

# **Socialised transport: Increasing travel mode diversity through open-source vehicle design, upcycling, natural production and distributed production methods**

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## **Abstract**

Road transport networks are becoming increasingly vulnerable - growing populations, peak oil, road congestion, space limitations, climate change and global financial instability are all putting pressure on vehicle makers to deliver new and more relevant products. There appears however, to be heavy inertia surrounding the development, manufacture, retail and social acceptance of alternatives to the traditional automobile. This paper explores a number of issues that could be contributing to this inertia including safety concerns, auto industry infrastructural limitations, prohibitive price points of alternative vehicles, road regulations and social perceptions. It goes on to outline a number of ways these issues can be countered, citing two design concept studies that propose ways to decrease society's reliance on traditional automobiles, and to build resilient networks through product diversity, distributed production and open-source design innovation.

## **1. Introduction**

It is well recognized that many issues threaten the long term sustainability of the motor car; Peak oil concerns and rising fuel prices threaten to increase not only the cost of vehicle usage, but also the price of food, services and commodities (see, for example; Garnaut, 2008; Hirsch, Bezdek, Wendling 2005; Deffeyes 2005; Monbiot 2006; Moriarty & Honnery 2007); Legislation by governing bodies to reduce carbon emissions and other factors concerning climate change will affect the development of vehicle power sources and the cost of energy (see, for example; Garnaut 2008; Johnston 2007); Strategic planning by local councils and communities to increase alternative transport modes in their municipalities will make negotiating urban thoroughfares increasingly difficult for those driving cars, especially at peak times (see, for example; City of Moreland 2008; Department of Urban Affairs and Planning 2001); Growing public perceptions linking our current internal combustion vehicles with climate change, health issues and the inefficient consumption of energy will make it difficult for manufacturers to sell vehicles with inefficient drivetrains to an aware public (see, for example; Australian Greenhouse Office 2005; AAA 2008); Increasing numbers of cars on our roads also spells higher congestion<sup>1</sup> and parking limitations in urban areas (see, for example; Shoup 1999; Litman T., 2001; BTRE 2007; City of Melbourne 2008). These issues, if taken singly, may be accounted for in current vehicle evolutionary design cycles;

however, any rapid collective developments could have serious implications for transport networks.

This places countries like Australia in a vulnerable position. Many Australian commuters are perceptually locked into motor car use for primary transport. In current urban environments the average commuter has few options when considering alternative modes, with most unable to fulfill their varied needs. Trips by train, tram, bus, ferry, or motorcycle do not singularly provide the flexibility, carrying capacity or convenience of the car; and public transport networks are neither widely distributed nor densely populated enough to provide adequate coverage to the sprawling outer suburbs (Currie & Senburgs 2007, p. 10). In addition to this, public transport systems in some of Australia's largest cities are already struggling to cater for peak hour travel (Fyfe & Sexton 2008).

Cycling, as a travel mode, is a good alternative to the car in many instances. Bicycles are one of the most energy efficient, low carbon forms of transportation. They are also cheap, easy to maintain, and there are health benefits when riding. However, given the varied topographies and the sprawl of our urban landscapes in Australia, they are unlikely to replace cars in the same way as they have in countries like Denmark and The Netherlands.

These issues make a good case for a nominal increase in alternative vehicle usage on Australian roads, but to date it has not been seen. This paper explores some of the reasons why: section 2 outlines some issues preventing the uptake of alternative vehicles, ranging from availability and price through to road legislation and safety; section 3 discusses some of the reasons cycling has not been a more widespread replacement for car travel; and, section 4 presents two in-progress research projects that combine the efficiencies of cycling and some of the comforts of the car into low cost velomobiles. To date, these types of vehicles have been largely overlooked as a viable alternative to the car.

## **2. Issues preventing alternative vehicle uptake**

It is important to inclusively consider alternative vehicles in the travel mode mix as a means to encourage the growth of environmentally and socially sustainable transportation and overall system efficiency (Rose, Richardson 2008, p. 108). However, there is no evidence of a marked increase in the number of alternative vehicles on the road to date. Viable low impact alternatives such as Pedal-Assist Bicycles (PABs), electric powered 3 wheeler cars, mopeds and microcars, if readily available, could offer feasible solutions to some transport system issues. However, as this section discusses, there are a number of issues that may be preventing their uptake in Australia.

