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# The Evolution of Cycles from Front Wheel Drive to Delta Tilting Trike

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## Abstract

Since 1983, a publication by Albert Gross and others (Gross, 1983) has given scientific closure on the aerodynamics of human powered vehicles and proof that recumbent cycles travel faster than safety bicycles for the same human effort. Despite this recumbents have only a small niche (Gryczan 2013) in the human powered vehicle market dominated by the rear drive safety bicycles developed in 1879 (Bijker 1995, p.69). This paper gives background and insight into how developers have combined front wheel drive recumbent bike technologies with tilting trike technologies to produce new types of cycles. The discussion highlights potential for sociotechnical change. It considers economics and social groups along with technology and science because these are essential parts of having designs move from 'being capable of improving the cycle fleet' to 'being seen as capable of improving the cycle fleet (After Bijker 1995, p.9).' It provides diagrams showing the contributions different actors have made to the bikes and trikes concerned.

## 1. Introduction

## 1.1 A framework for change

*'Our language takes on new words and alters old ones, as technical artefacts are assimilated into our discursive codes and frameworks.'* (Jamison 2003)

This paper is framed by Wiebe Bijker's writing on Sociotechnical Change (Bijker 1995) which uses the example of cycles evolving in the late 1800's.

Different social groups have different values and view an artefact in different ways and this is called *interpretive flexibility*. An obvious example is a chicken sandwich meaning different things to meat-eaters and to vegetarians. Bijker discusses the high bicycle we know as the Penny Farthing in interpretive flexibility terms. In 1873 when the high bicycle dominated, young fit men considered it a macho bicycle, risky but useful, while for women and elderly men it was an unsafe bicycle and unacceptable for use. To the women and elderly men, it was a non-working machine. (Bijker 1995, p. 74)

Linear narratives about inventions and inventors' biographies are not enough for stories describing sociotechnical change. A richer narrative including details of concerned social groups and interactions between actors is required because no sociotechnical change occurs without scientific, technical, social and economic factors (Bijker, 1995, p.7).

As artefacts become more accepted and the number of alternatives decreases, the language around the artefact uses fewer qualifying terms and reaches *stabilisation*. In 1888, the term for the safety bicycle was "Rear Driven Safety Bicycle", in 1888 it became the RD Safety Bicycle, in 1889 it was the Safety Bicycle and by 1895 just the Bicycle. There is an exertion of *power* tied up with the ability to use simple language. If a word is listed in dictionaries and is used without qualification it implies that it describes a dominant form. So *"bicycle"* would mean "rear wheel drive safety bicycle" to most people. However "*recumbent bike"* might only convey that a bike is somehow different, and need further qualification for a full description. Another aspect of an article becoming dominant is *closure*, where a consensus of the views of different social groups lets a dominant meaning of an artefact emerge (Bijker 1995. P.100).

*Obduracy* is the maturity of a technology to the point that is hard to change. The dominance of an obdurate form within a field (safety bicycles within human powered vehicle design) exerts unavoidable *power* and economic influence. Lastly, a *presumptive anomaly* is an event or discovery implying that under a future set of circumstances, an obdurate system may fail (Bijker 1995, pp.4, 278).

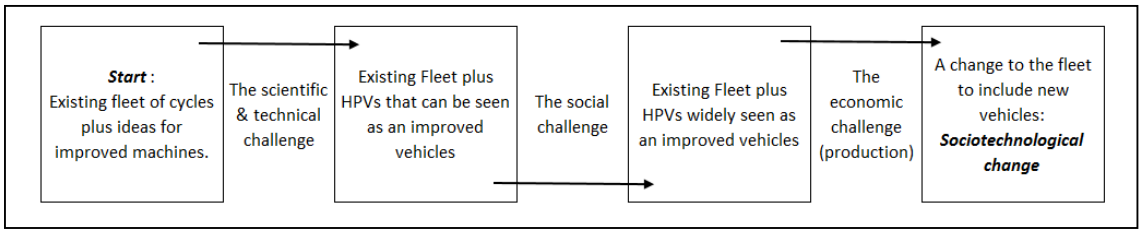
Bijker's work can assist cycle designers to understand how their cycles might be perceived by others, something critical to a cycle's success.

## 1.2 The Human Powered Vehicle Movement

This paper discusses designers who have worked in the last 20 years in a common background for HPV development. The formation of the IHPVA (International Human Powered Vehicle Accociation) in 1976 started a wave of cycling scientific discovery and invention. Albert Gross' 1983 article in Scientific American represented scientific closure on cycle aerodynamics and showed that recumbent cycles with streamlining (low frontal area and drag coefficient) could travel faster than more conventional safety bicycles for the same human effort. (Gross 1983, pp.146, 149) This article was based on first-hand accounts of HPV's (ie work documented in IHPVA 1978). Its exposure of the aerodynamic issues of the safety bicycle can be seen as a presumptive anomaly. Designers could improve the safety bicycle using aerodynamics, even though for most cyclists the safety bicycle was a working machine (Van De Walle 2004, p.32).

Within the HPV movement, new types of vehicles were discovered, tested, discussed, raced, reported in magazines and books, refined, made and eventually sold. This was the beginning of a modern societal recognition for the cycles, allowing them to move from being ideas and inventions to becoming technological artefacts.

**Figure 1: Progression of cycle fleet during 1880's sociotechnical change. Meeting scientific, social, technological and economic challenges resulted in increased mobility for women and possibilities for cycle commuting.**




Since Gross's 1983 article, development of recumbent cycles has taken place in the context of a powerful bicycle manufacturing system. The internet has emerged as a nation transcending communications and marketing tool (Leiner 2003), which can be seen as another context for recumbent cycle development. To succeed, cycle designers need to work with the dominant manufacturing system, form alliances where they can, and use and create cross-boundary, cross-nation social groups. It is easy to see one's own product as better than existing products but potential customers need to be convinced of that as well. This implies an awareness of interpretive flexibility.

