National College of Art and Design

Faculty of Design
Department of Industrial Design

The Development of the Human Powered Vehicle as a Viable Form of Transport.

By
Brendan McCaffrey

Submitted to the faculty of History of Art and Design and Complementary Studies in Candidacy for the Degree of Bachelor of Design.

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And especially Dr. Paul Caffrey.

List of Illustrations.

Introduction

This thesis will examine the viability of human powered vehicles as a form of urban transport for the future. It is constantly being proposed that the environment is in danger. The danger comes primarily from the burning of fossil fuels. The main contributors are industrial consumption and transport consumption. The over use of cars in the city has resulted in an excess in air pollution. In this respect human powered vehicles seem to present a valid solution. This thesis will be asking what advantages and disadvantages human powered vehicles have over conventional forms of transport, both car and bicycle. In particular the environmental advantages

While a substantial number of people realise the benefits of human powered vehicles there is many problems which this form of transport does not or cannot overcome and hence they are limited in their application.

This thesis will be examining human powered vehicles in their current form and will be asking how the future of this market can be influenced by industrial designers. This thesis will show the current approach to design and the change that is occurring through examination of current and proposed vehicles. The public acceptance of any product is essential, this thesis will ask what the public response to human powered vehicles is and how designers can help to change this perception.

The development of materials and technologies have found applications in the human powered vehicles industry. This thesis will be examining the relevant developments and showing how they can progress the development of human powered vehicles.

What are human powered vehicles? There are many forms of human powered transport from the bicycle to human powered flight. All are fully or partly powered by humans using mechanical transmission. This thesis is addressing the use of human power in urban transport so only ground based vehicles will be used. Also alternative forms, as opposed to the conventional bicycle, will be considered. These include recumbents and other solutions for urban transport. These forms of human powered vehicles are rare in the mass produced market but could become the successor to the bicycle.

The aims of this thesis is to show how the industrial designer can present HPVs in such a way that they will be accepted by the general public as a viable form of transport. That is if human powered vehicles are a viable form of transport inherently. Also to determine what benefits HPVs have for the environment. To determine the approach of designers today and how this approach should change and develop. This will be achieved by looking at examples of human powered vehicles as they exist at present and by looking at the advances in technology which will aid the development of future vehicles. The development of better inner city infrastructure will also be examined, as the future of human powered vehicles depends greatly on the way cities integrate them.

These questions will be answered by looking at the current state of the industry and the current role of the designer, what technological advances are improving the design and how awareness of environmental and social needs can determine the design approach of today's and tomorrow's designers.

Information for this thesis came primarily for journals which present up to date information about the range of human powered vehicles in development and in production. The most useful were Cycling Today and Bicycling. These journals provided a good technical reference in relation to the featured vehicles however they were lacking in any critical analysis of the product, attempting to sell the vehicle. The articles concerning road and city planning were useful, illustrating the views of regular commuter cyclists

The primary reference book was Richard's Ultimate Bicycle Book by Richard Ballantine, an encyclopaedia of all forms of human powered transport. This was a good reference for the development of the bicycle and human powered vehicles. There is no critical analysis of the vehicles. The design aspects of human powered vehicles are not addressed in any main texts.

Chapter 1 - Early History of Human Powered Vehicles.

Human powered vehicles are older than the bicycle. They were developed during the race to produce an efficient and practical form of human powered transport in the nineteenth century. A race which saw the Rover Safety Bicycle of 1890 emerge as the template for human powered transport for almost a century. The domination of bicycles was a result of achieving the best solution for the technology available. The bicycle provided a stable and fast form of transport which was acceptable to the public.

The bicycle was a result of nearly three centuries of development. The development began with what would be considered human powered vehicles today. The first patent for a human powered machine was in 1645 by Jean Theson, a French man. His machine had four wheels and was propelled by two seated men. There were many imitations and improvements on this design in the 18th century and particularly in the 1880s with such machines as the Sociable (plate 1). The middle 18th century saw many concepts for tricycles (plate 2) and recumbents in the search for the perfect machine.

In the 18th and 19th century the primary raw material for most engineering applications was wood, iron and steel. While these materials were suited to static objects such as bridges and buildings they also were used in the construction of vehicles. The use of such materials in human

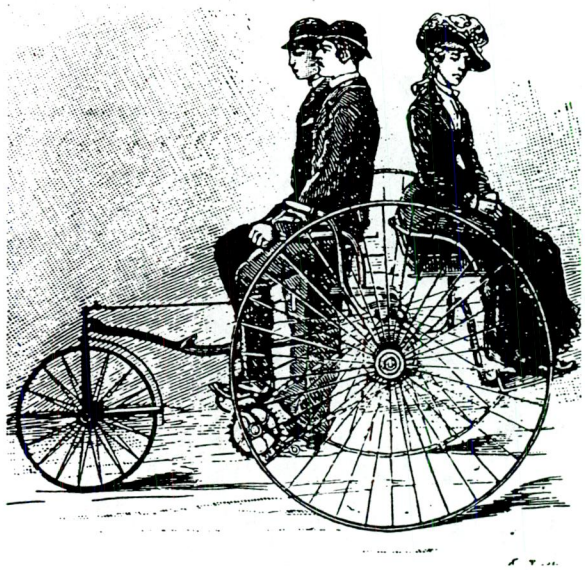

Plate 1: The Sociable for three people, 1883.
Early example of a HPV.

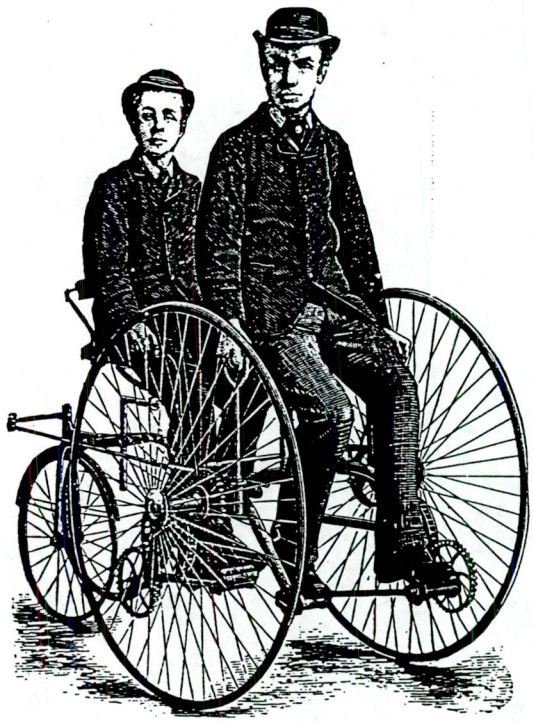

Plate 2: The Duplex Excelsior Tricycle, 1883.
Early example of a HPV.

powered vehicles was impractical primarily because of the weight. To provide the strength which the vehicles needed the materials could not be used in small cross sections and hence early machines were large, heavy and cumbersome. This made them extremely difficult to ride.
These early machines also had heavy wooden wheels with iron rims making them very uncomfortable to ride on cobbled roads. This was overcome partially by the introduction of pneumatic tyres by James Boyd Dunlop in 1888. This was a very substantial invention as it was eventually used in all forms of transport. The invention was inspired by Dunlop's son riding a tricycle on a cobbled road, he set out to make the ride more comfortable. He achieved this by putting an inflatable tube around the rim of the wheel. This increased the comfort of cycling by giving the machine a form of suspension. The invention of tangential spoking by James Starley in 1874 also improved the comfort of cycling. Tangential spoking involved a method of suspension rather than compression and used light steel spokes as opposed to heavy wooden spokes. This dramatically reduced the weight of wheels and made them more shock absorbent. The combination of these two inventions made human powered transport more comfortable.

Early human powered vehicles were designed primarily by inventors who worked on them as a pass time or as an off shoot of their businesses. In 1861 the coach builder Pierre Michaux produced his first velocipede which was a hobby horse with cranks fitted to the front wheel. In 1867 he introduced a model with a bigger front wheel and other refinements (plate 3).

James Starley, the designer of the Penny Farthing, was a foreman at the Coventry sewing machine company. He used his knowledge of production techniques, materials and engineering to develop a lighter and more refined bicycle. The Penny Farthing was produced by an experienced engineer as it is primarily a very practical vehicle although it proved a little difficult to ride. Starley under stood the principles of direct drive wheels. That is the bigger the wheel's circumference the further it would go for every stroke of the pedals and hence the faster it would go. However it tended to throw the rider forward if it hit an obstacle and this tendency to pitch forward meant that the machine could not use effective brakes.

