Mechanical Shredder

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Introduction.

Present day paper shredders are electronically driven. This limits them to being only available to a nearby power source and draining electricity while they are plugged in and not in use. The task team 10 was given was to create a mechanically operated paper shredder that relied on no electronic components at all. The group discussed many aspects of the project with our client and finally decided to retrofit and existing paper shredder so we would have a reliable mechanism, but also cut down on our budget to make the product very cost effective.

Statement of Problem

Schools, companies, and personal information are exposed to random individuals. Tossing important documentation in trash bins is not enough to prevent stolen ideas, identities, and frauds. Unlike the United States, Third World countries have limited access to electricity, thereby, they do not have to pay about $65.00 /year on operating an electric shredder at $0.12 per kW/hr. Which will lead to emitting greenhouse gases into the atmosphere [1]. The disadvantage of not having electricity is disposing important information. A disadvantage of using electricity to operate an electric shredder can be random power outages. It can occur at the most crucial time, preventing an individual from destroying their documents.

These are aspects we considered to avoid this dilemma. That is why our team wanted to assist those in need of disposing credit cards, tax returns, company research, and CD files with a mechanical paper shredder.

Goals, Objectives, and Constraints

The ultimate goal was to design a mechanically operated shredder that holds no source of electrical components and is human driven. Our team researched and communicated with our client to perfect our design accurately. The outline below are the specific project goals, objectives, and constraints that show relation to designing the mechanical shredder.

Goals

- Mechanical shredder needs to be highly reliable, and portable
- Environmentally friendly system
- Mechanically operated with no electrical sources

Objectives

- Competes with present-day electrical paper shredders
- Has a container to hold shredded paper
- Mechanical shredder has to be inexpensive
- Shreds paper with minimum power (leg or hand operated)
- System has to be able to shred paper, credit cards, and CDs
- The system has to be wall mounted or be able to stand alone

Constraints

- Total design cost must be less than $100.00
- Mechanical system needs to shred at maximum 10 sheets per feed
- Operate and shred 36 pages per minute
- Required paper size is a standard 8.5 inches by 11 inches or less
- Volume of system is $5ft^3$
- To operate at a noise level that is less than 65 decibel (dB)

Quality Function Deployment (QFD)

Two competitors that we looked into for a mechanical paper shredder was the Premium Connection Paper Shredder shown in Figure 1, and the Manual Paper Shredder developed by IDEA as shown in Figure 2. Both of these mechanical paper shredders are fully mechanical, but are not reliable enough. These shredders are close to novelty items and the client asked our group to develop a reliable mechanical paper shredder that is going used constantly in a busy office environment. These two shredders are the common types of mechanical shredder that you can find on the internet.

Figure 1: Competitor 1: Premium Connection Paper Shredder [2]

Figure 2: Competitor 2: Manual Paper Shredder from IDEA[3]

As shown in our Quality Function Deployment (QFD) **(Table 1),** both competitors do not properly meet with our customer requirements. They are not reliable systems and not durable enough for the office use that is requested for this project. Trends in our QFD shows that our system has to have a focus on reliability, being inexpensive, but also being cost effective. We focused on meeting these customer requirements by focusing on the weight and size of the system and made sure it performed its required tasks of being able to shred 36 pages per minute, and being able to shred at least 10 sheets of paper in one cycle. Unfortunately these requirements were not fully met and will be discussed further within our results section.

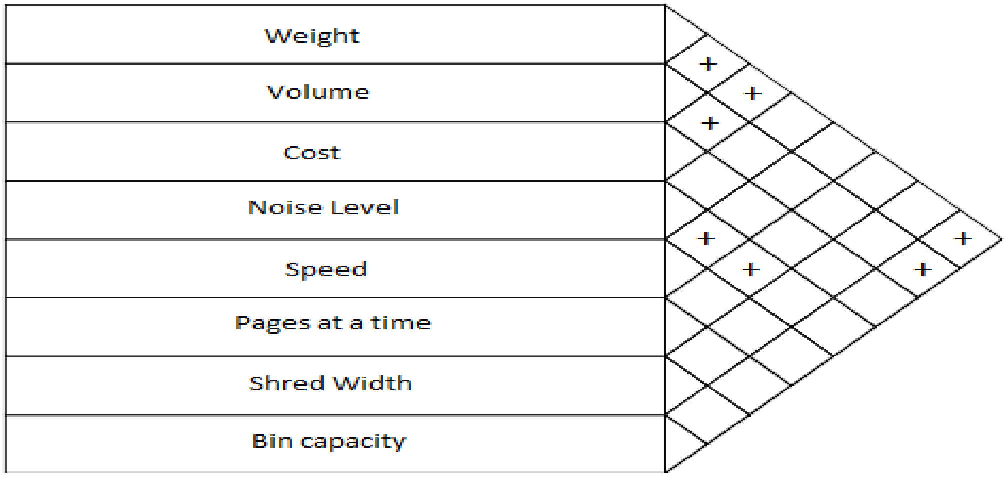
Table 1: Quality Function Deployment

		Engineering Requirements								Competitors	
		Weight	Volume	Cost	Noise Level	Speed	Pages at a Time	Shred Width	Bin Capacity	Product 1	Product 2
Customer Requirements	Minimum Carbon Footprint		X								
	Reliable					X	X	X			
	Inexpensive	X	X	X					X	O	O
	All Mechanical System				X	X				O	O
	Cost Effective			X		X	X			O	
	Units	lbs	ft^3	$	db	Pages/Min	x Pages/Iteration	inches	gallons		
		20-25	5	100	65	36	10	0.25	5.25		

