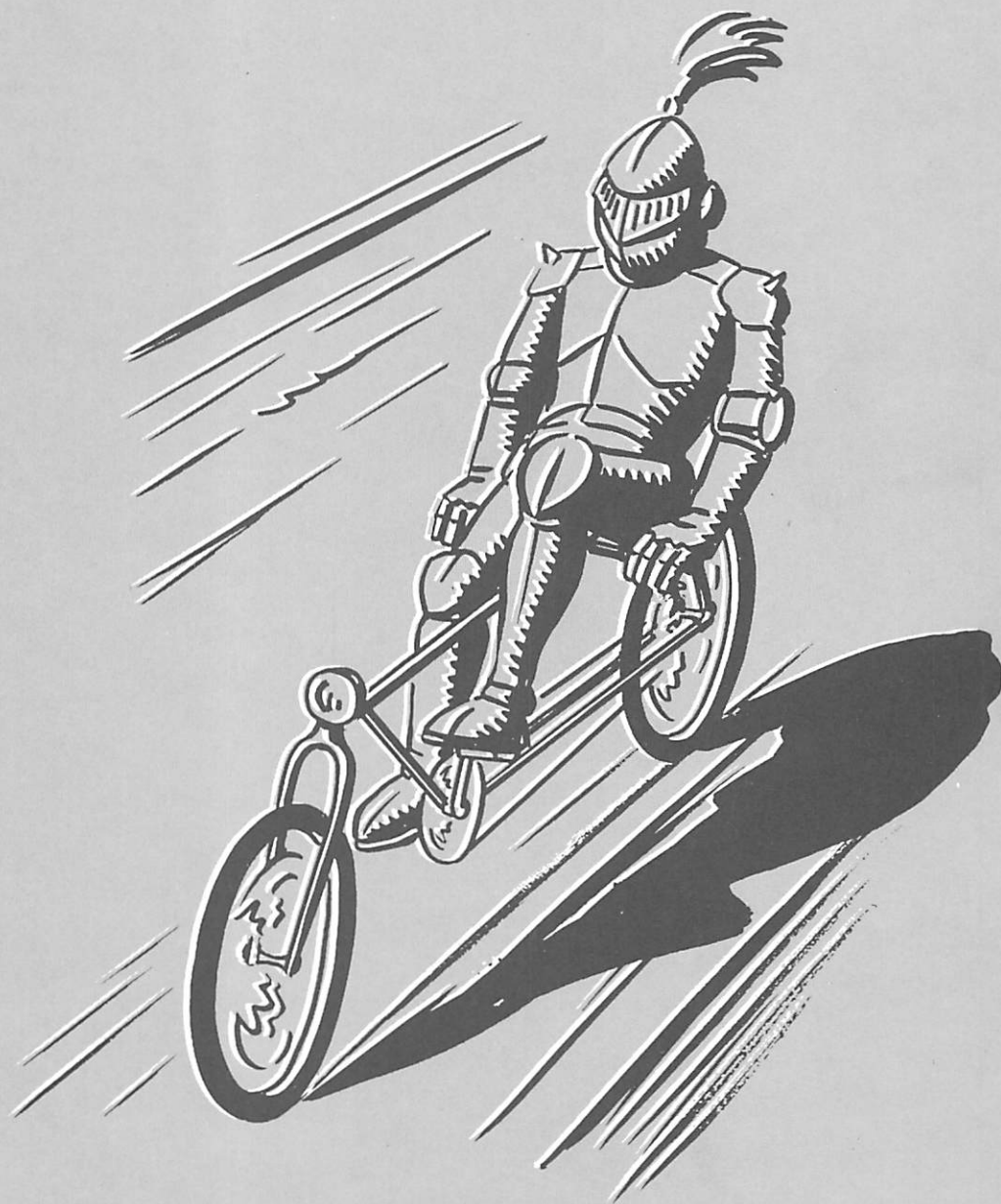


PROCEEDINGS OF THE
SECOND EUROPEAN SEMINAR ON VELOMOBILES / HPV
LAUPEN CASTLE, SWITZERLAND, AUGUST 25, 1994

SAFETY AND DESIGN



IS SAFETY JUST ARMOUR? – REAL KNIGHTS ALWAYS MOVE IN STYLE!

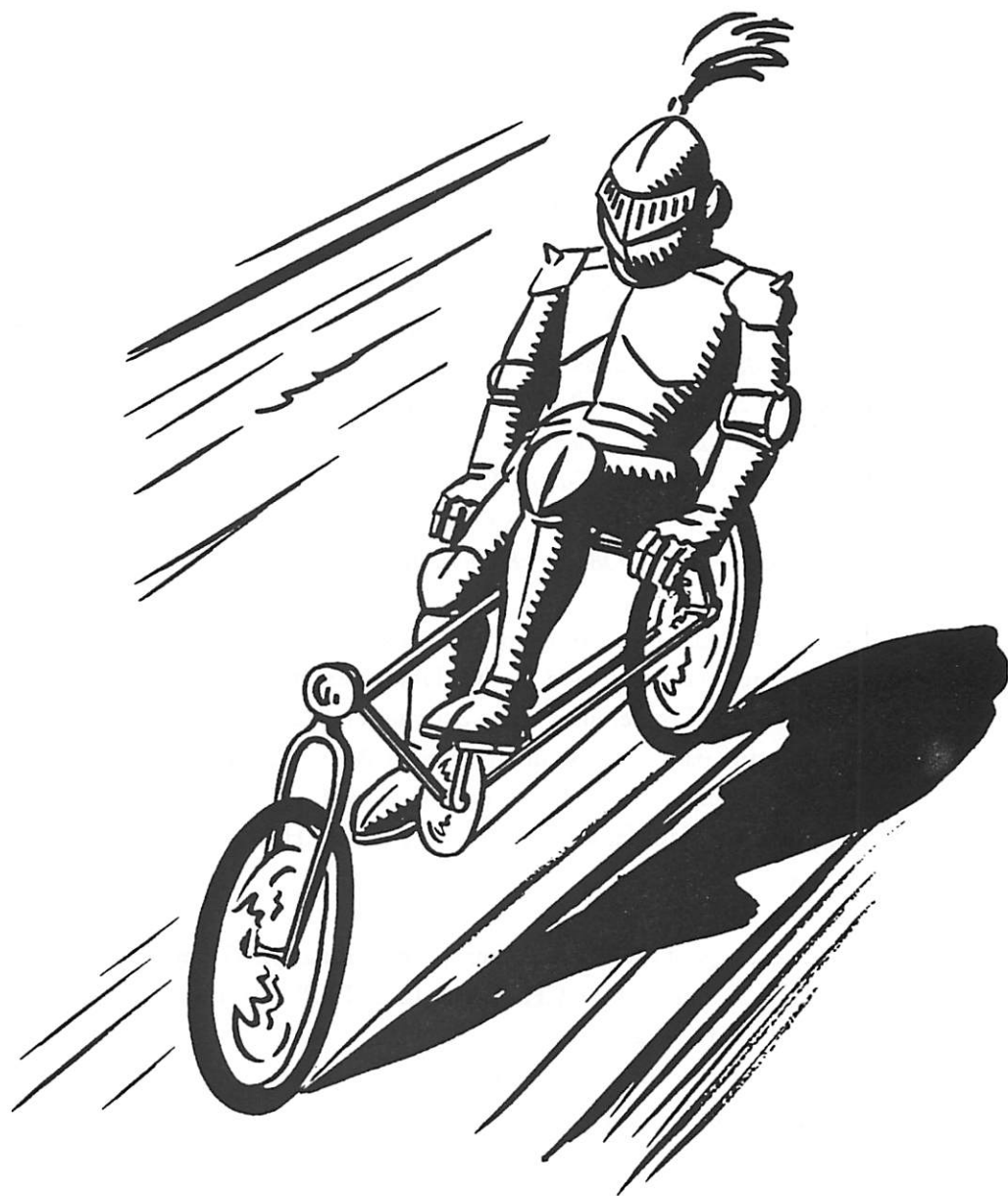
PUBLISHED BY FUTURE BIKE SWITZERLAND (IHPVA SECTION)



future bike.ch

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The Second European Seminar on Velomobiles (European expression for Human Powered Vehicles HPV) took place August 25, 1994 on Laupen castle, near Bern, Switzerland, and preceded the European HPV Championships 1994, August 26 to 28, also at Laupen.

The main subject was "Safety and Design" of velomobiles because safety and design of human powered vehicles are subjects which have so far rather been neglected even though these are presumed to be the key factors for a broader acceptance.

The seminar was organized by a committee consisting of members of Future Bike CH, the Swiss section of the International Human Powered Vehicle Association IHPVA, P.O. Box 51255, Indianapolis, IN 46251-0255, USA

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Carl Georg Rasmussen, organizer of the "First European Seminar on Velomobile Design", was responsible to send the "Call for Papers" for the second seminar to the participants of the first seminar. Theo Schmidt and Andreas Fuchs mainly organized the scientific part of the seminar, whereas Peter Zeller produced the "Call for Papers" and the proceedings. Paul Rudin took over the job to run the logistics at Laupen castle. Jürg Hölzle, secretary of Future Bike CH, also helped with the secretarial work.

These proceedings of the "Second European Seminar on Velomobiles" are published by Future Bike CH, Switzerland (IHPVA section).

For availability please contact:

Jürg Hölzle, Secretary of Future Bike CH

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The Second European Seminar on Velomobiles “Safety and Design”

This seminar is the second of hopefully more to come in conjunction with future European HPV Championships. At the “First European Seminar on Velomobile Design” held on July 8th, 1993 at the Technical University of Denmark, the variety of subjects was broad. We hoped that the focus on “safety and design” during this second seminar would stimulate the development and marketing of really sound human powered vehicles throughout Europe. Even though more papers were submitted now than for last year’s seminar, our hope was not fulfilled: this years programme has also turned out quite general, with the intended subjects not covered in any great depth. This is most probably due to lack of (university, engineering and design schools) research groups working in the field of velomobiles and due to the fact that today’s velomobile producers are very small firms and can not afford design centers and rigorous safety tests of their vehicles as can the automobile industry. Even in Switzerland without such an industry and with a government policy committed to energy saving and emission reduction, vehicular research is mainly on small electric and hybrid vehicles with very few HPV projects. It appears that HPVs are not considered “real” vehicles and funding is only obtainable if a motor is added somewhere...

The “Call for Papers” was sent to numerous design and engineering schools in Switzerland and a few other European countries without any echo. Upon reading articles about design schools one gets the impression that the automobile still is the very subject studied!

This lack of a wide spectrum of professionalized research is no reason for us not to hold the “Second Seminar on Velomobiles”: It is our hope that the mere existence of a series of annual seminars about velomobiles will induce professionals and students to become involved in velomobile research. That this already may be happening is indicated by the participation of the Institut für Fahrzeugbau Wolfsburg at this seminar, whom we welcome here most cordially. A hearty vote of thanks is of course also due to all participants, be they professional institutions or individuals.

The word “European” in the name of the seminar should not mean that researchers from elsewhere be excluded. But since the European and e.g. the American hpv-scenes are slightly different – in the US the priority seems to be more on racing and less on commuting – we kept that geographic designation in this seminar’s name, even though North America is prominently represented here by the past and present editors of HPV News and with one of the most relevant papers submitted by a doyen of the HPV movement and HPV safety expert, David Gordon Wilson.

We hope very much that other European HPV associations will continue the series of “Seminars on Velomobiles” and are looking forward to attending them!

For the Seminar Committee:
Andreas Fuchs and Theo Schmidt

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Who is who in these proceedings

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Jürgen Eick

Prof. Eick is an expert in "Wärmetechnik und Energiewirtschaft" and works at the Fachhochschule Wiesbaden. He uses his Leitra velomobile daily since 1989.

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Joachim Franke

Metal work teacher at a vocational school. Different groups build single track recumbents, trailers and special tools. A rear steered tricycle is under development.

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Andreas Fuchs

Physicist, is engaged in environmental physics and is doing a study on atmospheric trace-gases at Bern University.

He is an active promotor of velomobiles and International Referee for the Future Bike Switzerland association.

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Gottfried Graupner

A keen bicyclist who has built several recumbents, a tandem and a trailer. Between 1991 and 1993 he collaborated in the Veloquent project "Fahrradverleih und Stadtentwicklung" and then joined "Ostrad", a producer of recumbents.

