MILESTONE 8: Concept Selection

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Introduction

The FSU-PC design team was tasked with constructing an autonomous boat for the 2021 RoboBoat Competition. Thus far, we have generated a function decomposition diagram from the interpreted customer needs and competition requirements, devised important targets and metrics, and produced a morphological chart that led to the generation of 5 medium fidelity sketches for a possible boat design. The final concept selection was achieved through the following processes: Binary Comparison Chart, House of Quality (HoQ), Analytical Hierarchy,Pugh Chart, and a final Decision Matrix.

Binary Comparison Chart

A binary comparison chart is used to compare customer requirements one by one to decide how important they are with respect to other customer requirements. However, when comparing requirements, they are not given weighted values at first. It is simply determined whether one requirement is more important than the other. After all requirements have been compared, the totals are taken to find the appropriate weighting for the requirements. These weightings are then used in the house of quality chart for the importance factor.

	1	2	3	4	5	6	7	Total
1. Weight	-	1	0	0	0	1	0	2
2. Size	0	-	0	0	0	1	1	2
3. Buoyancy	1	1	-	1	1	1	1	6
4. Stability	1	1	0	-	0	0	1	3
5. Sensing	1	1	0	1	-	1	1	5
6. Maneuvering	0	0	0	1	0	-	1	2
7. Safety	1	0	0	0	0	0	-	1
Total	4	4	0	3	1	4	5	n-1=6

Figure 1: Binary Comparison Chart

House of Quality (HoQ)

The House of Quality is used to relate our customer needs to engineering characteristics to determine priority. Using the importance factors found by the binary comparison chart, we can directly compare how our engineering requirements will relate to our customer needs. This allows us to focus our attention on characteristics that will more heavily impact the ability of our final design to meet our found customer requirements.

		Engineering Characteristics								
Improvement Direction		↑	↑	↑	↓	↓	↓	↑		↓
Units		N	M	MHz	cm	cm	kg/m3		N/A	N
Customer Requirements	Importance Factor	Thrust	Sensing Distance	Processing Speed	Center of Gravity	Localization Accuracy	Material Density	Strength/Density	Coating/Seal	Drag Force
Weight	2	3			9		9	9	1	3
Size	2	1	1		3	3	3			9
Buoyancy	6				9		9	1	3	1
Stability	3	3			9		3	3		1
Sensing	5		9	9		9				
Maneuverability	2	9	3	3	3	3	1			9
Safety	1	1	1	1		1	1	9	3	
Raw Score (517)		36	54	52	111	58	90	23	51	42
Relative Weight %		7	10.44	10.06	21.47	11.22	17.6	4.5	9.86	8.1
Rank Order		8	4	5	1	3	2	9	6	7

Figure 2: House of Quality

Each engineering characteristic is compared to the given customer requirements and rated based on a scale of 0,1,3,9 for how related they are, with a 0 having no correlation and a 9 having a high correlation. By doing this comparison we were able to determine that our most influential characteristic is the center of gravity, which will heavily impact the stability and buoyancy of our final design. This also finds that the least impactful characteristic is the coating, which will directly affect how the boat will interact with the water but is not as influential to the success of the final design as the other listed characteristics.

AHP

The AHP chart is used to compare how much more important the row is versus the column, or vice versa. To do this, we assign either a 1, 3, 5, 7, or 9 to whatever is more important, depending on level of importance. 3 low on importance and 9 being a higher importance. This is read as "row compared to column".The only time a 1 is used is when the same two categories are compared to each other, or two categories are very similar. Once we declare the importance level between two categories with either a 3, 5, 7, or 9. We write the inverse of the whole number when they are compared again (every category will be compared twice in different orders). Once the chart is filled out, all the scores are added up and recorded on the SUM row at the bottom. Using the categories in the respective column, the column with the lowest sum results in being the most important while the column with the highest sum results in being the least important. The order from most to least important characteristics are: Maneuverability, Reliability, Reparability, Hull Design, Cost, Hull Material, and Speed.