Published statistics (NBDA 2014) still give power to the safety bicycle as an artefact: the American National Bicycle Dealers Association lists eight categories of safety bicycle in its sales figures and one imprecise recumbent category (recumbent / tandem cycles) with 2% of sales. This categorization obscures sales results for the recumbent niche.

## 1.3 Safety and Accommodation

This study found no papers on whether recumbent cycles are more or less safe than safety cycles, but observation clearly shows that a recumbent with rider is lower and less visible than a safety cycle with rider. This can be mitigated through conspicuity aids such as flags and reflective vests.

Cycling safety studies (Johnson 2011 p.325, Raftery 2012 p.5) mention recumbent cycles but can group them so data on recumbents becomes meaningless, adding power to the represented safety bicycle group. (for example Raftery includes recumbents in an 'other' group defined as 'BMX, "fixie" or single speed bicycles, recumbent bicycles, unicycles, or tricycles') or only mentions them by preclusion (Johnson 2010).

More helpful studies such as that by Landis (2004) assesses needs of emerging USA bike path users, including handcyclists, recumbents (2.8% of 1215 vehicles tested) and cyclists with trailers, comparing bike paths standards with new user's requirements. Recommendations include increasing centre of road refuge island width for long cycles including bikes with trailers and recumbents.

Cyclists ride amongst high SUV vehicles which are increasingly popular (Nicholson, 2016) and make all cyclists less visible in traffic, but there is no suggestion that radically increased conspicuity is required for the safety bicycle of today.

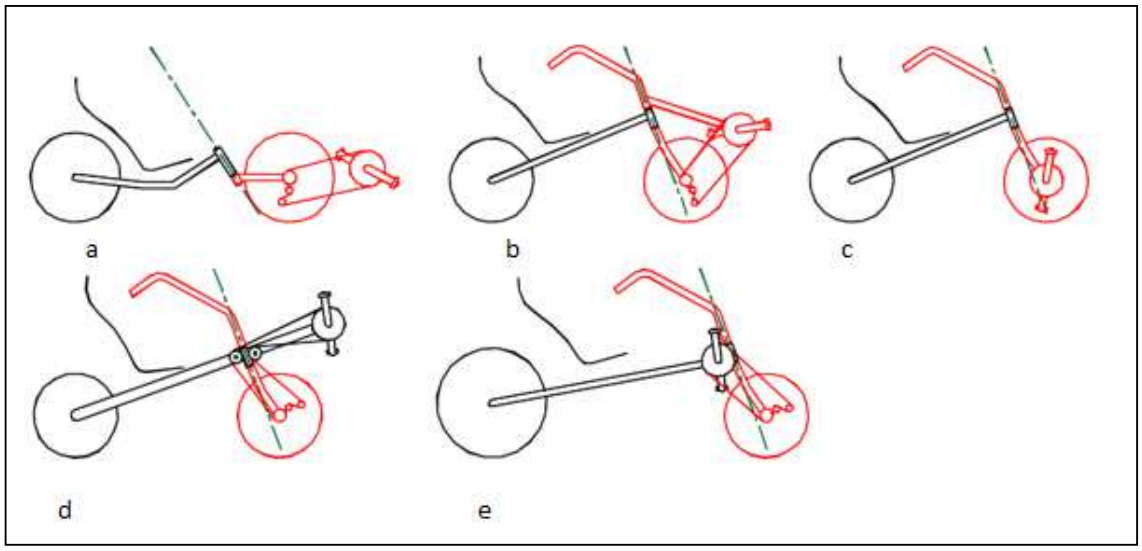
Referring to the 1870's and the emergence of cycling per se, Ritchie (1975 p.85) wrote that opposition to bicycles became harder to sustain: "Innkeepers and blacksmiths realized that riders bought them business and were after all quite nice people". Today, SUV's have been accommodated on our roads and recumbent cycles should be accepted as well, however further research on recumbent cycle safety seems warranted.

# 2 The actors

This paper considers artefacts, classes of artefacts, inventors and social groups as actors contributing to sociotechnical outcomes, such as the widespread adoption of inventions. This follows Bijker's example (1995, p.53) which includes traditions, problems, social groups, parts and successful and failed technologies as important contributors to change. This section contains a technological and historical context for the discussion.

## 2.1 Front Wheel Drive Recumbents

**Figure 2: FWD recumbent schematics, Red = moves with steering, Dotted Green = steering axis a) Python MBB b) Cruzbike MBB c) Kervelo Style MBB d) Zox Bike FBB e) Bevo bike FBB.**




Front wheel drive (FWD) is an old cycle technology. Pedalled bicycles *were* front wheel drive from their inception as a Michaux velocipede in 1865 (Bijker 1995, p27) until rear drive safety bicycles' invention in 1879 (Ritchie 1975, p.125). However modern front wheel drives are often multigear, recumbent cycles with no resemblance to their high wheeled ancestors. FWD recumbents can make good candidates for conversion to tilting trikes (Nurse 2013), and keep transmission chain, brake cables and gear cables short and away from luggage (Eliasohn 1991, p.11) The two streams of design for FWD bikes are moving bottom bracket / MBB and or fixed bottom bracket / FBB.

**MBB** or moving bottom bracket cycles have the pedal axis moving with respect to the main frame and either no chain or no steering-related twisting of the chain. Because the feet twist with respect to the seat during steering, practised riders can use foot steering control to accomplish *'hands off steering'* (Eliasohn 1991 p.12).

**FBB** or fixed bottom bracket cycles have the bottom bracket fixed with respect to the main frame and require chain twisting for steering.

**Python** style MBB cycles (fig. 2a) rely on the rider's weight to stabilise steering. They take time to learn to control, can be steered by leg movements alone, and homebuilders sometimes make them without handlebars. Few commercial variations exist and they are discussed and documented online and across many countries through the openbike website (Openbike 2016) and mailing list (Python 2015)

**Cruzbike** style MBB cycles (fig. 2b) were developed by Tom Traylor and discussed by Eliasohn. These bikes do not rely on body weight for steering stability. The Frontrunner is a DIY version of this bike style offered by Atomic Zombie (Graham 2015).

