OD Waste Collection Device Project Final Report

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ME 286 Section 5

Executive Summary

This final report reviews the ways in which design team 53 used to design and construct an original design of a waste collection device. It also contains sections for customer needs, which the team used to form and analyze the House of Quality, Black Box & Hypothesized Functional Models. These models guided us to concept generation, where we used the Bio-inspired, C-sketch, and Morphological Matrix methods. After evaluation, the team landed at twelve different concept variants. Figure 1 shows the SolidWorks assembly of the intended design that the team got from a pugh chart and decision matrix. The final device used for competition day is to collect and sort any pieces of waste placed into a randomly-sorted arena.

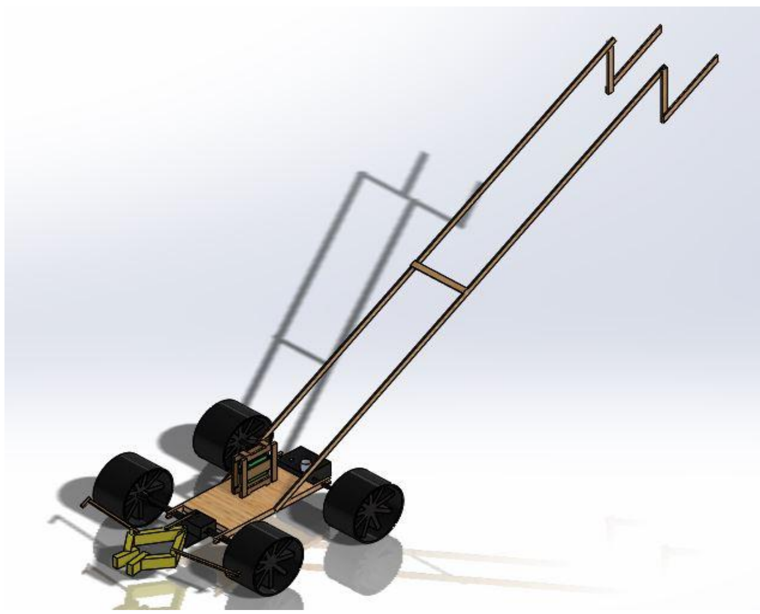

Figure 1: SolidWorks Assembly

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1 Introduction

Project 2 was focused on original design and this report will demonstrate the many steps taken by team OD 53. The purpose of this project was to create a device that could collect and separate waste into the correct disposal bin. The team utilized the design process and its steps to make device that would effectively serve its purpose. Techniques, methodology and lessons learned will also be discussed. Challenges and constructive criticism will be addressed. The final parts of this report will show the prototyping and the resulting device that was used in the competition. This report will also give information about the team members and how we worked together to finish this assignment.

1.1 Team Outline

Team for original design 53 was composed of four sophomore mechanical engineering students. They are Barry Benson, Martin Dorantes, Jelani Peay, and Austin Vest. We all want to be engineers because we want to live comfortably and have grown a strong passion for problem-solving. Like any team, the personalities of its members are distinct with their strengths and weaknesses. Barry's MBTI scores are; 34% extrovert, 16% intuitive, 25% thinking, and 47% judging. He can bring a lot of conversation to the project allowing others to speak freely. Martin's MBTI scores are 37% extroversion, 6% sensing, 30% sensing, and 22% perceiving. He excels at taking other's ideas and criticisms into consideration in how the team can use that feedback in a positive manner. Jelani's MBTI score: Introvert- 12% Sensing- 6% Feeling- 4% Judging- 37% Jelani possesses the ability to make decisions based on intuition and feelings. He is also a great listener when ideas are being exchanged within a group. Austin's scores are; 56% introvert, 9% sensing, 19% thinking, and 3% judging. He can help the team break problems up into small parts and accomplishable tasks. During this project all these strengths were used to an effective device.

1.2 Motivation

The motivation for this project primarily stemmed from the need to pass ME 286 as integral class on our paths to graduation, but it also came from the desire to practice the skills we are learning and have learned thus far in our engineering careers. The design process is very meticulous with many subdulties and our team needed this project to practice and find ways to complete the given tasks. Being able to practice and make mistakes was and is crucial to becoming the good engineers that will be able to get jobs in the future.
The premise of this project to make a device that can collect waste products was intriguing because of its relevance. The world could actually use a device like this in and around areas where litter and trash is a huge problem which gave the team more motivation. There was also small amount of guilt to try to make something that could fix the mess we made as humans. Another final source of motivation came from knowing that what each member did or did not do and how well they did it affected the three other member's grades and success.

