MMF092 group 16

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1 Preface

This report documents the design and development process of a coffee machine that was undertaken as part of a course at Chalmers University of Technology in Gothenburg, Sweden, during the fall semester of 2022. Our team had several goals for this project, including reducing the cost of manufacturing, improving the overall performance of the coffee machine, creating an environmentally friendly product, designing an aesthetically pleasing product that meets the requirements and desires of the presumed consumers, and implementing a modular product architecture. To achieve these goals, we conducted extensive research and analysis, including:

- Variation analysis to understand and quantify sources of variation
- Stability analysis to evaluate the stability of the system over time
- Contribution analysis to understand the individual contributions of different variables
- FMEA (Failure Modes and Effects Analysis) to identify potential failures and evaluate the consequences
- LCA (Life Cycle Assessment) to assess the environmental impacts of the product throughout its life cycle
- DFA (Design for Assembly) to design the product for ease of assembly
- DSM is a tool used to analyze and manage the relationships between components in a system or product
- Material selection to choose the appropriate materials based on factors such as strength, durability, cost, and environmental impact

We developed a number of concepts and tested and evaluated them to finalize the design of the coffee machine. This report details the process that we followed to design and develop the coffee machine, as well as the challenges and successes that we encountered along the way

Contents

2 Introduction

Originally, coffee comes from what is today Ethiopia. Archaeological excavations have shown that coffee has grown wild in the region for as long as the area has been inhabited. The best way to get a coffee fast is by using a coffee machine. By what even is better is to build a coffee machine with Reduced cost of manufacturing and more environmentally friendly than the ones before.

2.1 Background to the assignment

The assignment to redesign a coffee machine was initiated because the existing coffee machine was not meeting the needs of the users. Some of the problems experienced by the users included frequent breakdowns, slow brewing times, and a lack of customization options. Additionally, the production process of the current coffee machine was inefficient, resulting in high costs and low profits. There was also a gap in the market for a coffee machine that was more user-friendly and efficient.

2.2 Problem statement

The problem that this project aims to solve is to design a new coffee machine that is reliable, efficient, and user-friendly. The most important requirement for the new coffee machine is that it must be able to consistently produce high-quality coffee while being easy to use and maintain.

2.3 Goals

The goals for the redesign project, in relation to existing products on the market therefore are

- Reduced cost of manufacturing Clear improvement of performance.
- The product must have a clear environmentally friendly profile.
- The aesthetics of the design must meet the requirements and desires of the presumed consumers.
- The product must have a modular product architecture.

2.4 Method

To solve the problem, we will be using a user-centered design approach. This means that we will be gathering feedback and input from potential users throughout the design process in order to create a product that meets their needs. We have chosen this approach because it has been shown to be effective in creating successful and user-friendly products.

2.5 Delimitation

This project is not aiming to cover the production or distribution of the coffee machine. Our focus is solely on the design and prototyping of the product.

3 Black-box model

The main idea behind black-box model is to only think about what is the inputs and what is the outputs. Next step is to think about how you can make the outputs from the inputs. In the figure 1 we can see the basic black-box model for the coffee machine from our viewpoint.

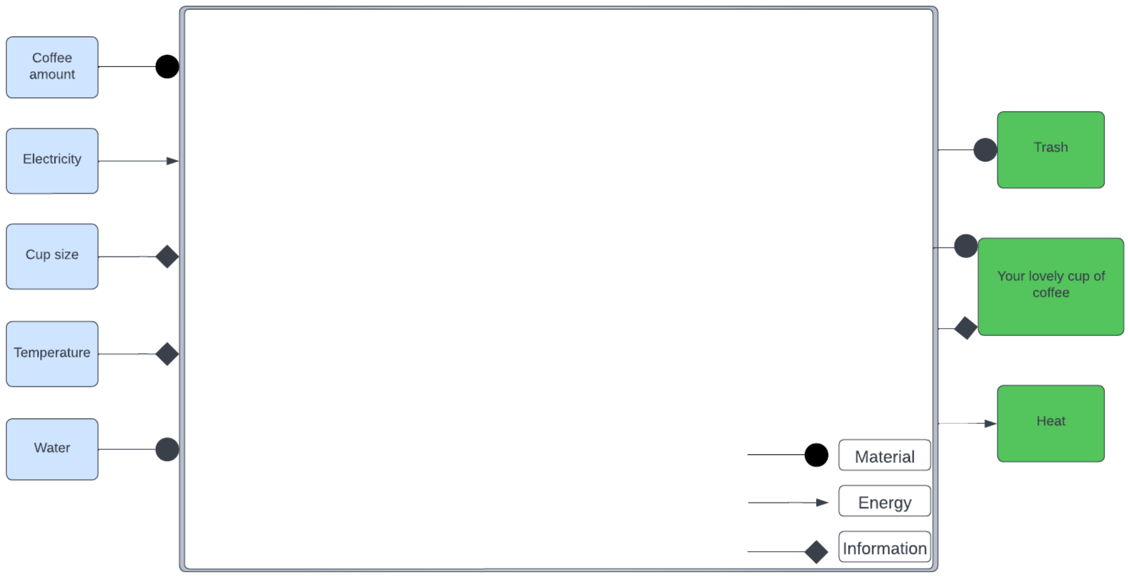


Figure 1: Black box model

4 Functional structure – hypothetic

Functional structure shows how the outputs can be retrieved from the inputs. Additional components can be added in the box.

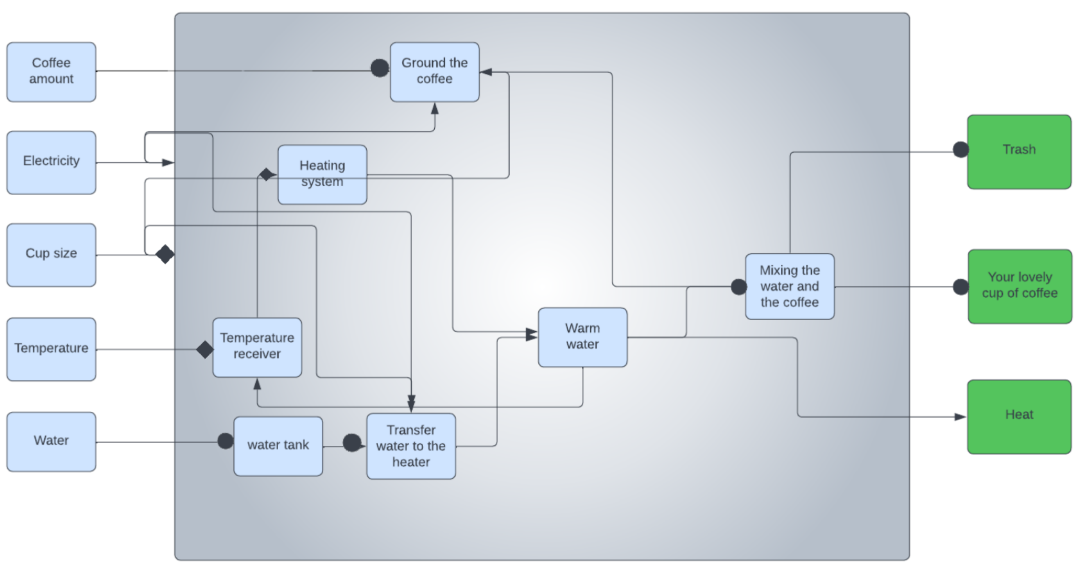


Figure 2: Functional structure – hypothetic

5 Functional structure – existing product

The Functional structure for the existing product works in slightly different way than the hypothetic one.

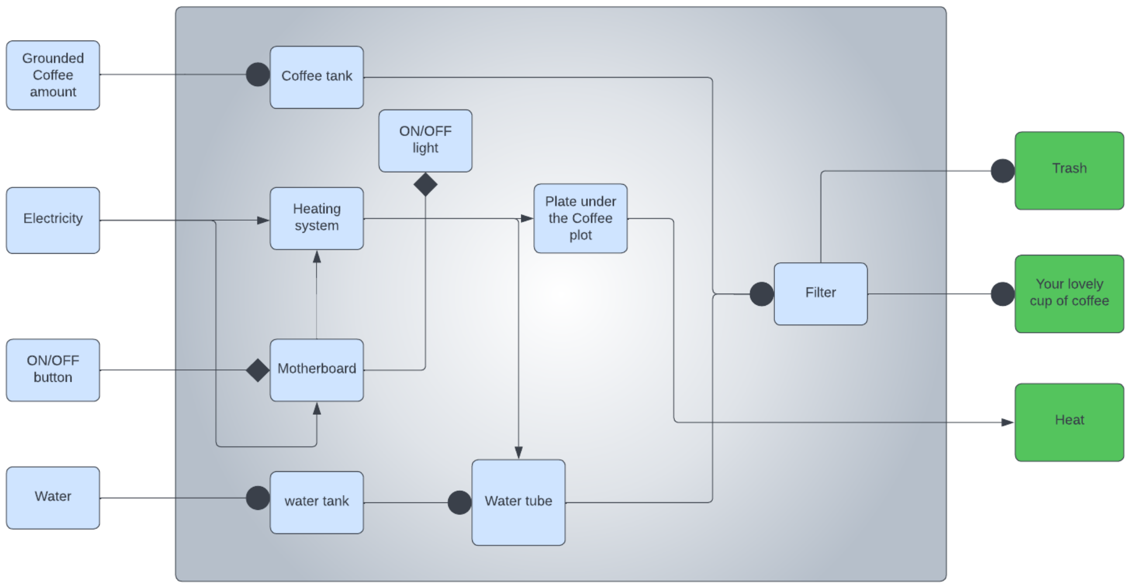


Figure 3: Functional structure – existing product

After disassembling all the parts in the product, we were able to see what is really inside the coffee maker. Our hypothetical and the real Functional structure are some differences which are pump, heating plate under the coffee plot and temperature meter. In our hypothetical, we included these because we thought that these components are important and without them you cannot build a coffee maker. For example, the pump would transfer water from the water tank to the coffee tank, but you can solve it with a simpler solution by heating the water and boiling it so as to let it evaporate and then the water will be lifted up because gas has less density than liquid. Therefore, we thought that it is a smart solution that is extremely simple and can save time, resources but also environmental impact.

Our hypothetical and the real Functional structure has the same input and output which was correct because most traditional coffee machines have the same functionality and thus will also have the same input and output

6 Functional structure – new product

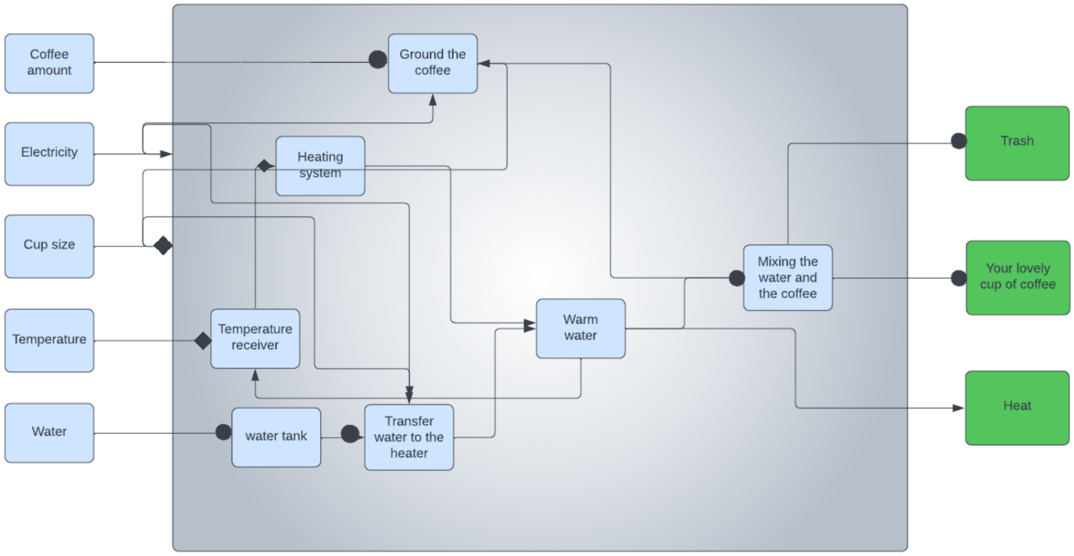
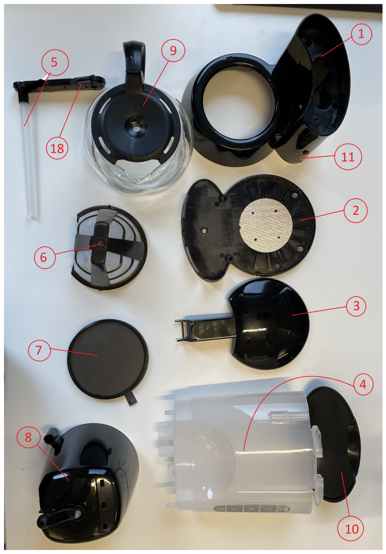


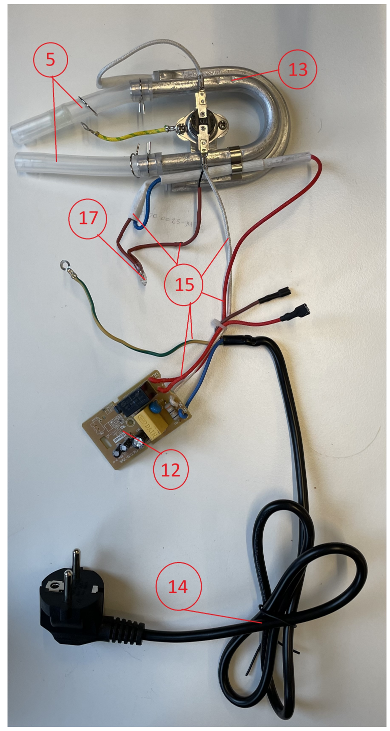
Figure 4: Functional structure – existing product

7 Exploded view – existing product

Figures 5 shows what the existing product consists of and 6 describes what is the quantity needed of each part, a description, the material used for each part and weight.



