A Brief Report on

Reverse Engineering

A Mini Sewing Machine

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Executive Summary

This consultancy report, authorized by Naylor-Marlow Design Elegantum (NMDE), analyses the Hobby Craft Mini Sewing-Machine in terms of its material choice, production method and design features. The goal is to demonstrate an in-depth understanding of the given product and use it as a starting point to reinvent one that fits NMDE’s brand image and target consumer better.

Starting with some background information of sewing machines and comparative analysis of the assigned model, this report presents methods used to perform a product tear down and its related findings. Due to NMDE’s will to remain the top 1000 most economically friendly companies based in South Kensington, the report includes a bill of the materials used to manufacture the Hobby Craft Mini Sewing-Machine. This is used alongside Edu pack’s eco audit tool to calculate its total embodies energy and carbon dioxide foot print. Finally, the product is reverse engineered to match NMDE’s image of being eco-friendly and eye-catchingly elegant.

Specifications

Bottom Spool.	This is the spool for the bottom thread, and is found in the lower part of your sewing machine. On some sewing machines, the bobbins are front-loading, meaning you insert them through the front of the machine. On other sewing machines, the bobbin is drop-in, so the bobbins are inserted through the top of the machine.
Bobbin Housing (or Bobbin Case).	The bobbin housing holds your bobbins inside your sewing machine.
Bobbin Winder Tension Disc.	This small metal disc helps to keep the thread taut as you wind a bobbin.
Bobbin Winder.	As you wind thread onto your bobbin, the bobbin winder will spin the bobbin.
Buttonhole Foot.	Automatically determines how big a buttonhole needs to be based on how big the button you're using for your project is. If you sometimes worry over whether your buttonholes are the right size for your buttons, you'll definitely appreciate having a buttonhole foot.
Feed Dogs.	These small, metal ridges are found in the middle of the throat plate (which you'll learn about later). The feed dogs are what pull your fabric through your sewing machine for you. How fast the feed dogs move the fabric through the machine will depend on how much pressure you are putting on the foot pedal. The harder you press down on the pedal, the faster your fabric will move.
Flywheel (or Hand Wheel).	The flywheel allows you to manually lower and raise the sewing machine's needle. When you're setting up a project to start sewing it, you'll lower the flywheel in order to lower the needle into the fabric. When you're ready to remove the project from the sewing machine, you'll raise the flywheel to remove the needle from the fabric.
Foot Pedal.	Controls the speed at which your sewing machine makes stitches. Press down harder on the pedal to make the machine stitch faster. Ease up on the pedal for slower stitching.
Needle.	The needle is what puts the thread through the fabric. Sewing machine needles come in many different sizes, and the needle you use will depend on the fabric you are sewing at any given time.
Needle Clamp (or Needle Bar).	This is what holds the needle straight and steady in the sewing machine.
Needle (or Throat) Plate.	The needle plate is the flat, metal plate under the needle that covers the bobbin. When you're making stitches, the needle goes down through the needle plate. The needle plate has marks that act as seam guides. These allow you to gauge how far your stitches are from the edge of your fabric.
Power Switch.	What you use to turn the sewing machine on and off. On many sewing machines, this switch is found near the power cord, and is probably attached to the pedal.
Presser Foot.	Found below the needle, the presser foot presses the fabric down against the feed dogs, which helps to keep the fabric from slipping. You can find both plastic and metal presser feet. Presser feet are also interchangeable. You can switch out your general purpose presser foot for a presser foot specially designed for specific sewing jobs (like making buttonholes and sewing zippers). Don't be surprised if a single sewing project, especially if it's a more advanced project, requires more than one type of presser foot.
Presser Foot Lever.	The part of your sewing machine that raises and lowers the presser foot.

Pressure Regulator.	Controls the amount of pressure use by the presser foot to hold the fabric down against the feed dogs.
Reverse Switch (or Reverse Button).	Use the reverse switch when you need to sew in reverse. Among other things, backstitching can make your seams more stable.
Slide Plate.	If you need access to the bobbin, you open the slide plate.
Spool Pin (or Spool Holder).	A spindle on top of your sewing machine that holds a spool of thread.
Thread Take-Up Lever.	One of the many parts of your sewing machine that will help to keep the thread taught while you sew. The thread take-up lever is the part of the machine that creates stitches by raising and lowering the thread. It also controls the flow of the thread.
Tension Discs.	Help regulate the tension of your thread.
Tension Regulator.	Allows you to raise and lower the tension of both the top thread and the bobbin thread in your sewing machine. The level of tension will determine how tight your stitches are.
Thread Cutter.	Allows you to quickly and easily cut your thread without having to reach for a pair of scissors.

1 Introduction

Asana Design Consultancy believes that a well-designed product always has materials and production methods that concur perfectly, aiding its design purpose. With this in mind, the team conducted a tear down and analyzed a sewing machine given by their client. They presented the tear-down process and created a bill of materials based on the data retrieved.

Based on the information from this sewing machine, the team re-designed its outer casing and interior to better reflect their client's brand. Instead of the ABS casing in the original sewing machine, the team proposed the use of recycled soda-lime glass. And instead of steel and acetal for the interior, the team recommended brass.

2 Background

2.1 Sewing Machine

The sewing machine as we know them today was invented owning to the collaborative efforts of several inventors during the industrial revolution the United Kingdom. Its primary function was to reduce manual labour in the clothing industry for sewing and joining leather and fabrics.