**Hub gear style** MBB cycles (fig. 2c) have their pedals and front wheels sharing a common axis and a multispeed gearbox varying the ratio between the pedal rpm and the front wheel rpm. Kervelo, Velotegra and Trivek have all developed machines working on this principle. (Garnet 2015, Page 2015, Le Borgne 2016)

**Zox** style bikes (fig. 2d) are FBB cycles with the chain '*running to the front wheel….over idlers* (pulleys SN) *to change the direction of the chain from horizontal as it comes off the chain ring to vertical as it runs to the wheel sprockets. The vertical portion of the chain twists as the wheel turns'* (Eliasohn 1991 p.11, Gomez 2015)

**Bevo** style bikes (fig. 2e) are FBB cycles with the chainring almost vertically above the front wheel axis and no pulley on the drive side of the chain. This configuration is used by Bevo bikes (Davidson 1996 p.34) and the lead author's research cycles. The cycles require guideplates on the sides of the chainring to ensure chain security. It brings the front wheel to the fore making tipping forward under heavy braking unlikely (Nurse 2009, p.93).

These FWD bike mechanisms have all been converted or incorporated into tilting delta tricycles and this paper focuses on some of the development practices.

## 2.2 Paul Sims and his Parallelogram Tilting Trike.

**Figure 3: a) Greenspeed found a market for touring trikes. b) Parallelogram leaning mechanism on Sims trike. c) Sims leaning trike showing front wheel drive with pulleys.**


Paul Sims worked for Australian HPV trike manufacturer Greenspeed from the early 1990's when they became pioneering suppliers of tadpole (two wheels front, one wheel back) non-tilting trikes for touring, pedal prix racing and for those with physical problems. In Bijker's terms, the early customers were a group for whom the less expensive safety bicycle was a non-working machine. Greenspeed's tadpole trike form has gone on to become a stabilised, recognised sales category (Gryczan 2013) for cycles and provides productive exercise for those with balance or weight problems which preclude alternatives.

Sims was involved in extension activities for the business, making and riding experimental front wheel drive bikes for racing in a company whose dominant production was trikes (Kotzur 1999). He made a delta tilting trike in 2000 after problems building a tadpole leaning trike. He had been involved in the structured three wheeled vehicle 24 hour track racing

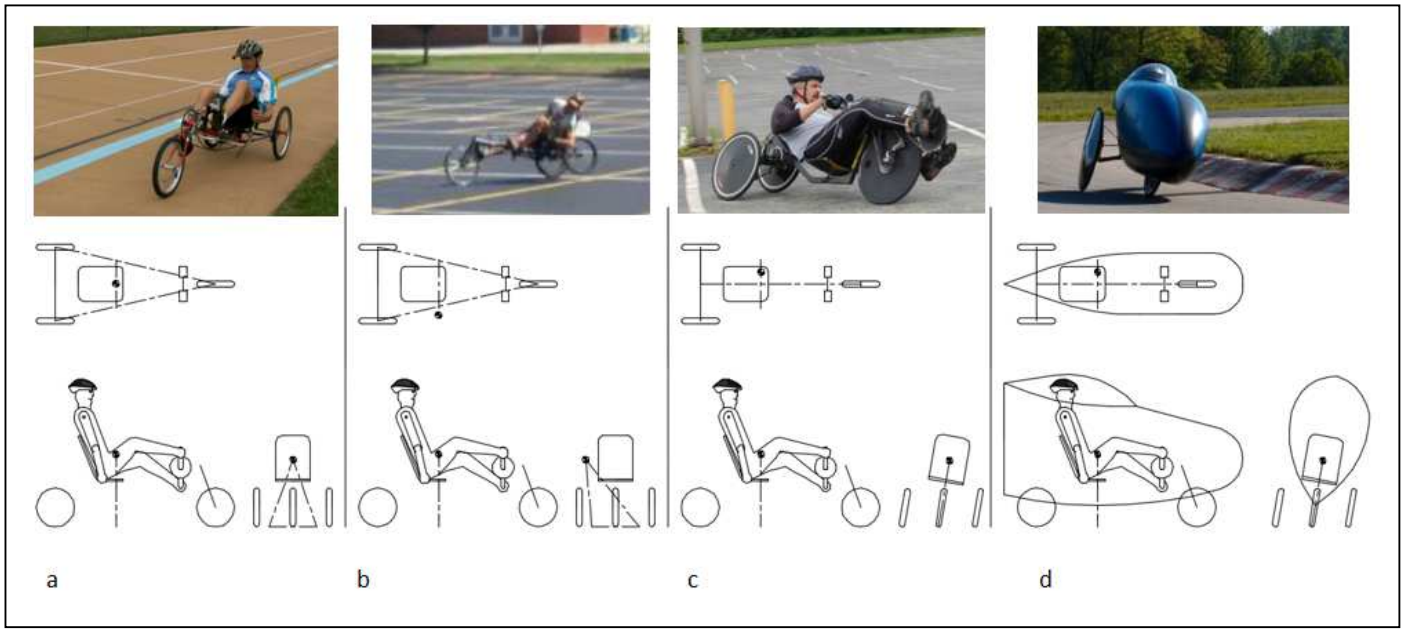
known as pedal prix and was sick of the tyre scrub, tyre wear and tendency to tip inherent in racing non-tilting trikes.

This demonstration trike used a parallelogram mechanism to keep the rear wheels parallel to each other when leaning into corners. The cranks were fixed to the frame and the chain ran over pulleys near the fork crown as per fig. 2d. Simplicity was key: '(This) *simplified the machine by already having everything separate….. only having to steer, drive and lean one wheel leaving the rear ones to lean freely'* (Sims 2000)

Paul's leaning trike was documented openly enough for highly skilled amateur HPV builders to copy the design. Like other machines Paul had built it was not part of Greenspeed's mainstream business or subject to secrecy.