(a) Exploded view of coffee machine



(b) Exploded view of coffee machine electronics

(c) Exploded view of coffee machine

Figure 5: Exploded view

8 BOM – existing product

BOM (Bill of material) is a list which contains all of the raw materials, product components and quantities of each part and how they are connected to each others.

Figure 6 shows the essential parts and components that are needed to build up the existing product. It shows also which components that are essential to build up sub-parts together for example electronics consists of power supply, heating tube, motherboard etc.

Part #	Name of part	Quantity	Part description	Material	Weight (g)	Manufacturing method
1	Skeleton-Top	1	The skeleton of the produkt	Plastic	130.1	INJECTION MOULDING
2	Skeleton-bottom	1	The bottom part of the produkt	Plastic	61.1	INJECTION MOULDING
3	Container lock	1	Lock for the cofee container	Plastic	28.1	INJECTION MOULDING
4	Water tank	1	Tank where to fill water	Plastic	110.3	Blow molding
5	Water tube	3	Tube for transferring the steam	Plastic	15,4	INJECTION MOULDING
6	Filter	1	Filter to stop coffee going on to the pot	Aluminium	15.9	Rolling
7	Heating plate	1	keep the pot warm		43.8	Metal punching
8	Coffee container	1	Tank where to fill caffee	Plastic	28.1	INJECTION MOULDING
9	Coffee pot	1	Holder when the coffee is ready	fiberglass and copper	194.7	Injection molding
10	Water tank lock	1	lock for the water tank	Plastic	21.1	INJECTION MOULDING
11	ON/OFF button	1	starter for caffee making progress	Plastic	6.3	INJECTION MOULDING
12	motherboard	1	Takes care of electricity	Fiberglass and copper	134,5	
13	Heating tube	1	Heat the water and heating plate	Aluminium	15.3	Foundry alloys
14	power supply	1	Tranfor electrocity from network to machine	plastic and coppar	180,6	Extrudering machine
15	Cablers	10	Needed to connect the motherboart with other components	plastic and coppar	13,4	Extrudering machine
16	Screws	10	Needed to hold the construction of the machine	steel	23	Crucible Process /Punching
17	ON/OFF light	1	Indicatesif the machine is on	Plastic	2	INJECTION MOULDING
18	Water pressure	1	Converts from steam to water	Plastic	20	INJECTION MOULDING

Figure 6: Exploded view of coffee machine

9 Ishikawa diagram (five) – characteristics

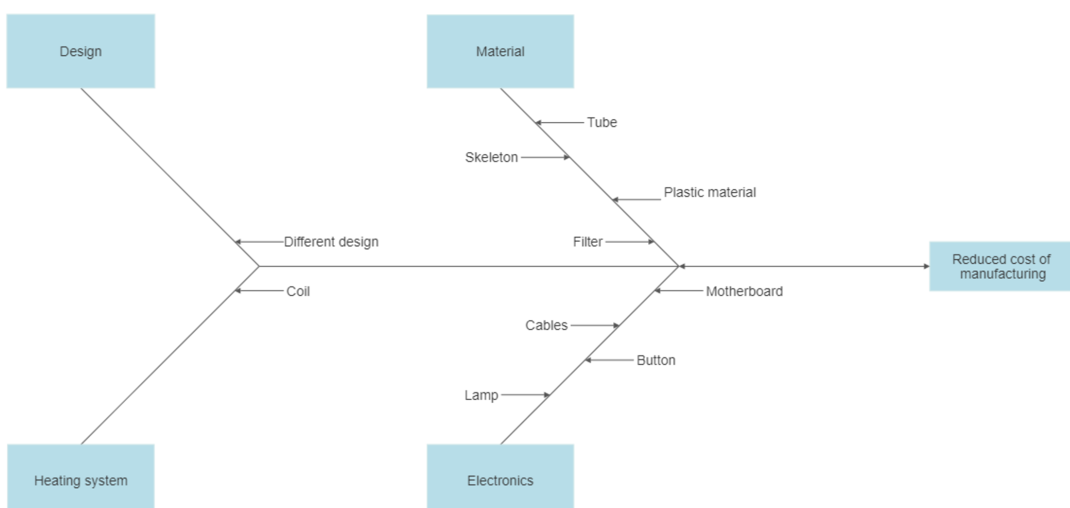


Figure 7: Reduced cost of manufacturing

There are many ways to reduce the cost of manufacturing a coffee machine. One option is to streamline production by using automation and more efficient equipment. Another approach is to negotiate lower prices for raw materials and components with suppliers. Using cost-effective materials that meet quality standards can also help lower costs. Outsourcing certain manufacturing steps to countries with lower labor costs is another option. Implementing these strategies can significantly reduce the overall cost of manufacturing a coffee machine, resulting in increased profitability and competitiveness in the market.

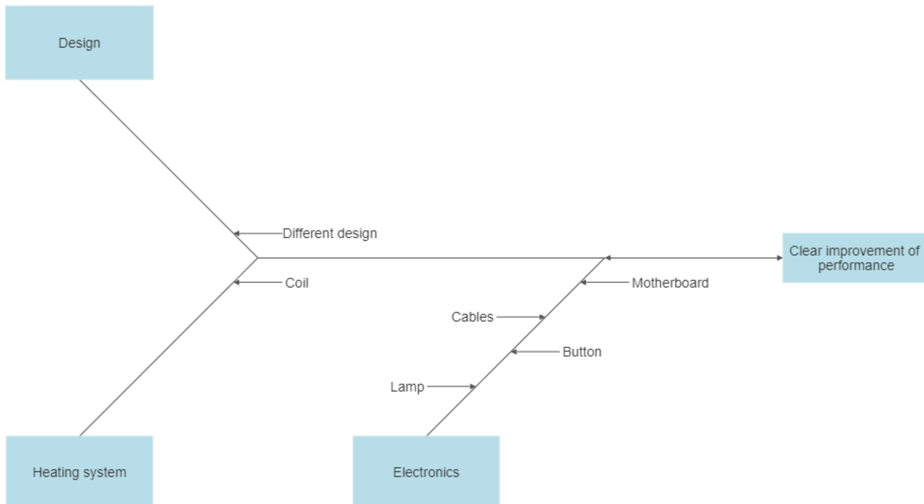


Figure 8: Clear improvement of performance

The functionality of coffee machines is to serve coffee, which is obvious, but not all coffee machines serve good coffee, that's where performance matters. In order to have a coffee machine that serves a good cup of coffee, it is important to have good performance as well. The figure 8 shows which aspects can affect the taste of coffee and the performance, for example the customers want the coffee to be made quickly and this depends on the electrical components such as the motherboard, how quickly it reacts and perceives them different orders.
Another example is the heating system. The taste of coffee depends very much on time and temperature, which means that if you want to make coffee quickly, the temperature must be high. Here it is important that you have a good heating system that heats it up to the desired temperature in order to get the good cup of coffee.

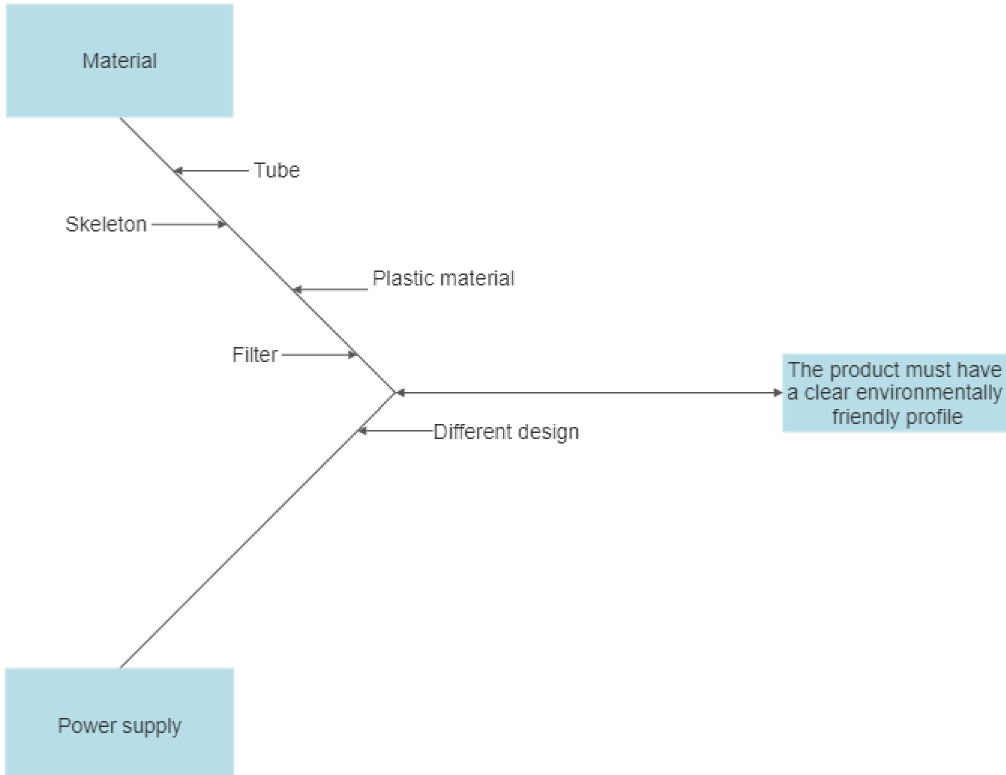


Figure 9: The product must have a clear environmentally friendly profile

Figure 9 shows the ishikawa diagram for the product profile. The product should be design with the environment as first priority. The two main factors for this is the material selection and how efficient the power supply is designed.

The material selection have a large impact on the environment. In order to decrease the environmental impact, the material must be chosen carefully.

The other factor is the power supply. The product should be designed efficient in order to minimize the power needed.

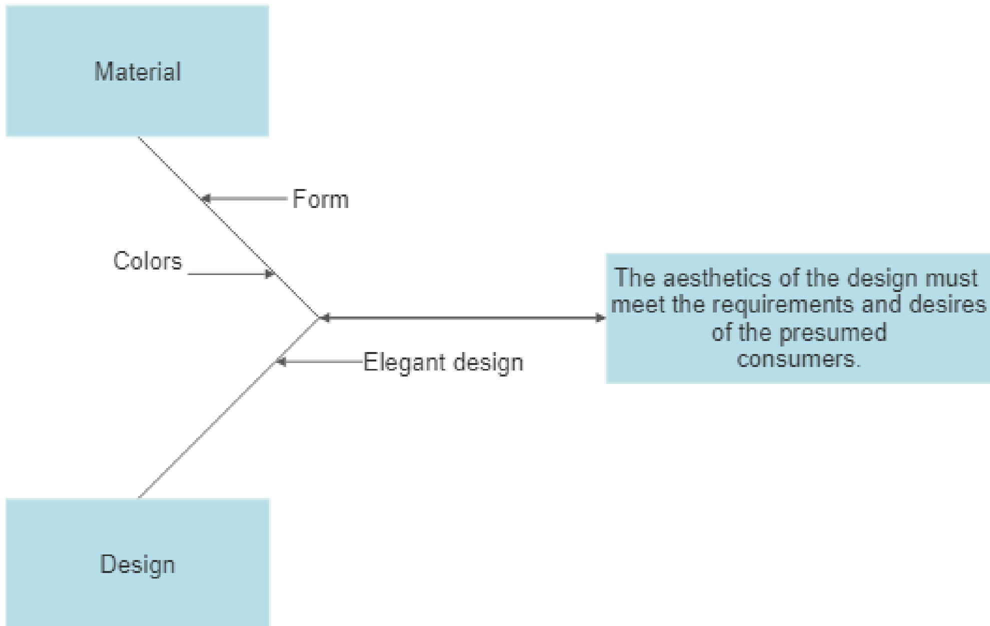


Figure 10: The aesthetics of the design must meet the requirements and desires of the presumed

Figure 10 is the ishikawa diagram for the aesthetics of the design. A good design is a must for our product. The design affects the material selection and the electronic/mechanical design.