The most important development came from Rover with the introduction of John Kemp Starley's Safety bicycle in 1885 (plate 4). This bicycle featured a chain-drive, gears, breaks and later pneumatic tyres. It used wheels of a more reasonable size and was more stable and comfortable than the high bicycles and also proved easier to ride.

In general no true human powered vehicle saw full mass production in the 19th century as they were expensive, costing the average worker over three months' wages, and in most cases impractical. The only mass produced human powered vehicle was the bicycle as they proved to be the most popular form of vehicle. It is strange that the bicycle, in the end, became more popular. The bicycle was neither the most ergonomic, efficient or fastest machine even at the end of the 19th century.

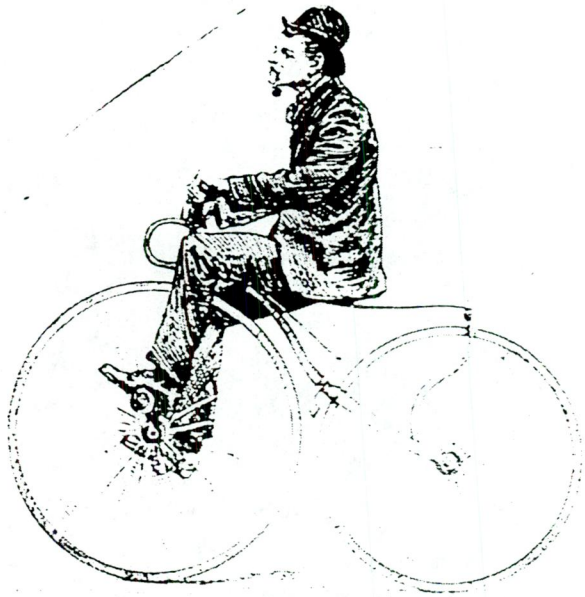

Plate 3: Michaux's Velocipede, 1867.
Initial development of modern pedal bicycle.

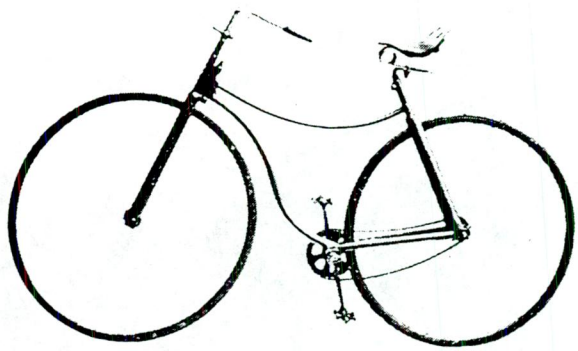

Plate 4: Rover Safety bicycle, 1885.
Defining the shape of human powered transport for a century.

Early recumbents provided a much better pedalling position and subsequently allowed the rider to go faster. The centre of gravity was lower making them more stable. They also provided more back support as the rider sat in a full seat rather than just a saddle. They did not require the rider to bend his back as much or climb out of the saddle to go up a hill. Because of the position of the back the rider could put more force on the pedals and hence make more efficient use of his body. A bicycle rider has no back support and has to rely more on his legs and shoulders while not exploiting the power of the back to it's full potential. Because of the position of riders on bicycles they often experience lower back pains.
At the end of the 19th century and the start of the 20th century speed was the primary objective for most inventors, manufactures and riders of human powered vehicles. The quest for speed records has always produced great competition and inspired designers to improve on existing designs. Although most designers concentrated on the bicycle other human powered vehicles such as recumbents have always proved to be faster because of the more efficient use of human power. However, as bicycles began to dominate, rules were made which made it impossible for other human powered vehicles to compete in the same events as bicycles making comparison difficult.

With so many engineers, designers and companies developing bicycles human powered vehicles were in general forgotten about. The bicycle proved more portable and manoeuvrable in most situations. It was more compact than the large recumbents and tricycles. Also because of the conditions of the roads in the 19th century being close to them was not

always a good thing. The upright riding position of a bicycle provided easy dismounting in an emergency. Bicycles became very popular with the Rover safety bicycle defining the shape of human powered transport for almost a century. Most manufacturers realised that the public gets what the public wants and bicycles were what the public wanted. Because the bicycle was being mass produced the cost went down, falling to less than a months' wages by 1909.

Chapter 2 - Current Status of Human Powered Vehicles, the State of the Art. (HPVs in the 20th century).

Although the bicycle took over as the primary form of human powered transport the interest in HPVs did not die. In the 1930s a Frenchman, Francois Feure, rode a recumbent bicycle to break the world speed records for both the mile and the kilometre. The records did not stand as the UCI (Union Cycliste Internationale) ruled that it was not a bicycle. This stunted the interest in human powered vehicles until the 1970s. Following the oil crisis of 1973, two Americans, Chester Kyle and Jack Lambie formed the International Human Powered Vehicles Association (IHPVA) with the intention of improving the bicycle by making it faster and safer. They encouraged designers to be unconventional and break with tradition in their search for a better solution while still remaining fully human powered. The resulting designs hold all significant speed records for human powered propulsion. Currently a human powered vehicle holds the land speed record of 65mph (105km/h).

It was individuals who produced these designs without manufacture in mind. It is this interest which started in the 1970s which has resulted in human powered vehicles available on the market today. It is not only in America that this has developed. Some of the most successful human powered vehicles and bicycles have come form England. In particular from engineer and inventor Mike Burrows (designer of the LotusSport pursuit bicycle). He has designed a number of commercial human powered vehicles manufactured under the name of WindCheetah (plate 5). There

are also many other companies getting involved as human powered vehicles have become more popular.

Plate 5: Mike Burrows' Windcheetah, 1995.
A commercially successful production HPV.

The Brox (plate 6) is a human powered multi-purpose vehicle. It was developed by David Wrath-Sharman and Chris Bell in Wales from an idea by Tony and Rob Brock. It has been specifically designed as an urban delivery van for medium sized loads which are too big for a bicycle. It provides a low cost alternative to a van hence reducing traffic congestion and pollution. It is a product which has been designed from first principles rather than being a converted bicycle. The designers have looked at user requirements in detail and produced a vehicle which is extremely functional, versatile (plate 7) and cheap to run.

The chassis of the Brox is H-shaped, with the cross bar of the H pointing in the direction of travel and it has four 20 inch wheels. The driver sits on a recycled plastic seat between the front wheels. A spar carrying a standard, single-ring chainset projects forward and transmits power to a crossover axle under the driver's seat via a standard seven gear derailleur system. A second crossover drive chain (as found on a tandem) on the left of the machine's spine then transmits power to the rear axle where a two-speed derailleur switches between seven medium-low and seven super-low gears (Field, 1995, p56).

On a conventional bicycle the rider has to keep riding fast enough to stay upright. On the Brox the rider can begin moving very slowly and keep moving slowly. It's bottom gear is low enough so even when fully loaded (about a quarter of a ton), uphill starts are possible without too much strain. The use of standard bicycle parts for the first part of the transmission allows it to be customised for specific people, loads and

Plate 6: The Brox, 1995.
Designed solution to urban delivery problems.

Plate 7: Variations available for the Brox.

terrains. At the rear, a differential takes the drive to both rear wheels and allows then to travel at different speeds when cornering. The differential was invented for the tricycle. Next to the differential and two-speed derailleur is a clutch which allows the gears to be changed while the machine is stationary, which is not found on bicycles or other human powered vehicle. The clutch is similar to that of a car, it works by engaging the clutch, spinning the pedals, selecting the correct gear and releasing the clutch to engage the drive. The Brox uses torsional suspension, which allows the front and rear wheels to rock independently. If any wheel hits a bump it is able to climb it. The suspension reduces the stresses on the frame which is made from square section steel tubing. Because of the suspension an economical use of frame material which keeps the unladen weight down to 35Kg. The steering is via a handlebar located under the seat which has standard brake and gear levers and a clutch lever. The maximum speed of the Brox is around 12mph. Because of the loads which can be carried the braking capacity of the Brox is very good with specially designed expanding drum brakes. Features which make the Brox ideal for city use are a folding handle allowing the Brox to be walked along, it also has a parking brakes and lights.

