UNIVERSITY OF LIVERPOOL

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School of Engineering

Design for Environment, Manufacture and Assembly (DfEMA)

MNFG413

Assignment 1 (DfE)

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Author: Swaraj Patra

ID: 201596665

Project Group 12,

product name- Cookworks Food Processor

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Academic Supervisor: Dr Ahmed Abass

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1. Executive Summary

SUMMARY

The main purpose of this report is to provide TDS Appliances Ltd to design a new product based on our skills and knowledge acquired from disassembling and examining the "Cookworks Food Processor" by concentrating on the environmental impact of the product and more likely to be recycled at the end of its life-span**.** So, the product was analyzed using the Design of Environment (DfE) perspective. In the initial stage, the product was disassembled to identify different parts and materials involved and to determine the scope for recycling and reuse of the parts. Based on the product, a bill of material was created and function analysis was performed. On the other hand, they are the four main DFE (Design for Environment) methodologies that were used: MET matrix, Macdonald-Smith analysis, Luttropp's 10 Golden Rules, and an additional method used to successfully redesign the product and with adjustments has been outlined for TDS Ltd and why this should be considered which is described in detail in this report.

2. Introduction

In the modern era of environmental crisis, it is vital for designers and manufacturers to examine and design products while considering their impact on environment. Now-a-days, lot of emphasis is given on conservation of resources and developing an environmentally friendly atmosphere for the future generation. Therefore, it has become a vital responsibility for industries and corporations to develop sustainable ways to design, manufacturing and assemble products. The DfE methodologies were developed and introduced in the design and manufacturing of the products. In this report Cookworks Food Processor was successfully redesigned using the DfE methodologies and best environmentally friendly design and manufacturing of products was developed and offered to our user TDS Appliances Ltd.

2.1 Product Description

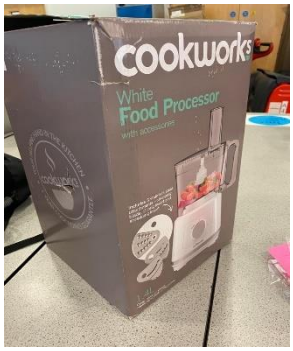
The Cookworks Food Processor is excellent food processing equipment that comes with a bowl capacity of 1.4L and with default stainless steel chopper blade and adds 3 different types of blades which are used for chopping, slicing, shredding, and beating the food items such as fruits, vegetables, etc. The power consumption is 500 watts of the product, having 2 speed and pulse function. This food processor has an overall dimension of 260 x 227 x 392 mm, weighing about 2.4 kg.

Based on the design the size of the product is found to be reasonable. While in use it cannot be used in one hand just to be on the safer side as due to pressure caused by the vibration the lid might open and end up being messy. It's advised to use a scraper or spatula and not use hands or utensils inside the processor while not in use as it can cut your fingers because the blades are very sharp. Although there is a safety measure installed which doesn't allow the machine to work when the padlock is not closed properly. As there are sharper products it is advised to keep them away from children unless they're taught how to use them properly in cooking classes with a minimum age of 12 or older. Product capacity of 1.4 L is considered an optimum design as it is estimated that it can process the required quantity for a 3- or 4-member household. It's Reasonable considering the capacity of the product. The product is not found to be dishwasher safe and easier to clean if taken necessary precautions as they have very sharp blades. The blades used for food processing are stainless steel hence they're are rust-free. Polypropylene (PP) is used for Motor housing and they're recyclable. The bowl is transparent which can be an issue if the storage place is small.

2.2 Product Disassembly

The Disassembling of the food processor could be divided into 4 major steps.

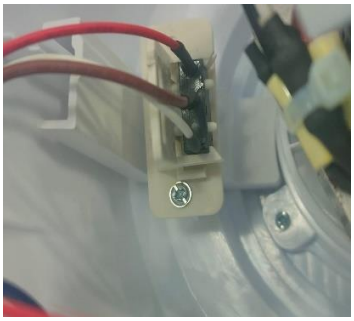
1. **Unboxing** the food processor comes in a carboard box unboxing involves
    - Removing the box seal.
    - Removing supports that holds the product in place.
    - Remove the Jar, Blades, and other accessories from the LDPE packaging.
    - Remove the motor unit from plastic packaging.

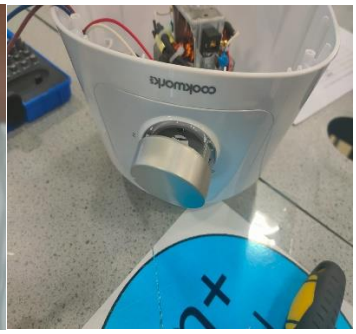



2. **Motor unit disassembly** this involved opening the main casing for the motor and other electronics.

- Remove 4 screws from motor housing base.
- Remove suction cups from bottom.
- Remove base housing connector.
- Unscrew wire and capacitor fixed on base.
- Unscrew jar fitter and micro switch.
- Unscrew main switch, remove regulator know and unscrew its housing.
- Unscrew the Gear box assembly inside the motor housing.
- Remove the gear box and unscrew motor outside motor housing.





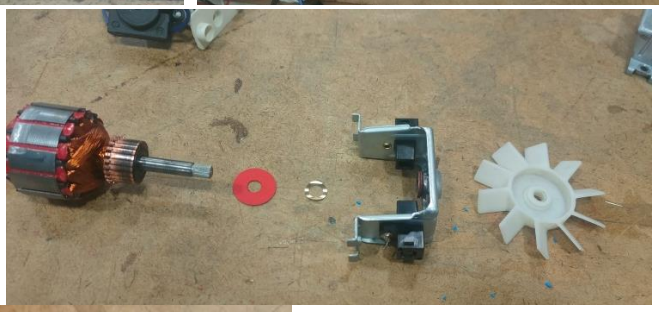
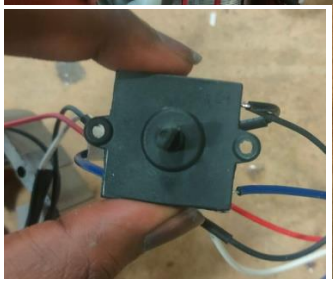





3. **Disassembling motor and wiring** where all the electronic and motor components are separated as much as possible.

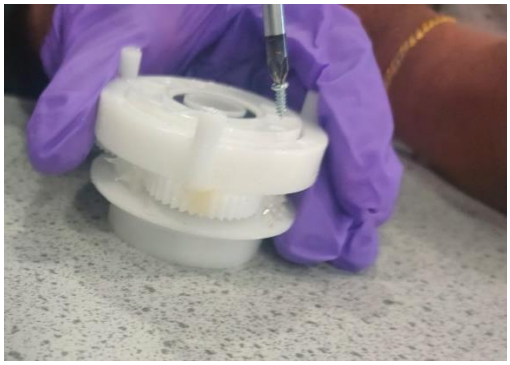
- Cut wire to Capacitor, micro switch, and main switch.
- Remove resistor from the plug.
- Using a Vise gear and fan of motor are removed.
- Unscrew brackets in both side of motor to separate all motor parts.
- Carbon brushes are removed using pair of pliers.