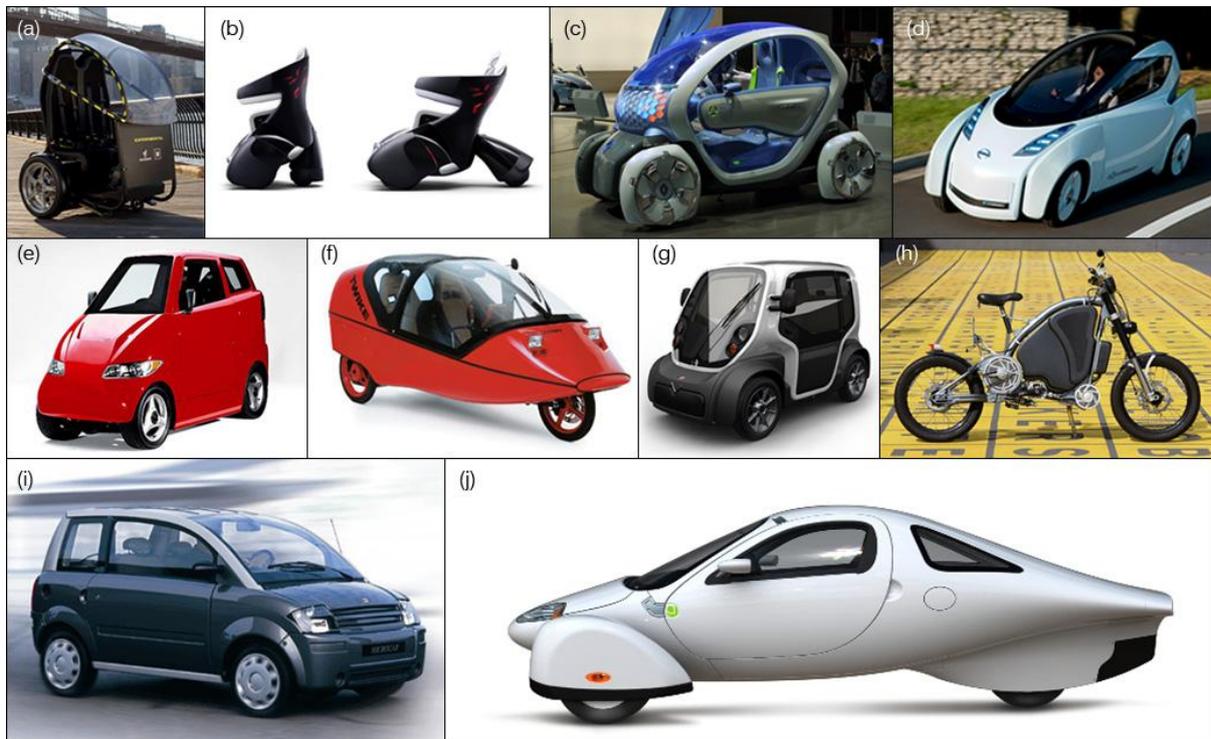
### **2.1. Lack of alternative vehicle availability**

While, globally, there is a relatively long history of alternative vehicles, they are rarely seen on Australian roads. Anecdotal evidence would suggest several reasons for this; first, current social, financial and environmental imperatives are not pressing enough to encourage a significant uptake of more efficient vehicles; second, the vehicles themselves have not been visually or functionally appropriate for market expectations; third, given low production volumes of niche-manufacturers, alternative vehicles are often introduced to market at a comparatively high price point. The major OEMs (Original Equipment Manufacturers, such as Ford, Chrysler and GM), who have the ability to mass produce vehicles at lower price

points<sup>1</sup>, have not yet fully committed to developing and manufacturing alternative vehicles for production.

In recent years, despite this reluctance, the OEM 'advanced design studios' have demonstrated a shift towards developing one-off alternative concept designs for international motor shows. Products such as the GM PUMA (Personal Urban Mobility and Accessibility) (Figure 1a), Toyota i-REAL (Figure 1b), Renault Twizy Z.E. (Figure 1c) and Nissan Landglider (Figure 1d), are likely to improve market awareness, and acceptance of alternative vehicles (Richardson, Rose 2010) and indicate a likely move towards alternative vehicle production in the future.

**Figure 1: Alternative vehicles**



## 2.2. High price and functional limitations of alternative vehicles

For many alternative vehicles, value-for-money is difficult to justify. For instance; a typical small family vehicle such as the Toyota Corolla 1.8 Accent five seater sedan retails in Australia at around AU\$20,000. The two seater Commuter Cars Corporation Tango T600 kit (Figure 1e), conversely, is available in the US for US\$108,000 (Commuter Cars Corporation 2008). The Tango is an ultra-slim, electric, tandem two-seater with the spatial footprint of less than half a regular family sedan. It provides equivalent performance and significantly improved energy efficiency, but lacks payload capacity – i.e. two people and a very small amount of luggage, which is characteristically common to these types of vehicles. The Corolla seemingly offers more value-for-money with better carrying capacity, greater travel range, and the perception of superior safety characteristics at a fifth of the price.

<sup>1</sup> OEMs have better equipped design facilities, broader marketing reach, greater capacity for capital investment, more robust infrastructures and larger economies of scale than niche alternative vehicle producers.

Much of the costs of alternative vehicles such as the Twike (Figure 1f), Venturi Eclectic (Figure 1g) and eROCKIT (Figure 1h) are likely to be associated with low production volumes, rigorous vehicle testing and the use of relatively new technologies – such as Nano-phosphate lithium batteries, integrated solar cells and lightweight materials and construction. In many cases these new products also have limited market reach, appealing primarily to early adopters.

### **2.3. A negative perception paradigm**

Car users are primarily concerned with speed, comfort, convenience and flexibility (Corpuz 2007, p. 9, 10). Currently, the 'need' for car ownership is still strongly defended and, in spite of emerging global issues, there is still a strong consumer demand for them. A mode captivity study in Redland shire, Queensland, for instance, found that 60% of respondents claim to be car 'captive' (not perceiving to shift to another mode of transport). Additionally, the more cars owned by a household, the less likely its occupants were to perceive shifting to another mode (Khan et al. 2007, p. 15).