The research and development for the Brox has cost in excess of £100,000 and is a serious commercial proposition, not just an inventor's hobby. The target market for the Brox is large courier companies. They will buy it to do medium-sized, local van jobs because it's operating costs being so low, with an initial investment of £1995 to £2300 (plus VAT) and nothing but maintenance after that. (Field, 1995, p56).

While this vehicle appears to be a substantial improvement in design for city transport, it is an entirely new type of vehicle which can only achieve it's full potential through a certain amount of social reorganisation. As most urban planners are reluctant to make any concessions to cyclist it is unlikely that they will recognise the 'Brox' or similar vehicles as important enough to make substantial changes in urban structure. This is a shame as it is only through inventiveness that humanity can hope to over come it's problems. When inventiveness is stifled others are reluctant to continue. Perhaps in a few years when inner city traffic will surely increase that businesses will start looking at other forms of transport to make short range deliveries.

The Electra Globe (plate 8), designed by Robert Egger, is a power assisted bicycle which is aimed at a wider market than traditionally catered for. It's features include seven-speed internal gears assisted by a Chronos electric motor that is powered by a rechargeable battery, which can be engaged when extra power is required, such as when climbing a hill or when riding in a headwind. The Electra Globe also has a suspension seat and handlebars, dual headlights, a windshield and an enclosed rear wheel. It is designed to virtually maintenance free. The open frame makes easy to mount and dismount so making it usable by a wide rage of people including the elderly and those who know little about maintenance. The electric motor makes it ideal for commuter use in the city as stopping and starting in traffic is energy draining.

Plate 8: The Specialized Electra Globe, 1994.
Electrical power assisted bicycle.

Unlike the Brox this machine is ideally suited to use in the city today. It has benefits for the owner as there is no need of a licence, insurance, registration or road tax as it is classed as a human powered vehicle. This is a substantial advantage over it's close relative, the moped. The fact that it is electric means that it will be one less vehicle pumping toxic fumes into the air. However the energy comes from somewhere. In this case the battery is charged from the mains and can be topped up from the pedalling. Because of this there is energy being used the only difference is that is it generated somewhere else. So while it may seem totally environmentally friendly it merely hides the source of power, a power station of some sort. Eventually a battery may be developed which can be fully recharged from the pedalling alone.

The approach to design among contemporary HPV designers in recent years seemed to revolve around the search for even faster and more refined vehicles. However this is changing to a certain degree. There is a lot of designers making machines for ordinary people. There is a move to make human powered vehicles more practical. The designers of the Brox took the approach of designing a practical vehicle rather than trying to produce a very fast machine which cannot be used.

For most of this century bicycles have dominated the market for human powered vehicles. This is because they are inexpensive (due to mass production) and versatile. This is not the case with other human powered vehicles, such as recumbents, which often cost between £1000 and £2000. The average bicycle is less than £200. The price difference is due to the

fact that recumbents etc. are typically specialised vehicles which are produced in small numbers by small manufacturing companies. In order to make a profit in a market which is, at the moment, of limited appeal. There is a certain market which can afford the machines but they are seen as being too expensive by the general public.

Although the majority of human powered vehicles are produced by enthusiasts for speed records, there is a change coming about. With the development of vehicles like the Brox and the Electra Globe, HPVs are finally being aimed at ordinary people for practical use. This was also the case with the development of the bicycle. The advancements are made by those seeking speed records and new trills, as with the mountain bike. The advancement filter down to the man on the street eventually. This is true in all fields of design. The family car industry has benefited from technology developed by Formula 1 engineers. Traction control and anti-lock breaks are now found on many family cars.

In general public acceptance of human powered vehicles is poor. This is mainly because of ignorance. It's rare that a recumbent is seen on the streets and when it is people generally see them as oddities. However HPVs are becoming more popular. This is especially true in America and mainland Europe. Many cyclists use them as touring machines, an application for which they are particularly suited. This is due to their load carrying ability and comfortable riding position.

The main problem human powered vehicles have to overcome is peoples natural resistance to change. As people become more aware of the benefits of HPVs to their health, the environment and to their bank account perhaps more people will use them. At the moment people are not fully aware of the benefits of alternative human powered vehicles over the conventional bicycle. human powered vehicles have very little exposure in the media or on the roads. This is especially true in the UK and Ireland. There are very few HPVs sold in Ireland, the only machines to be seen are those ridden by tourists. human powered vehicles are also not represented in bicycle shops and are only available through mail order. This makes them inaccessible to the public.

A significant reason for the lack of interest in human powered vehicles in Ireland and England is that the people are very conservative and are unwilling to buy HPVs as they do not want to stand out. Anything different is very noticeable. In the USA human powered vehicles are more common, this being much to do with the American mentality as the practicality of the vehicles. This is also true of certain European countries such as Holland, who are considered to be more liberal.

The bicycle also suffered this when it first appeared, but this was overcome by exposure to it. Perhaps the same will happen of other HPVs. It is unlikely that human powered vehicles will have as big an impact on the world as the bicycle.

- The Advantages and Disadvantages of Human Powered Vehicles.

At the present what advantages and disadvantages do human powered vehicles have in comparison to cars.

Advantages:

They are much cheaper to run than a car as there is no road tax or insurance.

They do not require the use of any combustible fuel.

They are easy and inexpensive to maintain by the owner.

They are fast even in heavy traffic.

Provide exercise for the user.

Enclosed HPVs provide weather protection.

Disadvantages:

Rider is often exposed to bad weather.

Rider is very exposed in event of an accident.

Many do not provide passenger room.

Many do not have enough load carrying space.

Can be difficult to park as most cities only provide bicycle parks.

Chapter 3 - Technological Advances Related to the Development of Human Powered Vehicles.

Many technological developments have contributed to the development of human powered vehicles but none more so than materials. Materials science has made huge leaps in the last two decades. The development of polymers, metals and composites have had far reaching benefits in many fields. human powered vehicles have benefited greatly from this revolution. Material technology has accelerated since the start of the American space program. Engineers were forced to develop new materials which could withstand the rigours of space travel, the physical stresses and the heat. Many of developments made in the space program have filtered in to common products, such as non-stick frying pans and car wax (AutoFom which contains fomlin A used on surfaces on the space shuttle to prevent ware). These advances in material technology have found many applications in human powered vehicles. These advances include improvements to traditional materials as well as totally new composites and alloys.

The most widely used material in the human powered vehicle industry has always been steel. However steel is not very strong in thin sections typical of HPV lightweight construction. This was compensated for by making tubing thicker and hence heavier. Through development, in the second half of this century, with alloys of steel manufacturers of tubing began to produce lighter and stronger steel tubing. Typically steel was alloyed with chromium and molybdenum to make it tougher and stronger.

Manufacturers, such as Reynolds and Columbus, have continued to improve steel tubing producing a wide range of tubing with different properties to suit most applications. Steel tubing is still the most popular structural material for all human powered vehicles.

The use of aluminium in human powered vehicles is as a result of developments of the space program. Aluminium is quite weak as a structural metal but by the use of alloys, such as nickel, the strength can be increased to that of steel. However aluminium has to be used in larger sections than steel because it soft and it fatigues easily, a problem which caused many accidents when it was first used in bicycle frames. The big advantage aluminium has is that it extremely light and when frames are built properly, using large section tubes, they are very rigid and strong. Rigidness is very important in order to maximise pedalling efficiency and reduce the effects of fatigue. Aluminium is not only used in structural form, it is the most popular material for the construction of wheels and components such as brakes and derailleurs.

Both steel and aluminium are well-developed materials which are near their performance limits now. However there are many new materials which offer lighter, stronger and more versatile options to steel or aluminium. Magnesium is the lightest structural metal on earth and it's supply is theoretically almost infinite because it is extracted from sea water. Magnesium can also be recycled very easily which makes it an environmentally good option. However magnesium is structurally weaker than aluminium and is best used in chunky pieces. If used in long thin

sections typical of HPV and bicycle construction, the strength and weight advantages are non-existent. Magnesium is also very vulnerable to corrosion, especially from electrolysis, (corrosion occurring when dissimilar metals). Magnesium is pressure die cast and has been used by Kirk Precision to produce a production bicycle (plate 9).