1.3 Scope and Limitations

The team's waste collection device needed to be able to get to the waste, collect it, and move it to the correct receptacle. After the final rules and regulation we posted by the profesor, more specifics were learn about how the device had to fit within given dimensions and had to have a functional 3D printed part. The competition area was also defined as well as the area where the trash was going to generally be in relation to the bins. There was an area where the trash was that only the device could go and a starting area where the team could stand meaning the device had to be able to be controlled from at least 15 ft away. These rules and regulations gave the team the specifics about what the device had to do and what the team could and could not do.

Some limitation were present in the rules and regulations during this project with respect to time and money. For example the team had a hard budget of $160.00. All the materials that were bought for the device had to be recorded and displayed in a bill of materials. We could also only use a remote and five subsystems from an off the shelf device. Our team chose to buy an remote control car and take the wheels and motors and incorporate them into our device. The rest of the parts had to be original or bought individually. Time limitations were felt by the team because we were all going to school full time and had jobs to maintain. Obviously if we had more time and money like practicing engineers, a high quality device could have been made hta worked reliably. In the end all team were given half of the semester to create a beta prototype and submit three memorandums and a final report details the team's steps.

2 Design Approach and Results

Section 2 of this report outlines all of the design principles and how they helped generate concepts and develop prototypes. It gives a summary of the steps in the design process and what our team did for each step.

2.1 Clarify Problem

The methods we did to understand the problem include creating a black box model, hypothesized functional model, functional model, and also asked the instructor and TA's detailed questions about the assignment. We also heavily referred to the parameters and directions set on Bblearn. The hypothesized functional model and the black box were the most difficult methods. Due to lack of information about how the arena would be assembled for the trash to be picked up we didn't have much to go off of for those methods. Creating ideas was an arduous task because we didn't know if they would apply to the situation in the future. Creating customer requirements (CR'S) that were going to be specific to the project was hard due to the ambiguity of the description in the beginning. For example a good customer requirement could length and width restraints but without the dimensions of the arena this would be nearly impossible to estimate. So, we had to settle for more general CR's like safety, weight, efficiency etc. Our QFD helped the team identify the most important CR's which overall was the easiest part of the "clarifying the problem" portion. Figure 1 depicts our black box model and Figure 2 shows the hypothesized functional model, which was difficult to be specific on before knowing exactly what the device was going to be.

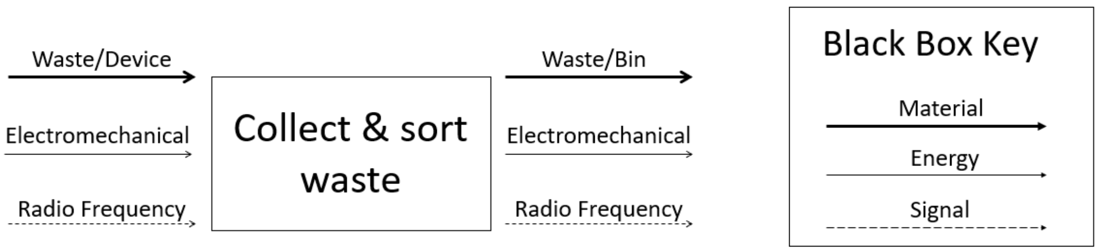

Figure 2: Black Box Model

2.2 Develop Concepts II

C-sketch, Morphological Matrix, Brainball, and bio-inspired were the methods we used to develop concept variants (CV's). Each of us created one of each to make a total of 12 CV's. From there we narrowed down our CV's by using the pugh chart in which we gave each CV a grade and the ones with the lowest score would be eliminated. Then the decision matrix narrowed down our CV's to about one or two. We used back of the envelope calculations for all our CV's. This was important because we can find out how much a certain material weighs and this can affect the amount energy, force, momentum etc. These calculations helped us determine which CV's would perform the best within our engineering requirements.

2.3 Embodiment

DOE, proof of concept, and the alpha prototype were the methods we used for the embodiment part of the design process. The proof of concept helped us test the motors subsystem. The DOE helped us choose two variables like the length, width, and durability our popsicle sticks. This way we could test out different variations of these variables. If the device was manufactured it would eliminate some possible causes of failure in the Failure Modes Evaluation Analysis by the recommendations made in the Design for Manufacture & Assembly. The team could have improved the design by replacing the yarn with something stronger to eliminate possibility of it breaking.