Perceptions of smaller alternative vehicles are likely to suffer when compared directly with motor cars. The benefits of car ownership – such as payload maximization, high speed capacity and the ability to travel long distances – have seemingly outweighed the benefits of alternative vehicle usage – which are both energy efficiency and have a reduced spatial footprint. However, if the context changes, and high fuel costs, increased congestion and reduced parking capacity in urban environments occur, the benefits of alternative vehicle ownership may be more highly valued.

The challenging visual characteristics of alternative vehicles are another possible reason for their slow uptake. In many cases the vehicle package is proportionally very different from most regular motor vehicles. From a design perspective, this requires taking a different approach to the vehicle's aesthetic qualities, and necessitates great care and experience to develop a product's proportion, scale, stance and surface language. As many of these vehicles have been designed by enthusiasts in cottage industries, it is difficult for them to compete with the sophistication of the highly refined products from the design studios of major OEMs.

### **2.4. Small vehicle safety issues**

Cars are becoming increasingly large, more fortified and suffused with technology to maximise personal safety and improve ride dynamics and handling. The onus is placed on car manufacturers to embed vehicle safety within products themselves, which encourages homogeneity between brands. Safety data indicates that, within the current road infrastructure, the best way to improve road safety would be to shift to a homogenous fleet of large luxury vehicles (Newstead et.al. 2004). The safety regulations applied to larger, heavier, faster vehicles, however, are not likely to accommodate the introduction of smaller, lighter, slower vehicles to the mix. Environmentally responsible vehicles, by their very nature, are implicitly smaller and lighter to acquire efficiency gains; a requisite for utilising distributed, variable energy sources (Honnerly & Moriarty 2004 p. 7). However, in a system where fortification is a key mechanism to ensure the safety of the individual, this becomes problematic.

For example, when considering the two measures of vehicle safety – crashworthiness, (which focuses on the capability of a vehicle to protect its occupants in a collision) and aggressivity (or the casualties caused by a vehicle to occupants of other vehicles and pedestrians in a collision) (Gabler & Fildes, 1999; Newstead et.al. 2004) many single vehicle crashes, weight offers no crashworthiness safety advantage. However, occupants of heavier vehicles in two-vehicle crashes fair better than those in lighter vehicles due to the heavier vehicle's aggressivity rating (ANCAP, 2008). Anecdotally, the public perception that heavier vehicles always offer greater occupant safety – even though this is not entirely supported by research – may, ironically, be perpetuating an on-road culture of increasingly heavier vehicles that are only advantageous in an impact with other heavy vehicles. This does not address system-wide safety concerns of a highly differentiated vehicle mix.

## **2.5. Lack of accommodating road legislation**

Until recently there has been limited need to establish a legislative framework for alternative vehicles, since numbers and demand have not been strong in Australia. However, the trend for alternative vehicles is increasing globally. In Europe, for instance, the acceptance for the integration of alternative vehicles in road transport systems is reflected in the regulations (see, for example Department of Transport 2005; European Commission 2009). Reduced car volumes in London, due to congestion charge, have opened the way for alternative vehicles such as the Microcar MC1 (Figure 1i) to be operated more safely on city roads. This vehicle can be driven by both car and motorbike license holders (Microcar 2008), and, along with similar vehicles, is free from the congestion charge. In the US, the three wheeled Aptera Typ-1 (Figure 1j) is classified as a motorcycle, allowing it to be driven in High Occupancy Vehicle lanes (HOV). It does not require a motorcycle license or an endorsement on a regular driver's license to be operated in the State of California, nor does it require a helmet to be worn since it is fully enclosed (Aptera 2008). With the growth of the alternative vehicle market overseas, Australia is likely to similarly face the choice to regulate for the inclusive integration of these vehicle types in future years.

## **2.6. Automotive industry inertia and regulatory policy shortfalls**

The automotive industry has been slow to respond to the global issues discussed previously. Many of these have been debated for a number of decades, and it would be fair to question preparedness on the industry's part to explore alternative personal transport devices. It can be argued that if the industry was actively designing, manufacturing, retailing and promoting the benefits of alternative vehicle ownership, the market would be stronger. The difficulty facing OEMs, however, is their high infrastructural investment and the prohibitive costs associated with operational renewal. A long history of incremental technology updates and manufacturing methods have grown the industry to a point where broad scale change is prohibitively expensive and culturally challenging. Consequently, without regulatory incentives, a business-as-usual mentality, with slow, predictable, incremental, low-risk change is likely to be maintained. A speech by Mr. Carlo Sinceri, the President of the International Organisation of Motor Vehicle Manufacturers (OICA), for example, highlights the issue. Sinceri stated that governments must take into account the constraints and complexities motor vehicle manufacturers face when developing a vehicle for production; they [the industry] need a stable and predictable policy environment in which to operate, and time to develop new technologies and bring to them to market (Sinceri 2008). Given

regulations for alternative vehicles have not been fully explored in Australia, the industry is unlikely to produce many products that fall in that that category in the near future.