House of Quality (HOQ)

Our House of Quality (Table 2) shows the common trends that we encountered when designing and fabricating this system. As the weight of the system goes up, that could possibly lead to an increase of volume, but we could increase the size of the paper collection bin. If we decided to build a bigger system that could potentially add in our cost. The categories such as: noise level, speed, pages at a time, and shred width, all factor into the reliability of the system. Being limited to $100.00 and a 5$ft^3$ volume, we had to find a way to maximize reliability while keeping to our given constraints.

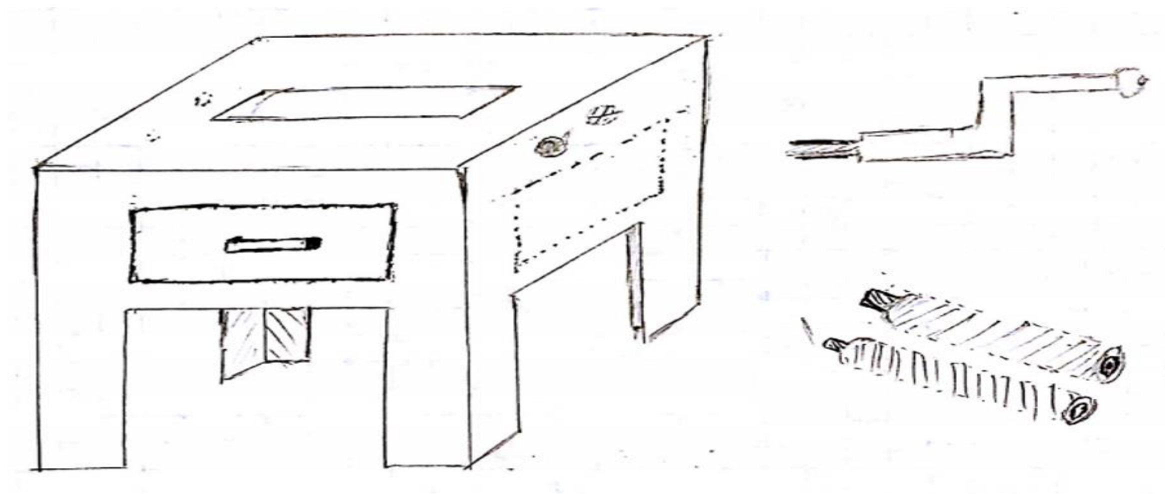
Table 2: House of Quality



Design Concepts Introduction

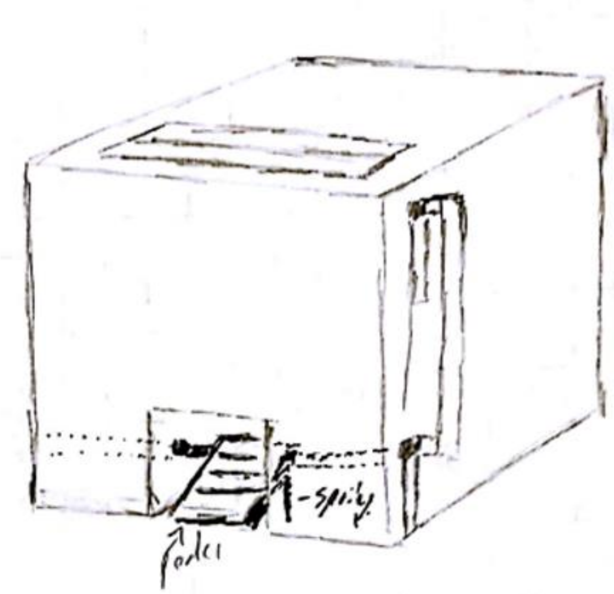
To begin our design concept and generation stage, each team member was assigned to create two design concepts of their own for our mechanical paper shredder. We set no restrictions, other than that it had to be a process that was completely mechanical. The team members had to come up with a full system for their designs. This would include: a paper shredding mechanism/system, a bin/storage system, and some way to dispense of the paper shreds when the system became full. Together, we came up with eight designs for the mechanical paper shredder system.

