Phase 3: Prototype

Problem Definition: Creating a more user friendly hands-free door opener

Presentation created by Team Nugget

Presented by:
Nate Saul, Luke Bame, Dingming Lu, Samuel Graham

Phase Progression Overview

Phase 1

Problem Statement:

- 12.7% of people in the U.S have some disability,
- Door handles are proven to be germ hotspots,
- Operating a door while carrying something in both hands is unwieldy and potentially dangerous

Potential Customer:

- Hospitals,
- warehouses,
- universities,
- handicapped people

Problem Definition: Creating a more user friendly hands-free door opener.

Phase 2

Item No.	Part No.	Part Name	Units	Qty	Material / Description	Source	Catalog No.	Unit Cost ($)	Unit Processing Cost ($)	Assembly Cost ($)	Line Total Cost ($)	List Price ($)
0100	0101	Pressure plate	m*m	1	Aluminum Alloy / Where people will step on	Custom	N/A	0.82	0	0.1	0.92	3.28
Pressure plate triggering and force transformation	0102	Spring	N/m, pcs	2	stainless spring steels / reset the pressure plate and close the door	The Spring Stor	PC060-296-350	0.46	0	0.1	1.02	1.84
	0103	Fluid Bag	in^2	1	Rubber / Shoots the fluid out due to the force of the pressure plate	Custom	N/A	7.26	1.5	0.1	8.86	29.02
	0104	Long tube	ft	1	Rubber / transfer fluid to top	Lowe's	Item #814315	1.89	0	0.1	1.99	7.55
	0105	Hydraulic Fluid	Liters	4.68	mineral-based fluids / transfer the force	Grainger	DTE 24	2.81	0	0.1	13.24	11.23
0200	0201	Main casing	m*m*m	1	stainless steels / hold the components	Custom	N/A	1.68	5	0.1	6.78	6.71
Door openinging	0202	Main casing screws	pcs	4	stainless steels / connect to the door	Grainger	G2584	0.01	0	0.1	0.13	0.03
	0203	Piston pack - arm	pcs	1	stainless steels / push the gear rack	Custom	N/A	0.15	3	0.1	3.25	0.60
	0204	Piston pack - cylinder	pcs	1	stainless steels / hold the arm and the fluid	Custom	N/A	0.79	3	0.1	3.89	3.17
	0205	Piston pack - seal ring	mm	1	Rubber / seal the fluid	Shadow Trailer	#DBC-225-SE	1.00	0	0.1	1.10	3.99
	0206	Piston pack - screws	pcs	3	stainless steels / secure the cylinder to casing and gear rack	Grainger	G2584	0.01	0	0.1	0.12	0.03
	0207	Piston pack - nut	pcs	3	stainless steels / secure the screws	Grainger	447J35	0.80	0	0.1	2.51	3.22
	0208	Gear rack	mm	1	stainless steels / transfer linear motion	McMaster-Carr	2485N242	5.39	0	0.1	5.49	21.54
	0209	Large gear	pcs	1	stainless steels / transfer linear motion to rotational motion	McMaster-Carr	5172T16	10.73	0	0.1	10.83	42.92
	0210	Main shaft	mm	1	stainless steels / transfer the force from gear to arms	Custom	N/A	0.11	2	0.1	2.21	0.45
	0211	Rotational Pushing Arm	pcs	2	stainless steels / rotate and push the door open	Custom	N/A	0.14	2	0.1	2.39	0.57
	0212	Connecting pin	mm	2	stainless steels / connect the arms together and to the door frame mount c	Custom	N/A	0.01	2	0.1	2.12	0.03
	0213	Door frame mount case	pcs	1	stainless steels / allows the arm connect to the door and rotate	Custom	N/A	0.71	5	0.1	5.81	2.82
	0214	Door frame mount Screw	pcs	4	stainless steels / secure the case	Grainger	G2584	0.01	0	0.1	0.13	0.03
0300	0301	Small gear	pcs	1	stainless steels / drive the slowing device	McMaster-Carr	5172T12	6.72	0	0.1	6.82	26.88
Door Closing	0302	Fluid tank	pcs	1	stainless steels / hold the liquid	Custom	N/A	5.12	5	0.1	10.22	20.48
	0303	Shaft	mm, pcs	1	stainless steels / drive the drag fin bars	Custom	N/A	0.11	2	0.1	2.21	0.45
	0304	Drag fins	pcs	4	stainless steels / create drag in fluid	Custom	N/A	0.04	2	0.1	2.27	0.17
	0305	Fin bars	pcs	4	stainless steels / hold the fins together and prevent opening to large	Custom	N/A	0.95	4	0.1	7.88	3.78
	0306	Long screws	pcs	2	stainless steels / adjust the height of the tank	Grainger	6JA46	0.07	0	0.1	0.23	0.26
	0307	Nut	pcs	2	stainless steels / hold the screws	Grainger	22UK82	0.00	0	0.1	0.11	0.02
	0308	Spring	N/m, pcs	2	stainless spring steels / secure the tank on the long screws	The Spring Stor	PC060-296-350	0.30	0	0.1	0.70	1.20
	0309	Drag Fluid	Liters	4.68	mineral-based fluids / source of drag	Grainger	DTE 24	2.85	0	0.1	13.45	11.41
0400	0401	Final Assembly	-	1	Final assembly of all parts	-	-	-	-	5.00	5.00	
Assmeblies	0402	Pressure plate assy	-	1	Assembly of the step plate	-	-	-	-	3.00	3.00	
	0403	Door opening assy	-	1	Assembly of door opening mechanism	-	-	-	-	3.50	3.50	
	0404	Door closing assy	-	1	Assembly of dor closing mechanism	-	-	-	-	3.50	3.50	

Concept Generation:

- **Came up with many ideas**
- Had to find which one suited requirements/ specifications
- Learned what was important/not important
- Takeaway that **not everything can be met**

Bill of Material:

- Finalized **product list**
- First look at overall cost
- Over what we though cost would be
- Can visualize how every part will come together to form final product

Financial Analysis:

- Found out **we were profitable**
- May **need to lower cost** a little
- Break even pretty quickly into the process
- Units needed to sell

Phase 3

CAD:

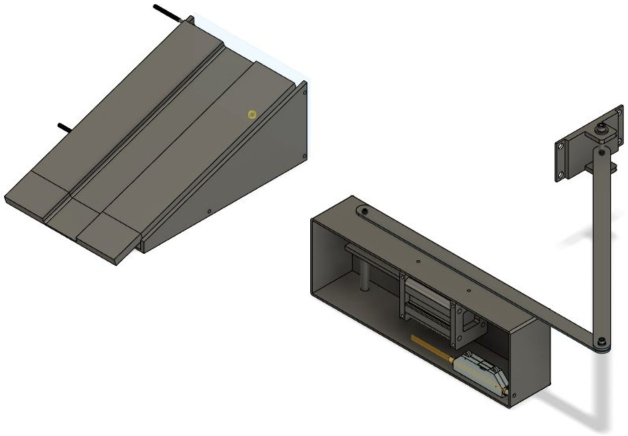
- First look at **final design**
- Learned **product was not perfect**
- Takeaway was step needed to compress down

Engineering Modeling:

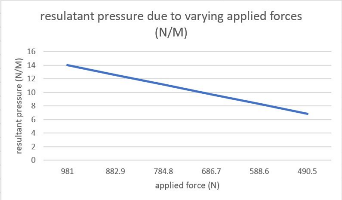
- Found forces needed and gear radius needed
- Learned may need to make force required less

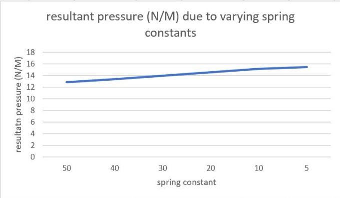
Prototype:

- Springs need less stiffness
- Fluid Bag



	A	B	C	D	E	F	G	H	I	J
1	varrying applied forces	varrying k values (using 100 lb input)								
2	13.99982484	12.83207801					k value:	50	applied force:	981
3	12.56787528	13.41595142		plate weight:	98.1	(N)		40		882.9
4	11.13592573	13.99982484		plate surface area:	68.508	(in^2)		30		784.8
5	9.703976178	14.58369825		max compression:	4	(in)		20		686.7
6	8.272026625	15.16757167		plate length:	10.38	(in)		10		588.6
7	6.840077071	15.45950838		plate width:	6.6	(in)		5		490.5





Design Presentation

Problem Definition

Specified our product idea:

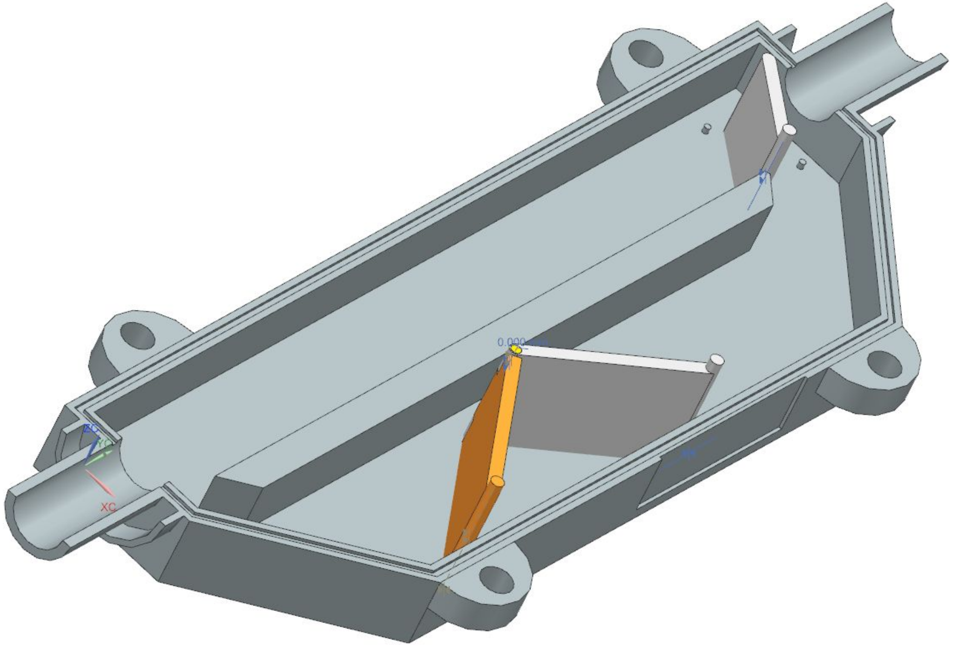
"Product" —> "Foot Operated Hydraulic Unit"

- "Hands-free" limits to operation with either torso, head, legs or feet and having our product be foot operated was most convenient for consumers
- Having the product incorporate hydraulics means that it functions similar to current door closers and remains purely mechanical.