	Hull Design	Hull Material	Reliability	Reparability	Speed	Maneuverability	Cost
Hull Design	1	3	0.3	0.3	7	1	3
Hull Material	0.3	1	0.2	0.3	5	0.2	1
Reliability	3	5	1	3	3	0.2	3
Reparability	3	3	0.3	1	3	0.3	3
Speed	0.14	0.2	0.3	0.3	1	0.14	0.2
Maneuverability	1	5	5	3	7	1	5
Cost	0.3	1	0.3	0.3	5	0.2	1
Sum	8.74	18.2	7.4	8.2	31	3.04	16.2

Figure 4: AHP

Normalization and Criteria Weight

Figure 4 shows the Normalization and the Criteria Weight. The normalization is found dividing each cell by the sum of the column it is in. Once each cell is calculated, all the cells should add up to be 1. Also the Criteria Weight column is all the values of each row averaged out. The sum of these should also come out to equal 1.

	Hull Design	Hull Material	Reliability	Reparability	Speed	Maneuverability	Cost	Criteria Weight
Hull Design	0.114	0.165	0.041	0.037	0.226	0.329	0.18	0.157
Hull Material	0.034	0.055	0.027	0.037	0.161	0.066	0.062	0.063
Reliability	0.343	0.275	0.135	0.366	0.097	0.066	0.18	0.21
Reparability	0.343	0.165	0.041	0.122	0.097	0.099	0.185	0.15
Speed	0.016	0.011	0.041	0.037	0.032	0.046	0.012	0.03
Maneuverability	0.114	0.275	0.676	0.366	0.226	0.329	0.309	0.328
Cost	0.034	0.055	0.041	0.037	0.161	0.066	0.062	0.065
Sum	1	1	1	1	1	1	1	1

Figure 4: Normalized AHP

Pugh Chart

A Pugh Chart is a tool used to evaluate multiple options of a design against each other. A baseline is used to compare to an existing or proven concept. Values found using the House of Quality and AFP were used to find how we would determine which concept was best based on the Pugh Chart.

Selection Criteria	Baseline		Concepts				
			1	2	3	4	5
Material	RoboBoat 2020 DATUM		+	S	-	-	S
Center of Gravity			-	S	-	S	+
Thrust			+	+	S	+	S
Drag Force			+	-	-	S	S
Cost			-	S	-	-	S
	Total	# of plus	3	1	0	1	1
		# of minus	2	1	4	2	0
		# of same	0	3	1	2	4

Figure 5: Pugh Chart

The datum used for the Pugh Chart is the 2020 FSU PC senior design teams concept, we compared it to their design to see if our new concepts would be better or improve their design. The material selection criteria was to determine which material had the best strength ratio (Figure 6), which was measured by taking the tensile strength and dividing it by the density. The center of gravity (CG) was analyzed by observing the component placement on each type of hull and estimating the CG location. The thrust force is related to the weight, drag, size, and amount of power we have supplied to the thrusters, to measure this we made assumptions to simplify the problem. The assumptions suggest that thrust is greater with lighter boats, and more thrusters distributes power evenly (making the total amount of thrusters generate the same thrust but can maneuver the boat more easily). The drag force of the boat was evaluated based on the hull shape and size of each concept, we considered that we would be moving more slowly through the water so boat hulls like the flat bottom and v-hull would not benefit from high speed planing effects. The cost of the boat was mainly evaluated based on the assumption that the GPS system is the system used from the RoboBoat club (same for each design), the LiDAR system is the same for each design, and that the electrical engineering side would be handling the battery. This left the material as the main cost consideration, therefore it was evaluated based on the cost to strength ratio of each material (Figure 6).

