Toast Modern

The Art of Toast

DFMSD 49-730 Fall 2018

Design for Manufacture & Sustainable Design

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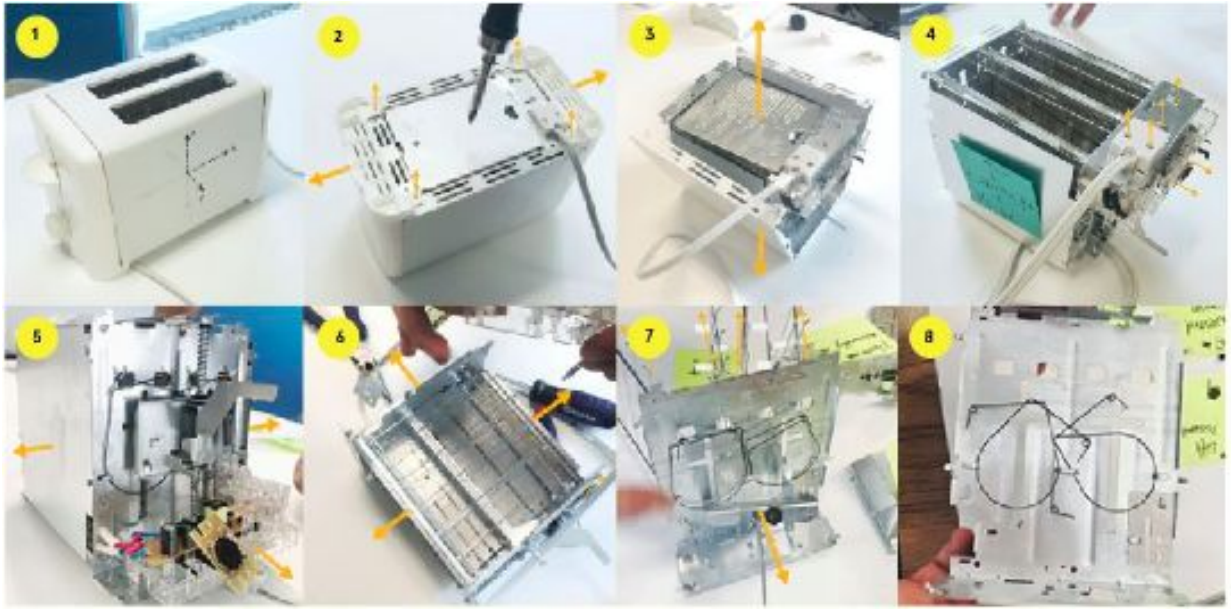
Introduction

To analyze and optimize the sustainability of our toaster product, we took apart a basic design to understand the fine nuances of every small part inside it.

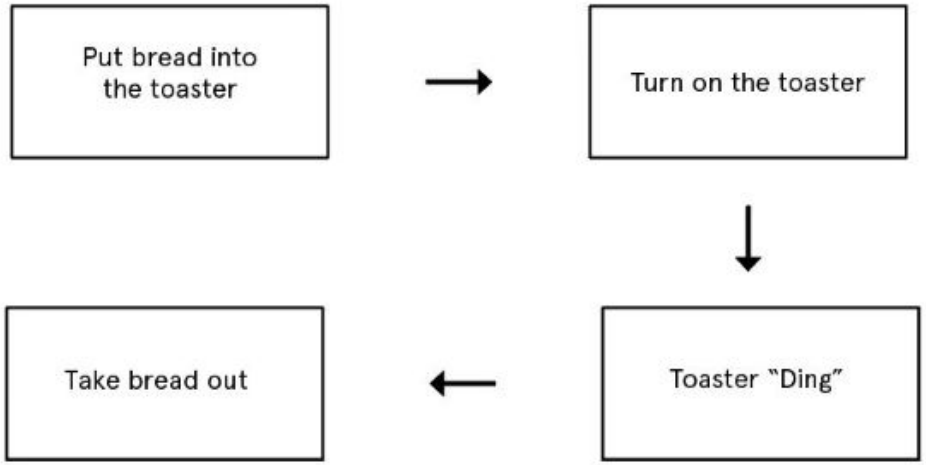
- **Handling, manipulation, manufacturing** and **inventory**
- **Cost** of materials and manufacturing processes
- Too many parts causing **complexity**
- Simplified by eliminating or combining parts
- Compared material and manufacturing alternatives
- LCA assessment: **Sustainability** as fundamental criteria
- Proposed toaster design: 6 parts, 5 steps of assembly, -118 ecopoints

Product Decomposition & Documentation

Sequence Flowpath



Functional Requirements Decomposition



FR 1 Put bread into the toaster	FR2 Turn on the toaster	FR3 Toaster ready	FR4 Take bread out
The key point in this requitement is that the toaster can hold toasters, probably with various sizes	For here, a knob is a necessary part to turn toaster on	Inner system and grilles need to heat the breat evenly and properly	Easy to take out bread without burning fingers

