Initial Testing Results

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Design Requirements

Customer Requirements

CR 1: Safety

CR 2: Towability

CR 3: Durability

CR 4: Portability

CR 5: Rope length fits competition area

CR 6: sufficient power

CR 7: Compact design

Engineering Requirements

ER 1: Tows 10 people

ER 2: Travels at about 2 m/s (60 people/hour)

ER 3: rope length of 200-300 ft

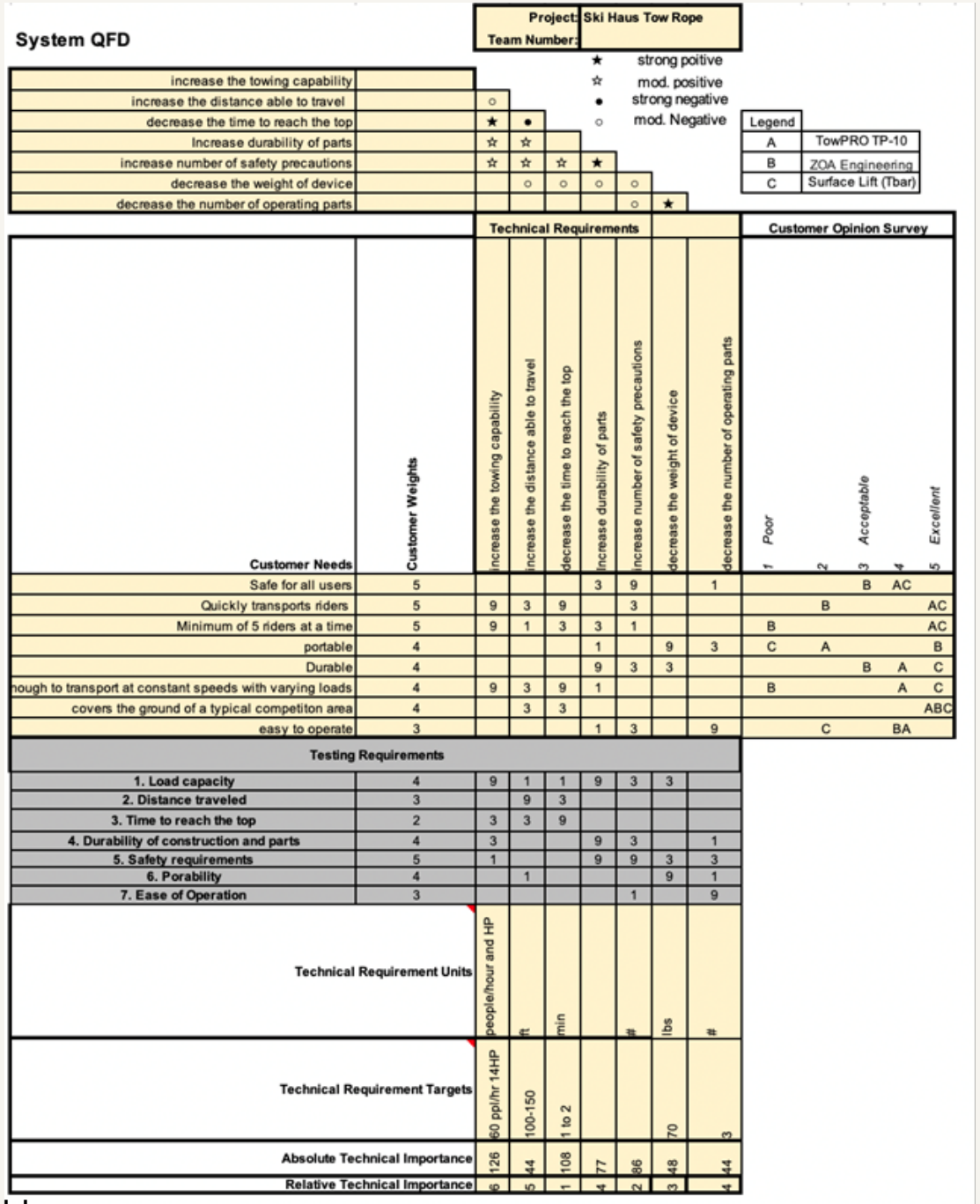
ER 4: weight of 300lbs +/- 50 lbs

ER 5: 2-3 safety features

ER 6: factor of safety of 3

ER 7: durable material properties

QFD



System QFD

Project: Ski Haus Tow Rope
Team Number:

★ strong poitive
☆ mod. positive
● strong negative
○ mod. Negative

Legend	
A	TowPRO TP-10
B	ZOA Engineering
C	Surface Lift (Tbar)

increase the towing capability									
increase the distance able to travel		○							
decrease the time to reach the top		★	●						
Increase durability of parts		☆	☆						
increase number of safety precautions		☆	☆	☆	★				
decrease the weight of device			○	○	○	○			
decrease the number of operating parts						○	★		

		Technical Requirements							Customer Opinion Survey					
Customer Needs	Customer Weights	increase the towing capability	increase the distance able to travel	decrease the time to reach the top	increase durability of parts	increase number of safety precautions	decrease the weight of device	decrease the number of operating parts	1 Poor	2	3 Acceptable	4	5 Excellent	
Safe for all users	5				3	9		1				B	AC	
Quickly transports riders	5	9	3	9		3					B			AC
Minimum of 5 riders at a time	5	9	1	3	3	1				B				AC
portable	4				1		9	3		C	A			B
Durable	4				9	3	3					B	A	C
hough to transport at constant speeds with varying loads	4	9	3	9	1					B			A	C
covers the ground of a typical competiton area	4		3	3										ABC
easy to operate	3				1	3		9			C		BA	
Testing Requirements														
1. Load capacity	4	9	1	1	9	3	3							
2. Distance traveled	3		9	3										
3. Time to reach the top	2	3	3	9										
4. Durability of construction and parts	4	3			9	3		1						
5. Safety requirements	5	1			9	9	3	3						
6. Porability	4		1				9	1						
7. Ease of Operation	3					1		9						
Technical Requirement Units		people/hour and HP	ft	min		#	lbs	#						
Technical Requirement Targets		60 ppl/hr 14HP	100-150	1 to 2			70	3						
Absolute Technical Importance		126	44	108	77	86	48	44						
Relative Technical Importance		6	5	1	4	2	3	4						

Top Level Testing Plan

Experiment/Test	Relevant DR's
Load capacity	CR2, CR3, CR5, CR6, CR8, ER1, ER2
Speed and time to reach the top	CR5, CR6, ER1, ER2, ER3
Durability of construction and parts	CR1, CR3, CR4, CR7, ER4, ER5, ER6, ER7
Safety requirements	CR1, CR3, CR6, CR8, CR9, ER5, ER6, ER7
Portability	CR3, CR4, CR7, CR8, ER4, ER7

Detailed Testing Plan:

Portability

Summary:

- The test for portability will determine if the device can be transported both in a truck bed and on the mountain
- These tests will analyze CR3, CR4, CR7, CR8, ER4, and ER7. With one of the customer requirements is that no more than 300 pounds or the equivalent of 3-4 people being able to carry it.
- It must also be able to be lifted and transported in the back of a standard truck bed.
- During testing, if all parts stay intact and are transported well, the device will be lifted out of the truck bed and placed on the ground.
- The calculations will be based upon the total combined weight of the system.

Portability: Procedure

1. Weigh the three components: drive unit, rope spool, and top pulley.
2. Measure the dimensions of a standard truck bed to ensure tow rope fits
3. Prep the tow rope for travel (attach wheels and proper handles tie down to truck bed)
4. Measure the time that it takes for 3-4 people to load the tow rope into a bed of a truck
5. Measure the time that it takes for 3-4 people to unload the tow rope out of the truck bed
6. Now measure the time it takes to bring the tow rope up to the competition area via a snowmobile
7. Complete these time measurements several times to determine the fastest method of transporting the tow rope

Portability: Results

Weight Results

$$W_{Total} = \sum W_{Rope} + W_{Top\ Pulley} + W_{Engine} + W_{Drive\ Unit} \leq 300 \text{ lbs.}$$

Component	Weight (+/- 1 lb)
Engine	75 lbs
Drive unit frame	35 lbs
Drive unit components	55 lbs
Top pulley	25 lbs
Rope (including spool)	101 lbs
Total Weight	**291 lbs**