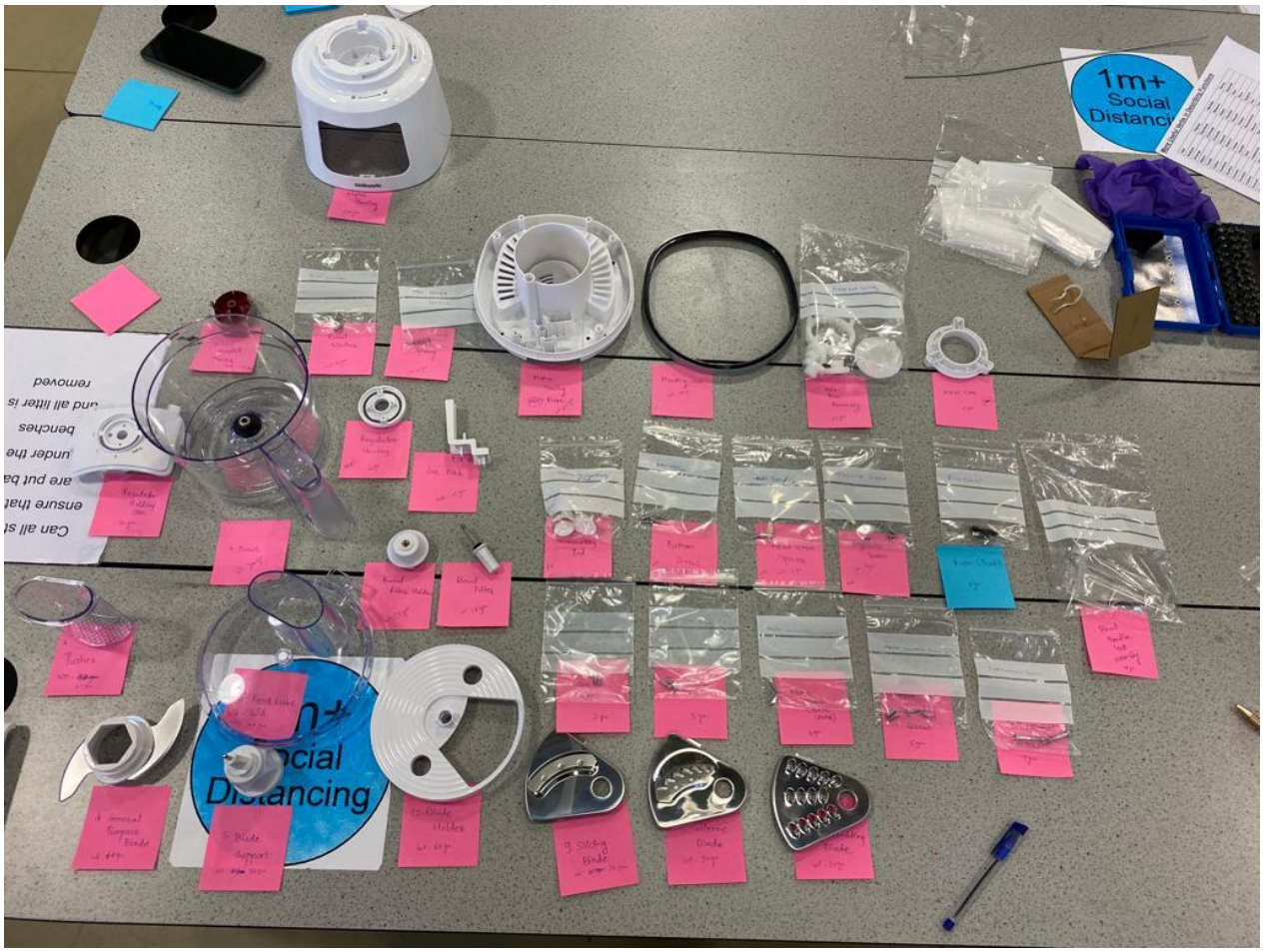



4. **Disassembly of jar components and gear box** involves removing attachments built in the jar separation of gear box.

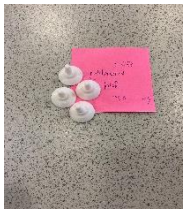
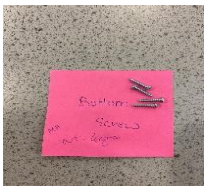
- Unscrew the bowl lock from the handle.
- Pull out the blade support.
- Unscrew the bowl fitter and remove the holder with set of pliers
- Remove shredding blade from blade holder.
- Unscrew casing of gear box.
- Separate planetary and its support from the ring gear.



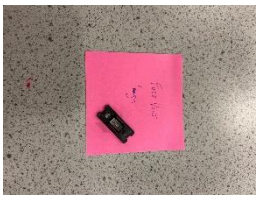
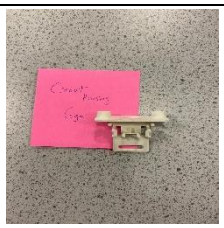
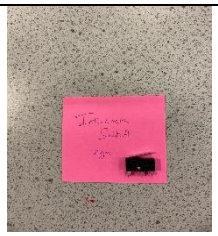
3. Bill of Materials

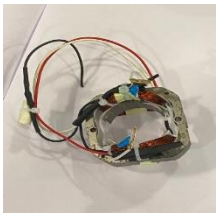
Bill Of Material						
Part Number	**Description**	**Material**	**Total Weight(kg)**	**Qty**	**Manufacturing**	**Image**
1	Transparent Lid	Acrylonitrile styrene	0.16	1	Injection Moulding	

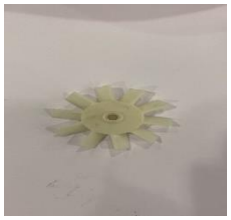
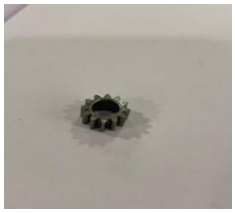
2	Pusher	Acrylonitrile styrene	0.047	1	Injection Moulding	
3	Bowl	Acrylonitrile styrene	0.394	1	Injection Moulding	
4	Motor Housing	Polypropylene	0.233	1	Injection Moulding	
5	Motor Housing Base	Polypropylene	0.215	1	Injection Moulding	
6	Suction Cap	PVC	0.0015	4	Injection Moulding	
7	Housing Bottom Screw	Steel	0.001	4	Thread Rolling Method	
8	Bowl Handle Lock Assm	Acrylonitrile styrene	0.018	1	Injection Moulding	

9	Jar Fitter Spring	PP	0.002	1	Injection Moulding	
10	Gear Box Screw	Steel	0.001	3	Thread Rolling Method	
11	Jar Fitter Screw	Steel	0.0015	2	Thread Rolling Method	
12	Gear Box Assm	Nylon	0.063	1	Milling/Hobbing	
13	General Purpose Blade	Blade -SS Body -PP	0.049	1	Progressive tooling	
14	Blade Holder	Polypropylene	0.065	1	Injection Moulding	
15	Bowl Fitter	Steel / Plastic	0.018	1	Thread Rolling	