Earlier models of the sewing machine were bulky and attached to a work bench. These machines were usually constructed from large chunks of wood while precise parts including feed gears, hooks, needle bar, and the main drive shaft were casted with iron. These models were only possible to be used industrially within factories for their immense size and weight (see Figure 1.1). A brief estimate for the embodied energy of Elias Howe's lockstitch machine using the CES edupack resulted in a total embodied energy of 3185 million joules, over 265 times that of the mini sewing machine provided by NMDE.

Home sewing machines were first commercialized by Isaac Merritt Singer from the United States in 1853. The Singer treadle machines were delicately crafted from coated steel and engraved with brass ornaments. They were attached to a smaller but more mobile work bench made from cast iron fences and one pieces of wood (see Figure 1.2). The estimated embodied energy for this product is just over 800 million joules, 4 times less than its predecessor thanks to the substantial reduction in mass. It is also worth noting that these machines were a symbol of elegance as they could only be owned by extremely wealthy families and clothes sellers due to their cost. The coated steel and brass used to manufacture these machines were also easily recyclable with very low embodied energy. They were also metallic, shiny, and had a classic design: perfectly aligned with the client's brand image and target consumer.

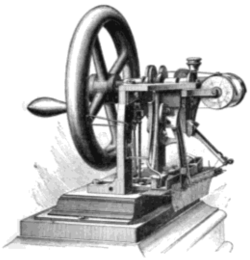


Figure 1.1:
Elias Howe's lockstitch machine, invented in 1845

Figure 1.2:
A Singer treadle machine, based on Isaac Merritt Singer's model.

Figure 1.3:
The Hobby Craft mini sewing-machine.

2.2 Hobby Craft Mini Sewing-Machine

Hobby craft mini sewing-machine is the main subject of this report. It is a mini home sewing-machine designed to be versatile, portable and cheap. In terms of the product's design purpose, the product can be considered very successful: it is priced at merely £30 and weighs as little as 800 grams even with its charging device. This was made possible using easily accessible thermoplastics like ABS to construct the majority of the product, injection moulding production line and the cheap human labour cost in China for assembly. However, there were no indications in the use of recycled ABS and the product was also imported from China: it is far from an eco-friendly one, especially when considering its giant rate of production and low market value.

Competition is fierce in the sewing-machines market, although mini sewing-machines like the Hobby Craft can take the advantage of being versatile, portable, and cheap, they lack the consistency, control and durability displayed by larger home sewing-machines. Many comments under the Hobby Craft mini sewing-machine complained about its speed control, precision, and how it was "too light to sit still". Considering NMDE's brand image, ADC's initial suggestion is for NMDE to consider larger home sewing-machines as they are often more elegant with better user experience.

3 Methods

3.1 Unboxing and Product Experience

The product was first unboxed. There were two layers of packaging for the machine and one additional layer of packaging for an accessory: the buttonhole foot (see Specifications). The surface layer packaging was made from cardboard (see bottom left corner in Figure 2.1), the second was from Styrofoam (see above cardboard cover in Figure 2.1) and the accessory was stored within a small plastic zip bag (see lower right hand side in Figure 2.1). The product also came with a power cable, a foot pedal, a manual, and some sample fabric for practice.

Figure 2.1: Unboxing of the Hobby Craft Mini Sewing Machine.

Before conducting the product tear-down, the group first operated the device to identify its moving parts and understand its functionality. The group connected the foot paddle to the sewing machine and plugged in the device. It was observed that the only moving parts visible from the surface of the product were the needle, needle clamp and bobbin winder spool. These were all made from metal presumably due to its higher fatigue resistance. The speed control foot paddle was also tested. The "range of sewing speed" portrayed on the user manual was not apparent as there seemed to only be 2 levels of speed. This was later proven by the tear down process as there were only 2 metal contacts present within the foot paddle. In a nutshell, the unboxing and user experience for this given product was extremely cheap and does not match NMDE’s brand image.

3.2 Product Tear-Down

Step 1: Unscrew to separate the plastic casing

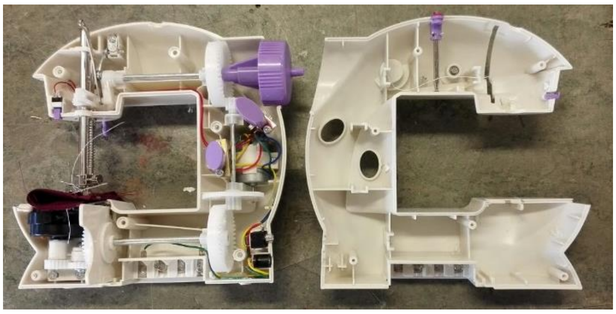


Figure 2.2: The separated plastic casing, with mechanism resting on the slots.

The two halves of the plastic casing for the product were attached mechanically by six horizontal Philips head screws with identical cap size but differing lengths. The screws were removed using a suitable Philips head screw driver and the two halves separated easily upon a slight pull.

Upon separating the covers, the group observed that most of the mechanism were simply fitted into the geometry of the two halves (see Figure 2.2). However, some other components were also attached to the case with glue or additional supporting structures with screws.

Step 2: Removing the switches and buttons

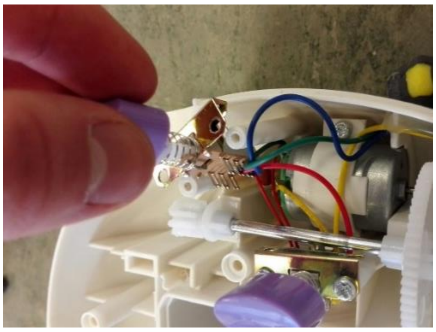
 

Figure 2.3 (left): Power and lamp switches mechanically attached to the casing.
Figure 2.4 (right): ADC team member Rowan removing the power switch from the sewing machine.