The chassie is an important part because it decides the shape of the system. In a design perspective the chassie should be as small as possible, however when designing for example the water container, the chassie should be large.

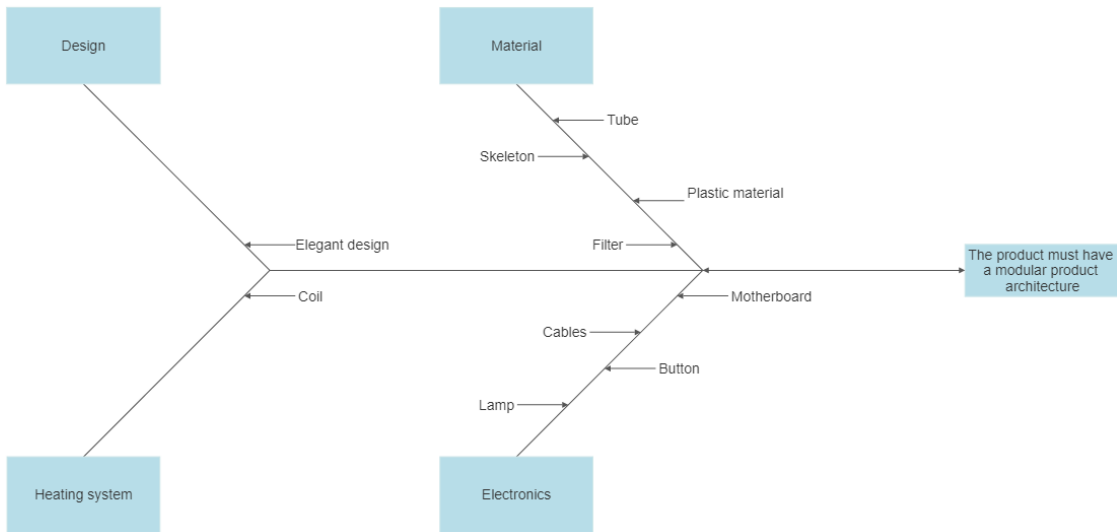


Figure 11: The product must have a modular product architecture

Figure 11 shows the ishikawa diagram for the product architecture. The product is designed for a modular profile. There are four main categories: Design, Heating system, Electronics and Material.

The design is of course important because it affect how much space the electronics have. The product should also have a design which helps with the modular profile.

Electronics and heating system should be separated because of the modular profile. This is positive because if the heating system is broke, it is not necessary to change all the electronics.

The material of each component should serve a specific purpose and therefore be made of different materials.

10 The way to the new product

Check appendix with the section "The way to the new product"

11 Component-based DSM

Component-based DSM is a matrix that shows the relationship between tasks. Where you can see what information each component needs from the other components in the coffee machine.

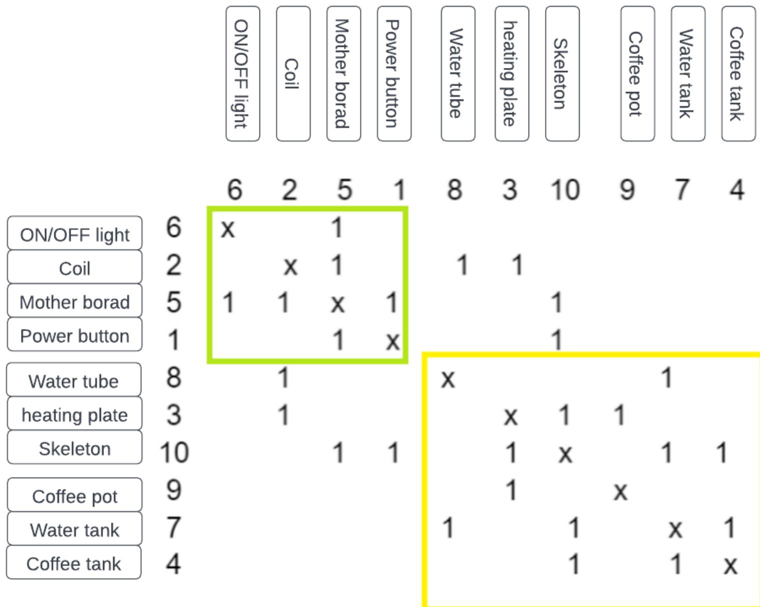


Figure 12: component-based DSM with Matlab

DSM stands for design Structure Matrix. It shows how components are related to other components. The reason why DSM is good is because it describe several problems in the product. E.x Interface problems. By rearranging the DSM matrix, two main system of components are shown. The first one is the green box which represents the electronic system. For example it shows that the heating system is connected to the mother board. The yellow box shows the skeleton part of the coffee machine. For example it shows that the water tube are connected to the water container.

12 Requirement specification (with support from Pugh's balloons and Fredy Olsson's matrix)

Check the Requirement specification file that has been sent.

13 One scenario description per marketsegment

13.1 Family

Abdulrahman is a 22-year-old guy studying at Chalmers University for an engineering degree. He likes coffee very much and unfortunately cannot wake up without drinking coffee in the morning. Abdulrahman usually wakes up at 7 in the morning to be able to have breakfast,take a shower and most importantly, drink coffee. The best coffee he likes is latte, where he himself usually boils water and then adds coffee and milk and the rest of the ingredients, which he thinks takes a long time every day, especially now that he is studying 5 courses and has two jobs.

Once upon a time, he woke up late and had an exam the same day in the morning. He prioritized going to the exam without drinking coffee in order to make it to the exam. After the exam, he realized that he didn't do so well because he didn't drink coffee in the morning. It made him very angry and then he decided to buy an automatic coffee machine that could make a good coffee in a minute while he could pack his things for school. Since the purchase, he thought it was a very good investment because now he can sleep longer and drink coffee even if he are stressed in the morning.

13.2 Companies

Philip is driving to his workplace. He thinks about what he has to do during the day and realizes that he has boring conference all morning. He has slept poorly during the night and is tired, now he is forced to sit still at a boring conference and can absolutely not fall asleep. There is only one thing that can save him, COFFEE.

Halfway through the conference, Philip has a break. He and his colleagues go to the coffee room to talk about what they are going to do this weekend and of course have a refill of coffee. This is the perfect opportunity to relax and have some fun. When the break is over, he feels energetic and creative again and it feels easier to continue the conference.

After the conference is over, Philip has the task of selling at least 1 product to a customer. When the customer arrives at the office, Philip greets him with a freshly brewed cup of coffee and the customer feels how he is filled with joy. Philip has succeeded in making the customer feel safe and comfort and therefore succeeds in selling his product.

14 One mood board per market segment

14.1 Mood board for family

Families want to save time, money and space. They also want the product to be of good quality and cheap. They also want the machine to be environmentally friendly, have good performance, repairable, safe and provide a good coffee that people enjoy.

Figure 13: mood board family

14.2 Mood board for companies

Figure 14: mood board compaines

Families want to save time, money and space. They also want the product to be of good quality and cheap. They also want the machine to be environmentally friendly, have good performance, repairable, safe and provide a good coffee that people enjoy

Compaines also want to save time and money. However they also want the people who works there to be happy. An easy thing to do that makes people happy is to invest in something which almost everybody uses. Namely our coffee machine.

15 Design-FMEA– new product

Design FMEA is a method for detecting and possible design errors in the product. The FMEA is evaluated using a scoring system where the highest RPN-score means that part should be fixed with other options if it possible and if the RPN-scoreit is too high. Figure 15 shows the FMEA of the new product that the team develops.

For example, we can see that in this design the filter has a very high RPN-score, this means that we should try to re-engineer the filter or in other way fix the problem to decrease the RPN-score and fix the error that may appear during construction. In this case we have fixed it with information to the consumer to clean the filter.

Components	Possible failure, use, enviroment and manufacturing	Cause	Effects	Detect.	Probab.	RPN	Actions
1- Water tank	Not stable and leads to vibrations	Construction failure	8	5	2	80	In order to reduce the vibrations between the water tank and the case, the problem has been solved by vibration damping rubbers between the parts.
2 - Coffe container	Cracks	Construction failure	4	7	2	56	To avoid cracks, a material that can withstand little pressure has been chosen
3- Filter	Some obstacle preventing water from flowing from the filter to the cup of coffee	Construction failure, Obstacle in the hole of the filer are stuck	8	4	3	96	The filter has been designed with respect to tolerance where it has been ensured that there are enough holes so that nothing gets stuck.
4- Coffe buttons	Can get stuck, not being able to press it down	Buttons not being used for a long time	8	1	3	24	To avoid dirt and dust, the material has been chosen for the location because plastic does not collect dirt and dust so easily
5 - shape of case	It may have flush or it may not be parallel	Errors in production or modeling of design	7	1	3	21	Qualiti controll, and controll the CAD - design
6 - grounders	That they are not close enough to each other and grind incorrectly	Releases large pieces of coffee	7	3	3	63	Maintenance and quality check

Figure 15: Desig FMEA shows the RPN-score

16 FMEA of new product for family

EMA new product is very similar to Design FEAM in section 14. Here the same principle applies except that you evaluate the functionality of the mask and not the design. You want to reduce the RNP score in the same way as in section 14. Figure ?? shows that the highest RNP score is the function/part "Pump" which pumps different amounts of water to the cup depending on what the customer want for the size of the cup. It received the highest RNP score because we believe that if the error occurs, it leads to more severe problems and therefore this should be addressed within the production of the coffee machine.

FMEA for family

Functions			Severity		Occurrence		Detection	RNP
Transfer of water in pipes								
Blocked in the pipes	Cracks	overflows of water	7	Not proper maintenance, dirt in water	1	-------	7	49
The water container								
Broken sensor (temp)	Very cold/warm water	Disgusting coffee (cold)	6	No maintance	2	Disgusting coffee (cold)	6	72
Water heater	Cold water	Disgusting coffee (cold)	7	Power failure, bad materials.	2	Cold water.	5	70
Crack in the container	Overflows	Don't get coffee	6	Bad material, drop during transport	1	Inspect containers	8	48
Pump								
Stops pumping	Little or no water to the filter	no coffee	8	power failure	1	It does not make a sound and no water comes	3	24
Wrong amount of pumping	A lot or a little water	Strong or weak coffee	7	the regulation, or current/voltage	2		9	126
Filter								
Start leaking	Some coffee comes out	Some coffee comes out	6	Wear	3	Starts to smell a lot of tea, coffee is spilled, some coffee comes out	2	36
Trash error of coffee from the filter	Motor gets stuck or does not work correctly	Coffee powder does not go to trash, stacks coffee	6	Obstacles that prevent the motor from moving, a cable breaks.	2	Bad smell, bad taste of the coffee, inspect the landfill	3	36
Coffee container								0
May crack	Start leaking coffee beans	Beans all over the floor	3	Wear and tear, user error	4	Beans are on the floor	2	24
Caffe graounder								0
Does not grind correctly	Wrong amount of coffee	Wrong taste of the coffee	8	Wear in gears	2	Doesn't sound, it comes with water without coffee or a little coffee	3	48
Stop grinding	No coffee	Hot water without coffee	8	Electrical fault, cable detached	1	Doesn't sound, there will be water without coffee	4	32

Figure 16: FMEA of new product for family shows the RNP-score

17 FMEA of new product for company

The FMEA of new product for the company is roughly the same as the product for family. The differs is not the design, but some small details in functionality as for example that in the product for companies there is a regulator to regulate the temperature in the water container and that it has another sensor that measures the volume of water in the container.
Thus, the function/party that gets the highest RNP score is the same as the machine for the family, which is "wrone amount of pumping". But second highest is "Broken sensor" in water container. If the sensor is broken, it can also lead to several problems such as for example that it starts to take in too much water to the water container and eventually starts to overflow. It's about the same problem as "Wrong amont of pumping". This can be solved with the software to reduce the RNP score. Figure 17 shows that the highest RNP score for different parts.

