Steering Systems

Steering systems come in two basic flavors: Over Seat Steering (OSS) and Under Seat Steering (USS). Each of these steering systems has several configurations.

Over Seat Steering- OSS

Advantages
- Lower weight
- Lower complexity
- Allows a narrow track wheels configuration
- Lowers overall frontal area, improved aerodynamics

Disadvantages
- Rider cannot use the tiller for support, requires a seat with lateral support to keep the rider from falling out.
- Not as popular as Under Seat Steering, due to arm fatigue or lack of intuitive design.
- Fatigue level is higher than an Under-seat steering system.
The Over Seat Steering (OSS) system is normally configured as a 'T' or 'Y' bar Single Handle Tiller. As for the better steering handle configuration, it is a matter of personal preference. From an inconclusive observation, the Single Handle Tiller (or 'Y' bar) is geared towards sport riding, as the rider's arms have limited support, but tight control. The 'T' bar fits the more traditional role as it is both user-friendly and a bit more comfortable than the 'Y' bar. Whatever the preference, the design of the OSS mechanism is a science. On higher quality trikes, the steering column rotates freely using a universal joint (U-joint). The U-joint allows the steering mechanism to move with the rider's body, as to allow body English. On cheaper trikes, the steering column is either fixed or restricted to a single axis movement.

**Under Seat Steering-USS**

**Advantages**
- Intuitive control makes it easier to master
- Provides comfortable support for arms
- Gives the rider support during high G turn, precludes the use of lateral seat support.

**Disadvantages**
- Heavier weight compare to OSS
- Increases the Frontal Area making the trike less aerodynamic.
- Places the riders hands dangerously close to the wheels or ground
- Requires ample room for U bar clearance that may compromise wheel track or seat width.

As for Under Seat Steering, the actual steering mechanism is either a U-bar configuration or dual lever design. Again, the choice is up to the rider, as to which configuration is better suited. The dual lever design is best suited for ultimate comfort, while the U-bar gives the vehicle a sportier and lighter feel. Additionally, the U-bar system tends to be simpler and cheaper as it requires fewer parts for operation. However, the expensive, dual-lever system offers superior linearity and better flexibility for adjustment.

**Steering Linkage Systems and How They Work**
The steering linkage is another factor in the equation. Although more than a dozen steering systems exist, I'll mention a few widely used steering linkage systems as they would apply to the Thunderbolt. These are shown and explained below:
Single Tie Rod and Drag Link System

This type of steering system was common on early automobiles and eventually found its way to farm tractors. A knuckle-to-knuckle Drag Link provides continuity between the wheels, while the Tie Rod provides linkage to a Bell Crank (Pitman Arm). The best attribute is that the main linkage consists of only two rod-end bearings. This allows the steering to remain relatively tight. Although this system uses more parts than the other two steering systems, it provides superior flexibility for adjustment and provides adequate Ackerman compensation. However, the system weighs slightly more than the other two systems mentioned. Misalignment of the Bell Crank orientation (caused by the Tie Rod deviating from 90°) causes a slight non-linearity throughout the steering range. This is compensated by applying Ackerman to the steering knuckle control rod that links it to the Bellcrank. The above drawing depicts an application for OSS (Over Seat Steering). For USS (Under Seat Steering U-bar), the drawing below applies.

As with the first example, this design also offers good Ackerman compensation.
Dual Drag Link System

Note
The illustration below refers to the geometry relationship as it applies to the Thunderbolt. As depicted, the bellcrank axle does not align with the kingpins. Obviously, a shorter bellcrank arm can be adapted with success if the bellcrank axle is moved aft so that the both control arms are almost parallel. However, the shorter length lever shall have some affect on the overall Ackerman.

This system offers lower weight, less parts than the Single Idler Arm system and is optimized for Over Seat Steering, as the Bell Crank is mounted almost at the kingpin plane. The major advantage to this system is that it provides near perfect Ackerman compensation. This design was used on the Volkswagen Bug over 50 years ago. The Bell Crank orientation and length must remain constant to maintain proper Ackerman. Adapting a USS steering system requires a U-bar mounted aft of the king pins. Unfortunately, the steering linkage becomes increasingly complicated as a second Pitman Arm (Bell Crank) and Tie Rod are required (refer to the drawing below). The Bell Crank length (from arm pivot to axle) must equal the Steering Knuckle Lever length (measured from the arm pivot to kingpin axle). Deviations to this relationship can diminish the Ackerman compensation.