## 2.3 Human Powered Racing America

**Figure 4: HPRA trike racing a) Delta trike b) Dennis Grelk tipping and losing control in tight cornering on a non tilter. Despite unscripted leaning of the body, the vehicle's CG is outside its stability triangle and tips. c) Tim Hicks with a tilting trike which allows bike-like stability. The trike experiences gravity and dynamic forces and balances above the tilt-line d) John Morciglio high speed aerodynamic tilting trike, dynamically the same as c, but with a fairing to reduce aerodynamic drag. (See also Nurse 2009, p.95)**



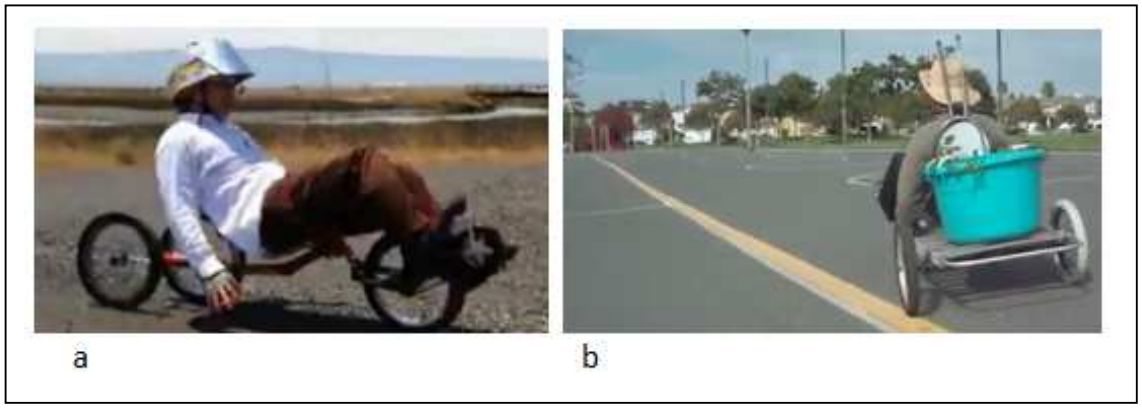

Human Powered Racing America meetings take place across the USA, and allow "open rules" cycle racing. Online event results go back to 1997, and the races have allowed friendships and friendly rivalries to develop. Races showcase riders' cycles and an online forum keeps interested parties informed of machines in development. The forum attracts posts from talented amateur and professional cycle builders. In March 2009, regular racer and cycle builder Tim Hicks announced he was building a tilting trike (Beauchamp 2009). Subsequent posts on the same topic cite Paul Sims' trike and are from as far afield as Britain and Australia. Tim's motivation seems only to make something that could win races: a tilting trike could offer more speed and dynamic stability on a winding course (Beauchamp 2015).

Tim commissioned his delta tilting trike and won races with it, and more tilters began to appear at HPRA events. Unfaired homemade machines from Dennis Grelk and Miguel Didolo, faired machines from Rose Hulman university and John Morciglio, and a commercial European Munzo trike all came on to the scene. The races created a platform for racing of

tilting trikes using parallelogram tilting. The Rose Hulman and Morciglio machines share technology with fast tilting velomobile trikes such as the Velotilt (Ruggiero 2015).

## 2.4 Vi Vuong's simple trikes.

**Figure 5: Vuong leaning trikes with Python / fig. 2a style front end : a) Simple version and b) version with wide rear axle for load carrying.**



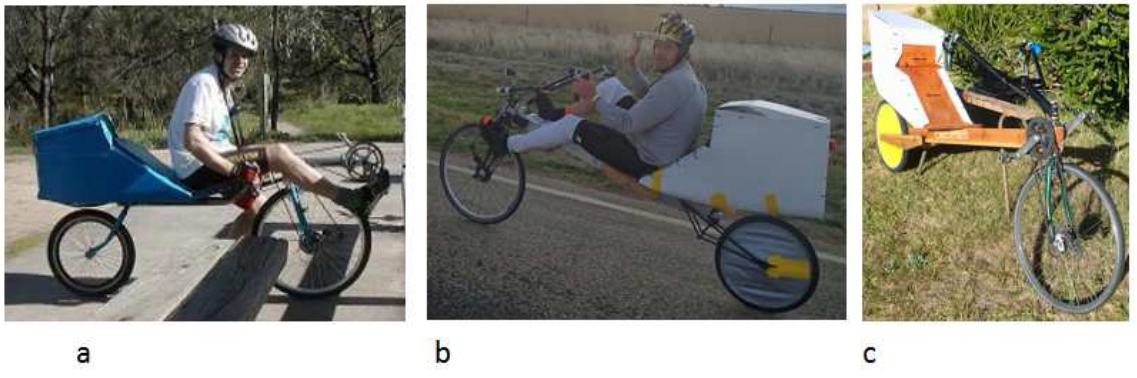

Vi Vuong is a California resident and an active builder of Python bikes and trikes. He reports his findings and machines on the Python HPV chat list (Python 2015). His work developing human powered vehicles '*has been a collaboration with my kids and their friends… We try to reuse bicycle components, incorporate recycled materials (bed frame, cardboard, plastic), simplify design and constructions for high school level, ...* (Leaning trike rear wheels as per fig. 5 SN) *were chosen to represent an "inexpensive" leaning solution that the mass can build…Although I mostly communicate with the forums, I shouldn't claim full credit for the work...*'(Vuong 2013) It seems Vi is just motivated by curiosity and the desire to educate, have fun and inform through making, riding and sharing HPV designs.

From his videos, Vi Voung seems to pay no attention to the aesthetics or durability of his cycles which are made with what is available in a bricolage (Jenks & Silver 2011, p.16) approach. His simple leaning trikes use old bicycle wheels, pedal axles and cranks as a tilting rear axle. Many bike tinkerers appropriate in this way and it is possible because in some countries bikes and their components are routinely sold cheaply or thrown away. The German cycle designer Burkhardt Fleischer described the old bike resource: "The people threw their old bikes which had been rusting in the cellars onto the hard rubbish" (1995, p.52).