16	Speed Switch Cover	Polypropylene	0.012	1	Injection Moulding	
17	Regulator Housing	Polypropylene	0.006	1	Injection Moulding	
18	Blade Support	Metal Part -SS Body - Polypropylene	0.05	1	Injection Moulding	
19	Bowl Fitter Holder	Metal Part - Brass Body - Polypropylene	0.017	1	Injection Moulding	
20	Regulator Holding Case	Polypropylene	0.03	1	Injection Moulding	
21	Regulator Case	Polypropylene	0.029	1	Injection Moulding	
22	Bowl Washer	Steel	0.001	3	Stamping	

23	Slicing Blade	Stainless Steel	0.036	1	Progressive tooling	
24	Shredding Blade	Stainless Steel	0.03	1	Progressive tooling	
25	Julienne Blade	Stainless Steel	0.034	1	Progressive tooling	
26	Fuse Holder	Plastic	0.001	1	Blow Moulded	
27	Fuse	Copper & glass	0.002	1	Blow Moulded	
28	Circuit Housing	Plastic	0.006	1	Injection Moulding	
29	Micro Switch	Plastic + metal lever and roller	0.002	1	Progressive tooling + Injection Moulding (plastic)	

30	Capacitor	metallized polypropylene film	0.004	1	Rolling	
31	Rotatory Switch	Plastic	0.014	1	Injection Moulding	
32	Connecting Wire	Aluminium wire with PVC Insulation	0.022	1	Drawing	
33	Cable Holder	steel screws, plastic	0.003	1	Thread rolling, Injection Moulding	
34	Jar Fitter Spring	Spring Steel	0.001	1	Coiling	
35	Motor Stator	Mild steel, copper coils, Al wires	0.346	1	CNC milling, drilling	
36	Motor Assembly Screw	Steel	0.001	4	Thread Rolling	

37	Motor Front Cover	Mild steel	0.034	2	Bending, forming, drilling, Riveting	
38	Washer	Carbon steel	0.001	4	Stamping	
39	Magnetic Spring	Steel, magnet	0.002	2	Coiling	
40	Washer	Carbon steel	0.001	4	Stamping	
41	Motor Fan	Nylon	0.004	1	Injection Moulding	
42	Motor Gear	Mild Steel	0.004	1	Milling/Hobbing	
43	Motor Rotor	Mild steel, Copper	0.198	1	CNC milling, Coiling	

44	Motor Base Screw cover	Steel	0.001	3	Thread Rolling	
45	Coil Motor Screw	Steel	0.002	2	Thread Rolling	
46	Regulator Screw	Steel	0.001	4	Thread Rolling	
47	Pulp Inserts	Cardboard	0.128	2	Pulp Moulding	
48	Plastic Bag	LDPE	0.001	4	Extrusion	
49	External Cover	Corrugated Cardboard	0.5	1	Corrugation, Pressing	
50	Base connector	ABS	0.1	1	Injection Moulding	

4. Met Matrix

MET Matrix	M Use of Material	E Use of Energy	T Toxic Emission
Pre-Production	***Plastics*** - acrylonitrile, butadiene, styrene, propene, vinyl chloride, ethylene, calcium carbide, etc. ***Metals*** - chalcopyrite, Bauxite, hematite, calamine, chromium, silicon, molybdenum ***Non-metals*** - latex, silica sand, limestone, and soda ash, pigments, wood pulp	***Plastics*** - Per kg - ABS:95.34 MJ, polypropylene: 73 MJ, PVC: 77.2 MJ/kg ***Metals*** - per kg- Iron (from iron ore): 20-25MJ, Steel (from iron): 20-50MJ, Aluminium (from bauxite): 227-342MJ, Copper (from sulfide ore): 60-125MJ, Brass - 17 MJ ***Non-metals*** - Rubber (natural): 15-16 MJ/kg, Fiberglass :13-32 MJ/kg, Paper (from standing timber): 16-25MJ,	***Plastics***- Phthalates, dioxins, vinyl chloride, ethylene dichloride, lead, heavy metals, carbon monoxide, hydrogen cyanide, fluorinated compounds, bisphenols, sulfur oxides, nitrous oxides, methanol, ethylene oxide, and volatile organic compounds. ***Metals***- coke oven gas, naphthalene, ammonium compounds, crude light oil, sulfur, coke dust, Sulphur dioxide, hydrogen sulfide, lead, cadmium, perfluorocarbons, sodium fluoride, sulfur dioxide, polycyclic aromatic hydrocarbon, and largest contributions of CO2 emissions. ***Non-metals***- heavy metals, toluene, and polycyclic aromatic hydrocarbons,

			styrene, volatile organic compounds (VOC), smog.
Production	Plastics parts made of PP, ABS and 33%glass filled PP are molded by injection moulding process. Brass and Stainless-Steel parts are made by machining processes. Aluminium parts like frame and discs are made by bending and punching processes. Process of drawing is used to manufacture Copper wire and Aluminium rods. Cardboard box and paper are manufactured by rolling. Plastics packaging is manufactured by blow extension. Ink is used in printing of manuals and other detailed information.	Average energy consumption of injection molding is 0.3 -0.6 kWh/kg depending on thickness. Machining and drawing are energy extensive process that needs electricity to convert into mechanical energy to perform a variety of processes. Aluminium parts production requires around 15kwh/kg. 1600kWh of energy goes into manufacturing of cardboard boxes. 300-500 watts of energy is needed by a printer when printing and 30 to 50 watts on standby.	Injection molding could produce substances like styrene, phenol, hydrogen chloride, butadiene, formaldehyde, acrolein and other aldehydes. Although most machining, bending, punching, and drawing process don't produce any toxic substances but sometimes they might produce nanomaterial particles. Cellulosic fibers, which congeal into toxic sludge; and chlorophenol wood preservatives and anti-sap stains are some harmful substances that might be produced during cardboard and paper manufacturing. Fumes that could be released from ink solvent are toluene,

			1.3259 kWh/kg is the energy used in blow extension molding process to make the Plastics cover.	isopropanol, 2-butanone, ethyl acetate, and methanol which could be Toxic.
Distribution		All parts are wrapped in plastic bags, and then packed in cardboard boxes with cardboard holders to keep all parts in position. Other documents like manual, warrant is added inside the box before sealing it using adhesive tape. Then multiple units are stacked together and packed with shrink wrap.	Energy used for packing all parts can either be manually or automatic but even in manually process there might be use of conveyor belt which operates at 1 HP = 0.746 kW. The pellets of boxes need to loaded and uploaded using machines like forklift that uses up to 15,000 kWh per year Then they are transported to distribution centers via trains, trucks, ships, and planes which needs a large amount to energy to operate.	Apart from Co2 and Co emissions Nitric acid, sodium dioxide, copper and lead are other toxic substances produced by ship travel. Jet engines produce volatile organic compounds (VOC) such as CO2, NOx, CO, SOx and low molecular weight polycyclic aromatic hydrocarbons (PAH). Nitrogen dioxide, carbon monoxide, hydrocarbons, benzene, and formaldehyde are some of the most harmful gasses produced by a truck
	Operation	The food processor can be used for a variety of processes like slicing, chopping, grating, and mincing of food. Which	Electricity needed to operate the food processor is 500W	

Use		makes cooking fast and easy.	The consumption of energy depends on the mode that's being used.	
	Servicing	Proper cleaning and dry is important before and after use of the device to maintain hygiene.		
End of Life	Recovery	The cardboard boxes and can be reused for storage or passed for recycling. In case of electrical failure parts like switch, capacitor, fuse could be easily repaired.		
	Disposal	If disposed by Proper means most of the device is recyclable. The hardest part of disposal will be dismantling and segregation.	Energy to transport the device to segregation plant. Recovery of ABS, PP, STEEL, ALUMINUM, COPPER, PAPER, glass filled PP, BRASS is possible	Materials like PVC, rubber, PU must throw as landfill where they could release toxic air due to UV from sun. They could also further break down to micro-Plastics and enter the food chain.