FMEA for company

Functions			Severity		Occurrence		Detection	RNP
Transfer of water in pipes								
Blocked in the pipes	Cracks	overflows of water	7	Not proper maintenance, dirt in water	1	-------	7	49
The water container								
Hot water regulator are breaking	It will be cold or very warm water	Disgusting coffee (cold)	8	Power failure, Broken sensor	1	Notice if the water is cold	4	32
Crack in the container	Overflows	Don't get coffee	6	Bad material, drop during transport	1	Inspect containers	8	48
Broken sensor (temp/volym)	Overflows, no water to container, very cold/warm water	overflows of water, disgusting coffee (cold)	9	No maintance	2	overflows of water, disgusting coffee (cold)	6	108
Water heater	Cold water	Disgusting coffee (cold)	7	Power failure, bad materials.	2	Cold water.	5	96
Pump								
Stops pumping	Little or no water to the filter	no coffee	8	power failure	1	It does not make a sound and no water comes	3	24
Wrong amount of pumping	A lot or a little water	Strong or weak coffee	7	the regulation, or current/voltage	2	A lot or a little water	9	126
Filter								
Start leaking	Some coffee comes out	Some coffee comes out	6	Wear	3	Starts to smell a lot of tea, coffee is spilled, some coffee comes out	2	36
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Stop grinding	No coffee	Hot water without coffee	8	Electrical fault, cable detached	1	Doesn't sound, there will be water without coffee	4	32

Figure 17: FMEA of new product for company shows the RNP-score

Product	Cost (SEK)	Weight (kg)
Gears	300	0.1
Servo motors	400	0.15
Coffee container	4	0.2
Filter	94	0.02
Trashcan	240	0.2
Servo for filter removal	360	0.075
Water container	2	0.2
Heating plate	590	0.4
Water tubes	8	0.05
Water pump	122	0.1
Temp. sensor	50	0.005
Water level sensor	21	0.01

18 Design evaluation of price segment

Our coffee machine consists of three processes, the heating system, the grinding of the coffee, the process and finally the mixing of the water and coffee that takes place during the filtration.

The first process takes place during the grinding of the coffee when choosing the size of the cup size, or how strong the coffee should be. For this process to be carried out, various components are needed to carry out the grinding of the coffee. The components needed are:

- Gears to press the coffee into powder.
- Servo Motor to move the gears.
- Coffee container to fill the coffee with.

Gears Costs approximately between 200-400 SEK per piece. Two pieces cost 600 SEK on average. Price of two motors 200-400 SEK. The last component is made of Polypropen termoplastic and the weight that needed is between 100-200 gram. 1kg is about 10-20SEK what means the cost of the Polypropen termoplastic that needed for the caffee container is 2-4SEK. The total cost of grinding caffe process is 920SEK.

- Filter (filterlink) 80,25 kr
- Trashcan 240 kr
- Servo for filter removal (servos) 360 kr

The heating system:

- Price of a water container 500 g
- Heating plate 200 g
- Water tube (Tube in to the coffee machine) 50 g
- Water tube (Tube to the mixer) Price of a water tube 50 g
- Price of a water pump 200 g
- Price of a temperature sensor 10 g
- Water level sensor 100 g

Heating plate

The coffee machine must be able to heat a liter of coffee to 95 degrees for 200 seconds. The calculation of the effect that the heating plate must have is as follows.

$$P = \frac{E}{T}$$

$$T = 60$$

$$E = m * c * \Delta T$$

$$m = 1 \quad kg$$

$$E = 1 * 2.21 * 10^3 * (95 - 10)$$

$$P = \frac{187850}{200} = 1565.5W$$

An example of 1.5kw heating plate could be this heating plate

19 Analyses of one or several critical measures

The group chose the program RD&T to do the variation analysis on the some significant part in the coffee machine.

The included parts

- The water container
- The pipe that connects water container to water pump

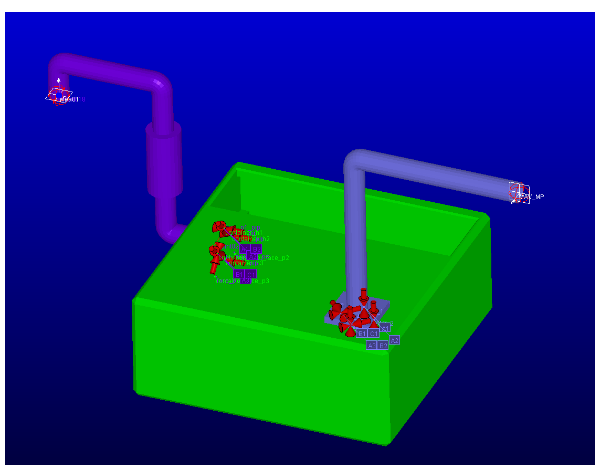


Figure 18: After assembly

19.1 The pipe that connects water container to water pump

19.1.1 Variation Analysis

The pipe that connects water container to water pump is the pipe on the left side in the figure 18

The group designed the parts in Catia/Autodesk inventor and then imported the parts into RD&T to make the variation analysis. All parts were converted to .wrl otherwise the program will not open the files. All the meeasure points were added one respective component in the assembly analysis. The points follow the 3-2-1 rule. Three points in the room, two points in the plane, one point in the line. The measure point is located on the top left part in the figure 18

Since the parts were now locked together. It was time to start the simulation, which ran for 1000 times. The result are presented in figure 19.

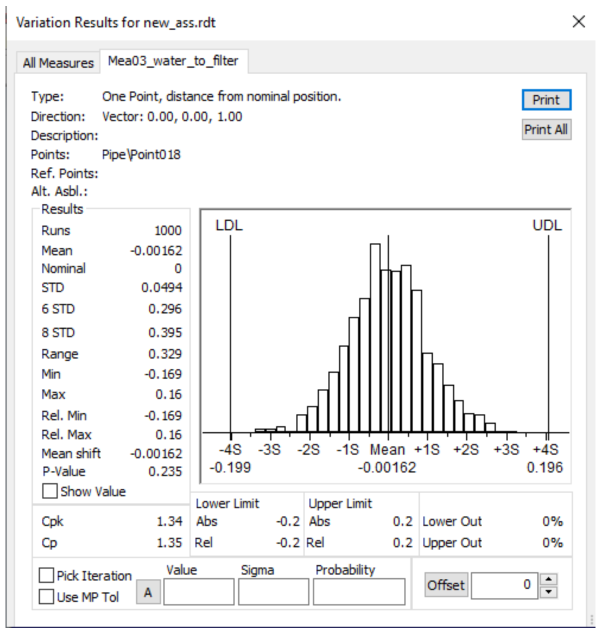


Figure 19: The pipe that connects water container to water pump

The conclusion of this is that the four screws that connect the pipe and the container are making the connection very robust. The screws makes the pipe to not differ much, which is what we wanted in order to not have leaking pipes. Perhaps an improvement would be to not have 4 screws, but instead 3. This could lead to higher differ in the measure point, although the product would be cheaper and easier to manufacture.

We can see how the tolerances in the screws affects the measure points. The measure point can change its position with roughly

$$\pm 0.2mm$$

The products that are in the red zone in the figure 19 are not accepted according to the tolerances for the measure point. In order to remove the red zone, we need to decrease the tolerances in the screws.

19.1.2 Stability Analysis

From figure 20, it is clear that point A2 and A1 are the points that makes the pipe most unstable/stable. One thing that we can do to improve the design is to make sure that the points that are affecting the measure point a lot, be stronger and have lower tolerances.

Part Name: Pipe

P-Frame	Target Part	Part\Point Name	Ref.Pt	Unit Dist.	Real Tol.
Pipe	water_cont...	water_container\contai...	A2	5.677406	0.000000
Pipe	water_cont...	water_container\contai...	A1	5.544549	0.000000
Pipe	water_cont...	water_container\contai...	A3	5.044375	0.000000
Pipe	water_cont...	water_container\contai...	B2	4.937192	0.000000
Pipe	water_cont...	water_container\contai...	B1	4.375477	0.000000
Pipe	water_cont...	water_container\contai...	C1	1.000000	0.000000
WW	water_cont...	water_container\C_4	C1	0.000000	0.000000
WW	water_cont...	water_container\C_1	A1	0.000000	0.000000
WW	water_cont...	water_container\C_3	B2	0.000000	0.000000
WW	water_cont...	water_container\C_2	A2	0.000000	0.000000
WW	water_cont...	water_container\C_4	B1	0.000000	0.000000
WW	water_cont...	water_container\C_3	A3	0.000000	0.000000

Figure 20: Table for stabilty

20 LCA - Life Cycle Assessment

LCA-Life Cycle Assessment, is a method for systematically analyzing the environmental impact of a product or service during the entire life cycle, this means that it analyzes the environmental impact that products have during production, distribution, use and end-of-life phases. The method also includes delivery emissions and waste management.

For each material there is a special environmental index or an ELU/unite- Environmental Load Units which is an externality corresponding to one Euro environmental damage cost.
The method is based on calculating values of ELU by taking the material's ELU and multiplying by the weight used for that particular material for e.g. during production and then during use, then you have to add up all the ELU values and see how much you affect and try to reduce the ELU value as much as possible to have the least impact on the environment.

In order to use the LCA method on existing coffee machines, we have had to identify all the materials that were used, weigh them all and find out the different ELU values for different materials. After carrying out the method, we have found that the existing coffee machine has 168.3 ELU.

For the new product we have two different segments, the first is the family variant and the second is for business. The difference between family and company variants is that the company variants are a little bigger and it has an extra function which is to connect to the water tap directly and it heats and keeps the heat in the water tank to the same temperature. This means that you need more material for company variants, which in turn leads to an increased ELU value.

The company variant got 1967 in ELU value and the family variant got 168 in ELU value. The reason that the company's version got such a high value is that you use more coffee and water during the life of the coffee machine, which is 10 years. See the excel file ”LCA - Product” for more detailed calculation.

21 DFA for existing product

DFA - design for assembly is a very useful method for making the manufacturing process simpler, more productive and more reliable, simplifying the structure of the product by reducing the number of assembly operations and components. The basic questions you ask yourself for each part in order to fulfill the purpose are:

- Does the part have to move relative to other parts in the assembly?
- Is the part made of a different material for aesthetic or functional reasons?
- Does the part need to be separate to ensure access to other

Parts or to perform repair and maintenance? When answering no to all questions, the parts should be combined with another part in the compilation.

Figure 21 shows how does the parts are related to each other and how well the structure of the machine is. For the product to be considered a good product, it must have approximately 80 percent of the score. The existing product gets 72 percent, which is not too far from the target of 80 percent.

									DFA Score						«
Component	Need to assemble part	Gripping by hand	Reachability	Insertion	Tolerances	Holding assembled parts	Fastening method	Separate operations	Score	Score (%)	Agg Score	Agg Score (%)	Time	Agg Time	Agg Time (%)
Brewing machine									0		775	72 %		157,8	292 %
[p1] Skeleton-top 1 pcs	9	9	9	3	N/A	N/A	9	9	48	89 %			3,2		
[p2] Skeleton-bottom 1 pcs	9	9	3	3	N/A	3	3	9	39	62 %			10,7		
[p3] Container lock 1 pcs	9	9	9	1	N/A	9	9	9	55	87 %			3,5		
[p4] Water tank 1 pcs	1	9	3	9	N/A	9	9	9	49	78 %			7,5		
[p5] Water tube 1 pcs	9	9	3	1	N/A	9	9	3	43	68 %			8		
[p6] Filter 1 pcs	9	9	9	9	N/A	9	9	9	63	100 %			3		
[p7] Heating plate 1 pcs	9	9	1	N/A	N/A	1	3	1	24	44 %			17		
[p8] Coffee container 1 pcs	9	9	9	9	N/A	9	3	9	57	90 %			6		
[p9] Coffee pot 1 pcs	9	9	9	N/A	N/A	9	9	9	54	100 %			3		
[p10] Water tank lock 1 pcs	9	9	3	1	N/A	9	9	9	49	78 %			8		
[p11] ON/OFF button 1 pcs	9	9	1	1	N/A	9	3	1	33	52 %			13,5		
[p12] Motherboard 1 pcs	9	9	3	3	N/A	9	9	3	45	71 %			7,7		
[p13] Heating tube 1 pcs	9	9	3	1	N/A	3	3	1	29	46 %			11		
[p14] Power supply 1 pcs	9	9	3	N/A	N/A	9	N/A	3	33	73 %			7,5		
[p15] Cables 1 pcs	9	9	1	N/A	N/A	3	1	3	26	48 %			18		
[p16] Screws 1 pcs	9	9	1	3	N/A	9	3	9	43	68 %			13,2		
[p17] ON/OFF light 1 pcs	9	9	9	N/A	N/A	9	3	3	42	78 %			6		
[p18] Water pressure 1 pcs	9	9	3	1	N/A	9	3	9	43	68 %			11		

Figure 21: DFA for existing product

22 DFA - new product

22.1 Coffee machine for company

Before improvements

This is our first DFA design analysis of how we want to make our coffee machine. The result did not really fulfill the qualifications which is over 80%. The result now is 66% and some necessarily improvements will be made.