Of the new materials available carbon fibre is the most practical in terms of structural strength and cost. Carbon fibre is typically available in two structural forms, tubular and as a monocoque, a one piece frame (plate 10). Carbon fibre has surpassed other conventional materials, such as steel and aluminium in lightness and strength. It is a composite material constructed from fibres of carbon which are weaved and bonded with epoxy resin to form a very light, rigid and strong material. Carbon fibre is ideal for use in the construction of human powered vehicles as it is light and strong in the section required. The pioneers of tubular carbon fibre bicycles were Peugeot (France) and Giant (Korea). The first successful application of carbon fibre in a monocoque for a HPV was Mike Burrows' LotusSport pursuit bicycle, (plate 11). Carbon fibre is used extensively in Formula 1 motor sport and is finding increasing application in human powered vehicle design.

Other materials which have found application in the HPV industry include titanium. Titanium is an extremely strong structural metal and is lighter than steel. Titanium is also immune to corrosion and is produced for aircraft hydraulic systems, in chemical and nuclear industries, for plumbing corrosive fluids and the military use it as bullet proof casings for

Plate 9: Kirk Precision magnesium bicycle, 1985.

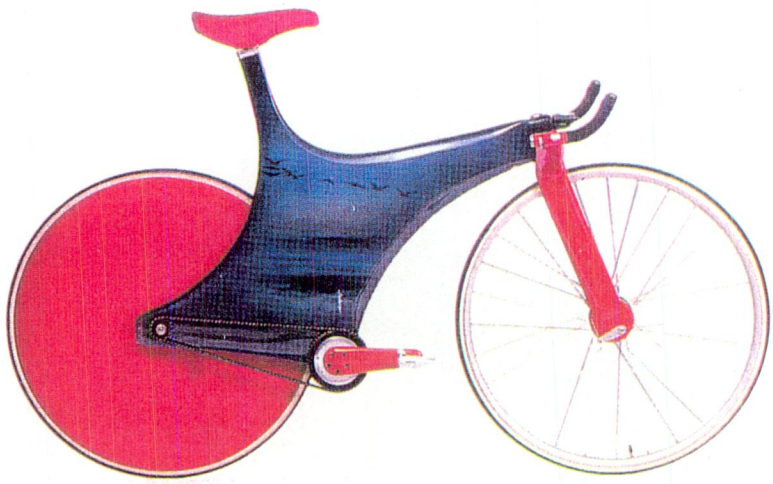

Plate 10: Carbon fibre monocoque frame.

Plate 11: LotusSport Pursuit bicycle, 1993.
The first successful application of carbon fibre in a monocoque bicycle.

pilots of combat aircraft. This makes it very useful in the design of human powered vehicles. Kevlar is also a result of the space program and is used by aircraft manufacturers in wing and fuselage panels and in helmets for American soldiers. Kevlar is often mixed with carbon fibre in the production of bicycles and human powered vehicles. Advancements in polymers have also been used in HPV design. Polymers have been used in fairings, enclosures and various components, such as seats.

Most of these new materials tend to be expensive and hence drive the price of machines up significantly. This makes it difficult for new materials to be accepted by buyers. However as supplies become greater and extraction processes become more refined the cost of these materials will be reduced. This has already been seen with titanium which is available in abundance in northern Russia. Because of the fall of communism and the poor economic situation of Russia the supply of titanium has increased and has been reduced in price.

In conjunction with material advancements, manufacturing techniques have also improved greatly. As new materials become available manufacturers have had to be able to adapt them to mass production. Also traditional techniques have had to be improved to meet new demands of strength, lightness and durability. Processes have also been evolved to be both quick and less expensive.

Traditional techniques within the bicycle industry involve hand made frames which are impractical in a mass production situation. They are

often very expensive to produce and hence to sell. However companies who produce hand made frames have used this as selling point for their product. This is common in Italy with companies such as Basso and DeRossa. It is similar in the HPV industry. The reasons for human powered vehicles being hand made is different. In most cases mass production is not viable as there is only a small market. In this case hand building is more practical. However as the popularity of human powered vehicles increases more mass production is being employed.

Manufacturing processes in general have achieved a very high standard in the last three decades. Machines now perform many of the skilled tasks to a higher degree of accuracy then a man. Frame building is the centre of the HPV and requires some precision. Today the frame can be designed and tested on a computer. All the flaws can be corrected before it is physically made. This is very important when dealing with monocoques of carbon fibre and kevlar, where the designer needs to know which point need to be stronger. The actual production of a frame is largely done by a machine also.

Joining techniques have also been vastly improved and can be completely done by a robot (plate 12). The joining of steel has been always been clumsy and the application of so much heat has caused damage of lightweight tubing. Traditionally steel tubes were joined using lugs which the tubes were inserted into and the brazed together. This added weight to the frame. The use of TIG (Tungston Inert Gas) welding for steel has eliminated the need for lugs, it has made the joining of steel very precise

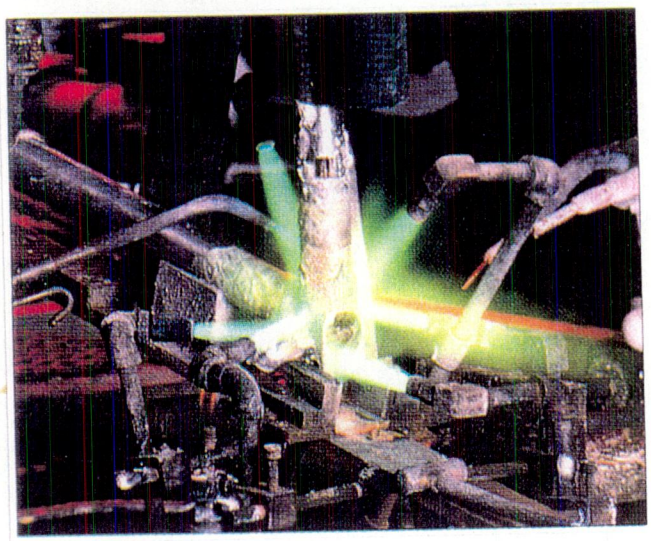

Plate 12: Robotic brazing rig.
Automated process for joining tubing.

and does no damage to the tubing. Aluminium has always been difficult to join because it is susceptible to heat damage. This problem was overcome initially by the use of TIG welding. However recently aluminium has been joined using glues, which eliminate the problem of heat damage. The glues used are usually stronger than the aluminium.

With the introduction of new materials, new processes for mass production were required. Initially these processes were time consuming. Carbon fibre manufacture initially was a messy, expensive and labour-intensive processes involving the layering of the fibres and the epoxy resin bonding. Now the process involves the use of cleaner, faster and cheaper thermoplastic binding. Instead of using epoxy resins, carbon fibre is woven with strands of thermoplastic to produce a dry fabric which is easy to cut, shape and set. This has significantly reduced the cost of manufacture of carbon fibre.

As production becomes more efficient the cost of human powered vehicles will be reduced. This is an important factor in the acceptance of human powered vehicles by the public. Very few can afford the current cost of human powered vehicles. The introduction of mass production into this industry will see a reduction in the price of human powered vehicles as it has done in other industries.

As with materials advances in ergonomics and aerodynamics have helped the designer create better human powered vehicles. They have become more important in increasing the efficiency and ease of use of human

powered vehicles. In the last ten years research has been conducted into efficiency of human power and what the best body position is for both ergonomic and aerodynamic efficiency.

The upright body position of a bicycle rider is not the most efficient position for maximum power output. This position is also inefficient aerodynamically. On a bicycle, as the speed increases, a proportionally greater amount of the riders pedal power is used to over come air resistance (Ballantine, 1992, p. 134). This has been over come to a large extent by designers of HPVs by providing alternative riding positions and by the use of enclosures.

There are two main riding positions used on human powered vehicles. The first is the recumbent position where the riders is lying back on the machine (plate 13). This position allows the rider to use his back more so making more efficient of his power. It is also a more comfortable position due to the fact that the rider sits on a full seat as opposed to a saddle. This position also reduces drag by 25% over bicycles (Ballantine, 1992, p. 130). Stability is also better as the rider is closer to the ground. The second position is the prone position (plate 14) in which the rider lies on the machine facing the ground. This is also a better ergonomic and aerodynamic position for speed. But as the rider lies on his front it can be uncomfortable.

Plate 13: Recumbent riding position.