The example above was initially used on the production Thunderbolts. Obviously, you can see why we are using the Single Tie-Rod steering system.
Crossed Dual Drag Link

The Crossed Dual Drag Link is optimized for a USS (U-bar system), as the Bell Crank (Pitman arm) is placed behind the steering Kingpins. This linkage system is used on Ian Sims' Greenspeed Recumbent Trike and many other inspired designs. Note that this is the only example rendered of a Leading Lever steering system. The Crossed Duel Drag Link system can be adapted for OSS by moving the Bell Crank forward. However, an Aft Lever Dual Drag Link steering system is better suited for an OSS configuration.

The science of maintaining a linear rod linkage system requires the application of the Right Angle Rule. The Right Angle Rule requires that both rod ends maintain a 90° angle to each linked lever arm when the wheels are in a neutral, forward position. Not only does this practice insure that both rods maintain a linear arc throughout the full range of motion, it also insures the stability of the linkage. As the rod ends approach an angle close to 0° or 180° in relationship to either of the lever arms, the linkage rod loses its ability to hold and control the arm. The Right Angle approach guarantees the steering linkage force is optimized throughout the 90° arc of steering travel. This principal is applied to the Crossed Dual Drag Link steering configuration shown above. To achieve the 90°-angle relationship with the above example, the two drag link rods require separate mounts on the Pitman Arm. To prevent tire scrubbing during turning, these mounting locations are angled back further on the Pitman Arm to provide the necessary Ackerman compensation.

Greenspeed has used this system for several years and has only recently changed it to a dual draglink system for better stability for braking.
Summary
Each steering system has its advantages and disadvantages depending on its application. My personal choice is an aft lever system using a Single Tie Rod and Drag Link System. My decision is based on cosmetics and practicality. Although I have described the mechanics, it is well worth the time and effort to experiment with Peter Elands magical spreadsheet.

Seating

Note
I do not have quantitative data that specifically addresses this subject. However, I have conducted numerous experiments in sling/webbing and rigid back seat design.

Seating is a preference. Basically, an HPV seat is divided into two types: Mesh or Rigid. In some incarnations, a combination of the two can be had. Each has its virtues and disadvantages. Some people indicate that foam-back rigid seats have the greatest efficiency, but none have substantiated their claim. The same applies to mesh seats.

Performance Criteria
The critical performance issue of an HPV recumbent seat is the provision for firm support of the rider's lower back. Deflection for the lower back of the seat should be less than 1.5 inches. Deflection for the buttocks and upper back can be exaggerated without much efficiency loss. Please note that this performance criteria may not apply to low angle seating.

Another important performance issue is seat weight. Lately, graphite composite materials have made rigid seats as light as the nylon mesh on aluminum frame seats.

A lower seat angle allows better aerodynamics. Aerodynamics play a critical role in an HPV's overall performance. With a low slung seat, the trike rider can cut through the wind like a hot knife through butter….right smack into a car! Low slung seats compromise the rider's vision, so beware!

Comfort Criteria
As for comfort, take your pick. My personal preference is a Mesh Sling seat. The fabric is breathable and is void of uncomfortable hard spots. A well designed, quality made sling seat has several adjustments that can fit the most discerning buttocks.

The virtue of a rigid seat is that it can provide firmness. However, in my experience, they have been scorned by many racers, as they retain heat and moisture and many are not adjustable. Easy Racer has addressed some of these
problems by using a set of contoured pillions. These pillions are designed for minimized area, but allow maximized support and comfort.

Seat angles and head rests are subjective topics. As for an efficiency advantage (disregarding aerodynamics), I have heard pros and cons from each camp. As for head rests, they’re great. However, bicycle helmets are designed for upright bicycles and not for recumbent trikes. Consequently, back rests and helmets don’t seem to get along these days.