### **3.0 The limitations of cycling**

One of the most recognizable forms of alternative transport to date – i.e. travel modes other than cars, motorbikes and walking – is cycling. Cycling offers high spatial and energy efficiency and can reward cyclists with the associated health benefits of incorporating physical activity into their daily life. The bicycle provides a means to travel quickly over short to medium distances by using human power as a renewable energy resource. Many bicycles are inexpensive and require very little effort and expertise to maintain. Compared with a car, bicycles also require minimal energy to manufacture; they contain few parts and require limited production processes. Given the simplicity of the mechanical system, if well maintained, they also have good longevity. Overall, the bicycle is an efficient way to travel.

So, why aren't we all riding bikes? Parkin, Ryley and Jones (2007, p. 67-82) suggest that the reasons for the limited use of bicycles range from environmental surroundings through to social drivers. Manufacturers of cars and public transport vehicles spend a great deal of energy developing appropriate indoor environments for their occupants. The 'cocooned' cabin of a car provides a consistent, comfortable and protected environment. It is a home away from home that offers the benefits of carrying passengers and luggage. A bicycle's 'interior' is the great outdoors, and it can be interpreted in many different ways depending on the environmental conditions.

Parkin (2007) suggests that the decision to ride can be determined by a number of factors. First, the characteristics of the chosen route, in terms of distance, the number of obstacles, volume of vehicular traffic, hilliness and road surface have been shown to influence the decision to ride. Evidence suggests that 2 to 5 kilometres is the distance most likely to be acceptable for a daily cycle commute; and those living in hilly regions, where it is necessary to take routes that require frequent stops or include heavy traffic congestion, are also less likely to want to ride (Parkin 2004, p. 67-82). Second, weather considerations are of importance; rain and wind can significantly reduce the comfort of a trip. The unpredictability of the elements, seasonal shifts and light conditions can be enough to deter individuals from choosing cycling as a preferred transport mode. Third, the quality of facilities for cyclists at the journey's end is a consideration. Given many wear cycling attire, and the exertion of riding often results in sweating, many riders are keen to have access to a shower and changing facilities. Forth, the type of bike and tyres used make a difference to exertion levels. A light bike – which is usually more expensive – with thin, hard road tyres, reduces the rolling resistance and improves the riding experience over a heavy bike with wide knobbly tyres. Fifth, age and health have been found to determine the willingness to ride, with those under the age of 34 being the most likely to do so (Parkin 2004). Sixth, there is some evidence to suggest that the requirement to use a helmet in Australia has prevented people from taking up cycling (Clarke 2008).

The following section outlines two in-progress research projects at Monash University which are attempting to rectify some of these issues in order to make the notion of cycling more appealing. It is hoped that the resulting products will provide a benchmark for accessible, low impact, socially embedded, resilient mobility.

## **4.0 Two case studies exploring Industrial Design opportunities for alternative vehicles**

Taking into consideration the issues outlined in previous sections, two Industrial Design projects at Monash University aim to help fill the product gap between cars and bicycles. The two vehicles fall into the categories of a vehicle type commonly known as a velomobile, velocipede or Human Powered Vehicle (HPVs) (a more detailed description is outlined below). These vehicles have the potential to increase distance travelled, improve cycling comfort and protect the rider from adverse weather conditions.

Both projects also propose alternative sustainable production processes that exist at either end of the current manufacturing spectrum. One delivers a product made from waste – ‘post-manufacturing’– and the other from natural processes – or ‘pre-manufacturing’. The first has a symbiotic relationship with current manufacturing processes, extending the life of materials and components at the end of waste product’s lives; the second requires very little manufacturing energy from the outset, relying largely on the energy from the sun to literally grow the product. Both of these projects offer potentials for alternative product accessibility, manufacture and use.

### **4.1. The P.U.U.N.K (Pedal-assist Upcycled Urban N-configurable Kit) velomobile – Mark Richardson**

The P.U.U.N.K (Figure 2) is an in-progress<sup>2</sup> design study exploring an electric pedal-assisted three wheel vehicle commonly known as a velocipede, velomobile or HPV. Such vehicles are typically pedal-powered and/or electric-assisted tricycles that are distinguished from regular bicycles and tricycles by their exterior shell, skin or bodywork. This outer covering is typically made from fiberglass or carbon fibre, though sometimes stretched fabric, sheet plastic or aluminium is used. It is generally understood that the aerodynamic gains from the outer covering can offset the energy deficit resulting from carrying extra weight.

#### **4.1.1. P.U.U.N.K. Hypothesis**

The project aims to ascertain whether it is possible to design a low cost, electric-pedal assisted velomobile, within an open source, digitally mediated framework<sup>3</sup>, that can be easily accessed, interminably reconfigured, and made from found materials while using generic household tools for its manufacture. The design also aims to adapt to individual needs, commute comfortably to a distance of up to 20km, carry a small amount of cargo and negate the need to wear a helmet.

#### **4.1.2. Accessibility**

The P.U.U.N.K is intended to be accessed as an open source DIY project i.e. the source design will be freely available online and can be developed further by users the same way as

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<sup>2</sup> The vehicle is currently under construction; being physically prototyped from plans that have been generated in a digital modelling program.