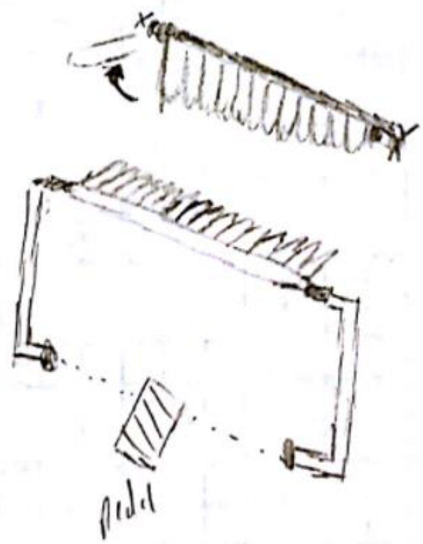
Design 1



This design concept is based off of the night stand. There are two gearing systems that rotate and shred the recommended materials. While one gear is stationary and the other is being rotated by a hand crank, the paper is inserted from the top of the design. On the front side of the design, there is a drawer to dispense wasted material. This allows the users easy access to determine what is causing the mechanical shredder to jam. This design is very portable and can be moved around an office space so as not to get in the way of the user. However, when operating the shredder, it may jam due to the stationary gear that is set in place.

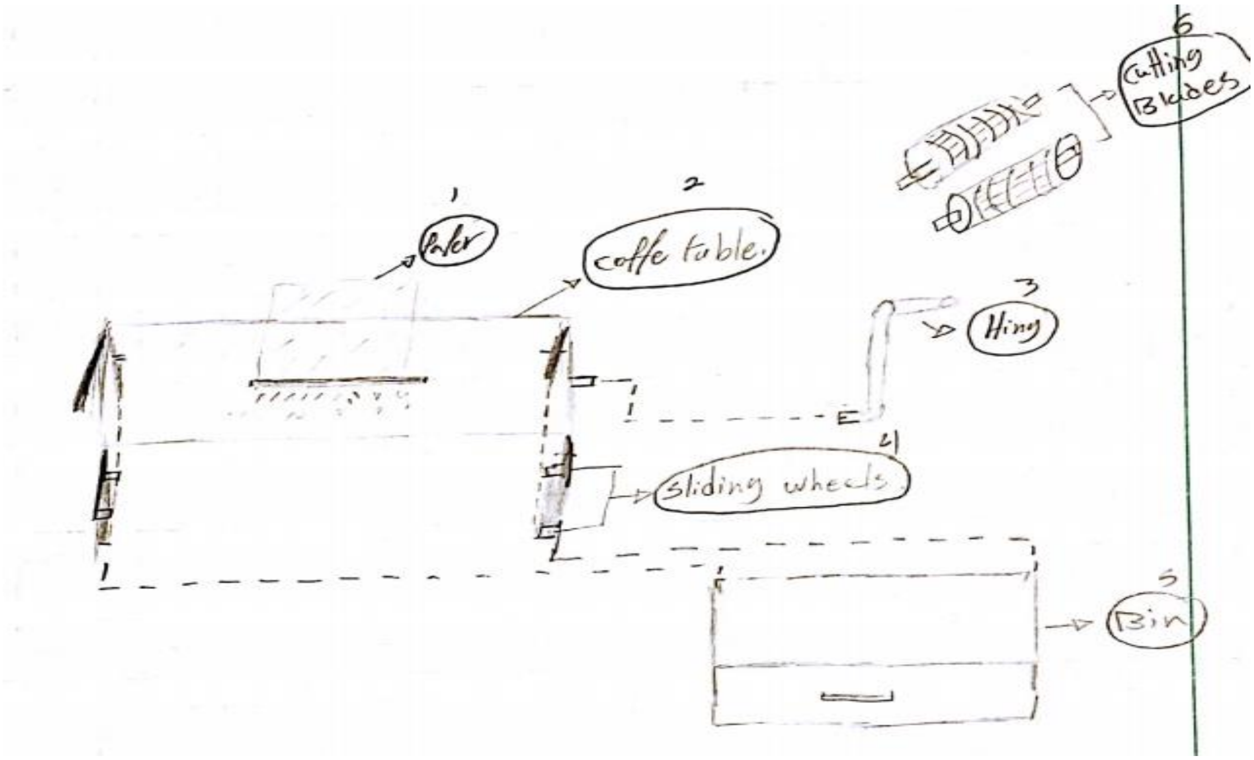
Design 2





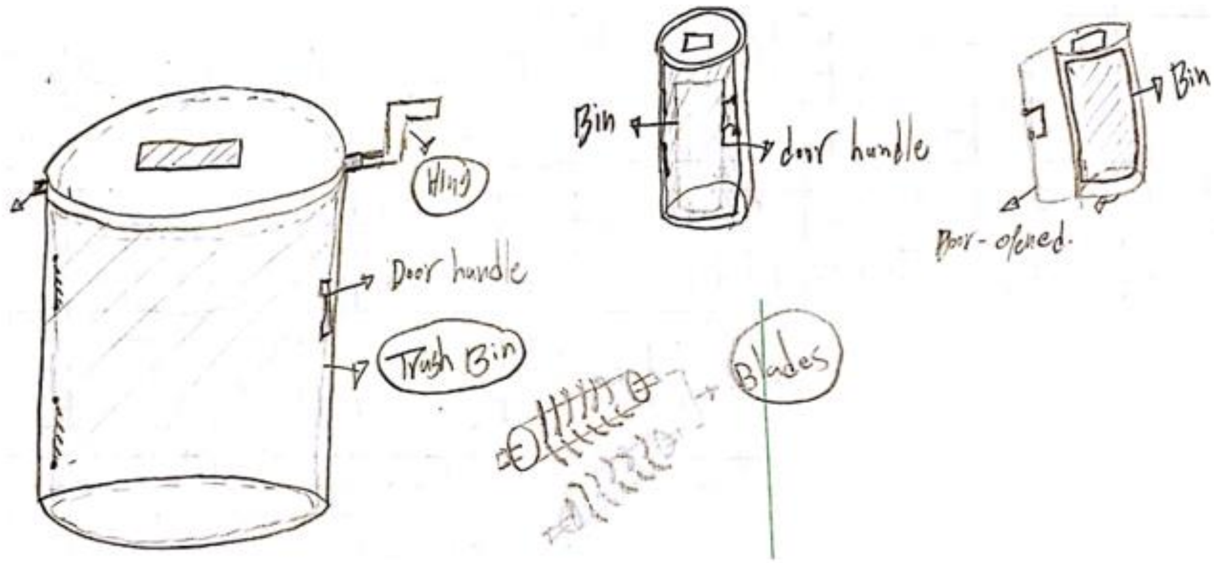
The following design is operated similar to a shear system, however used with a foot pedal. Once the user pushes down on the foot lever; the shears disengage and cuts the recommended material that is inserted through the top of the mechanical box. There are a couple of shears that will operate this