5. Product Analysis

5.1 Product Lifecycle

MATERIALS

Polypropylene, Acrylonitrile Butadiene Styrene, Polyvinyl chloride, Steel, Stainless steel, Plastic Ceramic Dielectric, and Aluminum wire are most of the product components. The metal component of the chopper consists of steel and copper, which are used in the motor, blade, and electronics, and are frequently purchased.

MANUFACTURE

Most of the material in the mini chopper are manufactured by Injection Molding Process and some are manufactured by Thread Rolling Method. Mini chopper components consist of Acrylonitrile Butadiene Styrene, Polypropylene, steel, and plastics.

TRANSPORT

The raw materials required for the small chopper are imported, assembled, and then packaged in a cardboard box for transportation. The commodity can be transported by ship, truck, vehicle, or train from one location to another.

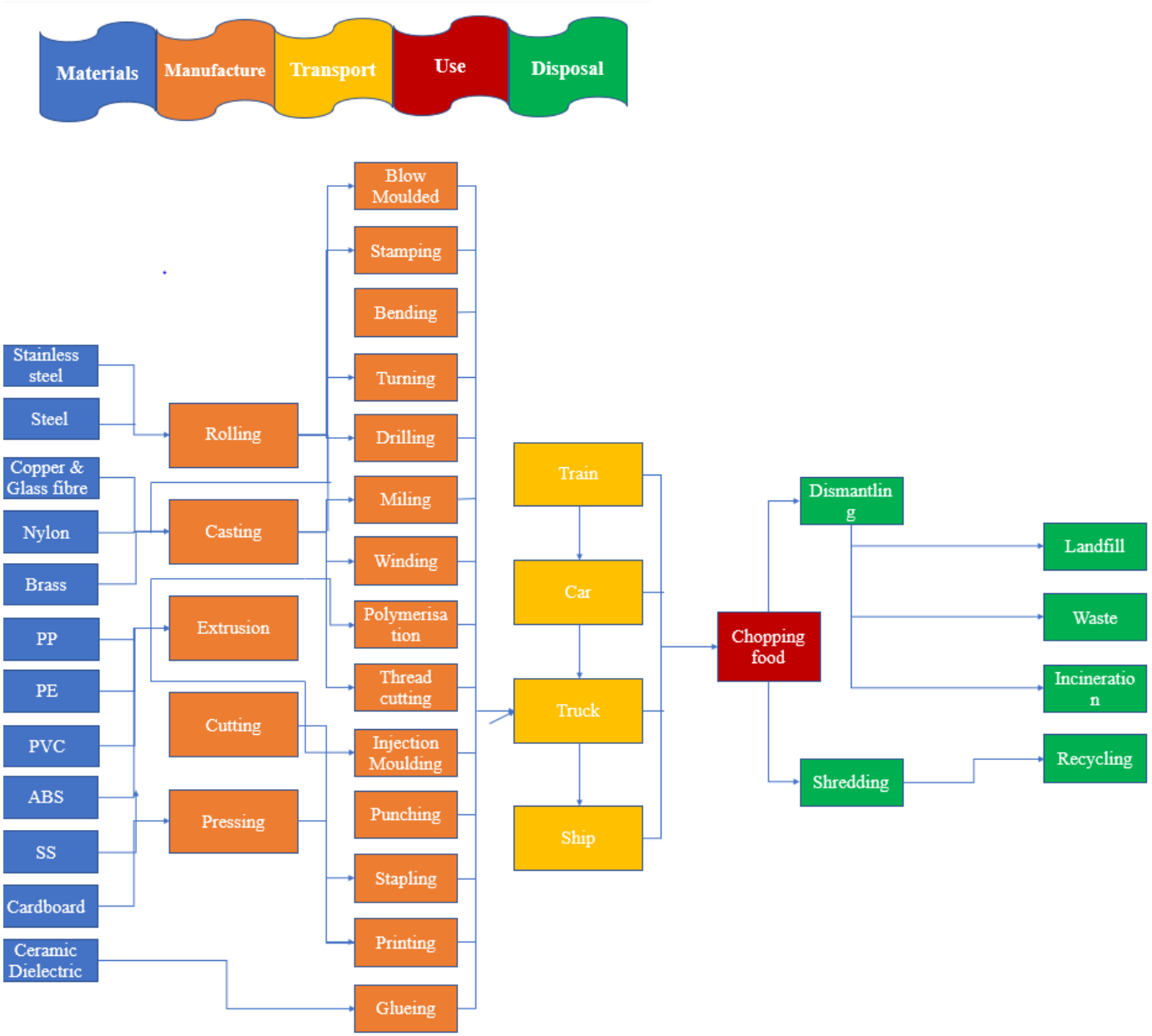
USE

Mini Chopper are small electric food processor designed for chopping vegetable, making dressing or pureeing food in seconds. It is easy to use and maintain continuous cleaning through its period of use would be mandatory.

DISPOSAL

Mini Chopper contains components composed of both recyclable and unrecyclable material. Therefore, it is very difficult to disassemble and recycle. The product design can be classed as “Cradle to Grave” which means it is most likely to end up in a landfill. Because of this the lifecycle needs to be addressed to minimize the environmental impacts it has. The main environmental impacts will be during Manufacturing and Transportation.

5.2 Life Cycle Mapping



6. Function Analysis

Functional analysis enables us to understand various features and their importance by dividing them into 3 categories **Primary**, **Secondary** and **Discretionary.** Based on this classification parts associated with these functions are given importance accordingly when redesigning the product.