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Student in mechanical engineering. As an everyday biker and member of the ADFC (Allgemeiner Deutscher Fahrrad-Club) he was motivated to develop a concept of a velomobile.

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Jim Kor

Mechanical engineer who runs his own design company in Canada, specializing in agricultural machinery. He was an editor for HPV News and here presented a five-year plan to get rid of his car. For the last few years Jim Kor has been working on the Skyway and Solos systems of personal/public transit, which are presented here.

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Theodor Schmidt

BSc, runs his own R&D office in Switzerland, specialising in energy efficiency applications. He has been involved with HPVs since 1980 with a major interest in lightweight and semi-amphibious water craft using efficient propellers and since 1985 also works on electric hybrid vehicles. Responsible for a safety study of electric vehicles and for choosing the subject for this year's velomobile seminar. Theo Schmidt is on the board of Future Bike, IHPVA representative for hybrid power, and (rather inactive) associate editor of Human Power. He would thus welcome articles, comments, and replies for possible publication.

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Jürgen Schnieders

Physicist, who did bicycle research at the University of Oldenburg. He chose a theoretical approach to find out whether rear steering was feasible for recumbents.

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Felix Walz

Prof. Walz works at the Institute for Legal Medicine of Zürich University and sees every day the fatal results of our transport system. Motivated by this, he has been researching traffic safety for over ten years, studying in particular automobile-pedestrian and automobile-cyclist collisions with recommendations on automobile bonnet shapes for minimal injuries. More recently, Felix Walz has formed a group to study the safety of lightweight vehicles e.g. small electric cars with quite astonishing results up to now. He is one of the few people in a position of authority to give proper regard to unprotected road users.

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David Gordon Wilson

Prof. Wilson has been teaching engineering and turbomachinery design at MIT and has been supervising research in design and in power and propulsion projects. In 1967 he offered a prize for developments in human powered transportation. Resulting was "Bicycling Science", co-authored by Frank Whitt, and a series of recumbent bicycles. He is a former president of the IHPVA and editor of Human Power.

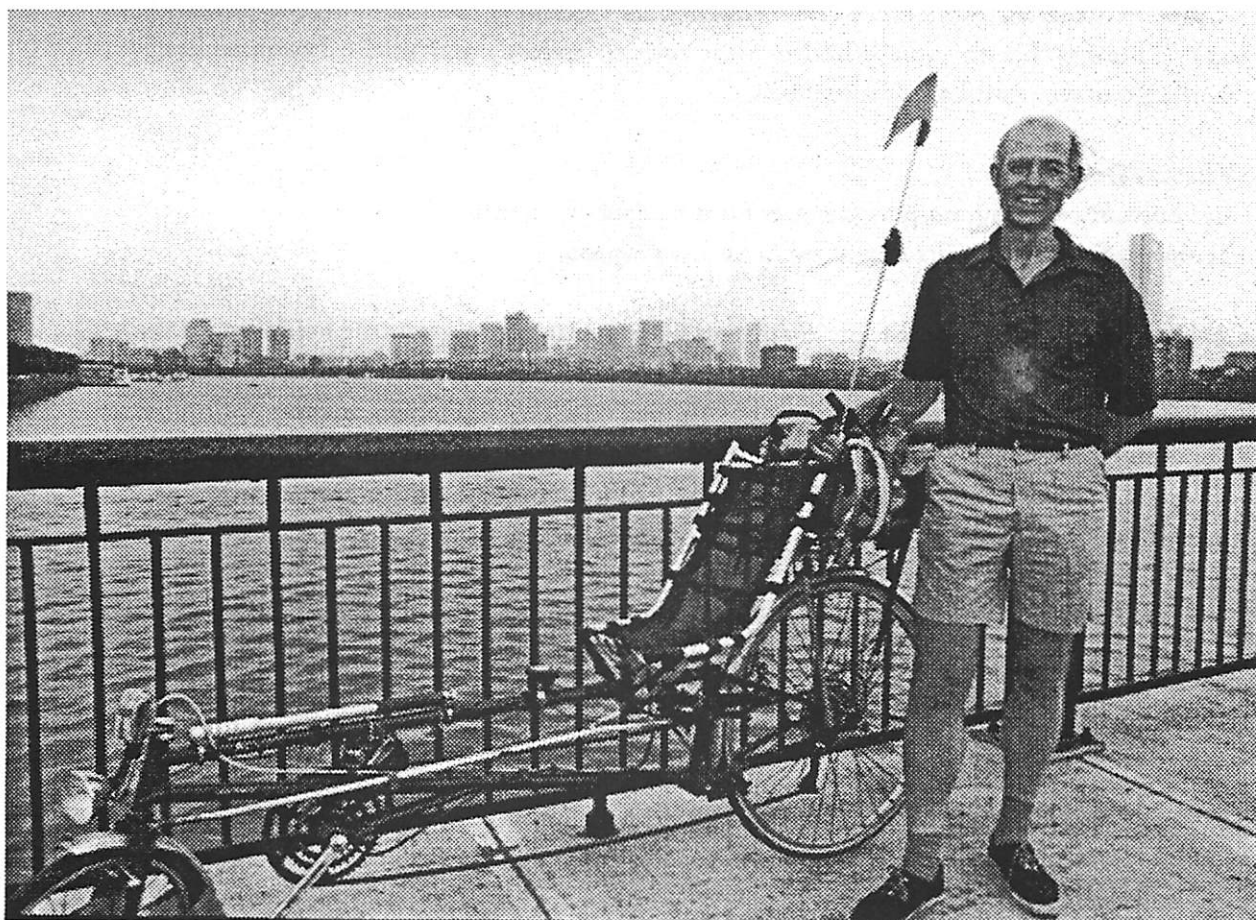
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David Gordon Wilson with his Avatar 2000

Abstracts in the complementary language

Zusammenfassungen

(in alphabetical order of the authors' names; translated by Andreas Fuchs and Theodor Schmidt)

Leonard M. Brunkalla

Sicherheit ... Kollisionen ... und anderer Schrott

Safety ... Crashing ... and related debris

Len Brunkalla beschreibt anhand seiner Erfahrung mit verschiedenen Liegerädern sehr anschaulich die Sicherheitsproblematik aus einer persönlichen Perspektive. Er wirft die Frage nach der "besten" Konfiguration auf – ob lang, kurz oder kompakt, ob Untersitzsteuerung oder normaler Lenker, ob Zweirad oder Dreirad – ohne zu einer definitiven Schlußfolgerung zu kommen. Anhand einiger Unfallberichte werden jedoch Len's Präferenzen deutlich.

Leonard M. Brunkalla

Heisse Ideen brauchen kühle Köpfe

Hot Ideas Need Cool Heads

In diesem kurzen Artikel schreibt Len Brunkalla über einige Aspekte des Velomobil-Marketing. Die wichtigste Aussage ist wohl die, daß ein erfolgreiches Produkt *gut* sein muß, da sogar kleine Fehler und Unzulänglichkeiten vom Kunden nicht toleriert werden, und solche Unzufriedenheit viel schneller verbreitet wird als Zufriedenheit.

Vytautas Dovydenas

Der Entwurf eines Biotransport-Gesetzes für die Republik Litauen

The draft of the Biotransport Law of the Lithuanian Republic

Im Vorkriegs-Litauen war der Fahrradtransport sehr populär, aber gegenwärtig herrschen im Verkehr alte Autos aus Westeuropa vor. Stau ist ein tägliches Problem. Der hochentwickelte öffentliche Transport wird immer teurer. Darum ist das Beispiel dänischer Städte sehr attraktiv. Wir möchten, daß Biotransport-Wege nicht nur Transportbedürfnisse befriedigen, sondern mehr Freizeit-Qualität aufweisen als traditionelle, dänische Fahrradwege. Die meisten sollten grüne Alleen werden, gesäumt von schönen Bauten, und nahezu ohne Autoverkehr. Dieser wird hauptsächlich über spezielle Straßen geführt.

Im angenommenen "General Law of Transport of the Lithuanian Republic" (Transportgesetz) wird der Biotransport vor dem motorisierten und dem schienengebundenen Transport erwähnt. Der in diesem Artikel präsentierte Entwurf eines Gesetzes ist auf Verlangen des Transportministeriums angefertigt worden.

Das Gesetz ist von Prof. Dr. Marija Burinskienė (Monographie über Fahrradtransport), dem Soziologen Alvydas Karalius, dem Vorsitzenden des Komitees zur Entwicklung der Gemeinde Vilnius und dem Autoren dieses Aufsatzes, sowie von Beamten des Transportministeriums entworfen worden.

Wir hoffen, daß unsere Regierung diesen Entwurf dem Parlament von Litauen vorlegen, und daß dieses ihm noch in diesem Jahr zustimmen wird.

Jürgen Eick

Ohne Auto mobil: Seit fünf Jahren Alltag und Urlaub mit dem HPV

Being mobile without a Car: five years of everyday life and holidays with the Human Powered Vehicle

Fünf Jahre Erfahrungen und ungefähr 25'000 km mit LEITRA: Als HPV-Benützer und Nicht-Autofahrer, durch Sommer und Winter, an Werktagen und in den Ferien, in der Arbeitskleidung und im schicken Anzug, im Flachland und in den Hügeln, auf Überlandstraßen und in der Stadt, sowie auf guten und schlechten Fahrradwegen. Dreiradtransport auf der Bahn und Kollision mit einem Mercedes. Sonst noch was?

Joachim Franke

HPV-Aktivitäten an einem Sekundarschulzentrum in Bremen

HPV Activities at a Secondary School Centre in Bremen, Germany

Am Schulzentrum Im Holter Feld arbeiten sogenannte STUDIO-Gruppen (Ziele: Kombination von Theorie und Praxis, Ausführen einfacher Forschungsarbeiten, Innovation etc.) an verschiedenen Themen. Eines davon ist Muskelkraft-Transport.

Begonnen wurde in den frühen 80er Jahren mit Liegeradbau, ergänzt durch Fertigung von "Flundern" (zerlegbaren Anhängern nach Dr. Falk Riess von der Fahrradforschungsgruppe der Universität Oldenburg). Neuerdings werden auch Spezialwerkzeuge für Fahrräder selbst gebaut und im Rahmen der Lehrerfortbildung wird die Produktion eines Allwetter-Velomobils vorbereitet. Geplant wird ein Dreirad mit Frontantrieb und Hecklenkung. Zur Bestimmung einer fahrtauglichen Hecklenkgeometrie wurden einfache Versuche gemacht, welche im Aufsatz beschrieben sind.

Andreas Fuchs

Der Velomobil-Sicherheits-Test an den HPV-Europameisterschaften 1994 in Laupen, Schweiz

The Velomobile-Safety-Test at the European HPV Championships 1994 at Laupen, Switzerland

Die Gründe für und die Philosophie hinter dem Velomobil-Test (und den Fahrzeugkategorien) an den HPV-Europameisterschaften 1994 werden diskutiert, und bestehende Bestimmungen und Normen bezüglich Fahrräder erwähnt.

Wichtig zu verstehen ist, dass das Ziel des Velomobil-Tests nicht darin besteht, diese einschränkend zu definieren – dies wäre entgegen der Ziele der nun weltweiten Muskelkraftfahrzeugbewegung – sondern die schlechten Sicherheitsstandards zu heben. Popularisierung von Velomobilen ist bei Unfällen während Rennen oder im Alltag unmöglich.

Die Kriterien an die Rennvelomobile und die Alltagsvelomobile werden aufgeführt und kommentiert und der Velomobil-Test wird erläutert, in der Hoffnung, andere HPV-Verbände würden ihn, entsprechend angepasst, übernehmen.

Gottfried Graupner

Different views on human beings and velomobiles

Verschiedene Sichtweisen auf Mensch und Velomobil

When considering velomobile safety it is common to regard only "outer" technical aspects and seldom to regard the human being and the interaction between rider and vehicle, even though emotions, comfort, reactions and personal attitudes are important for traffic safety. I would like to discuss three aspects associated with safety: 1) The human being as part of the environment, outer influences, ergonomics and in particular the choice of clothes. 2) Inner working and composure of human beings. Here the manner of thinking and perceiving is very important. Using body movements as examples, the concept of kinesiology and the functioning of the two brain halves together is explained. 3) Mobility. Have we ever asked the question why the longing for mobility is so great? Why acceleration, speed and stress are sought? Is it not dangerous to aim for a target destination and regard the way there as a hindrance rather than to experience and "live" the path? Who else is interested in such subjects and would like to cooperate?