mechanism. One is positioned to the container while the other operates. The springs that are placed underneath the foot pedal will recoil the shears to its original position once the user removes their foot. This design will most likely jam depending on what the user is trying to shred. The user can remove the shredded material by opening the backside and taking out the bin container

Design 3



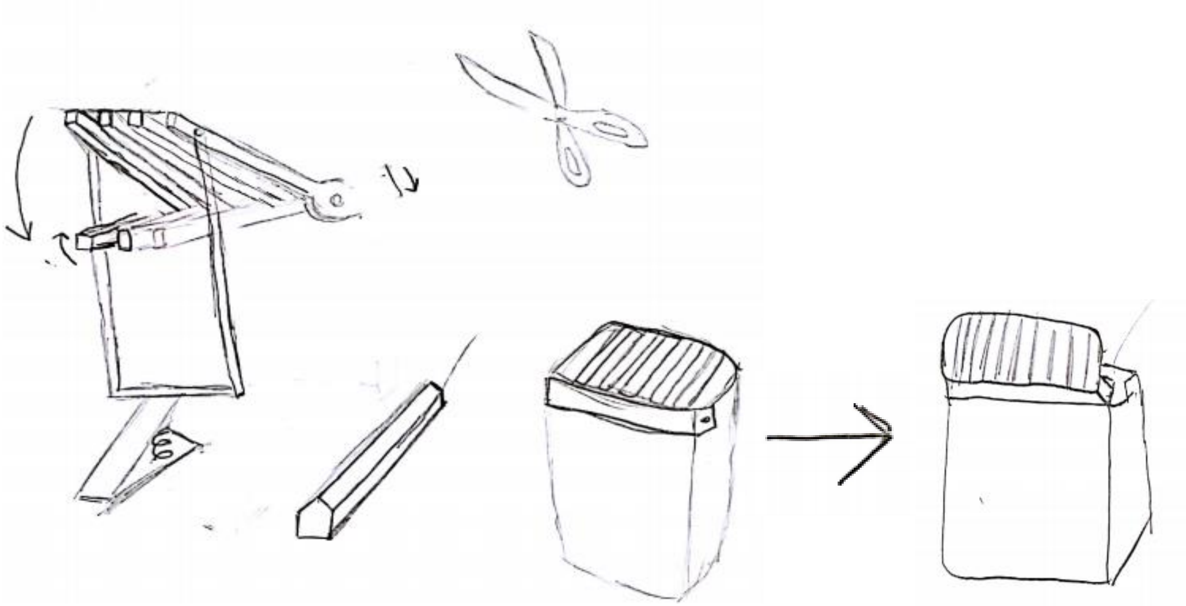
This design is a combination of a coffee table and a paper shredder. The system is a multi-directional cross bladed shredder that can allow a multiple sheets of paper to be shredded per feed. It has a big bin size that can carry a large amount of shredded items. The bin is easily disposed of because it is a drawer system that pulls out of the main body, so the waste can be disposed of quickly and efficiently. When shredding items, the system remains stable and silent to maintain a quite working environment through the use of the hand-crank mechanism. The table also fits into an office environment and can be used to keep drinks on, and even decorate.