Area Results

$$A = L \times W$$

$$A_{Spool} = \pi r^2 = \pi(122) = 452.39 \text{ in}^2$$

$$A_{Total} = \sum A_{Spool} + A_{Drive\ Unit} + A_{Top\ Pulley} \leq A_{Truck\ Bed}$$

Area of F150 short bed (client's truck)= **4858 in²**

Component	Area (+/- 1")
Rope spool	452.39 in^2
Drive unit + Top Pulley	756 in^2
Total Area	**1208.39 in^2**

Alternative Area Result

Frame + Top Pulley = 27" x 28"

Rope spool diameter = 24"

Truck bed dimensions = 77.75" x 62.49"

Components Loaded = 52" x 28"

Detailed Testing Plan:

Speed and time to reach the top

Summary:

- This test is to determine how long it takes to reach the top
- The distance will be determined by the length of the rope in which the team splices. The test will focus on CR5, CR6, ER1, ER2, and ER3.
- To perform this test, the entire tow rope will need to be set up on an inclined surfaced will all equipment running
- The isolated variables are the rope and engine for this test as it will be evaluating the length and speed for moving 60+ people per hour.
- The calculations to be made from this test are the overall speed of the rope.

Speed and time to reach the top: Procedure

1. Set up the drive unit, top pulley, and rope for extended use.
2. Measure the length of the rope once set up to evaluate the total distance able to be traveled
3. Have one person ride the rope while timing to see how fast they reach the top
4. Fully load the tow rope and have people continuously use the rope for an hour
5. Keep track of how many people have traveled the full length of the rope after an hour

Results

Drive Shaft ø2.45 " pulley to Shaft 1 ø6.25 " pulley:

$$VR = \frac{6.25}{2.45} = 2.5510$$

$$OS = \frac{3600\ RPM}{2.5510} = 1411.2\ RPM$$

Shaft 1 ø6.25 " pulley velocity = Shaft 1 ø2.45 " pulley velocity

Shaft 1 ø2.45 " pulley to Shaft 2 ø6.25 " pulley:

$$VR = \frac{6.25}{2.45} = 2.5510$$

$$OS = \frac{1411.2\ RPM}{2.5510} = 553.19\ RPM$$

Shaft 2 ø6.25 " pulley velocity = Shaft 2 ø2.45 " pulley velocity

Shaft 2 ø2.45 " pulley to Shaft 3 ø6.25 " pulley:

$$VR = \frac{6.25}{2.45} = 2.5510$$

$$OS = \frac{553.19\ RPM}{2.5510} = 216.85\ RPM$$

1:1 Ratio gearbox attached to Shaft 3 and Vertical Shaft 1
∴ Shaft 3 velocity = Vertical Shaft 1 Velocity

Driving Sheave fixed to Vertical Shaft 1
∴ Driving Sheave angular velocity = 216.85 *RPM*

Converting angular velocity to linear velocity of Driving Sheave
Driving Sheave radius = 3 inches = 0.0762 meters

$$V_{Linear} = \frac{215.85\ RPM}{60\ s} \times 2\pi \times 0.0762\ m = 1.73\ \frac{m}{s}$$

Driving Sheave linear velocity = Rope velocity = **1.73** $\frac{m}{s}$

Test	Time (s)
Test 1	1.68
Test 2	1.88
Test 3	1.81
Average	1.79

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Specification Sheet Preparation

Customer Requirement	CR met? (✓ or X)	Client Acceptable? (✓ or X)
CR3 – Durable	✓	✓
CR4 – Portable	✓	✓
CR5 – length of rail jam competition	x	x
CR6 – constant speed w/ varying loads	x	x
CR7 – compact design	✓	✓
CR8 – internal combustion engine	✓	✓

Engineering Requirement	Target	Tolerance	Measured/Calculated value	ER met? (✓ or X)	Client acceptable? (✓ or X)
ER1 –people on the rope	8 people	+/- 2 people	1 person	x	x
ER2 – people/ hour travel	60 people/hour or 1.66 m/s	+/- 10 people	1.73 m/s	✓	✓
ER3 – distance traveled	250 ft	+/- 50 feet	22.75 ft	x	x
ER4 – weight of unit	300 lbs.	+/- 50 lbs.	291 lbs.	✓	✓
ER7 – material durability	250 MPa	+/-50 Mpa	276 Mpa	✓	✓

It Pulls!

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