<sup>3</sup> i.e. Using digital tools, such as CAD and visualisation software, to make virtual models and build instructions that can be accessed online. Information, developments and user/builder experiences can be exchanged through social networking sites and forums.

open source software packages like Linux and Mozilla Firefox. Free build instructions<sup>4</sup>, drawings, digital models and photographs will be available for download; however, kits and complete preassembled units are also likely to be available. This follows the precedent of projects such as the Reprap rapid prototyping machine (Reprap, 2010) – a 3D printer made from easily accessible parts that can replicate many of its own parts to make another machine – and the Lumenlab DIY Projector (Lumenlab, 2008) – a digital projector that can be made from LCD screens and various other parts that are easily sourced in most countries around the world. Open source design has also been used in this project to encourage poly-nodal, distributed manufacturing. This allows micro manufacturing hubs to be embedded within communities to reduce product miles and to encourage the use of local materials and service systems.

**Figure 2: The P.U.U.N.K velomobile**



#### **4.1.3. Price**

Price is one of the limiting factors of the velomobile market; the Greenspeed Glyde, for instance, retails at \$12,990 at the date of this publication, and recumbent trikes vary from \$1,500 upwards (Greenspeed Recumbents, Date Unknown). The price of the P.U.U.N.K however, may vary depending on how the customer engages with the making process. At present there are no plans for a formal pricing structure, however the full DIY version may cost the end user/maker as little as their material costs: which can be kept at a minimum by upcycling<sup>5</sup> waste materials.

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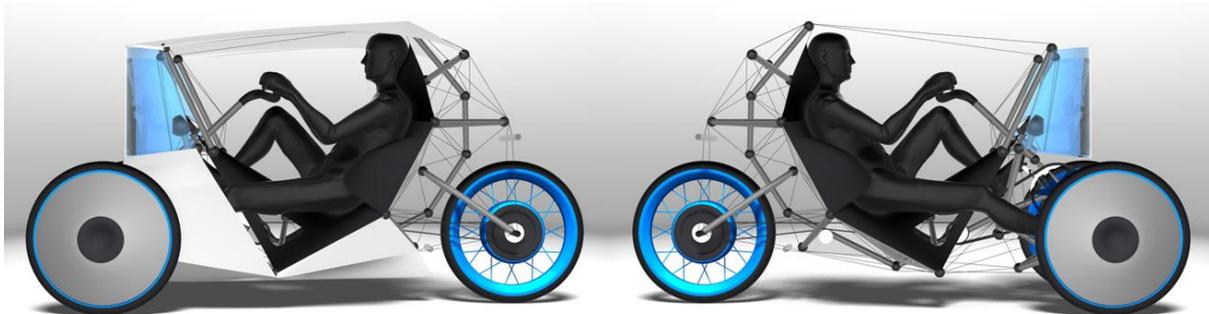
<sup>4</sup> Otherwise known as an 'instructable'; a complete set of instructions for making DIY projects that can be sourced from websites such as <[www.instructables.com](http://www.instructables.com)>. These are typically open source, encouraging new developments of existing projects to be documented and uploaded to the site.

<sup>5</sup> Upcycling is a term used for reusing waste resources to make new products of an equal or greater value than the product they were recovered from (McDonough & Braungart 2002).

#### **4.1.4. Construction and Safety**

The construction of the P.U.U.N.K is intended to provide a balance between light-weight assembly, vehicle safety and ease of build. The frame structure is an adaption of Kenneth Snelson and Buckminster Fuller's notion of tensegrity; i.e. three dimensional structures that use compression masts within comprehensive triangulated tensional networks. The compression elements (usually a length of tube) and the tensile elements (usually high tensile wire) are held in a state of equal tension and compression (Buckminster Fuller, 1961).

**Figure 3: The P.U.U.N.K with and without its exterior skin**



The safety attributes of the vehicle have not yet been measured; however, they are anticipated to exceed those of a bicycle. First, the stability of the vehicle's geometry and wheelbase means riders are less likely to fall; second, the frame encompasses the rider, offering rollover and low speed front and rear impact protection; third, the seat – intended to be made from impact foam – is being designed to offer equivalent safety attributes to that of a bicycle helmet, but with greater body area coverage; fourth, a restraining system for the rider is being explored; fifth, the higher ride height, compared to other velomobiles, is likely to improve visibility in traffic, both from the perspective the rider and other road users.

A potential negative aspect of the design is, given its longer wheelbase and restricted steering in comparison with a bicycle, is an increased turning circle and reduced maneuverability – the safety implications of this, however, will be explored further in the initial testing phase of the prototype.

#### **4.1.5. Comfort**

The P.U.U.N.K is designed to traverse short to medium distances with greatly reduced effort. This will be primarily achieved with electric-assisted pedaling and appropriately designed aerodynamic bodywork. Ergonomic comfort is also intended to be improved by seating the rider in a reclined position on a stable, three wheeled platform. The tensegrity structure is also intended to provide a soft ride; one typically associated with bicycles such as the Moulton, whose suspension system and triangulated frame allows the comfortable use of small wheels (Moulton Bicycle Company, 2009), and the Pedersen, whose cable suspension seat is slung between the seat post and head stem (Dursley Pedersen Cycles, 2010). The frame design also provides a small cargo carrying capacity behind the rider, and the rollover

bar, harness and optional bodywork is intended to negate the need to wear a helmet. **4.1.6. Renewable Energy**

The drivetrain of the vehicle is intended to be powered by renewable energy. The two front wheels are designed to be enclosed by PV (Photovoltaic) covers, and a brushless DC motor in the rear wheel provides regenerative braking. The increasing development of flexible PV coatings indicates it is also likely that a lightweight PV skin on the body and roof will be possible in coming years. At present, the system is intended to be run in conjunction with a household PV and wind generation system to boost the charging capacity. However, it is possible to charge the batteries from mains power in a similar fashion to many current pedal assisted bicycles.