Design 4



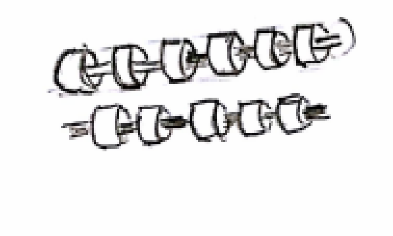
The design is based on a simple trashcan. Almost the entirety of the container can be used to store waste, with the exception of the space the shredding mechanism takes up at the top of the system. The bin can be emptied by taking off the top, so a garbage bag can be removed or the system can be directly tipped over and disposed of, or a side door can be attached to the system, so no lifting of the entire mechanism is entirely necessary. The system is designed to be durable and light-weight, so it might be unstable when using the hand-crank to rotate the shredding mechanism.

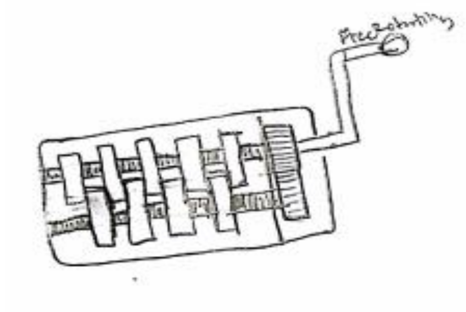
Design 5

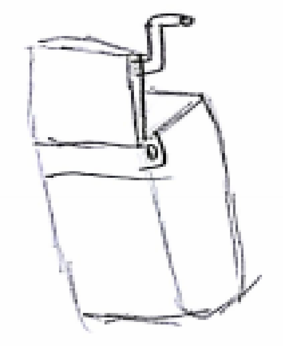


This design derives from a simple scissor-shear design. The shear mechanism is attached to a foot-pedal that brings that top half of the system down, essentially cutting the paper into strips like multiple scissors would. When the foot-pedal is let go, the top row half of the system comes back up for more paper to be placed. The system is designed to fit on top of a bin, while the mechanism attached to the foot-pedal rests along the inside wall of the bin. The system would be locked onto the top of the bin, and when needed to be empty, it would need to be unlocked through a latch, and the other side of the mechanism would be attached to a hinge, so the system could be lifted from one side and be emptied out, or a trash bag could be lifted from the bin and easily replaced.

Design 6

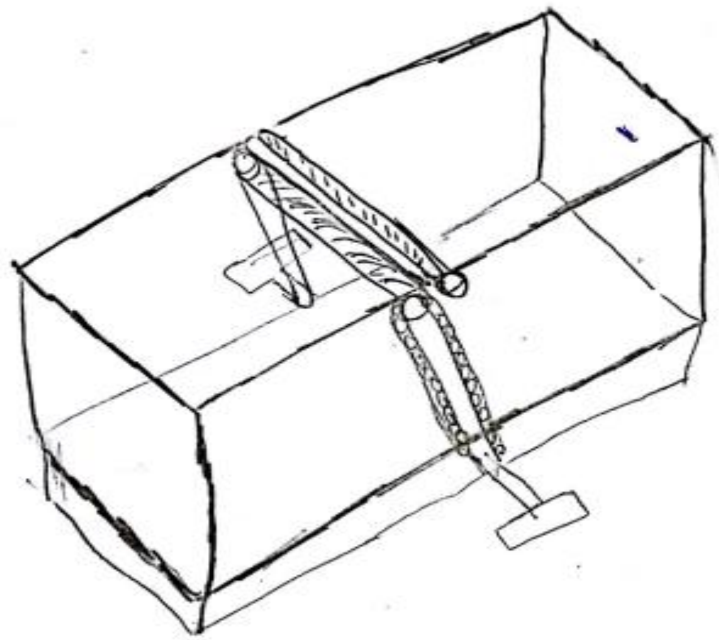






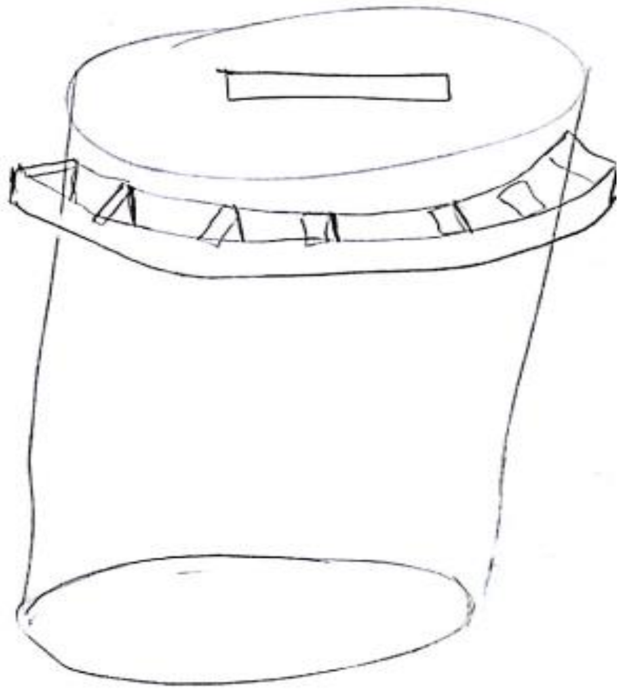
This design is inspired by the common paper shredder mechanism. There are two rows of gears that are parallel to each other and the gears align side-by-side to the parallel row so they can shear and tear the paper. A hand-crank is attached to one row of gears that is connected to a gear that rotates the parallel row of gears. This simple gear system lets both gears rotate inwards to bring paper down to grind it, and if a jam occurs, rotating the hand-crank in an opposite direction will allow the system to reverse the paper flow and fix up jams that occur. Similar to design 5, this system will be attached to the top of a bin that is attached to a hinge on one side, and has a locking mechanism on the opposite side so the system can be opened easily to rid of waste, and easily be put back together. A trash bag can be put into the system to collect waste, and just emptied out and replaced, so the system does not need to actually be lifted.