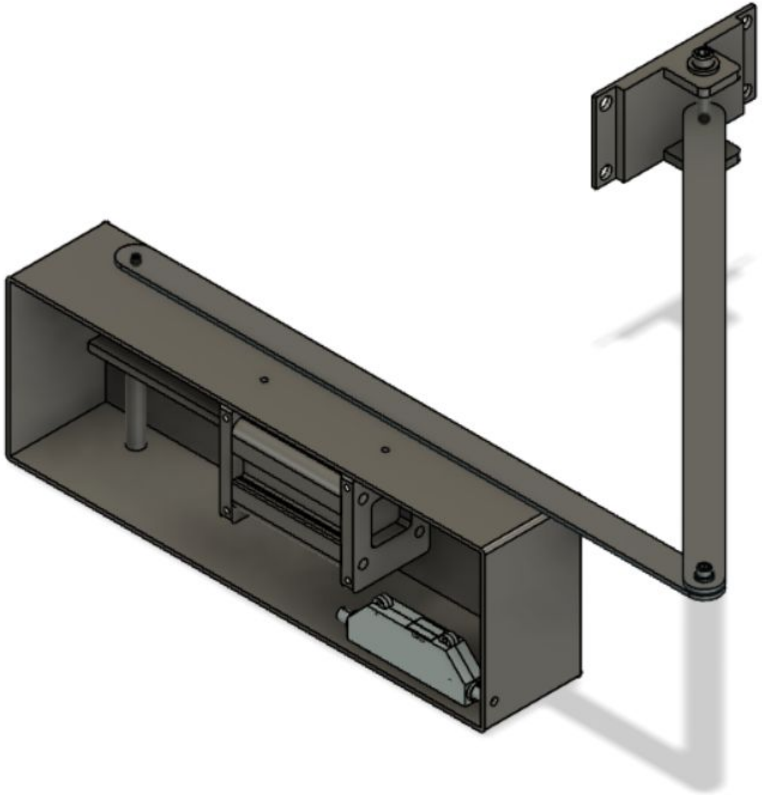
Design Description

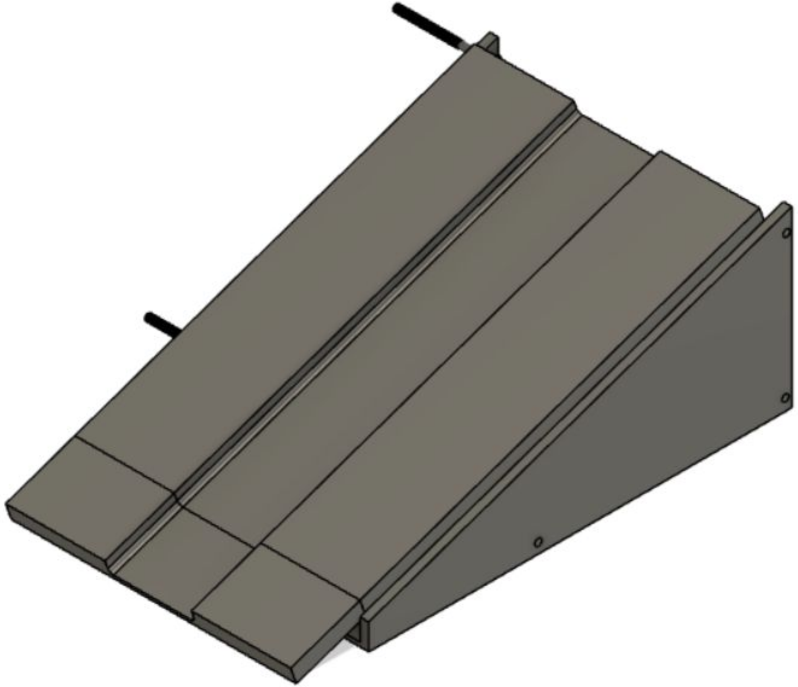
- Can’t use hands, then use feet
- Need a trigger **designed for feet**, so we have a **pressure plate**
- Need **something** to open the door **at the top** so it doesn’t block the way
- So we need a way to transform the force. We chose **hydraulic system**
- Force transformation is **linear**, but opening the door is **rotational**, so we have **“Bob”**
- We also need a way to **slow down** the door only when it’s closing, so we have **OWD**

3D Models



3D Models

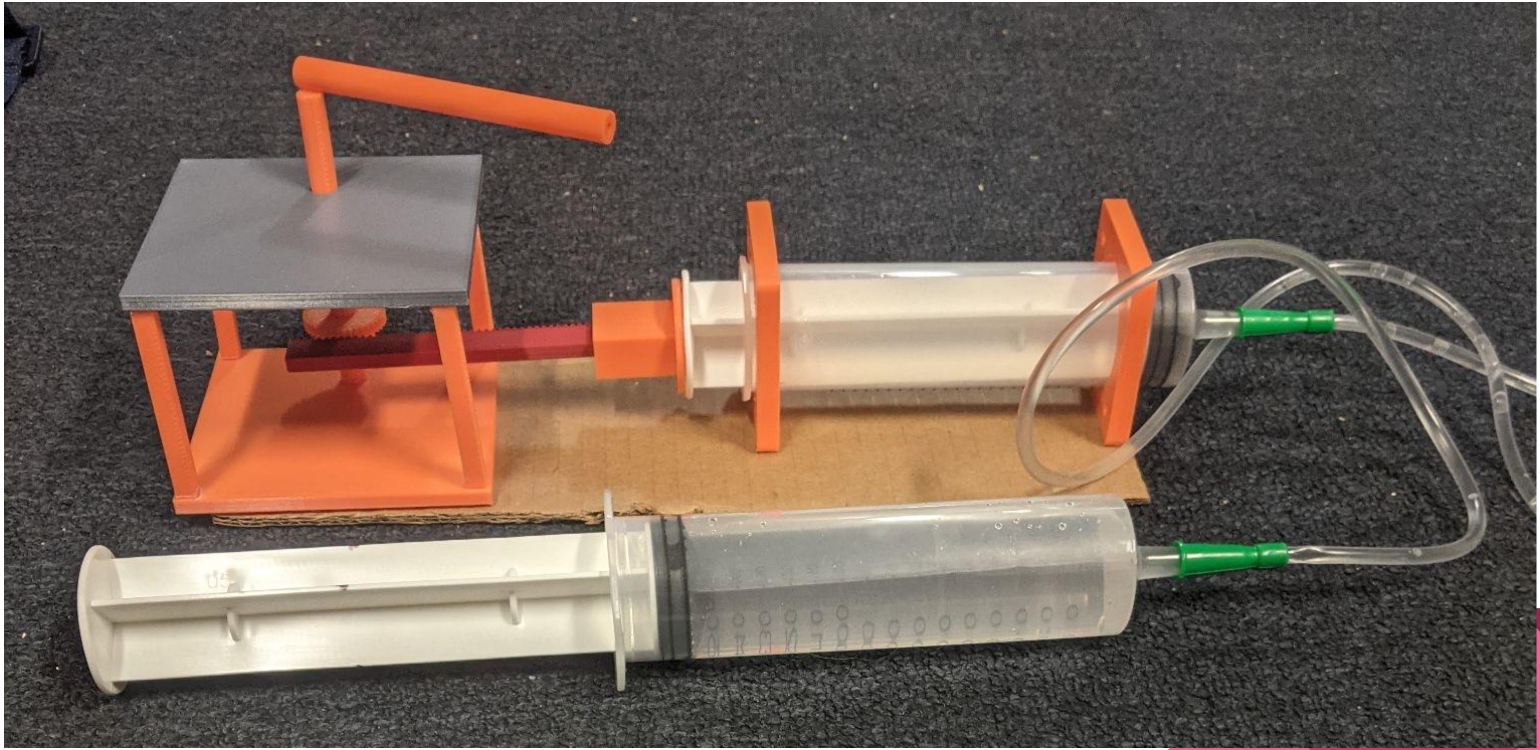




Prototype

Pressure Plate

“Bob” - Force Transformation



OWD - One-Way Drag

Engineering Analysis Overview

Pressure Plate

- This model was designed with the primary intent of **testing the effects of varying applied forces** and **spring constants** on the output pressure shift of the hydraulic fluid.