The file for the DFA analysis will be sent with the PDF.

DFX | DFA2 part level (MA) | DFA2 product level

									DFA Score						
Component	Need to assemble part	Gripping by hand	Reachability	Insertion	Tolerances	Holding assembled parts	Fastening method	Separate operations	Score	Score (%)	Agg Score	Agg Score (%)	Time	Agg Time	Agg Time (%)
Coffee_machine									0		520	66 %		132,3	339 %
[p1] Coffee_conatiner 1 pcs	1	3	9	3	N/A	9	3	9	37	59 %			6,2		
[p2] Pipe_coffee_to_filter 1 pcs	1	9	1	1	N/A	1	3	9	25	40 %			17,5		
[p3] Grounder 1 pcs	9	9	3	9	N/A	9	3	9	51	81 %			10,5		
[p4] Motors 1 pcs	1	9	3	N/A	N/A	9	3	9	34	63 %			10,5		
[p5] Pipe_filter_to_mug 1 pcs	1	9	3	N/A	N/A	1	1	9	24	44 %			19,5		
[p6] Filter 1 pcs	9	9	3	1	N/A	3	3	9	37	59 %			11		
[p7] Pump 1 pcs	9	9	1	1	3	3	3	9	38	53 %			13,7		
[p8] Pipe_water_to_pump 1 pcs	9	9	3	1	N/A	1	3	9	35	56 %			15		
[p9] Water_container 1 pcs	9	3	3	1	N/A	9	9	9	43	68 %			8		
[p10] Sensors 1 pcs	9	9	3	N/A	N/A	9	9	9	48	89 %			7,5		
[p11] Pipie_water_to_water_container 1 pcs	9	9	9	1	N/A	9	3	9	49	78 %			6,5		
[p12] Chassie 1 pcs	9	3	9	N/A	N/A	N/A	9	9	39	87 %			3		
[p13] Trash_can 1 pcs	9	9	9	3	3	9	9	9	60	83 %			3,4		

Figure 22: Improvements

After improvements

- Coffee container (P1): We thought that it would be better for this part to be integrated, The scored differed only wiht 1%. So, we changed to modular due to the complex form in production. For example: Integrating Coffee container with chassie.
- Grounder (P3): "Pipe coffee to filter" are now Integrated with the grounder. Makes it easier to assemble
- Motors (P4): The group thought motors and grounder would be better to be integrated, however it was not. The group made motors to be modular due to if the components become worn out during time. Then it will be easier to just change the grounder.
- Filter (P6): Integrated with "Pipe filter to mug", otherwise the pipe and filter will be glued together. This process are removed because the part got integrated.
- Pump (P7): Added chamfers and a wire to lock the pipe in place the pump. This led to a better insertion and reachability for the pump.
- Pipe water to pump (P8): Insertion and reachability were changed. Chamfers to the pipe has been added.

After these changes, we managed to achieve a score of 77%. The trade off is that since we integrated certain parts with each other, these parts will be more expensive to buy or be manufactured. However it will take less time to assemble, leading to more produced products.

Chamfers were added to every element that would be inserted. Many pipes decreased the score of DFA analysis. therefore, we integrated them with neighboring elements to be able to have a better score.

DFX | DFA2 part level (MA) | DFA2 product level

									DFA Score						
Component	Need to assemble part	Gripping by hand	Reachability	Insertion	Tolerances	Holding assembled parts	Fastening method	Separate operations	Score	Score (%)	Agg Score	Agg Score (%)	Time	Agg Time	Agg Time (%)
Coffee_machine									0		510	77 %		83,8	254 %
[p1] Coffee_conatiner 1 pcs	9	3	9	3	N/A	9	3	9	45	71 %			6,2		
[p3] Grounder 1 pcs	9	9	3	9	N/A	3	9	9	51	81 %			7,5		
[p4] Motors 1 pcs	9	9	3	N/A	N/A	9	3	9	42	78 %			10,5		
[p6] Filter 1 pcs	9	9	3	N/A	N/A	3	3	9	36	67 %			10,5		
[p7] Pump 1 pcs	9	9	3	9	3	3	3	9	48	67 %			10,7		
[p8] Pipe_water_to_pump 1 pcs	9	9	9	9	N/A	1	3	9	49	78 %			10		
[p9] Water_container 1 pcs	9	3	3	1	N/A	9	9	9	43	68 %			8		
[p10] Sensors 1 pcs	9	9	3	N/A	N/A	9	9	9	48	89 %			7,5		
[p11] Pipie_water_to_water_container 1 pcs	9	9	9	1	N/A	9	3	9	49	78 %			6,5		
[p12] Chassie 1 pcs	9	3	9	N/A	N/A	N/A	9	9	39	87 %			3		
[p13] Trash_can 1 pcs	9	9	9	3	3	9	9	9	60	83 %			3,4		

Figure 23: Improvements

22.2 Coffee machine for Families

Before improvements

This is our first DFA design analysis of how we want to make our coffee machine. The result did not really fulfill the qualifications which is over 80%. The result now is 66% and some necessarily improvements will be made.

The file for the DFA analysis will be sent with the PDF.

DFX | DFA2 part level (MA) | DFA2 product level

									DFA Score						
Component	Need to assemble part	Gripping by hand	Reachability	Insertion	Tolerances	Holding assembled parts	Fastening method	Separate operations	Score	Score (%)	Agg Score	Agg Score (%)	Time	Agg Time	Agg Time (%)
Coffee_machine									0		522	66 %		127,3	326 %
[p1] Coffee_conatiner 1 pcs	1	3	9	3	N/A	9	3	9	37	59 %			6,2		
[p2] Pipe_coffee_to_filter 1 pcs	1	9	1	1	N/A	1	3	9	25	40 %			17,5		
[p3] Grounder 1 pcs	9	9	3	9	N/A	9	3	9	51	81 %			10,5		
[p4] Motors 1 pcs	1	9	3	N/A	N/A	9	3	9	34	63 %			10,5		
[p5] Pipe_filter_to_mug 1 pcs	1	9	3	N/A	N/A	1	3	9	26	48 %			14,5		
[p6] Filter 1 pcs	9	9	3	1	N/A	3	3	9	37	59 %			11		
[p7] Pump 1 pcs	9	9	1	1	3	3	3	9	38	53 %			13,7		
[p8] Pipe_water_to_pump 1 pcs	9	9	3	1	N/A	1	3	9	35	56 %			15		
[p9] Water_container 1 pcs	9	3	3	1	N/A	9	9	9	43	68 %			8		
[p10] Sensors 1 pcs	9	9	3	N/A	N/A	9	9	9	48	89 %			7,5		
[p11] Pipie_water_to_water_container 1 pcs	9	9	9	1	N/A	9	3	9	49	78 %			6,5		
[p12] Chassie 1 pcs	9	3	9	N/A	N/A	N/A	9	9	39	87 %			3		
[p13] Trash_can 1 pcs	9	9	9	3	3	9	9	9	60	83 %			3,4		

Figure 24: Improvements

After improvements

- Coffee container (P1): We thought that it would be better for this part to be integrated, The scored differed only wiht 1%. So, we changed to modular due to the complex form in production. For example: Integrating Coffee container with chassie.
- Grounder (P3): "Pipe coffee to filter" are now Integrated with the grounder. Makes it easier to assemble
- Motors (P4): The group thought motors and grounder would be better to be integrated, however it was not. The group made motors to be modular due to if the components become worn out during time. Then it will be easier to just change the grounder.
- Filter (P6): Integrated with "Pipe filter to mug", otherwise the pipe and filter will be glued together. This process are removed because the part got integrated.
- Pump (P7): Added chamfers and a wire to lock the pipe in place the pump. This led to a better insertion and reachability for the pump.
- Pipe water to pump (P8): Insertion and reachability were changed. Chamfers to the pipe has been added.

After these changes, we managed to achieve a score of 76%. The trade off is that since we integrated certain parts with each other, these parts will be more expensive to buy or be manufactured. However it will take less time to assemble, leading to more produced products.

Chamfers were added to every element that would be inserted. Many pipes decreased the score of DFA analysis. therefore, we integrated them with neighboring elements to be able to have a better score.

Removing the Pipe water to water container (P11) decreased the score of the DFA analysis with 1%. This happened because the other lower scoring elements have more influence on the average score.

DFX | DFA2 part level (MA) | DFA2 product level

Component	Need to assemble part	Gripping by hand	Reachability	Insertion	Tolerances	Holding assembled parts	Fastening method	Separate operations	DFA Score: Score	Score (%)	Agg Score	Agg Score (%)	Time	Agg Time	Agg Time (%)
Coffee_machine									0		461	76 %		77,3	258 %
[p1] Coffee_conatiner 1 pcs	9	3	9	3	N/A	9	3	9	45	71 %			6,2		
[p3] Grounder 1 pcs	9	9	3	9	N/A	3	9	9	51	81 %			7,5		
[p4] Motors 1 pcs	9	9	3	N/A	N/A	9	3	9	42	78 %			10,5		
[p6] Filter 1 pcs	9	9	3	N/A	N/A	3	3	9	36	67 %			10,5		
[p7] Pump 1 pcs	9	9	3	9	3	3	3	9	48	67 %			10,7		
[p8] Pipe_water_to_pump 1 pcs	9	9	9	9	N/A	1	3	9	49	78 %			10		
[p9] Water_container 1 pcs	9	3	3	1	N/A	9	9	9	43	68 %			8		
[p10] Sensors 1 pcs	9	9	3	N/A	N/A	9	9	9	48	89 %			7,5		
[p12] Chassie 1 pcs	9	3	9	N/A	N/A	N/A	9	9	39	87 %			3		
[p13] Trash_can 1 pcs	9	9	9	3	3	9	9	9	60	83 %			3,4		

Figure 25: Improvements

23 Requirements and characteristics matrix, material selection for two of the most important parts

The group wanted to analyze the water container and the coil isolation. Each component has its own requirements that will be discussed more in this chapter.

23.1 Water container

The material of the water container must fulfill the following requirements:

- The material should withstand heat, maximum service temperature of 120 degrees
- It must be suitable for food
- The thermal insulation, transitional has to be minimized.

It turns out that one of the most suitable material for this is PET (unfilled, semi-crystalline). GRANTA were used in order to select the best material. We used the level 3 sustainability database: all bulk material for this task were the limit function was used in order to sort out the more suitable materials. The following categories was changed in order to find the best material:

- Price: maximum: 100 sek/kg
- Maximum service temperature: minimum: 120 degrees
- Food contact: Yes
- Durability: Fresh water: Excellent
- Recycle: Yes

Maximum service temperature was set to a minimum of 120 degrees because it must withstand hot water. The water inside the water container can not be contaminated, therefore the food contact box were checked. Since the water container always has contact with water it must have excellent durability in water.

These requirement left about 70 materials. Next step was to minimize the mateial index which was done in the following way:

$$M = a = \frac{\lambda}{\rho \cdot C_P} \Rightarrow log(M) = log(\lambda) - log(\rho \cdot C_P) \Rightarrow log(\lambda) = 1 \cdot log(\rho \cdot C_P) + log(M) \quad (1)$$

If the axles are logarithmic, this equation will appear as a linear function $y = kx + m$ were the material index is the m-value (k=1). Since the material index should be minimized the intersection with the y-axle should be as small as possible. After this the remaining materials left are represented in figure 26:

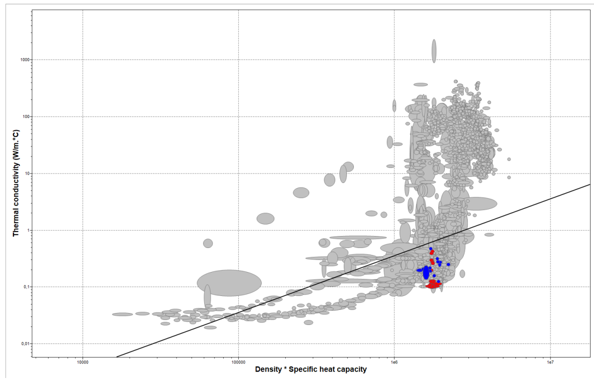


Figure 26: Thermal insulation, transitional VS Density * specific heat capacity

We chose to minimize the material index because according to GRANTA-program, the material index in this case represent the thermal stability. Since we want the water to remain warm inside the water container (i.e. stable temperature), this value should be as small as possible.