2.4 Concept Analysis

Once the team had all twelve CV's to work with, they generated a Pugh Chart to eliminate the variants with the biggest negatives, pictured in Table 1a & 1b. The Pugh Chart is used to help identify which aspects of a variant are not useful in satisfying the customer needs or engineering requirements. It allows the team to attack each negative in comparison to a datum point while trying to find a solution or in making the most positive variant better. This chart is to help pool the team down to four variants to use in the Decision Matrix in order to find what the final design will be.

Table 1a: Pugh Chart

	Duct Tape	Puffer Fish 1	Pool Net	Longboard Vacuum	Scorpion
Reliability	-	-	+	-	0
Safety	+	+	+	+	0
Efficiency	+	+	+	+	0
Portability	+	+	-	+	0
Cost	+	-	+	+	0
Originality	-	+	-	-	Datum CV

Table 1b: Pugh Chart

Sweeper Tank	Snake Arm	Puffer Fish 2	Flexible Scoop	Tongs	
+	+	-	-	+	Reliability
+	+	+	+	+	Safety
+	+	+	+	+	Efficiency
-	+	-	-	+	Portability
-	-	-	-	+	Cost
-	-	+	+	-	Originality

Our team was able to pull four CV's from the information in the Pugh Chart to form the Decision Matrix in Table 2. The criteria used were the measurable engineering requirements and their weights from the QFD in comparison to the four CV's from the Pugh Chart. The Decision Matrix revealed that the team did not collaborate with each others ideas, because a consensus was formed to combine parts of each CV in the Decision Matrix to find what the final design would be. Our team agreed to an remote-controlled car with a claw, enforced with some adhesive for additional friction on collections, and an attached "scorpion" tail that would pull the bin to tip over so the claw can easily grip and release trash into the opening.

Table 2: Decision Matrix

Criteria	Weight	RC Car Pool Net	Trash Tongs	Duct Tape Pad	Scorpion
Speed	0.17	**90 \ 15.3**	**60 \ 10.2**	**70 \ 11.9**	**80\13.6**
Device weight	0.16	**75 \ 12**	**100 \ 16**	**40 \ 6.4**	**50\8.0**
Price	0.11	**50 \ 5.5**	**15 \ 1.65**	**20 \ 2.2**	**40\4.4**
Thickness of Material	0.13	**40 \ 5.2**	**45 \ 5.85**	**50 \ 6.5**	**30\3.9**
Power	0.10	**10 \ 1**	**30 \ 3**	**40 \ 4**	**60\6**
Safety Factor	0.10	**100 \ 10**	**100 \ 10**	**100 \ 10**	**100\10**
Force against Gravity	0.23	**40 \ 9.2**	**65 \ 14.95**	**70 \ 16.1**	**10\2.3**
Totals	**1**	**\ 58.2**	**\ 61.65**	**\ 57.1**	**\48.2**
Relative Rank		**2**	**1**	**3**	**4**

2.5 Detailed Design - Cost Analysis

The team decided to do a cost analysis of the entire product. The team estimates their design time should cost about $30 dollars per hour for the amount of knowledge that they currently have. The team dedicated about 40 hours to the project combining all the steps of the design process including gathering customer needs, creating requirements for the project, generating concept variants and building a prototype.

Figure 3: Estimated Cost for Mass Production

To manufacture a large portion of the waste collectors made mostly of a rigid steel it would cost about $2269.88 USD per device. The cost analysis of this product showed the team how different the prototype version of a product is vastly different from a mass production of the product. Our prototype would have been more reliable if the team had access to the resources to create sturdier subassemblies and parts. Instead of making the body of popsicle sticks, the team could have made the body out of an aluminum. If the product was manufactured by a client the product would become more reliable, durable, and easier to assemble.

2.6 Beta Prototype

For our teams beta prototype the team decided to change from a small track RC base to a wider and longer RC base. This would give the device more stability and more room to add needed parts. Once the team was far enough into the design process, they realized their original base for the device contained too many pre manufactured sub-systems made by this RC company which interfered with the rules and regulations. Last minute, they had to create a new base out of popsicle sticks to eliminate enough sub-functions to allow it for use on competition day. The team had an original idea to tip the bin over with the front of the RC car, but with the base replacement, the car was no longer strong enough. Instead, the team used extended arms coming off the back of the base to hook and pull the top of the bin to tip over, pictured in Figure 4. This prototype worked during testing, so the team expected it to be successful on competition day.