	Density (g/cm^3)	Cost ($/Kg)	Tensile Strength (Gpa)	Strength Ratio (GPa/(g/cm^3))	Cost/ Strength Ratio
Carbon Fiber	0.9721	21.5	3.8	3.91	5.66
Fiber Glass	0.7869	5.51	1.02	1.298	5.402
Aluminum Alloy	2.7	15.98	0.339	0.1256	47.14
Wood	0.75	4.5	0.047	0.0627	95.74

Figure 6: Material Characteristic Comparison

Based on the Pugh Chart we found that the first concept was the best choice, with 3 of the selection criteria being better than the datum and 1 being worse than the datum.

Decision Matrix

The Decision Matrix was used to determine if our concepts are feasible based on data found in the Pugh Chart.

	Importance Weight Factor	Concept 1	Concept 2	Concept 3	Concept 4	Concept 5
Aesthetics	1	3	3	3	3	3
Component Space	3	3	1	9	3	3
Stability	9	9	3	3	9	3
Manufacturability	9	3	1	9	3	3
Total	198	120	42	138	120	66

Figure 7: Decision Matrix

The decision matrix found that Concept 3 was the easiest to manufacture and would have the most space for our components. Although considering the benefits found from the pugh chart, AHP and HoQ, it is determined that it would be worth the more difficult manufacturing to have the catamaran design. Therefore we acknowledge that it will be more difficult to manufacture, but will be pursuing the catamaran.

Final Decision

Therefore based off of the concept selection tools it is deemed that concept 1 would be the best design to pursue. There should be some modifications that will occur during the future design phase of the project, as one issue found with this concept is that the CG may need to be corrected based on component placement. It was also found that it would be worth it to use fiberglass for this design over carbon fiber as it is more cost effective for its strength and weight. It will use 3-4 differential thrusters to ensure good maneuverability in combination with high thrust.