For the remaining materials, our priority was to get the most environmental friendly material to the lowest cost. Therefore, the price vs environmental data was compered and compromised. These graphs are shown in figure 27 and figure 28.

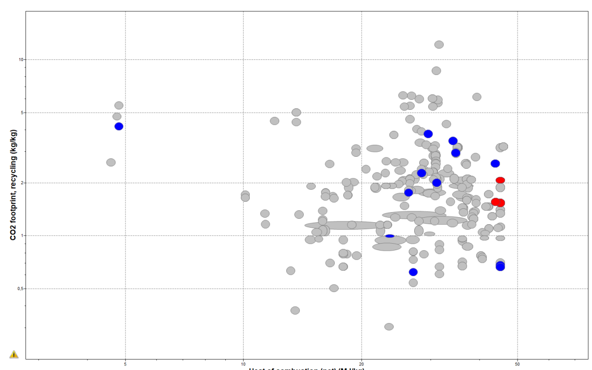


Figure 27: CO2 footprint, recycling vs Heat of combustion

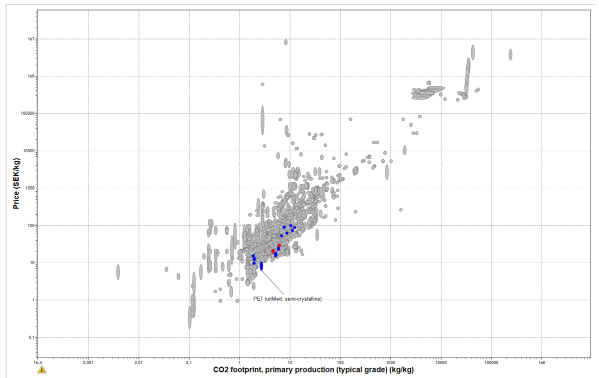
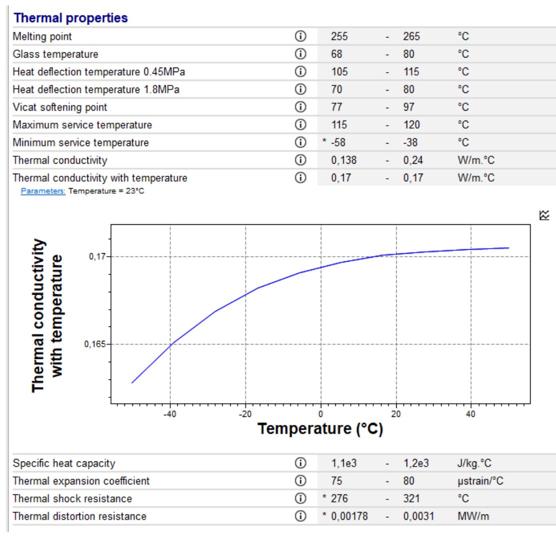


Figure 28: Price vs CO2 footprint, primary production (typical grade)

At last, the most suitable material was "PET (unfilled, semi-crystalline)", some material specification are shown in figure 29



Thermal properties

Melting point	255	-	265	°C
Glass temperature	68	-	80	°C
Heat deflection temperature 0.45MPa	105	-	115	°C
Heat deflection temperature 1.8MPa	70	-	80	°C
Vicat softening point	77	-	97	°C
Maximum service temperature	115	-	120	°C
Minimum service temperature	* -58	-	-38	°C
Thermal conductivity	0,138	-	0,24	W/m.°C
Thermal conductivity with temperature	0,17	-	0,17	W/m.°C

Parameters: Temperature = 23°C

Specific heat capacity	1,1e3	-	1,2e3	J/kg.°C
Thermal expansion coefficient	75	-	80	µstrain/°C
Thermal shock resistance	* 276	-	321	°C
Thermal distortion resistance	* 0,00178	-	0,0031	MW/m

Figure 29: PET (unfilled, semi-crystalline) data

The processing method chosen for this is "thermoforming", this is shown in figure 30. This method was chosen because it is the most efficient in order to get the form we need and is also particularly suited for PET plastics. It is the most efficient because since a hollow box is needed, the inside must be empty. In order to get the inside empty it is not efficient to use machinery to carve it out. It has high labor intensity but can produce many products per hour.

An alternative method is "Material jetting". This is also a suitable method when using PET plastics. The reason we chose thermoforming was because it can produce more products per hour, even though it is more expensive to buy the tools for thermoforming, over time it becomes cheaper.

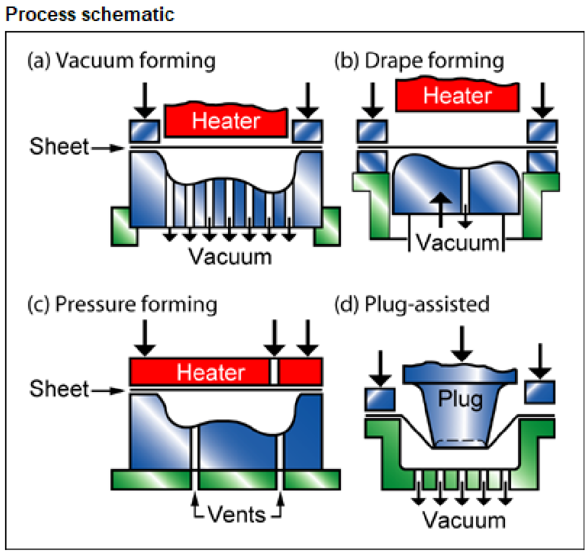


Figure 30: thermoforming step by step

23.2 Coil isolation

The Coil consists of a wires that have a current running in it. High resistance in the wires will make the wires warm and therefore warm up the water. Therefore, an isolation metal is needed to be between the wires and the water in the water container.

Requirement specification for the metal around the coil:

- It should withstand heat with maximum service temperature 120
- It should not be soft
- Suitable for food
- Thermal insulation, transitional (Max)

The Thermal insulation, transitional need to be maximized in order to warm the water as fast as possible when the wires are warm.

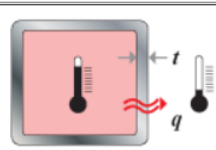
FUNCTION AND CONSTRAINTS			MAXIMIZE[1]	MINIMIZE[1]
Thermal insulation, transitional		optimize thermal stability; temperature difference, time fixed; thickness free	$1/a = \rho C_p/\lambda$	$a = \lambda/\rho C_p$

Figure 31: Thermal insulation

After applying the the limits in Granta EduPack. The program chose 88 different materials out of 3242 different materials. Next step is to plot different diagram to try to find the best material that fulfills most our requirement specifications.

The value of M in the figure 31 has to be maximized in in the following figure 32. Aluminium (6016) Has the height M value relatively to other candidate materials.

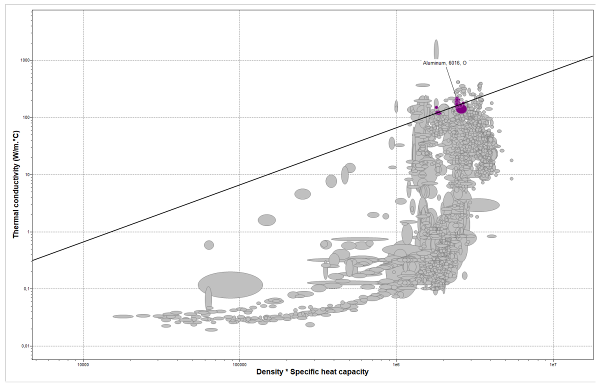


Figure 32: Thermal insulation, transitional VS Density * specific heat capacity

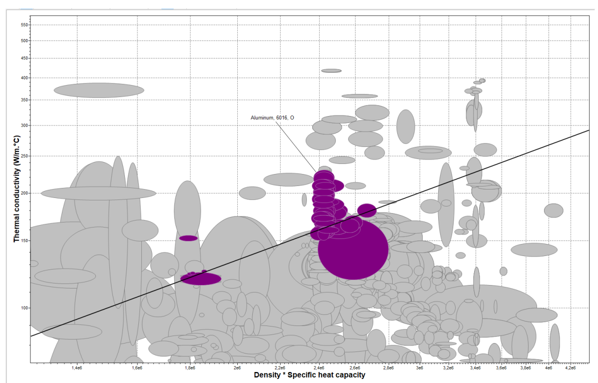
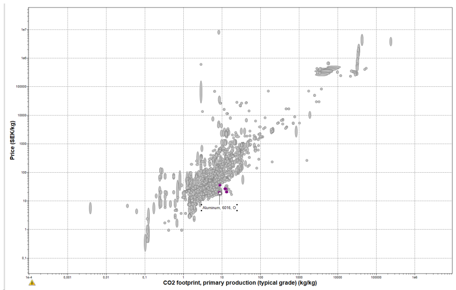
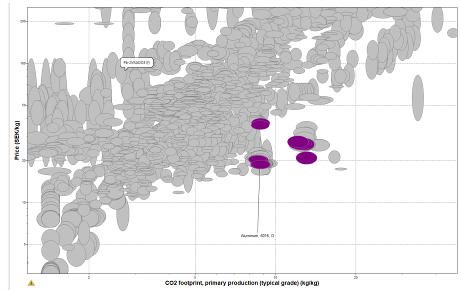


Figure 33: Thermal insulation, transitional VS Density * specific heat capacity

Now, we concluded that Aluminium (6016) is a good chose. But there are more factors about why we chose this materials. Price of the material and CO2 footprint primary production (typical grade) of the material is a significant aspect when it comes why you want to use this material specifically.



(a)



(b) label 2

Figure 34: Price VS CO2 footprint

In the figure 34, We can see that the material Aluminium (6016) has one of the lowest cost price among the other. In addition it has It has one of the lowest CO2 footprint among the others. In conclusion, Aluminium has the height M value in the figure 32 and the lowest price and CO2 footprint among the others in the figure 36, Therefore the group decided the this material suits the requirement specifications much better than the other materials.

Some thermal properties about the chosen material Aluminium (6016):

Thermal properties				
Melting point	610	-	655	°C
Maximum service temperature	130	-	150	°C
Minimum service temperature	-273			°C
Thermal conductivity	* 210	-	230	W/m.°C
Specific heat capacity	880	-	916	J/kg.°C
Thermal expansion coefficient	2,28e-5	-	2,4e-5	strain/°C
Thermal shock resistance	28,3	-	33,5	°C
Thermal distortion resistance	* 8,92e6	-	9,89e6	W/m
Latent heat of fusion	3,84e5	-	3,93e5	J/kg
Electrical properties				
Electrical resistivity	* 2,8e-8	-	3e-8	ohm.m
Electrical conductivity	* 3,34e7	-	3,57e7	Siemens/m
Galvanic potential	* -0,79	-	-0,71	V
Magnetic properties				
Magnetic type	Non-magnetic			
Optical, aesthetic and acoustic properties				
Transparency	Opaque			
Acoustic velocity	5e3	-	5,14e3	m/s
Mechanical loss coefficient (tan delta)	* 1e-4	-	0,002	
Healthcare & food				
Food contact	Yes			

Figure 35: thermal properties

Price				
Price	* 17,5	-	20,1	SEK/kg
Price per unit volume	* 4,68e4	-	5,5e4	SEK/m^3
Physical properties				
Density	2,67e3	-	2,73e3	kg/m^3

Figure 36: Price Aluminium

24 Verification

The new product we have two different segments, the first is the family variant and the second is for business. The difference between family and company variants is that the company variants are a little bigger and it has an extra function which is to connect to the water tap directly and it heats and keeps the heat in the water tank to the same temperature.

The Goals for the two different segments are the same and this section will show and verify which requirements have been fulfilled in Table 1

Requirements	If fulfilled ?	Comment
Regulation of temperatures	Yes	There is a regulator in company-product
Brewing up in 200 seconds	Yes	Our machine has an effect of 1570W wich means it is able to warm up in 2 minutes, 11
Not overheat	Yes	Our machine has a termometer and regulator and can cut of the current to be safe in case the temperature exceeds the risk zone temperature.
Filter the water	-	Due to lack of time, in water filters could not be implemented in any of our products for any segment
No need for service	Yes	The costumer can by the product and there is no need to do service for the machine.
Long time product	Yes	Our definition of long time for a product is 5 years and our machine is designed to works at least for 10 years.