- The purpose of this component of the product is to **translate a downward force** due to a users weight **into pressure within the hydraulic system**, with the springs acting to reduce this pressure potential

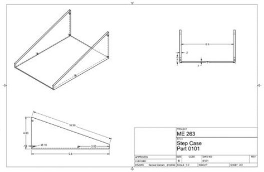
- Through model analysis calculations, we were able to establish and visualize the **linear relationships** between **output pressure**, **applied force**, and **spring constants**

Noise factors:

Fluid bag pressure variability, applied force variability, hangle angle discrepancies

Inputs:

-Applied force from user



Outputs:

-hydraulic pressure

Control factors:

-Spring constant (k)

-Dimensions of step case (length, width, height)

-Weight of plate

	A	B	C	D	E	F	G	H	I	J
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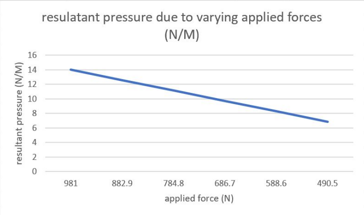
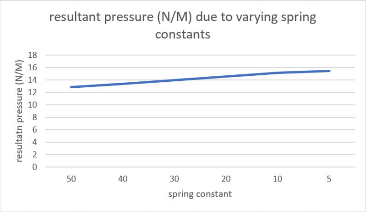
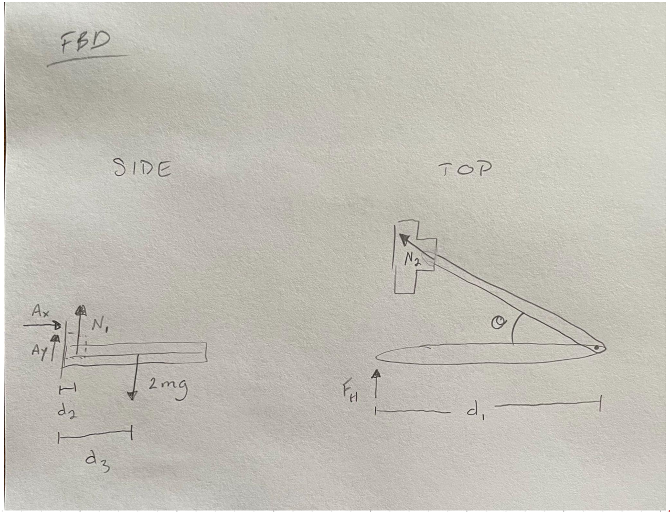




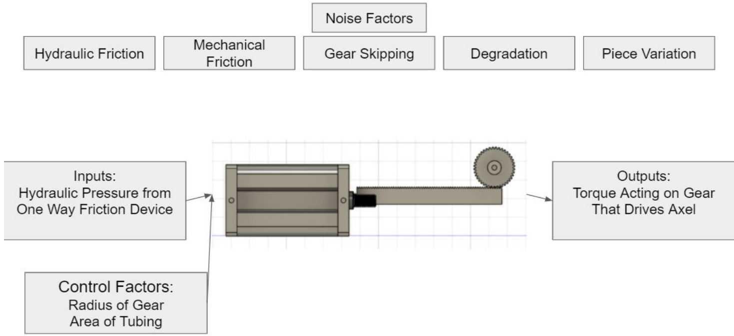
“Bob” - Force Transformation

Purpose: develop model of arm closing/opening device and analyze force/velocity

- In the model, it shows how the **max velocity is at the beginning and end of the door opening process**, which will affect how a person can go through the door.
- **The middle is the slowest part** of the door opening process, which allows the user to hurry through the door before it closes again.
- find a way to lower this in order to allow for easier access for children or any smaller adults

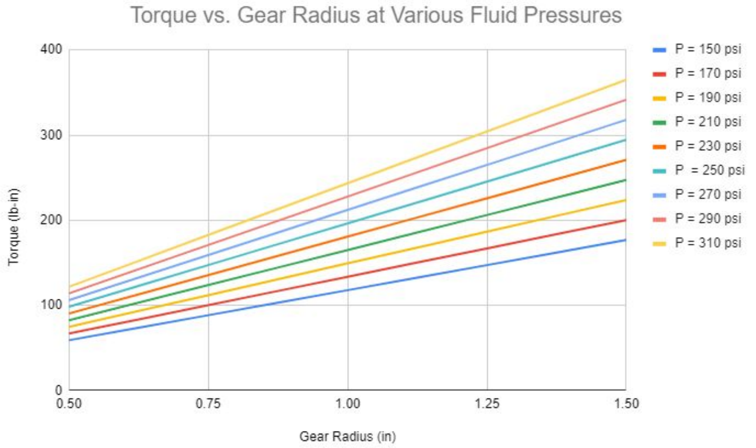


“Bob” - Force Transformation cont.



Purpose: develop a model of the **hydraulic cylinder and the torque generated** depending on fluid pressure and gear radius

- The device is meant to **intake fluid at a pressure and output torque**.
- To achieve this and acquire estimates of torque values, a **range of pressures** were selected along with a **range of gear radii**.
- The resulting plot gives us an idea of how much torque will be outputted by the system and can be used to get future estimates given different conditions. Using this model along with other models, **designs can be adjusted to find the optimal output pressure and gear size** in order to open doors most effectively.



OWD - One-Way Drag

*Sketch not to scale

Purpose: **slowing down the door only when it's closing.**

$$w_2 = w - 2t_1 - t_2 - w_1$$

$$b = \sqrt{l^2 - a^2}$$

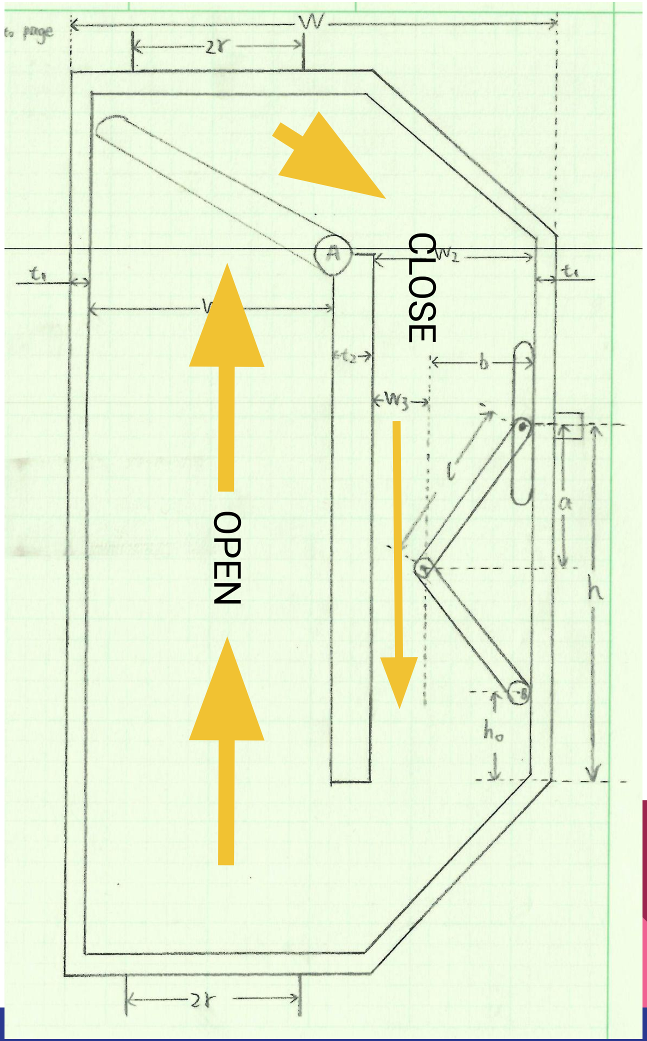
$$a = \frac{h - h_0}{2}$$

$$w_3 = w_2 - b$$

$$w_3 = w - 2t_1 - t_2 - w_1 - \sqrt{l^2 - (\frac{h-h_0}{2})^2}$$

$$A = dw_3$$

$$A = d(w - 2t_1 - t_2 - w_1 - \sqrt{l^2 - (\frac{h-h_0}{2})^2})$$



OWD - One-Way Drag

Final Equation

$$t_{close}(h) = \frac{V}{\dot{V}} = \frac{V}{Av} = \frac{V}{vd(w - 2t_1 - t_2 - w_1 - \sqrt{l^2 - (\frac{h-h_0}{2})^2})} \quad (4)$$