**Side/Lateral Support Criteria**
A trike seat is unique in that it must provide lateral support for the rider. However, this is not always true. In the case of the Greenspeed GTS and GTR model trikes a piece of nylon mesh (simple potato sack) is stretched over the seat frame and offers no lateral support. In this design, the Under Seat Steering ‘U’ bar provides the lateral support for the rider. In other cases lateral support is built into the seat. A primary example is the Windcheetah. The Windcheetah or Speedy was designed as a narrow track, Over Seat Steering configured trike. Thus lateral support is required to keep the rider in the cockpit during high G turns. As mentioned, everything is a compromise, even the seat.
Before I go off the deep end on this subject, I must mention that most tadpole trikes use only front brakes. A back brake is rarely used. Therefore, this discussion focuses on front wheel brakes. I'll elaborate on the rear brakes later. Basically, three types of braking systems are employed: Drum, Disc, and Caliper.

**Drum Brakes**

The standard drum brake used for the majority of recumbent trikes is the Sachs VT5000. This drum brake is classified as a single, leading shoe brake. The basic drum brake uses two brake shoes inside a cylinder drum. When the brakes are applied, an actuator rotates an oblong cam that forces both brake shoes outward against the cylinder drum. See the illustration below.

**Drum Brakes, Pros and Cons**

The major advantage of the drum brake is that it provides solid and reliable braking and is optimized for Tadpole trike designs. The disadvantage is that a drum brake performs poorly in wet weather conditions (if moisture gets into the drum) and is susceptible to heat fading. Additionally, the self-energizing drum brake action is nonlinear and may be slightly unpredictable.

**Single Leading Shoe Drum Brake**

The single leading shoe drum brake is a self-energizing brake system. The principle behind the self-energizing brake is that when the brake shoe is applied to the drum, the brake mechanism diverts some of the rotating energy and applies it to the shoe for additional contact force to the drum, hence more friction and stronger braking force. In essence, the self-energizing mechanism operates as a positive feedback system. The chief component of the self-energizing system is the leading shoe. As
mentioned, the shoe moves on a stationary axis. On the opposite end, a cam is used to push the shoe against the drum. The leading shoe is designed in such a fashion that when the cam pushes that shoe against the rotating drum, the initial friction grabs the shoe and forces it even harder against the drum. As the name implies, only one of the two shoes is self-energized. The direction of rotation dictates which shoe is leading (self-energizing). In most cases, the drum brake manufacturer designs the leading shoe slightly larger and heavier than the passive shoe. The Single Leading Shoe Drum Brake is widely used for bicycles and HPVs.

Dual Leading Shoe Drum Brake
The dual leading shoe self-energizes both brake shoes. In this configuration, the stationary axis is replaced with another Cam. The Cam profile is changed from an oblong shape to a half-crescent. This applies to both cams. The new shape allows each cam to operate a single brake shoe. The rounded portion of the crescent shape cam acts as a stationary axis for one shoe while the flat portion of the cam actuates the other shoe. In summary, the leading shoe is the near pinnacle of drum brake design. Unfortunately, the Dual Leading Shoe has not found an application on production bicycles or HPVs.

Drum Brake Fading
Brake fading is the degradation of braking power over a defined time of constant usage. An example is traveling down a steep and long descent, applying the brakes constantly to maintain a safe speed. During the descent, the brakes may appear weaker, requiring extra force.

Contrary to popular superstition, brake fading is caused by the expansion of the brake shoes and drum that occurs during extreme heat. When brakes are cold or at room temperature, the brake shoe fits flush against the drum. When both of these components get warm, they began to expand. Consequently, the brake shoe no longer fits flush against the drum and braking is impaired. The brake shoe material does not compromise due to heat, and hence does NOT cause brake fading! Over the last century, scientists and engineers have perfected several composite materials that stand up well to excessive heat and wear. Braking is a science, not voodoo magic.
Disc Brakes
The problems with brake fading and sensitivity to moisture have both been remedied by the advent of the Disc Brake system. The disc brake applies a set of flat pads on opposing sides of a revolving rotor. Since both brake pads and rotor surfaces are flat, the brake is infallible to fading or moisture buildup.

Disc Brake Pros and Cons
The major advantage of a Disc Brake is that they provide excellent and reliable braking and are optimized for Tadpole trike designs. The disc brake action is proportional and provides smooth braking even during the harshest weather conditions. As for disadvantages, the majority of disc brakes are heavy as compared to drum brakes. Lighter disc brakes are available, but are very expensive. Performance reliability for disc brakes is another problem, as most disc brakes are prone to rubbing. Not only is this rubbing an annoyance, it is also a performance robber.