Vi posted a video of his original "simple trike" in October 2012. Several variations on the technology had appeared by August 2013, and he started a webpage (Vuong, 2015) to curate them. One of his videos (Vuong, 2012) has been played 146, 000 times and effort has gone into it, as well as displaying an exciting original machine, there is editing and music to make the video appealing. This reflects the role Vi has made for himself as a provocateur, providing ideas for innovation in cycling and displaying them tastefully, encouraging internet users to like and spread his ideas.

## 2.5 Steve Nurse's bikes and trikes.

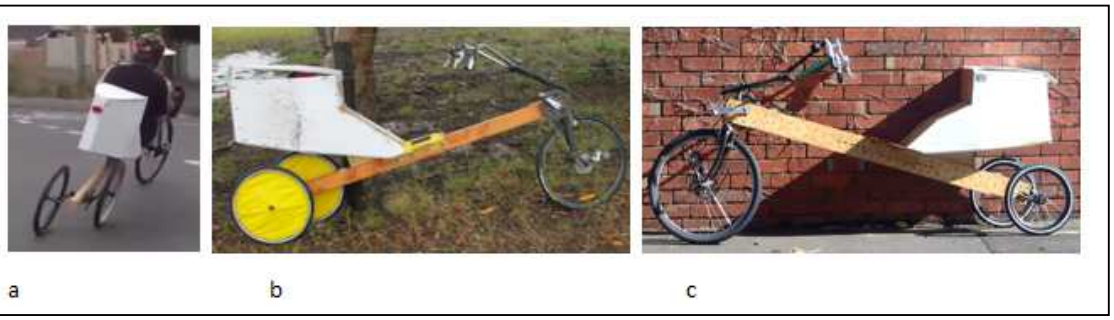
**Figure 6: a) "Zeica" front wheel drive bike with pulleys, 2004, type 2d. b) Aluminium framed bike, 2014, type 2e. It has rear suspension and the large front wheel is far away from the rider making for a comfortable ride. c) Similar hollow-chambered timber framed bike, also type 2e.**




Since 1997, the lead author has made several recumbent bikes, with layout changes over sequential versions. Suspension has been improved by having a large wheel (rise slower over bumps than small wheels) right at the front of the bike (the further away a wheel is from a rider the less bumps are felt, fig. 6b, c, Fitzpatrick 1980, p.132, Nurse 2009, p.11).

Production techniques have gradually improved. For example, seats have changed from rough, fixed, handmade constructions to NC machined plywood assemblies allowing for leg length adjustment. Designs now have elements of Third Wave DIY as defined by Stephen Fox (2013): *Firstly, ideation for new types of goods can be fuelled by browsing the latest Third Wave DIY examples……. Next, on-demand digital design tools and manufacturing equipment can be accessed as necessary for the creation of goods. These can be one-off for personal use, a series of evolving prototypes……*

**Figure 7: "Nurse leaning trikes, or NLTs: a, b) Solid timber frame & tailbox for luggage NLT1 c) Hollow plywood & tailbox NLT5.**




In early 2013, Vi Vuong's trike videos inspired simplification of the bike frames through conversion to the tilting trike wheelset design. The bikes' suspended rear wheel frame had been hard to build and the Vuong setup seemed able to replace it. A "Nurse Leaning Trike NLT1" (fig. 7a, b) was made using a solid timber beam as a frame and by the end of 2013 a 200k Audax ride was completed on it. The followed an article about the Vuong wheelset's suspension effect and scope for further use (Nurse, 2013). The trike was functioning, (capable of carrying a person and her luggage) but for most not working (widely considered for use).

"NLT5" was finished in 2016 and uses a single sheet of NC routed hoop pine plywood for the frame and seat (fig. 7c). The frame is structural and internally reinforced and uses steel

plates where highly stressed parts join the plywood. 2941 km were completed on this trike from January to September 2016.

The NLTs made to date are not fully refined but have served well for commuting, shopping and occasional long distance day rides: they serve to ask questions about how they could be turned from curiosities to serious transport. The gap in current cycle products they could fill is a commuting and touring cycle with inbuilt load capacity, exploiting DIY to make it comparable in price to a quality touring bike. As well as filling a product gap, they could fill a manufacturing gap by being Australian made from sustainably harvested plywood materials (Grace 2012).

## 2.8 Cruzbike bikes and leaning trikes.

**Figure 8: Cruzbikes: a) Bicycle seat parts appropriated for Cruzbike Kit seat, b) Jim Parker on Cruzbike made from conversion kit c) Maria Parker shopping on a QX100.**


John Tolhurst founded Cruzbike when he lived in Perth, Western Australia, and Dennis Perry has compiled an account of its beginnings on the Australian Cruzbike website (Perry 2007). John started recumbent cycling when he built a long wheelbase rear wheel drive bike with a colleague. He saw problems with its design such as the stresses the long chain placed on the frame. Tom Traylor's FWD bike plans (Eliasohn 1991 p.18) were purchased, and an adaptation of the plans was used to build a mountain bike-based front wheel drive recumbent. John's brother Kim built another bike along similar lines.

Tolhurst wanted to make better bicycles available and ideas from his homemade bikes were used to develop the Cruzbike Kit, a set of parts for converting a mountain bike "donor cycle" into a recumbent bike. He saw benefits in basing the kit on an already-owned or easily acquired bicycle: it made the step of owning a recumbent a small one, made the step of accepting a recumbent a small one, kept the kit package small to avoid transport costs, and allowed damage-free swapping out or upgrading of the donor cycle.

The kit was made in a factory using industrial production techniques using appropriated bike parts (ie seat support fig. 8a) when necessary. The DIY kit enabled more people to afford, build and own a recumbent. People building this sort of kit have pride of ownership (Fox 2013, Norton 2011).

