8 Prototype Specification and Testing

8.1 Most parts should be off the shelf

- Use standard front wheel used for small bikes
- clip-less peddles will be used
- standard rear shock is used off of a different tool
- side mounted wheel hubs used for both rear wheels
- standard spokes are utilized
- standard track utilized for foot swagger track

8.2 Easy Assembly (in bike shop)

- breaks into two sections (front and back) for storage and when stowed
- all usual fasteners utilized.

8.3 Under 500 for raw materials + Sponsored materials

- For further inquiry on this project, in order to rapidly create a prototype to use in the evaluation of the general concept, a prototype would like to be considered that would be constructed using a combination of plywood and honeycomb cardboard core material. Frame, seat and rear swing-arms will be constructed from these materials. The final design will include different materials for added strength at much lower mass but the basic construction concepts should remain unchanged.

8.4 Testing performance

- Accurate mathematical calculations that have been tested to ensure all parts of the UTRB can be assembled properly and function correctly guarantee the vehicle will perform effectively on a theoretical basis. However, due to time and financial constraints, the report is not able to provide data for actually testing the UTRB's performance and is strictly a theoretical simulation UTRB. The report includes accurate measuring and estimating for dimensions of parts, their performance, and design.

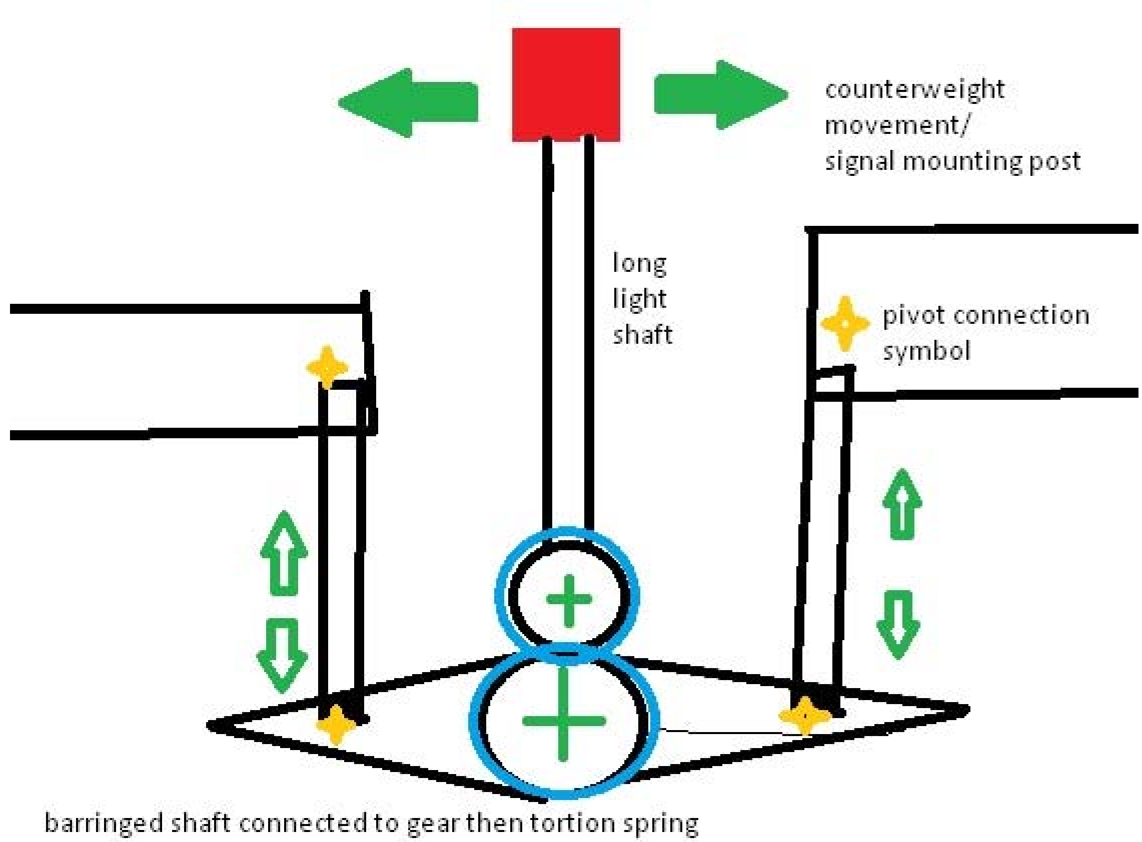
9 Discussion

9.1 What we accomplished to put together

We designed and drew up blueprints to a fully functioning working UTRB if anyone so chooses to create one. This vehicle would be practical not just for locomotion and travel, but extremely effective for individuals wishing to keep in great physical shape and health. The specific parts, names of the parts, and dimensions for the entire UTRB assembly can be seen in section 7: *Subsystems, their properties and their sources.*

9.2 What you would have liked but could not find, make, afford

- If given time, the locking mechanism on the Munzo TT tilting linkage could be further improved so that the bike would remain upright at stops without the use of an on-off switch or lock. Several ideas have been developed in the course of this project to address this but none that were sufficiently simple to develop to be completed within the project timeline. One idea was to use a torsion spring and a long lever that acts to counteract the spring while the vehicle is in motion. This combination is perfect because such a long lever arm can be deployed as the post for a signaling tower used to alert drivers and make the vehicle's presence known. The following is a crude description of this solution. A driven tilt system with some linkage that allows the steering handle to also control tilt-angle would have been the best solution because it makes possible 'anticipatory tilting' that seems to make the Tripendo more sporty than other systems. It is not clear whether or not the above momentum-based tilting actuator would be able to induce a lean fast enough to allow for rapid turn actuation and provide for equal performance to a driven system.



