Concept Selection

Team 510

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Table of Contents

Concept Selection Process

From concept generation, a mix of 8 high fidelity and medium fidelity concepts were selected from the 100 concepts the team created. The first three concepts in Table 6.0.1 are the high-fidelity concepts and the remaining are medium fidelity. To select the final concept, the team conducted several concept selection analyses including binary pairwise comparison, house of quality, Pugh charts, and the analytical hierarchy process. After completing the concept selection process, the team agreed with the results and chose 67, as the final concept.

Table 6: *Selected Concepts for Concept Selection*

Concept #	Description
53	A latch mechanism that uses the pre-existing ZombieLock gate attachment but adds an angle adjusting arm that the user can adjust when needed.
67	Keeping the pre-existing ZombieLock design but adding a small ramp attached to the receiver at the end to guide the gate to a closed position.
71	Making a modified version of ZombieLock that has a series of magnets on both the gate and gate post. When at rest, the magnets on the gate side will be aligned with the magnets on the gate post side, causing them to be magnetically attracted to one another. When unlocking, an electric DC motor will be used to misalign the magnets, voiding the magnetic attractive force.
15	A painted lock mechanism made of stainless steel utilizes an electric motor powered by an external battery to release the latch. The mechanism resists mechanical wear using grease and can be passively released by a physical key. Both the lock and catch will be mounted to the gate and gate post, respectively, via direct mounting using bolts or screws. While closing, bounce in the horizontal axis and sag in the vertical axis will be accounted for using shock absorbers. Additionally, weight will be relieved from the hinges by the reciever picking the gate up as it is being latched. Once latched, the gate will be kept closed with a deadbolt lock.
30	A sealed lock mechanism made of an aluminum alloy uses an electric motor powered by an internal battery to release the latch. The mechanism resists mechanical wear using oil and can be passively released by an external release arm, as the latch is engaged by a spring.

	Both the lock and catch will be mounted to the gate and gate post, respectively, via direct mounting using bolts or screws. While closing, bounce in the horizontal axis and sag in the vertical axis will be accounted for using springs. Additionally, weight will be relieved from the hinges by the reciever picking the gate up as it is being latched. Once latched, the gate will be kept closed with physical chains.
33	A sealed lock mechanism made of an aluminum alloy uses an electric motor powered by an internal battery to release the latch. The mechanism resists mechanical wear using grease and can be passively released by an external release arm, as the latch is engaged by a spring. Both the lock and catch will be mounted to the gate and gate post, respectively, via direct mounting using a universal tube bracket kit. While closing, bounce in the horizontal axis and sag in the vertical axis will be accounted for using shock absorbers. Additionally, weight will be relieved from the hinges by the receiver picking the gate up as it is being latched. Once latched, the gate will be kept closed with a spring-loaded latch.
87	An adaptation of the current zombie lock mechanism made of aluminum. The receiver and lock are swapped, but the receiver has two rotating "latch" members like French doors.
98	An adaptation to the current receiver design of the ZombieLock. Swap the receiver and latch functions. Create a sliding cylindrical bolt that triggers top-down once the gate is within range. The receiver on the gate is now a circular opening bound of the receiver. The design is similar to a pool gate.

6.1 Binary Pairwise Comparison

The Binary Pairwise Comparison chart shows the customer needs, which were determined earlier, and sets them against one another. In doing so, their order of importance is established. Going through the chart, if the customer need in the row is considered more important than customer need in the column, it receives a "1". On the other hand, if it is deemed less important, it receives a "0". Summing the rows of this matrix resulted in the importance weight factor matrix of our customer needs. This factor is used as a metric in the following table, the House of Quality, and will be discussed in further detail later. For Team 510, the binary pairwise comparison, shown below in Table 6.1.1, resulted in the customer needs "Gate can stay locked in the closed position" and "Product must be mechanical in nature but use power to unlock" to receive the greatest importance weight factors, 7. Inversely, the customer needs "Product is intended for no contact gates" and "Improvement to lock costs less than the current market competitors" received the lowest importance weight factors, 1.