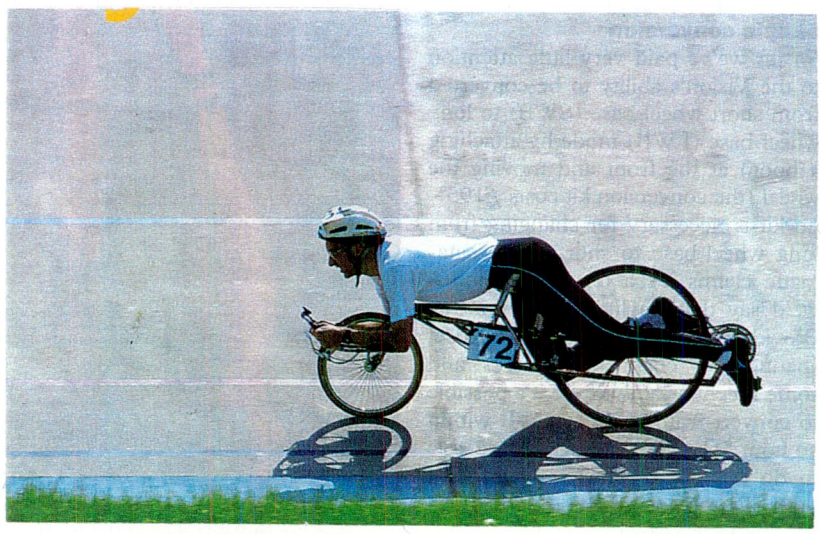

Plate 14: Prone riding position.

The use of enclosures or fairing can significantly increase the aerodynamic efficiency of human powered vehicles (plate 15). A well designed fairing can reduce aerodynamic drag by 80% which reduces the riders effort by 70% (Ballantine, 1992, p. 135). This is the main factor in increasing the speed of human powered vehicles without increasing the riders effort. The practical application of this is that a commuter using a faired HPV can expend less energy than that of a cyclist. Fairings are also practical for shelter from the weather, which is a significant factor for cyclists.

Components are a very important part of human powered vehicles. In the last century many companies, such as Shimano and Campagnolo, have developed components for bicycles. Most of these have found application on human powered vehicles. However HPVs have specific requirements which are generally not catered for by the manufacturers. This is especially true of drive systems which do not always meet the needs of the HPV. Enclosed human powered vehicles often have little room for conventional pedal drives as plenty of room is needed for the circular motion. Recumbence with chain drives encounter the problem of long chains which stretch and break (plate 16). Standard calliper brakes are not always suitable. Solutions to these problems have to come from the designers of these human powered vehicles and are often expensive to produce, unless put into manufacture by a big company. Many of these ideas are as yet undeveloped.

The belt drive (plate 17) is a lighter, quieter, lubrication free alternative to the bicycle chain, but as it uses a notched rubber belt, the inherent

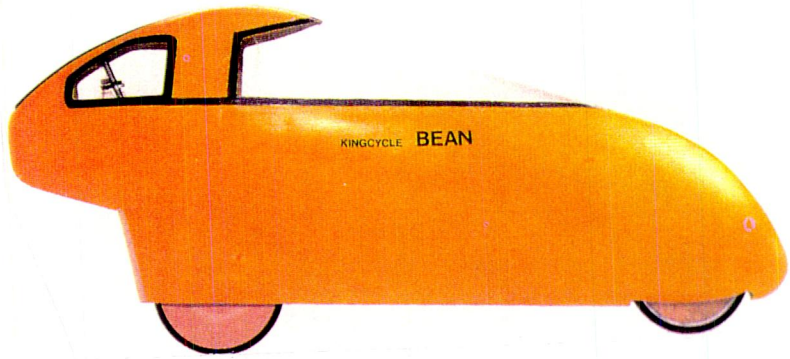

Plate 15: Recumbent with enclosed fairing.
Faired HPVs can have 80% less aerodynamic drag than an unfaired HPV, reducing the riders effort by 70%.

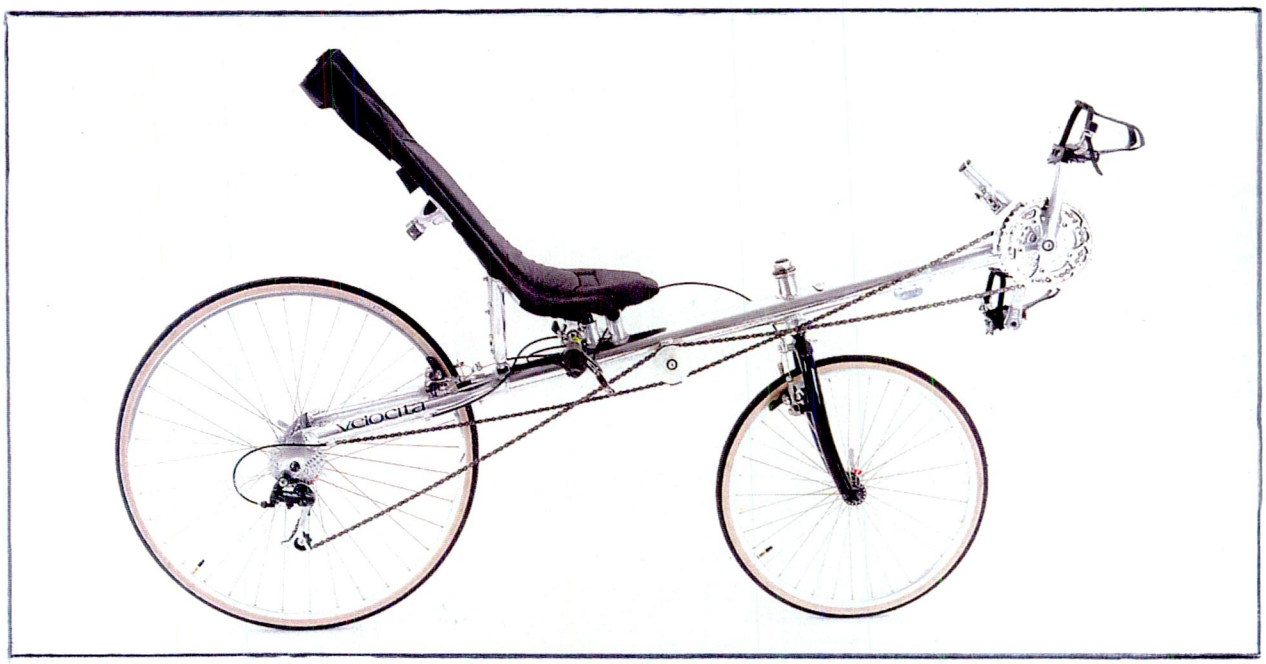

Plate 16: Long chain usually found on recumbents.
These chains usually stretch and break easily.

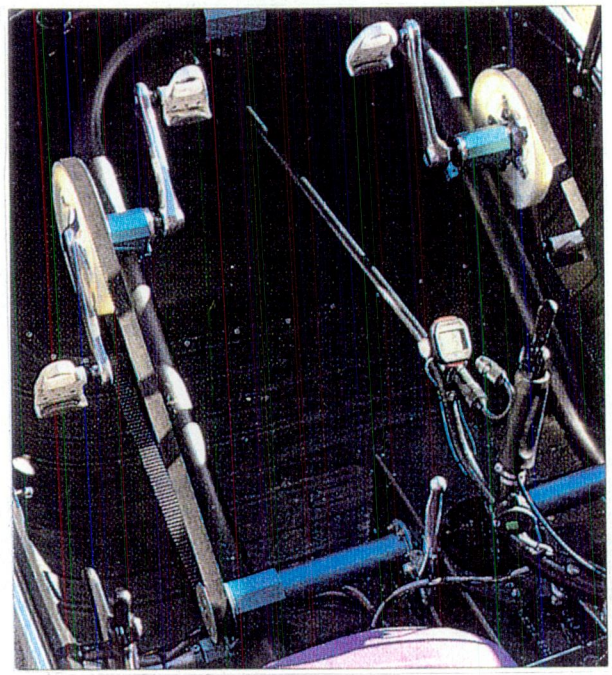

Plate 17: Belt drive system.
A lighter, quieter, lubrication free alternative to the bicycle chain.