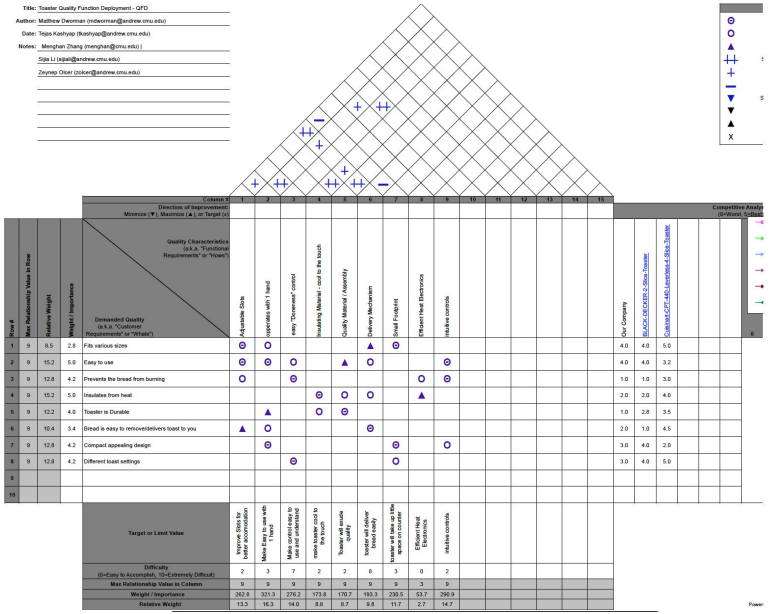
What We Learned from QFD

Focus on high importance rating FRs:

- Slots to fit different size of breads
- Can operate with one hand
- Intuitive controls

Design opportunities from competitive analysis:

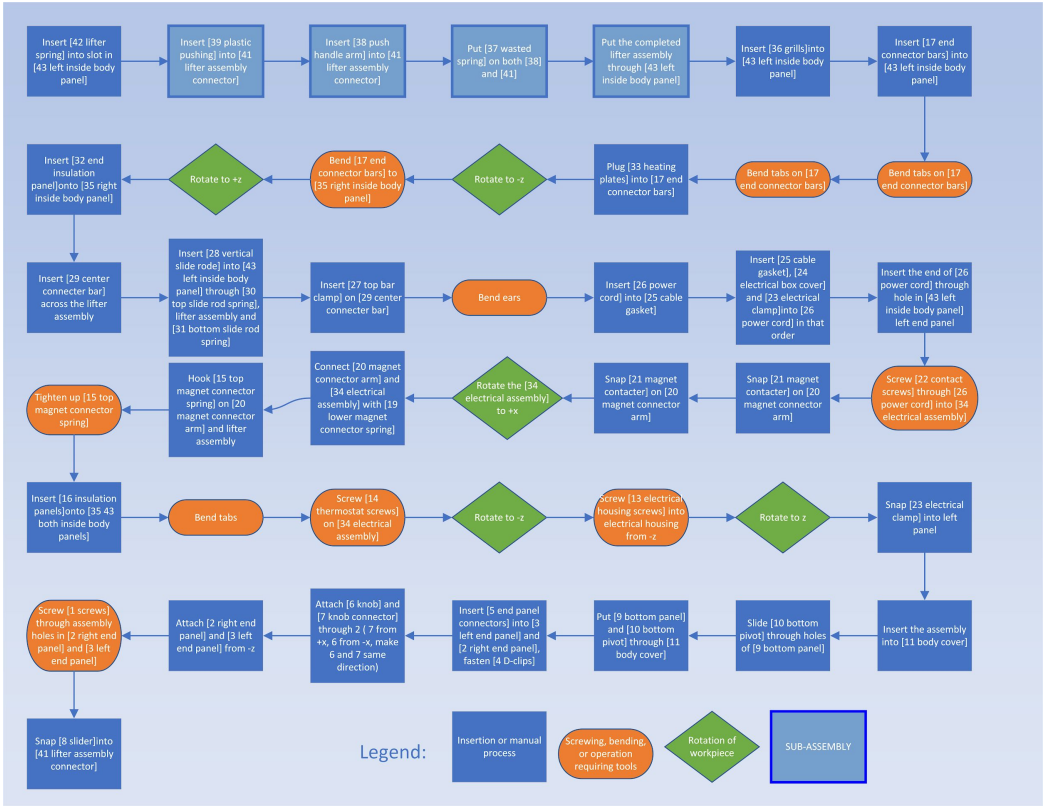
- A **delivery mechanism** to deliver the toasted bread without touching the hot bread.
- Balance simplicity and usability by making the structure of the toaster more **compact** and **simple** while providing **easy** and **intuitive** controls.



DFM Analysis

- **41 ASSEMBLY STEPS**

- **24** Insertion or manual processes
- **10** Screwing, bending, or operation requiring tools related processes
- **5** Rotation of workpiece processes
- **4** Sub-assembly processes



Current Materials and Processes

- Over 50 parts
  - CFE: 53 parts
  - Part Count Efficiency: 24.3%
- 6 Materials
- 6 Assembly axes
- 41 Assembly Steps
- Impossible to recycle
- MFG Cost: $3.47