7. MacDonald Smith and T Short

7.1 Materials

Materials		AS		PVC				LDPE			Aluminium	Nylon			Mica
Essential Materials	Cardboard		PP		Copper	Steel	Stainless steel		Spring Steel	Brass			Grease	Glass	
Notes	Biodegradeable	Thermal, solvent and stress cracking Resistance	Low Density, Good chemical and mechanical resistance	inherent flame retardant and excellent electrical insulation properties	Good electric conductor	Good Hardness	Good corrosion resistance and durable	Soft, flexible material used for packaging	Thermal and mechanical strength	Corrosion resistance, Antibacterial	Good Conductivity	Lightweight, non rusting	good lubricant	Good insulator	Good insulator
Revised Materials				mPPE				Cardboard					Grease made from vegetable oil, synthetic esters		
Notes				Lighter, Tougher , Superior Dielectric , 100% recyclable				Biodegradeable					Biodegradeable		

Colour Code	environmentally sustainable, friendly and biodegradable	recyclable, waste byproducts	neutral materials	toxic/hazardous	Volvo grey list	Volvo black list

7.2 Manufacturing

Manufacturing																
Process and Materials	Injection Moulding (Thermoplastic)	Thread Rolling Method	Milling/ Hobbing	Soldering	Stamping	Bending	Casting	Punching	Inkjet Printing	Wire drawing	Glass moulding	Coating	Drilling	Winding	Cutting	Glueing
Energy Use	High	Medium	Medium	Low	Medium	Medium	High	Medium	Medium	Medium	High	Medium	Medium	Low	Medium	Low
Emission	Medium	Low	Low	Medium	Low	Low	High	Low	Low	Low	Medium	Medium	Low	Low	Low	toxic solvent
Waste/ Scrap/ Byproducts	High	Medium	Medium	Low	Low	Low	Medium	Medium	Low	Low	Low	Medium	Medium	No waste	25-30% scrap recyclable	Low
Revised Process					Laser Cutting			Laser cutting								
Notes	High volume of Waste is recylced			Lead free solders to be used											Laser Cutting	

Colour Code	eco friendly (no energy, no emissions, no waste, etc	Sustainable (recycled waste, non pollutant emissions, renewable energy	producing minimal waste, emissions and using minimal energy	toxic/hazardous, using excess energy, significant waste and emissions

7.3 Packaging and Distribution

Packaging and Distribution									
Product Type	Motor Base & Driver	Processing Bowl	Transparent Lid	Pusher	Blades				Blade Holder
					General	Slicing	Shredding	Juliene	
Weight /Volume	1.5kg	0.394kg / 1.4L	0.160kg	0.047kg	0.049kg	0.036kg	0.03kg	0.034kg	0.065kg
Revised weight/Volume	Reducing the Base volume								
Notes	Use of efficient motor with smaller frame size with sufficient air flow	For the given capacity of Bowl, Size cannot be varied and ABS material is preferred due to its specific properties	For the given capacity of Bowl, Size cannot be varied and ABS material is preferred due to its specific properties	Pusher is designed considering different kind of food and size	All parts are neccesary for required functions				

Swaraj Patra

Packaging Type	Corrugated Cardboards	Pulp Packaging Inserts	Plastic Bags	Manual	Foam
Weight	0.520kg	0.220kg	0.002kg	0.1kg	0.005kg
Re-designed Packaging			Bio degradable		Bio-degradab
Notes	Based on the product dimension	Prevent product damage in transit			Green cell foam derived from corn starch can be used

Colour Code	no packeging required	recycled, recycable, compostable materials	small weight and volume of packeging with	toxic/hazerdous, significant weight and volume relative to

Transport Type	Fork Lift	Truck	Aeroplane
Re-designed Transport	Electric Fork Lift	Electric Truck	Train
Notes	Versatile , Efficient and Environment friendly	Low pollution	

Colour Code	no transport required	efficient transportation, using renewable energy sources	energy efficient transport system using non-renewable energy	non efficient transport system

7.4 Product Use

Product Use										
Product Sub Assembly	Base	Motor driver	Processing Bowl	Transparent Lid	Pusher	Blades				Blade Holder
						General	Slicing	Shredding	Juliene	
Energy Consumption Use time	Low	High	Low	Low	Low	High				High
Lifetime Repair/ Upgrade/ Reuse	Non-repairable as it is made of plastic& reuse possible	Lifetime Repairable, Upgradable, Reuse not possible	Non-repairable as it is made of plastic& reuse possible	Non-repairable as it is made of plastic& reuse possible	Non-repairable as it is made of plastic& reuse possible	Reusable however after long use blades can get blunt and it will take longer time for processing the food				Non-repairable as it is made of plastic& reuse possible
Redesign		Use of suitable capacity motor based on the food to be processed, Proper lubrication, cooling & voltage control	Food handling capacity should be marked on the bowl using measurement scale to avoid overload and damage bowl							
Notes						Resistance to Rust, Less brittle				

Colour Code	no energy used, long life, repairable, upgradable, reusable	energy used renewable, long life, repairable, upgradable, reusable	minimal non-renewable energy and use time, maximum life time	significant energy used, high use time, short life time

7.5 End of Life

End of Life				
Components	Base	Motor driver	Processing Bowl	Blade assembly
Disassembly Requirement	Use of screwdriver and manual removal of snapfits	Complex disassembly involving many components such as Stator, Rotor, Screws, wiring, coils with different tools required	Blades and Blade adaptor can be easily disassembled. Other part like handle is integral part & cannot be disassembled	Blades can be easily removed from the blade holder as it is press fitted assembly, However general purpose blade is integrated with the plastic which is difficult to diassemble
Redesign		Use of smaller motors and non-toxic glue & grease	Bowl mounter can be redesigned to have threads instead of press fit	Avoid mixing plastics with the metal parts as it is hard to recycle
Notes		Welded parts cannot be diassembled		

Colour Code	no disassembly, all components reusable, recycable, biodegradable	no energy for disassembly, some effort for component reuse, etc	minimal energy for disassembly, significant disposal, some effort to reuse etc	significant energy for disassembly, disposal, hazardous, effort to reuse

8. Luttropp's 10 Golden Rules

GOLDEN RULE	EXPLANATION	SATISFIED?
1. Don't use Toxic substances; if necessary, think of disposal.	– All the parts which are used in these products are toxic free material except the motor and the circuit board. – Which may have toxic materials such as motor oil, mercury, or lead.	YES
2. Minimize energy and resource consumption in production and transport through Minimize housekeeping.	– The rectangular box shape cover makes it easier to store all the components and easy for transportation. – Injection Molding is the most significant production method. But the size of the box can even be reduced to smaller size, which would make it much more efficient for transportation. – If they were manufactured locally and reduced using different components, it would help to reduce energy use in transportation and resource consumption.	NO
3. Use structural features and high-quality materials to minimize weight.	– All parts in the blender are necessary for its function and are made up of lightweight plastic materials. – The only main component and heaviest part of the product is the motor. – If the size of the motor is reduced, the whole product weight will be reduced. – Smaller and more efficient motors are present in the market, which are expensive. – Though it affects the expense of the product, it will boost the quality and performance of the product.	NO
4. Minimize energy and resource consumption in their usage phase.	– The motor used here is big, so it consumes lots of energy. – So, using small and efficient motor would reduce energy consumption. – By reducing the motor size, the base of the product will be reduced to smaller size, thus it helps in reducing the weight.	NO
5. Promote repair and UPGRADING, especially for system dependent products.	– It only required one screwdriver to dissemble the major parts of this product. – But disassembling the blade and blade holder from the jar was difficult and it needed supervisor help.	YES