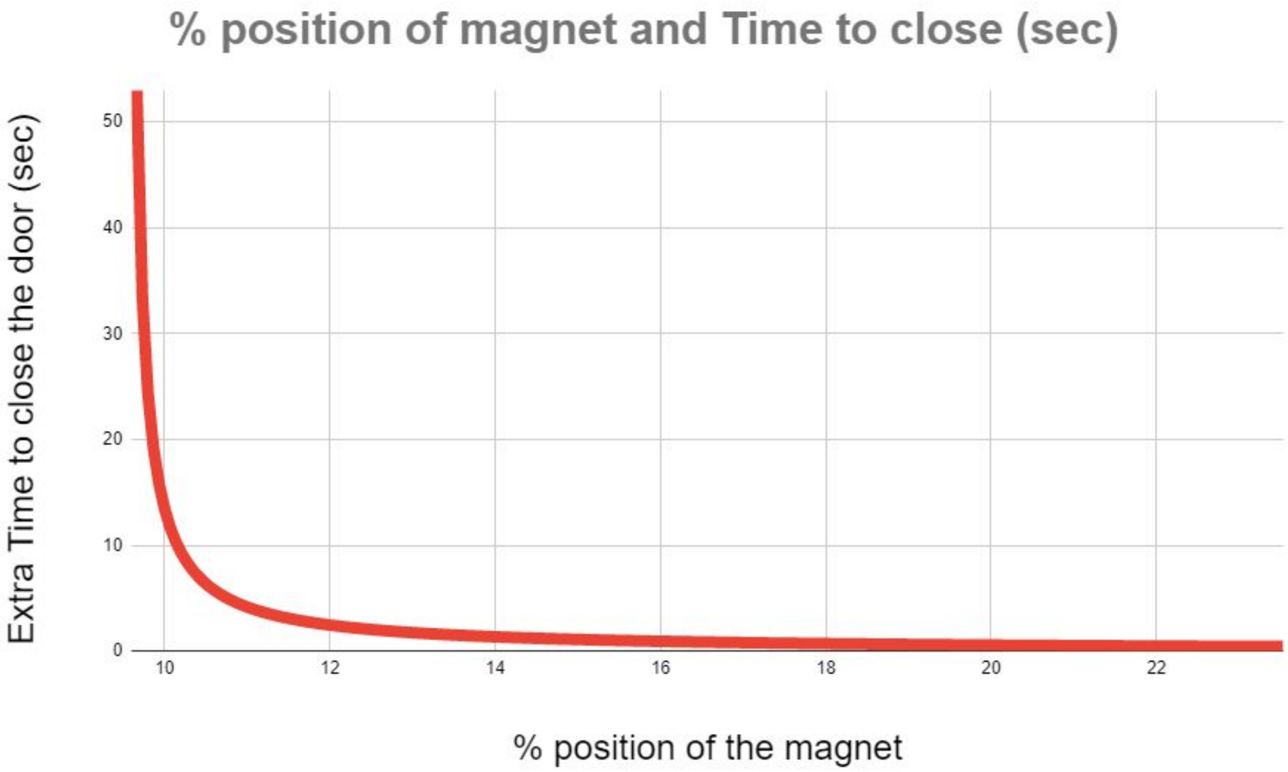
$$0 < t_{close} < \frac{V}{2\pi r^2 v}$$

Limit of time

57.8 mm < h <71.3 mm

Limit position of magnet

OWD - One-Way Drag Model Results Graph



Design Conclusions

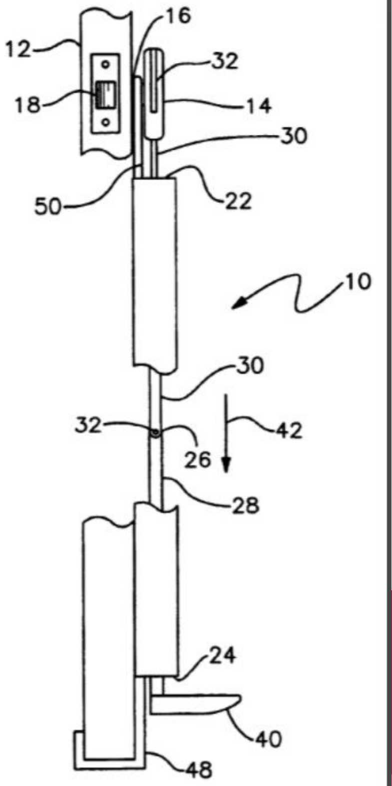
Engineering Specifications

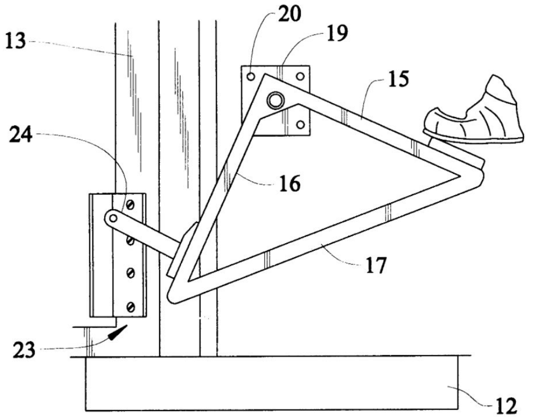
HOUSE OF QUALITY	How (ES)								
	Force of operation	Strength of material	Longevity	Unit Cost	Size of Unit	Use of Standardized Parts	Sound Produced	Time to open door	Number of Pinching Parts
	Newton	ksi	years	$	in^3	#	Decibles(dB)	Seconds	#
What (Customer Requirements)	↓	↑	↑	↓	↓	↓	↓	↓	↓
Effort to open the door	9	1	1	0	0	0	0	3	0
Ease of operating the door	9	0	3	0	1	0	1	3	0
Time required to operate door	0	0	0	3	0	0	0	9	0
Space filled by unit	0	1	0	1	9	3	0	0	1
Ease of installation	0	0	3	3	3	9	0	0	1
Low Cost	3	3	3	9	1	1	0	0	0
Durability	1	9	9	3	0	1	3	0	0
Aesthetically pleasing	0	1	0	3	1	1	9	0	1
Ease of repair	1	1	3	1	1	9	0	0	0
Safe to operate	3	9	0	0	1	0	0	3	9
Retro-Compatibility	0	0	1	1	3	3	0	0	0
Quiet	1	1	0	3	0	0	9	1	1
Purely Mechanical	0	0	1	3	3	3	1	1	1
Customizability of door operation time	0	1	0	1	1	9	0	9	0
Total	27	27	24	31	24	39	23	29	14

Customer Requirements

Effort to open the door (low)	4	- Not Tested
Ease of operating the door (easy)	5	- Met
Time required to operate door (short)	3	
Space filled by unit (small)	2	
Ease of installation (easy)	3	
Low Cost (low)	4	-Not met, unit cost is high
Durability (durable)	5	-Not tested, met in theory due to quality and material of parts
Aesthetically pleasing (good)	1	
Ease of repair (easy)	2	
Safe to operate (safe)	4	-Met
Retro-Compatibility (compatable)	2	
Quiet (true)	1	
Purely Mechanical (true)	1	
Customizability of door operation time	1	

Benchmark Comparisons



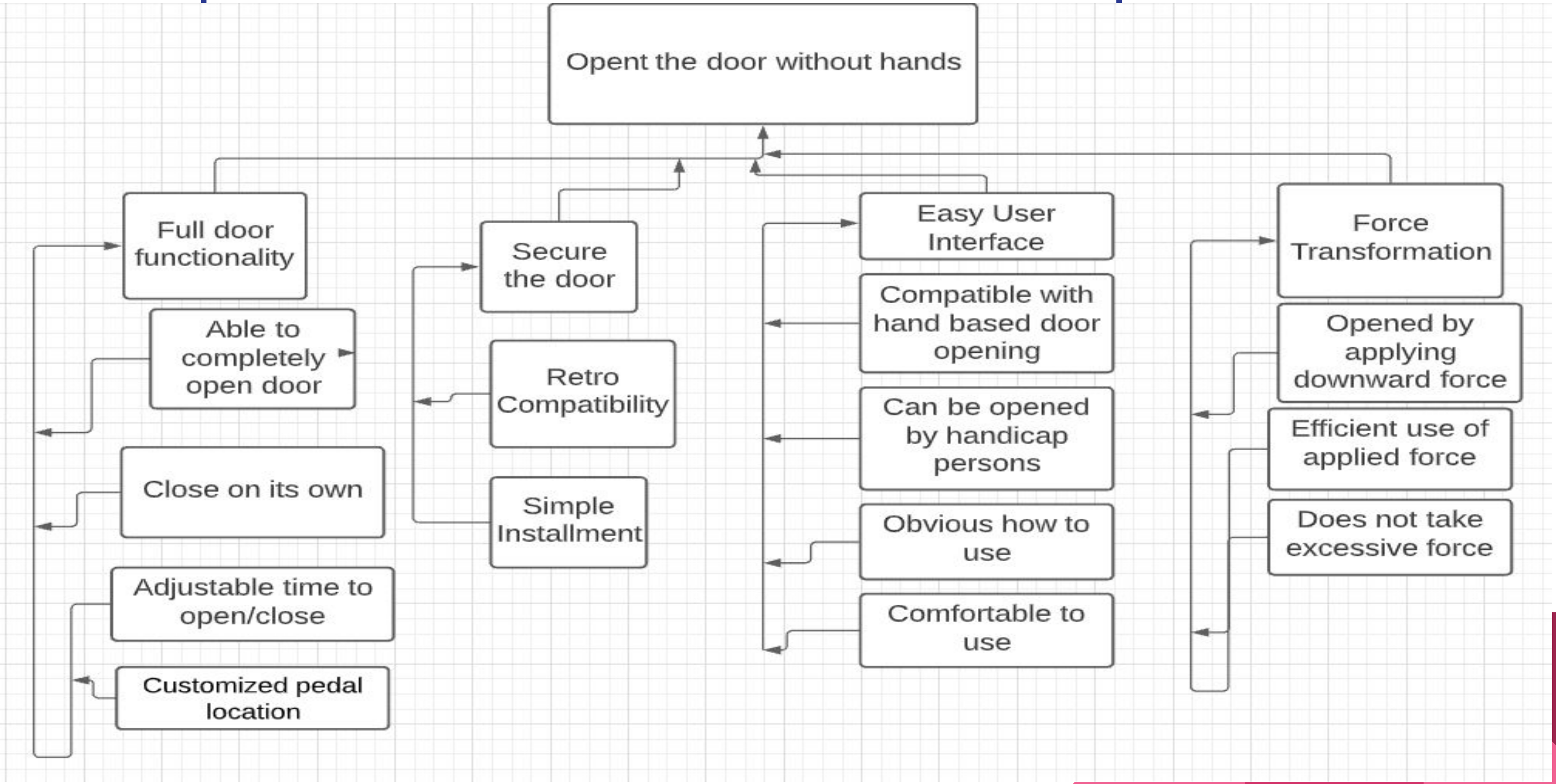


Future Improvement

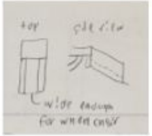
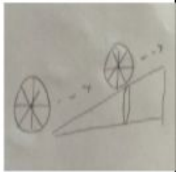
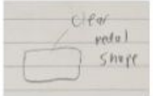
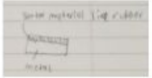
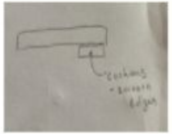
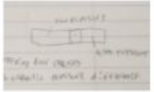
- Create an **easier step force** and allow **for smaller users**
- Add **wheelchair accessible component** for final design
- Try to use some **cheaper components** to reduce overall cost of product
- Work on **overall ease of use** and try to reduce that