The first layer of mechanisms that was removed were the switches and buttons because they were the closest to the surface. Not only were these switches mechanically attached to the casing with screws, they were wired to the rest of the machine and therefore the wires had to be removed first. Although both un-soldering and cutting were legit choices, the group ultimately chose to cut at a distance away from the end of the wires for better demonstration on the tear-down board.

After cutting away all the wires, the team unscrewed the screws using a suitable Phillips head screw driver. The team removed the power switch, lamp switch and speed buttons (see Figures 2.3, 2.4) (see Specifications) and proceeded to labelling and weighing the removed objects on an electronic scale.

Step 3: **Removing the Needle Components**

The needle of this sewing machine was attached to the needle clamp via a large thumb screw, unscrewing this releases the needle effortlessly. However, the needle clamp is attached to a polyethylene block with a screw and the block is also attached to the case with another screw. Starting from the one holding the needle clamp, both screws were unscrewed using a suitable Phillip's head screw driver and released for weighing. Similar procedures were followed for removing the presser foot (see Specifications) as well. Both items were labelled and weighed.

Step 4: **Removing the Three Gear Shafts**

Upon removing the needle holder module and presser foot. The two horizontal gear shafts, along with the flywheel attached to the upper gear shaft were removed without the need of any other tools. The gears on these gear shafts are fitted tightly with an adhesive in between, this ensures that the gears turn perfectly with the shaft. After removing these two horizontal gear shafts, the vertical gear shaft can also be taken out by hand. All three gear shafts were labelled and weighed.

Step 5: **Removing the D.C. Motor and Power, Foot Paddle Connection Ports**

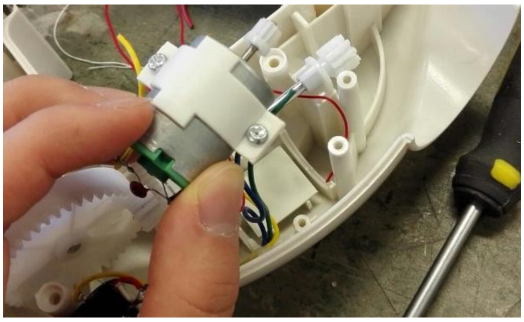


Figure 2.5 (left): Power and foot paddle connection ports for the machine. Figure 2.6 (right): ADC team member Ryan removing the D.C. motor from the sewing machine.

After removing the three gear shafts, the team unscrewed the motor's supporting structure from the case (see Figure 2.6). However, the motor is also wired to the power and foot paddle connection ports, therefore these must all be removed together. ADC first removed the ports by hand as they were only fitted within their slots (see Figure 2.5). Then, using a suitable screw driver, the team unscrewed the motor and its support. These items were labelled and weighed

Step 6: **Disassembling the Bobbin Assembly**

Figure 2.7: The bobbin assembly

The bobbin assembly is the last but most inconvenient component to tear away. The entire assembly was attached to the casing with four Phillip's head screws (see Figure 2.7) along with three other ones: two on the bottom of the gears and one on top of the black bobbin housing (see Specifications). These individual parts were labelled and weighed, and then the empty casings followed.

Step 7: **Foot Paddle Tear-Down**

The foot paddle is an external accessory that aids the machine's function by controling the sewing speed. This item consists of two polypropylene semi-casings connected with a hinge geometry. A spring is fitted into the middle of the paddle to provide push-back. Two pieces of copper metal stands were juxtaposed so that they meet when pressure is applied to the paddle. Wireing starts from each copper strand and runs all the way back to the machine's foot paddle connection port. Removing the cover without damaging the foot padle requires some experience fiddling with plastic items. Using the flexible nature of plastics, one case has to be slightly squeesed and tilted until one of the hinge's tip can be taken out of its socket. The entire case can them be removed. The copper stripes were removed using a suitable Phillip's head screw driver. All pieces were labeled and weighed.

Note: **Some smaller and unimportant pieces of the machine were taken off by hand during the beginning of the tear down, these pieces were not included in the tear-down guide, but are listed below:**

Needle Plate; Pressure Regulator; Bottom Spool (see Specifications).

3.3 Plastic Identification

The team conducted several different tests on distinctive plastics to determine exactly what it was composed of.

Step 1: Three small pieces of plastic were broken off using a pair of piers to use as samples. These plastics had distinct colours and texture and were taken from distinct parts of the machine including the casing, gears, and foot paddle.

Step 2: Following an identification flow chart, a hot soldering iron was first pressed against the samples. All plastics in the sewing machine were identified to be thermoplastics by this step. This is because they softened and changed shape upon heating.

Step 3: The samples were dropped into a bucket of water and pushed down to break the surface tension of water. The foot peddle casing sample was the only one that floated, meaning that it was either polyethylene or polypropylene which is less dense than water. The other two samples were also shown to be denser polymers.

Step 4: Finally, the sample were held by an elevated clip and burned. The polymers were identified depending on whether it ignited, dripped, the colour of the flame, how quickly the polymer was consumed by the flame and the smell of the smoke.