In recent times, the disc brake systems adapted for bicycles have advanced dramatically. In the past, the bicycle disc brake had a negative reputation as being heavy, noisy and having lackluster performance. However, due to many technological breakthroughs (chiefly in material science), disc brakes are now smaller, stronger, and quieter.

Disc Brake Characterization
Several variations of the disc brake exist. A disc brake is categorized by Actuation and Execution.

Actuation
Actuation is how the brake is activated. Three types exist: Mechanical Cable, Hydraulic, and Hybrid.

Mechanical Cable Systems use much of the same hardware as a standard bicycle caliper brake. The brake is actuated using a conventional handle and cable/housing. A levering or cam system constricts two brake pads against the rotor in order for braking. On the Avid disc brakes, a cam and ball bearing system is used for even braking. The advantage of a mechanical disc brake is that the cabling is simple and parts are always readily available. The major disadvantage of this system is that the inherent cable-stretch and cable housing compression reduces the overall effective force that can be applied to the brake mechanism.
**Hydraulic Systems** rely on a Master and Slave cylinder system to provide the actuation. As with all hydraulics, the medium is a lightweight oil that is moved through a semi rigid line from the brake handle (Master Cylinder) to the disc caliper. The amount of force developed by the Master Cylinder depends on the cylinder’s displacement. The direct force that can be applied by a hydraulic system is awesome! However, no system is without its problems. Replacement parts are difficult to find, and if you don’t like the handles that came with your brakes, well... too bad.

The **Hybrid System** uses standard brake cables, but actuates a mechanism that contains both Master and Slave cylinders. The reason for this system is it allows a cable linkage system to be optimized by the caliper. Additionally, the hydraulic actuator provides better performance than a total mechanical system. As a mixed blessing, conventional cabling and brake handles can be used. This type of disc brake is slowly being phased out due to the unneeded complexity.

**Execution**
The mechanics of a disc brake are simple: Squeeze two brake pads against a turning rotor and voila! However, preventing the brake pads from rubbing against the rotor (when the brake is not engaged) has always been a problem. I’ll describe two methods how this is accomplished.

In the **Floating Rotor** design, a Caliper containing the actuator and brake pads is situated in a fixed position (e.g., mounted to the steering knuckle). The Rotor is mounted to a spline shaft on the wheel hub where it has restricted horizontal movement. When the rotor is rotating, it can brush up against either of the two opposing pads. When this occurs, the rotor bounces off the pad and is resituated (hopefully) in a position where it is not touching either pad. The premise of this design is that rotor and pad rubbing cannot be avoided, but can be reduced to a tolerable level. Advantage: no calibration or adjustment and the system is light and simple. Disadvantage: always slight rubbing and the spline is prone to wear out quickly. We can be thankful that these types of brakes are all but obsolete.

In a **Floating Caliper** design, the caliper is either floating or is biased to a location where neither pads contact the rotor. On the Practical Innovation's disc brake, the caliper was designed so that it was in a fixed or biased position during no braking. During braking, the caliper became free-floating so that both pads could contact the rotor with identical force. Advantage-least susceptible to rotor/pad rubbing. Disadvantage- many adjustments and weight penalty. As with the floating rotor, this design is quickly sinking to obscurity.

The Fixed Caliper design is built around the assumption that the rotor is perfectly true and will remain so. As the name implies, this caliper design is stationary mounted using either a concentric washer or spacers to make the final adjustments. Once adjusted, the pads should not touch the rotor until the brake lever is actuated. These disc brake systems are used for both mechanical and hydraulic and are usually the lightest and most common system available.
Caliper Brake System

The venerable caliper brake offers adequate performance and reliability. Since several books exist on this subject, I will not elaborate much. The caliper brake system can only be used with the Steering Stirrup that supports a standard BMX wheel. This additional ancillary can compromise weight constraints. However, the caliper brake is readily available and so are the BMX standard wheel sets. The economy and practicality of this system makes it a very attractive alternative for the home builder.

Summary

As a designer and innovator of disc brake systems for tadpole trikes, my opinion stands as an authority on this subject. Currently, I feel that the drum brake is the most practical choice (not always the best) for recumbent trikes. The drum brake is inexpensive and easy to adapt to tricycle needs. In addition, the wheel can be easily removed. Even though the hydraulic disc brake beats the drum in almost all categories, the price is normally higher for most people.