Although recently discontinued, the Cruzbike conversion kit is what started Cruzbike production, and what led the Parker family of the USA to invest in Cruzbike and eventually buy out John Tolhurst and own the company outright. (Parker 2014). Jim Parker is a successful doctor from Florida and he and his wife Maria became fans of the Cruzbike kit after converting a Walmart bike to a recumbent. Jim and Maria bought into the Cruzbike business and

'*a partnership was formed, rooted in a shared mission and belief that these bikes can change the world. Together, Jim and John transformed Cruzbike into a company that sold not just kits, but fully built bikes. Over the next few years John designed faster, smarter and more*

*beautiful front wheel drive bikes while Jim and I rode them, raced them and managed the day to day operations of a growing Cruzbike*. (Parker M. 2015).

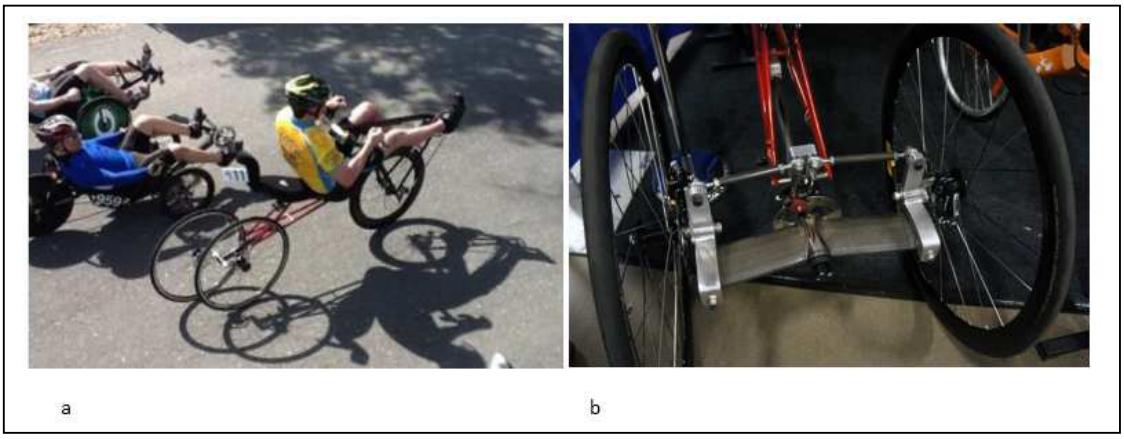
Cruzbike's first complete bikes were modelled heavily on a mountain bike frame with a conversion kit (Sofrider), and later, faster, lighter, more aerodynamic "native" machines fully exploiting front wheel drive were built. Some models are built for comfortable riding and commuting (QX100) and others for speed (Vendetta).

Cruzbike have kept DIY options available for bikes such as the Vendetta, which have been designed to take racing bike wheels and the components (brakes, brake levers, chain, bottom bracket, crankset, clusters) referred to as a groupset (Brown 2015). This "frameset plus groupset" bike construction is spread throughout a range of recumbent bikes (from Bachetta, Performer etc. ,PedalWiki 2015) called highracers. The highracer grouping represents a stabilisation of part of the recumbent scene. Riders on these bikes participate in races such as those held by the Ultra-Marathon Cycling Association which encourages recumbent participation (Ultracycling 2015).

It could be said that Cruzbike designs are compromised because they're based on a safety bike or safety bike parts but that misses the point. They exist because basing the bike on the safety bike (the customer may have already owned) brought down costs, saved on shipping, and made for an affordable acceptable recumbent which let the safety bike rider keep their favourite bike or groupset. John Tolhurst "got it", and offered the full suite of requirements for a viable recumbent shown in figs. 11 and 12.

Cruzbike reach the cycling community via web forums such as a "Find a Local" forum pairing people wanting test rides with Cruzbike riders. Recumbents are not available for tests at most bike shops, and this forum uses the internet's power to transcend geographical, financial and language barriers to create a virtual showroom and test track. This counters the power of safety bicycle establishments which always have stocks of bikes available to see and try. (Cruzbike 2015)

**Figure 9: Cruzbike leaning trikes a) Feb 2015 at HPRA races Ttrike 1, b) Nov 2015 Ttrike 2**




Jim Parker from Cruzbike is a leaning trike fan: *'A lightweight convertible bike-trike, that does both jobs well, is the Holy Grail of the recumbent world…….. Trikes are more stable, can carry more load, and are easier to ride, but they are lower, slower, and heavier than most bikes. Sometime in the near future a convertible Cruzbike-Cruztrike may solve this dilemma.'* (Parker 2015)

In 2014, Jim contacted the lead author to make a bolt-on adapter to convert a Cruzbike Vendetta bike into a tilting trike. An adapter was made and sent to Cruzbike late that year.

The adapter was fitted to a bike and Cruzbike announced the 'Ttrike' (fig. 9a) in a February 2015 blog post. Cruzbike were delighted with the adapter and stated that once fitted, it improved handling and stability compared to the bike it was based on, despite it being a 'free leaner' without obvious tilt restraint. Later in February, Jim Parker and Cruzbike won trike-only events on the 'Ttrike' in HPRA races. Cruzbike blog reports were followed by comments on HPV bulletin boards in France, Brazil, Germany and the U.S.A. (Nurse 2015).

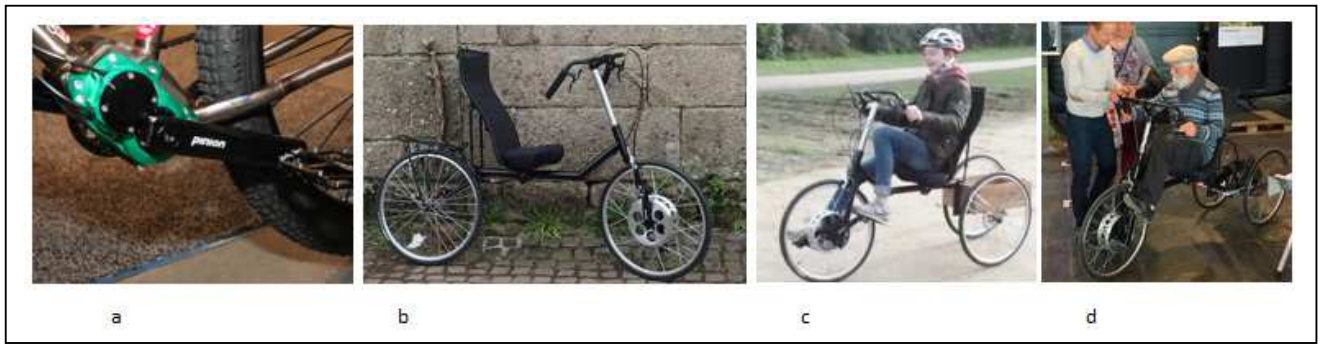
The reaction to the initial Ttrike (Ttrike1) had been positive and the prototype served its purpose of gauging feeling about tilting trike technology. In November 2015, Cruzbike revealed a new tilting trike (Ttrike2, fig. 7b) whose mechanism had reverted to a parallelogram type. The tilting trike is now part of the Cruzbike website which shows a cad image of this tilting technology with a "2016 / 2017" development announcement. (Overholt, 2015, Cruzbike 2015)