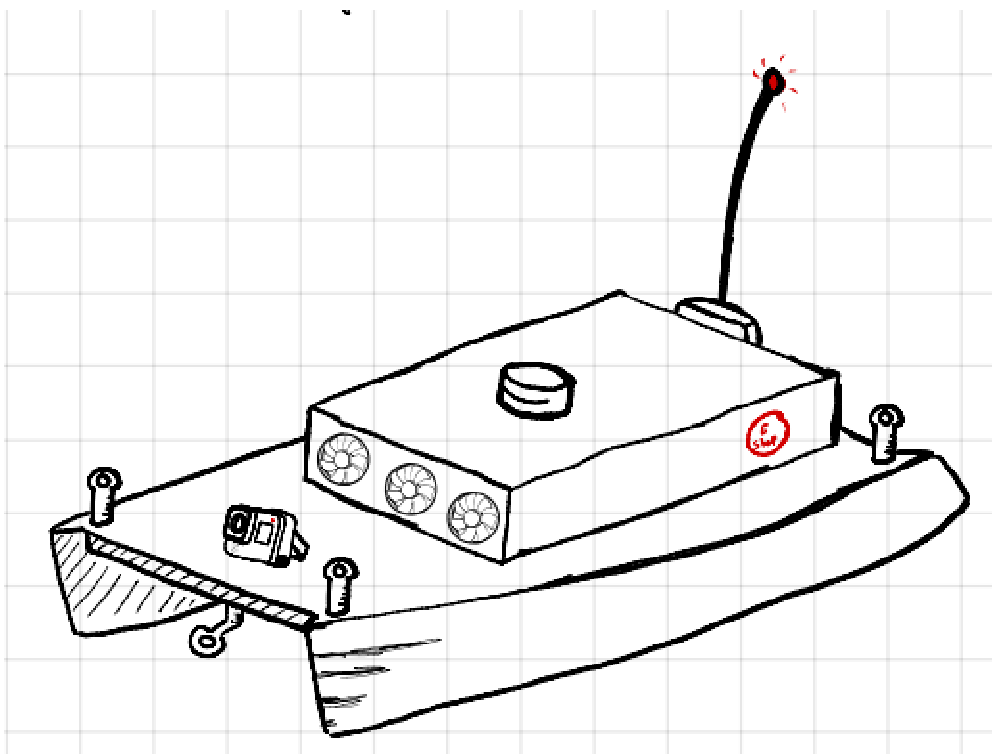

Figure 8: Perspective View

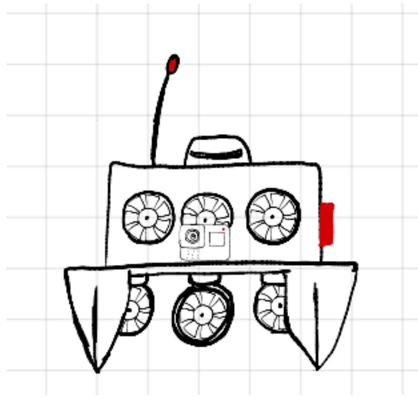

Figure 9: Front View

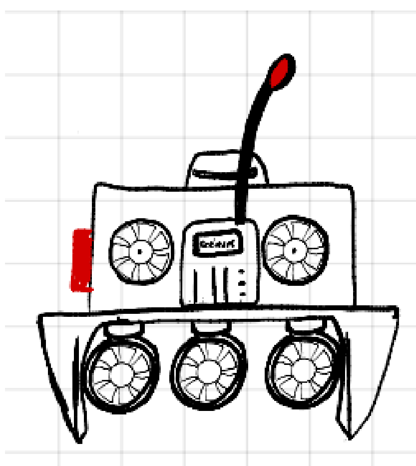

Figure 10: Rear View

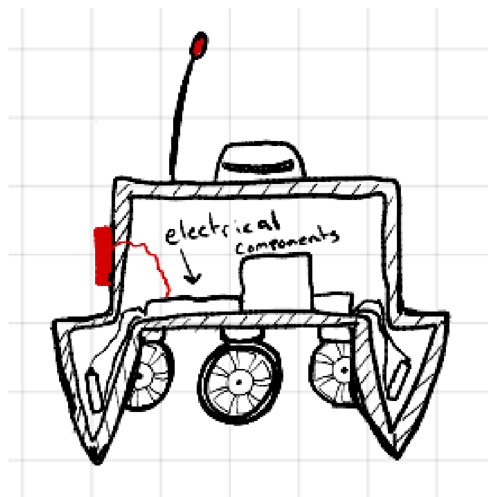

Figure 11: Cross-Section View

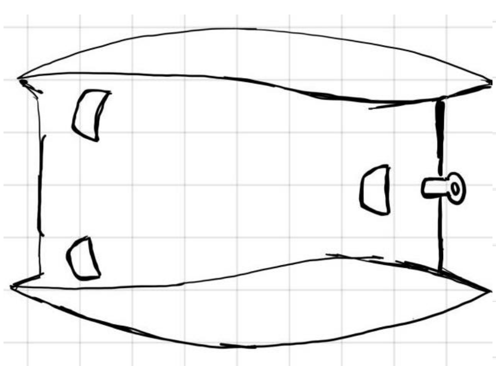

Figure 12: Bottom View

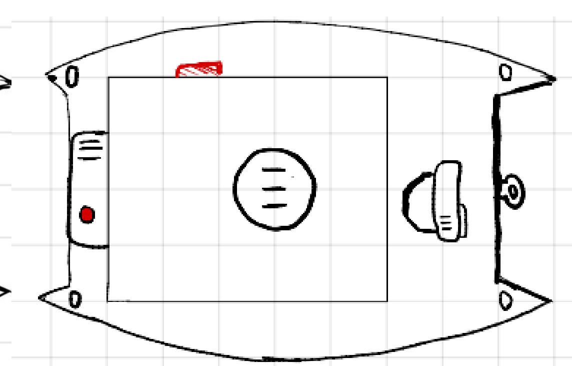

Figure 13: Top View