Side Note

As the former owner of Practical Innovations, my mission was to produce a product that was technologically ahead of its time. I spent many months and thousands of dollars developing a practical disc brake system. My first two generations of disc brakes were utter failures. However, perseverance prevailed and I finally developed a high performance disc brake system that was reliable. The disc brake was the main selling point for all models of Zephyrs sold. Although there are now disc brake systems that offer better performance than my own, I am the only manufacturer that has successfully implemented a proprietary brake and linkage system to a recumbent.

Wheel Bearings

The biggest misunderstanding in designing a recumbent trike is the requirement for both front and rear hub bearings. For years we have been tantalized by all the great custom hubs built by Phil Wood and countless other manufacturers. Most of these hub builders use sealed cartridge bearings. When we hear the word "Cartridge Bearing" we think of performance, quality, and reliability. What we are not told, is that sealed cartridge bearings are specifically designed for radial loading and not optimized for axial loading.
Radial loading is the amount of weight placed vertically above the axle. Sitting on a trike places an axial load on the bearings. The drawing below is a cross-sectional view of a radial bearing.

Axial or Thrust loading is the amount of force placed against the horizontal plane of the axle. Negotiating a tight corner at high speeds places a radial load on all three wheels. A cross-sectional view of a cup-and-cone axial bearing is shown below.

Although all bicycles use a combination of both axial and radial loading, the recumbent tricycle places much more emphasis on axial loading. Therefore, the venerable cup-and-cone bearing arrangement is still the most effective.

If an axial load rated bearing is the best, why are they less reliable than the sealed cartridge bearing? It turns out that the seal makes the biggest difference in the cartridge bearing. If a similar seal existed for the axial cup-and-cone bearing, the longevity would exceed that of the cartridge bearing.

Another advantage of the cartridge bearing is the easy serviceability. In most axial bearings, the cup is an integral part of the hub and cannot be replaced.

Summary
Although the cartridge bearing appears attractive, it is not always the ultimate solution.
Chain Line Management

Polyethylene Tubing
In today's trike market, the polyethylene garden sprinkler tubing is widely accepted as the standard. This tubing is light, offers a slick surface, and is inexpensive. Another important feature about this tubing is that it protects the chain from grime and dirt, hence extending its longevity. However, efficiency can be compromised if the wrong lubricants are used on the chain. It's best to use very thin oil when using this tubing, as it offers the least amount friction between chain and the polyethylene surfaces.

The reason why a chain can pass through this type of tubing with little friction is very elementary. In a straight path, only outside edges of the chain contact the polyethylene. What is important is finding the correct diameter of tubing to use, as three basic sizes exist, along with several thicknesses. If the tubing is too small in diameter, the chain surfaces have more contact with the tubing creating higher friction. A diameter of tubing that is too large makes the system heavy and allows too much chain slop. Polypropylene tubing with ~.7 OD and an ID of ~.6 inches seems to work the best. However, those who have an endless supply of money and resources can purchase the ultimate friction free solution; Teflon, tubing goes for $5.00/ft. BTW- We sell this stuff on our website!

The application of this tubing should be restricted to a straight chain line. This is especially important when applying the tubing to the drive side of the chain. On the non-drive side (the side of the chain where the derailleur pulleys take up the tension) routing the tubing in an arc may increase friction. If an arc is required, make it as gradual as possible, as to decrease the chances of friction. Another way of increasing the efficiency is to keep the chain tensioned, as to make it self supporting so that it never has to rest fully on the inside of the tubing.

Chain Pulleys
Ok, so they're actually skate board wheels. They work great if you get the right ones. Look for a durameter of at least 98 and a diameter of 50 mm. Almost every recumbent uses a chain pulley. In most successful trike designs the pulley is used almost exclusively on the drive side of the chain to change the chain line angle.
Mid-Drive Systems
To my knowledge, Steve Delaire is probably the strongest proponent of the mid drive system besides myself. The mid drive system solve two problems with relative simplicity and efficiency; 1) Most recumbent trikes use smaller rear wheels that require higher gearing 2) The chain line angle needs to be altered. A mid-drive system handles these common problems, but requires a bit of consideration. First, two separate chains are used, and in most cases a second derailleur is needed (this is especially true when multiple gears on the mid-drive are used). With a second derailleur on the mid drive, the designer must insure that adequate ground clearance can be achieved. Lastly, an extra derailleur requires an extra shifter, this can complicate the ergonomics and design of the trike. My suggestion is to use a manual type of derailleur with a very short cage. This manual derailleur can span only two extreme gears. This combination allows an extremely wide gear range, but simple, light, convenient, inexpensive, and efficient when compared to a Schlumph drive or SRAM 3X7 combination.