## 2.9 Trivek and Kervelo

Trivek (Alan Page, Perth, Australia) and Kervelo (Marc Le Borgne, Norway) are new companies launching recumbent tilting trikes through crowdsourcing. Their products use multigear hubs with fig. 2c type drive and the pedal axis running through the front wheel. Cycle designs can require expensive tooling for economical production, and traditionally startups would develop business plans, then apply for loans to buy tooling. The entrepreneur takes on the risks of borrowing, making tooling, production and sales. Internet based crowdfunding breaks tradition by having early adopters assume risk, pledging to buy if sufficient funds are raised (Fox 2014). A DIY bamboo bike kit has been successfully crowdfunded (Chuah 2015, Page 2015, Le Borgne 2016).

Trivek trike's rear wheels do not tilt with respect to the ground, instead the seat pivots on top of the rear wheel frame. It has a 2-chain transmission with a multispeed hub gear placed above the front wheel.

**Figure 10: a) Mountain bike using Pinion gearbox, Kervelo HPV's, all have drive as per fig. 2c: b) Bike, c) Development trike with Vuong rear wheelset, d) Later version trike.**

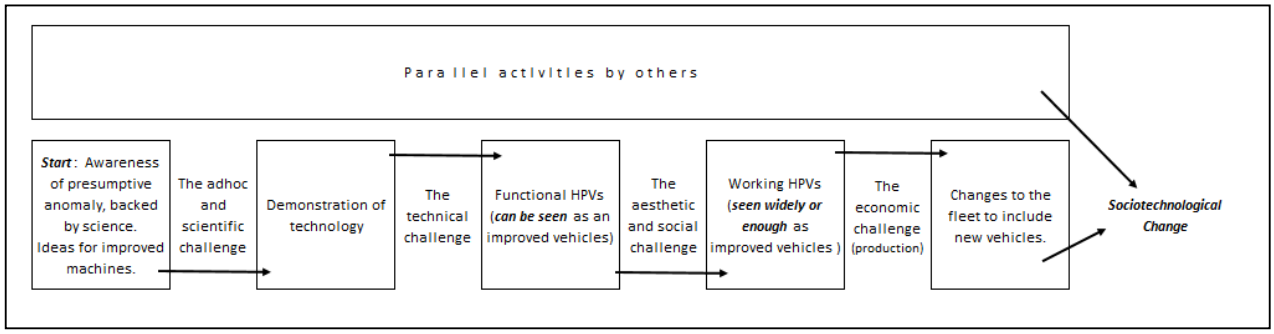



Marc Le Borgne from Kervelo has adapted a Pinion-brand gearbox for use within the front wheel of recumbent cycles (Joakim Nilsson had made this adaptation in October 2014 and similar bikes have been made by Jeremy Garnet of Velotegra). This use of parts in different contexts is common in recumbent building. Components designed for one purpose are used for another, initially in a prototype form (ie as shown in Eliasohn, 1991). In later manufacture, the new use of a part can become fully engineered (Nilsson 2014, Garnet 2015).

Kervelo have announced simultaneous launch of bikes and tilting trikes using the "front hub Pinion" technology. During the development stage of the trikes, they used the simple Vuong tilt mechanism but have opted for parallelogram style tilting for production versions. The frame allows a swap-out between bike and trike modules.

## 3. Discussion

**Figure 11: Improved diagram of development. "Parallel activities" contributing to sustainable transport could include telecommuting or car and ride sharing schemes.**