Design 7



This designed is based off of a bicycle, in that it has a bike pedal on each side that you use to rotate the gears that shred the paper at the top. Each pedal is attached to a chain and gear system that convert power from the pedals to the shredding mechanism. The idea of the shredder is that it can be portable, but won't take up office room because it would be used in the commonly empty space between a person's legs while sitting in an office chair. The rectangular shape of the system allows it to fit between someone's legs while sitting in a chair and will not be uncomfortable or feeling as if it is in the way and inconvenient. The system will be composed of two rows of gears for shredding paper, attached to two gears, two chains, and finally two bike pedals for transmitting power. The paper can be disposed of with a drawer on one of the smaller faces of the system.

Design 8



Design 8 is based off of the idea of a coffee blender. The container will be cylindrical and have the appearance of a metal trash can. A wheel will installed around the outer perimeter of the container that when rotated, will shred the paper that is inserted within it. The wheel will rotate gears inside the system that will shred and grind the paper into small pieces.

Decision Matrix Criteria

From looking at our QFD and HOQ, we found common trends in both the dimensions of our system, and the reliability of the system. We pulled criteria from our customer and engineering requirements and used those as the basis of our decision matrix. Then we used the common trends that were found to rank our criteria in an order of priority. We reached the rank and dispersed the weights in an order that we felt fitting to the priorities we arranged and managed to create the final criteria for the decision matrix, as seen in **Table 4**.

Table 4: Decision Matrix Criteria

Criteria	Weight
Reliability	15%
Cost Effective	13%
Materials (Strength of System)	13%
System Operation	11%
Volume	9%
Speed	8%
Ease of Use	7%
Stability	6%
Bin Size	5%
Shred Width	5%
Noise Level	4%
Portable	4%

We ranked reliability as the highest because we defined it as how the system operates and if it meets the requirements without maintenance. If the system cannot do its job, then we do not consider it to be a successful project overall. We ranked criteria that dealt with system operation rather high because they determine if the system works or not. Next, were the dimensions of the product, which we ranked around the middle of our criteria because we felt as long as we fit within the restrictions given to us in those areas, we would be satisfied with the system. Shred width and noise level ranked low because we are comparing those measurements to those of an electrical shredder, which we assumed to be a non-difficult task to accomplish, given that we are designing a mechanical system with no motors. Finally, a portable design was the lowest on our criteria because we imagine this product to be used mainly within a single office space. Since, moving the mechanical system from room to room on a daily basis, is not an aspect that we are considering.

Averaged Group Decision Matrix

Each group member went home after we presented our concepts to one another and graded each concept in our decision matrix, in which we used a grading scale of 1-10. After each member finished their copy of the decision matrix, a final group average decision matrix was put together, and designs 1 and 6 were our top concepts, as seen in **Table 5**.

Table 5: Group Decision Matrix (Graded on Scale of 1-10)

Group Decision Matrix Average								
	Design 1	Design 2	Design 3	Design 4	Design 5	Design 6	Design 7	Design 8
Reliability (15%)	1.2	0.975	1.0875	1.0875	1.0125	1.1625	1.0125	1.0125
Cost Effective (13%)	0.9425	0.8775	0.8775	0.9425	1.0075	1.04	0.8775	0.91
Materials (Shredded material+10 Pages) (13%)	1.0075	0.845	0.8775	0.8125	0.845	0.975	1.04	0.715
System Operation (11%)	0.88	0.825	0.825	0.825	0.825	0.88	0.825	0.6875
Volume (9%)	0.54	0.7425	0.5625	0.54	0.72	0.6975	0.5175	0.72
Speed (8%)	0.54	0.56	0.52	0.52	0.54	0.56	0.68	0.44
Ease of Use (7%)	0.6125	0.6125	0.5775	0.5775	0.6125	0.595	0.525	0.4725
Stability (6%)	0.51	0.465	0.465	0.405	0.465	0.45	0.435	0.3
Bin Size (5%)	0.2625	0.375	0.3375	0.325	0.4	0.3875	0.325	0.4
Shred Width (5%)	0.375	0.3625	0.375	0.35	0.3375	0.3625	0.4	0.35
Noise Level (4%)	0.28	0.29	0.27	0.26	0.29	0.27	0.26	0.24
Portable (4%)	0.26	0.26	0.24	0.31	0.35	0.34	0.24	0.34
Total:	7.41	7.19	7.015	6.955	7.405	7.72	7.1375	6.5875

Common trends we found in the outcome of the decision matrix were in the reliability score, because it is the highest weighing criteria. Materials was another section where these designs excelled, and helped their total scores extend beyond the other designs. Design 5 came at a very close 3rd, which is one of the few foot pedal designs, and we will also take a look into how plausible and efficient the system can be for us, and look into it along with our main two designs.