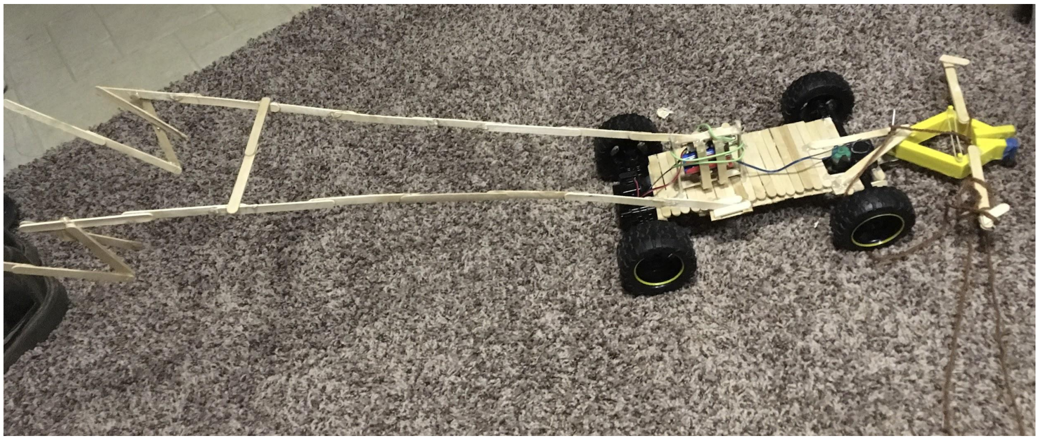

Figure 4a: Beta Prototype

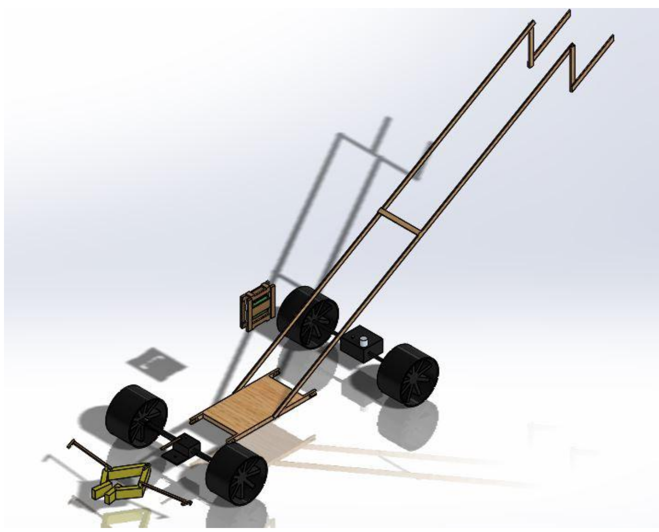

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Figure 4b: Beta Prototype Exploded View

The team created the Bill of Materials to document how much the device costed the team and if it fell well within the project parameters, provided in Table 3. The team was surprised to see that they were able to create a device of this caliber at a relatively low cost. The lesson learned was that it is still possible to create a project device without any fancy equipment or resources. The team did not use a wide variety of parts, keeping the device as simple as possible at the lowest cost.

Table 3: Bill of Materials

Bill of Materials						
Project 2 WDS Beta Prototype						
Team Number: OD 53						
Part #	**Part Name**	**Qty**	**Description**	**Material**	**Cost**	**Source**
#1	Wheels	4	RC wheels that have multi directional turn radii.	Rubber, plastic	$2	Walmart
#2	Body/Wood Base	1	A base that holds the wheels, motor, and wires in place.	Popsicle sticks	$5	Walmart
#3	Motor	2	The motors provide torque so the wheels will spin.	Varying metals and plastics	$1.95	Walmart
#4	3D printed Claw	1	The claw allows the user to pick up the selected piece of trash.	ABS Plastic	$6	Cline Library
#5	Batteries	2	Supplies the motors with a certain voltage.	Lithium	$4	Walmart
#6	CPU	1	Allows the car to move through the process of coding.	Silicon	$10	Walmart
#7	Axles	2	Keep the body and the wheels in place for turning.	Plastic	$8	Walmart
#8	Bolt and nut	1	Secure attachments	zinc	$2	Home Depot
#9	Washers	3	Attach objects without friction	zinc	$2	Home Depot
Total Cost Estimate:					$40.95 -	

2.7 Assembly Drawing

The team learned many things through the assembly drawing such as how the product is supposed to fit together. This gave the team a visual that could be precisely referenced so all team members were on the same page at all times. The assembly drawing allowed the team to analyze the cost of the prototype and the cost of the manufacturing of the device. Figure 5 documents how the device is put together with all the corresponding parts from Table 4.