- An additional idea that could make the signaling system better is to incorporate an "air brake" into the signal tower depicted above. This air brake would serve the duel role of providing greatly increased aerodynamic drag to assist in stopping while also drastically increasing the visibility of the vehicle to motorists. The internal surfaces of such an air break could be painted a bright shade of red and illuminated from the top to further signal motorists. This particular concept would be a very unique sight and would also add considerably to the tilting trike 'gene pool'.

- Another concept that would have been interested to try but was too complex was to re-design the hydraulic components and pressure versatile used in the Apex *hydraulic*;leaning and shock absorption system. In it's present state, the Apex system uses existing hydraulic rams and off-the-shelf components. Very few hydraulic applications require small form-factor and light weight and for this reason the components have of room for improvement as part of a bike suspension. If this project had unlimited time and financing it would have been interesting to develop light hydraulic components.
- It would have been interesting to re-work the Black Max design below to incorporate a low-cost suspension linkage for each rear wheel. A power-assisted version that utilizes this linkage could incorporate one or two hub-motors to provide power while incorporating a sealed-track system to control the travel of each wheel. Such a system would be very stiff and allow for reduced material

weight because there would be no need for long arms. Another advantage of this particular design is that it can be configured to provide 45 degree tilting angles without lowering the center of the vehicle.

Image Source: http://www.fleettrikes.com/blackmax.htm + Own Work

- Yet another design idea that I would have liked to be able to develop is a tilting delta trike with active control over tilt angle via some linkage. A fly-by-wire solution would be well suited for this task the bike is well balanced and does not require excessive force to control. Perhaps a more feasible approach is to attach two lines to the handle bar instead of just one. As the handle is pulled asymmetrically one a pulley mounted where they join would turn. This turning action could wind a separate cord that travels back to the rear linkage. Yet another idea is to have paddles mounted next to the seat such that tilting can be controlled by pushing back with elbows at the end of a stroke. In general, stokes would be made on flat ground or when exiting a turn and thus having the rider remain in the compact position while entering a sharp turn would not pose real limitations on power production. This final idea would preserve the simplicity ideals of the Munzo TT and this project.