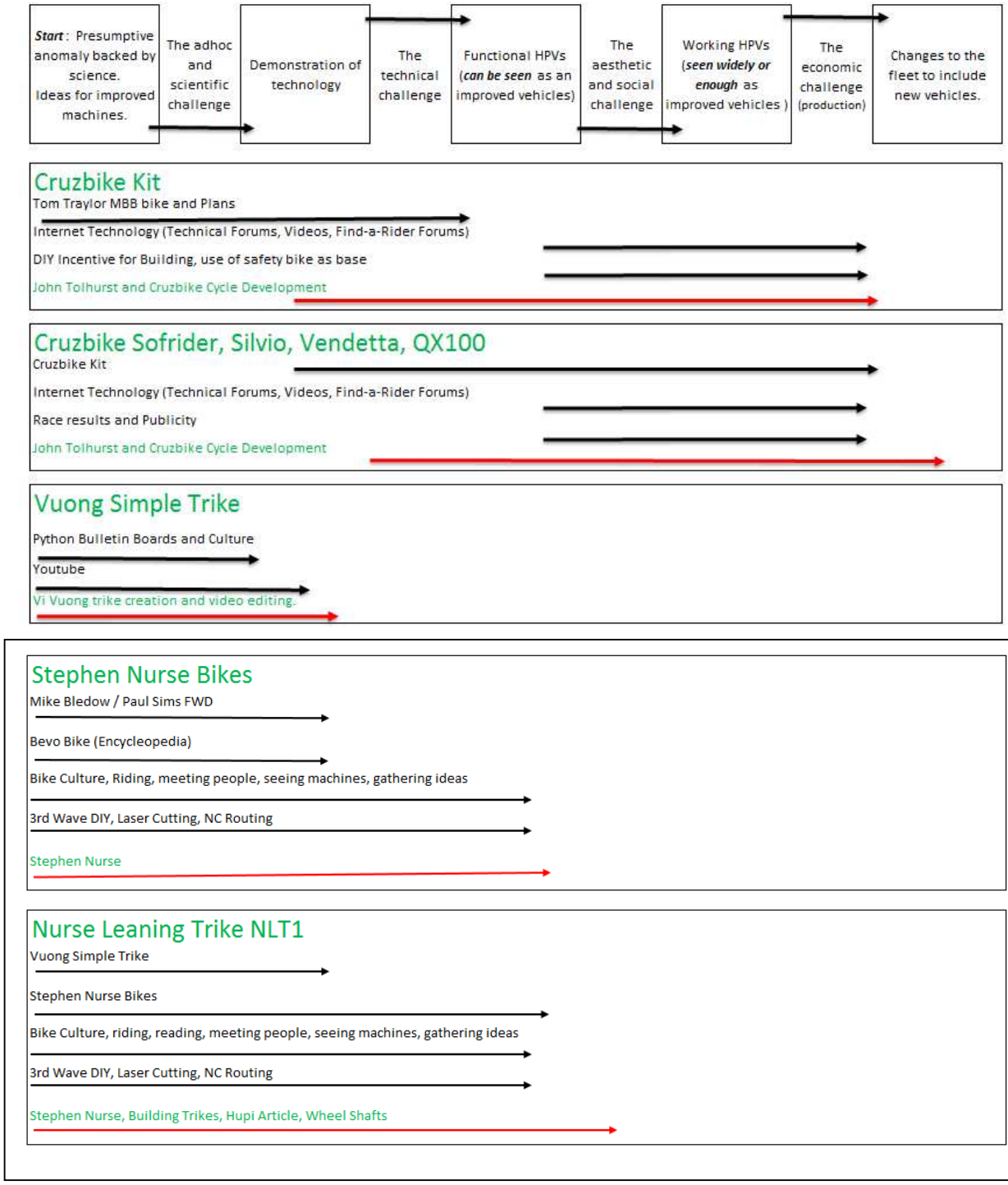



We are in an age when environmental concerns are no longer ignored on national levels and should no longer be ignored on personal levels. The attitude that nature should be overwhelmed and that only fossil fuels should be used for transport is being questioned (Mcdonough 2002, p.31). Some would consider it outdated. Cycling and electric assisted cycling could and should become standard for short distance transport, not just because they address environmental concerns but because they promote mental and physical wellbeing (Pretty 2007).

To some extent, a re-imagining or reimaging of cycling might be necessary. The cycling of the Tour De France or Giro D'Italia bears little resemblance to the local shopping and commuter cycling we can or should do to be sustainable (Cox 2006) and a broad range of cycles need to be considered for use if cycling is to reach its potential for sociotechnical change resulting in sustainable transport. Recumbent cycles, front wheel drive cycles and tilting trikes are all emerging cycle types which can contribute, joining more common human powered vehicles such as Greenspeed's recumbent tadpole trikes (parallel activities by others, Fig 11) as roadgoing vehicles.

Social groups play an important part in the development and uptake of human powered vehicles. Inventors of cycle technology are often part of riding and internet groups such as Openbike, OzHpv and HPRA who readily take on, discuss and extend new cycling technology, but the more important groups are amongst those men and women who are or could be riding cycles as transport. The cycle products which may appeal could be those offering easy acceptance, involvement, learning, enjoyment and even culture such as John Tolhurst's original Cruzbike conversion kit.

**Figure 12: Development diagram showing (top): stages needed to reach commercial success and below: red line indicates contributor's work specifically for named invention, black lines = enabling inventions or infrastructure setups (ie youtube for Vi Vuong).**




Human Powered Vehicles can have the advantage of good ergonomics and aerodynamics making them comfortable to ride, facilitating long distance travel. They could allow people to ride and commute further for the same amount of effort and improve the cycle fleet, yet they are still considered exotic and unusual. These vehicles need to be celebrated as "alternative

hedonisms" which are shows of status and wellbeing but nevertheless contribute to health and society (Murray 2011, p.18).

## 4. Conclusions

Luca Berchicci has warned against rampant ambition in the field of Green Entrepreneurship as follows: *'aiming high and having a strong vision and mission is important for starting any innovative activities, however strong commitments and environmental ambition should not lock the environmental entrepreneur's vision into a fixed-ideological frame'* (2005, p205). In fact nobody and no small group can expect to create sociotechnical change, but creating or being involved in a branch of it is more achievable.

The HPVs of this article depend on internet, social and technical precedents, and didn't depend on one innovator, and noting important precedents and cultures can help us make sense of them. Bold innovative cycles like the Trivek and Kervelo HPV's keep appearing and we are not likely to see an end to them anytime soon.

Berchicci titled his paper "The Green Entrepreneur's Challenge" and perhaps a subtitle for this paper could be "The Green Entrepreneur's Challenges", seeing the big challenges as a series of doable smaller challenges and giving descriptions and diagrams to help us understand them.

## Glossary:

Bottom bracket: Bearing housing for bicycle pedals.

FBB: Fixed Bottom Bracket FWD bike with the bottom bracket (pedal axis) fixed to main frame and requiring a twisting chain to transmit power.

FWD: Front Wheel Drive

HPV: Human Powered Vehicle

HPRA: Human Powered Racing America

IHPVA: International Human Powered Vehicle Association

MBB: Moving Bottom Bracket FWD bike with the bottom bracket fixed to the front fork and requiring twisting legs to transmit power.

NC: Numerically Controlled.

OzHpv: Australian HPV club, promoting racing and social rides.

NLT: Nurse Leaning Trike (trike series)

Pedal Prix: Circuit racing event for schools and other groups. Trike are subject to strict safety regulations and teams race them for 6 to 24 hours.

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