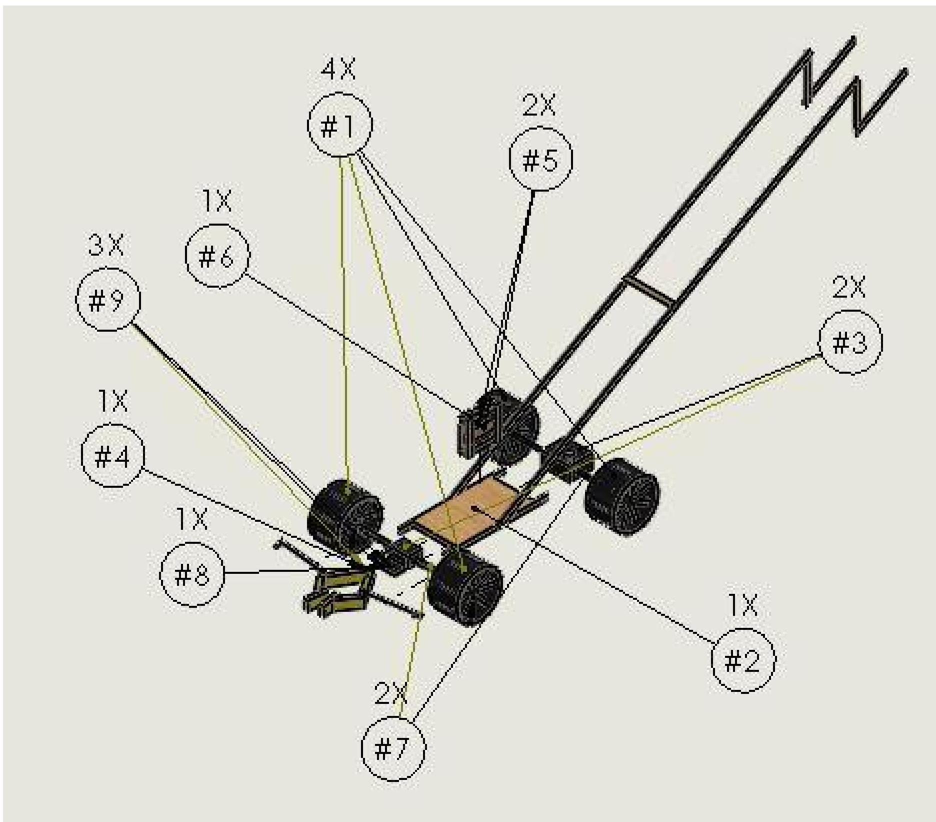


Figure 5: Exploded View of Assembly Drawing in Solidworks

Table 4: Part numbers and composition for Assembly drawing

Part #	Part Name	Required	Material
1	Wheels	4	Plastic
2	Wooden Base	1	Popsicle Sticks
3	Motor	2	Varying Metals and Plastic
4	3D Claw	1	ABS Plastic
5	Batteries	2	Lithium
6	CPU	1	Silicon
7	Axels	2	Plastic
8	Bolt and Nut	1	Zinc
9	Washers	3	Zinc

3 Conclusions

This report outlines the steps team OD 53 took to get from an assignment prompt given by the professor to a beta prototype that was used on competition day. Some of the initial steps were examining the customer needs learned from the professor and the rules and regulations and then relating those customer needs to make a black box and hypothesized functional model. The customer needs were revisited by the team repeatedly to assure the design would earn us the highest possible grade and do well on competition day. The team then generated concepts using methods like the morphological matrix in Appendix A and bio inspired designs shown in Appendix B. The pugh chart and decision matrix were then used to see which design yielded the best results. The team started prototyping various parts and subfunctions of the device to culminate into the beta prototype, used on competition day.

This report also contain key information about the team members and some criticism about the ways we could have improved our device and working together as a team. There is also a section about our team's proposal for manufacturing if our device was manufactured on a large scale of hundreds of devices. As previously mentioned there is a beta prototyping section and a cost of our one device and the device if it was mass produced. The below section discusses the results of our device on competition day along with how the group could have improved and what went well for the group.

3.1 Results

This section will be discussing competition day and how our device and our team performed. This was the day that half a semester's worth of work had been leading up to, making it a very important day in the minds of the entire team and ME 286 as a class. The team thankfully helped each other keep their cool. After arriving early to get a feel for the recently revealed competition area and scaling up the competition in earlier sections, two wooden support members seen in Figure 6a were added to the device under the hooks which would ensure durability. Team OD 53 collected themselves and their device in the waiting area. They discussed strategy and specific roles ahead of time to give the team more confidence and relaxation. We did final checks and got our device pre-evaluated by the profesor which revealed that our device did not fit within the volume requirements. Realizing that the long hooks in Figure 6b would obviously mean a loss of points added to the pressure and made us feel embarrassed that we had forgot about one of the simplest and important specification. Our team's first attempt showed that their was some practice needed as well as a little more testing. There was success in pulling the bin over but during that time the two long strings tangled and ate up too much time to collect a piece of trash. The claw failed to grab a piece of trash that first round because the string had to be untangled and was not kept away from the wheels as the device was moved into a position near the center of the arena where the trash was. The first step of out plan went well with good communication but the challenges with communication and attention to detail came during the second part. The team members tried to encourage each other knowing there was a second chance and the first could be considered practice.