Part I.D. Number	Type of material	Number of Parts	Cost of material/kg. (see chart in lectures)	Weight of part (g.)	Cost of part (mtl. only) (4) x (5)	Mfg. process	Cost to produce one part (see processing parameters)	Operation Cost ($) (6)+ (8)	Total Cost (3)x(9)
1	steel	4	$ 0.90	0.5	$0.001	screw production	$ 0.003	$0.00	$ 0.02
2	polypropylene	1	$ 1.17	52	$0.061	plastic injection molding	$ 0.039	$0.10	$ 0.10
3	polypropylene	1	$ 1.17	53	$0.063	plastic injection molding	$ 0.039	$0.10	$ 0.10
4	steel	4	$ 0.80	0.25	$0.001	metal stamping	$ 0.003	$0.00	$ 0.02
5	Nylon	4	$ 4.00	1	$0.004	plastic injection molding	$ 0.013	$0.02	$ 0.07
6	polypropylene	1	$ 1.17	4	$0.005	plastic injection molding	$ 0.016	$0.02	$ 0.02
7	hdpe	1	$ 0.90	2	$0.002	plastic injection molding	$ 0.016	$0.02	$ 0.02
8	hdpe	1	$ 0.90	4	$0.004	plastic injection molding	$ 0.016	$0.02	$ 0.02
9	aluminum	1	$ 3.00	42	$0.126	Metal Stamping	$ 0.067	$0.19	$ 0.19
10	steel	1	$ 0.80	1	$0.001	wire	$ 0.111	$0.11	$ 0.11
11	steel	1	$ 0.80	245	$0.196	Metal Stamping	$ 0.067	$0.26	$ 0.26
12	steel	2	$ 0.80	51	$0.041	Metal Stamping	$ 0.067	$0.11	$ 0.22
13	steel	6	$ 0.80	4	$0.004	Metal Stamping	$ 0.067	$0.07	$ 0.42
14	steel	1	$ 0.80	0.25	$0.001	metal stamping	$ 0.067	$0.07	$ 0.07
15	Steel	1	$ 0.80	12	$0.010	pressed metal	$ 0.067	$0.08	$ 0.08
16	Steel	1	$ 0.80	5	$0.004	metal stamping	$ 0.067	$0.07	$ 0.07
17	wire	1	$ 0.80	0.25	$0.001	wire	$ 0.111	$0.11	$ 0.11
18	wire	1	$ 0.80	0.25	$0.001	wire	$ 0.111	$0.11	$ 0.11
19	Steel	1	$ 0.80	28	$0.023	metal stamping	$ 0.067	$0.09	$ 0.09
20	steel	1	$ 0.80	49	$0.040	metal stamp	$ 0.067	$0.11	$ 0.11
21	steel	4	$ 0.80	14.5	$0.012	grating welding	$ 0.111	$0.12	$ 0.49
22	steel	1	$ 0.80	0.25	$0.001	wire	$ 0.111	$0.11	$ 0.11
23	steel	1	$ 0.80	18	$0.015	metal stamp	$ 0.067	$0.08	$ 0.08
24	hdpe	1	$ 0.90	0.25	$0.001	injection molding	$ 0.016	$0.02	$ 0.02
25	steel	2	$ 0.80	5	$0.004	metal stamp	$ 0.067	$0.07	$ 0.14
26	steel	1	$ 0.80	22	$0.018	metal stamp	$ 0.067	$0.08	$ 0.08
27	steel	2	$ 0.80	0.25	$0.001	wire	$ 0.111	$0.11	$ 0.22
28	steel	1	$ 0.80	57	$0.046	metal stamp	$ 0.067	$0.11	$ 0.11
		48						Mfg. Cost	$ 3.47

Current Material and Process

When examining the current toaster, we disassembled the product into 48 separate parts, excluding the heating and electrical elements. We needed to rotate the axis of the toaster's placement 3 times while disassembling (used 4 axis in total).

Handling and manipulation of the parts were very difficult, using 6 different axes and requiring all group members' help in some steps. We calculated Assembly Efficiency as 24.29%, which signals high potential of improvement . The overall inefficiency of the current design led to complexity in inventory, assembly, manufacturing and service, as well as high cost of assembly.

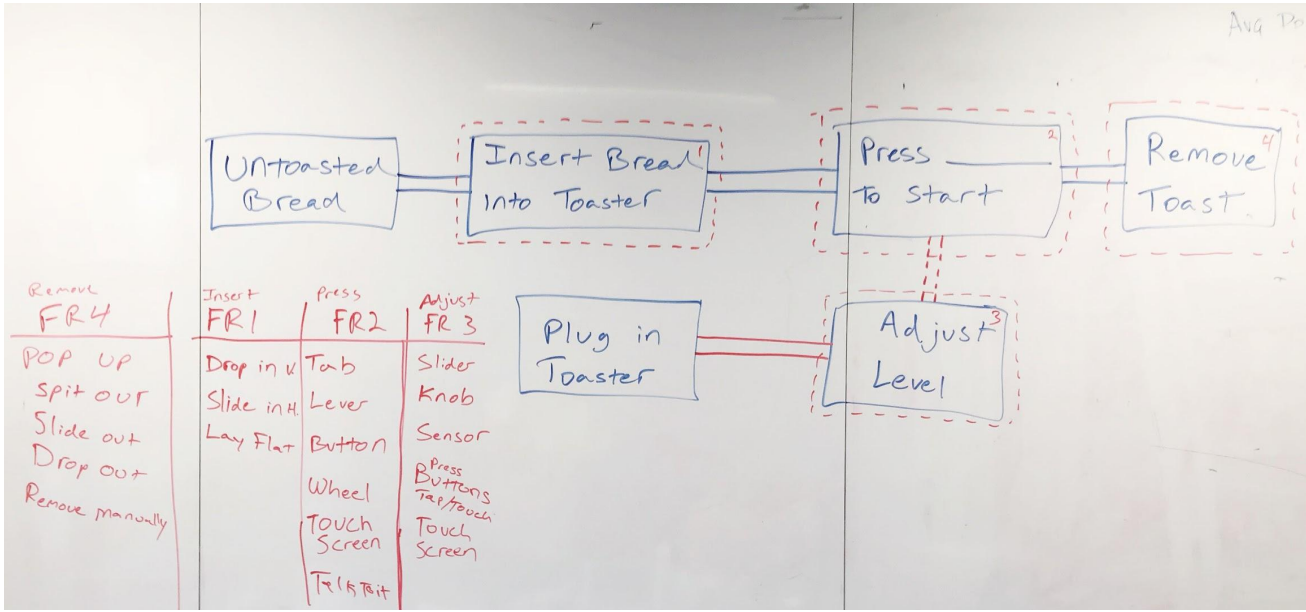
The current design also required a lot of post-processes, which made the manufacturing very costly and complex.