Results: The foot paddle casing sample was identified as polypropylene; the gear sample as polyoxymethylene; and the casing sample as polyurethane. However, the casing sample was later proven to be ABS by observing a stamp on the bottom of the case. In the flow chart, the only methods that can distinguish polyurethane with ABS were whether it drips upon ignition, its flame colour and smell (see Appendix C). However, our sample of ABS did not drip and all flame colours appeared to be yellow: the feature for polyurethane. Moreover, due to the crowded work space where other consultancy members were testing different plastics, the smell of the smoke could not be distinguished, and had no effect on the identification process. In short, the group found that it was impossible to accurately determine different plastics using the given method but agrees that it gave an acceptable estimate.

4 Discussion

4.1 Bill of Materials and Processes

The complete bill of materials is presented in Appendix X, and was generated using the CES eco-audit tool by imputing information collected during the product tear down process. These include the weight and material of each individual components and are listed in Appendix X.

Note that due to the limited selection of materials and processes in the eco-audit tool have limited the accuracy of the imputed materials and processes. Furthermore, some components like the motor could not be further disassembled and therefore was imputed as a fan, which closely resembles the component. The bill of materials and processes should still mostly accurate nevertheless.

Table 1: shortened bill of key materials and processes (Embodied Energy > 1.5MJ)

Component Name (see Specifications)	Material	Total mass (g)	Energy (MJ)	%	Process	Amount processed (g)	Energy (MJ)	%
Power Switch, Lamp Switch, Speed Button, Flywheel, Tension screw, Bobbin Case, Throat Plate, Power supply Casing, Foot Pedal Casing.	Polyethylene (PE)	97	7.9	10.4	Polymer moulding	97	2.1	17.5
Power Switch, Speed Button, Flywheel, Tension Screw, Thread Spindle, Thread Take-up Lever, Bobbin Casing, Needle clamp and Screw, Pressure Foot, Feed Dog, Motor, Vertical Gear Shaft, Hook Gear Assembly, Power Supply Case, Foot Pedal Casing.	Medium carbon steel	160	4.4	5.7	Rough rolling	160	0.54	4.4
Battery Compartment, Motor Support, Hook Gear Assembly, Main Cover Half (L), Main Cover Half (R).	Acrylonitrile butadiene styrene (ABS)	390	37	49.4	Polymer moulding	390	8.1	66.9
Foam Cushioning.	Polystyrene (PS)	25	2.4	3.2	Polymer moulding	25	0.47	3.9
Power Switch, Lamp Switch, Flywheel, Motor Gear, Vertical Gear Shaft Gears, Hook Gear Assembly Gears.	Polyoxymethylene (Acetal, POM)	19	1.7	2.2	Polymer moulding	19	0.33	2.7
Motor.	Fan	42	10	13.7	-	-	-	-
Power Supply Transformers.	Transformer	24	2.1	2.7	-	-	-	-
Cardboard Packaging.	Paper and cardboard	130	6.4	8.5	-	-	-	-
Total		940	76	100			12	100

4.2 Key Materials and Processes Analysis

The processing method for all polymers were identified as injection moulding. Evidence include the presence of seams where the mould was separated; presence of circular pits where parts were mechanically pushed out; and the extremely precise dimensional accuracy demonstrated by the mostly adhesive free housing for the components. These traits were observed in all distinct plastic components from the machine. Injection moulding is at an advantage for the product because it is cheap and fast in large production volume.

The most influential polymer used in the product was Acrylonitrile butadiene styrene (ABS), contributing to over 41% of the product's mass. This thermoplastic was used mainly for the casing and structural support of the device, directly in contact with the user. This material is one of the cheapest polymers in the market, but is also very impact resistant, scratch resistant, durable, and rigid. It is therefore perfect for providing structure and protection and large scale manufacturing. Furthermore, ABS is widely used for injection moulding and 3D printing for its low melting point and ridiculously high dimensional stability, eliminating die-swell. At the same time, ABS is very easy to recycle even when compared to other thermoplastics. However, ABS is one of the most brittle plastics due to its rigid and dimensionally stable nature. This is a disadvantage as it can be easily cracked as the cover of the product.

Polyoxymethylene (Acetal) is also a crucial material for the product. Although only contributing to 2% of the product's total mass, it is at the heart of the moving components of the product. Acetal was used for the gears and for holding the moving needle shaft vertical, both constantly under friction when the machine is in operation. Acetal's properties include extremely low coefficient of friction, superb strength and stiffness, superb long-term dimensional stability and great fatigue resistance. The polymer structure of Acetal causes its surface to be a natural lubricant, making it ideal for using against moving components. Acetal is however, less scratch resistance and has a higher melting point than ABS, it is also much more expensive, making it less ideal for large scale injection moulding or as casings.

The processing method for all carbon steel components was determined to be rolling. This is because all steel components of the machine were clearly processed from steel strips and rods. Further evaluation of the components showed that these steel pieces were most likely cold rolled. This is because all pieces were relatively small and the cross sections of the steel rods showed evidence of strain hardening. Hot rolling is usually used for larger products, and are not strain hardened. It is also logical that the manufacturing firm would prefer tougher and more dimensionally correct steel pieces for their sewing machine.

Steel was used for low friction, high fatigue and high torsion parts of the design. Such as the needle clamp and the gear shafts. This is because steel is a cheap and easily accessible metal that can be machined to have an extremely smooth surface, it is tougher and more stress and fatigue resistant than plastics and isn't brittle like ABS. A mixture of techniques was used to manufacture different steel components in the product. Including the use of raw cold rolled steel rods and roll formed geometries from cold rolled steel strips. Also, the surface of the shafts has most likely been machined to reduce friction.

