Concept Selection

House of Quality

To analyze our customer needs gathered from Corning, the team used the binary pairwise comparison chart shown in *Table 1* below. During this process, the customer needs are weighed against each other and given a 1 or 0 correlating to more importance or less importance respectively. The result of this is an importance weight factor for each of the customer needs which depicts protection of the ceramic and conveyor compatibility as the most critical needs for our project to accomplish.

Using the importance weight factor that the pairwise analysis provided, the House of Quality (HOQ) was created to determine the rankings of the engineering characteristics of the device. The HOQ scores the correlation of the weighted customer needs with the engineering characteristics of the project targets. The correlation score is multiplied by the weight factor of each of the customer needs to get a weighted ranking of the team's engineering characteristics. This ranking revealed that the most important characteristics are the return height, pallet securability, pallet surface area, and human interactions. These rankings allowed us to separate out the top characteristics to use as selection criteria when comparing the concepts against each other.

Table 1 :Binary Pairwise Comparison

	Customer Needs
1	Protects ceramic
2	Scaleable for ceramics
3	Limit human interaction
4	Works with given space
5	Works with conveyor conditions
6	Material choice
7	Improves current method

Customer Need	#1	#2	#3	#4	#5	#6	#7	Sum
#1	-	1	1	0	1	1	1	5
#2	0	-	0	0	0	1	0	1
#3	0	1	-	0	0	1	0	2
#4	1	1	1	-	1	1	1	6
#5	0	1	1	0	-	1	1	4
#6	0	0	0	0	0	-	0	0
#7	0	1	1	0	0	1	-	3

Table 2: House of Quality

	Targets/Metrics
1	Limit Movement
2	Damaged Percent
3	Top Pallet Area
4	Bottom Pallet Volume
5	Time Before Scanability
6	Return Height
7	Interactions Per cycle
8	Weight Capacity
9	Secure to pallet DOF
10	Max device weight
11	Assembly Time
12	Recycleability

		Engineering Characteristics											
Improvement Directions		↓	↓	↓	↓	↓	↓	↓	↑	↓	↓	↓	
Units		in	%	in2	in3	sec	in	#	lbs	#	lbs	sec	n/a
Customer Needs	Importance Weight	1	2	3	4	5	6	7	8	9	10	11	12
Protects Ceramics	5	9	9	0	0	0	0	0	9	9	0	0	0
Scaleable for Ceramics	1	0	1	3	1	0	1	0	9	0	0	9	0
Limit Human Interaction	2	0	0	0	0	9	9	9	0	1	0	3	0
Works with Given Space	6	0	0	9	9	0	9	3	0	3	0	0	0
Works with Conveyor Conditions	4	0	1	9	9	9	9	9	0	9	9	3	0
Material Choice	0	3	3	0	0	0	0	0	9	1	9	1	9
Improves Current Method	3	9	9	9	0	3	9	9	0	9	0	1	0
Raw Score	559	72	77	120	91	63	136	99	54	128	36	30	0
Relative Weight %		13	14	21	16	11	24	18	10	23	6	5	0
Rank Order		7	6	3	5	8	1	4	9	2	10	11	12

Up	Down	Null
↑	↓	

Scale	
0	Not at All
1	Slightly
3	Moderatly
9	Significantly

Pugh Chart

Pugh charts are a simple method of comparing the high and medium fidelity concepts and narrowing down possible designs into a smaller group that can more feasibly be tested in the time allowed for the project. To start the pugh chart analysis, a datum that is known to perform similar functions as the project is chosen and compared to the high and medium fidelity concepts. Each concept is rated on how well it fulfills the customer's needs compared to the datum and is given a plus (+), minus (-), or satisfactory (s). This process is repeated after eliminating the concept(s) given more negative ratings than others. The first iteration of the Pugh charts shown in *Table 3* compares the three high and five medium fidelity concepts to the selected datum, this being Corning's current stabilization method, the plexiglass T supports.

Table 3: Initial Pugh Chart

		Concepts							
Selection Criteria		Magnetic Swivel	Pincer	4 Bar	Sand Bag	Sensor Gate	2 Long Poles	Swedish Wheels	Self-nesting T
Protects Ceramics	Datum: Current T System	s	s	s	s	s	s	s	s
Scaleable for Ceramics		+	+	s	+	s	+	+	s
Limit Human Interaction		+	+	+	+	+	+	+	+
Works with Given Space		+	s	+	s	s	-	+	+
Works with Conveyor Conditions		+	s	+	+	s	+	+	+
Material Choice		-	-	-	s	-	s	-	-
Improves Current Method		+	+	+	s	s	s	s	+
# of Pluses		5	3	4	3	1	3	4	4
# of Satisfactory		1	3	2	4	5	3	2	2
# of Minuses		1	1	1	0	1	1	1	1

After consideration of each idea's potential performance, the scores were tallied with the sensor gate design being eliminated for meeting the least amount of customer needs. Swedish wheels had a significant amount of positives but were removed due to the negative scoring in protecting the ceramic. The magnetic swivel concept earned the most positive scores and was then used as the datum for the next iteration of the Pugh charts. Following iterations of Pugh charts can be found in Appendix F.