We identified … number of parts as Candidates of Elimination and discussed alternative part solutions, materials and manufacturing processes to simplify our design for a more sustainable consumer product.

Solutions Options

Critical Fundamental Requirements:

- Insert Bread into toaster
- Start the toaster
- Adjust level
- Remove toast



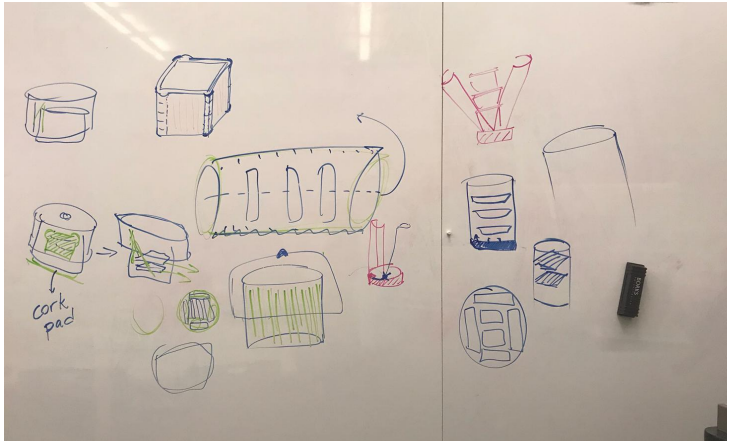
Solutions Options

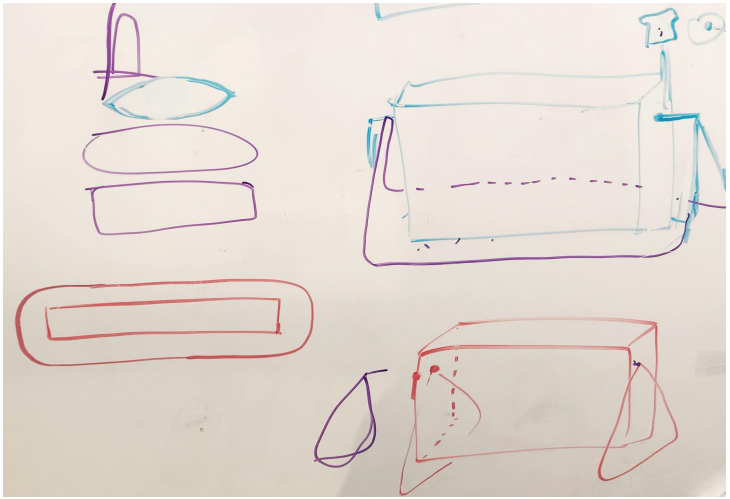
Potential Material:

- Ceramic
  - We gave up the ceramic idea for body material because of low cost-efficiency in production and recycling processes

Final Decision:

- Glass
  - We decided on glass since it looks aesthetically appealing and more eco-friendly





Design Ideations

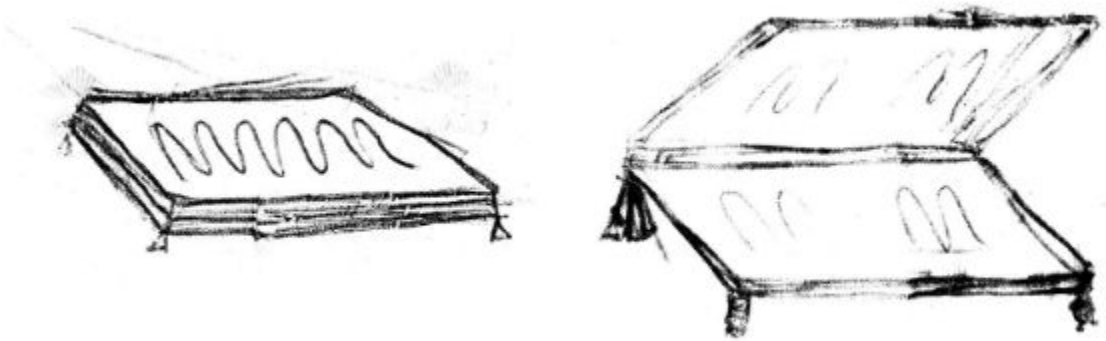
Subsolution combination 1: **Drop in + Button + Button + Slide out**