- Designing an electrical assist to be attached to the UTRB would be an ideal inclusion to be considered as a further part of the project. The principle of including an electrical assist would be to take advantage of the pre existing mechanical work performed by a rider to go into a dynamo and induce an electrical current that can be stored for power. This power can further be used to operate a motor, if in the event a rider starts getting tired or assist in going up hills or terrain that would have greater resistance than just a flat plain. For more specifics on the feasibility of this, refer to section*: 6.3.4 Power Assist Sizing & Power Requirements (theoretical addition to the UTRB)*

9.3 Comments on future manufacture at scale

In order to apply this design to the market and attain the desired cost profile there are a number of important steps that need to be completed. This step should be associated with a complete cost model and a vendor selection process. The cost savings with volume should come from material bulk price reductions and in improved assembly speeds but should not come from optimization. These bikes should be built using 2D construction methods and should be made to order. The prototype should mirror the final design but with different materials and using more manual cutting and assembly steps. One key element in the preparation for the sale of this product is to complete a full set of drawings with appropriate tolerances. These drawings must be associated with computer simulations of structural strength in each frame member. Computer modeling will support a process of continued improvement of the structure and composition of the frame design such that the cost continues to fall over time. It is expected that new composite materials using fibers such as synthetic spider silk and carbon nanotubes will dramatically reduce the cost of high-strength composite materials and thereby make the above fabrication methods drastically more cost-effective than welded-metal alternatives. Up until this point the process of manufacturing carbon fiber composites has been constrained by the energy intensiveness of the fiber production processes to date. The advent of new materials that utilize low-energy biotic processing methods completely change the cost dynamics of creating high-strength fiber. Within 5-10 years fiber-reinforced fibers will be a cost-effective alternative to metals.

9.4 Suggest next steps or improvements

- Incorporation of an enclosure for better all-weather use and for increased top speed is one thing that would make this bike concept more useful in larger urban areas, rural areas and in cities that have more rain.
- Computer modeling and optimizing a single carbon-fiber frame can significantly reduce the weight of the bike and may not cost more to produce because of the reduced component count. It is imagined that the leg support, seat and all mounts and pivots be made in a single integrated piece. The other parts would be the fork, handlebar, leaning/suspension linkage and the main swing-arms.
- A full design for manufacturing is required in order to convert the designs developed in this report into a low-cost option for urban transport. An assessment of minimal production volume in order to achieve low cost is one element of this assessment.

10 Conclusion

It is clear that rowing as a mode of human power is both a superior means of transit and an excellent full-body conditioning workout compared to cycling. The strategy of simplifying the bike design as much as possible in order to meet the cost-reduction goals of the project, while still maintaining the benefit of reducing weight has been considered. The use of the 'THYS' style bungee rowing bike pulley system for propulsion provides a more effective gear system and drive train [4] provides a more effective design as opposed to a chain or spring system that adds resistance for a rider and has a greater chance of rubbing against adjacent parts. Because there is only static contact by using bungee cables, the tolerances can be much wider, further reducing cost in production. Even though it's not included for this particular design, the most expensive system in this bike design is the notion of adding an electrical power assist. At low-volume production, the power assist accounts for a large cost and pushes the bike outside of the design specification, but if produced in high volume it can be produced within the budget of $1,000. Battery and motor technologies are improving rapidly and their costs are falling at the same rate. Over time, this bike concept will become much more affordable and accessible to a wide range of people.

As population increases, the health risks associated with carbon dioxide and a sedentary lifestyle make new and innovative methods for incorporating exercise into daily life a necessity [5][6]. The UTRB is one practical solution that makes the necessity of commuting to work a benefit for the health of the individual and the environment.