Michael Gronau und Markus Hampe

Project MOVEO: a Novel Design of a Fully-Faired Recumbent Tricycle for Everyday Use

Projekt MOVEO: ein neuer Entwurf für ein alltagstaugliches, vollverkleidetes Liegedreirad

The stifling traffic situation in cities is largely caused by private cars which are not used to their full capacity. This made us think about why cars are used instead of bicycles to travel even short distances. Nearly every car driver owns a bike but most car trips are shorter than 10 kilometers. Although the bicycle is well suited for commuting, it is mostly used for sport and leisure. At the beginning we worked out some serious disadvantages of bicycles compared to cars, apart from the fact that one has to use muscular power to move. The disadvantages are mainly the absence of weather protection, the lack of passive safety, and the poor transportation capacity and lockable storage. The result of our effort is the draft of a fully-faired, three-wheeled "velomobile" with conventional pedal drive and a height-shiftable recumbent seat position. It is basically created under the main emphases of ergonomics, everyday use, safety and design. It offers many novel detail solutions that are not yet realised in similar shape in existing velomobiles. The construction of a prototype shall begin shortly.

Daniel B. Irányi

Dringend nötig – Design für HPVs

Bare Necessity – Design for HPVs

Liegeräder haben bei einem Grossteil der Bevölkerung Akzeptanzprobleme. Diese rühren (seit der Verbannung aus der "offiziellen Rennszene") vor allem von Vorurteilen im Vergleich zum Diamantrahmen her oder, bei verschalteten Velomobilen, von der optischen Rivalität zu anderen volumendefinierten Produkten wie etwa Autos, denen sie in Sachen Styling und Qualitätsvermittlung klar unterliegen. Ein Produkt kann noch so gut sein, wenn die Benutzer damit lächerlich wirken, das Gesamtprodukt emotional nicht überzeugt, wird es scheitern.

Liegeräder (auch Alltags-) müssen das Renn-Image nutzen und die technischen inneren Reize auch nach aussen hin durch Formsprache, Detail und Grafik vermitteln.

Gute Designer arbeiten nicht nur an Konzept, Ergonomie, Benutzerbedürfnis und Styling, sie sind auch in engem Kontakt mit dem/der Ingenieur/-se, um die Herstellbarkeit zu prüfen und Herstellungskosten zu senken.

Jim Kor

Solos – ein Transportsystem auf Schienen

Solos Personal Transit – a transportation system on tracks

Eine kanadische Firma schlägt eine völlig neue Richtung ein: Ultraleichte Fahrzeuge (< 100 kg) für 1–2 Personen fahren auf Schienen und teilweise in verglasten Röhren. Der Antrieb ist elektrisch, mit Muskelkraft oder mit beidem. Die Energiezufuhr läuft über Stromabnehmer. Das Ganze ist als öffentliches Verkehrssystem mit Zubringerfunktion gedacht. Gegenwärtig wird eine erste Versuchsanlage in Winnipeg geplant.

Carl Georg Rasmussen

Charakteristika von Verschaltungen für Alltagsvelomobile

Characteristics of a Practical Velomobile Fairing

Bei Rennfahrzeugen sind geringer Luftwiderstand und geringes Gewicht die zu optimieren- den Größen an Verschaltungen. Alltagstaugliche Verschaltungen hingegen müssen zusätzliche Bedingungen erfüllen: Fahren in der Stadt, Pendeln und Tourenfahren muß das ganze Jahr über, Tag und Nacht, möglich sein.

Dazu kommt, daß Alltagsvelomobile nicht vor allem von jungen Sportlerinnen und Sportlern benutzt werden, sondern von Radfahrern, die vollen Wetterschutz, erhöhten Komfort und genügend Nutzlastkapazität wollen.

Dieser Aufsatz zählt die wichtigsten Kriterien auf, welche eine alltagstaugliche Verschaltung erfüllen muß, und illustriert, wie sie im LEITRA-Velomobil implementiert und getestet wurden.

Gerhart Rinne und Paul Wollschläger

Entwicklung und Bau des Hochgeschwindigkeits-Velomobils MUFA II

MUFA II – Design and Construction of a High Speed Velomobile

MUFA I ist ein vierrädriges, mit einer Plane gedecktes Muskelkraftfahrzeug, welches zwei nebeneinander sitzenden Personen Platz bietet. Dieses Fahrzeug war durch Studenten der Fachhochschule Braunschweig/Wolfenbüttel seit 1984 im Rahmen von Diplomarbeiten entwickelt und gebaut worden. Wegen seines selbsttragenden Chassis aus Stahlprofilen war es zu schwer für weite Fahrten.

Seit 1991 ist ein neues Konzept MUFA II durch Studenten am Institut für Fahrzeugbau Wolfsburg (IFBW), einer Annexanstalt der Fachhochschule Braunschweig/Wolfenbüttel, ausgearbeitet worden. MUFA II ist ein vollverschaltetes, einspuriges Vehikel für große Geschwindigkeiten ($> 100 \text{ km/h}$). Dies erfordert geringes Gewicht ($< 20 \text{ kg}$) und einen c_w -Wert $< 0,1$.

MUFA II ist aus Aluminiumrohren und Kevlar-Sandwichlaminat aufgebaut, wobei CAD/CAM (Computer Aided Design / Computer Aided Manufacturing) angewendet wurde. Mit der CAD-Geometrie wurden Belastungsrechnungen mit Finite Element Programmen (FEM) ausgeführt. Ein maßstäbliches Modell (1:10) wurde auf einer CNC-Fräse gemäß 3D-CAD Oberflächen-Plot angefertigt. Mit denselben Daten bauten wir ein 1:1-Modell zur Messung des c_w -Wertes im Windkanal der Volkswagen AG.

Die laminierte Verschalung stellte FES (Institut für Forschung und Entwicklung von Sportgeräten e.V.) in Berlin her. Die Negativformen wurden mit Hilfe von CAD-Daten des IFBW durch die Prototypenwerkstätte der Volkswagen AG aus Polyurethanschaum herausgefräst. Der Aluminiumrohrrahmen wurde von der Firma Müsing (welche in 1991 noch in Braunschweig beheimatet war) hergestellt.

In der Zwischenzeit haben wir Fahrversuche mit einer GFK-Version (Verschalung aus Fiberglas, laminiert in derselben Negativform) unternommen.

Das Besondere an diesem Projekt ist die Anwendung von CAD/CAM, eine gute Voraussetzung für die Massenproduktion.

W. Rohmert und Stefan Gloger

Die Zukunft von Velomobilen – Design-Konzepte zur Abdeckung individueller Bedürfnisse

The future of Velomobiles – Design-concepts for individual necessities

Die Design-Konzepte von Alltagsvelomobilen wie der LEITRA, dem ALLEWEDDER und der DESIRA-2 orientieren sich an der Idee universeller Gebrauchseigenschaft, wie sie dem Automobil eigen ist. Der größte Nachteil solcher Fahrzeugkonzepte ist der relativ hohe Preis. Beispielsweise ist der Produktionspreis von DESIRA-2 rund 6500 DM, wenn die Bedingungen eines Segelflugzeugherstellers als Rechnungsgrundlage genommen werden.

Wie wir wissen, werden die vielen Eigenschaften des Automobils nicht von allen jeden Tag genutzt. Darum ist ein möglicher Weg der, Fahrzeuge für individuelle Bedürfnisse zu entwickeln. Erreicht werden kann dieses Ziel durch "Diversifikation von Funktionen".

Vier Beispiele für die Kombination von Funktionen in Alltagsvelomobilen werden anhand von DESIRA-2, DESIRA-quattro, DESIRA-light und DESIRA-classic gegeben.

W. Rohmert und Stefan Gloger

Typische Design-Probleme bei Velomobilen – Lösungen für DESIRA-2

Typical Design-problems of Velomobiles – Solutions for the DESIRA-2

Für die typischen Design-Probleme Fahrgastraumklima, Sicht, Ein- und Aussteigen, Beladen, etc. werden die Lösungen gezeigt, welche für den DESIRA-2-Prototypen gefunden wurden. Sogar die getesteten aber verworfenen Lösungen werden beschrieben und die Gründe für die Nichtanwendung genannt.

W. Rohmert und Stefan Gloger

Beispiele für die Psychologie der Gestaltung von Velomobilen

Examples for the psychology behind the physics of Velomobiles

Für jedes Problem existieren mehrere Lösungen, aber für die gegebenen Bedingungen kann man eine optimale finden. Designer von Velomobilen nehmen meistens physikalische und technische Kriterien als Grundlage ihrer Entscheide. Anhand der Beispiele Energiespeicherung, Wetterschutz und Form der Verschalung wird gezeigt, daß in einigen Fällen nicht objektive, aber psychologische Kriterien die Akzeptanz der Lösung bestimmen. Dies beweist, daß subjektive Beurteilungsmuster potentieller Benutzer bei der Gestaltung des Fahrzeugkonzeptes in Betracht gezogen werden müssen.

W. Rohmert, Stefan Gloger, Martin Heintze

Steuerbarkeit eines Muskelkraftfahrzeuges mit spiegelsymmetrischer Vorderradgeometrie

Evaluation of the Handling Characteristics of a HPV with a mirror-symmetric Front-Wheel Geometry

In einem Experiment basierend auf der neuen, spiegelsymmetrischen Vorderradgeometrie des Versuchsfahrzeuges MULTILAB mit 19 Personen – jede testete 6 verschiedene Konfigurationen auf einer speziellen Teststrecke – wurde jeweils der Steuerkopfwinkel und die Spur variiert. Messungen physikalischer und physiologischer Größen wurden vorgenommen und subjektive Eindrücke festgehalten.

Erfahrene wie unerfahrene FahrerInnen bevorzugten dieselbe Geometrie. Mit der gefundenen Geometrie kann jede und jeder das Fahrzeug leicht fahren. Messungen des Steuerwinkels und Aufnahme des Elektromyogramms des musculus vastus medialis zeigten, daß Ganzkörperbewegungen zur Stabilisierung beitragen. Dieser Mechanismus spielt in Abhängigkeit der Eigenfrequenz der Steuerung.

Es scheint als ob generelle, quantitative Bedingungen für die Handhabbarkeit von Einspur-Muskelkraftfahrzeugen existierten.

W. Rohmert, Stefan Gloger, C. Kern

Einflüsse von Federungen bei Liegerädern

Impact of Suspensions on Recumbent Bicycles

In einem Experiment mit 9 Personen wurden 3 verschiedene Federungen auf einer Stadtstrecke untersucht. Subjektive wie auch objektive Größen wurden festgehalten.

Nicht alle FahrerInnen bevorzugten die weichste Federung. Einen Einfluß der Federung auf die Handhabbarkeit konnte nicht festgestellt werden.

Messungen der Vertikalbeschleunigung, der Herzschlagrate und des Zustandes des musculus vastus medialis zeigten, daß die physiologische Belastung durch die Federung geringer wird: Die Beschleunigungs-Amplituden sind signifikant kleiner und die Herzschlagrate ist um etwa 5 bis 10 Schläge pro Minute vermindert. Dies weist darauf hin, daß wegen Vibrationen ein Leistungsverlust auftritt.

Theodor Schmidt

Was bedeutet Velomobil-Sicherheit?

What is HPV Safety?

Die Verkehrssicherheit kann für Fahrer, für Fahrzeugbenutzer, für Drittpersonen oder für alle zusammen definiert werden und zwar für Fahrabschnitte, für gesamte Fahrten, pro Streckeneinheit, pro Zeiteinheit oder pro Lebenszeit. Bei diesen verschiedenen Betrachtungsweisen entstehen ganz unterschiedliche Werte. Aus der Windschutzscheibenoptik betrachtet sind Velomobile fahrende Särge, betrachtet man die Verkehrssicherheit für alle, gehören Velomobile wohl zu den sichersten Fahrzeugen, in den meisten Fällen besser als konventionelle Fahrräder. Die Diskrepanz zwischen der Objektivität und subjektivem Empfinden ist eines der Hindernisse für die Verbreitung von Velomobilen und Leichtfahrzeugen. Es sind verschiedene Irrmeinungen entstanden, die von sehr vielen Leuten geglaubt werden, und auch manche Erbauer von Velomobilen tragen der psychologischen Komponente wie auch der Sicherheitsproblematik zu wenig Rechnung. Der vorliegende Beitrag versucht, die verschiedenen Sicherheitsdefinitionen zu vergleichen und die Auswirkung einiger Massnahmen auf diese Definitionen zu untersuchen.