4.3 Environmental Impact

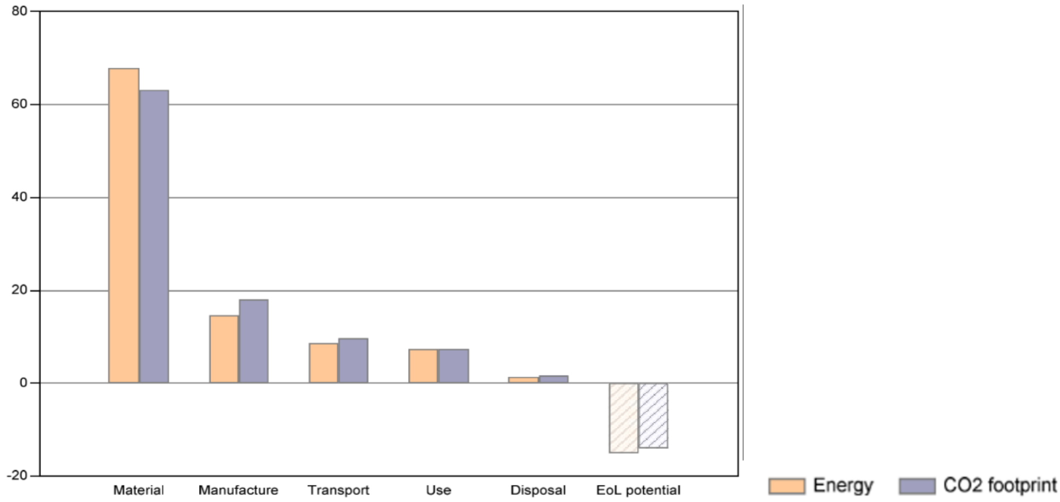


Figure 3.1: Relative Contribution of life phase (%)

From Figure 3.1, it was apparent that the biggest contributor to CO2 emission originated from the materials itself. The collection and refinement process of materials produced 66.7% of the CO2 and consumed 71.3% of the energy. Whereas the second largest contributor manufacturing only produced 16.5% of the CO2. This information was critical to the team as it conveys that more effort should be allocated to material selection for the redesigning process.

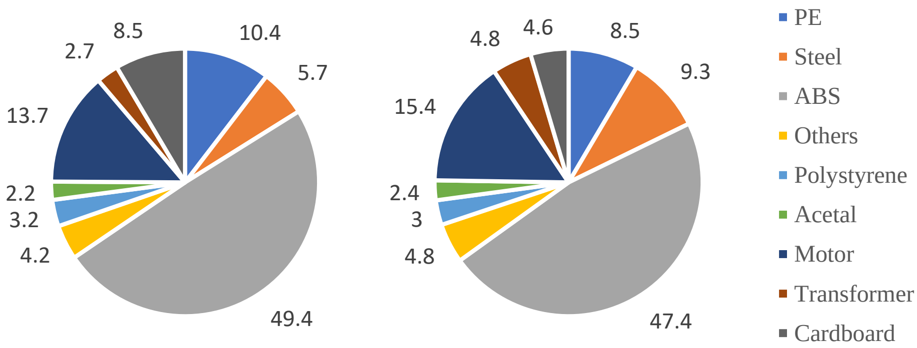


Figure 3.2: % Contribution of embodied energy (left) and CO2 foot print (right) for each key material

From Figure 3.2 we can see that there exists a strong correlation between the embodied energy and CO2 foot print of each material, this is because the production of energy is the main contributor to CO2 emission.

Also from Figure 3.2 it is shown that ABS is by far the biggest contributor to both energy consumption and CO2 emission at 49.4% and 47.4% respectively. This is not only because ABS has a relatively high primary production embodied energy-weight ratio at 10,000 kcal/lb, but also the fact that it single handed constituted 41% of the product's Total mass. This is a critical reverse engineering candidate.

Another large contributor to CO2 production was the Motor. This is because although the crude material for manufacturing motors, mainly steel and copper is not especially CO2 heavy, the immense number of processes required to manufacture it is. However, this component is crucial to the machine's functions and there are no suitable replacements.

All the key components use for the sewing machine are recyclable. The benefits this will bring was shown in the bottom right corner in Figure 3.1. As most of the product was manufactured from plastic and steel, the steel can be easily removed using a magnet. However, it is slightly harder to sort the ABS, PE and Acetal, as they will either have to be separated manually or by rates of density.

Moreover, the plastic components of the product is sometimes glued together, making it harder to sort and recycle.

Table 2: Transportation induced CO2 footprint per product

Stage name	Transport type	Distance (km)	CO2 footprint (kg)	%
Import from China	Sea freight	2.4e+04	0.58	98.8
From Port to London Centre	32 tonne truck	1e+02	0.0069	1.2
Total		2.4e+04	0.59	100

Table 2 shows the amount of CO2 produced per sewing machine, at 0.59 kg, constituting over 10% of the entire product's CO2 footprint. This is staggering and mainly due to the long distance in sea freight.

To summarize, the mini sewing machine at 76 MJ of embodied energy and CO2 foot print of 4.9 kg (see appendix A) is already relatively eco-friendly. However, materials like ABS have room to be improved. Furthermore, the use of multiple different plastics for the same device and adhesive in the assembly process should be avoided as it greatly increases the difficulties in recycling. The shipping distance of the product must also be greatly reduced.