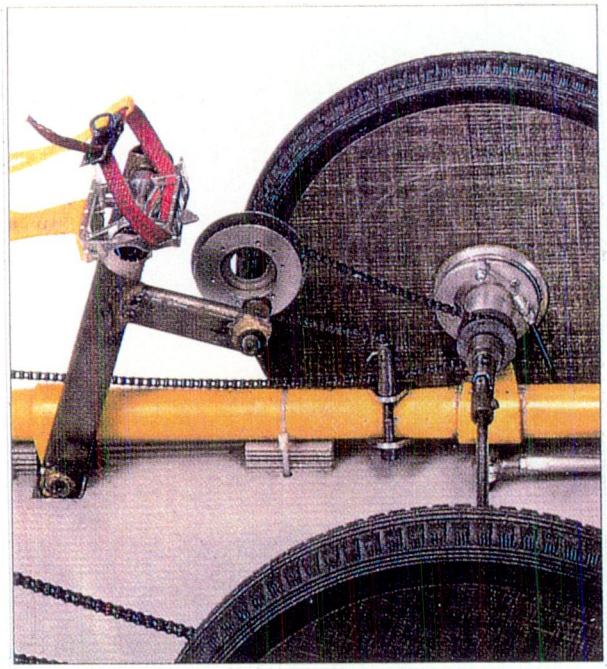

Plate 18: Treadle drive system.
Reduces the space needed for a conventional drive system.

problems of stretch and tension have to be overcome. The belt drive is undeveloped for the market place and could provide a good option for human powered vehicles. The treadle drive (plate 18) is also undeveloped, but could prove very popular for human powered vehicles. The treadle drive uses a short downwards stroke to drive the wheel. Since it does not require circular motion less space is needed for it in an enclosed HPV. It also makes better use body muscles, without loss in mechanical efficiency. Designers of human powered vehicles have also adapted the drum and disc brake systems used in cars for use on human powered vehicles.

If small manufacturers have to make specialised components for their machines then the cost of the product will be higher. If the market for such vehicles grows then companies such as Shimano may be forced to develop components specifically for this market. This in turn could benefit the main stream market range.

New materials and technologies are gradually becoming part of everyday life. These many technological developments have the potential to change human powered transport and in some cases have already. They provide designers with many new options for both technological and aesthetic improvement..

Chapter 4 - Environmental and Social Concerns for Human Powered Vehicles.

As an alternative form of transport, human powered vehicles are by far the more considerate of the environment. human powered vehicles use less energy and materials than cars and produce no emissions. Even the electric car needs fuel which is usually produced at the expense of the environment. A person riding a bicycle for a mile burns about 35 calories, to walk the same distances burns 100 calories and an engine burns 1860 calories (Ballintine, 1992, p.11). This is the most efficient form of transport known to man. However very few people at this point in time are willing to give up the comfort of a car and get even an ordinary bicycle. This is not surprising as modern western society tends to revolve around cars. For the last century man has been obsessed with speed in every thing, from work to transport. The ethos is to make things faster. This is a result of greed, as the faster things happen the more money is earned and the less work time is lost. The owner of Microsoft, Bill Gates advocates sleeping under ones desk in order to put in the most amount of work. He even supplies sleeping bags for his staff. human powered vehicles represent a much more relaxed way of life. They provide a good method of relaxation and exercise combined with an efficient way to commute to work. They are cleaner, quieter and take up less space than cars.

The protests of the last thirty years has had little effect on the general public of the western world. It has been established that emissions of

carbon dioxide are linked directly to the green house effect, which at present does not pose a major threat to mankind, but soon may do. Although industry shares the blame, cars are one of the main causes of this . The man in the street can do little to prevent industry spoiling the atmosphere but can make a difference himself by using human powered vehicles more. Yet people tend to shift the blame to industry and overlook their own part. The reluctance to act is causing even more pollution day to day. It will probably take an imminent disaster to force a change.

The problem of environmental damage does not stop at air pollution in the city. Motorised leisure vehicles such as snow mobiles, dune buggies and off-road motorcycles pollute, erode and cause noise problems in wilderness areas. This problem has been compounded by the recent interest in off-road jeeps. In Britain this is causing a lot of damage to common ground. The people who drive these machines generally have no off-road experience and little regard for the damage they are doing to the country side. This becomes a serious problem when the ground is wet. Motorcycles have also been responsible for the degradation of many forest trails through over use. The Boniville salt flats in the US, famous for land speed records, have suffered severe erosion due to the excessive use. The salt level has drop to 7 inches in places. There is an effort being made to replace the salt but it will take years to return it to pre-1940s level. There is little effort being put in to stopping the racing. The Salt Flats is a place of great beauty and is one of the few places on land where the curvature of the earth can be seen.

human powered vehicles provide a great alternative to motorised leisure vehicles if used sensibly. Mountain biking is becoming a very popular pastime, especially in America. Even though some conservationists have complained about the high level of erosion caused by the excessive use of tracks, this has occurred due to the overuse of these tracks. In moderate use tracks would not suffer as much abuse as they would from a motorbike.

As well as the obvious environmental advantages provided by human powered vehicles, the lack of emissions, manufacture is also much more environmentally friendly than that of cars. At present bicycle production outnumbers car manufacture by three to one (Ballantine, 1992, p..11). Despite the difference in manufactured units the amount of material used in the two products is vastly different. The amount of material used to produce a car would produce several bicycles. This provides many advantages, primarily that at the end of it's life a bicycle contributes less waste to the environment. Rarely is there seen a scrap yard heaped with bicycles as is the case with cars. Because the manufacture of bicycles is a light process the manufacturing techniques are often less harmful to the environment. The processing and finishing of steel and plastic requires a lot of energy and water. Steel production heats the water used which is usually ejected in to rivers causing pollution. Processes involved in car production such as chroming creates a toxic sludge which is difficult to dispose of safely. This process was used to a certain extent in the bicycle industry but has become unfashionable and has been mostly discontinued.

Manufactures of cars have claimed to have made many efforts to make cars more environmentally friendly but their efforts are merely cosmetic and do little to curb the damage cars do. BMW have recently set up a recycling factory in England where a BMW owner goes to scrap his car. The car is stripped and the parts are either used again as spares or recycled completely. It solves the problem of cars lying in scrap heaps, rusting. This however does not address the real issues of what cars do to the environment. It is only by laying down strict guidelines to manufactures that any real improvements can be made. This has been done already in Switzerland. The Swiss have put strict limits on the consumption of engines. They hate cars so much that a in recent referendum it was decided to raise the price of petrol.

Human powered vehicles as well as making sound ecological sense also have many benefits for people. This benefits are social, physical and economic. The most obvious advantage of human powered vehicles is the cost of running them. A car is the second biggest investment anyone makes in their lives after a house. The expense of a car is ongoing as fuel and maintenance must be paid for. 'The average motorist spends four hours a day either driving, maintaining, or earning the money for a car' (Ballantine, 1992, p.11). This is a huge investment in time and money. Even if motorists used a bicycle for journeys of under three miles they would save hundreds of pounds a year in fuel costs alone. Western society has become lazy because of the convenience of cars in comparison with poorer countries such as China and most of Asia and Africa. Industrialised countries have come to rely on the car even for short journeys. In the UK

one in four people own a bicycle yet only one in fifty commuting journeys are made by bicycle (Johnston, 1995, p.64). In China the majority of people use a bicycle to commute. The bicycle usage in the world, shown in plate 19, shows that industrialised countries have high ownership of both cars and bicycles. However they generally tend to rely on the car more.

Human powered vehicles make much more use of road space than cars. This is even more true when it is considered that the majority of journeys made by cars in cities are made by one person. On average a car uses the same road space as eight bicycles. Space in cities has become increasingly important the number of cars increase. Most cities were planned with little foresight. The planners failed to realise that the car would become an integral part of peoples lives and as the economy improved more people would be able to afford them. This has resulted in overcrowded roads in most cities. Americans spend a billion hours a year stuck in traffic, wasting two billion gallons of petrol at a cost of $10-30 billion (Johnston, 1995, p.64). This is an incredible waste which could be avoided if more people chose to commute using human powered vehicles. Human powered vehicles make very sound economic sense for individuals also. This is due to the fact that there are no fuel costs, road tax or insurance to pay, just the initial cost of the machine and some maintenance.