Theodor Schmidt

Die subjektive Geschwindigkeit als wichtiger Sicherheitsfaktor

Subjective Speed as a Major Safety Factor

Entgegen mancherlei Behauptung ist nicht die objektive Geschwindigkeit eines Fahrzeugs von Bedeutung, sondern viel mehr die subjektiv erlebte Geschwindigkeit bei der Verwendung desselben. Diese These und deren Auswirkung wird im vorliegenden Beitrag untersucht. Die gefahrene Geschwindigkeit ist der wichtigste einzelne Faktor, der über Leben und Tod im Strassenverkehr entscheidet. Diese auf die gegebenen Umstände konsequent anzupassen fällt den meisten Leuten aber schwer, und rein technische Massnahmen zur Geschwindigkeitsbegrenzung sind zum Scheitern verurteilt, wenn sie nicht von der Mehrheit der Bevölkerung akzeptiert werden. Ein besserer Weg zum Erlangen von angepassten Geschwindigkeiten liegt in der Vergrösserung des Verhältnisses von subjektiver zu objektiver Geschwindigkeit. Wie dies geschehen kann, wird hier angeschnitten, aber bei weitem nicht abschliessend behandelt.

Jürgen Schnieders, Thomas Senkel

Hecklenkung beim Liegerad

Recumbents with rear wheel steering

Es wird allgemein angenommen, daß Fahrräder mit Hecklenkung nicht fahrbar sind. Einige Versuche solche Räder zu bauen, schienen dieses Vorurteil zu bestätigen. Aber haben die Erbauer eine optimale Lenkgeometrie gewählt? Wir haben einige computeroptimierte Lenkgeometrien mit unserem dynamischen Fahrradmodell berechnet. Nach den Ergebnissen sollte es möglich sein, ein Liegerad mit Hecklenkung zu bauen, das gutmütige Fahreigenschaften hat. Die Vorteile gegenüber normalen Liegerädern wären der Frontantrieb mit kurzer Kette, kleine Abmessungen und geringes Gewicht. – Dies sollten genug Gründe sein, solch ein Rad zu bauen.

Felix Walz

Bicycle Accidents as seen by the Safety Researcher

Velounfälle aus der Sicht des Unfallforschers

Felix Walz is a professor for legal medicine, a foremost researcher in the field of vehicular safety, and one of the few people to correctly assess measures benefitting pedestrians and lightweight vehicles. In this short article the inaccuracy of cycling statistics is discussed and measures for improving cycling safety are given:

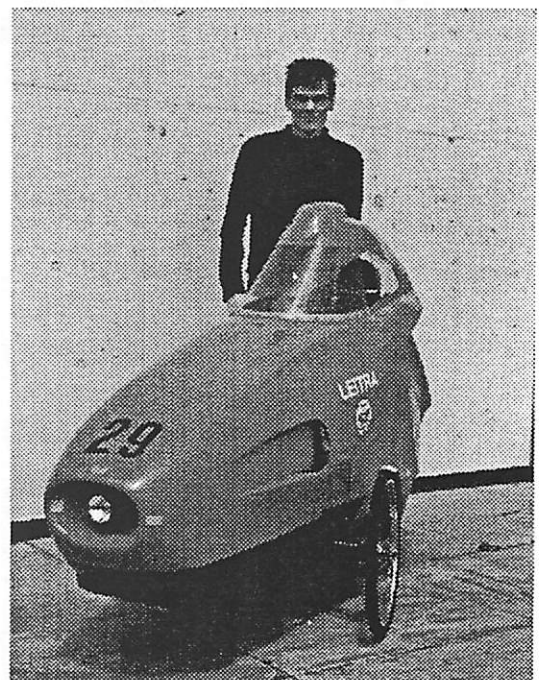
- Drivers of all vehicles should assume more responsibility.
- Wearing cycle helmets should be encouraged but not made mandatory.
- Cycle paths must be planned by cyclists and properly maintained.
- Lower speed limits (e.g. 30 km/h in town) are necessary.
- Goods vehicles should have smooth side skirts as overrun protection and improved mirrors.

David Gordon Wilson

Welche Sicherheitsvorkehrungen sind für HPVs notwendig?

What safety measures are needed for HPVs?

Obschon wir in der Muskelkraftfahrzeugbewegung glauben, "unsere" Fahrzeuge seien sicherer als traditionelle Fahrräder, können wir wegen Mangel an wissenschaftlich gesicherten Daten nichts beweisen. Sogar wenn wir Daten hätten, wie sie für Normalräder gesammelt worden waren, wären unsere Kenntnisse schlecht, denn Daten über Fahrradunfälle sind generell schlecht und Mangelware. In diesem Aufsatz werden stark verbesserte Methoden zur Sammlung von Daten über Fahrrad- und HPV-Unfälle vorgeschlagen. Ausgehend von solchen Daten könnten vernünftige Entscheide getroffen werden hinsichtlich Verbesserungen an Fahrzeugen, Gestaltung des Straßenraumes und der Verkehrspolitik der Regierung.



Andreas Fuchs with his LEITRA

SAFETY



What is HPV Safety?

Theo Schmidt

Introduction: Public Perception of HPV Safety

A frequent reaction from people seeing HPVs the first time sounds like this: "My goodness, aren't these things dreadfully unsafe?", or: "You wouldn't catch me riding in one of those coffins!". Yet David Gordon Wilson, the developer of the first modern recumbent bicycle "Avatar", was primarily motivated by the wish to improve the safety of cyclists. He saw the recumbent as a major improvement, because the rider has less falling height and will tend to hit things feet first instead of head first.

Some years ago, Clive Sinclair introduced the first mass-produced small personal human/electric powered hybrid tricycle, the C-5. This was immediately condemned by the media and the public as being a vehicle for suicide candidates, yet a study by the British Department of Transport came to the conclusion that this was actually an exceptionally safe vehicle.

As these examples show, there is a large difference between perceived danger and actual danger. What is understood by the term "safety" is very much an emotional judgement which varies from person to person. Even hard statistics are open to interpretation in countless different ways as people tend to define safety to fit their own experiences.

Many years ago, the first bicycles were banned in many places, not because anyone cared about the cyclists falling off, but because they were considered a danger to the population as a whole. At the same time, the largely horse-drawn traffic injured and killed countless people. The first automobiles in Britain had to drive at walking pace preceded by a man waving a flag and in the Swiss canton "Graubünden" automobiles were banned completely until 1925. Safety then was thus interpreted as safety for pedestrians and users of horse-drawn vehicles; cyclists and automobilists were considered a danger and a nuisance.

Today opinion has changed completely. Automobilists are still a minority within the whole population but a majority within the sector of the active population and even most of those who can't drive or don't wish to drive are often forced to be car passengers. Safety is thus mainly associated with people inside vehicles and the reaction of judging a vehicle's safety is: "How safe will I be when driving this vehicle?" rather than "What is the potential danger of this vehicle to all road users?". This personal or egotistic definition of safety has led to something like an arms race: safety-conscious people buy heavier and heavier cars, i.e. more and more armour, typified by the family Volvo with the "Baby on board!" sticker, not realising or not caring that they really represent an increased danger to the traffic mix as a whole, especially to lighter cars, pedestrians and other unprotected road users.

Users' Perception of HPV Safety

So what do we mean by velomobile safety? Do we react as above and mainly regard the safety of only the velomobile drivers themselves? Do we include the safety of pedestrians or other vehicles the velomobile could hit? Or do we regard safety as the increased lifespan of the whole population, including the effect of

exercise for the velomobilists and the cleaner air for everyone? Do we compare safety per trip, per distance, per year, or even per lifespan? Do we differentiate according to "innocently" or "willfully" acquired injuries? The possible combinations are endless and people can interpret traffic statistics to suit their own outlook.

One person will see a faired two-wheeler wobbling on the road and think the rider is crazy to take such risks, while another may regard the rider's safety as actually enhanced against that of the ordinary cyclist, because even a thin fairing gives good protection against abrasion and glancing collisions. Even experts see different things: a safety researcher whose work consists of improving the crashworthiness or the handling of high-quality, heavy cars may regard the lightly-skinned and wobbly HPV with contempt and demand that these "obviously highly dangerous" vehicles be banned because they are incompatible with REAL vehicles, while the safety researcher who is studying the effect of vehicle construction on traffic safety overall may come to the conclusion that the faired HPV is actually the safest vehicle on the road, by comparing existing statistics for bicycles, which show that the danger for the bicycle rider is of the same order as for the car driver (actually more per distance, but less per trip) but the danger from bicycles for other people is very much less than that from cars for others. He will then argue that a properly constructed faired HPV is a considerable improvement on the bicycle, because even the thin skin of a fairing is very much better protection than nothing and it also protects other people or vehicles from coming into contact with sharp metal parts. Therefore, by inductive reasoning, the well-built faired HPV must be the safest vehicle!?

So, two experts, two completely contradictory evaluations. Whom to believe? Whom do YOU believe? Unfortunately for velomobilists, the former category of researcher probably outnumbers the latter category by about a thousand to one, so it is no wonder that public and official opinion is so car-oriented.

The constructors and drivers of velomobiles however also harbour conflicting and irrational safety attitudes: the many who know exactly the great benefits of wearing a helmet yet usually don't, the hoards of cyclists with poor brakes and no lights, and the HPV constructors who bemoan the dangerous cars yet equip their vehicles with sharp hardware just waiting to rip open someone's skin.

HPV Safety in a Traffic Context

Although improving the construction of velomobiles is a clear priority, what is the overall picture, i.e. what effect will this have on traffic safety as a whole and what other measures are required to improve the safety of velomobilists? To answer this question we must look at the sum of trips undertaken in different vehicles and study their interactions.

Vehicle accident statistics are usually regarded in a "single-mode" manner, i.e. it is assumed that a given trip is travelled completely with the same vehicle. Although this does apply to some trips, the majority are actually "multi-mode", as most people will have to walk at least a short distance unless able to park exactly at their destination. Trips incorporating public transport also involve walking or cycling in any case and many commuting trips use combinations of three or more different vehicles. For example, for me to get from my home to here in Laupen, I usually cycle to the train station in Thun, take a train, and walk from Laupen station unless I have taken my bike with me. Or I can walk a short distance and take a bus to Thun

station instead. My overall safety and that of others interacting with my trip thus depend on the sum of risks associated with each part of the journey.