Final Product Design

After further analysis and discussion with our client, we decided that the most cost effective way to go about our project would be to buy a paper shredder, take out its shredding mechanism and finally just retrofit it's system. The majority of the money would go towards buying the system, but most of the retrofit design could be done in 98C with very few parts requiring purchase.

Chosen Product

The product that we chose to retrofit is an AmazonBasics 12-Sheet Cross-Cut Paper, CD and Credit Card Shredder [4] as seen in figure 3. Compared to many competitors, this shredder meets our requirements and is also the most cost effective. The shredder comes out to $54.99, which is more than half our budget, but the shredder blades and gearing system in the shredder are essential components to our design.

Figure 3: AmazonBasics 12-Sheet, Cross-Cut Paper, CD and Credit Card Shredder

The shredders dimensions come out to 8.9 x 12.5 x 15.7 inches, which comes out to roughly 1.01ft^3. The shredder fits within our volume limitations, which allows us to design a bigger bin size, or let our mechanism expand so we have a substantial amount of space to work with. The system comes with a 4.8 gallon bin, which is a decent space for waste storage.

Engineering Analysis

The group received the AmazonBasics 12-Sheet Cross-Cut Paper, CD and Credit Card Shredder and took apart the system to analyze the shredding mechanism contained within the shredder. When analyzing the system, we took note of the gear system used to operate the system, what parts could be reused, and what parts were not necessary when turning the system into a fully mechanical system, such as the motor. We used the current mechanism inside the shredder to come up with ways that we could design and retrofit the system to meet our customer requirements. **Figure 4** shows the main shaft extruding from the system that the electric motor of the paper shredder was attached to. Rotating this shaft allowed for rotation of the parallel shaft to produce a shredding motion and also rotated the CD shredder at the same time. Our analysis showed us that we could attach the handle directly to this shaft and be able to operate the entire system.

Figure 4: Existing Mechanism

Retrofit Assembly and Parts

As shown in **Figure 5**, the retrofit design involves using an electric arbor shaft to act as an adapter over the main shaft of the shredder. This adapter slides onto the shaft and locks on with a pair of set screws and the threaded end of the arbor shaft can be used to screw the hand crank on.

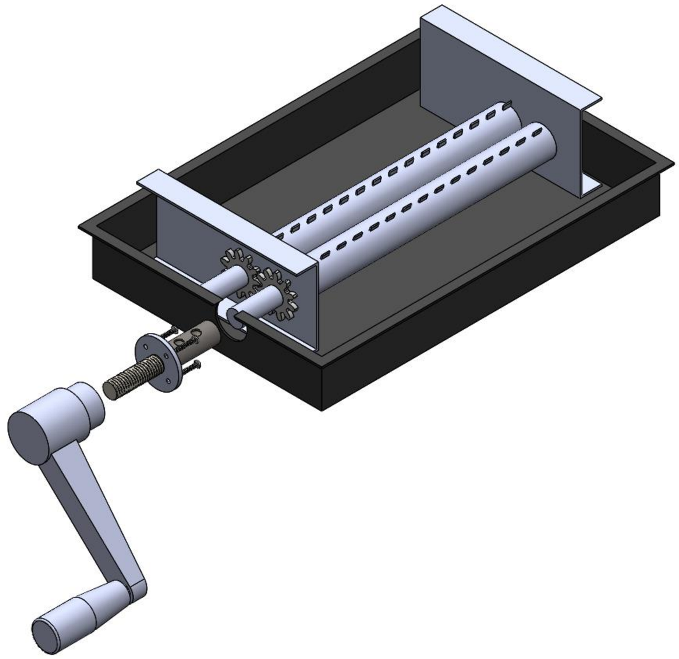


Figure 5: Retrofit Design

The first piece that we needed to install into the system was the motor shaft arbor extension [5] (Figure 3). This piece has a small sleeve that attached over the shaft of the shredder and was locked on using the set screws. The shaft extension is 3 ½” long, which extends from the main shaft to outside of the housing where the hand crank was directly attached. The diameter of the bore of the extension and of the threaded side are ½’ which is consistent to the size of the shaft and bore of the hand crank.

Figure 6: Motor Shaft Arbor Extension [5]

Finally the hand crank [6] was attached directly to the threaded shaft and was able to rotate the cutter teeth directly. The hand crank (Figure 4) has a rotating handle that allows the user to not have to adjust their grip constantly while operating the system. The hand crank also has an overall length of 7.29” and gives a significant amount of torque to the user to aid them in rotating the system. The hand crank is also made of a Glass-Fibre Reinforced Technopolymer that will prove durable for the quality of work needed of it.