Compact, transparent delivery system; easy to clean

Design Ideations

Subsolution combination 2: **Lay flat + Button + Button + Remove by hand**

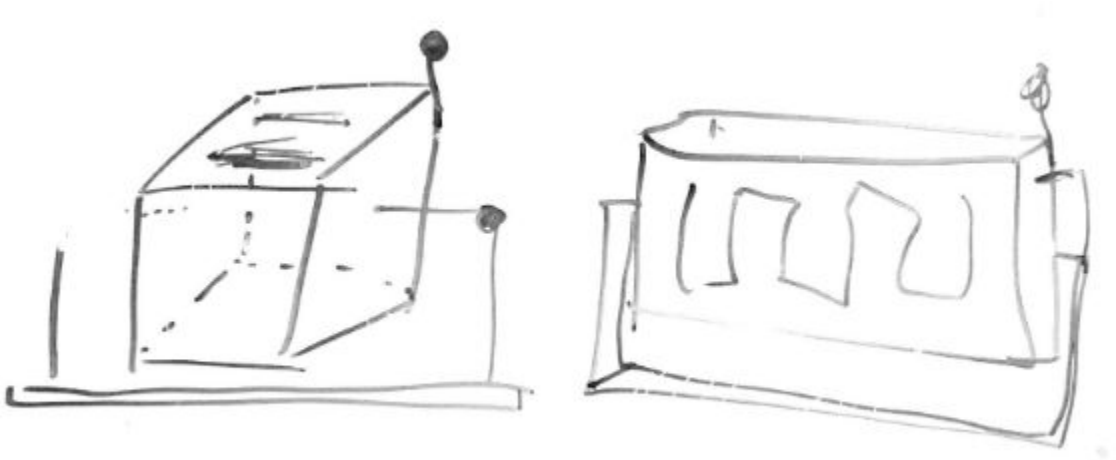
Intuitive, press toasting system; transparent to see toasting level



Design Ideations

Subsolution combination 3: **Slide in + Button + Knob + Slide out**

Secure (burnt-free) and easy delivery system; transparent to see toasting level



LCA

	Part Name	**Production** (materials, processing, transport and extra energy) material or process	weight (kg)	indicator	result
1	Body	Glass	1.005	58	58.29
2	Knob half	polypropylene	0.001	280	0.28
3	Knob half	polypropylene	0.001	280	0.28
4	Button	polypropylene	0.003	280	0.84
5	Stand1	Aluminum	0.227	60	13.62
6	Lever	Aluminum	0.091	60	5.46
7		**TOTAL**	1.328	1018	78.77
8					
9					

	Part Name	**Use** (transport, energy and any auxillary materials) **process** (or material if required)	**Distance** (km)	indicator	result (/2000)
			0	1.1	0
		Rail Transport (coming from Mexico to Pittsburgh - warehouse)	1000	3.9	1.95
		Truck 16t (delivery to Walmart)	64	34	1.088
1		**TOTAL**	1064	39	3.038
2					
3					

	Part Name	**Disposal** (disposal process per type of material) material and type of processing	weight (kg)	indicator	result
6					
7	Body	Recycling glass	1.005	-15	-15.075
8	Knob half	recycle pp	0.001	-210	-0.21
9	Knob half	recycle pp	0.001	-210	-0.21
	Button	recycle pp	0.003	-210	-0.63
	Stand1	recycling aluminum	0.164	-720	-118.08
	Lever	recycling Aluminum	0.091	-720	-65.52
		TOTAL	1.265	-2085	-199.725
		TOTAL (all phases)	**1.265**	**-1028**	**-117.917**

Current Design

	weight (kg)	indicator	result
TOTAL	0.4575	1353.00012	99.82948063

Revised Proposed Design

	weight (kg)	indicator	result
TOTAL	1.265	-1028	-117.917
Versus Current	277%	-232%	-185%

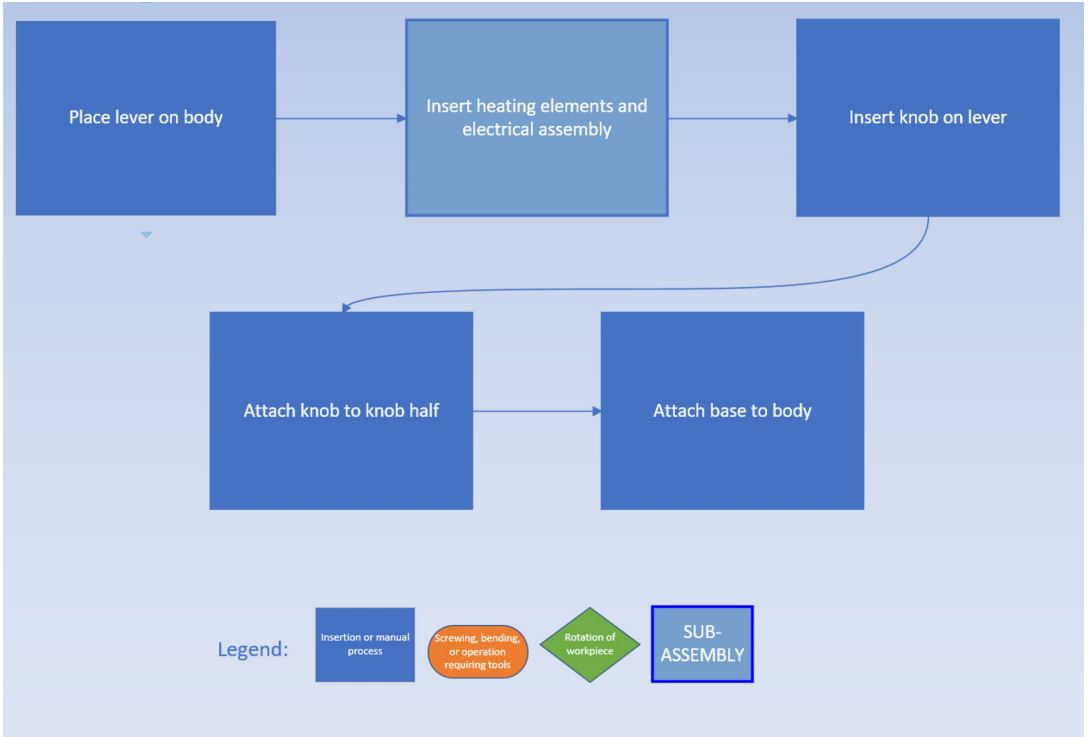
LCA

- In the LCA, **materials, processes, transportation** and **disposal** were optimized
- Polypropylene and steel **body** was replaced by a glass design
- Made **manufacturing easier**
- **Internal structure** had 7 steel pieces, made assembly complex
- Cut that down to 3 parts, the material changed to Aluminum
- **Manufacture in Mexico or U.S.** - reduced shipping costs
- **Recycling all components** - glass, steel and plastic instead of landfilling/incineration