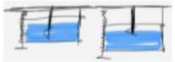
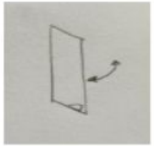
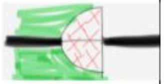
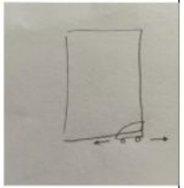
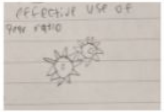
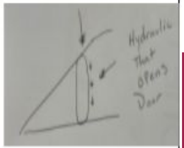
Questions?

Concept Generation - Functional Decomposition



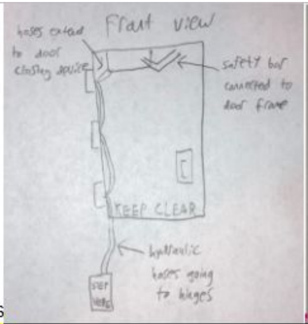
Concept Generation Overview

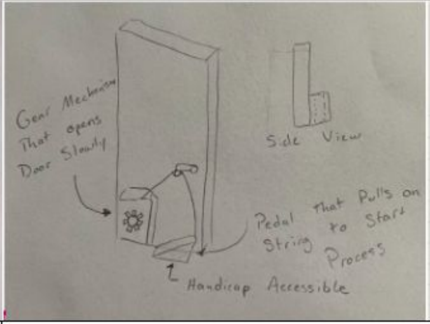
Can be opened by handicapped persons				
Obvious how to use				
Comfortable to use				
Closes on its own after opening				

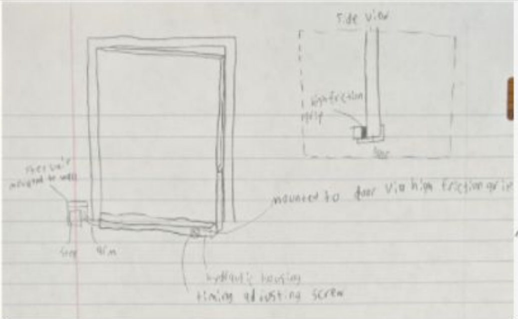
Adjustable time to open/close				
Customized pedal location				
Opened by applying downward force				
Efficient use of applied force				

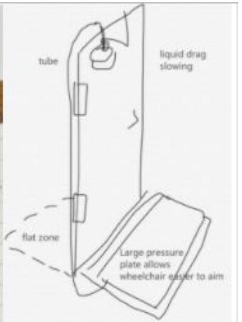
Concept Selection

3









1.(House of Quality)

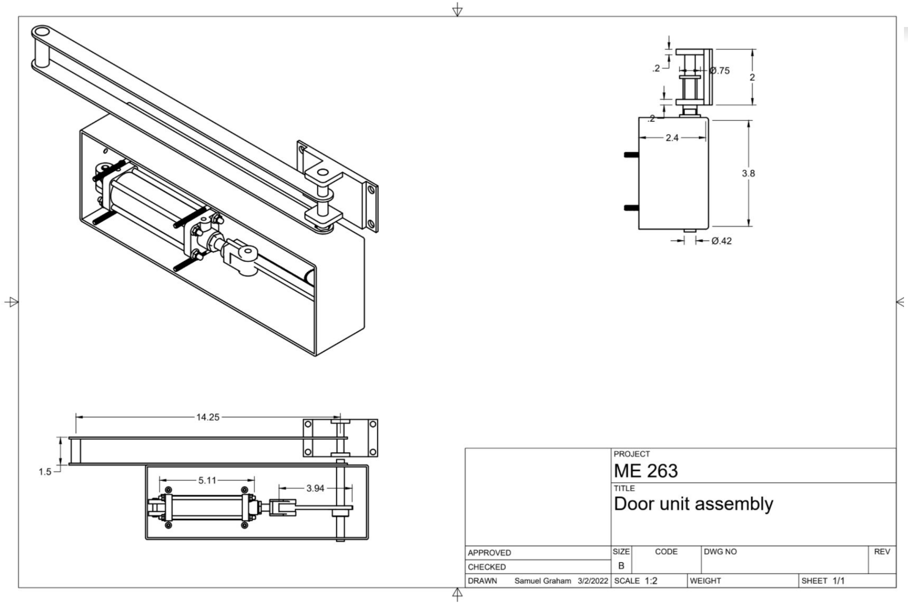
2

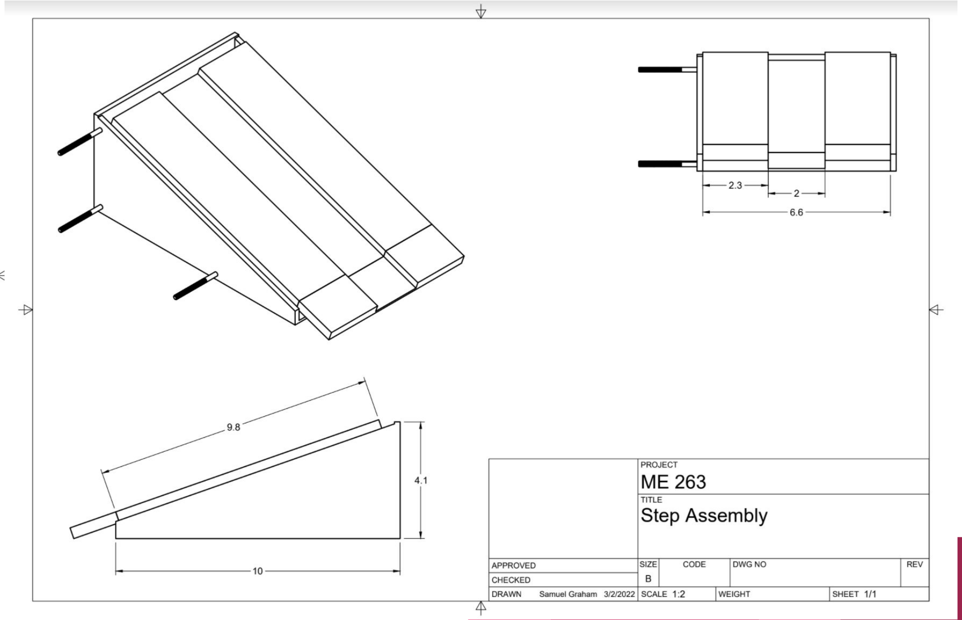
4

5

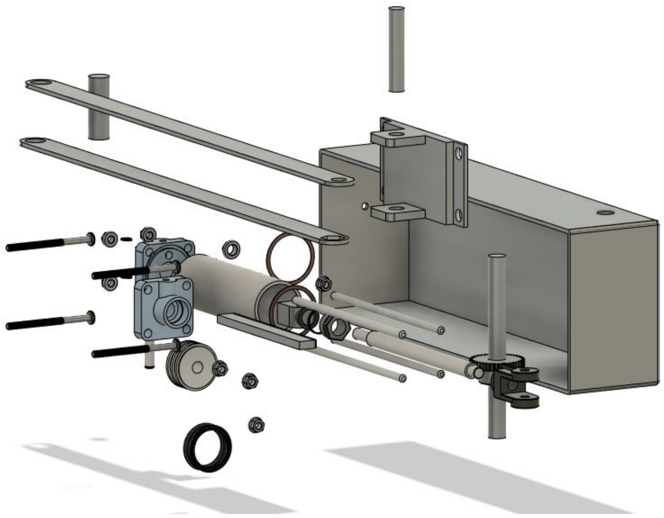
Customer Requirements	Weights				
Effort to open the door (low)	4	1	1	1	1
Ease of operating the door (easy)	5	1	1	1	1
Time required to operate door (short)	3	0	-1	1	0
Space filled by unit (small)	2	1	-1	0	-1
Ease of installation (easy)	3	0	0	0	0
Low Cost (low)	4	0	-1	-1	-1
Durability (durable)	5	0	0	0	1
Aesthetically pleasing (good)	1	0	-1	0	1
Ease of repair (easy)	2	0	-1	-1	0
Safe to operate (safe)	4	1	1	1	1
Retro-Compatibility (compatable)	2	1	1	1	1
Quiet (true)	1	1	-1	1	1
Purely Mechanical (true)	1	1	1	1	1
Customizability of door operation time	1	1	1	0	1
Total +		8	6	7	9
Total -		0	-6	-2	-2
Overall Total		8	0	5	7
Weighted Total		**20**	**4**	**14**	**18**
		GOOD	BAD	NOT SO BAD	NOT SO GOOD

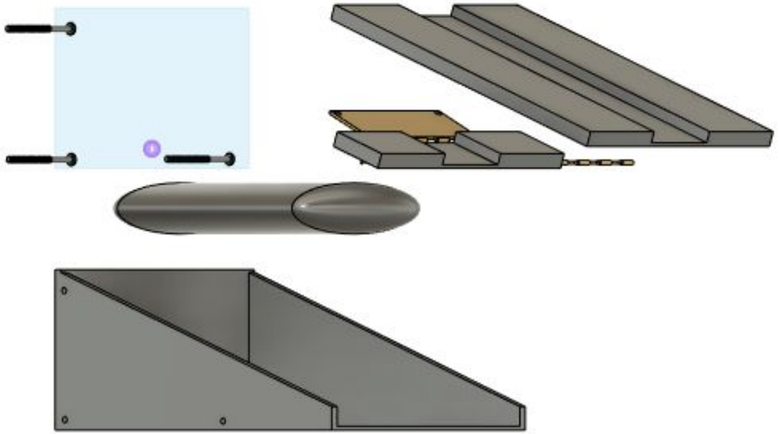
Description of Final Product and Prototype (Cont.)