#### **4.1.7. Legislation**

Given the functional similarities between the P.U.U.N.K and a typical PAB – a 200W pedal-assisted motorized system (Victoria Government Gazette, 2010) – it is likely that it will fall under the same road regulations i.e. it can be ridden on both on roads and bike lanes without a license or registration.

#### **4.1.8. Opportunities and Further development**

There are a number of issues and opportunities for further exploration. First, an impact study relating to the quality assurance of open source DIY built velomobiles on road networks and regulations needs to be undertaken. Second, there is an opportunity to explore the ‘leaning’ capabilities of the vehicle to improve its stability and ride dynamics. Third, the geometry of the frame could be explored as to its capacity to carry an extra passenger and to be folded to be taken on public transport.

## **4.2 “Ajiro” bamboo velomobile – Alex Vittouris**

The “Ajiro” (Figure 4a - 4d), is a HPV made with non-traditional manufacturing processes. It challenges current manufacturing methods by suggesting that it is possible to literally grow a vehicle using energy from the sun.

#### **4.2.1. Experimental hypothesis: Grown transportation**

The aim of this project is to ascertain whether the overall structure and shape of a vehicle can be built using bamboo grown in many varied shapes, using only simple restrictive profile formers.<sup>6</sup> There are a number of benefits for approaching its design and construction in this way:

- First, there is very little in terms of production waste energy; energy from the sun, nutrients from the soil and water contribute directly to the growth of the plant itself.
- Second, the construction approach dispenses with the traditional complexities of mass production. ‘Multiple’ construction processes such as the tradition of pressed sheet metal, welded sections, and joined mouldings are distilled to a single simplified

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<sup>6</sup> (van der Lugt, 2008, p. 50) References (Hidalgo, 2003) whilst describing “... the manipulations of the form of the bamboo stem during the growth phase with molds...providing opportunities for many new exciting applications.”

grown form. This allows many structures, including complex compound curves, to be grown seamlessly by using only growth control. Once removed from a mould, bamboo will hold its shape.

- Third, by using natural, plant based materials as a basis for production methods, it is a renewable, regenerative commodity.
- Forth, local producers and other interested groups can constructively work on creating the materials to be harvested, as well as being involved in the assembly process, effectively minimising material transportation costs (Vélez 2000).
- Fifth, the vehicle can develop its own character with owner input, modification and care for the 'living' canopy.
- Sixth, bamboo construction is easily recyclable (Vélez 2000, p. 153).

Figure 4 (a - d): Conceptual visualisation, authors own images.



#### **4.2.2. Alternative material: Bamboo - Capabilities, Materiality and diversity of applications**

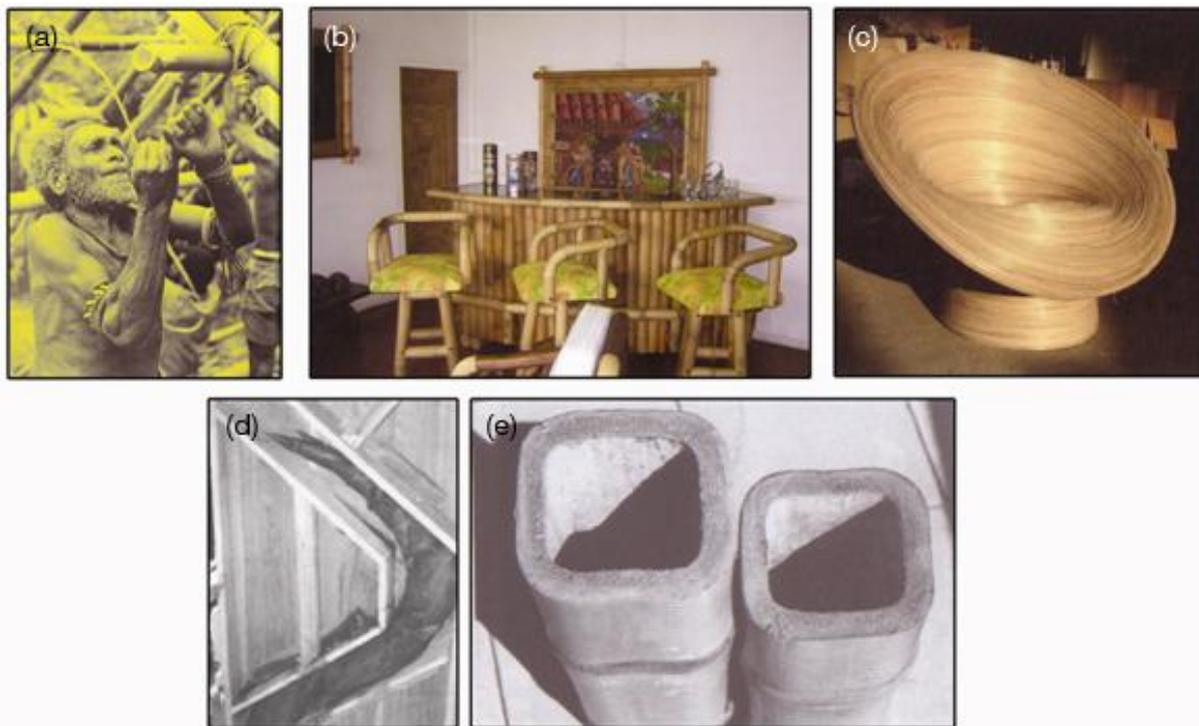
Bamboo was chosen for this investigation for its unique properties, especially its rapid growth (Postrel, 2004, p. 6); i.e. in some cases it can grow nearly five times faster than other naturally sourced materials (van der Lugt 2007, p. 43). Growth patterns of Bamboo can be compared to grasses like jute and kenaf, and include species such as *Phyllostachys pubescens* which have a growth rate of 1.22 meters in a twenty-four hour period (Hidalgo, 2003). Bamboo also has favourable material properties. Hidalgo (2003, p. 3) states that:

*“Bamboo is stronger than wood or timber in tension and compression. The tensile strength of the fibers of a vascular bundle could be up to 12,000 kilograms per square centimetre, almost twice that of the steel”*

The versatility of Bamboo allows it to be manipulated into an array of states (Farrelly, 1996, p. 15), all stemming from the natural material itself. These can be grouped into various subcategories of materiality: raw material (culms), Laminate, composite and fibrous Strands. Bamboo fibres, like most other natural fibres, compare well to glass fibre used in composites (Yamaguchi & Fujii, 2004, p. 306). The rapidly regenerative qualities of bamboo are harnessed for use in a myriad of applications.

*“Bamboo’s characteristics of lightness, strength, and flexibility, plus its natural sheen, have led to its utility as construction material, rope, fencing, fish and animal traps, bows and arrows, fly fishing rods, farm and garden tools, furniture, kitchen implements, musical instruments, religious articles, and of course, for baskets.”*  
(Coffland 1999, p. 7)

**Figure 5(a - e): Bamboo applications**



In some cultures bamboo is described as ‘indispensable’ (Stangler, 2002), whereas in western cultures, ‘modern’ materials have rendered natural materials obsolete<sup>7</sup>. Regarded generally as kitsch, bamboo is often viewed as a symbol of a bygone era (as demonstrated in Figure 5a - 5c). It has been stigmatised as a material of ‘craft’, and identified as demonstrating less technical advancement than other engineered materials. However, we can see from the numerous uses outlined above the utility and variability of the material. In previous generations, it has had a further link towards holistic, spiritual intertwining

<sup>7</sup> (Stangler, 2002, p. 14) details the traditionalism as well as the symbolic strength of Bamboo in Eastern c  
*“...bamboo is the equivalent of steel in the West, bamboo scaffolding is a common sight.”*

throughout all applications in culture (Coffland 1999, p. 7). This has been largely lost in western culture. In order to change the perception of bamboo and make use of its full potential, new processes of cultivation and high-tech manufacturing techniques may need to be explored.

#### **4.2.3. Three experiments in growing bamboo for vehicle construction**

The first research trial, (Figure 6a, “Experimental version 0.5”) attempted to explore plant shape manipulation for a small, quarter scale vehicle. Accordingly, a smaller bamboo species was selected – *Bambusa multiplexes*. In the second growth trial (Figure 6b – 6c, “Experimental version 1.0”), the species *Bambusa oldhamii* was chosen for its fast growth characteristics and large total height of twelve meters – characteristics that will be required to produce a full scale vehicle. The third experiment involved the growth of *Bambusa textilis gracilis* to make the seat attachment side railings (Figure 6d – 6e, “Experimental version 1.5”). Whilst this plant has different height characteristics to the species used in Version 1.0 – specifically a smaller overall growing height of five to six meters – an interesting growth pattern has been observed: new culms sent from the established parent plant contain no leaf or side shoot mass. Whilst this was an unforeseen characteristic, it may be desirable for achieving ‘clean’ sections of growth for part sections not requiring the use of side shoot growth.

#### **4.2.4. The “Ajiro” concept**

The “Ajiro” concept is based on *Experimental version 1.0: “Ajiro”*<sup>8</sup> (Figure 6d - 6e) with simplicity in overall parts count in mind. This has been achieved through the use of two continuous crossover sections which form the structural spine for the other components to attach to. The origin of the plant growth begins at the rear of these elements where, when pared from the root structure, it forms two points for attaching the left and right wheel swivel pivot bearings. These two elements then form overlapping cross points which provide an attachment point for secondary structural elements. They also provide attachment points for the:

- Seat insert and basket storage,
- Canopy support structure,
- Stabilising reinforcement/bracing piece from canopy section to lower seat frame,
- Wind visor,
- Headlight ancillaries, wiring and brake cable routing within the hollow bamboo sections,
- Wheel bearing anchor for the front wheel hub and pedal assembly,
- Longitudinal members forming the chassis linkage between front and rear wheels.

The use of bamboo continues throughout other areas of the vehicle, such as specific weaving patterns incorporated into the seat, storage basket and front wheel. Given the process of weaving is intrinsic to the structure, it offers the possibility for product

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<sup>8</sup> The name “Ajiro” refers to a style of Japanese bamboo twill weaving pattern

personalisation and material localisation. The general goal is to use a mono-material in as many aspects of the design as possible.