Figure 7: Hand Crank with Revolving Handle [6]

One issue arose when retrofitting the system, and it was that the handle would unscrew from the arbor shaft when rotated in the counterclockwise rotation. We developed a locking mechanism onto the set screw with a washer and four screws as seen in **Figure 8**. The washer was welded onto the arbor shaft and the screws went through the washer and into the handle to make the pieces rotate equally, without the rotation direction mattering. Also, the initial threading of the arbor shaft was not compatible with the hand crank, so we used a handsaw to remove it and replaced the threading with a cut off section from a 10” bolt that had compatible threading.

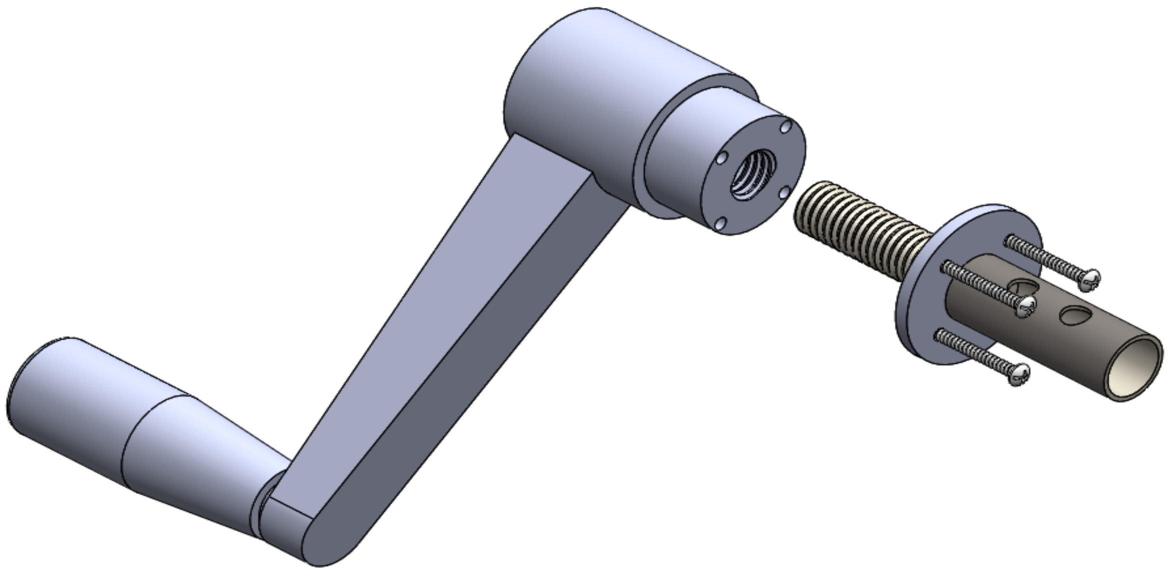


Figure 8: Custom Lock for Arbor Shaft and Crank Handle

Bill of Materials

Table 6 shows the Bill of Materials needed for final product. The arbor shaft came relatively cheap and the custom work on it was free, thanks to 98C. The hand crank was the second priciest part, but the team still managed to remain under budget by roughly $8. All other previous ideas for this system went highly past budget so we do still believe that this was the better and most cost effective method to get this project done.

Table 6: Parts and Prices

Parts	Price
AmazonBasics 12-Sheet Cross-Cut Paper, CD, and Credit Card Shredder [4]	$54.99
½ in Arbor Attachments for Electric Motors [5]	$6.06
Crank Handle with Revolving Handle [6]	$29.21
10 in Bolt	$1.50
Total	**$91.76**

Prototype Results

While testing the system, various results could be observed in **Table 7**. The system did fall within our budget, but we couldn't quite meet the objectives of the speed and strength. The system showed to be very top heavy, so if work was to be done very fast, a big moment was created and the system would move too much. At a comfortable speed the group could shred 20 pages in a minute. While the shredder can go beyond 4 pages in one iteration, the system would start to become unstable past that, so 4 was the limit of easy operation. Finally the paper shredder was able to shred the credit card and CD very smoothly with very little effort required.

Table 7: Objectives and Results

Objectives	Results
Inexpensive	$91.76
36 pages/min	20 pg/min
10 Pages/Iteration	4 pg/iteration

Credit Card	Yes
CD	Yes

Conclusion

For the last two semesters the team was tasked with developing a mechanical paper shredder. Various concepts were designed to meet the objectives, but because of the cost constraint, many ideas had to be compromised until the group decided to retrofit an already existing paper shredder. The analysis was easy from there as we only had to analyze the mechanism and see how we could retrofit the design to have it working fully mechanically. The arbor shaft and hand crank were the main parts needed to operate the shredder and after a few customizations to the arbor shaft, the group managed to create a working product. The product fell below our budget and met certain constraints, but in the end, the mechanical paper shredder just couldn't work as fast and efficient as the electric motor that ran the system. The system as a whole does work well for an office setting that disposes of paper in smaller quantities.

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