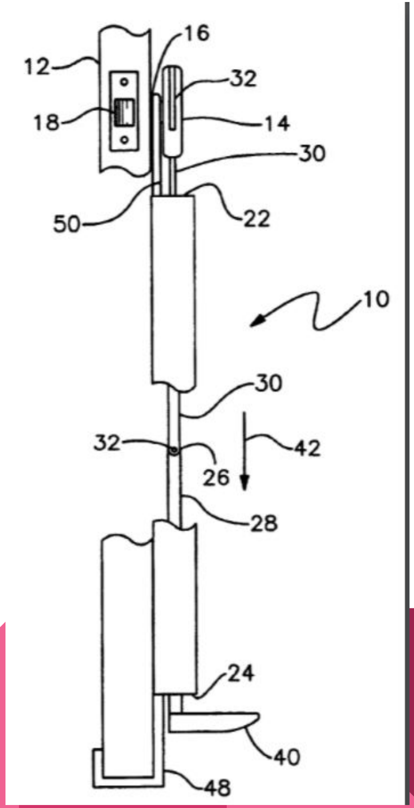


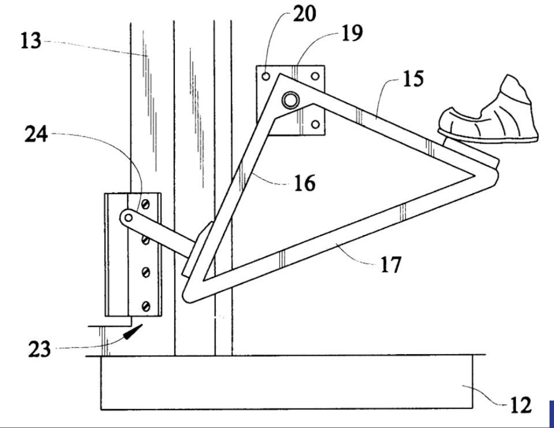
Description of Final Product and Prototype (Cont.)





Comparison to Relevant Benchmarks and Patents





Bill of Materials

Item No.	Part No.	Part Name	Units	Qty	Material / Description	Source	Catalog No.	Unit Cost ($)	Unit Processing Cost ($)	Assembly Cost ($)	Line Total Cost ($)	List Price ($)
0100	0101	Pressure plate	m*m	1	Aluminum Alloy / Where people will step on	Custom	N/A	0.82	0	0.1	0.92	3.28
Pressure plate	0102	Spring	N/m, pcs	2	stainless spring steels / reset the pressure plate and close the door	The Spring Stor	PC060-296-350	0.46	0	0.1	1.02	1.84
triggering and	0103	Fluid Bag	in^2	1	Rubber / Shoots the fluid out due to the force of the pressure plate	Custom	N/A	7.26	1.5	0.1	8.86	29.02
force	0104	Long tube	ft	1	Rubber / transfer fluid to top	Lowe's	Item #814315	1.89	0	0.1	1.99	7.55
transformation	0105	Hydraulic Fluid	Liters	4.68	mineral-based fluids / transfer the force	Grainger	DTE 24	2.81	0	0.1	13.24	11.23
0200	0201	Main casing	m*m*m	1	stainless steels / hold the components	Custom	N/A	1.68	5	0.1	6.78	6.71
Door	0202	Main casing screws	pcs	4	stainless steels / connect to the door	Grainger	G2584	0.01	0	0.1	0.13	0.03
openinging	0203	Piston pack - arm	pcs	1	stainless steels / push the gear rack	Custom	N/A	0.15	3	0.1	3.25	0.60
	0204	Piston pack - cylinder	pcs	1	stainless steels / hold the arm and the fluid	Custom	N/A	0.79	3	0.1	3.89	3.17
	0205	Piston pack - seal ring	mm	1	Rubber / seal the fluid	Shadow Trailer	#DBC-225-SE/	1.00	0	0.1	1.10	3.99
	0206	Piston pack - screws	pcs	3	stainless steels / secure the cylinder to casing and gear rack	Grainger	G2584	0.01	0	0.1	0.12	0.03
	0207	Piston pack - nut	pcs	3	stainless steels / secure the screws	Grainger	447J35	0.80	0	0.1	2.51	3.22
	0208	Gear rack	mm	1	stainless steels / transfer linear motion	McMaster-Carr	2485N242	5.39	0	0.1	5.49	21.54
	0209	Large gear	pcs	1	stainless steels / transfer linear motion to rotational motion	McMaster-Carr	5172T16	10.73	0	0.1	10.83	42.92
	0210	Main shaft	mm	1	stainless steels / transfer the force from gear to arms	Custom	N/A	0.11	2	0.1	2.21	0.45
	0211	Rotational Pushing Arm	pcs	2	stainless steels / rotate and push the door open	Custom	N/A	0.14	2	0.1	2.39	0.57
	0212	Connecting pin	mm	2	stainless steels / connect the arms together and to the door frame mount c	Custom	N/A	0.01	2	0.1	2.12	0.03
	0213	Door frame mount case	pcs	1	stainless steels / allows the arm connect to the door and rotate	Custom	N/A	0.71	5	0.1	5.81	2.82
	0214	Door frame mount Screv	pcs	4	stainless steels / secure the case	Grainger	G2584	0.01	0	0.1	0.13	0.03
0300	0301	Small gear	pcs	1	stainless steels / drive the slowing device	McMaster-Carr	5172T12	6.72	0	0.1	6.82	26.88
Door Closing	0302	Fluid tank	pcs	1	stainless steels / hold the liquid	Custom	N/A	5.12	5	0.1	10.22	20.48
	0303	Shaft	mm, pcs	1	stainless steels / drive the drag fin bars	Custom	N/A	0.11	2	0.1	2.21	0.45
	0304	Drag fins	pcs	4	stainless steels / create drag in fluid	Custom	N/A	0.04	2	0.1	2.27	0.17
	0305	Fin bars	pcs	4	stainless steels / hold the fins together and prevent opening to large	Custom	N/A	0.95	4	0.1	7.88	3.78
	0306	Long screws	pcs	2	stainless steels / adjust the height of the tank	Grainger	6JA46	0.07	0	0.1	0.23	0.26
	0307	Nut	pcs	2	stainless steels / hold the screws	Grainger	22UK82	0.00	0	0.1	0.11	0.02
	0308	Spring	N/m, pcs	2	stainless spring steels / secure the tank on the long screws	The Spring Stor	PC060-296-350	0.30	0	0.1	0.70	1.20
	0309	Drag Fluid	Liters	4.68	mineral-based fluids / source of drag	Grainger	DTE 24	2.85	0	0.1	13.45	11.41
0400	0401	Final Assembly	-	1	Final assembly of all parts	-	-	-	-	5.00	5.00	
Assmeblies	0402	Pressure plate assy	-	1	Assembly of the step plate	-	-	-	-	3.00	3.00	
	0403	Door opening assy	-	1	Assembly of door opening mechanism	-	-	-	-	3.50	3.50	
	0404	Door closing assy	-	1	Assembly of dor closing mechanism	-	-	-	-	3.50	3.50	

Bill of Materials (cont.)