APPENDIX:

Appendix A

How typical exercise rowing machines improve cardiovascular fitness

Like cycling, an exercise rowing machine will improve cardiovascular fitness. For simple cardio health, a person should be working within an intensity anywhere between 60-85% of their target heart rate for at least 15+ minutes. For body fat loss, they should be active over a period of 25-30+ minutes [1]. The higher the intensity of the exercise, the more calories will be burned in one session in less time. In general, glycogen stores are used before reserved energy stores from fat are recruited in greater amounts. Usually, glycogen stores are not really being used up in aerobic activity for the body to induce the need to use fat reserves until after around 25 minutes of aerobic activity. And truthfully, this will only happen effectively if the aerobic activity is being done at a specific intensity 60-85% target maximum heart rate. The higher the intensity of the aerobic activity is, the more likely it is to start using these reserves of energy. Therefore, because the activity of rowing is requires the effort of more major muscle groups than just the legs, rowing proves to be a great cardiovascular exercise while simultaneously building muscles more effectively.

Appendix B

The principles behind a human body burning calories

The trick to really 'burning calories' due to this kind of exercise will occur if a person is in repeated motion as specified by these guidelines: whatever the motivation to stay active on a UTRB for over a period of 25-30+ minutes at an intensity within at least 60 – 85% of a person's target heart rate zone will burn calories effectively. Anything less than that may not be functional. The higher the intensity, the more calories burned. The more calories burned, the more body fat lost**.**

Furthermore, because the UTRB is designed to recruit more muscles in the body to be used in an aerobic state than other forms of aerobic exercise, by the sheer laws of thermodynamics, it will collectively burn more calories than other forms of aerobic activities, such as jogging or bicycling, even at lower intensities.

If the resistance of rowing the T bar is even greater than having to row the UTRB on any surface inclined greater than 0 degrees, in principle, the chances of developing muscle mass and strength in the target muscles being worked (as described in the next section of this report) will increase. This is because of the simple principle of hypertrophy occurring to muscles due to greater resistance. (See Figure B.1 below for a visual function of the T bar).