Someone who has studied this in some detail is N. O. Jorgensen, who is a professor at the Technical University of Denmark. He has done a model study using traffic data from the city and suburbs of Copenhagen, which can be regarded as typical for many European cities. Jorgensen divides the data up into a number of door-to-door trips and works out the distances required by different modes of transport. A few simplifying assumptions are made, e.g. complicated trips such as walk-bus-train-walk have not been treated. Two types of trips are considered: those beginning and ending in the central area (average length 4.5 km) and those beginning or ending in the suburbs (average length about 14 km). Using the accident statistics¹ for the two areas, the risks for the different trips are compared:

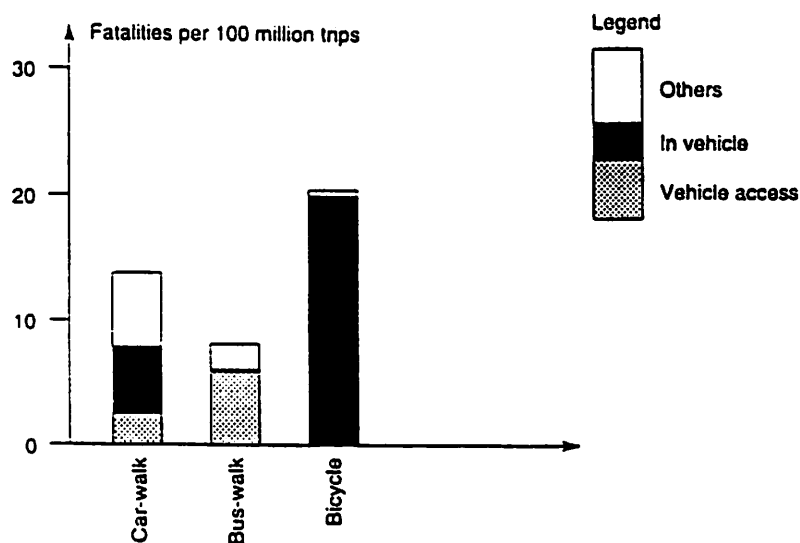


Fig. 1: Comparisons between fatality rates for different trip types in the central area of Copenhagen, from Ref. [6]

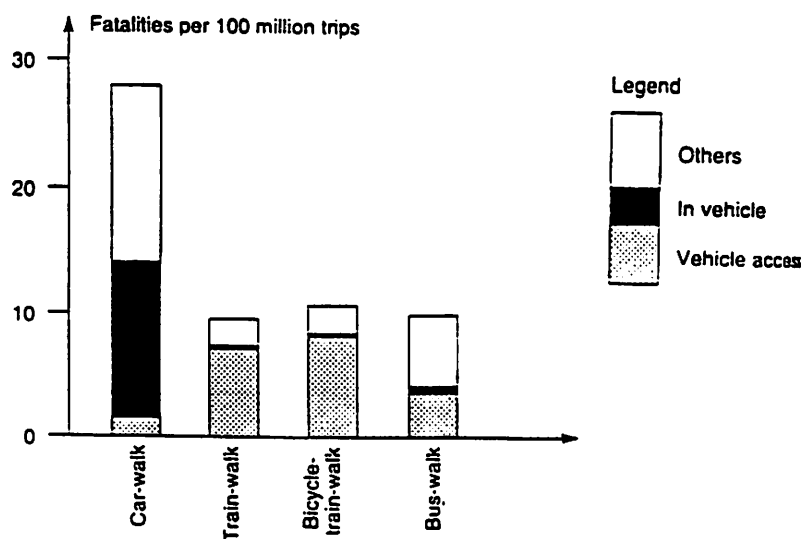


Fig. 2: Comparisons between fatality rates with at least one trip end in the suburban area of Copenhagen, from Ref. [6]

¹ Only the statistics for fatalities are considered here. These are more accurate than statistics for injuries, as pedestrians' and cyclists' injuries are largely unreported and can outnumber the reported cases by a factor of up to 20. [5]

| Travel mode | Own rate | Others' rate |
|-------------------------|----------|--------------|
| Pedestrians | | |
| Dense | 98 | 1 |
| Suburban | 20 | 0.3 |
| Cyclists | | |
| Dense | 45 | 1 |
| Suburban | 28 | 1 |
| Bus passengers | | |
| Dense | 0.5 | 5 |
| Suburban | 0.5 | 5 |
| Car occupants | | |
| Dense | 13 | 14 |
| Suburban | 10 | 11 |
| Train passengers | 0.2 | 1.6 |

Fig. 3: Death rate per billion kilometers in the Copenhagen area, from Ref. [6]

In-vehicle and outside-vehicle risks (others) are clearly distinguished, as are main vehicle risks and vehicle access risks. Note that these results apply only to the trips in the computer model and cannot be assumed to be universally valid. For example, the cycling risk given in Fig. 1 applies to trips of average 4.5 km, as does the car-walk risk. Cycle trips are however on average much shorter than car trips and if this were included in the model, the trip risk for cyclists would look much more favourable than here. Given the context, however, the following conclusions can be drawn, which are more or less expected:

- 1) Walking and cycling are rather dangerous to the walker/cyclist and top priority should be given to reducing this risk.
- 2) In spite of this, walking/cycling should be encouraged where feasible, as risk to others is extremely small.
- 3) Public transport should be improved with regard to risk for others but mainly with regard to passenger access: shorter access distances with dense networks and especial attention to the area around stations or stops.
- 4) Car trips are the most antisocial travel mode possible because of the very high risks presented to others and the considerable risks to passengers. Note that most of the "vehicle-access" risk of all vehicles is also due to the "others" risk of the cars. Therefore car driving should be made very much less dangerous (speed reductions, improved car construction, etc) and/or reduced in quantity as much as possible (car-free cities, etc). Note that both these measures are also desirable from a health point of view (pollution, noise) and an energy point of view (today's cars are extremely inefficient).²

Going back to conclusion 1 and figure 1, it is seen that small improvements in cyclists' "in-vehicle" safety will save relatively many lives. Well-known measures with which anybody can reduce personal risk considerably are wearing a helmet and taking some traffic-awareness training. Less well-known, but of greatest interest to the reader are technical measures for improving the system "bicycle", as is being done

² Much of this also applies to motorcycles and heavy goods vehicles, which are not treated in the Copenhagen study. They are very dangerous, for completely different reasons, and also very noisy and polluting.

by many HPV constructors. As the number of HPVs on the road except for bicycles is far too small to have any meaningful accident statistics, most information available on the effectiveness of a given measure are the qualified experiences and estimates of very few people. It is the purpose of this seminar to bring some of these people and their ideas together.

Improving HPV Safety

The purpose of this article is not to discuss the details of safety engineering but to give an overview. The important but often forgotten distinction between "in-vehicle" safety and "others'" safety has been described above and we can also differentiate between passive and active safety:

Passive safety has to do with measures which become effective during a collision, i.e. protection of persons in and out of the vehicle. Well known examples are the crumple zones of cars, seat belts and crash helmets. It is immediately obvious that the standard bicycle offers almost no protection at all and indeed has several sharp parts liable to injure a person. This also means that improvements are easy to implement and that many velomobiles are probably safer than bicycles, even if by coincidence and not intent:

- The recumbent position can help avoid head injuries at low speeds and also lowers falling height.
- Multi-track vehicles can prevent falls in slippery conditions.
- Fairings of any type give some protection against abrasion and more substantial fairings can give quite good protection and absorb some impact energy as well, even if not nearly to the same extent as the heavy armour found on cars.

The survival technique for HPVs can in any case not lie in head-on collision duels with heavy vehicles, but in trying to turn any collision into a glancing or oblique one, rather like in Judo. The purpose of a fairing is then to provide a smooth slippery surface for this, to absorb and distribute the collision as well as physically possible, and to protect the rider or collision partner from abrasion when sliding or from secondary collisions.

Many HPVs also contain distinctly unsafe features and it is high time to open the discussion on how to design parts in order to avoid being impaled on them or on the safety merits of the different types of steering systems.

Active safety has to do with avoiding conflicts and collisions in the first place and has top priority for the vulnerable road users. Most people are aware of the importance of good steering, handling and braking, and also good visibility. Less well-known are the psychological and some physiological mechanisms which govern the behaviour of every human being.

- Risk adaption can pervert safety engineering completely, as is the case when the perceived value of a safety measure is greater than the actual physical benefit. For example, due to irresponsible advertising, people believe that anti-blocking brakes for cars are far more effective than they actually are, so that people who buy such brakes tend to drive faster and have more accidents [4]. It can also work the other way: HPVs or even bicycles with trailers are so unusual on the road at present that many automobilists give them very wide berth when overtaking. Most risk adaption effects result in changes of speed, and speed is

the single most important factor in vehicle safety. This is treated in more detail separately in this seminar.

- Physical activity and stress produce and destroy chemicals in the body. For example, prolonged muscular activity produces endorphins which results in a feeling of well-being and can lead to addiction. More relevant to safety is adrenalin and high blood pressure brought about by fright, anger and stress. This and other chemicals usually prepare the body for fight or flight. The velomobilist can do this in a sense by pedalling furiously and "use up" these unsafety-promoting chemicals. The drivers of most motor vehicles are trapped in their boxes and condemned to muscular inactivity, thus producing more anger and stress and higher levels of these chemicals. This positive feedback can lead to unnaturally high levels which promote irrational behaviour of just about everyone in some traffic situations.

- Communication with other road users is extremely important [3]. There is more to this than just indicating turns. People are continuously communicating in countless ways and often these signals are misinterpreted, leading to dangerous situations, for example if you slow down to let someone pass and he thinks you are trying to obstruct him. In such situations a glance or a smile can make all the difference. The upright bicycle allows more accurate "body language" than almost any other vehicle and also gives superior vision and visibility. Velomobil designers should keep this in mind when designing fairings. A good view of the rider's face should be a minimum.

Overall HPV Safety

Whether the goal is to increase traffic safety for just velomobilists or for the whole population, it is necessary to replace as many of the "dangerous" trips with "safe" trips as possible. Thus it is not enough to *make* a safer HPV, it must also be used, it must be manufactured and sold in quantity, and ideally it should be so good that as many cyclists and automobilists as possible stop driving their relatively dangerous vehicles and use the safer velomobile instead.

For this goal we may have to compromise, as human beings tend to be lazy and have such strong emotions about automobiles that even sensible people have great difficulties to cut down on driving cars. Therefore it is not enough to make better HPVs likely to appeal to the cyclist, but also to make vehicles likely to appeal to the car driver. These can range from hybrid HPVs, e.g. electric bicycles, to more powerful mobiles like the TWIKE³, even to vehicles which no longer have a set of pedals but are still much better than present day cars. Amory Lovins of the Rocky Mountain Institute calls such vehicles "Supercars" and believes that they could be made vastly more efficient, lighter and safer than present vehicles [7].

Getting back to our assisted or hybrid velomobile, the purpose of adding a small motor should not be to go fast, but to make the vehicle popular even in hilly, hot and humid areas and to allow carrying a small additional amount of basic passive protection.

Whatever the type of vehicle, in order to be sold and used, our new safer mobiles have to perform well, they have to be cheap, and they have to look good. Therefore safety in this context has just as much to do with "sexy" design and successful marketing as with technical improvements, and so the second part of this seminar has to do with design.

³ The TWIKE is a two-person human/electric hybrid tricycle soon to go into limited production.

And finally, as most people are engaged in a love-affair or at least an addiction with the most dangerous form of transportation there is, and since the traffic situation continues to worsen, campaigning to reduce the quantity and to improve the quality of automobiles, motorcycles and goods vehicles is most necessary if we are to survive, literally, and this is the reason the seminar participants have been asked to come to Laupen castle without cars.

Conclusion and Summary

The interpretation of HPV safety is very dependent on one's point of view. The very same vehicle can be honestly regarded as extremely safe or as extremely dangerous, depending on the background of the beholder. Because of psychological adaptation effects, vehicles which seem safe are often dangerous and vice versa. The HPV community has so far given little thought to safety and it is mainly the simple nature of these vehicles which has prevented widespread and frequent tragedy. A small amount of effort should be able to increase the relative safety of velomobiles by a great amount. The automobile community fosters vehicles which give the users some degree of protection but are a grave danger to all others. A major contribution to HPV safety is thus improving aspects of conventional *motor vehicles*, segregating them, slowing them down, and discouraging their use by designing and marketing extremely good and cheap alternative vehicles to take their place.

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WHAT SAFETY MEASURES ARE NEEDED FOR HPVs?

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SUMMARY

While we in the human-powered-vehicle movement believe that "our" vehicles are safer than traditional bicycles, we have no scientific data to back up our beliefs. Even if we had data similar to those collected for bicycles our knowledge would be poor, because the data collected on bicycle accidents are generally poor. In this paper we propose greatly improved methods of collecting data on bicycle and HPV accidents. From these data rational decisions on improvements in vehicle and roadway design and in governmental policies could be made.

BACKGROUND

We have excellent information on what is needed to design fast human-powered vehicles because the data we collect are extremely accurate. A result of this accuracy in measurement is that our progress in increasing our record speeds and distances has been amazing. This is not true as regards the safety of HPVs. Proponents argue the merits of under-seat and above-seat steering and of short-, mid- and long-wheelbase machines, for instances, as regards safety with just anecdotes and personal preferences as references. If we knew precisely what design, manufacturing, or usage factors had good and bad effects on safety, the improvements in safety that would be introduced would rival those in top speed. While the population of HPVs is relatively small the lack of an accurate basis for safety information is not of great importance because design is still in rapid development. However, a breakthrough of HPVs, or at least of recumbent bicycles, into the popular mass market is increasingly likely. If the HPV that achieves this breakthrough has safety deficiencies that could have been easily remedied in the design stage, the cost in human suffering could be great. There could also be a backlash against the whole HPV movement.

Most present data on US accidents come from a system used by the Consumer Product Safety Commission, the National Electronic Injury Surveillance System (NEISS). Data come to the NEISS from a statistical sample of 119 emergency rooms chosen from among 5,000 such facilities in the United States. This extremely valuable system has given far better information on accidents and injuries than was ever available previously.

