel	Virgin (0%)	0.72	1	0.72	23	1.0	1.7	1.1
Covers	Polypropylene (PP)	Virgin (0%)	1.3	1	1.3	86	3.8	3.6	2.3
Wheel	Polypropylene (PP)	Virgin (0%)	0.025	4	0.1	6.9	0.3	0.29	0.2
Air filter	Silica glass	Virgin (0%)	0.05	1	0.05	2	0.1	0.12	0.1
Deck	Low alloy steel	Virgin (0%)	3.5	1	3.5	1.1e+02	4.7	8.7	5.6
Total				**12**	**40**	**2.3e+03**	**100**	**1.6e+02**	**100**

*Typical: Includes 'recycle fraction in current supply'

Use:

Static mode

Energy input and output type	Fossil fuel to mechanical, internal combustion
Country of use	United Kingdom
Power rating (kW)	2.6
Usage (hours per day)	2
Usage (days per year)	30
Product life (years)	10

Relative contribution of static and mobile modes

Mode	Energy (MJ)	CO2 footprint (kg)	%
Static	1.9e+04	1.3e+03	100.0
Mobile	0	0	
Total	**1.9e+04**	**1.3e+03**	**100**

Manufacture:

Summary

Component	Process	Amount processed	Energy (MJ)	%	CO2 footprint (kg)	%
Handle bars	Extrusion, foil rolling	0.96 kg	17	3.6	1.3	3.7
Cover collector bag	Polymer molding	0.3 kg	8	1.7	0.64	1.8
Mover pan	Casting	5 kg	57	12.1	3.5	10.1
Engine	Casting	28 kg	3.1e+02	66.5	24	67.9
Blades	Casting	0.72 kg	8.2	1.7	0.61	1.8
Covers	Polymer molding	1.3 kg	26	5.6	2	5.7
Wheel	Polymer molding	0.1 kg	2.1	0.4	0.16	0.5
Air filter	Glass molding	0.05 kg	0.72	0.2	0.058	0.2
Deck	Casting	3.5 kg	39	8.2	2.9	8.4
Total			**4.7e+02**	**100**	**35**	**100**

Transport:

Summary

Breakdown by transport stage

Stage name	Transport type	Distance (km)	Energy (MJ)	%	CO2 footprint (kg)	%
Factory to SE Asia Port	32 tonne (4 axle) truck	3e+02	11	11.6	0.81	11.6
SE Asia Port to UK port	Ocean freight	1.1e+04	78	80.6	5.6	80.6
UK port to Retailer	32 tonne (4 axle) truck	2e+02	7.5	7.7	0.54	7.7
Total		**1.1e+04**	**97**	**100**	**7**	**100**

Breakdown by components

Component	Mass (kg)	Energy (MJ)	%	CO2 footprint (kg)	%
Handle bars	0.96	2.3	2.4	0.17	2.4
Cover collector bag	0.3	0.73	0.8	0.052	0.8
Mover pan	5	12	12.5	0.87	12.5
Engine	28	68	70.2	4.9	70.2
Blades	0.72	1.7	1.8	0.13	1.8
Covers	1.3	3	3.1	0.22	3.1
Wheel	0.1	0.24	0.3	0.017	0.3
Air filter	0.05	0.12	0.1	0.0087	0.1
Deck	3.5	8.5	8.8	0.61	8.8
Total	**40**	**97**	**100**	**7**	**100**

LIFE-CYCLE BASED ANALYSIS - CONTINUED

Disposal:

Component	End of life option	Energy (MJ)	%	CO2 footprint (kg)	%
Handle bars	Landfill	0.19	2.4	0.013	2.4
Cover collector bag	Landfill	0.06	0.8	0.0042	0.8
Mover pan	Landfill	1	12.5	0.07	12.5
Engine	Landfill	5.6	70.2	0.39	70.2
Blades	Landfill	0.14	1.8	0.01	1.8
Covers	Landfill	0.25	3.1	0.018	3.1
Wheel	Landfill	0.02	0.3	0.0014	0.3
Air filter	Landfill	0.01	0.1	0.0007	0.1
Deck	Landfill	0.7	8.8	0.049	8.8
Total		**8**	**100**	**0.56**	**100**