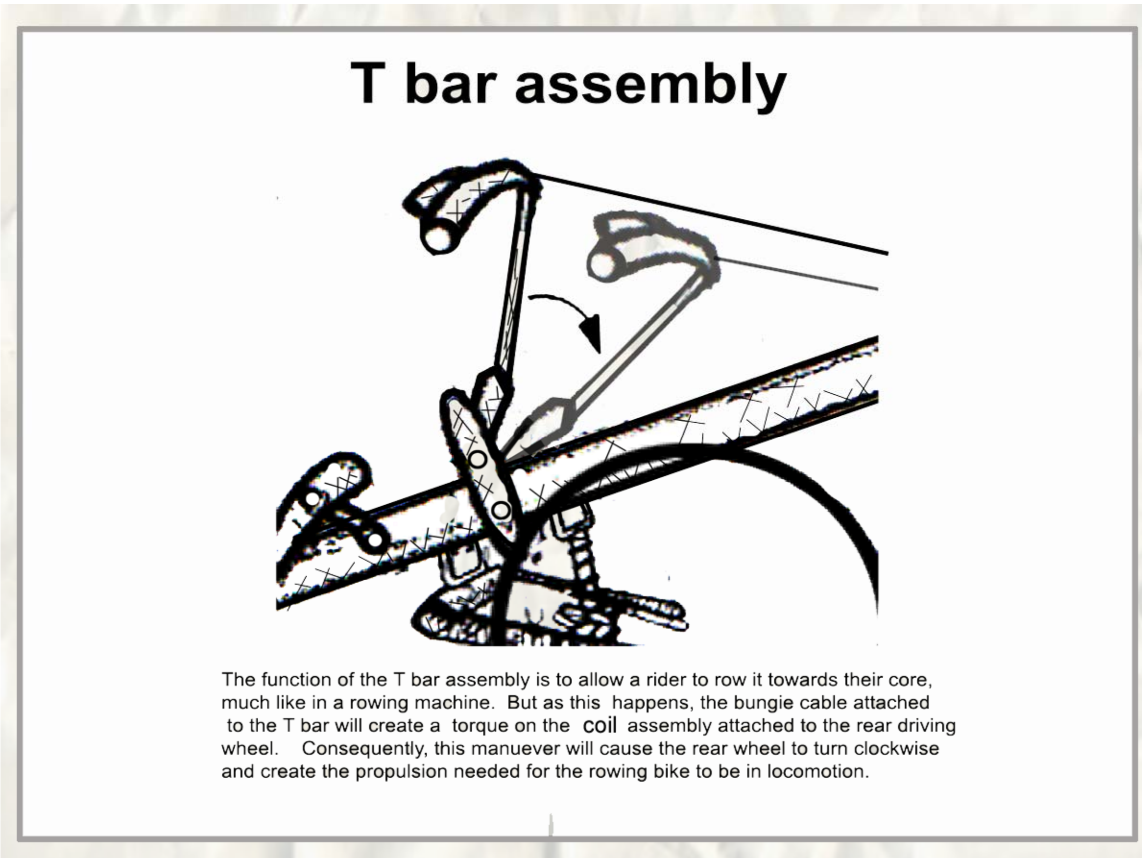


Figure B.1

Appendix C

What is the V02 max rate principle in aerobic respiration?

An individual's V02 is also known as their maximal oxygen uptake. It is an important variable that can determine an athlete's capacity to carry out sustained exercise, and in the case of the UTRB, the aerobic exercise that can be performed. VO2 max refers to the maximum amount of oxygen that an individual needs in order to sustain intense or maximal exercise. This systematic unit measurement is in reference to the milliliters of oxygen used in one minute for every kilogram of body weight existing for the individual. In lay terms, the better an individual's VO2 max capacity (which can be improved through aerobic exercise), the better that individual can utilize oxygen efficiently and thus not be winded because they can get more energy for aerobic respiration out of every breath that person takes.

Appendix D

Works cited

3.2.1 and 3.2.2 (appendix A)

[1] *Principles of aerobic fitness* http://www.shapefit.com/cardio-exercises.html

For more detailed information, refer to the National association of sports medicine Essentials of Personal Fitness Training Textbook.

3.2.4

[2] PeerTrainer.com: Weight Loss Motivation
http://www.livestrong.com/article/456083-rowing-machine-pros-cons/

Machine magic: ten important benefits of machine movements - *Hardgainer's Ultimate Growth Enhancement System* by Mike Matarazzo
http://findarticles.com/p/articles/mi_m0KFY/is_6_20/ai_98488514/

What are the benefits of using a rowing machine?
http://worldvillage.com/what-are-the-benefits-of-using-a-rowing-machine

3.3.1 and 10

[3] Note that UV, weather corrosion and constant elastic strain are the most common variables for deteriorating a bungee chord's efficiency
http://www.briontoss.com/spartalk/showthread.php?t=1761

[4] The THYS style rowing system is the acronym for the Rowing bike design which

turned out to be similar to our own design as seen from the makers of rowingike.com, who have successfully designed and marketed a functional ergonometric transportation vehicle, as popularly seen in various parts of Europe. http://rowingbike.com/site/EN/10.0

[5] *Spark*: *The Revolutionary New Science of Exercise and the Brain,* by John J. Ratey MD

[6] The Sun's Heartbeat: And Other Stories from the Life of the Star That Powers Our Planet by Bob Berman

3.3.2 Energy Conversion

[7] http://www.engineeringtoolbox.com/heat-units-d_664.html
Also reference: http://www.unitarium.com/energy

[8] http://www.fitday.com/webfit/burned/calories_burned_Rowing_stationary_ergomoeter_general.html

[9] How to C*alculate power in rowing over watts:*
http://www.concept2.com/us/interactive/calculators/watts.asp

6.4 Conceptual Feasibility

[10] http://rowingbike.com/site/EN/Technical/Revolver/

Appendix E

How ATP stores are restored in a person's system for exerting energy.