New DFM Analysis w/ Assembly flow path

The new design has **5** assembly steps concerned in the manufacturing process of our current toaster, and most of them are unnecessary:

- **5** Insertion or manual process
- **0** Screwing, bending, or operation requiring tools related processes
- **0** Rotation of workpiece processes
- **1** Sub-assembly processes



Proposed Materials and Processes

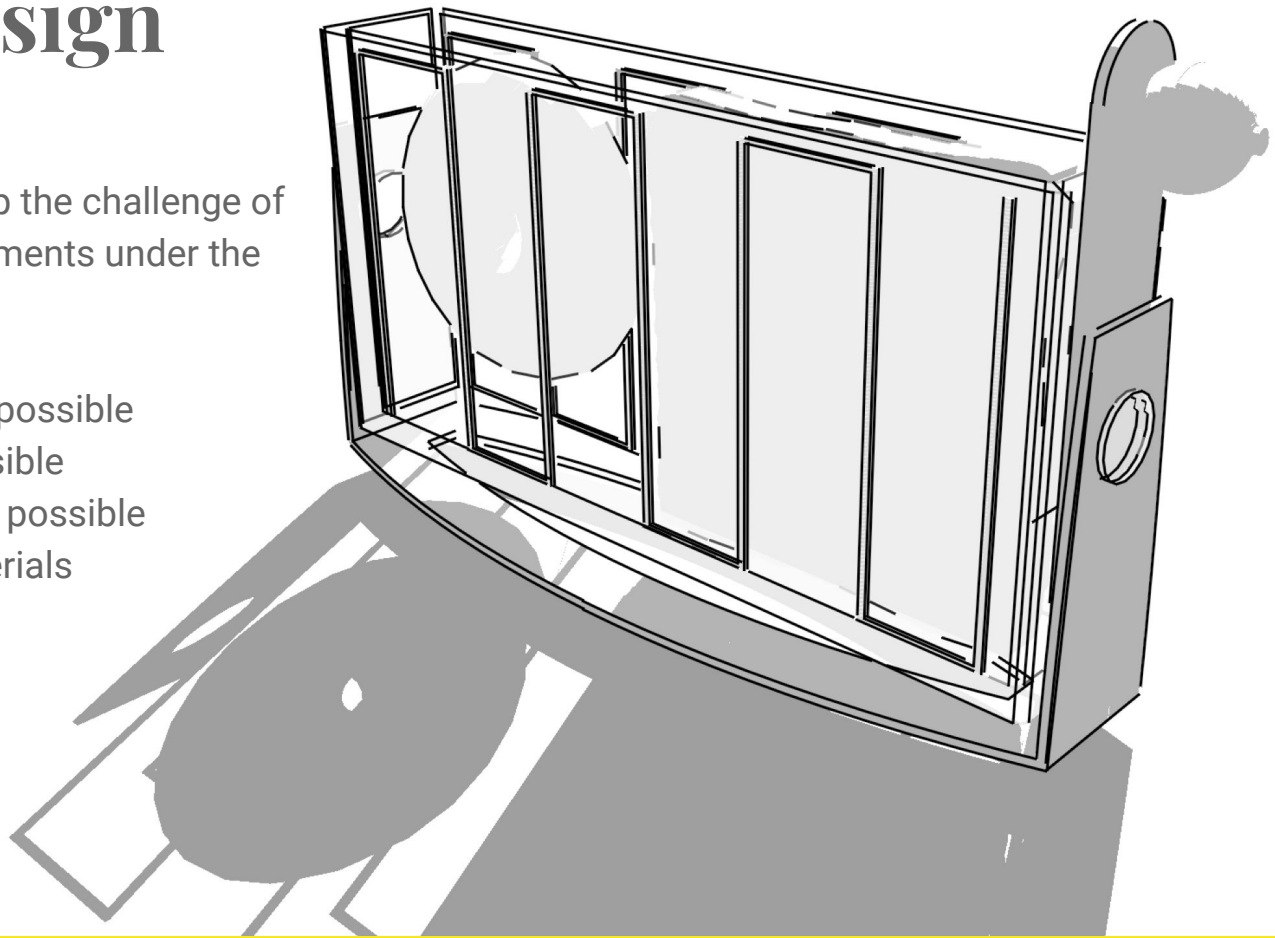
- **6** parts
- **1** Assembly axis
- **3** Materials
- **5** Assembly Steps
- Mfg. Cost $2.66
- **EASY** to recycle

1	2	3	4	5	6	7	8	9	10
Part I.D. Number	Type of material	Number of Parts	Cost of material/kg. (see chart in lectures)	Weight of part (g.)	Cost of part (mtl. only) (4) x (5)	Mfg. process	Cost to produce one part	Operation Cost ($) (6)+ (8)	Total Cost (3)x(9)
1	**Glass**	1	**$ 1.35**	1005	**$1.357**	**Glass Molding**	**$ 0.065**	**$1.42**	**$ 1.42**
2	**polypropylene**	1	**$ 1.17**	2	**$0.003**	**injection molding**	**$ 0.019**	**$0.02**	**$ 0.02**
3	**polypropylene**	1	**$ 1.17**	2	**$0.003**	**injection molding**	**$ 0.019**	**$0.02**	**$ 0.02**
4	**polypropylene**	1	**$ 1.17**	2	**$0.003**	**injection molding**	**$ 0.019**	**$0.02**	**$ 0.02**
5	**Aluminum**	1	**$ 3.00**	227	**$0.681**	**Metal stamping**	**$ 0.111**	**$0.79**	**$ 0.79**
6	**Aluminum**	1	**$ 3.00**	91	**$0.273**	**wire bending**	**$ 0.111**	**$0.38**	**$ 0.38**
								Mfg. Cost	**$ 2.66**