In between rounds the strings were untangled and wound again. We also checked the hook which had broken a tip off a popsicle tip off during the first attempt at pulling the bin over. This break was not critical, so we did not stress fixing it. The steps of the plan were reviewed and specific techniques were practice repeatedly.

The second round went faster in general and the device did succeed in grab a piece of trash but got stuck trying to place that piece in the overturned bin. We regrettably did not complete the task before the teaching assistant called time. The communication was not perfect, but it was an improvement from the previous round. Although it was close, our device failed to complete its task.

In testing our device had been successful, so failing twice on competition day was unexpected. Testing was done in the same room with the same bin, but the mistake probably was not timing ourselves enough and taking into account the added pressure of a competition with peers and judges watching the team's and the devices every move. As a team we learned again that communication is vital to success and that testing in an environment as close to the one we will be judged in as possible will improve performance. Competition day also revealed how crucial the testing phase of original design is. We also learned that although this was a project to teach engineering topics, most of the score or grade for our device came from performance during the competition. In general there were most likely more mistakes made during the middle and end of the our team's design process than specifically on competition day, but there were still challenges with the device and team that day.

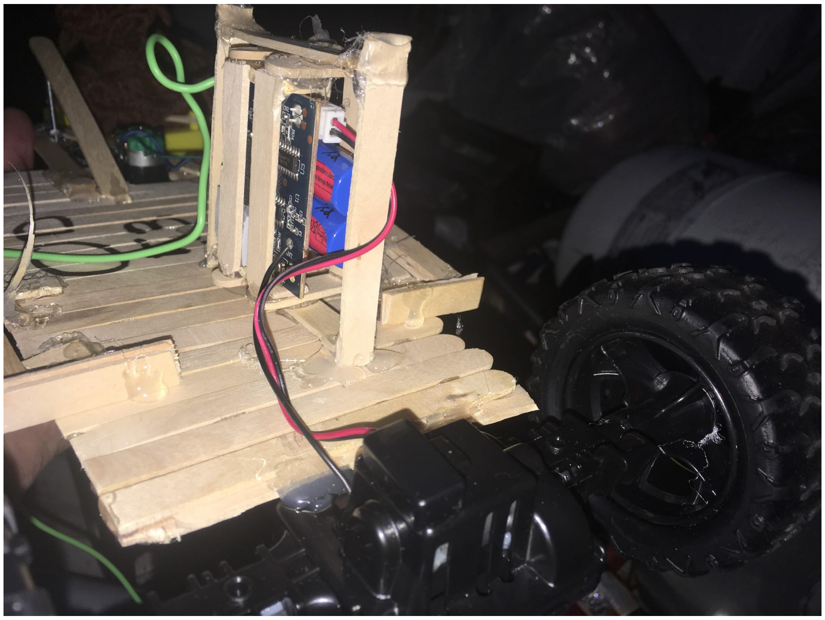


Figure 6a: Showing the added support without the hooks attached.