Human powered vehicles as they exist today, i.e. the bicycle, are a very efficient and useful form of urban transport. They provide a very fast means of commuting in the city as the can dodge through the traffic jams, can be parked easily and are cheap to buy and maintain. However they

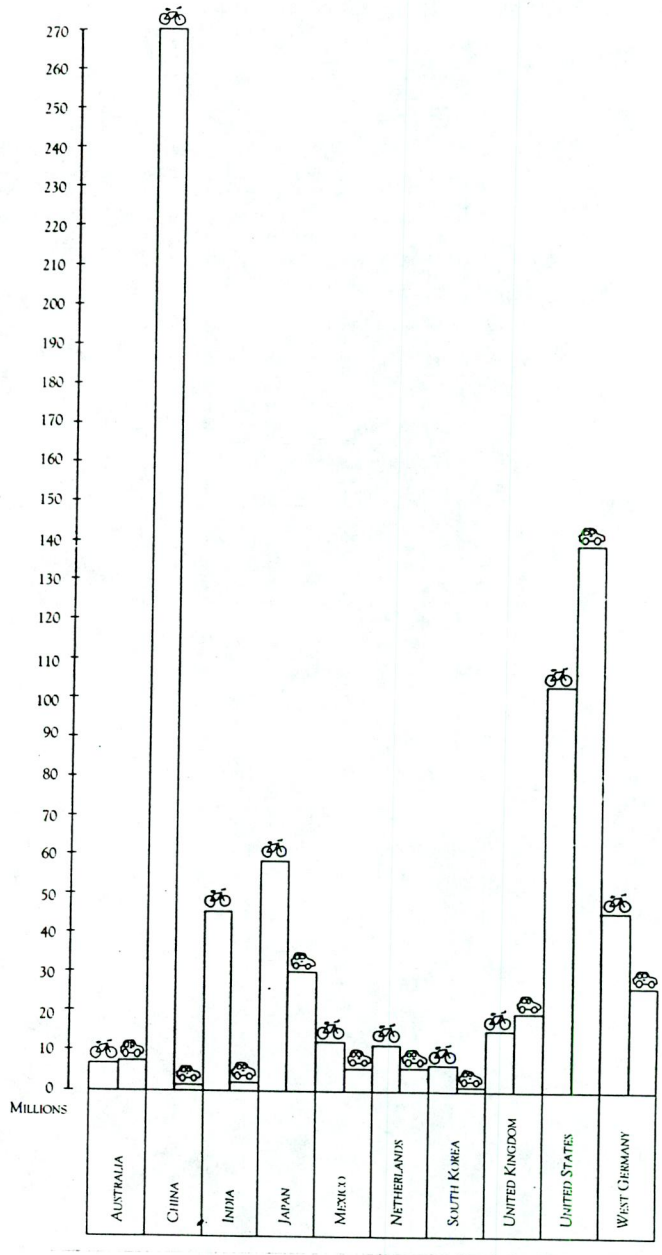

Plate 19: Bicycle usage in the world.

have flaws. This is particularly evident in countries like Ireland. The weather is a big problem as bicycles do not provide any shelter from wind or rain. Also motorists have very little respect for cyclist and tend to see them as a nuisance rather than as another road user. Very little work has been done in Dublin to accommodate cyclists apart from three cycle lanes on the North and South bound roads. This has made cycling twelve times more lethal per mile than driving (Johnston, 1995, p.64). It is little wonder that so few people are commuting by bicycle. In European countries such as Holland and Denmark extensive networks of cycle roads were laid in order to reduce the risk to cyclists. This has resulted in one in five journeys now being made by bicycle. It has been shown that it is possible to provide for bicycles however planners in other countries tend to ignore cyclist and design roads for cars only.

In order for human powered vehicle to succeed as a form of transport for the future city planner must realise that they must be considered when structuring roads. There must also be a change in existing road designation as has been done in pedestrianising inner city streets. Confining roads specifically to human powered vehicles has already been done in some small towns in Belgium and has had a dramatic effect, to the better, on town life.

Chapter 5 - The Role of the Designer in the Future of human powered vehicles.

So, what is the role of design in the future of human powered vehicles. At present human powered vehicles have little public attention, mainly due to the lack of exposure. It is a largely underdeveloped form of transport. Because it is in it's infancy there is few existing products on the market and those that are available are not advertised to a large number of people. The people who are aware of them have seen them advertised in specialised publications. The majority of bicycle shops would not have any in stock. In order for the human powered vehicle industry to expand and develop they must be able to sell their products. This means advertising and exposure. They have to reach the public, who they expect to sell to. This is true of all products but particularly so of a new kind of product.

The mountain bike is a good example of good marketing and advertising. Originally a machine designed by people looking for a new experience in cycling. The bicycles were ordinary bicycles striped down and strengthened for down hill racing. They became very popular as a sport. The bicycles were eventually packaged and sold as a marketable product to all kinds of people. This was achieved primarily by Japanese and Korean companies, Trek and Giant. The production bicycles were far removed from the original machines with all the refinements of other road bicycles. The image of excitement and freedom was conveyed through the design and heightened by the advertising (plate 20 & 21). The mountain bike has been hugely successful and is outselling all other types of bicycle on the

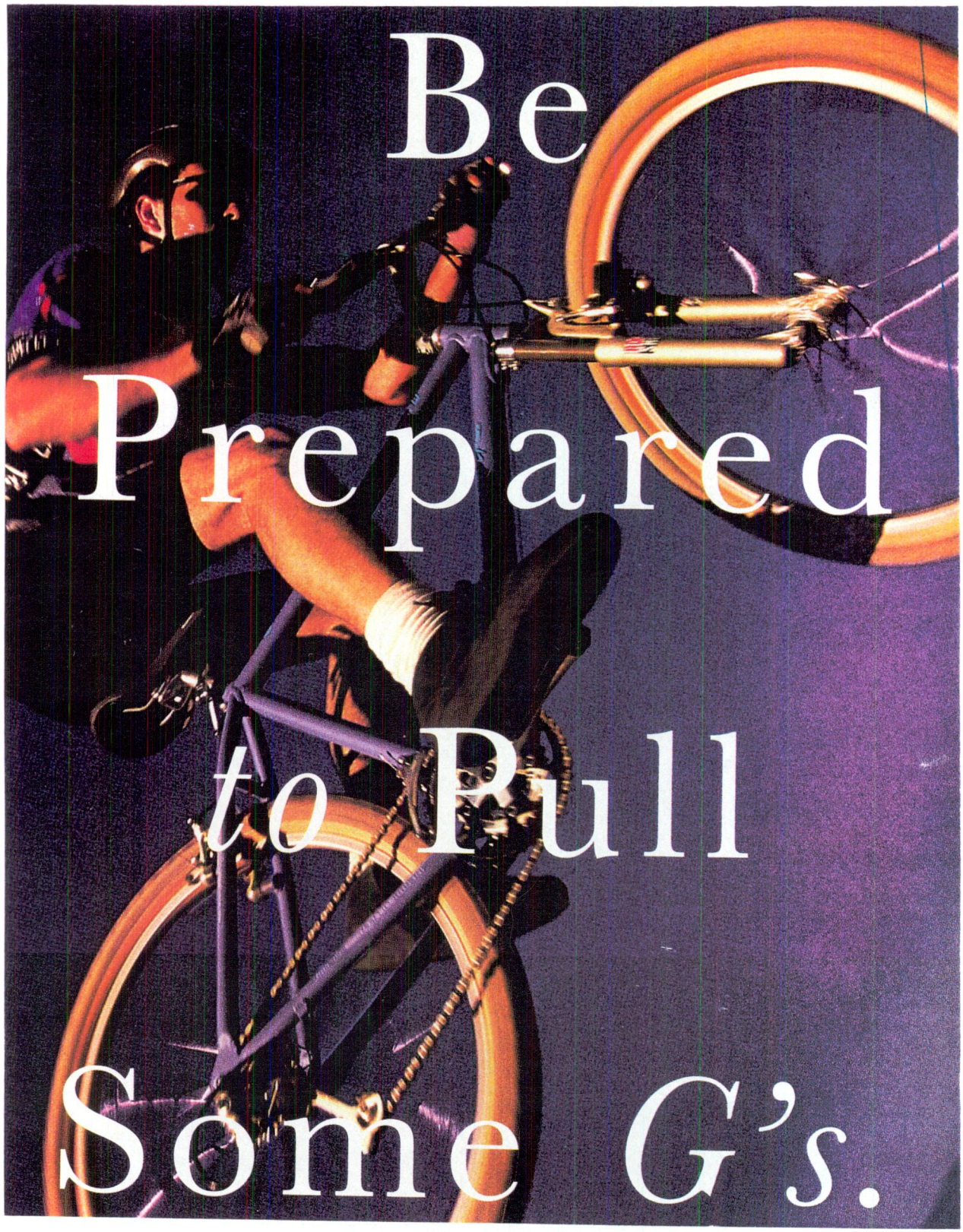

Plate 20: Mountain Bicycle advert, Specialized, 1994.
Showing the techniques used by advertisers to sell a new product.