Table 4: Final Pugh Chart

Selection Criteria		Magnetic Swivel	Pincer	[redacted]	Self-nesting T
		Concepts			
Protects Ceramics	Datum: Pincer	s	s	[redacted]	+
Scaleable for Ceramics		s	s	[redacted]	-
Limit Human Interaction		s	s	[redacted]	s
Works with Given Space		s	s	[redacted]	+
Works with Conveyor Conditions		s	s	[redacted]	-
Material Choice		s	s	[redacted]	-
Improves Current Method		s	s	[redacted]	s
# of Pluses		0	0	[redacted]	2
# of Satisfactory		7	7	[redacted]	2
# of Minuses		0	0	[redacted]	3

On the final iteration of the Pugh charts, shown in *Table 4*, the concepts that were determined to be most suitable at satisfying the customer needs were the magnetic swivel, pincer, and self-nesting T designs.

Analytical Hierarchy Process

The Analytical Hierarchy Process is another method used in the concept selection process that mathematically evaluates the importance of each criteria of the project. This method helps to remove any personal bias the team may have towards any one or more concepts. To do this, each of the customer's needs are compared to one another based on their importance and a score of 1, 3, 5, 7, or 9 is given to reflect that relative importance where 1 shows equal significance and 9 means an extreme difference in significance. These scores can be found in Appendix G. The sums of each need's scores are used in the Normalized Comparison Matrix in *Table 5*.

Table 5: Normalized Comparison Matrix

	Normalized Criteria Comparison Matirx [NormC]	1	2	3	4	5	6	7	Criteria Weights {W}
1	Protects Ceramics	0.046	0.039	0.043	0.020	0.161	0.055	0.158	0.075
2	Scaleable for Ceramics	0.418	0.352	0.304	0.415	0.290	0.382	0.158	0.331
3	Limit Human Interaction	0.046	0.050	0.043	0.020	0.032	0.042	0.053	0.041
4	Works with Given Space	0.139	0.050	0.130	0.059	0.161	0.055	0.053	0.093
5	Works with Conveyor Conditions	0.009	0.039	0.043	0.012	0.032	0.042	0.053	0.033
6	Material Choice	0.325	0.352	0.391	0.415	0.290	0.382	0.474	0.376
7	Improves Current Method	0.015	0.117	0.043	0.059	0.032	0.042	0.053	0.052
	Sum	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

In this Matrix, the scores given in each comparison are then divided by the sum of each need's score and then the average value is determined to get the Criteria weights. The Criteria weights are further used in the Consistency Check table shown in *Table 6* to create the weighted sum and consistency vector.

Table 6: Consistency Check

Consistency Check		
Weighted Sum	Criteria	Consistency Vector
0.557553809	0.075	7.469371743
2.766375086	0.331	8.349286392
0.320443704	0.041	7.808246878
0.757455667	0.093	8.185058034
0.237870159	0.033	7.206816237
3.010201813	0.376	8.014437331
0.395484937	0.052	7.628974353

Average Consistency (λ)	7.808884
Number of Criteria	7
Consistency Index	0.134814
Random Index Value (RI)	1.35
Consistency Ratio (CR <0.10)	0.10

The average of these consistency vectors is taken and used to determine the consistency index which was determined to be approximately 0.1348. Dividing the consistency index by the random index value of 1.35, a number determined by the number of criteria, gives a consistency ratio of 0.10. This number is the most that this value is allowed to be but still states that the team's bias is successfully eliminated.

Analytical Hierarchy Process Alternatives

For the final step of concept selection the top three concepts are compared against one another for each engineering need. This analysis allowed the team to see how each concept worked better than the other. The designs were given a score of 1, 3, or 5 on how well they would satisfy each of the customer's needs. The sums of each score are normalized and compared to get their criteria weights before being put through another consistency check to ensure a lack of bias by having a consistency ratio of less than 0.1. This process is repeated for each of the customer’s needs and the criteria weights for each concept are used in the Final Rating Matrix in *Table 7* to determine our final concept. The tables of values for each repetition of this procedure can be found in Appendix G.

Table 7: Final Rating Matrix and Concept Alternative Values

Final Rating Matrix	Pincer	Swivel	Spring T
Protects Ceramics	0.600	0.200	0.200
Scaleable for Ceramics	0.333	0.333	0.333
Limit Human Interaction	0.333	0.333	0.333
Works with Given Space	0.600	0.200	0.200
Works with Conveyor Conditions	0.299	0.106	0.633
Material Choice	0.143	0.429	0.429
Improves Current Method	0.619	0.143	0.429

Concept	Alternative Value
Pincer	0.320057036
Swivel	0.329440441
Self-nesting	0.361652386

From the Alternative Values chart above, the weights of each need are compared to the score each concept received in the Final Rating Matrix. Here it shows that, while each alternative value is fairly close to one another, the self-nesting T is the most suitable design for the project.

Final Selected Concept

The final selected concept is the self-nesting T design. This design had the highest alternative value among our final 3 concepts in the AHP chart. Also, this design received the most support from our academic advisor because it is utilizing a stabilization method that has been proven to effectively protect the ceramic.

This concept utilizes a self-nesting design with the same dimensions as the current T being used by corning. The T will be locked upright by a spring or a scissor mechanism and locked down by a trigger clip. The unlocking of the T will be done by a switch at the beginning of the conveyor system and the locking will be done by a switch right before the imaging station. This design allows us to use the aspect of Corning's solution that worked well, while also eliminating the height, positioning, and required interaction issues that they experienced.