ATP, also known as adenosine triphosphate, stores and releases energy by adding or breaking off one of the phosphate molecules on its cha*in*. When a phosphate molecule breaks off of ATP it releases energy. This phenomenon happens when an individual is exerting forces (or in laymen's terms, performing exercise). When this happens, the energy molecule in a muscle loses a phosphate group, which in simplicity can be viewed as a simple chemical unit responsible for expending energy to carry on a process. The adenosine triphosphate store in question has become an adenosine diphosphate group. If an ADP (an ATP with one less phosphate group than ATP) gains a phosphate group, energy is stored and that molecular group converts back into a fully recharged ATP group [1].

[1] http://biologyinmotion.com/atp/index.html

Appendix F:

The principles for determining the most optimal angles for performing ergonometric movements

When a muscle is used to work against a certain resistance, it will contract in a flexion and back to an extension position, and indirectly this activity in any muscle group can assist in allowing the larger system as a whole (the human body) to exert some type of force to perform physical work. If the resistance is too great (suppose 6 to 10 repetitions of flexion and extension of that muscle are obtained before the rider can not move that muscle any more due to lactic acid buildup in that muscle), the rider may benefit from a great hypertrophy workout but in terms of functionality, only be able to use the rowing machine to move short distances.

If the seat of the rowing bike is raised at any higher elevation than at most 15 degrees, the muscles in the lower abdomen, and hip flexor complex will be used up more effectively. There is a negative consequence to this: the higher the seat is elevated, the quicker these muscles will tire.

If the rail itself is elevated so that the feet upon sliding elevate at a higher angle, the muscles in the lower back and upper rectus abdominal muscles will sustain a great workout, but tire out quicker. The reason for this is because at any angles, the legs, core, and other muscles have to not only work against any tensile forces, torques, or similar resistance coming from the bike, they also must work against gravity itself.

Appendix G:

What is the lactic acid threshold?

The lactic acid threshold in aerobic respiration is a muscle's maximum ability to continue to perform mechanical work before lactic acid completely depletes a muscle group into exhaustion. Lactic acid thresholds can be improved through strength endurance training

Appendix H:

Math calculations

Section 3.3.2 Energy Conversion

Based on International Steam Table (1956) 1 calorie is defined to be exactly 4.1868J.

Considering the case study of a 35 year old woman who is 5"4 weighing 135 pounds rowing for one hour. The amount of calories she would be burning through rowing would be 8.9 calories per minute: In terms of her energy expenditure

$$j = \frac{4.1868 \ \ j}{1 \ cal} = \frac{j}{8.9 \ cal} \rightarrow \frac{8.9cal}{1 \ cal} \cdot 4.1868 \ \ j = 37.2652 \ \ j$$

Zeb Appendix

A. Intermediate Wants Vs. Needs

I Design Goal

The goal of this project is to produce a vehicle concept that will appeal to people living in cities who would like to incorporate more physical exercise into their daily schedule without having to commit extra time to do so. This class of individuals is made up primarily of young professionals, college students and generally health and environment aware individuals. One of the earliest decisions we faced in the design process was what the maximum speed of the vehicle should be. The decision to maintain a cost of less than a small car ($12,000) is a condition that governs the top speed that the vehicle can attain. For this reason the project's specifications include a top speed more in-line with that of a cyclist rather than an automobile. Power assist technology is used to enhance acceleration and smooth out the power delivered at the wheel. The other major consideration is that the vehicle be designed so that it is safe while turning in any road condition. The overall goal of this project is to accommodate the needs of an urban traveler by providing an active alternative to public transit that uses new modes of power management.