4.4 Recommended Design for NMDE

The client NMDE is listed as one of the top 1000 eco-friendly design companies located in South Kensington. Based in one of UK's most prosperous districts, NMDE has built a strong brand image of being extremely elegant and high class. Time magazine has voted the company's recent toilet seat design as "the future of upper class toilet seats". This is evidence that NMDE is strictly targeting the high-end market, where lowering price may create an adverse effect.

Table 3: The client's profile

Brand Image	Elegant, high class, metallic and shiny, classic, eco-friendly.
Target Market	High class, Local in the UK.
Target Consumer	Middle age and above, rich, upper-class individuals with a great, elegant taste. Money means power to them and they want to show it off. Like most people at their age however, they like to worry about their children's future and are very conscience about the environment.

Table 3 shows a profile of ADC's client NMDE, collated from conversations with their founder and CEO Naylor Marlow. From it, we can see that strong emphasis is put on elegance and eco-friendliness.

Using CES Edupack, the team first selected a list of potential material categories choices that were commonly associated with elegance but is also tough and rigid enough to be used as a replacement for ABS. Next, the team ranked these materials in terms of their embodied energy and only kept the top five. Finally, the team collated a semantics differential survey using pictures of cubes of the material and tested it against 50 individuals at the client's area South Kensington. Pictures of ABS and Polyurethane were also included for reference. Figure 4.1 demonstrates the results.

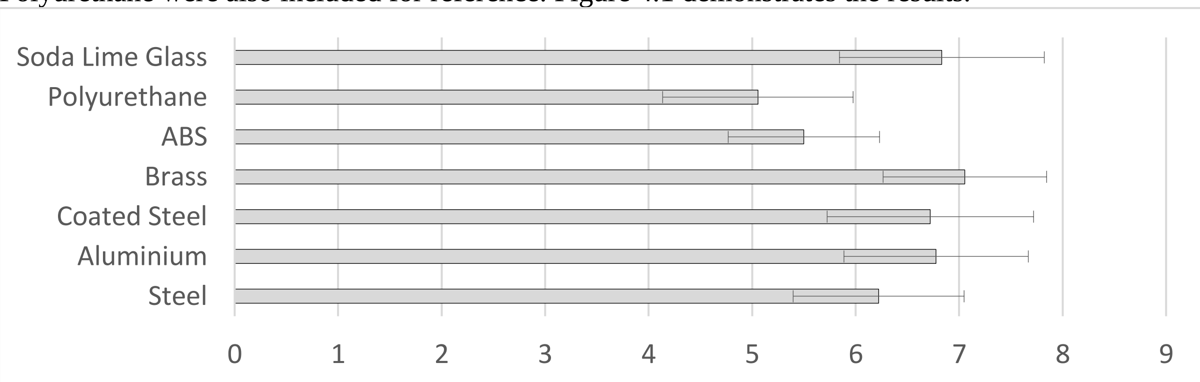


Figure 4.1: Semantic differential scale for elegance on 9 different materials.

As shown in Figure 4.1, the most elegant material was brass, followed by soda lime glass, aluminum and coated steel. Out of these choices, aluminum had the most embodied energy per unit weight at 23,000 kcal/lb, higher than that of ABS, and was therefore not considered.

Figure 4.2: An elegant skeleton watch, resembling the team's material choice.

Using the results from the selection process, the group envisioned a design, with the casing made from soda lime glass and moving parts like gears and shafts from brass. Resembling a skeleton watch like the one in figure 4.2. The group felt that it strongly supports all of our client's requirements.

Instead of ABS for structure and casing, the group suggests recycled injection molded soda-lime glass. This is because soda lime glass is extremely thought, rigid and scratch resistant. Although prone to breaking, it is unlikely that the users of the sewing machine would move it a lot. At 1,000 kcal/lb it also has way less embodied energy when compared to ABS, which has 10,000 kcal/lb.

Instead of steel and acetal, the group suggests recycled brass for the moving parts and gears of the product. For centuries brass has been used for gears in watches, it is hard, strong, easily recyclable and castable. For this reason, it is recommended that the brass is injection molded, as this reduces the number of steps required to machine the gears.

5 Summary

Ever since Isaac Merritt Singer first commercialized home sewing machines, the sewing machine market never stopped to grow and the models have never ceased to change. The Hobby Craft mini sewing machine was far from the one Singer had envisioned, it was less elegant. However, this does not mean that Hobby Craft has failed in delivering their best product. But because the mini sewing machine was made to be less elegant and cheap.

During the analysis of Hobby Craft's machine, Asana Design Consultancy found that even though the product was cheap, every single distinct material that was chosen had a strict reason, and reflected Hobby Craft's goal. Using the same approach, the team reverse engineered the Hobby Craft mini sewing-machine and suggested recycled injection molded soda-lime glass to be used as replacement for the machine's casing. And that recycled brass to be used as the gears and moving shafts. The team believes that the chosen materials and production methods best reflects the client NMDE's image.