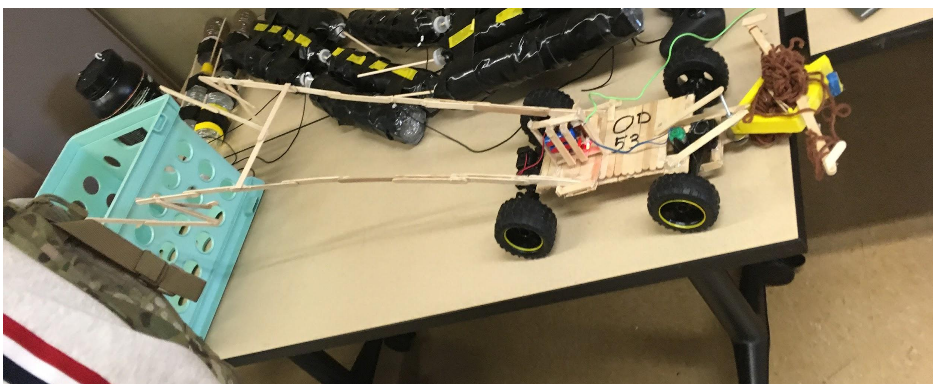
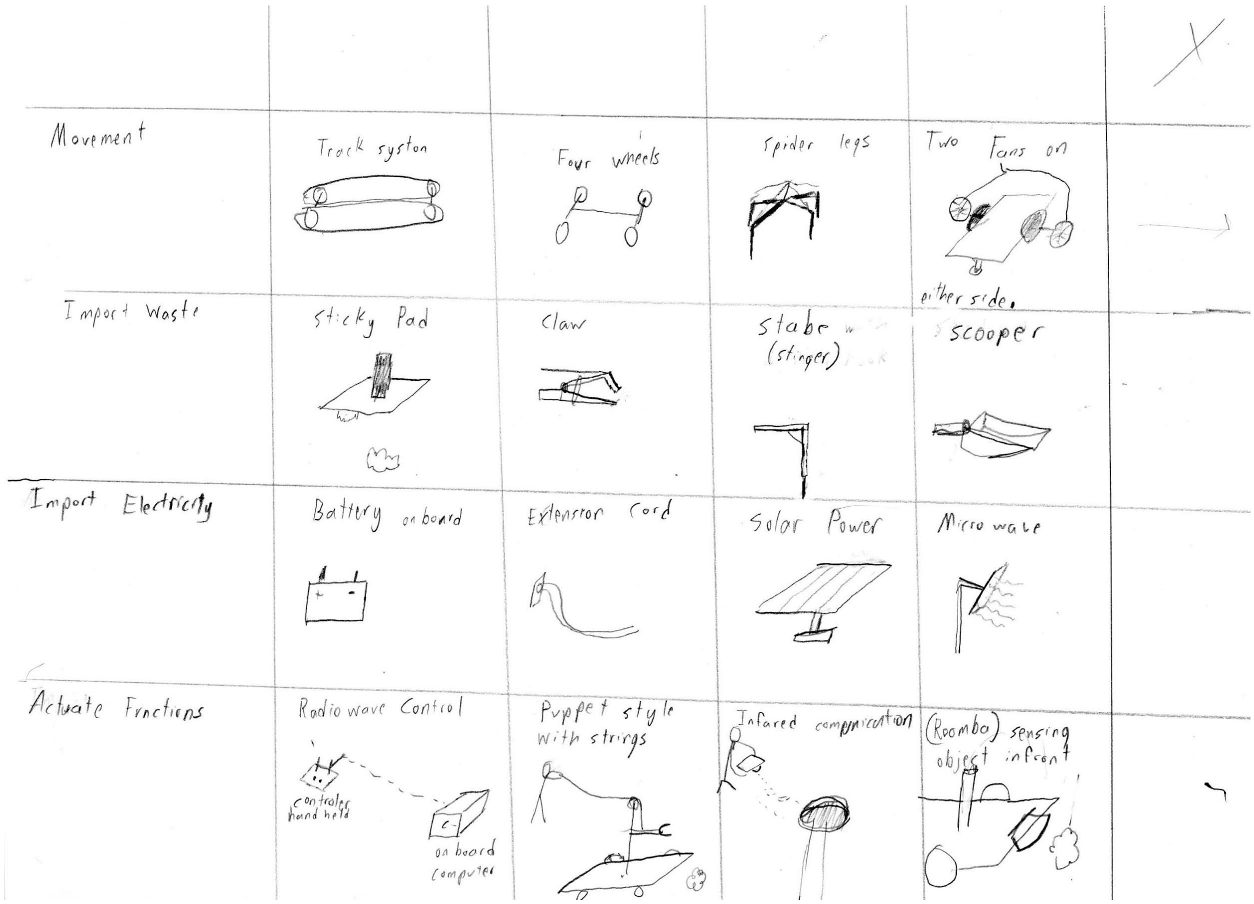


Figure 6b: Device with long hooks attached.