Table 7: *Binary Pairwise Comparison*

	Binary Pairwise Comparison									
Customer Needs	1	2	3	4	5	6	7	8	9	Total
1. Mechanism works for lengths up to 20 feet	-	1	0	1	0	0	0	1	0	3
2. Gate lock design can resist 50 lbs. of force	0	-	0	1	0	0	0	1	0	2
3. Gate can stay locked in the closed position	1	1	-	1	0	1	1	1	1	7
4. Product is intended for no contact gates	0	0	0	-	0	0	0	1	0	1
5. Product must be mechanical in nature, but uses power to unlock	1	1	1	1	-	1	1	0	1	7
6. The gate performs in rugged environments	1	1	0	1	0	-	0	1	0	4
7. Gate adjusts system to account for the sag	1	1	0	1	0	1	-	1	1	6
8. Improvement to lock costs less than the current market competitors	0	0	0	0	1	0	0	-	0	1
9. Product contains a fail-safe method of unlocking	1	1	0	1	0	1	0	1	-	5
	5	6	1	7	1	4	2	7	3	n-1 = 8

6.2 House of Quality

Following the binary pairwise comparison, the house of quality was created next. On the leftmost axis, the customer requirements were listed, while the engineering characteristics were listed on the top axis. Going through the chart, each engineering characteristic was ranked depending on its level of contribution to fulfilling the customer requirement. The engineering characteristic relationship was measured as weakly, moderately, or strongly related to the customer requirement. The corresponding values were 1, 3, and 9, respectively. Using the importance weight factor matrix, along with the values now assigned to the chart, each engineering characteristic was given a ranking of importance. The most important characteristic for our product was determined to be the engagement of the lock, while the least important was relieving gate weight from the hinge.

The purpose of ranking our project's engineering characteristics is to eliminate the less important ones, helping to simplify our concept selection process. We decided to eliminate some of these based on their relative weight percentages. If any of the characteristics had a lower relative weight percentage than the threshold, it was eliminated from our process. The threshold was decided by considering the average of the relative weights, as well as the median since it is a small sample size. To aid in making a reasonable threshold, the average of these two values were used. This left 7 remaining engineering characteristics to be used in the creation of the Pugh charts. The house of quality is shown below in Table 6.2.1.

Table 8: *House of Quality*

House of Quality															
		Engineering Characteristics													
Improvement Direction		↑	-	↑	-	-	↑	-	-	↓	-	↑	↑	↑	↑
Units		n/a	K	n/a	n/a	n/a	kg	n/a	n/a	V	n/a	in	in	in^3	$
Customer Requirements	**Importance Weight Factor**	**Resist Mechanical Wear**	**Account for Thermal Expansion**	**Resist Environmental Factors**	**Release Passively**	**Engage Lock**	**Relieve Gate Weight From Hinge**	**Mount to Gate Post**	**Mount to Gate**	**Draw Power to Release Latch**	**Keep Gate Closed**	**Account for Bounce in Horizontal Axis**	**Account for Bounce in Vertical Axis**	**Volume**	**Cost**
1. Mechanism works for lengths up to 20 feet	**3**		3			9		3	3			9	9	1	1
2. Gate lock design can resist 50 lbs. of force	**2**			3		3		9	9		9	3	3		
3. Gate can stay locked in the closed position after opener is used	**7**	1	3	1		9		3	3		9			3	3
4. Product is intended for no contact gates	**1**			3	3			9	9	9		3	3		9
5. Product must be mechanical in nature, but uses power to unlock	**7**	1	1	1	9	9				9	3			3	3
6. The gate performs in rugged environments	4	9	9	9	3	3		1	1		1			1	
7. Gate adjusts system to account for the sag	**6**	1	1				9					9	9		3
8. Improvement to lock costs less than the current market competitors	**1**														9
9. Product contains a fail-safe method of unlocking	**5**	1	1		9	1				3				9	3
Raw score	**1242**	61	84	59	123	176	54	61	61	87	106	90	90	94	96
Relative Weight %		4.9	6.8	4.8	9.9	14.2	4.3	4.9	4.9	7.0	8.5	7.2	7.2	7.6	7.7
Rank Order		10	9	13	2	1	14	10	10	8	3	6	6	5	4

6.3 Pugh Chart

Team 510 used the Pugh charts to whittle down the number of concepts. These decisions were made based on the important engineering characteristics determined in the House of

Quality. The Pugh charts are used to compare the selected concepts to a datum. The chart uses (+), (-), or (S) to dictate if a concept is better, worse, or satisfactory when it is compared to the datum. The chart uses a (+) symbol to dictate if an engineering characteristic has a more positive effect on the product when compared to the datum. The (-) symbol determines if the concept characteristic is worse than the respective datum. The (S) symbol, satisfactory, is used to represent that the concept is equivalent in function of the engineering characteristic when compared to the datum.

The datum selected for the first iteration Pugh chart is the current lock product offered by Ghost Controls, the ZombieLock. The two concepts that proved to have the lowest total, shown in red in Table 6.3.1, were then excluded from the concept selection process. The remaining six concepts moved onto the second iteration of the Pugh chart. Concept 98 made for a good datum for iteration two because it received a score of -3 in the first iteration of the Pugh chart. This was the median of the results, so it offered room for improvement when compared to the other concepts.