6 Appendices

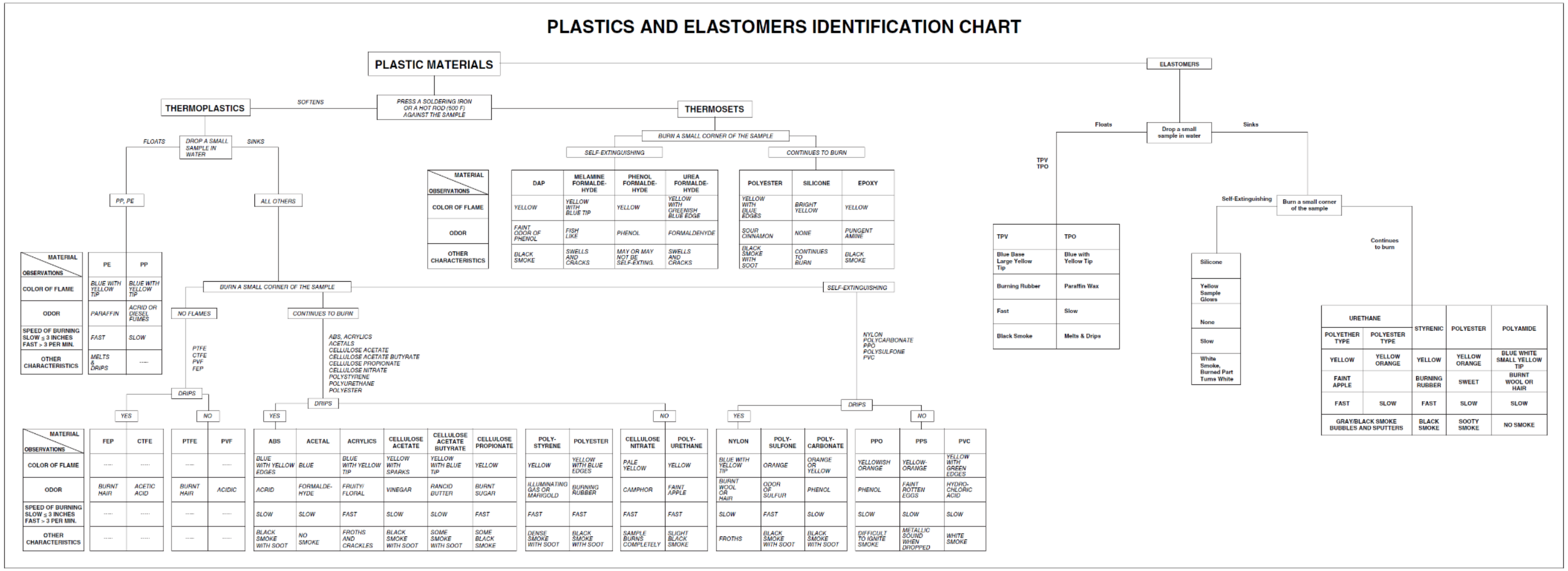
6.1 Appendix A

Component	Material	Part mass (kg)	CO2 footprint (kg)	%
Power Switch, Lamp Switch, Speed Button, Flywheel, Tension screw, Bobbin Case, Throat Plate, Power supply Casing, Foot Pedal Casing.	Polyethylene (PE)	0.097	0.77	17.3
Power Switch, Speed Button, Flywheel, Tension Screw, Thread Spindle, Thread Take-up Lever, Bobbin Casing, Needle clamp and Screw, Pressure Foot, Feed Dog, Motor, Vertical Gear Shaft, Hook Gear Assembly, Power Supply Case, Foot Pedal Casing.	Medium carbon steel	0.18	0.65	14.6
Battery Compartment, Motor Support, Hook Gear Assembly, Main Cover Half (L), Main Cover Half (R).	Acrylonitrile butadiene styrene (ABS)	0.7	1.3	28.4
Power switch, Speed Button, Motor, Wires, Foot Pedal Contact.	Copper	0.85	0.64	14.4
Wires.	Polyvinylchloride (tpPVC)	0.024	0.092	2.1
Needle.	High carbon steel	0.022	0.082	1.8
Screws.	Stainless steel	0.015	0.037	0.8
Plastic Packaging.	Polyethylene (PE)	0. 025	0.00045	0.0
Foam Cushioning.	Polystyrene (PS)	0.0005	0.0025	0.1
Power Switch, Lamp Switch, Flywheel, Motor Gear, Vertical Gear Shaft Gears, Hook Gear Assembly Gears.	Polyoxymethylene (Acetal, POM)	0.001	0.0028	0.1
Throat plate.	Polypropylene (PP)	0.025	0.095	2.1
Motor.	Fan	0.004	0.012	0.3
Power Supply Transformers.	Transformer	0.042	0.49	11.0
Cardboard Packaging.	Paper and cardboard	0.024	0.15	3.5
User Manual.	Paper and cardboard	0.13	0.15	3.3
Total		0.01	0.012	0.3
Component	Material	2.1	4.5	100

6.2 Appendix B

Figure 5: The foot paddle in two pieces.

6.3 Appendix C



The Plastics identification technique is laid out in flowchart for eash step-by-step identification by process of elimination. This is shown in the plastics Identification Chart. There are some basic guidelines one must follow in order to simplify the procedure. The first step is to determine whether the material is thermoplastic or thermoset. This distinction is made by simply probing the sample with a soldering iron or a hot rod heated to approximately 500°F. If the sample softens, the material is thermoplastic. If not, it is thermoset. The next step is to conduct a flame test. It is desirable to use a colorless Bunsen burner. A matchstick can also be used in place of a Bunsen burner. However, care must be taken to distinguish between the odor of the materials used in the match and the odor given off by burning plastic materials. Before commencing the burning test, it is advisable to be prepared to write down the following observations:

1.Does the material burn? 2.color of flame 3.Odor 4.Does the material drip while burning 5.Nature of smoke and color of smoke.
6. The presence of soot in the air. 7. Self-extinguishes or continues to burn. 8. Speed of burning--fast or slow

To identify the material, compare the actual observations with the ones listed in the flowchart. The accuracy of the test can be greatly improved by performing similar tests on a known sample. While performing the identification tests, one must not overlook safety factors. The drippings from the burning plastic may be very hot and sticky. After extinguishing the flame, inhale the smoke very carefully. Certain plastics like acetals give off a toxic formaldehyde gas that may cause a severe burning sensation in the nose and chest.