Performance Considerations
The most frequently asked question I get is, "What makes a high performing recumbent trike?" This answer assumes we want ultimate efficiency and handling on both flat and hilly roads. The first and foremost criteria for performance are aerodynamics followed by weight and rolling resistance. I'll elaborate each of these attributes and explain how they are addressed in a performance trike design.

Aerodynamics
The majority of energy lost is through wind resistance. The science of aerodynamics is very complex and sometimes controversial. I confess that I only understand the basics of this field. However, applying these basics to an un-faired trike design provides 90% of what we need to know.

Note
The mention of a front fairing and tail box has been omitted form this discussion. Although both accessories provide an ultimate solution to reducing aerodynamic drag, I don't have the expertise to elaborate.

Reducing the overall frontal area make the vehicle more aerodynamic. There are several ways to reduce the frontal area of a trike. I have provided a few of the major ones here:

Increasing the seat angle provides an aerodynamic advantage. Most sport recumbent trikes have seat angles less than 35 degrees. Some have angles down to 25 degrees. As mentioned earlier in this chapter, a low angle seat does have controversy as to comfort and visibility.

Decreasing the wheel track or the overall width of the trike is an obvious way of reducing the frontal area of the trike.
Tucking the rider’s arms towards their torso decreases the amount frontal area. This is accomplished using an OSS Joystick.

Using smaller front wheels reduces the frontal area. This is a paradox. Although reducing the wheel size down 20% (20” Vs. 16”) will obviously yield better aerodynamics, the performance edge is completely eroded away by the decreased roll-over efficiency of the smaller wheel. We will explain this later.

Vehicle Weight  
*Note*
In several periodicals and articles, I have found conflicting definitions of “Sprung” and “Unsprung” weight. In the automobile industry, Unsprung weight refers to the weight not supported by springs (e.g., wheels, steering linkage, etc.). People talking about bicycles have contradicted terms referencing both Sprung and Unsprung weight as the same. Consequently, I am avoiding the semantics of both definitions, as they officially do not apply to HPV’s (according to my Webster’s).

Frame Weight
As a preface, I wish to explain the virtues of weight or lack there of. A light-weight trike allows faster acceleration and the ability to climb hills much easier than a heavier trike. An out-of-shape, grossly obese rider on a light trike is like ordering a diet coke with a super size of fries and a triple cheeseburger. A light trike is best suited for an athlete, as it is they that best benefit from this performance attribute. Obviously, a light weight trike will not compromise on stiffness or reliability.

Dynamic Weight
The performance merit of any bicycle or HPV is based chiefly on gross weight; however, more important is where the weight resides. Weight or mass residing in the moving parts (e.g., wheels, cranks, chain) significantly compromises overall efficiency. This is what I refer to as Dynamic Weight. In simple physics, the larger the mass, the more energy it takes to alter its motion (and the more energy stored, too). Mass that maintains a constant velocity or subtle changes there of, does not require as much energy to maintain its motion. The key phrase is altering or changing velocity. Obviously, it takes more energy to achieve a velocity than to maintain it. That is why the dynamic weight of the vehicle (the wheels, cranks, and chain) must be as light as possible.

Weight residing in non-moving parts (e.g., rider’s torso, HPV frame, and accessories) presents less of a performance penalty, as it only plays a factor during acceleration, up-hill riding and added wheel resistance.
In summary, lighter wheels and drive train is the key to optimum performance. Weight loss in non-moving components should be of secondary concern.

Decreasing Dynamic Weight
Throughout this chapter I mention that a trike design is the sum of many compromises. Consequently, lowering the dynamic weight of any HPV will be a fine balance of compromise.
Lighter Components
Assuming money is no object, an ultra light chain, Crankset, pedals, and wheels provides the most effective means of reducing Dynamic weight. Lighter tires are perhaps the most effective and cheapest way of reducing weight while switching to Titanium spokes provides the most expensive method.