From the computer tabulation of the NEISS data, cases are selected for which in-depth investigations are performed. These investigations are made to determine the associations of the various environmental factors and events leading to consumer-product accidents. The NEISS data are also used to estimate national totals for various injury-related parameters such as age, sex, type of injury, etc. The NEISS data are also used to draw up the Consumer Product Hazard Index.

However, good as the NEISS system is, it has shortcomings. Some were detailed in a report prepared for the Bicycle Manufacturers Association by the Highway Safety Research Institute of the University of Michigan¹. The principal shortcoming is that, in general, accidents and injuries are merely associated with products, rather than with design aspects of products.

Even the in-depth investigations, which are based on open-ended questions, are, in many cases, not specific enough to pin down the relative importance of factors that led to the accident, and many elements of the cost of accidents are not recorded.

The data that are collected for bicycle accidents generally are therefore very good as regards deaths, fairly good as regards injuries, and poor as regards "causes". This word is put in quotations because it is extremely subjective. Here is a hypothetical but not unrealistic example.

A bicyclist is severely injured in a collision with a car at an intersection. His injuries are precisely recorded. A police report will show a diagram of the intersection and of the positions of the bicycle, the victim and the car, some boxes to be checked off if the officer detects liquor or drugs, speeding, or wrong-way driving, and space for a statement that usually includes the "probable cause" of the accident. The bicyclist is usually blamed, often because the bicyclist is immobile in hospital and the driver states that the cyclist "came out of nowhere" or "ran the lights". If a thorough study of this hypothetical accident is made, it might be found that the traffic lights were of the type that do not trigger for bicyclists, who get tired of waiting at an unchanging red light and ignore it. It may also be found that the bike was an old one with steel rims, that it had been raining, and that the brakes were consequently almost inoperative. The bicyclist was not wearing a helmet and suffered severe head injuries. He had not taken any course in traffic safety. Nor had the motorist had any concern for the rights of bicyclists included in his driving-licence examinations. One could go on thinking of the possibility that one or both of the participants had been drinking or the motorist had been changing a radio channel and so forth. The important point is that when an expert is asked to give "the cause" of the accident on a report form, the answer depends almost completely on the expert's interests. A specialist on helmets and head injuries will blame the lack of a helmet; someone knowledgeable about brakes will blame brakes that are ineffective in wet weather; and so on. "To the person with a hammer, everything looks like a nail".

Causative factors

These experts would be partly right. The factors they feel are important are "causes" of the accident, but none is the whole cause. They are all "contributory causative factors". Most accidents are the result of the simultaneous occurrence of several causative factors. If any one factor is not there, that accident either would not happen or would have a lower cost. If the bicyclist in the above scenario had been wearing a helmet there would have been a collision but a far less damaging injury. If the brakes had been of the type that work in wet weather there may have been no collision, and so on. To reduce HPV accidents it may be desirable that many safety measures are enacted, but for this particular accident to have been prevented or modified, introducing only one safety measure could have been enough. For another accident, the same safety measure might be effective, but it is also possible that another measure might be required. What should a policy-maker do? We want to save lives and reduce injuries as effectively as possible. We could easily take a lot of expensive, irritating, and inappropriate steps and not be very effective at reducing suffering.

Data not collected are lost forever

If data that would answer the policy-maker's questions are not collected close to the time of the accident, they cannot be accurately reconstructed subsequently. A large proportion of accident analysis consists of making assumptions about the contributing causes of accidents, but they are no more than assumptions. To make the right decisions we need accurate and reasonably complete data taken at the scene and after interviewing the participants. If the procedure is automated, it need not take much longer than filling out the standard report sheet. However, now that there is new technology in the form of HPVs, some of the questions should concern the influence on the cost of the accident if various broad types of HPV had been used.

The following sections describe the type of questions that should be asked at the scene, and the subsequent analysis that arrives at the rank-ordering of policy and design options.

THE PROPOSED METHOD

The proposed method is applied to individual accidents. It requires skilled investigators each preferably equipped with a hand-held data recorder that presents a sequence of questions

to the investigator, who can respond from a keyboard or a mouse. When investigating an accident, the investigator must first estimate the medical, material, lost-time, and pain & suffering costs of the accident. If there are serious injuries or deaths involved, estimates of the costs would be impossible to make soon after the accident, and pre-agreed values would be entered. The the investigator would answer the questions posed by the data recorder. Each question would be associated with a causative factor.

The investigator would estimate the percentage reduction in the overall cost of the accident if the specified causative factor were not present (which, in practice, usually means that a remedial action or situation would have been in effect). The estimates are made by questions of the following type: "Estimate Reduction In the Cost of the Accident (ERICA) if (a specified causative factor) had not been present."²

For instance, in a hypothetical bicycle accident in which the rider has been injured in the head, an ERICA question would be: "Estimate the reduction in the cost of the accident if the rider had been wearing an approved bicycling helmet."

This question presupposes a knowledge of the general performance specifications of helmets, and enough knowledge of the accident for a judgment to be made about the effectiveness of the helmet. The response might in this case be that there would a "90 percent" or even a "100 percent" reduction in total accident costs.

Possible variations in ERICA estimations

This type of estimation, of course, is subject to possible errors and variations in the judgment of investigators, who would need training and calibration. However, if some investigators estimated high, say 80% for the reduction in accident cost if a safety measure were introduced, and others estimated 60%, the data would average out. Only if there were consistent bias would the recorded data lead to slightly nonoptimum policies. I believe that errors in estimation of known factors are likely to be considerably less than guesses of unknown factors.

The analysis and the overlap problem

The investigation of a representative sample will, by definition, provide the accident analysts with enough information to estimate the reduction in the overall costs of accidents that would result from the nationwide application of a given remedial action. For this to be accurate, the "overlap problem" must be faced.

Suppose that data from several-thousand HPV accidents had shown that if a regulation that padded gloves were worn the savings in the costs of hand injuries in skidding accidents would far outweigh the calculated individual and government costs of this requirement. Suppose further that another finding was that accident costs would be greatly reduced if HPVs were required to have partial fairings. If the fairing requirement were introduced there would be little benefit in requiring that gloves be worn.

In a study of this method carried out by M.I.T. for the Consumer-Product-Safety Commission³, several methods, too specialized to describe here, were developed to handle this overlap problem within the computer program that was developed to analyze the data. The simplest is, however, easy to state: there would be some questions of the following type: "estimate the reduction of the cost of the accident if it were required that all riders wear gloves, given that another regulation required that partial fairings be used had been introduced."

The analysis and the new-technology problem

Some questions are preferably of the type that can help to predict the benefits of introducing new technology. Much can, of course, be inferred from the detailed data. The benefits of an improved helmet can be estimated from the derived costs of head injuries. However, the person(s) drawing up the question sequence should be able to dream up a few science-fiction-type

improvements that might occur years hence. Cars nowadays have air-bags, a technology hardly dreamed of only a few years ago. Suppose that riders of HPVs were equipped with "air-bag collars" that would inflate to protect the head and spine of riders when some "smart" sensors detected an accident situation. A question on the estimated effectiveness of such a future device would give better data on whether it would be worthwhile trying to develop one than would data simply inferred from existing head- and spine-injury data.

These questions will be particularly challenging when new forms of HPV are considered. It will be necessary to estimate costs of introduction of new technology quite separately from the estimates of the costs of accidents and of the percentage of the costs that are saved. Some new technology may increase other accidents that the accident investigator cannot possibly consider. Multi-track (three- and four-wheeled vehicles) will be safer than single-track bicycle-type vehicles in many circumstances, but in others may suffer accidents that the single-track presumably narrower vehicles could avoid. This problem is, therefore, out of the province of the accident investigator but is of great importance to the policy maker who uses the new accident data. Accurate prediction of all introduction costs, public and private, and including those for additional accidents, must be made.

THE RESULTS OF A TRIAL OF THE NEW SYSTEM

The Consumer-Product-Safety Commission awarded a small research grant to M.I.T. to carry out a test of the new system when applied to accidents involving bicycles, power lawn-mowers and architectural glass such as doors and walls. We will report some of the results of the bicycle-accident part of the study (see reference 3). We recruited a dozen investigators, mainly students, only one of which had any previous experience with accident investigation. We gave them two or three hours of training on hypothetical accidents. Their subsequent performance was far more consistent than we had expected. We advertised for people who had had recent bicycle accidents involving non-trivial injuries to volunteer to be investigated. This group of volunteers was not, therefore, a representative sample, and no conclusions can be drawn from the trial analysis of data. Nevertheless, we present an analysis as if the sample were statistically relevant.

The costs of applying the remedies were estimated, principally by the author, and are also not representative. The benefits in the form of reduction in accident costs were estimated by the investigators. The results were benefit-cost ratios for the alternative policies (the elimination of causative factors). These then could be ranked by benefit-cost ratio.

Discussion of results.

Table 1 shows the results of a trial on a random collection of accidents involving injuries to riders of regular bicycles. Most of the causative factors listed are the absence of desirable equipment, such as helmets or pads. In the sample there were many accidents resulting from poorly functioning brakes, and many injuries from impact with handlebar stems, pedals, fenders (mudguards) and stays, crossbars, and from getting bare feet caught in the chain-sprocket engagement. The HPV movement was in its infancy, and we asked no questions on the potential reduction in accident costs should the victims have been riding recumbent bicycles, for instance. The cost of the remedies was increased from that given in the original study to allow approximately for inflation. Two columns giving the benefit-cost ratios are shown, one including just the monetary benefits (mostly the reduction in hospital costs) and the other including allowances for pain and suffering.

Improvements in brake design or maintenance and protection from contact with injury-causing components and projections had the largest monetary benefit-cost ratios, and presumably (i.e. if the accident sample were fully representative) could justifiably be regulated. Helmets were only just favorable on monetary cost alone. A benefit-cost ratio of 1.57 may seem

to be very favorable, but a decision-maker will have an array of calls on her/his treasury, all having ratios well above unity. When pain and suffering were included, a requirement that helmets be worn seemed much more justifiable - but was the discomfort of those many who don't like helmets priced correctly? It is interesting that two measures that are either required or highly recommended in most jurisdictions - a bell or horn and an annual safety inspection - did not seem worthwhile even on the "pain-and-suffering" benefit-cost ratio.

CONCLUSIONS AND RECOMMENDATIONS

The author has made the case that if good decisions are to be made on HPV safety, they must be based on accurate data, and these must be collected as close to the time and place of accidents as possible. A methodology has been outlined (the full description is in the references) by which data can be collected. The author hopes that a group will be sufficiently convinced to give the system a trial. He would like to help.