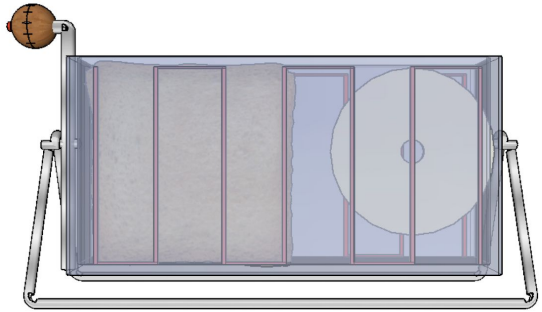
Proposed Design

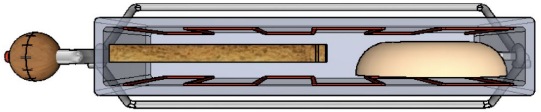
For our final design, we took up the challenge of meeting the functional requirements under the following constraints:

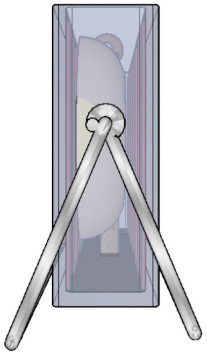
1. Use as few materials as possible
2. Use as few parts as possible
3. Use recycled materials if possible
4. Use only recyclable materials