EoL potential:

Component	End of life option	Energy (MJ)	%	CO2 footprint (kg)	%
Handle bars	Landfill	0		0	
Cover collector bag	Landfill	0		0	
Mover pan	Landfill	0		0	
Engine	Landfill	0		0	
Blades	Landfill	0		0	
Covers	Landfill	0		0	
Wheel	Landfill	0		0	
Air filter	Landfill	0		0	
Deck	Landfill	0		0	
Total		**0**	**100**	**0**	**100**

Selected mitigations - BATNEEC

Item	Measures
Carbon Steel	Production of steel using a blast furnace (BF) emits 1700 kg of CO2 per 1000 kg of steel. Electric arc furnace (EAF) emits 4.25 times less emissions at 400 kg of CO2 per 1000 kg of steel. EAF steel is cheaper to make and sold cheaper as it is made from recycled material. It is sold over 3 times as cheap than BF produced steel [1] [2].
Recycle the metals	Rather than disposing the lawn mower to landfills the carbon steel can be recycled, this reduces overall costs and provides sustainability in the industries.
Power supply	Electricity from battery supplies is generally cheaper than petrol fuelled engines, but this can massively depend on efficiency of motors/engines.

Is residual mitigated risk ALARP

Relating to Stakeholders;

As Design quality Managers, we are tasked with achieving a high level of quality within the product at the lowest possible cost.

When evaluating risks, mitigation should be done methodically controlling the risks with the highest RPR ratings as a priority regardless of cost as these features could be detrimental to customer satisfaction and likely breaks government guidelines.

Effective mitigation guarantees that for a small cost, sustainability is achieved through preservation of the environment and the life cycle of the parts themselves. This guarantees a quality product for a sustainable business keeping all stakeholders happy.

The reduction in mitigation cost is to maximize the profit margin and reduce cost of the product for consumers which ultimately keeps all direct stakeholders satisfied such as the CEO and investors getting a larger return on their investment trickling down to the demands of the consumers able to get a good quality product at a fair price.

The government guidelines are to make sure no corners are cut and common standards are meat, this produces a reliable and trustworthy product.

ALARP		Risk Priority Ratings	
Level O f Risk	**Risk**	**RPR (i)**	**RPR (r)**
Unacceptable: Control measures to implement in order to nullify risks. Imperative despite high costs.	If exhaust material becomes too weak holes can form allowing the fumes to be directed to internal parts causing further damage.	200	80
	Clogged exhaust would re-direct hot fumes back into engine damaging internal parts.	175	30
	Failure to collect grass without proper attachment of the collector.	180	72
	Toxic fumes are released into the atmosphere from carbon build-up in engine.	168	56
	Blade breaches body of safety.	216	54
Tolerable: Measures to control risk should be implemented as long as cost isnt excessive compared to the safety of the device.	Moisture can intervene with the electrical circuit of start button.	147	70
	Engine over-heating, poor suction for grass collection.	96	32
	Air filter contributes to the cooling of motor so if broken additional heat would be added to the system.	112	40
	inefficient carburator Spoils balance between fuel and air within the motor releasing toxic fumes.	140	30
Acceptable: Risks should be controlled where cost is small or regulations specify it.	Poor cutting of grass due to blunt blade	24	12
	Toxic fumes are released into the atmosphere from low oil.	45	6
	Grass fall out from the mower grass collector leaving mess on lawn.	40	8

Critical evaluation (options appraisal & decision-making)

- A major failure modes were due to exhaust, push-button, and grass collector faults.
- Material selection and maintenance were observed as a common risk that can be certainly avoided.
- The use of EAF steel proved to be more environmentally friendly than carbon steel which makes BATNEEC necessary when evaluating the lawnmower.
- Battery-powered lawnmower is a good alternative to petrol-powered lawnmower which diminishes fumes and noise produced by the engine but produces other forms of failure.
- With sufficient lubrication, detachment in the engine and wheels won't be a high priority.
- Any new failure can be identified gradually.

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