Table 1: verification matrix

25 Manufacturing cost

The cost was estimated with help from GRANTA. First, the right manufacturing method was chosen. After that, the mass and the price (per kg) was changed and from that a graph was plotted. An interval was showed were a low number was chosen, this was because our forms are not complex, only boxes and pipes.

Component	Batch size	Manufacturing cost per unit (kr)	Cost of components (kr)
Coffee container	1000	24	4
Case	1000	30	12
Grounders	1000	-	300
Filter	1000	11	94
Water container	1000	28	2
Pipes	1000	20	100
Motor	1000	-	360
Water pump	1000	-	122
Cables	1000	-	2
Electronics	1000	-	100

26 Summary

To summarize, the assignment was to design a coffee machine with following goals:

- Reduced cost of manufacturing
- Clear improvement of performance.
- The product must have a clear environmentally friendly profile.
- The aesthetics of the design must meet the requirements and desires of the presumed consumers.
- The product must have a modular product architecture.

The project begun with a black-box model and functional structure for these two new products, see figure 2 and 4. This was done so that the goals could be visualized and what was needed in order to accomplish them.

Next was an Ishikawa diagram. This was done because it divided the main goals into smaller goals. It was now easy to see what effect what. These is shown in figure 9-13.

After the smaller goals was set, it was time to choose what type of coffee machine we should design. It came down to three different types of machines; capsules, auto-drip coffee and drip coffee. A comparison was made through grading which was best, see figure 14. The auto drip was the best.

Next up was failure mode and effect analysis, FMEA. FMEA is an important part of this project. Before the analysis was done, no one in the group thought about different things that could go wrong because of the design. This led to a better designed product. The "Design-FMEA" is shown in figure 20 while functional FMEA is in figure 21 and 22.

RD&T was used in order to see how much misplaced components affect the product. In this case, the design of the pipes was examined. The placement of the pipes is an very important step because if something leaks inside the product, many things will be destroyed. This is shown in figure 21-23.

After RD&T, a life cycle assessment was made. This was done so that the design would be as environmental friendly as possible

Next up was the design for assembly, DFA. DFA was made in order to reduce the cost of assembly for the product and minimize number of parts. Firstly, a DFA was made for our first design. Thanks to DFA it became apparent that our design had flaws, so a second DFA was made in order to further improve the design. The DFA is shown in figure 26-30.

Lastly, a material selection was made for the most important parts, which in this case was the water container and the coil that warms up the water. The material selection was decided from several parameters; CO2 footprint, price, Thermal insulation among others. Some data for the material selection is shown in figure 31-42.

27 Distribution of work

A brief description of the distribution of work for the deliverables.

- Mohammad contributed to the Preface and Introduction sections of the report.
- All group members worked on the functional structure of the coffee machine.
- Abdulrahman was responsible for the exploded view and bill of materials (BOM).

- The group worked together on the Ishikawa diagram and Design Structure Matrix (DSM).
- All group members contributed to the requirement specification.
- Abdulrahman and Philip focused on the market segmentation and FMEA analysis.
- Mohammad worked on the price segment and, together with Philip, carried out the research, development, and testing (RDT).
- Abdulrahman and Philip completed the Life Cycle Assessment (LCA).
- The group worked together on the Design for Assembly (DFA).
- Mohammad and Philip were responsible for material selection.
- Abdulrahman carried out the verification process.
- Philip contributed to the Summary section of the report.
- Mohammad wrote the Discussion section.
- Philip wrote the Conclusion section.
- All group members worked on the product representation

28 Discussion on the methodology

During this course, we used a variety of methods to develop the design of our coffee machine. These methods included component-based Design Structure Matrix (DSM) to analyze and manage the relationships between components, variation analysis to understand and quantify sources of variation, and stability analysis to evaluate the stability of the system over time. We also utilized contribution analysis to understand the individual contributions of different variables or factors, FMEA (Failure Modes and Effects Analysis) to identify potential failures and evaluate the consequences, LCA (Life Cycle Assessment) to assess the environmental impacts of the product throughout its life cycle, DFA (Design for Assembly) to design the product for ease of assembly, and material selection to choose the appropriate materials based on factors such as strength, durability, cost, and environmental impact.

Material selection was an important consideration in the design of our coffee machine. We conducted extensive research to identify materials that would meet the performance requirements of the product, such as strength and durability, while also being cost-effective and environmentally friendly. We weighed the pros and cons of different materials and ultimately selected those that we believed were the best fit for the application.

One of the strengths of the methods that we used was their ability to help us identify potential bottlenecks or areas of risk in the design process. By visualizing the dependencies between components using the DSM, we were able to identify potential issues and make changes to the design as needed. The use of variation and stability analysis allowed us to evaluate the performance of the system over time and identify any potential problems that may arise. Additionally, the contribution analysis and FMEA helped us to understand the most important variables and potential failure modes, respectively, and take steps to mitigate risks. The LCA provided valuable insights into the environmental impacts of the product, helping us to design a more sustainable solution. The DFA and material selection methods helped us to optimize the assembly process and choose the most appropriate materials for the application.

One of the difficulties that we encountered was the time and effort required to properly apply these methods. The DSM in particular was a time-consuming process, as it required a detailed analysis of all the components and their relationships. Additionally, some of the methods, such as FMEA and LCA, required a significant amount of data collection and analysis. However, we believe that the effort was worthwhile, as it helped us to create a more robust and efficient design.

Overall, we found these methods to be very useful in the development of our coffee machine design. While they did require a significant investment of time and effort, they allowed us to identify and address potential issues early in the design process, resulting in a more successful outcome. The experience and opinions of our group were instrumental in guiding the use of these methods and interpreting the results. The careful material selection that we conducted was a key factor in the success of the project, as it ensured that we were using the most appropriate materials for the application.

29 Conclusion and recommendation

29.1 Conclusion

In conclusion, the goals that was set in the beginning is now fulfilled. The first goal "Reduced cost of manufacturing" was reached when the material selection was done. Another factor that contributed to this goal was the DFA analysis which the score went from 72% to 77% for companies and 76% for the family variant.

The second goal "Clear improvement of performance" was done under the while project. The functional structure gave some ideas to improvement and these ideas were later fulfilled, for example the warm water box in figure 2. This idea grew to a self regulated water container.

The third goal "The aesthetics of the design must meet the requirements and desires of the presumed consumers" was mainly met when the CAD started.

Lastly the final goal "The product must have a modular product architecture" was met when the DFA analysis was done.

Since all the goals are met, this is a good product which is price worthy.

29.2 Recommendation

Some recommendation if this project would be redone is the following; start the DFA and FMEA early. Both these steps had the biggest impact of the design.

29.3 Proposals for future work

Some proposals for future work is: calculation for the pipe diameter, the control system for the water container with sensors and more material selection to for example the grounders.

The calculation for the pipes is necessary because the water pump will pump the water through the system. While the water travels the temperature could raise even further.

The control system for the water container is another crucial part of this system. The system has to regulate the water temperature to the right degree and do this with help from different sensors.

Lastly another material selection would be good for the grounders. The grounders should not wear out within several years.

30 Product representation and Drawing for 3 most important parts

Check appendix.