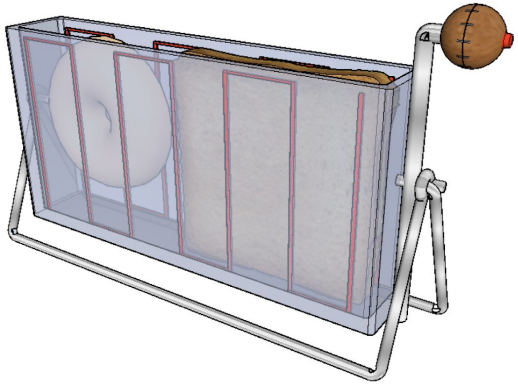


Proposed Design: 1st Iteration

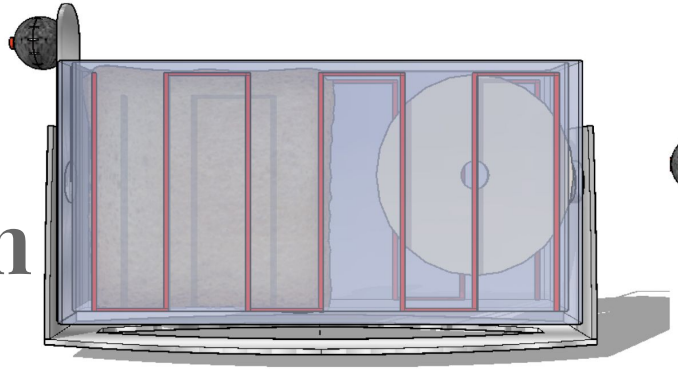


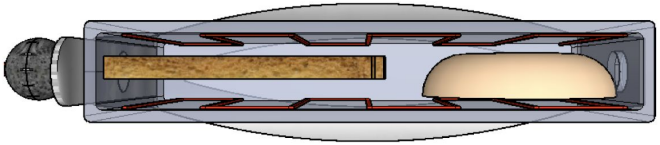






Proposed Design: 2nd Iteration





SIMPLE DESIGN

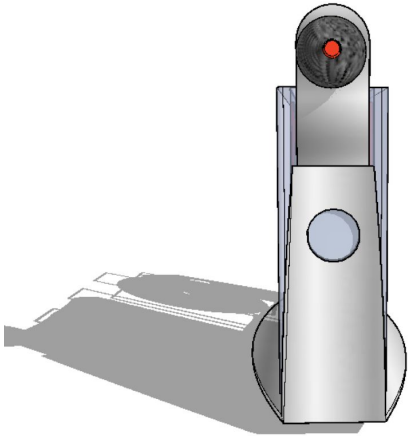
MEETS ALL FR'S

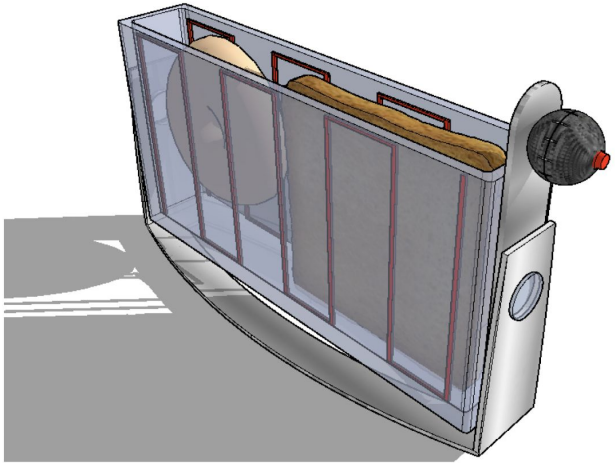
3 MATERIALS

6 PARTS

EASY TO ASSEMBLE

EASY TO RECYCLE





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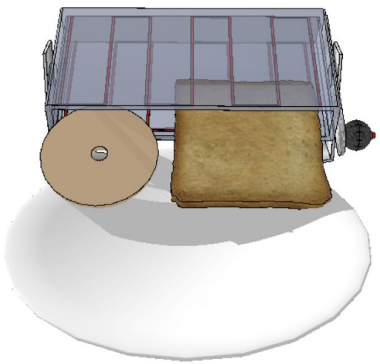
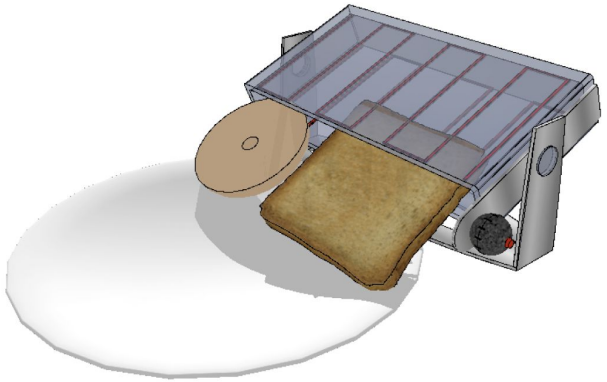
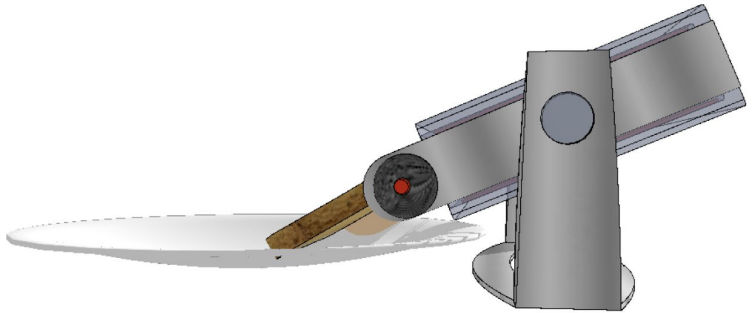
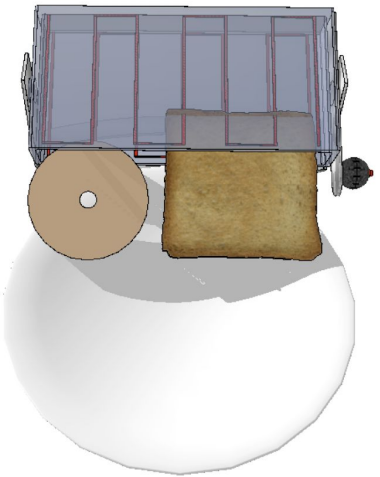
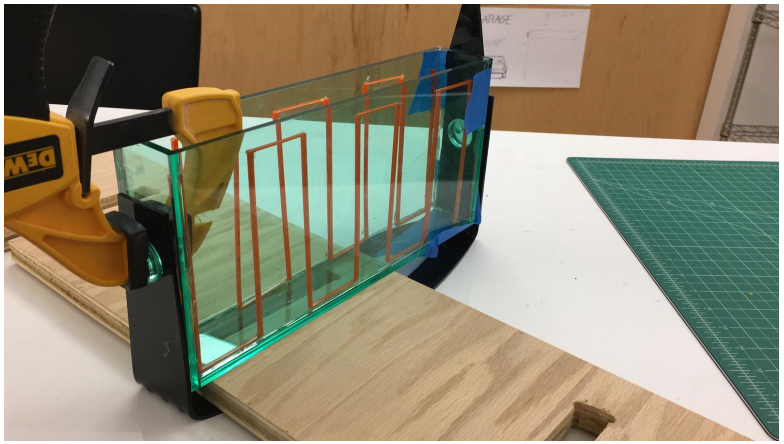




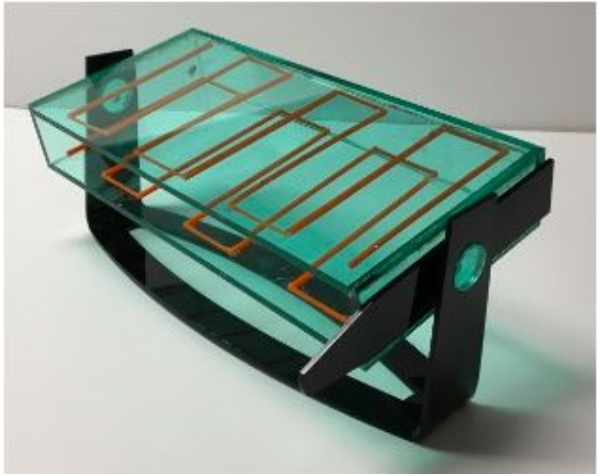




Prototyping



Final Product



Conclusion

- Taking the toaster apart - frustrating experience
- Huge scope of improvement
- QFD gave our work a structure
- LCA allowed quantifying sustainability
- Tremendous learning opportunity

References:

- Leonard, Annie, and Ariane Conrad. The Story of Stuff: How Our Obsession with Stuff Is Trashing the Planet, Our Communities, and Our Health--and a Vision for Change. Free Press, 2011.
- Stoll, Henry W. The Design for Everything Manual: a Guide to Good Design. HSC Books, 2012.
- Thompson, Rob. Manufacturing Processes for Design Professionals. Thames & Hudson, 2015.