6.4 Appendix D

Component	Material	Total mass (kg)	Qty.	Total mass (kg)	Energy (MJ)	%	Process	Amount processed (kg)	Energy (MJ)	%
Power Switch, Lamp Switch, Speed Button, Flywheel, Tension screw, Bobbin Case, Throat Plate, Power supply Casing, Foot Pedal Casing.	Polyethylene (PE)	0.097	1	0.097	7.9	10.4	Polymer molding	0.097	2.1	17.5
Power Switch, Speed Button, Flywheel, Tension Screw, Thread Spindle, Thread Take-up Lever, Bobbin Casing, Needle clamp and Screw, Pressure Foot, Feed Dog, Motor, Vertical Gear Shaft, Hook Gear Assembly, Power Supply Case, Foot Pedal Casing.	Medium carbon steel	0.16	1	0.16	4.4	5.7	Rough rolling	0.16	0.54	4.4
Battery Compartment, Motor Support, Hook Gear Assembly, Main Cover Half (L), Main Cover Half (R).	Acrylonitrile butadiene styrene (ABS)	0.39	1	0.39	37	49.4	Polymer molding	0.39	8.1	66.9
Power switch, Speed Button, Motor, Wires, Foot Pedal Contact.	Copper	0.022	1	0.022	1.3	1.7	Wire drawing	0.022	0.33	2.7
Wires.	Polyvinylchloride (tpPVC)	0.015	1	0.015	0.87	1.2	Polymer extrusion	0.015	0.089	0.7
Needle.	High carbon steel	0.00025	1	0.00025	0.0067	0.0	Wire drawing	0.00025	0.006	0.0
Screws.	Stainless steel	0.0005	1	0.0005	0.042	0.1	Wire drawing	0.0005	0.029	0.2
Plastic Packaging.	Polyethylene (PE)	0.001	1	0.001	0.081	0.1	Polymer molding	0.001	0.022	0.2
Foam Cushioning.	Polystyrene (PS)	0.025	1	0.025	2.4	3.2	Polymer molding	0.025	0.47	3.9
Power Switch, Lamp Switch, Flywheel, Motor Gear, Vertical Gear Shaft Gears, Hook Gear Assembly Gears.	Polyoxymethylene (Acetal, POM)	0.019	1	0.019	1.7	2.2	Polymer molding	0.019	0.33	2.7
Throat plate.	Polypropylene (PP)	0.004	1	0.004	0.32	0.4	Polymer molding	0.004	0.086	0.7
Motor.	Fan	0.042	1	0.042	10	13.7	-	-	-	-
Power Supply Transformers.	Transformer	0.024	1	0.024	2.1	2.7	-	-	-	-
Cardboard Packaging.	Paper and cardboard	0.13	1	0.13	6.4	8.5	-	-	-	-
User Manual.	Paper and cardboard	0.01	1	0.01	0.51	0.7	-	-	-	-
Total			15	0.94	76	100			12	100

6.5 Appendix E

Table 1: Crude tear down data for sewing machine components

Part	Number of parts	Material	Total Weight (g)
Battery cover	1	ABS	15
Light switch	1	N/A	1
Main on/off switch	1	Polyurethane, Steel, Acetal and copper	N/A
Needle	1	Stainless steel	3
Needle pole	1	Stainless steel	12
Needle clamp	1	Stainless steel	10
Needle clamp screw	1	Stainless steel	2
Speed switch	1	Polyurethane, Acetal and Copper	6
Throat plate	1	Polypropolene	4
Main cover (left side)	1	ABS	185
Main cover (right side)	1	ABS	185
Flywheel	1	Polyurethane, Steel and Acetal	37
Bobin winder	1	Steel	5
Stitch selector spring	1	Steel	5
Stitch selector	1	Polyurethane	2
Thread cutter	1	Polyurethane and Steel	0.5
Motor + Support	1	Steel, copper, ABS and Acetal	42
Spool pin	1	Polyurethane and Steel	7
Wire casing	1	PVC	N/A
Vertical gear shaft	1	Steel	9
Vertical gear	1	Acetal	3
Power and control in (including wiring)	1	Steel, Copper and PVC	5
Take up leaver	1	Steel	7
Bobbin case	1	Polyurethane and ABS	33
Hook assembly	1	Steel, Acetal and ABS	48
Feed Dog	1	Steel	17
Feed spring	1	Steel	15
Screws	11	Steel	5.5

Table 2: Crude tear down data for foot peddle components

Part	Number of parts	Material	Total Weight (g)
Pedal	1	Polyurethane	12
Case bottom	1	Polyurethane	13
Screws	3	Steel	1.5
Spring	1	Steel	2
Contacts	2	Copper	1
Foam Feet	4	VLD	1
Wiring	1	PVC and Copper	17

Table 3: Crude tear down data fir power supply components

Part	Number of parts	Material	Total Weight (g)
Case Front	1	Polyurethane	7
3 Pins	1	Steel	19
Wiring with male head	1	Steel, Copper and PVC	22
Case back	1	Polyurethane	13
Internals	1	N/A	24

Table 4: Crude tear down data for packaging

Part	**Number of parts**	**Material**	**Total Weight (g)**
Box	1	Card	124
Plastic bags	3	LDPE	1
Literature	2	Paper	10
Packing	2	Polystyrene	28