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TABLE 1
RESULTS OF THE BENEFIT-COST ANALYSIS - BICYCLES

| CAUSATIVE FACTOR Description | REMEDY Cost per Unit ** | LIFESPAN Lifespan of Remedy, Years** | BENEFIT- COST RATIO Monetary only | BENEFIT- COST RATIO including non- monetary benefits | BASIS OF CALCULATION |
|---|--|--|--|--|---|
| Not wearing helmet | \$15/helmet | 5 | 1.57 | 15.44 | 99% of all bicycles* (one helmet per bicycle) |
| Light padding not used between knee and ankle | \$5.00/rider | 2 | 0.57 | 1.32 | 100% of all bicycles |
| Unsatisfactory performance of brakes | \$3.00/bicycle (for brake modification) | 10 | 3.99 | 24.22 | 100% of all new bicycles |
| Lack of two brakes (one a front hand brake) | \$5.00/bicycle (avg.) | 10 | 1.45 | 8.56 | 52% of all new bicycles |
| Lack of fully functioning front light | \$10/bicycle | 2 | 1.02 | 5.3 | 20% of all bicycles (since less than 5% of all bicycle riding is done at night, a great majority of bicycles are never used at night) |
| Lack of protective padding on elbows | \$4.50/rider | 2 | 0.56 | 3.8 | 100% of all bicycles (1 pair of pads per bicycle) |
| Lack of bright reflecting stripes on rider's clothing | \$3.00/rider | 2 | 0.77 | 3.44 | 90% of all bicycles (stripes are useful during the day because of the attention their bright colors attract) |
| Lack of padding on bicycle | \$3.00/bicycle | 10 | 0.95 | 85.47 | 100% of all bicycles (1 set of padding per bicycle) |
| Lack of reflecting flag on bicycle | \$4.00/bicycle | 5 | 0.54 | 2.24 | 95% of all bicycles |
| Bicycle not in good condition | \$6.00/bicycle (for annual inspection) | 5 | 0.14 | 0.93 | 100% of all bicycles |
| Sharp edges on bicycle | \$1.50/bicycle | 10 | 3.32 | 384.32 | 100% of all bicycles |
| Lack of fully functioning horn | \$6/bicycle | 5 | 0.27 | 0.38 | 90% of all bicycles |
| Lack of spoke guards | \$8/bicycle | 10 | 0.33 | 6.4 | 83% of all bicycles |

*Note: All bicycles = 55 million bicycles; annual sales = 9 million; all riders = 80 million

**MIT estimates (costs are revised since original estimates to allow for inflation).

Velounfälle aus Sicht des Unfallforschers

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Problem der Velounfälle massiv unterschätzt

Im Durchschnitt der letzten zehn Jahre wurden von der Stadtpolizei Zürich jährlich 225 verletzte Velofahrer registriert. Die Velofahrer liegen zahlenmässig zwischen den Mofalkern mit durchschnittlich 125 Verletzten und den Fussgängern mit durchschnittlich 400 Verletzten. Die Todesfälle liegen bei Velofahrern bei 2 bis 5 pro Jahr. Von ausländischen Studien weiss man - und vorläufige Abklärungen in der Schweiz bestätigen deren Aussagen -, dass der Polizei weniger als die Hälfte aller verletzten Velofahrer gemeldet werden. Das ist natürlich nicht der Fehler der Polizei; sie kann ja nur die ihr gemeldeten Unfälle abklären. Insbesondere bei Alleinunfällen wird die Polizei in höchstens 10% der Fälle beigezogen, auch wenn relativ schwere Verletzungen aufgetreten sind. Bei verletzten Autoinsassen hingegen liegt die Erfassungsquote bei fast 90%. Will man nun einen einigermaßen richtigen Vergleich der Verletzungszahlen anstellen, so muss man die Zahlen der Polizei bei den verletzten Autoinsassen um ca. 10% nach oben korrigieren, während bei den verletzten Velofahrern ungefähr der dreifache Wert eingesetzt werden muss. Die korrigierten Zahlen der im Jahresdurchschnitt Verletzten lauten für die Stadt Zürich also: Autoinsassen ca. 600, Velofahrer ca. 650. Damit erlangt das "Problem Velounfall" innerorts in Tat und Wahrheit eine grössere Bedeutung als das "Problem Autounfall", während nach den bisherigen Zahlen der Polizei der Autounfall wesentlich mehr Opfer zu fordern schien.

Bezüglich Kopfverletzungen gelten bei den mässigen und schweren Fällen ähnliche Verhältnisse wie bei den Mofalkern. Die realisierbaren Geschwindigkeiten können beim Velo sogar höher als beim Mofa sein und sind sicher nicht als Argument für die "Ungefährlichkeit" des Velofahrens geeignet.

Helm für Velofahrer?

Wenn auch Massnahmen, die es gar nicht zu einer Kollision kommen lassen, im Vordergrund stehen (z.B. Tempobegrenzungen, aufmerksames Fahren (Velo- und Auto-!), sichere Velowege), so ist auf Seite der passiven Sicherheit auch bei Velofahrern in erster Linie der Schutzhelm zu nennen, allerdings nicht im Sinne einer Tragpflicht, sondern als sinnvoller Selbstschutz aus Einsicht in die hohe Gefährlichkeit.

Die genauen Kenntnisse über die Lokalisation der Kopfverletzungen führten zu verbesserten Velohelmen, die an die speziellen Bedürfnisse der Velofahrer angepasst sind. (Gewicht maximal 500 Gramm, Schutz auch der Gesichtsregion,

Aussparung oder Ventilationsöffnungen über dem Scheitel, somit kein starker Wärmestau). Da insbesondere die Altersgruppe der 10-14jährigen betroffen ist, sollten auch entsprechende Helmgrössen angeboten werden.

Seit längerer Zeit setzen sich Kreise aus der Unfallmedizin für Velohelme ein. Leider haben die entsprechenden publizierten Forschungsergebnisse in der Schweiz bei den verantwortlichen Behörden und bei den Benützern erst stark verspätet genügend Beachtung gefunden. Erfreulich sind die Helm-Aktionen der SUVA, die seit 1988 um 30 Franken verbilligte Velohelme ermöglichen.

Wenn man das Tragen eines Helmes bei Motorradlenkern als selbstverständlich und bei Mofalenkern als sinnvoll ansieht, sollte man bedenken, dass Velofahrer in vergleichbarer Weise im Kopfbereich gefährdet sind und sich das Tragen eines speziellen Velohelmes ebenso (auf freiwilliger Basis) aufdrängt. Eine Tragpflicht steht nicht zur Diskussion. Die in Australien und in den USA gesammelten Erfahrungen mit Velohelmen neuerer Konstruktion sind sehr positiv. Es wird aber häufig vergessen, dass auch die strengsten Helmtests mit Aufprallgeschwindigkeiten unter 30 km/h gefahren werden. In erster Linie ist also auch für Helmträger die Aufprallgeschwindigkeit bei einer möglichen Kollision durch entsprechende Fahrweise so niedrig wie möglich zu halten.

Die Verletzungen

Die häufigste Todesursache bei Velofahrern ist wie bei motorisierten Zweiradfahrern die Kopfverletzung. Auch wenn eine Kopfverletzung nicht zum Tod führt, so kann sie doch häufig schwere Hirnschädigungen und damit langdauernde Invalidität zur Folge haben.

Im Vordergrund stehen bei den Kopfverletzungen - in aufsteigendem Schweregrad geordnet: Gesichtswunden, Gesichtsschädelbrüche (z.B. Nase, Kiefer), Hirnerschütterungen, Schädeldach- und Schädelbasisbrüche, die sehr schwierig zu behandelnden Hirnschwellungen, lokale oder diffuse Hirngewebsschädigungen und Risse von Blutgefässen mit entsprechenden Hirnblutungen. Je nach Lokalisation der Hirnschädigung können die Steuerzentren für die entsprechenden Funktionen ausfallen. Solche Lebensfunktionen sind z.B. Bewegung der verschiedenen Körperteile, Sinnesfunktionen wie Sehen, Hören etc., Gedächtnis, Sprache, Persönlichkeitsstruktur, Atmung etc. Bei Velokollisionen liegt der Ort des Hauptanpralles am Kopf meistens seitlich rechts oder vorne. Die obere Kopfhälfte (Scheitel) ist wesentlich seltener betroffen.

Schädelfrakturen sind ab Aufprallgeschwindigkeiten gegen eine harte Struktur ab ca. 20 km/h die Regel. Dies ist ungefähr die Aufprallgeschwindigkeit in senkrechter Richtung bei einem Sturz vom Velo, unabhängig von der Fahrgeschwindigkeit. Diese senkrechten Geschwindigkeit (Fallhöhe) beträgt zwischen 20 und 25

km/h. Die (horizontale) Fahr- bzw. Sturzgeschwindigkeit hingegen bestimmt die Anprallgeschwindigkeit gegen senkrecht stehende Strukturen wie Autos, Mauern etc. Aus dieser Schilderung wird klar, dass ohne Anprall gegen eine senkrechte Struktur auch Stürze mit relativ hohen Geschwindigkeiten ohne bedeutende Kopfverletzungen ablaufen können, selbst wenn kein Helm getragen wird, also beim Sturz auf die ebene Strasse.

Es darf aber nicht vergessen werden, dass Beinverletzungen durch Anprall an ein Auto oder beim Sturz auf die Strasse die zweithäufigste Verletzungsart darstellen; sie sind bezüglich der Langzeitschäden von besonderer Bedeutung. Beim Sturz können auch Brüche von Handgelenk oder Schlüsselbein entstehen.

"Geringe" Eigengeschwindigkeit schützt nicht von alleine, da die Geschwindigkeit des anderen Fahrzeuges die Unfallschwere bestimmt.

Die Kosten eines seitlichen Unterfahrschutzes für Lastwagen von ca. 2000.- oder eines speziellen Rückspiegels, der den toten Winkel vermeidet, sind gegenüber dem Preis für einen ganzen Lastwagen zu vernachlässigen. Erst zögernd rüsten aber die Hersteller ihre Fahrzeuge damit aus. Wiederum wird das Ziel erst mit staatlichen Vorschriften zu erreichen sein, dass die Zweiradfahrer nicht mehr buchstäblich "unter die Räder" geraten". Ab 1. Oktober 1994 tritt in der Schweiz die EU-Vorschrift des seitlichen Unterfahrschutzes in Kraft, der allerdings leider nur Rohre vorsieht, in denen sich ein Velofahrer verfangen kann, anstatt der von der Unfallforschung geforderten glatten Vollschatz (wie beim Postauto, Car.)

Schlussfolgerungen

Durch richtiges persönliches Verhalten jedes Einzelnen sind aus unfallmedizinischer Sicht noch wesentliche Verringerung der Unfallopfer möglich. Dazu gehören:

- **gegenseitige Rücksichtnahme.** Der Lastwagen- bzw. Autofahrer muss sein massenbedingt grosses Gefährdungspotential rücksichtsvoll einsetzen. Keinesfalls darf sich aber der Velofahrer auf die richtige Reaktion der anderen verlassen oder gar gefährliche Situationen durch Nichteinhalten der Verkehrsregeln provozieren. Insbesondere jüngere Velofahrer und solche, die sich als Velofahrer für "bessere" Verkehrsteilnehmer halten, weil sie keine Luftverschmutzung und Lärm verursachen, sollten ihre teilweise aggressive Fahrweise überdenken. Dies gilt auch im Hinblick auf ihr Verhalten gegenüber Fussgängern auf dem Trottoir, auf das die Velofahrer aus Angst vor den Autos ausweichen.

- **Freiwilliges Tragen eines speziellen Helmes für Velofahrer.** Die Ablehnung des Helmtragens durch besonders engagierte Velofahrer, die anstelle davon Massnahmen nur für die Autofahrer und bei der Radwegführung fordern, sind psychologisch zwar verständlich; im Hinblick auf die schweren Folgen von Kopfverletzungen schon bei Geschwindigkeiten unter 30 km/h und auch bei selbstverschuldeten Alleinunfällen musste schon mancher Velofahrer seine Ablehnung des Helmes bitter bereuen.

Gleichzeitig (nicht anstatt!) müssen die verkehrstechnischen bzw. gesetzgeberischen Massnahmen optimiert werden. Dazu gehören z.B.

- Konsequenter Bau von **sicheren Radstreifen** (auf der Strasse) oder auch Radwegen (von der Strasse abgetrennt). Nach wie vor bestehen unnötigerweise gefährliche Einmündungen von Radstreifen oder -wegen in andere Fahrspuren. Meist geht es um Details, die aber schwere Unfälle provozieren können. Jeder Velowegplaner muss selber Velofahrer sein! Die Radwege müssen auch jederzeit bestimmungsgemäss funktionieren. Es darf nicht passieren, dass nur die Autofahrspuren vom Schnee geräumt werden, oder dass rücksichtslos auf Radwegen parkierte Autos unbehelligt bleiben.
- Für die Sicherheit von Velofahrer sind **Niedriggeschwindigkeits-Szenarien** (z.B. Tempo 30 Zonen) nötig. Dies verhindert die gefährlichen Ueberholmanöver und es steht für alle Beteiligten mehr Zeit zur Beurteilung der Situation zur Verfügung. Allfällige Bodenschwellen dürfen die Sicherheit von Velofahrern nicht beeinträchtigen (Berliner-Kissen, Velo-Furten).
- Lastwagen sollten mit glattwandigen seitlichen Unterfahrschutz-Vorrichtungen versehen sein. Ebenso müssten auch die nicht von den neuen Vorschriften erfassten älteren Fahrzeuge mit verbesserten Rückspiegeln ausgerüstet werden.

