Concept Selection

Binary Pairwise Comparison

Binary Pairwise Comparison												
Customer Requirements	1	2	3	4	5	6	7	8	9	10	11	IWF:
1. Under 12 Kg	-	1	0	0	1	0	0	0	0	1	1	4
2. Starts with LED (under 3 sec)	0	-	1	0	1	1	1	1	0	1	1	7
3. Size Contraint Followed	1	0	-	0	1	0	1	0	0	0	1	4
4. Battery Powers Robot	1	1	1	-	1	1	0	1	0	1	1	8
5. IR Camera Works in Cave	0	0	0	0	-	0	0	0	0	0	1	1
6. Intakes Material	1	0	1	0	1	-	1	1	0	1	1	7
7. Reads April Tag	1	0	0	1	1	0	-	0	0	0	1	4
8. Feedback System	1	0	1	0	1	0	1	-	0	1	1	6
9. Autonomous	1	1	1	1	1	1	1	1	-	0	1	9
10. Detect Materials	0	0	1	0	1	0	1	0	1	-	0	4
11. Sort Different Materials	0	0	0	0	0	0	0	0	0	1	-	1
Total:	6	3	6	2	9	3	6	4	1	6	9	10

The binary pairwise comparison (BPC) compares each of the customer requirements to each other and helps determine the most promising design solutions. The result of every comparison is either a 1 if that option is preferred or a 0 if that option is not preferred. The scores are added together across each row. The requirements with the highest scores were the robot being autonomous, the battery powering the robot, the robot intakes material, and the robot starts within 3 seconds after the LED is lit.

House of Quality

		Engineering Characteristics											
Improvement Direction		↓	↑	↑	↓	↓	↓	↓	↓	↓	↓	↑	↑
Units		lbs	V	ft	sec	min	ft^3	sec	sec	#	sec	ft	lb-ft
Customer Requirements	Importance Weight Factor	Weight	Voltage from Power Supply	Stability	Time to Move	Time to Complete Collection	Volume	Time to Place Beacon	Time Place Bins	Sensors	Speed of Shutoff	Mobility	Wheel Torque
1. Under 12 Kg	**4**	9		3			9	1				9	9
2. Starts with LED (under 3 sec)	**7**				9			3		3			
3. Size Contraint Followed	**4**	3		3			9					9	9
4. Battery Powers Robot	**8**	3	9				1			9			
5. IR Camera Works in Cave	**1**						1			3			
6. Intakes Material	**7**			1		9	3		1			3	3
7. Reads April Tag	**4**						1		9	3			
8. Feedback System	**6**			3			1	9			9		
9. Autonomous	**9**			1			1	9		9			
10. Detect Materials	**4**					3	1		3	3			
11. Sort Different Materials	**1**			1		1	1					1	
Raw Score:	1125	72	72	59	63	76	126	160	55	201	54	94	93
Relative Weight %:	100.0	6.4	6.4	5.2	5.6	6.8	11.2	14.2	4.9	17.9	4.8	8.4	8.3
Rank Order:		7	7	10	9	6	3	2	11	1	12	4	5

The House of Quality (HoQ) compares the customer requirements to measurable engineering characteristics in order to help the team prioritize features that best address the customer's priorities. Customer requirements are given a weight factor, and the engineering characteristics are given a score corresponding with each requirement. The possible scores were 1, 3, 9, or nothing if it was not applicable. The scores were multiplied times their respective weight factor, and the products for each engineering characteristic were summed together to get an overall score. The results of our HoQ show that sensors, time to place beacon, volume, wheel torque, and mobility are the most important engineering characteristics the team will need to prioritize due to having the highest overall scores. Those lower in priority are speed to shutoff, time to place bins, and stability due to having the lowest overall scores.