6. Promote LONG LIFE, especially for products with most significant environmental aspects out of usage phase.	– Size-able portions of the product were made with plastic, which is easily breakable. – Anti-static coating present in the product gives long life span from external wear and tear. – The stainless-steel material used in the blades will wear off in a shot span of time. – Some of the parts are not easily replaceable if damaged. – Motor brushes will wear out in use.	NO
7. Use better materials, treatments or structural arrangement to PROTECT products.	– The base of the product is protected by dampers. – The jar is made up of ABS material, which has high impact resistance. So, it won't break easily. – The stainless blade will not corrode in a brief period. – Some of steel parts should be replaced with stainless steel materials e.g., Screw etc..	YES
8. Prearrange upgrading, repair and recycling through access ability, labeling, manuals.	– It does not have any details about upgrading and most importantly recycling the materials which are used. – The operation manual shows the use and power output of the product.	NO
9. Promote upgrading, repair and recycling by using a few SIMPLE, not blended, materials.	– Some extra tools are needed for the disconnecting of the parts of the motor. – It is only a complex part of the product, which gives tough time while disassembling,	NO
10. Use as few joining elements as possible through careful STRUCTURAL arrangement.	– The joints are connected using screws. Disconnecting every part required tools. – Most of the plastic materials are ABS, not lots of materials are mixed in this product.	YES

9. Additional Methods

9.1 Product DFS Matrix

It is a process of comparing various parameters using a matrix format to determine environmental impact of a product throughout its lifecycle. Results from this tool helps designers to make changes to the product to meet the company's needs.

The matrix can be customized by addressing questions that are designed to bring potential environmental impacts caused during it lifecycle which includes manufacturing, transporting, use and disposal of the product into focus of design team and highlights areas of environmental concern.

The process involves making a matrix and award marks to **Percentage-based** questions and **Yes** or **No** questions. In percentage-based questions **0-5** points are assigned to a percentage and for yes or no questions **Yes** is designated with a certain value while **No** is equal to **zero.** The value of an option can be determined based on the importance of the factor related to the question. The scores from the questionnaire are added to the matrix and a sum of values in each row and columns are calculated then the total of all the sums is calculated, which gives a final score for the product. A matrix is created for the product that are disassembled and for the redesigned model, so it is easier to compare both based on individual factors and as a whole product which also helps to improve the redesign to get a better score.

Product Design Matrix: Design for Environment Toolkit

LIFE STAGE	Environmental Concern					Total
	1 Materials	2 Energy Use	3 Solid Residue	4 Liquid Residue	5 Gaseous Residue	
A Premanufacture	(A.1)	(A.2)	(A.3)	(A.4)	(A.5)	
B Product manufacture	(B.1)	(B.2)	(B.3)	(B.4)	(B.5)	
C Distribution, packaging	(C.1)	(C.2)	(C.3)	(C.4)	(C.5)	
D Product use, maintenance	(D.1)	(D.2)	(D.3)	(D.4)	(D.5)	
E End of life	(E.1)	(E.2)	(E.3)	(E.4)	(E.5)	
Total						

Cookworks Food Processor

LIFE STAGE	1.Materials	2.Energy	3.Solid residue	4.Liquid residue	5.Gaseous residue	Total
A) Pre-manufacturing	0	0	0	0	0	0
B) Product Manufacture	3	3	3	2	2	13

C) Distribution, Packaging	1	5	3	5	2	16
D)Product Use, Maintenance	2	3	5	5	5	20
E) End of life	4	3	0	5	5	17
Total	10	14	11	17	14	**66**

Possible questions-

Premanufacture

As indicated by the survey of your suppliers:

A.1: Premanufacture, Materials

What percent of your company's suppliers for this product or component have an Environmental Management System (EMS) in place? (circle one)

0% or unknown = 0 points
1 to 5 % = 2 points
6 to 25% = 3 points
26 to 50% = 4 points
>50% = 5 points

A.2: Premanufacture, Energy

What percent of your company's suppliers for this product or component have formal energy conservation practices in place, such as the Environmental Protection Agency's Green Lights Program? (circle one)

0% or unknown = 0 points
1 to 5 % = 2 points
6 to 25% = 3 points
26 to 50% = 4 points
>50% = 5 points

A.3: Premanufacture, Solid Residue

What percent of your company's suppliers for this product or component have ISO 9000 or ISO 14000 in place or regularly publish a company environmental report? (circle one)

0% or unknown = 0 points
1 to 5 % = 2 points
6 to 25% = 3 points
26 to 50% = 4 points
>50% = 5 points

A.3: Premanufacture, Liquid

What percent of your company's suppliers for this product or component have a water conservation program ? (circle one)

0% or unknown = 0 points
1 to 5 % = 2 points
6 to 25% = 3 points
26 to 50% = 4 points
>50% = 5 points

A.5: Premanufacture, Gaseous

What percent of your company's suppliers for this product or component have a formal program in place for minimizing air emissions? (circle one)

0% or unknown = 0 points
1 to 5 % = 2 points
6 to 25% = 3 points
26 to 50% = 4 points
>50% = 5 points

Product Manufacture

B.1: Product Manufacture, Materials Choice

(for each question circle one number)

For this product or component:	Yes	No
1) Is as much **recycled** material used in your product as possible?	1	(0)
2) Is the use of **hazardous** materials avoided or minimized? (see *figure 5 page 58, Hazardous Chemical Index, page 32)*	(2)	0
3) Are the amounts of materials that are used minimized?	1	(0)
4) Are the number of types of materials that are used minimized?	(1)	0

Total Points for Matrix Element B.1: 3

B.2: Product Manufacture, Energy Use

For this product or component:	Yes	No
1) Do the manufacturing process minimize the use of **energy- intensive** processes? *(for example, multiple cycles of heating and cooling, inefficient motors, see Motors Challenge Program page 63 etc.)*	(2)	0
2) Do manufacturing processes use cogeneration, heat exchange or other techniques to utilize wasted energy?	2	(0)
3) Is there minimal transportation between manufacturing and assembly points?	(1)	0

Total Points for Matrix Element B.2: 3

B.3: Product Manufacture, Solid Residue

(for each question circle one number)

For this product or component:	Yes	No
1) Are waste materials minimized and reused to the greatest extent possible during manufacturing? *(e.g., mold scrap, cutting scrap etc.)*	1	(0)
2) Have raw material and parts suppliers been contacted to encourage them to minimize the amounts and types of packaging materials entering your facility?	1	(0)
3) Has your company maximized the opportunities to reuse and reduce packaging waste when parts are shipped between facilities?	(1)	0
4) Has intentional introduction of all lead, cadmium, mercury and hexavalent chromium into the product materials been avoided?	(2)	0

Total Points for Matrix Element B.3: 3

B.4: Product Manufacture, Liquid Residue

For the manufacture of this product or component:	Yes	No
1) If **hazardous** solvents or oils are used have alternatives been thoroughly investigated? *(see vendor lists in the Reference Information section for information on alternative solvents and oils, if no solvents or oils are used in the manufacturing process the answer is "2" or no environmental impact)*	2	(0)
2) Are opportunities maximized to capture and reuse liquid by-products generated during the manufacturing process? *(if no solvents or oils are used in the project the answer is "2" or no environmental impact)*	1	(0)
3) Is the generation of **water pollutants** avoided or minimized?	(2)	0