———-Thank you———-

31 Appendix

31.1 Product representation and Drawing for 3 most important parts

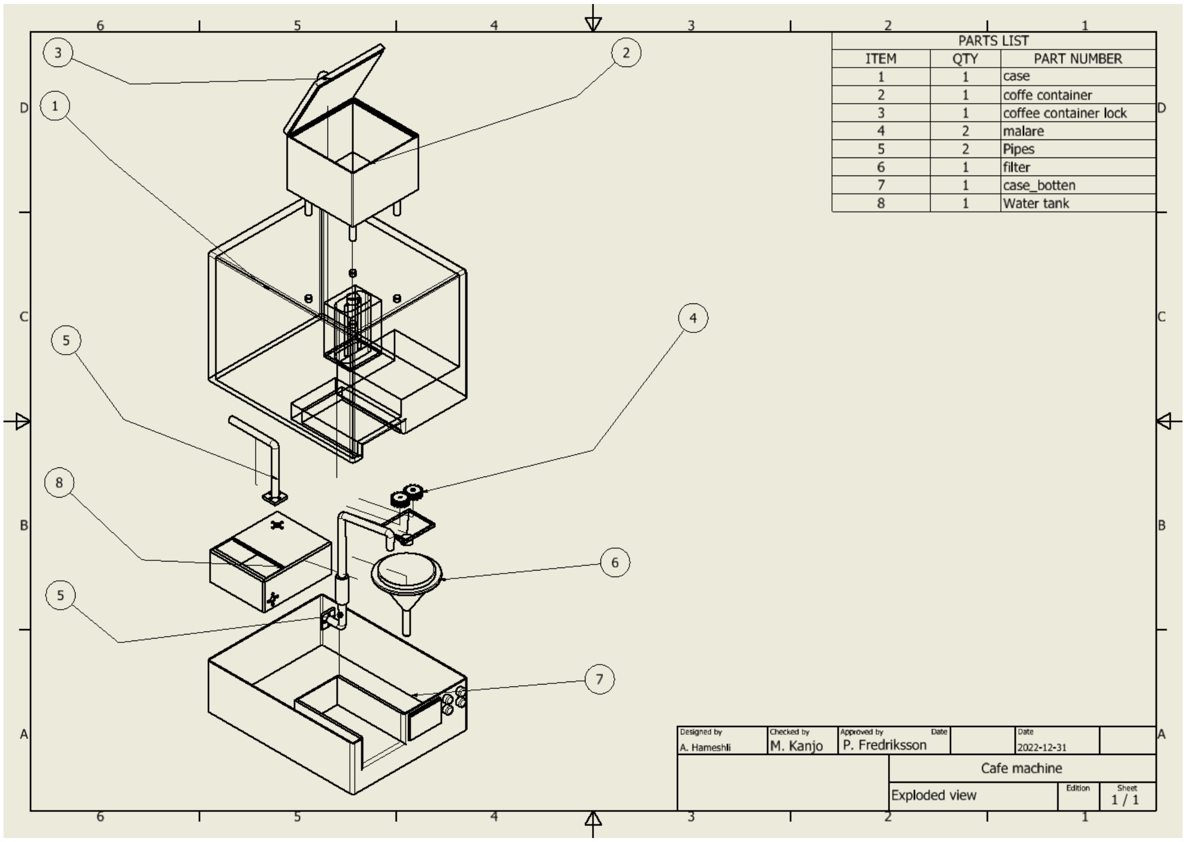


Figure 37: Drawing of exploded view

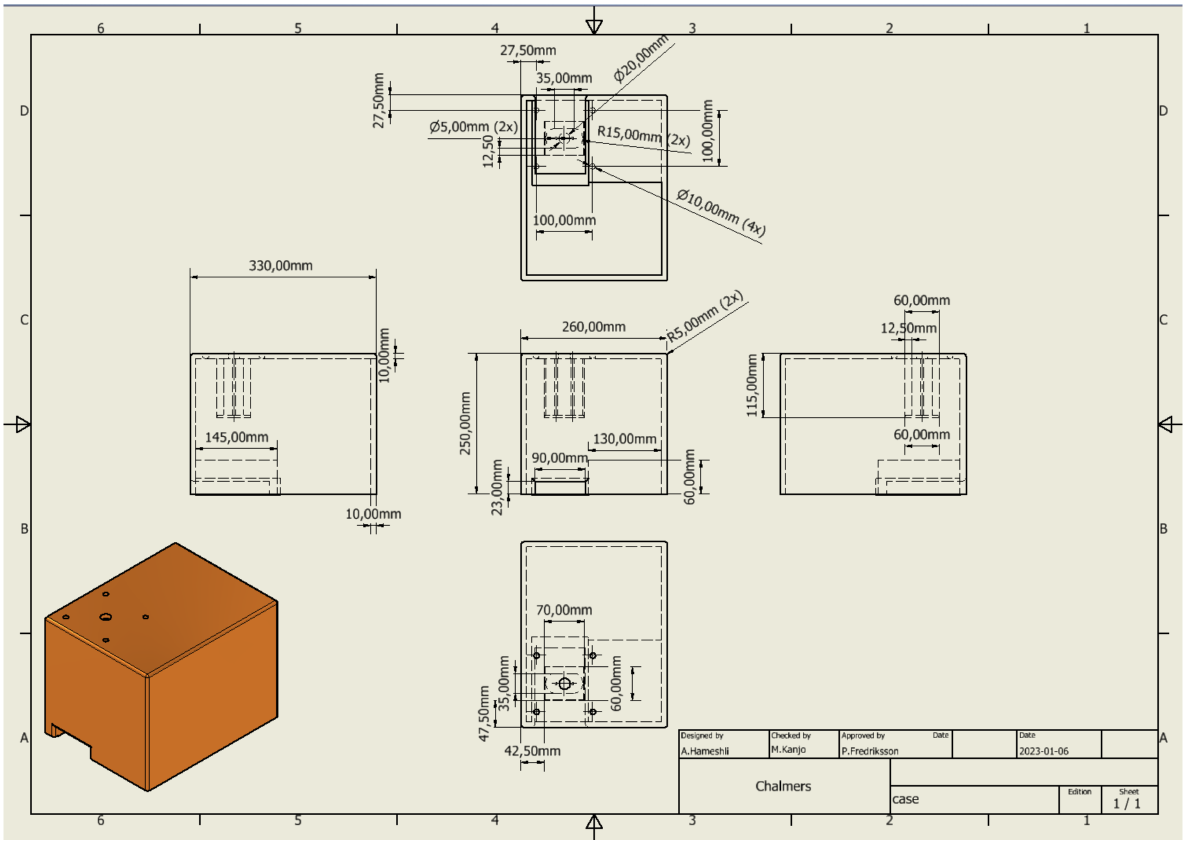


Figure 38: Drawing of the case

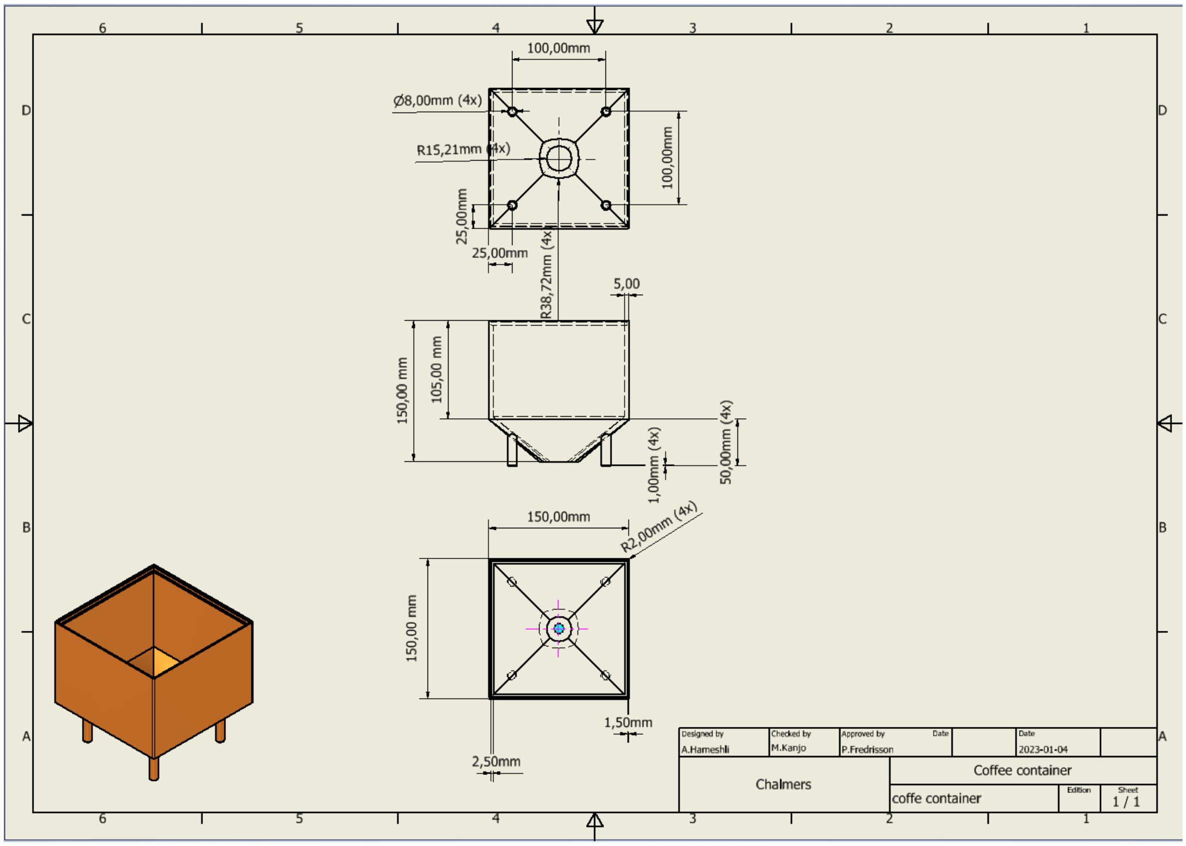


Figure 39: Drawing of coffee container

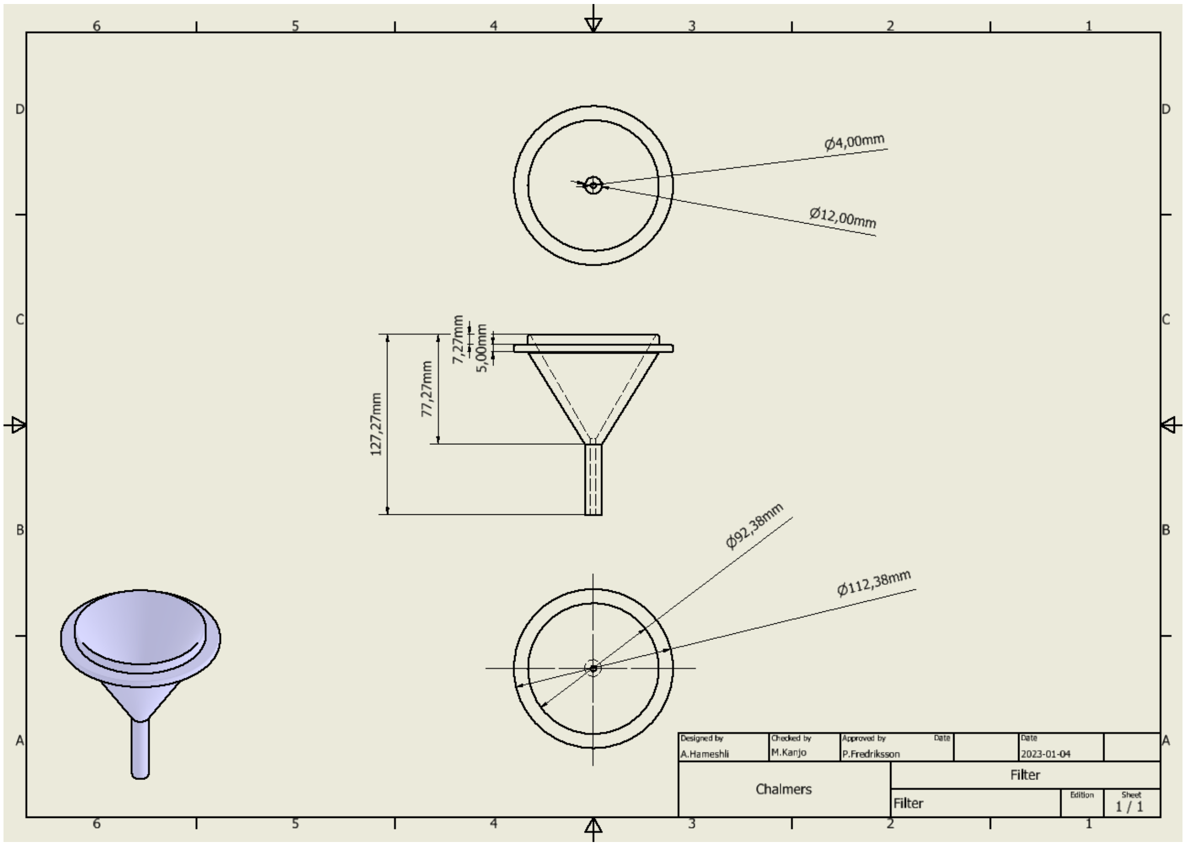


Figure 40: Drawing of filter

31.2 The way to the new product

The coffee machine to be designed by us will be mainly for companies. In order to choose the most adapted machine for the companies, A matrix analysis 41 has been conducted where we scale the different type of coffee machines if fulfill our requirements and goals. The scale ranges from 1:3 where 3 is the best and 1 is the worst.

Missions	Capsules	Auto-Drip Coffee	Drip Coffee
Reduced cost of manufacturing	2	1	3
Clear improvement of performance (Fast)	3	2	1
The product must have a clear environmentally friendly profile	2	3	1
The aesthetics of the design must meet the desires of the consumers.	3	1	2
The product must have a modular product architecture	2	3	1
Coffee cost	1	3	2
Coffee quality	1	2	2
Total	14	15	12

Figure 41: Comparing different type of coffee machines with the goals

The reason why every goal has its score is exampled in the following:

31.3 Capsules

This coffee machine is a pod-based coffee machine.

Figure 42: Capsules Coffe machiens

Reduced cost of manufacturing:

List of component that are needed to build a Capsules coffee machine are the following:

- Water Housing
- Pod Housing
- Pod
- Controls
- Drip Tray
- Water Heater
- Water Pump
- Air Compressor

The reason why it got 2 because it has less components that the auto-drip coffee machine and more little more than the drip coffee machine.

31.3.1 Clear improvement of performance (Fast):

The Capsules got 3 because it is faster than the drip coffee machine and it does it have to ground the coffee as the auto-drip coffee machine

The product must have a clear environmentally friendly profile:

The Capsules machine got 2 because it does a better user experience when making the coffee. Another reason why it got 2 is because of the plastic leftovers from capsules. Compared to the other coffee machine, where you only have filters as considered as trash.

The aesthetics of the design must meet the requirements and desires of the presumed consumers:

The Capsules machine does provide an elegant experience and a decent look more than the other coffee machines.

The product must have a modular product architecture:

The reason why Capsules coffee machine got 2 in this part becasue the client will get no coffe at all if the water pump does not work. Water pump is number 2 in the figure43.

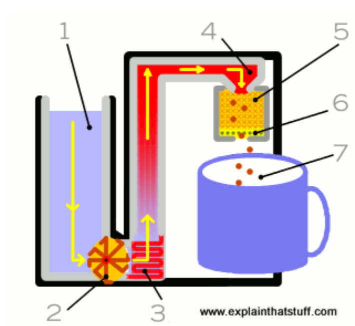


Figure 43: Capsules Coffe machine internal structures

Coffee cost:

The reason the capsules machine got 1 is because the coffee capsules are little expensive compared to the grounded coffee

31.4 Auto-Drip Coffee

Auto-Drip Coffee is a machine that brews coffee in a short time where it takes care of all the flow automatically. The flow consists of grinding beans, heating water and then serving a finished good coffee.
Below is a description of how the rating is set and why for our conditions and goals:

Reduced cost of manufacturing:

The rating is 1 because there are more components that have to be produced, which means more production costs.

Clear improvement of performance:

The rating is 2. It is fast in brewing coffee but compared to the Capsules machine it is slower because it has to grind the coffee as well

The product must have a clear environmentally friendly profile:

The rating is 3 because from the environmental asphalt, the material it is made of can be environmentally friendly, but also that after the product union it does not require as much trash as the Capsules machine because in the Capsules machine you have to throw away the capsules that consist of plastic. In terms of energy, it is difficult to compare the three different coffee machines because they are used in different environments.

The aesthetics of the design must meet the requirements and desires of the presumed consumers:

The rating is 1. In design world, you can design how you want and make machines cooler and prettier, but we have chosen to start from the standard, where most of them are square designed, which we think is not attractive.

The product must have a modular product architecture:

The reason it got Auto-Drip Coffee is because it has a lot of parts and every part has one job.

Coffee cost

The reason why it got 2 is Because the coffee is cheaper if you buy it in large amounts compared to buying coffee capsules.

31.5 Drip Coffee

Reduced cost of manufacturing:

The Drip Coffee machine is the cheapest one in terms of the number of parts that are needed to build each coffee machine.

Clear improvement of performance:

The reason why Drip Coffee got 1 is because it is slower than the other types of coffee machine.

The product must have a clear environmentally friendly profile:

The aesthetics of the design must meet the requirements and desires of the presumed consumers:

The reason why Drip Coffee got 1 is because it has a simple looking

The product must have a modular product architecture:

The Drip Coffee does not have a modular system because of how the coil boils the water and heats the plate under the pot at the same time.