II Design Elements

- Rowing
- Tilting
- Small windshield
- 2D construction methodology
- Minimize: Cost
- Minimize: Complexity
- Maximize: Smooth ride

III Basic Requirements: Feature List

A. Pick up groceries and run local errands. Commute to work and back. (effective)
B. All-weather operability (effective)
C. To provide an exciting riding experience that is comparable to that of a sports car or a motorcycle (fun)
D. It must have a human-powered component so that the rider will gain exercise and a feeling of auto-locomotion. (fun)   This provides the duel commute/workout experience. (convenient)
E. Stoerable small form factor for off-street parking and easy shipping. (convenient)
F. Comfortable with good air circulation, an ergonomic chair with healthy body positioning and a low ambient noise level. (effective)
G. Low cost (effective)
H. Safety: must both protect passenger from impacts while providing better situational awareness to avoid accidents (effective)
I. Reliable, requiring low maintenance and delivering low risk of failure (convenient)
J. Good range, comparable to an average car with heavy peddling. Maximize the impact of human power by reducing weight while still achieving a min range of 150 miles @ 55-65mph. (effective)
K. Passenger is of a reasonable range of size and shape and only one adult person(convenient)
L. All (non-freeway) roadway operability (effective)
M. Easy to use (convenient)
N. A means to achieve a good cardiovascular workout

IV Weighted Table: Derived from (III)

Value (1-5)	Parameter	source	Want Value	Need Value

4	Max Speed	A, C	40mph in order to maintain secondary highway speeds	25mi/hr for safe urban transport
5	Min Range	J	Enough for a long trip, 50 miles @ 40mph average speed w/ backup power source for longer trips	Same as twike, 20 miles @ 55mph average speed, backup power supply for longer trips
4	Parking	E	small enough to fit in a bicycle parking spot	small enough to fit in a motorcycle parking space or smaller space.
4	ergonomics	F	comfortable seat with venting, quickly understood controls, comfortable neck angle	comparable to a recumbent bicycle, "sporty"
4	Safety	H	faring, roll bar plus, an airbag system that deploys when appropriate biofeedback is received from driver, 5 point harness.	wind shield, helmet
4	Entry/exit (novel)	N	Vehicle can be somersaulted into or pulled down and entered from through the top	entry through the top
4	Overall Look	N	Appealing enough to justify a 50k price tag	looks more like 15k
3	fun to ride	C	Like a motorcycle in performance	Like a road bike in performance
3	Acceleration	C, A	0-60 5seconds	0-60 10second
3	Total Device Weight	E	100-150lbs	250-300lbs
3	Sweat Consideration	F	A misting device is included to wash away sweat so the rider can change in the parking lot or at a restaurant	Work locations must have showers
3	Signals	H	turn, break, hazard, headlamps, a directional horn	turn, break, lamp, basic horn
3	Visibility	H	All cars can be seen though a combination of cameras and a large windshield area	A large windshield provides for good visibility
3	Corrosion resistance	I	lasts 5 years without maintenance	repaint every 2 years
3	Fatigue life	I	500,000 miles equivalent	100,000 mile equivalent