Smaller Rear Wheel
Decreasing the size of the rear wheel from 26” to 20” appears as an easy and convenient method of reducing the rotational weight of a trike. Although there is a 90 gram difference in wheel weight, a smaller wheel requires a larger chain ring to achieve the high gear inch range as the 26” wheel. A 68 tooth chain ring increases the overall weight by at least 42 grams, not to mention 16 extra links of chain would add yet another 41 grams of weight (2.55 grams per link x 16). The total weight saved diminishes down to only 10 grams. The greatest attribute using a smaller wheel is where the weight is saved. After all, all weight is not created equal when we throw angular velocity into the equation. Are we confused? Let me explain:
I have two rear wheels that weigh 4 lbs ea. However, one wheel uses a heavy hub while the other uses a heavy rim. Which wheel has a higher rotational mass? The wheel with the heavier rim of course!

Rolling Resistance
I may be splitting hairs on the hierarchy of this discussion. Some may claim that rolling resistance is more paramount than vehicle weight. Having three wheels instead of two may be a valid point to this claim.

The subject of rolling resistance is a very touchy subject, as many people have their own strong preconceptions. Therefore, I’ll present all the factors that affect rolling resistance, but will not place them in a hierarchy.

Tire Rolling Resistance
Several years ago, Ian Sims built a rolling machine that was intended to test the rolling qualities of wheels and tires. Although his test could not measure the efficiency of a tire size, it was able to produce some interesting results with different brands of tires. More importantly, some European groups had also conducted empirical testing of tires with results that paralleled much of the results conducted by Ian. Some of the winners in this group of 20” size tires include Tioga Comp pools and Schwalbe Stelvios. Although the rolling resistance for some tires may be extremely low, it is best to consider other important factors too, such as tire weight, and application.

Roll-Over Resistance
Warning!
There are people that will always believe that small diameter wheels have a rolling advantage to larger diameter wheels. This article is not to evangelize, but to educate. Although my method and conclusion of research are open for debate, I don’t spew self-serving propaganda to promote my product or design.
Small tires small minds? Not exactly, up until ten years ago, almost all tadpole trikes used larger 26” or 700c rear wheels. The Greenspeed trikes became an almost instant success with their 20” rear wheel design. Not only did the 20” rear wheel make the trike slightly smaller and more convenient, but it made the rear much stiffer too. As the popularity increased, the question concerning the efficiency of a 20” rear wheel came under scrutiny. As mentioned previously, Ian Sims attempted to defend his position by using rolling test data that favored the 20” wheels. However, many discovered that the test methods used by Ian were only conducive at determining tire rolling resistance and not for comparing wheel size. At the time of these results I too, strongly questioned the validity of testing, as his test results for larger wheels greatly contrasted data generated from other empirical testing published elsewhere.

The subject of larger vs. smaller wheels is a very controversial subject. The answer to this is understanding the simple concept of Roll-Over Resistance. Roll-Over Resistance is the ability or inability of a wheel to roll over an uneven or aggregate surface. Example I have a skateboard that rolls fast over a smooth sidewalk, but doesn’t roll well over the coarse aggregate of asphalt. Apply this principal to trike wheels. Over a smooth gymnasium floor the difference between a 20” and 26” tire is very little. As the surface becomes increasingly coarse, the 26” wheels will roll better than a 20” every time.

Roll-Over Resistance is measurement that can only be accurately measured by comparing two wheel sizes over a known aggregate surface. Although rolling resistance of a tire can be accurately measured in a controlled laboratory experiment, Roll-Over Resistance is best measured by empirical road test methods. In my expert opinion, Roll-Over Resistance is as important if not more important as Rolling Resistance.

The problem applying this to a recumbent trike is that using smaller wheels in front is a requirement, as they reduce wind resistance, handle side loading, and allow adequate room for steering. The same applies to many recumbent bicycles, as a smaller front wheel allow easy foot clearance from the crank set and reduces wind resistance. However, on a trike we have three wheels instead of two. Since the front two wheels cannot change for the reasons mentioned, we have but the rear wheel to be concerned with. Consequently, changing the efficiency of one out of three wheels will not have the amount of success as that of a bicycle. Regardless a larger wheel will provide better roll-over resistance.