Table 9: *Pugh Chart: Iteration 1*

Pugh Chart: Iteration 1									
Engineering Characteristic	ZOMBIELOCK	**Concepts**							
		15	53	33	87	67	30	71	98
Engage Lock	Datum	-	S	-	+	+	-	S	-
Release Passively		-	S	-	S	S	-	-	+
Draw Power to Release Latch		S	S	S	S	S	S	-	-
Keep Gate Closed		S	S	S	-	S	-	S	S
Accounts for Misalignments		+	+	+	+	+	S	S	+
Volume		-	-	-	-	S	-	-	-
Cost		-	-	S	-	-	S	-	-
Plus (+)		1	1	1	2	2	0	0	2
Satisfactory (S)		2	4	3	2	4	3	3	1
Minus (-)		4	2	3	3	1	4	4	4
		-4	2	-1	0	6	-5	-5	-3

The 2nd iteration of the Pugh Chart can be seen below. For this iteration, concepts 30 and 71 were removed as they scored the lowest in the previous Pugh Chart iteration. Once the chart was completed, concept 67 scored significantly higher than the other concepts analyzed as noted in green. The lowest concept ratings were marked red and similarly the neutral marked yellow.

Table 10: *Pugh Chart: Iteration 2*

Pugh Chart: Iteration 2						
Engineering Characteristic	**CONCEPT 98**	**Concepts**				
		15	53	33	87	67
Engage Lock	Datum	-	-	S	S	S
Release Passively		-	S	-	-	+
Draw Power to Release Latch		+	-	S	-	+
Keep Gate Closed		S	-	S	S	S
Accounts for Misalignments		-	+	-	S	S
Volume		-	+	+	+	+
Costs		-	+	+	+	+
Plus (+)		1	3	2	2	4
Satisfactory (S)		1	1	3	3	3
Minus (-)		5	3	2	2	0
		-7	1	3	3	11

6.4 Analytical Hierarchy Process (AHP)

The Analytical Hierarchy Process is applied to identify what engineering characteristics are deemed most significant for the project. From the House of Quality, the 7 top characteristics were selected for evaluation. The characteristics were compared against each other to establish relative importance. Each cell in the matrix has a reciprocal value to maintain balance and cells compared to themselves are assigned a 1.

Table 10: *Criteria Comparison Matrix*

Development of Candidate Set of Criteria Weights {W}							
Criteria Comparison [C]							
	1	2	3	4	5	6	7
1 Engage Lock	1.00	7.00	5.00	7.00	5.00	9.00	9.00
2 Release Passively	0.14	1.00	1.00	0.20	7.00	9.00	5.00
3 Draw Power to Release Latch	0.20	1.00	1.00	0.20	0.33	9.00	3.00
4 Keep Gate Closed	0.14	5.00	5.00	1.00	5.00	7.00	7.00
5 Accounts for Misalignments	0.20	0.14	3.00	0.20	1.00	5.00	7.00
6 Volume	0.11	0.11	0.11	0.14	0.20	1.00	3.00
7 Cost	0.11	0.20	0.33	0.14	0.14	0.33	1.00
Sum	1.91	14.45	15.44	8.89	18.68	40.33	35.00

The rankings in the columns were summed vertically and then normalized by diving each value by its respective column sum. A consistency check was also performed to assess any bias, adjusting rankings if ratio exceeded 0.1. These tables can be seen in Appendix ?.

6.5 Final Selection Matrix

The final rating matrix below shows that concept 67 slightly outperformed concept 53. These ratings were based off the three most important criteria found using the AHP charts. Concept 53 and concept 67 performed similarly in the 'reducing sag' and 'misalignment with the gate' categories. However, based on the performance analytics deduced in the chart below, concept 67 will be selected as the final design.

Table 11: *Final Rating Matrix*

Final Rating Matrix		
Criteria	Concept	
	53	67
Engage Lock	0.5	0.8
Keep Gate Closed	0.25	0.5
Release Passively	0.25	0.25
Total	1	1.55

6.6 Final Selection

Our team has selected concept 67 as the best design for this project. This concept involves creating a ramp that will be attached to the receiver at the end of the gate to guide it into the closed position. This concept will ultimately address the primary criteria of correcting gate misalignment through the guided ramp, allowing the lock to engage properly. This selection was made using the pairwise comparison table, house of quality, and analytical hierarchy process. Overall, concept 67 outperformed all design concepts making it the best choice to fulfill our project's performance requirements.