Pugh Charts

		Concepts							
Engineering Characteristics	Datum	1	2	3	4	5	6	7	8
Weight		+	S	+	+	S	+	S	S
Voltage from Power Supply		S	-	S	S	-	-	-	S
Stability		+	S	+	+	-	-	+	+
Time to Move		+	+	+	-	-	-	S	S
Time to Complete Collection		-	+	+	-	-	-	S	-
Volume		+	S	+	S	S	S	-	+
Time to Place Beacon		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Time Place Bins		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Sensors		S	S	S	S	-	-	+	S
Speed of Shutoff		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Mobility		+	S	+	+	-	-	-	S
Wheel Torque		+	+	+	+	-	S	-	S
# of pluses		6	3	7	3	0	1	2	2
# of minuses		1	1	0	2	7	6	4	1

1	Compactor	☑
2	Multi-Conveyor	☑
3	Lazy Hercules	☑
4	The Band Box Bot	☑
5	Magnetic Bulldozer	
6	Robotic Claw	
7	Frank	
8	Clamp and Lift	☑

High Fidelity
Medium Fidelity
Datum: Nothing But Net Robot
Eliminated

		Concepts			
Engineering Characteristics	4	1	2	3	8
Weight		-	-	S	S
Voltage from Power Supply		-	+	+	S
Stability		-	+	+	+
Time to Move		+	+	+	+
Time to Complete Collection		-	+	+	+
Volume		S	-	S	S
Time to Place Beacon		+	+	+	+
Time Place Bins		+	+	+	-
Sensors		-	+	S	S
Speed of Shutoff		S	S	S	S
Mobility		+	S	S	-
Wheel Torque		-	S	S	S
# of pluses		4	7	6	4
# of minuses		6	2	0	2

1	Compactor	
2	Multi-Conveyor	☑
3	Lazy Hercules	☑
8	Clamp and Lift	☑
4	The Band Box Bot	DATUM

Selected:	
1	3
2	2
3	8

For Pugh Chart 1, team 507 used a video from a robotics competition titled "Nothing but Net" as a datum. We compared our 3 high fidelity and 5 medium fidelity concepts to the datum based on the criteria in the first column. Some criteria could not be compared to the datum and is why some cells have N/A. Concepts 5, 6, and 7 performed poorly in this chart. None of these concepts received more than 2 pluses, or less than 4 minuses. For this reason, those three were eliminated. Concepts 1 and 3 performed well, receiving 6 and 7 pluses. Concepts 1, 2, 3, 4, and 8 were kept and used in Pugh Chart 2.

In Pugh Chart 2, concept 4 was used as the datum. After comparing the remaining concepts to the datum based on the criteria in the first column, concept 1 scored the worst with 4 pluses and 6 minuses; therefore, it was eliminated. The three remaining concepts, in order of performance in the chart, are listed as 3, 2, and 8.

AHP

Criteria	Weight	Voltage from Power Supply	Stability	Time to Move	Time to Complete Collection	Volume	Time to Place Beacon	Time Place Bins	Sensors	Speed of Shutoff	Mobility	Wheel Torque	Sum
Weight	1	5	7	5	3	1	7	7	7	7	5	5	60.03
Voltage from Power Supply	0.20	1	3	7	7	0.33	7	7	7	7	7.00	7.00	60.53
Stability	0.14	0.33	1	3	3	0.20	5	5	7	7	7.00	7.00	45.68
Time to Move	0.20	0.14	0.33	1	0.20	0.14	1	1	0.33	0.33	0.20	0.14	5.03
Time to Complete Collection	0.33	0.14	0.33	5	1	0.20	3	3	0.33	5	3.00	3.00	24.34
Volume	1	3	5	7	5.00	1	7	7	5	7	5.00	5.00	58.00
Time to Place Beacon	0.14	0.14	0.20	1	0.33	0.14	1	0.33	0.33	3	0.33	0.33	7.30
Time Place Bins	0.14	0.14	0.20	1	0.33	0.14	3.00	1	0.33	3	0.20	0.20	9.70
Sensors	0.14	0.14	0.14	3	3.00	0.20	3.00	3.00	1	7.14	5.00	5.00	30.77
Speed of Shutoff	0.14	0.14	0.14	3	0.20	0.14	0.33	0.33	0.14	1	5.00	5.00	15.58
Mobility	0.20	0.14	0.14	5	0.33	0.20	3.00	5.00	0.20	0.20	1	1.00	16.42
Wheel Torque	0.20	0.14	0.14	7	0.33	0.20	3.00	5.00	0.20	0.20	1.00	1	18.42
Sum	3.84	10.48	17.64	48.00	23.76	3.90	43.33	44.67	28.87	47.88	39.73	39.68	