Total Points for Matrix Element B.4: 2

B.5: Product Manufacture, Gaseous Residue

For the manufacture of this product or component:	Yes	No
1) Is the generation of **global warming or ozone-depleting gases** avoided? (see *Climate-altering Chemical Index, page 60)*	(2)	0
2) Is the generation of **hazardous** air pollutants avoided during the manufacturing process?	2	(0)
3) Is the use of solvents, paints, coatings or adhesives with high evaporation rates eliminated or minimized? *(i.e., materials that emit high VOCs or volatile organic compounds)*	1	(0)

Total Points for Matrix Element B.5: 2

Distribution, Packaging

C.1: Distribution, Packaging, Materials Choice

(for each question circle one number)

For this product or component:	Yes	No
1) Have **reusable transport packaging options** been explored for distribution between company facilities?	1	(0)
2) Have **reusable transport packaging options** been explored for distribution between your company and your suppliers?	2	(0)
3) Are **recycled** materials used in the transport and retail packaging ?	1	(0)
4) Are **recyclable** materials used in the transport and retail packaging ?		
5) Is the number of different types of materials used in the packaging minimized?	(1)	0

Total Points for Matrix Element C.1: 1

C.2: Distribution, Packaging, Energy Use

For this product or component:	Yes	No
1) Is either reusable packaging or material of the lightest weight and volume, yet functional transport and retail packaging material used?	(5)	0

Total Points for Matrix Element C.2: 5

C.3: Distribution Packaging, Solid Residues

For this product or component:	Yes	No
1) Is the packaging designed for easy separation of materials for reuse or recycling?	(1)	0
2) Are the types of packaging used commonly recycled?	2	(0)
3) Are the packaging materials clearly marked or easily identified by material type? *(e.g., plastics with resin type label etc.)*	(2)	0

Total Points for Matrix Element C.3: 3

C.4: Distribution, Packaging, Liquid Residues

(for each question circle one number)

For this product or component:	Yes	No
1) Have maximum precautions been take to prevent hazardous liquid spills during transport? *(e.g., extra containment layers or safety valves, if there are no hazardous liquids in the product or component the answer is "5" or yes, for no environmental impact)*	(5)	0

Total Points for Matrix Element C.4: 5

C.5: Distribution, Packaging, Gaseous Residues

For this product or component:	Yes	No
1) Does the transport or retail packaging not contain chlorinated polymers or plastics which may produce hazardous emissions if incinerated at low temperatures? (see Polymers page 62)	3	(0)
2) Does the packaging not contain bromated flame retardants that may produce hazardous emissions if incinerated at low temperatures?	(2)	0

Total Points for Matrix Element C.5: 2

Product Use, Maintenance

D.1: Product Use, Maintenance, Materials Choice

For this product or component:	Yes	No
1) Is the product or component easily disassembled for upgrade, repair or reuse?	1	(0)
2) Are parts readily available for the repair of this product or component?	(1)	0
3) Are potential barriers to recycling avoided such as using fillers, additives, or imbedded metal threads in plastics, applying paint to plastics, or using materials of unknown composition?	2	(0)
4) If plastics are used are they clearly marked by resin type?	(1)	0

Total Points for Matrix Element D.1: 2

D.2: Product Use, Maintenance, Energy Use

(for each question circle one number)

For this product or component:	Yes	No
1) Does the design facilitate minimal energy use while the product is in service?	2	(0)
2) Can this product or component adjust energy use based on the level of activity? (e.g. go into "sleep mode" during inactivity)	(3)	0

Total Points for Matrix Element D.2: 3

D.3: Product Use, Maintenance, Solid Residue

For this product or component:	Yes	No
1) Does the design avoid building in disposable components such as "one-time- use" cartridges, containers or batteries?	(1)	0
2) Are snaps, darts, screws of the same head type or other removable fasteners used and are adhesive or welds avoided for joining parts to make it easier to disassemble, repair, reuse or recycle?	(2)	0
3) Is this product designed to be easily repaired and/or upgraded rather than replaced entirely?	(2)	0

Total Points for Matrix Element D.3: 5

D.4: Product Use, Maintenance, Liquid Residue

For this product or component:	Yes	No
1) Does use of the product avoid the release of substances known to be **water pollutants**? (see Hazardous Chemical Index, page 32)	(5)	0

Total Points for Matrix Element D.4: 5

D.5: Product Use, Maintenance, Gaseous Residue

(for each question circle one number)

For this product or component:	Yes	No
1) Is the emission of hazardous **air pollutants** avoided during use or maintenance? *(see Hazardous Chemicals List, page 32)*	(2)	0
2) Is the emission of **global warming** and **ozone- depleting gases** avoided during use or maintenance? *(see Hazardous Chemical Index, page 32)*	(3)	0

Total Points for Matrix Element D.5: 5

End of Life

E.1: End of Life, Materials Choice

For this product or component:	Yes	No
1) Are the materials are easily reused or commonly recycled?	(1)	0
2) Are the materials easy to separate and identify by type?	1	(0)
3) Upon disposal are none of the materials required to be disposed of as hazardous waste?	(1)	0
4) Has the intentional introduction of lead, cadmium, mercury and hexavalent chromium into the product materials been avoided?	(2)	0

Total Points for Matrix Element E.1: 4

E.2: End of Life, Energy Use

For this product or component:	Yes	No
1) Can the plastic or fiber parts be safely used for energy generation ? (i.e., incineration, see Polymers on page 62, if there is no plastic or fiber materials used the answer is "2" or yes)	2	(0)
2) Upon disposal are there no hazardous materials that need to be transported to hazardous waste management facilities? (i.e., additional energy use is required to transport materials for special handling)	(3)	0

Total Points for Matrix Element E.2: 3

E.3: End of Life, Solid Residues

(for each question circle one number)

For this product or component:	Yes	No
1) Does the infrastructure exist (inside or outside the company) to recover/recycle the solid material(s)?	2	(0)
2) Does the product design avoid joining dissimilar materials in ways that are difficult to reverse?	3	(0)

Total Points for Matrix Element E.3: 0

E.4: End of Life, Liquid Residues

For this product or component:	Yes	No
1) Is the product designed so that problem liquid materials can be recovered during disassembly? *(if there are no liquids in the product or component the answer is "5" or yes, for no environmental impact)*	(5)	0

Total Points for Matrix Element E.4: 5

E.5: End of Life, Gaseous Residues

For this product or component:	Yes	No
1) Is release of substances known to be **ozone-depleting** and/or **global warming gases** avoided upon disposal of this product or component? *(see Climate-altering Chemical Index, page 32)*	(2)	0
2) Can gases contained in the product be recovered at the time of disassembly rather than lost? *(if there are no gases contained in the product or component the answer is "2" or yes)*	(1)	0
3) Is release of substances known to be **air pollutants** avoided upon disposal of this product or component?	(2)	0

Total Points for Matrix Element E.5: 5

From the table it is determined that the score for the product is **66** now different sections can be focused to be improved in the redesigned model to improve the score.