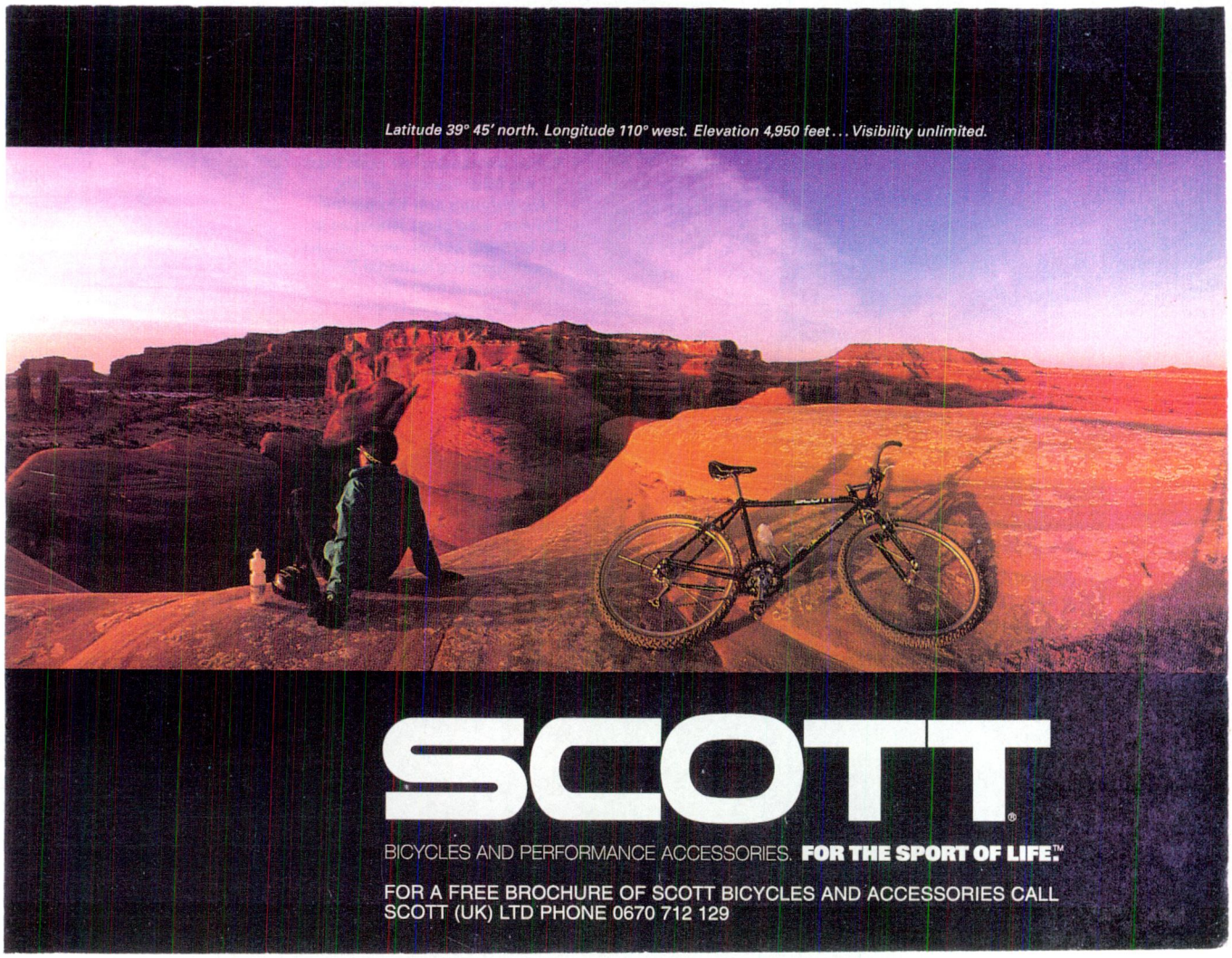

Plate 21: Mountain Bicycle advert, Scott, 1994.
Showing the techniques used by advertisers to sell a new product.

market in America and Europe. It is no longer used solely for plunging down mountains but has found favour with many city commuter due to it's ruggedness and comfort. This is a product which has been successfully marketed and has hence achieved enormous sales.

In the future it will be important for manufactures of human powered vehicles to broaden the scope of their advertising to include a larger amount of people. The more casual cyclist must be made aware of the benefits of human powered vehicles in order for them to buy one. Presence of human powered vehicles in a showroom is also essential as customers often make decisions on what they see in a showroom rather than waiting weeks for the model they want to arrive. In many ways the marketing of human powered vehicles should be under taken in the same way as that of bicycles. Emphasis has to be put on the problems that HPV solve and the benefits they have over other forms of transport. Initially they will be a very hard product to market as they are relatively new and unusual. To most people this is a very good quality to have in a product but quite a lot of people feel awkward using something unusual. This is especially true of the Irish and English, however less true of the Europeans. The Europeans have already showed this by their initial acceptance of human powered vehicles. The Twike has been quite popular in Switzerland (plate 22).

The designer's role in the popularisation of human powered vehicles will have a lot to do with the aesthetics of them. Packaging has always been an essential element of selling products. New products are very hard to sell

Plate 22: The Swiss designed Twike, 1990.
Popular Swiss HPV.

without making them look inviting. The microwave oven, a totally new technology, was styled like a television so customers would identify with it. This is different with human powered vehicles as bicycles already exist and define what human powered transport means to people. To date the main successes in the human powered vehicle market has been recumbent bicycles. This is due to the fact that they look like bicycle with a different seating position. The wheels and component are usually the same as can be found on bicycles. These are the designs which are selling at present. However this format does not always provide the best possible solution. Designers now have to look further than this method in order to realise the full potential of human powered vehicles. They must combine the best features to produce a machine which people will want to buy. Styling will be very important as it is in the car industry, as people will only buy thing that they like, while assuming it will perform the function for which it was intended. People buy cars because they think their choice of car reflects their aspirations and makes a statement about themselves. An environmentally conscious person might buy a green electric car, while a wealthy person might buy a BMW or Mercedes. This will also be true for human powered vehicles. People seeking good practical no-nonsense machines will want a HPV which reflects this. Others will want a more stylish option. It is the responsibility of designers to cater for all the potential markets.

The designer must be careful that in an effort to sell the product he must realise what the product represents and to reflect this in the design.. In the case of human powered vehicle they represent clean, pollution free

transport. It is important to respect this when choosing the materials and processes which are used in the manufacture. It is impossible to mass produce any product without any damage to the environment as power has to be generated in large quantities and raw materials must be acquired. However efforts can certainly be made to reduce the damage that is done by carefully choosing the materials which are used and by using more recycled material. The responsibility to the environment is an important issue for all designers today. We live in a world which is gradually being destroyed by products of man. Designers have to do all that is possible to ensure that new product do little to add to the problem. This can be difficult as the designer operates within a market-orientated profit-driven system in which a deviation from these values is difficult to achieve.

As well as the responsibility to the environment the designer also has a responsibility to the customer. The most important person in the design equation is the user of the product. The future human powered vehicle should approach and solve all the functional problems with current HPVs such as bicycles. These problems are some of the reasons why more people are not using human powered vehicles today. The problem of weather protection is very important, especially in wet and cold countries, but has never been successfully solved. Luggage space is also important as it is difficult to carry a lot of shopping, or any bulky loads, on a bicycle at present. New and more efficient use of human output must applied to designs in order to reduce the effort which is required from the rider. A lot of the solutions to these problems exist already but have not been

successfully applied due to the unsuitability of bicycles. There also exists a variety of materials available to the designer with which he can make human powered vehicles lighter and stronger along with the ability to efficiently produce them. All the tools and raw materials are available to the designer. With them it is possible to create the perfect solution to all the problems with human powered transport as it exists. If the public can be convinced of the benefits of this solution then human powered vehicles will succeed.

As with all forms of design the designer must reflect something of the spirit of the time. This includes applying new materials and processes in the design of products. The human powered vehicle industry has always been ready to experiment with new materials, usually with great success. However their has been little change to the face of human powered transport. The bicycle has always been the only commercial form of HPV. It is time that the fundamental problems were solved and the forms diversified. Designers should not be afraid to create something radically different, as it is only through innovation that progress can be achieved.

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