**Figure 6: Authors own images : (a) Experimental version 0.5, (b) - (c) Experimental version 1.0, (d) - (e) Experimental version 1.5, (f) Detail climbing pea tendrils**



Rear wheel steering has also been used to reduce the number of components needed to make the vehicle and to simplify its construction. This removes the need for a chain drive, cable shifter, derailleur and cassette sprockets. The front wheel contains a simple, all-in-one internal gear hub, such as the Shimano 'NEXUS' 8-speed Internal Hub (Shimano Australia 2010).

Further to the vehicle construction, opportunities for additional product benefits are being explored – for example; trials are being conducted to produce a living canopy of food-crop plants. The canopy is grown from seasonal crops planted in a small planter box attached to the seat back. Since the bamboo plants naturally send quite vigorous side shoots from sections of along the length of the stem (as discovered in “Experimental version 1.0”), they would be trained to form a workable roof lattice for the plant crops to be trained to grow around. The living canopy cleans the air, while providing a beneficial shelter and an edible resource.<sup>9</sup> Shown here is a particular variety of Pea, *Pisum sativum* 'Alderman - Tall Telegraph', which has characteristics of fast growth and hardiness. This species is tall (about two meters total), so it can cover a reasonable surface area, while the tendrils savagely cling to the structure (Figure 6f). It is recognised that the canopy will only provide shelter from the elements, rather than isolation, which is aligned with the initial philosophy of the design.

#### **4.2.5. Social implications and future directions**

<sup>9</sup> (Brendon, 2010, pp. 16-17) Discusses the effects of global warming, how it undermines human food supplies, and the need to reduce the distance food travels from growing area to point-of-sale.

As one of the many potential social outcomes derived from this research development, it would be hoped that grown vehicles could improve the accessibility to personal mobility, given the simplicity of the production processes. These ideas have large scale potential efficiencies for developing localised production bases for personal transportation. Once an established 'farm' is created, the production cycle length can be reduced, as more robust bamboo plants tend to send up new 'culms' at a much faster rate. Rotational farming techniques, therefore, lead to vigorous production capabilities in terms of product output.<sup>10</sup>

Future directions of the research could extend further into the ability of bamboo to provide a growing, *living* personal mobility structure, given its largely uncompromised structural properties when green (Hidalgo, 2003, p. 73). These techniques have been explored in the field of 'grown furniture' (Arborsculpture), and are now being used as an educational tool to inform people of the value and effort it takes to produce materials. Dr Christopher Cattle, a practitioner of grown furniture techniques states that:

*"By showing people, particularly children, how it is possible to produce useful and attractive things by working with the natural process of growth, I'm trying to change their attitudes to their surroundings"*<sup>11</sup>

## 5.0. Conclusion

Growing concerns over climate change, fuel price rises, congestion, parking, and policy shifts against motor vehicle use in certain urban areas indicate that our road transport networks are becoming increasingly vulnerable. Alternative vehicles such as electric pedal assist bicycles, electric powered 3 wheeler cars, mopeds and microcars, if readily available, could offer viable solutions to some transport system issues, however, there are a number of forces currently preventing their nominal increase. These include a lack of availability, safety concerns, cultural paradigms and the high cost of new technologies and vehicle platforms. This paper has explored a number of these issues and has outlined ways they can be countered, citing two design concept studies that propose alternatives to the motor car. It is hoped that products like these will help build resilient networks through increasing mode diversity, distributing production and opening avenues for further design innovation.

The "P.U.U.N.K" (Pedal-assist Upcycled Urban N-configurable Kit) and "Ajero" velomobiles are two in-progress Industrial Design projects at Monash University that respond to these issues. The P.U.U.N.K aims to adapt to individual needs, comfortably commuting a distance of up to 20km without the need to wear a helmet while carrying a small amount of cargo. The project has reached the end of the concept design stage and is now ready for a prototype build. It aims to demonstrate that it is possible to design a low cost, pedal assist Velomobile, within an open source, digitally mediated framework that can be easily accessible, interminably reconfigured, and made from found materials using generic household tools. The open source nature of the project allows it to be socially embedded in DIY culture and be made inexpensively. For those not wishing to make their own vehicle, it can be

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<sup>10</sup> (Hidalgo, 2003, p. 62) Bamboo under three years old is considered immature, with less strength, and not suitable for construction. As a response to this, the farming technique would have to consider the specific age of the culm growth before harvesting specific sections.

<sup>11</sup> (Reames, 2007, p. 102)

manufactured in poly-nodal community hubs, thus improving the proximity of production to the end user.

The “Ajiro” is a HPV that uses the growth of bamboo to achieve multiple production processes in one single stage. The viability for commercialisation is still under investigation, as is the design. However, the research intends to reinvigorate this traditional material by capturing knowledge from artisans within sculptural fields. The approaches for manipulating bamboo make use of the intrinsic structural properties of the material. The project hopes to encourage the appreciation of natural materials within industries which tend to rely on the complex processing of mass produced materials such as those derived from petroleum.

Both projects will be completed in the first half of 2011, at which stage a complete review of the outcomes will be published.

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