Criteria	Weight	Voltage from Power Supply	Stability	Time to Move	Time to Complete Collection	Volume	Time to Place Beacon	Time Place Bins	Sensors	Speed of Shutoff	Mobility	Wheel Torque	{W}
Weight	0.260	0.477	0.397	0.104	0.128	0.256	0.162	0.157	0.242	0.146	0.126	0.126	0.215
Voltage from Power Supply	0.052	0.095	0.170	0.146	0.295	0.085	0.162	0.157	0.242	0.146	0.176	0.176	0.159
Stability	0.037	0.032	0.057	0.063	0.126	0.051	0.115	0.112	0.242	0.146	0.176	0.176	0.111
Time to Move	0.052	0.014	0.019	0.021	0.008	0.037	0.023	0.022	0.012	0.007	0.005	0.004	0.019
Time to Complete Collection	0.086	0.014	0.019	0.104	0.042	0.051	0.069	0.067	0.012	0.104	0.076	0.076	0.060
Volume	0.260	0.286	0.283	0.146	0.210	0.256	0.162	0.157	0.173	0.146	0.126	0.126	0.194
Time to Place Beacon	0.037	0.014	0.011	0.021	0.014	0.037	0.023	0.007	0.012	0.063	0.008	0.008	0.021
Time Place Bins	0.037	0.014	0.011	0.021	0.014	0.037	0.069	0.022	0.012	0.063	0.005	0.005	0.026
Sensors	0.037	0.014	0.008	0.063	0.126	0.051	0.069	0.067	0.035	0.149	0.126	0.126	0.073
Speed of Shutoff	0.037	0.014	0.008	0.063	0.008	0.037	0.008	0.007	0.005	0.021	0.126	0.126	0.038
Mobility	0.052	0.014	0.008	0.104	0.014	0.051	0.069	0.112	0.007	0.004	0.025	0.025	0.040
Wheel Torque	0.052	0.014	0.008	0.146	0.014	0.051	0.069	0.112	0.007	0.004	0.025	0.025	0.044
Sum	1	1	1	1	1	1	1	1	1	1	1	1	1

The analytical hierarchy process (AHP) was started to rank engineering characteristics from the Pugh Charts and determine which are the most important when selecting a concept. The team had both the columns and rows summed though only the column summation was used when normalizing to make sure there was variation from the binary pairwise comparison. Due to the tightly regulated customer needs and requirements, it was difficult to compare the engineering characteristics against each other and pick which ones had higher importance. All of the characteristics are required and must follow a strict rule book. The volume and weight, for example, have strict requirements that must not be deviated from, and this ties into most other characteristics. The weight determines the wheel torque as a motor needs to be spec-ed to the right value to be able to move the robot. Then the voltage required to power the motor determines the voltage required to power the robot. As a team it was determined that there was no need to carry on with the AHP process any further due to all the requirements being so necessary and tightly tied together when most of the concepts generated and in the high and medium fidelity categories follow these characteristics.

Final Selection

After deliberation, Team 507 concluded that the third concept generated, referred to as “Lazy Hercules”, is the best concept to move forward with. It has been determined to not be overly mechanically difficult to design and construct, while also being mobile. It doesn’t have an overly specific collection mechanism, so attaching any further improvements to the conveyor belt system will be simple. This design is a good modular base to iterate upon and a great prototype to begin working on.