Total Purchased Parts $	58.57
Total Custom Manufactured Parts $	58.80
Total Assembly Cost $	15.00
Total Cost $	131.67

Total Purchased Parts $	98.20
Total Custom Manufactured Parts $	52.92
Total Assembly Cost $	15.00
Total Cost $	166.11

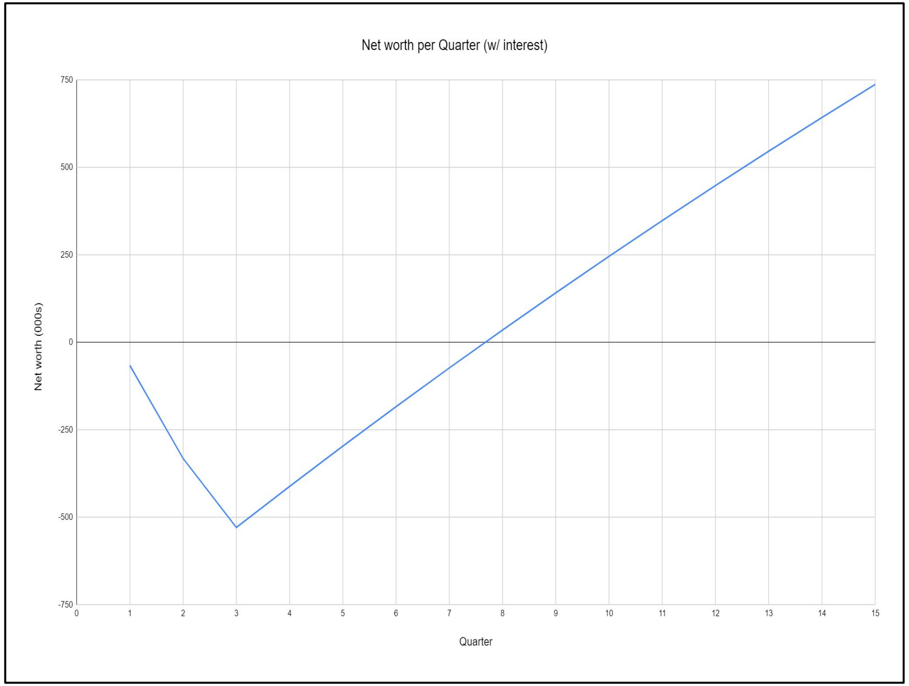
Financial Analysis - Values

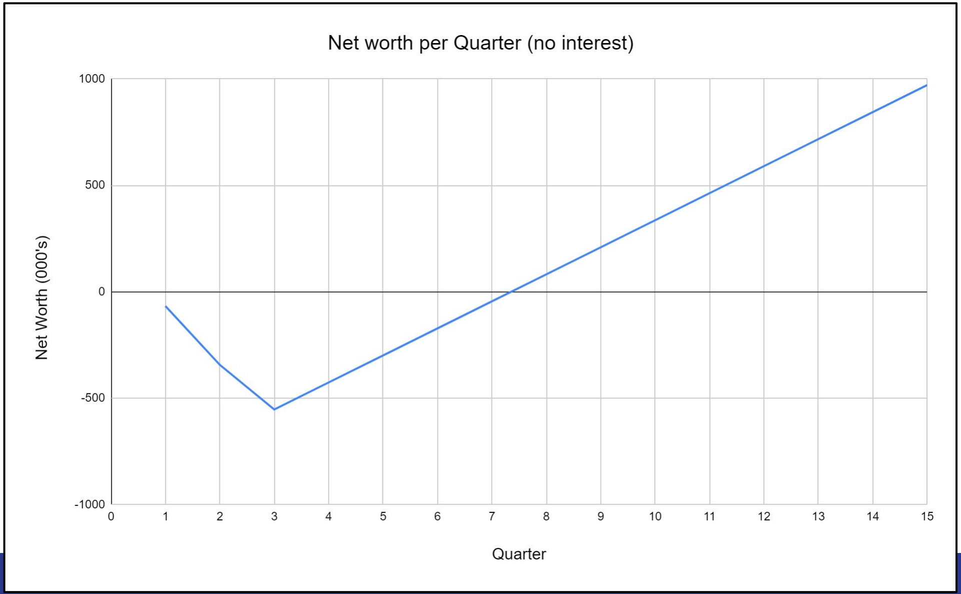
Input		
Interest Rate / year	8	%
Analysis Periods / year	4	#
Tooling and Fixtures	419000	
Annual Production	19200	#
Estimated Purchased Parts	58.57	$
Estimated Fabricated Parts	58.8	$
Estimated Assembly Cost	15	$
R&D Costs	134264	$
Cost % of Retail	25	%
Return to Project % of Retail	30	%

Calculated		
Intereset Rate per Period	0.02	rate/period
Estimated Mfg. Cost	132.37	$
Retail Price	529.48	$
Build per Period	4800	#
Total Program Build	57600	#
Total Retail Sales	30498048	$
Return to Project	9149414.4	$
Net Present Value	737.23	$(000)
Net Worth (excl. interest)	971.64	$(000)

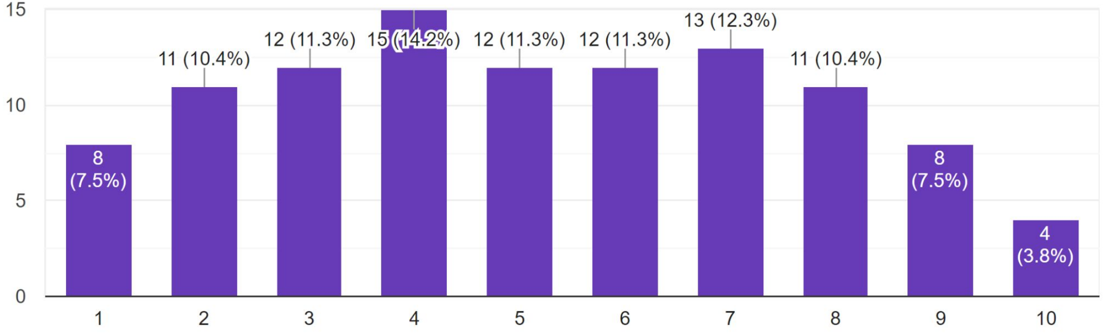
ROI=	46.83	% per year	Min production with no interest=	1741
ROR=	69.19	% per year	Min production with interest=	2005
PB=	8th	Quarter		
NPV=	737.23	$(000)		

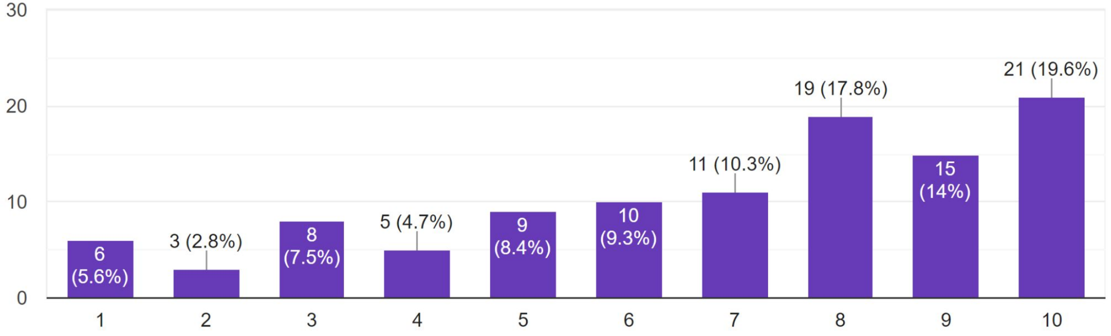
Financial Analysis - Net Worth Charts





What do our customers want?

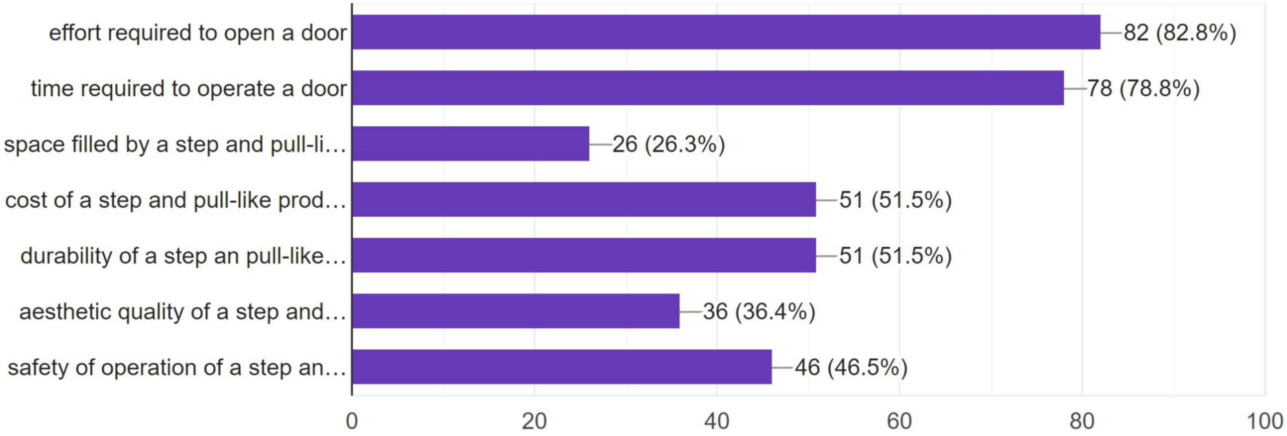




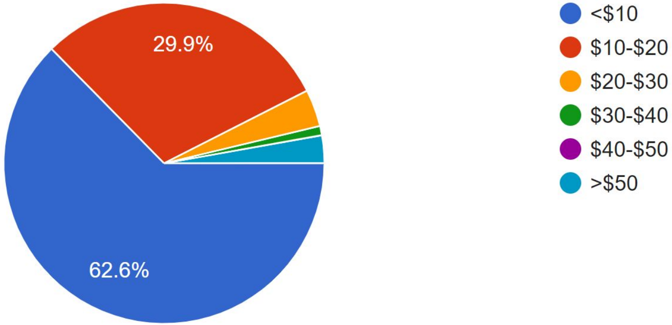
In the top graph, we asked respondents to rate their **level of care for/awareness of the spread of germs** from door handles. Our results roughly display a bell curve pattern.

In the bottom graph, we asked respondents to rate their **affinity for ease of use of a door**. Here, we see a clearly defined bias toward a higher ease of use.

What do our customers want?