Some of the area of concern discovered by following this process are-

- Avoiding fusing of dissimilar materials.
- Need for an infrastructure for recovery of solid waste.
- Better way to identify materials.
- Ways to facilitate minimum energy use.
- Nonhazardous packaging so it does not release toxins when incinerated.
- Incorporating reusable transport packaging.

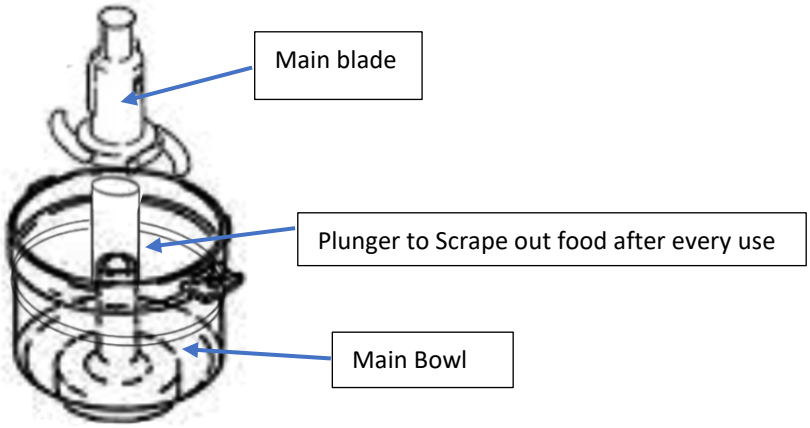
10 Redesign

Redesign in container and blades-

1. Adding a plunger between the main bowl and the blade. The plunger could be made from PP or ABS like rest of the bowl. It will be helpful scooping out the food after every use.

Benefits

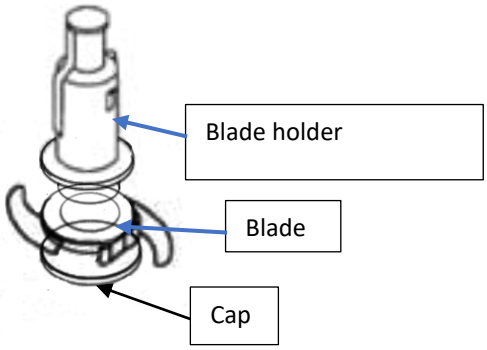
- *Need less water and effort to clean the main bowl after every use*
- *Waste less food.*
- *Lesser food gets clogged in sinks.*



2. Blades that are screwed to main blade holder and the screws are covered with a cap.

Benefits-

- They can be separated for recycling.
- It's easier to replace the blades in case they are damaged or get blunt.
- The cap prevents screw from loosening.



Redesign in motor housing-

QR code embossed on the plastic base linked to website containing information regarding disposal materials and spare parts.
Benefits.

- Makes it easier to identify the materials during recycling process.
- Makes it easier for customer to order spares if needed, extending its life.

Connecting the motor holder and gear housing to the top of motor housing using same screws.
Benefits

- Needs lesser number of screws.
- Easy to remove both motor and gear box in one go in scenarios where they might need to be repaired.
- No need to go through two extra steps to remove the motor from the housing making the dismantling easier.

Material change-

Using **Natural Rubber** suction cups for base instead of PVC suction cups although they are not as durable as PVC, they are more sustainable option. The user can be provided with extra two pcs in case any one of them get damaged.

Replacing PVC parts like PVC wires with **mPPE** wires that are superior to PVC in terms of Performance has specific gravity 25% less than PVC and is relatively easy to recycle.

Use of **Vegetable oil or synthetic ester** grease instead which are easier to source and ecofriendly.

Using **Recycled Aluminum** for the motor housing, knob, and knob housing. Although they increase the Cost and overall weight of the product, they are more durable, aesthetically pleasing and highly sustainable when compared with PP. Considering the price increase and Robust built user may be convinced to use it for a longer time increasing its product life.

Packaging Redesign-

Instead of Packing everything separately all parts should be stacked and covered in one single plastic covering.
Benefits-

- Saves product from water damage while being shipped.
- Less material is used.

The gap between the packaging and product should be less so the amount of support material used is less.

Instead of adding a lot of graphical printing on the packaging they could be kept minimalistic without use of toxic coatings that may be released when the degrade or burn.

11 Discussion

DfE works like every other product development processes. Product development could be done in one of two ways either sequential where there is sequence of steps that area followed with very little exchange of information regarding parameters related to that process and other is integrated where there is feedback from people involved in manufacturing, marketing, transport etc. which makes the design development process much efficient and faster.

Integrated design processes are more suitable for DfE. The growing concern regarding the environmental impacts caused during lifecycle of a product has taken the current development processes one step further, making developers to consider all life-cycle phases from the conceptual design stage through the detailed design stage to minimize environmental impact this includes development, production, usage, and disposal or recycling.

Various tools have been developed to help the DfE process. These tools or steps allows a designer to understand and focus on all possible variants. DfE processes used in redesigning the food processor involved.

- Dismantling – let us experience the troubles one might face while disposing or repairing the product. Also helps in deciding the structural changes that could be done.

- BoM- list down all materials, weight, and manufacturing processes so it is easier to predict replacement for existing parts or process.
- MET Matrix- brings focus to different life stages and the Material, Energy, Toxic impact created at that stage for the product.
- Product Lifecycle- It brings focus to the sub processes involved in an products lifecycle.
- Functional Analysis- This highlights the importance of different functions which in turn help in improving the parts associated with the function to achieve overall improvement.

Apart from these basic functions a lot of different methods have been developed by companies to optimize the DfE process suitable to their market. The processes used in this Project are

MacDonald Smit and T short- matrixes of materials, manufacturing, packaging & distribution, product use and end of life are made and filled with relevant data. The data is then color coded based on their environmental impact. Which helps in deciding the changes that are needed to be made to the system.

Product DFS Matrix- This a method where points are awarded based on yes or no questions if the product satisfies the criteria. The score is then calculated and could be compared with other products or for redesign process optimizations are done to improve the score of the product.

12 Conclusion

The aim of this report was to determine aspects of Cookworks food Processor that could be redesigned to improve its environmental impact throughout its life. Design for environment was used as the development process to reverse engineer the product and develop better understanding of the product lifecycle and its impact on different stages of its life cycle. The BoM makes it easy to keep track of all major components, their material and manufacturing processes used. Then process of developing a life mapping chart, MET matrix and functional analysis helps in getting to better understand the various factors, processes and impact of a product during all stages from Cradle to End.
DfE Tools are helpful to design product that could be closer to Cradle to Cradle. The tools used in the report are MacDonald smit and DFS Matrix that help to identify gaps in design that could be filled to make the product more sustainable. Both processes use visual indicators like colors and numbers to draw attention to more urgent environmental concerns.
The current redesign is made to reduce the waste from packaging and make it less toxic without endangering the product. The new suggestion for material involves use of aluminum body one of the biggest trends in sustainable products. It also aims at some of the lesser used materials that could be harmful to the environment. The redesign of jar makes the disposal and cleaning process easier. These changes should be considered by TDS LTD to bring the product closer to Cradle-to-Cradle Design.

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