3	Passenger dimensions	K	120lbs and 5'3" to 220lbs and 6'4"	180lb and 6ft with a range of +/- 10lb and +/- 2in respectively
3	Modularity	M	Each component can be replaced in 10 min	some components take 6 hours to replace
3	Faring Shape	N	An attractive appearance, low cross sectional area and Cd	Comfortable and safe cornering at higher speeds
3	Exercise level	O, D	Variable resistance to fit rider and workout type	Single resistance setting, or linked to speed
2	Storage	A	4 bags of groceries or a weekends trip supplies	One back pack
2	human power impact	D	50% range extension	30% range extension
2	Legal Classification	E, G	Bicycle classification so that it can be operated without a license (this requires that it not go over 30mph under power only.)	Can be classified as a motorcycle and operated as such.
2	Noise Level	F	Like that of a road bike, nearly no noise	like that of a moped, use an Ipod
2	Interior	F	roomy interior with the same spaces as the carver	a small shell slightly bigger than a two wheeled streamer
2	Cost	G	under 3,000 or about twice a good mountain bike	Under 15,000 which is about how much a new touring Yamaha motorcycle costs
2	Control equipment	H,C	GPS, front and rear cameras, body tension sensors to activate safety measures, radar, battery level indicator, strain gauge indicator on frame	rear view mirror, battery level indicator
2	Occupancy	K	Room for two with the passenger straddling the driver, adding 2 ft of length.	One person and cargo space
2	Ground clearance	L	4 in	2in
2	Roadway Conditions	L	Gravel, Snow and trail: OK	only paved roads that a sports car could ride
2	Battery chagrin	M	Detachable battery can be interchanged and charged	one permanent power source
2	Charging Time	M	6 minute charge with ultra capacitors	6 hour full charge
1	Weather	B	Hot, cold, heavy rain, high winds, some snow	hot, cold, medium rain, mild impact of heavy winds, no snow

1	Lateral Acceleration	C	nearly 1 gravitational constant (same as the carver)	Equal to the tripendo, 0.48 gravitational constants
1	Transport	E	Battery and wheels can be removed to be stored in a station wagon.	needs trailer
1	Maintenance	I	every 1 year	every 4 months
1	Battery cycle life	I	1000 (150,000 miles)	500 (50,000 miles)

B Project Scope Outline Report

Zebediah Tracy, 09/29/09
Title: Project Scope and History

Documents Created Thus Far

Phase One: (complete)

Initial project objective statement and rationalization created. The general goal was to create an interesting vehicle that would be useful as a means to commute to work and around town while getting a workout.

Needs vs. wants table was created in which all of the key variables related to the vehicle were turned into parameters and given a subjective value 1-5.

State of the art was conducted resulting in a spreadsheet of roughly 10 of the most interesting "edge cases" of personal, human-powered and leaning vehicles. This list included entries ranging from velomobiles to the 150 hp carver.

Phase Two:

A blog was created to chronicle our progress as Claudio and I began to re-develop the project concept and work out our roles in the new team.

Robust State of the art form was created in order to track the many new technologies that we were finding ranging from the RowingBike to the GreenWheel and others. (this form has proven overly complex and very difficult to use without it breaking).

Email correspondence with the ***designer of the CarCycle*** including feedback on various ideas including the concept of integrating a larger electric assist to discussing the trade-offs involved in going with a rowing design. This is a valuable contact given that the CarCycle is one of the most impressive velomobiles I have encountered after reviewing thousands.

Email correspondence with the designer of ***the Thys Rowingbike*** who had developed a new driveline and linkage specific to long-distance riding. The system may even be an improvement over traditional chains and cogs because it has far fewer moving parts and is lighter.

First Choice:

1) create a human vehicle that is practical and fun (5K price range)

2) create a fast vehicle that uses some human power to extend the range and create a more fulfilling riding experience. (50K price range)

We are forced by sheer economics to stick with the former option because we intend to actually build something and it is far outside of our budget to construct a high-speed vehicle.

Summary of design objectives:
The goal is to create a single occupancy vehicle with the following criteria;

1. Has a Thys Rowingbike power-train
2. **A secondary power source in the form of an electric motor and battery are included for short bursts of speed (GreenWheel)**
3. Has three wheels either two in the front or two in the back in order to give it more stability on wet, icy and loose tarane.
4. **A mechanism that allows the bike to “lean into turns"**
5. Target price: $5,000

Stuff other people can worry about:

- Improving the electric drive train
- building a good enclosure
- incorporating a suspension linkage
- building a production spec and prototype
- Integration of a protective roll cage
- Vehicle will fold up so that it occupies less space on the sidewalk & can be entered from the back by flipping into the cockpit.