Appendix A - House of Quality

Table A-1: Binary Pairwise Comparison

Customer Needs	Binary Pairwise Comparison 1	2	3	4	5	6	7	8	9	Total
1. Mechanism works for lengths up to 20 feet	-	1	0	1	0	0	0	1	0	3
2. Gate lock design can resist 50 lbs. of force	0	-	0	1	0	0	0	1	0	2
3. Gate can stay locked in the closed position	1	1	-	1	0	1	1	1	1	7
4. Product is intended for no contact gates	0	0	0	-	0	0	0	1	0	1
5. Product must be mechanical in nature, but uses power to unlock	1	1	1	1	-	1	1	0	1	7
6. The gate performs in rugged environments	1	1	0	1	0	-	0	1	0	4
7. Gate adjusts system to account for the sag	1	1	0	1	0	1	-	1	1	6
8. Improvement to lock costs less than the current market competitors	0	0	0	0	1	0	0	-	0	1
9. Product contains a fail-safe method of unlocking	1	1	0	1	0	1	0	1	-	5
	5	6	1	7	1	4	2	7	3	n-1 = 8

Table A-2: *House of Quality*

House of Quality															
		Engineering Characteristics													
Improvement Direction		↑	-	↑	-	-	↑	-	-	↓	-	↑	↑	↑	↑
Units		n/a	K	n/a	n/a	n/a	kg	n/a	n/a	V	n/a	in	in	in^3	$
Customer Requirements	Importance Weight Factor	Resist Mechanical Wear	Account for Thermal Expansion	Resist Environmental Factors	Release Passively	Engage Lock	Relieve Gate Weight From Hinge	Mount to Gate Post	Mount to Gate	Draw Power to Release Latch	Keep Gate Closed	Account for Bounce in Horizontal Axis	Account for Bounce in Vertical Axis	Volume	Cost
1. Mechanism works for lengths up to 20 feet	3		3			9		3	3			9	9	1	1
2. Gate lock design can resist 50 lbs. of force	2			3		3		9	9		9	3	3		
3. Gate can stay locked in the closed position after opener is used	7	1	3	1		9		3	3		9			3	3
4. Product is intended for no contact gates	1			3	3			9	9	9		3	3		9
5. Product must be mechanical in nature, but uses power to unlock	7	1	1	1	9	9				9	3			3	3
6. The gate performs in rugged environments	4	9	9	9	3	3		1	1		1			1	
7. Gate adjusts system to account for the sag	6	1	1				9					9	9		3
8. Improvement to lock costs less than the current market competitors	1														9
9. Product contains a fail-safe method of unlocking	5	1	1		9	1				3				9	3
Raw score	**1242**	61	84	59	123	176	54	61	61	87	106	90	90	94	96
Relative Weight %		4.9	6.8	4.8	9.9	14.2	4.3	4.9	4.9	7.0	8.5	7.2	7.2	7.6	7.7
Rank Order		10	9	13	2	1	14	10	10	8	3	6	6	5	4

Appendix B - AHP

Table B-1: Development of Candidate Set of Criteria Weights

Development of Candidate Set of Criteria Weights {W}							
Criteria Comparison [C]							
	1	2	3	4	5	6	7
1 Engage Lock	1.00	7.00	5.00	7.00	5.00	9.00	9.00
2 Release Passively	0.14	1.00	1.00	0.20	7.00	9.00	5.00
3 Draw Power to Release Latch	0.20	1.00	1.00	0.20	0.33	9.00	3.00
4 Keep Gate Closed	0.14	5.00	5.00	1.00	5.00	7.00	7.00
5 Accounts for Misalignments	0.20	0.14	3.00	0.20	1.00	5.00	7.00
6 Volume	0.11	0.11	0.11	0.14	0.20	1.00	3.00
7 Cost	0.11	0.20	0.33	0.14	0.14	0.33	1.00
Sum	1.91	14.45	15.44	8.89	18.68	40.33	35.00

Table B-2: *Consistency Vector*

Weighted Sum Vector {Ws}=[C]{W}	Criteria Weights {W}	Consistency Vector {Cons}={Ws}./{W}
4.136	0.435	9.50
1.213	0.138	8.78
0.630	0.084	7.53
2.104	0.216	9.72
0.737	0.085	8.68
0.204	0.021	9.84
0.175	0.021	8.35

Table B-3: *Normalized X Criteria Comparison*

Table B-4: X *Consistency Check*

Table B-5: *Normalized X Criteria Comparison*

Table B-6: *X Consistency Check*

Table B-7: *Normalized X Criteria Comparison*

Table B-8: *X Consistency Check*

Table B-9: *Normalized X Criteria Comparison*

Table B-10: *X Consistency Check*

Table B-11: *Normalized X Criteria Comparison*

Table B-12: *X Consistency Check*