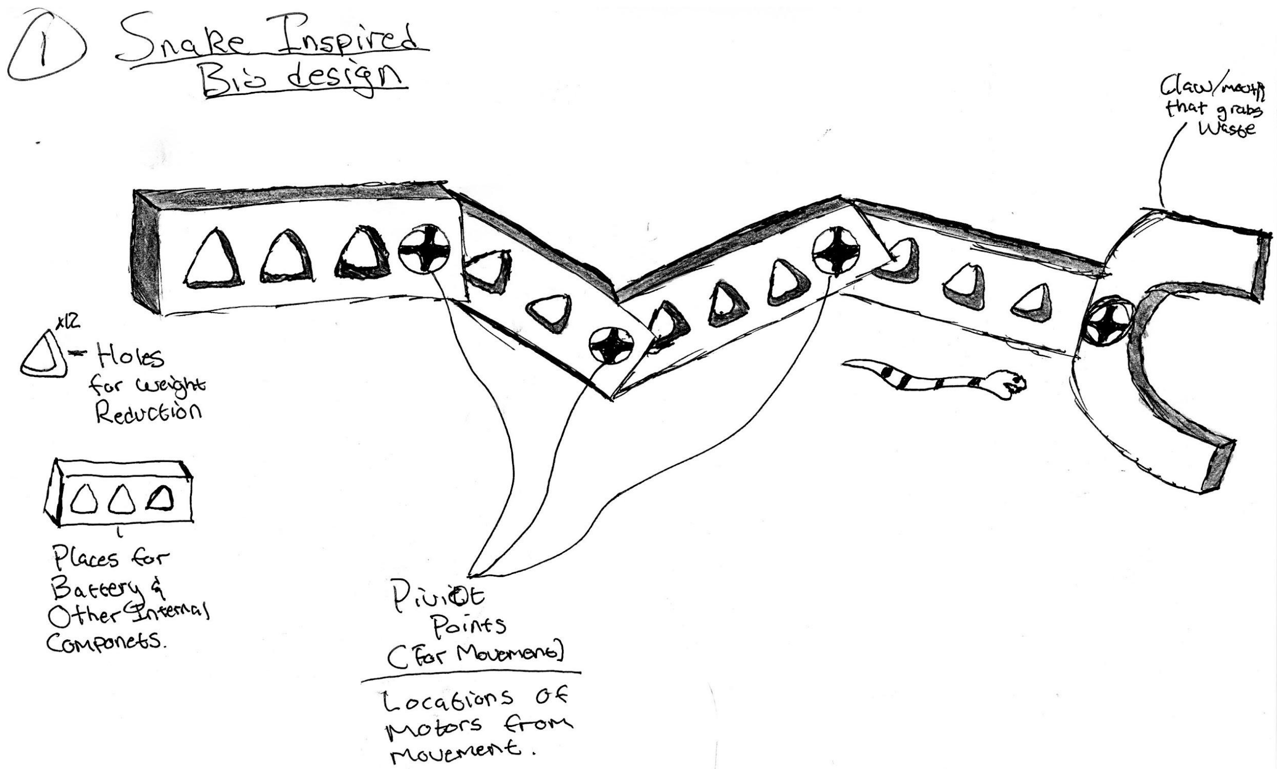
3.2 Post Mortem

Unfortunately the team did not complete the mission given to us, the team failed at picking up at least one single piece of trash and put it into a trash bin. Cost of prototypes and development were some of the most positive aspects of the project performance. The quality of the prototype and the manufacturing cost were the most negative parts of the project's performance, during the trial a small piece of the rear tipping device broke off into the waste collector making the device less durable and therefore have less quality. Some of the methodologies that helped the team in completing this project were the QFD (house of quality), and the functional models and the tool that helped us the most was the prototyping of our design. This is because the prototyping phase in the design process gave us devices that physical experiments to test different aspect instead of just theoretical although finding time for these experiments was difficult. Some of the problems the team encountered were finding times to meet. The team had very different work and school schedules and on most occasions the entire team was not able to meet and had only three or two at a time, however it was mostly a rotation of members for example to teammates would meet up and then a third would join then one would leave and another would come and join. The only times the entire team was able to meet up was later at night and designated class periods. Further planning ahead or a better use of the gantt charts would improve performance of the team and designated sections that are supposed to be done. The value of putting customer needs into models such as a black box model, hypothesized functional model, and QFD were important technical lessons learned. The value of prototyping and learning to evaluate concepts variants through pugh charts and decision matrix. These tools were important in making the final product of our design. Throughout this team focused original design project, important engineering and team oriented skills were learned and practiced which will help us for the rest of our engineering careers.

Appendix A


Movement
Track syston
Four wheels
Spider legs
Two Fans on either side.
Import Waste
Sticky Pad
Claw
Stabe (stinger)
scooper
Import Electricty
Battery on board
Extenson Cord
Solar Power
Micro wave
Actuate Fnctions
Radio wave Control
controler hand held
on board computer
Puppet style with strings
Infared communication
(Roomba) sensing object infront

Appendix B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Snake Inspired
Bio design
Claw/mouth that grabs Waste
x12
Holes for Weight Reduction
Places for Battery & Other Internal Componets.
Pivot Points (For Movement)
Locations of Motors from Movement.