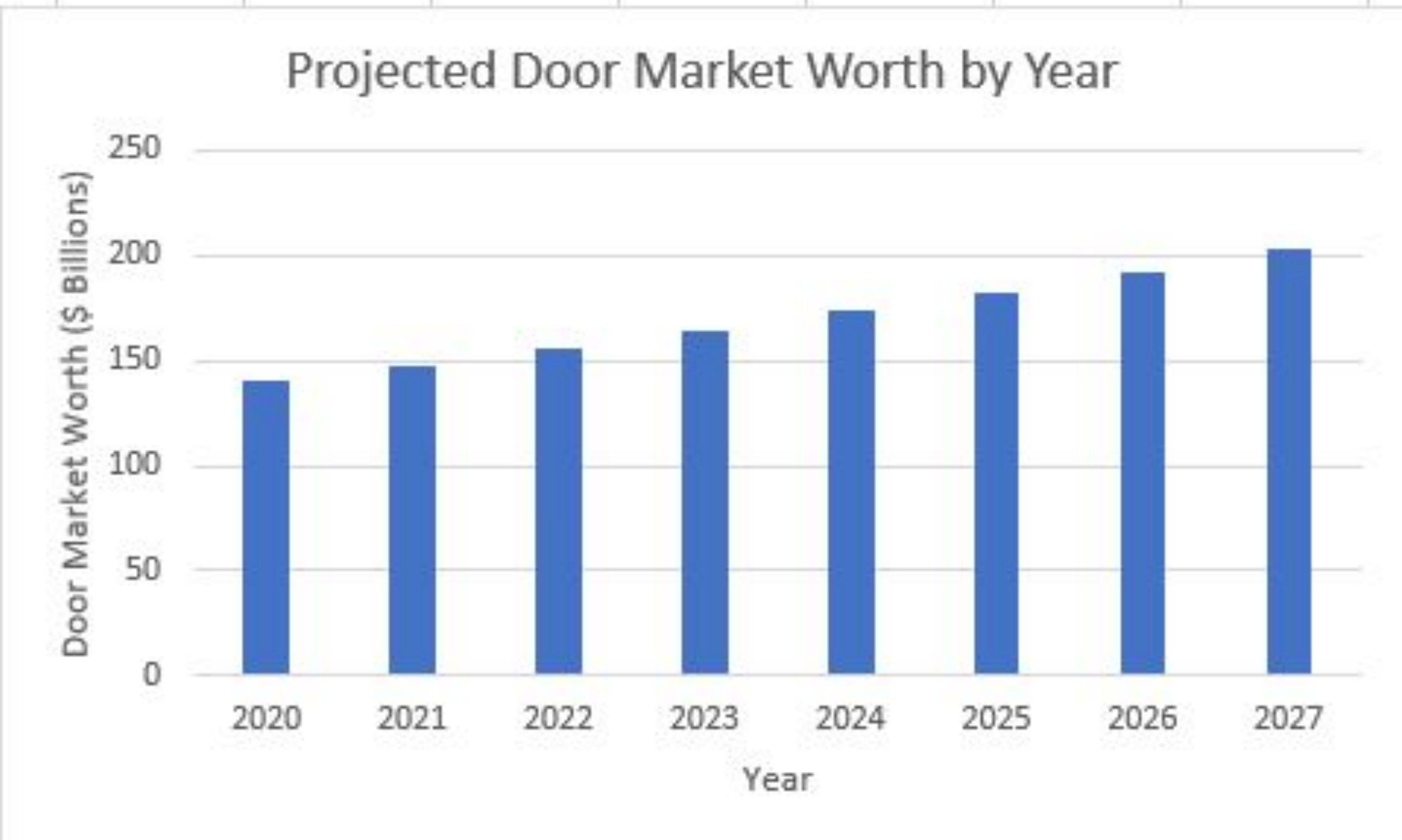
In this graph, we asked respondents to check **every factor (if any) that they care about in a step N pull-like product**. The time and effort customer requirements proved to be the most important of the categories tested.



Here, we asked respondents to place a **price range** on what they would be willing to spend on a step N pull-like product. Low price/cost of manufacturing will definitely need to be an important factor for our product.

Current Market

- “People with disabilities are the **largest and fastest-growing minority in the U.S**. They **control $1 trillion in total annual income**.” - Americans with Disabilities Act National Network
- “**Doors Market** size is valued at **USD 140.5 billion in 2020** and will **grow at a CAGR (Compound Annual Growth Rate) of around 5.4%** from 2021 to 2027.” -Global Market Insights
- “StepNpull could now sell 150,000-200,000 units in 2020 – and that’d be **an increase of at least 1,000% over 2019**.” - SBJ
- “Spending on nonresidential building construction [is expected] **to increase by 5.4 percent in 2022, and accelerate to an additional 6.1 percent increase in 2023**.” - American Institute of Architects
- “Each accessible entrance (**at least 60% of public entrances** in newly built facilities must be accessible to individuals who use wheelchairs or have mobility impairments).” Along with many other requirements- Americans with Disabilities Act National Network


Projected Door Market Worth by Year
Door Market Worth ($ Billions)
250
200
150
100
50
0
2020
2021
2022
2023
2024
2025
2026
2027
Year

Customer Requirements

What (Customer Requirements)	Warehouses	Handicapped People	Hostpital	Universities	Weight averages	
Effort to open the door	10%	15%	11%	7%	10.75%	3
Ease of operating the door	17%	12%	13%	10%	13.00%	1
Time required to operate door	10%	9%	5%	5%	7.25%	6
Space filled by unit	3%	5%	5%	5%	4.50%	
Ease of installation	8%	5%	8%	10%	7.75%	7
Low Cost	10%	5%	8%	14%	9.25%	5
Durability	15%	11%	12%	14%	13.00%	2
Aesthetically pleasing	0%	5%	5%	5%	3.75%	
Ease of repair	11%	7%	7%	6%	7.75%	8
Safe to operate	10%	10%	13%	10%	10.75%	4
Retro-Compatibility	3%	5%	8%	8%	6.00%	9
Quiet	0%	5%	5%	5%	3.75%	
Purely Mechanical	0%	3%	0%	1%	1.00%	
Customizability of door operation time	3%	3%	0%	0%	1.50%	
Total	100%	100%	100%	100%	100.00%	

Most Important:

1. Ease of operating the door (is it complex to open?
2. Durability
3. Effort to open the door
4. Safe to operate
5. Low Cost
6. Time required to operate door
7. Ease of Installation
8. Ease of Repair
9. Retro-Compatibility

Engineering Specifications

HOUSE OF QUALITY	How (ES)								
	Force of operation	Strength of material	Longevity	Unit Cost	Size of Unit	Use of Standardized Parts	Sound Produced	Time to open door	Number of Pinching Parts
	Newton	ksi	years	$	in^3	#	Decibles(dB)	Seconds	#
What (Customer Requirements)	↓	↑	↑	↓	↓	↓	↓	↓	↓
Effort to open the door	9	1	1	0	0	0	0	3	0
Ease of operating the door	9	0	3	0	1	0	1	3	0
Time required to operate door	0	0	0	3	0	0	0	9	0
Space filled by unit	0	1	0	1	9	3	0	0	1
Ease of installation	0	0	3	3	3	9	0	0	1
Low Cost	3	3	3	9	1	1	0	0	0
Durability	1	9	9	3	0	1	3	0	0
Aesthetically pleasing	0	1	0	3	1	1	9	0	1
Ease of repair	1	1	3	1	1	9	0	0	0
Safe to operate	3	9	0	0	1	0	0	3	9
Retro-Compatibility	0	0	1	1	3	3	0	0	0
Quiet	1	1	0	3	0	0	9	1	1
Purely Mechanical	0	0	1	3	3	3	1	1	1
Customizability of door operation time	0	1	0	1	1	9	0	9	0
Total	27	27	24	31	24	39	23	29	14

Benchmarks

	Now (Benchmarks)		
	Automatic Door and Hardware	StepNPull	FortStrong
Effort to open the door	5	1	3
Ease of operating the door	5	1	3
Time required to operate door	2	3	4
Space filled by unit	5	5	5
Ease of installation	2	5	4
Low Cost	1	4	2
Durability	4	5	4
Aesthetically pleasing	3	3	3
Ease of repair	2	5	3
Safe to operate	5	4	4
Retro-Compatibility	4	5	4
Quiet	4	5	4
Purely Mechanical	1	5	5
Customizability of door operation time	4	3	3
Total	47	54	51

Benchmarks vs. Engineering Requirements

		How (ES)								
		Force of operation	Strength of material	Longevity	Unit Cost	Size of Unit	Use of Standardized Parts	Sound Produced	Time to open door	Number of Pinching Parts
		Newton	ksi	years	$	in^3	#	Decibles(dB)	Seconds	#
Universities	Weight averages	↓	↑	↑	↓	↓	↓	↓	↓	↓
Automatic Door and Hardware		67	~30	N/A	$1,600	269	~3	N/A	6	3
StepNPull		67	~40	N/A	$30	30	0	N/A	3	0
FortStrong		67	~30	N/A	$130	372	~3	N/A	2	3
Target (Delighted)		22	45	15	$10	100	6	10	1.5	0
Threshold (Disgusted)		132	25	3	$1,600	500	0	70	10	6

Engineering Requirements

Engineering Specification	Target (Delighted)	Threshold (Disgusted)
Force of Operation (N)	22	132
Strength of Material (ksi)	45	25
Longevity (years)	15	3
Unit Cost ($)	10	1600
Size of Unit (in^3)	100	500
Use of Standardized Parts (#)	6	0
Sound Produced (dB)	10	70
Time to Open Door (seconds)	1.5	10
Number of Pinching Parts (#)	0	6