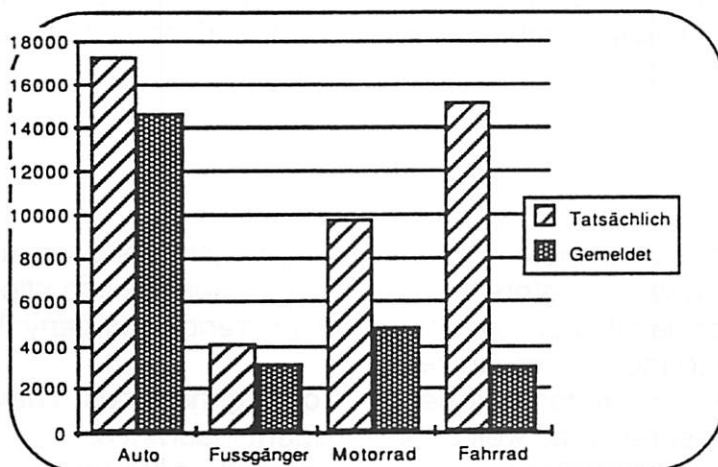


Fig. 2. Gemeldete und tatsächlich verletzte Verkehrsteilnehmer in der Schweiz 1989 (Bundesamt für Statistik 1990) korrigiert. Die tatsächliche Zahl der verletzten Velofahrer erreicht fast diejenige der Autoinsassen.

The Velomobile-Safety-Test at the European HPV Championships 1994 at Laupen, Switzerland

Andreas Fuchs, Reviewer of Future Bike

Abstract:

The reasons for and the philosophy behind the velomobile-test (and the vehicle categories) at the European HPV Championships 1994 are discussed and existing regulations concerning bicycles and HPV's are listed.

Please note that the aim of the velomobile test is not to define HPV's precisely - this would be a contradiction to the main goal of the now worldwide HPV movement - but to improve the still poor safety standards. Popularisation of velomobiles is impossible if a lot of accidents happen either in (promotional) races or in everyday use.

The criteria to be applied to the racing velomobiles and to the commuting velomobiles are listed and commented and the velomobile test is briefly described to allow other HPV associations to modify it according to their needs.

The velomobile classes

The organising committee of the European HPV Championships 1994 thoroughly discussed which races to hold and what rules (Ref. 1, 2, 3, 4, 5 and 6) to apply. It found that the classification scheme "unfaired, partially (how much?) faired and fully faired (if the head is not covered by a canopy, is that still fully faired?)" is comparable to the UCI-rules (Ref. 7; UCI: Union Cycliste Internationale. The UCI-rules contain few safety rules but many measures to classify bicycles) in the sense that it is somewhat artificial. The committee members believe that it is more natural to classify according to velomobile purpose:

- The racers (RV) and the commuting velomobiles (CV) or practical velomobiles (PV)
- Tandem (T) and multi-rider-velomobiles (MRV)
- Arm Powered Vehicles (APV)

In order not to break totally with traditions and to make comparisons of the same riders at different European HPV Championships possible the performance of the fastest partially faired velomobile will be acknowledged.

Legal problems and insurance

Among all the velomobiles that may participate in championships there are always some that are illegal according to local laws. Therefore the traffic authorities have to allow exceptions. This is needed - otherwise it is difficult to find an insurance company that is willing to sell a liability insurance to the race organizer.

Even then, the riders are fully responsible for their behavior during the races. They themselves must have a liability insurance as well as an accident insurance.

The allowance to race is given by the traffic authorities based on the rules for the velomobile (safety) test.

The race organizer also should not forget to insure the officials and the helpers correctly:

The liability insurance may not cover accidents of own personnel.

Only velomobiles passing the velomobile test are allowed to race in the endurance races on public roads. The others (such as sprint velomobiles with a large turning radius and arm powered velomobiles lacking good brakes or being near to overturning in corners because their tracks are as narrow as those of wheel chairs) can still be used in closed-off areas.

Criteria for every velomobile: RV's, CV's, Tandems and APV's

I. Basic characteristics:

I.a. Flaps (on both sides of the velomobile) for the feet and a cockpit that can be opened by the rider himself: The rider must be able to start, stop, enter and leave his velomobile without any help (no tape to fasten the cockpit).

(A further test for this will be the start to the long-distance race: Le Mans-start)

I.b. Direct view into the 180 degrees of the front half space. At most two mirrors. If no direct view to the rear is possible there must be at least one mirror.

I.c. The velomobile must be properly fitted to the size of the rider and the steering angle has to be sufficient (Interference of feet and chain with the wheels, interference of legs and knees with the steering linkage. Steering and driving has to be quite independent in APV's).

I.d. Sufficient ventilation (danger of fainting in heat under a closed canopy in dense traffic)

II. Stability (on straights and in corners)

II.a. Stable straight ride has to be possible

II.b. Safe cornering without putting feet down

II.c. Diameter of the turning circle (between walls) at low speed with all wheels touching the ground at maximum 14 meters (45.9 feet). If possible, the turning circle diameter will be measured for left and right turns. If there is not enough space in the test area, then the diameter of right turns only will be measured.

(Small turning circle diameter: Bonus for the CV-test)

II.d. Multitrack velomobiles: Wheels with enough lateral stiffness for cornering at high speeds

III. Braking

III.a. At least two independent brakes acting onto the wheels

III.b. Minimum braking deceleration using all brakes while the velomobile remains stable (No overturning):

Flat street, dry pavement: $3 \text{ m/s}^2 = 9.84 \text{ feet/s}^2$ (BAV, Ref. 10)

Flat street, wet pavement: $1.4 \text{ m/s}^2 = 4.59 \text{ feet/s}^2$ (DIN, Ref. 11)

(High braking deceleration: Bonus for the CV-test)

III.c. Multitrack velomobiles: Brake force divider to equalize the pull on the brake cables on multiwheel-axes, parking brake

IV. Protection when falling over and in crashes

IV.a. Helmet in use (fit to the rider's head has to be demonstrated). Riders of fully faired velomobiles need at least a traditional racing-bicyclist's helmet. Riders of partially or of unfaired velomobiles need to wear a modern bike helmet (SNELL-, ANSI-, BFU-certified or certified by another renowned organisation). Ref. 18.

IV.b. Sharp corners and sharp edges and chainrings need to be covered. (Chainring

covers on un- or partially faired velomobiles need to stay intact in crashes at typical velomobile speeds).

V. Craftmanship and Maintenance

V.a. Brazing, welding and glueing have to be well done

V.b. No worn tires (cracks/carcass covered by rubber/dimensions)

V.c. State of the brakes: Travel of the brake levers potentially still at least 2 cm (0.8 inches) when the brakes start to act. (Rim brakes: Brake pads still thicker than 3 mm (2/16 inch). Disk brakes: Braking surfaces not worn too much. Drum brakes: Precise braking possible)

V.d. Brake cables in good shape. No frayed cables. The testers will actuate the brakes strongly to check them under worst conditions.

Additional criteria for CV's (Check of belonging to proper racing category)

I. Basic characteristics:

I.e. Signs have to be given by arms and or hands (Blinkers are not allowed in Switzerland but if there are any on your velomobile you need not dismantle them).

I.f. The rider has to be able to see the surface of the street as near as 3 m (9.84 feet) from the nose of the velomobile.

I.g. Bell

I.h. Lights (headlight and taillight firmly mounted to the fairing or to the frame). Ref. 8.

I.i. Fenders

I.j. Racks and bags

II. Stability

II.e. Diameter of the turning circle (between walls) at low speed with all wheels touching the ground at maximum 6 meters (19.7 feet).

Comments to the criteria for the velomobiles

I.a. The long distance endurance race takes place on public roads. The RV and CV will mix with the normal traffic. In case that on a crossing cars do not give way to a velomobile to turn to the left, they have to stop and wait for a situation in which no car is approaching. Therefore single track velomobiles need to be equipped with flaps that allow the feet to be put down.

Helpers are present only at the most difficult crossings and therefore could not help a rider of a fallen-over single track velomobile. Therefore the cockpit has to be fastened in a way (no tape!) that the velomobile can be exited without any support from the outside.

The Le Mans-start procedure (long distance endurance race) is a test for whether or not a rider can enter and close the velomobile as well as start without any help.

I.b. On crossings the riders need to look to the left or to the right if there is not traffic coming from either side and they need to look back if there is free way to turn to the left. Therefore the forward 180 degrees have to be direct vision and to look back, at least one mirror allowing that has to be installed.

With the help of the rear view mirror of his Leitra the author is able to see the street up to 10 meters rear of the velomobile tail. The fields of view through the windscreen and over the mirror overlap. Full 360 degrees vision is therefore given in a Leitra (The windscreen of the Leitra of the authors was made longer on each side for ease of looking sideways).

I.c. The interferences between arms, legs, feet and heels and any moving parts and the

interferences between these parts (handle bars, chains, steered wheels) have to be minimal in order to allow safe riding, cornering and braking.
 Inert masses should not be supported by parts linked to the steering system as is the case on normal bicycles (weight of the upper body supported by the handlebars).
 The transmission and the steering should be independent enough to allow precise steering at any power input by the rider.
 I.d. Ventilation should be sufficient in order to avoid sickness due to exhaust fumes or low oxygen concentrations and/or heat.

II.a. A stable straight ride is required at any speed, but mainly at low speeds typical during hill climbing.

II.b. Safe cornering is required without putting down feet or devices to prevent the velomobile from falling over.

II.c. If a velomobile can turn 180 degrees (between walls) within an area 14 meters wide, its turning radius is 7m or less. Single track velomobile then need a lane width (on a plane, no walls to the sides of the lane) of 2.05 meters for a 90 degrees turn (formula 1). This means that such velomobiles can be ridden on the main roads (two lanes) in Kanton Bern, Switzerland, since these are typically 6 to 7.5 meters wide (One lane 3 meters or wider).

Form. 1
$$S = \ell \frac{\tan 67.5^\circ}{\sin 45^\circ} = 3.41 \cdot \ell$$

S = Radius of circle

ℓ = Lane width

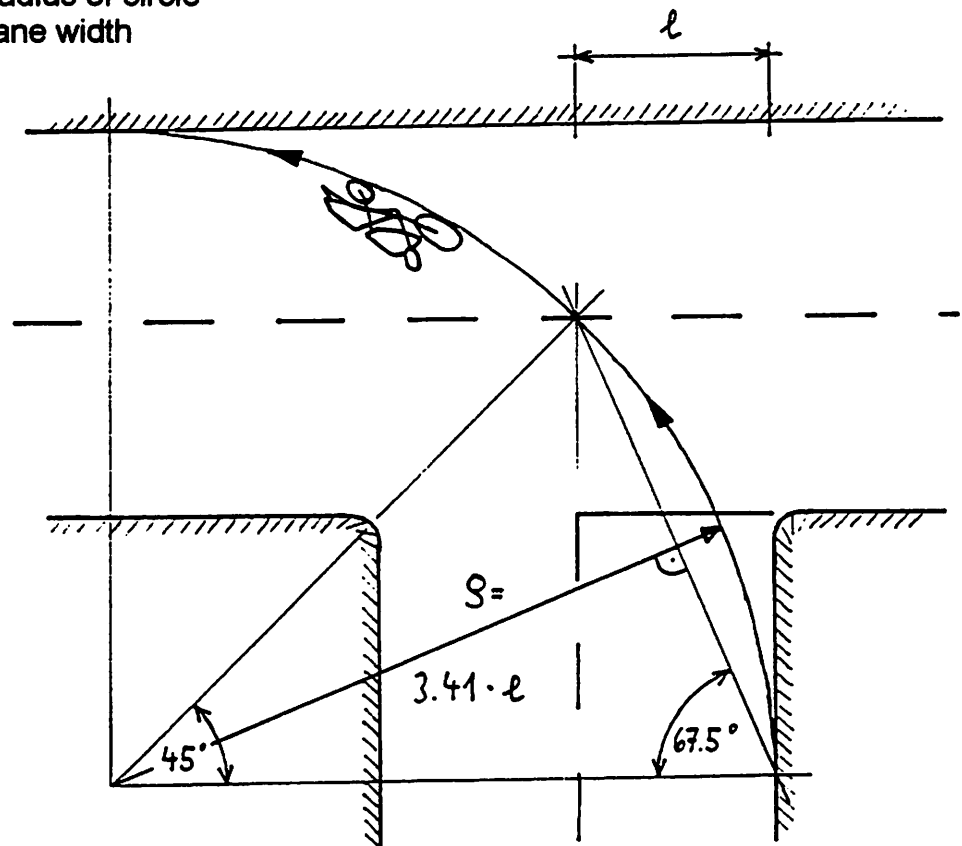


Fig. 1 Width of a lane and turning radius.

If due to lack of space or time the turning radius cannot be measured to both the left and to the right, then the turning radius to the right should be tested. Some kinds of single

track velomobiles have different turning radius when turning to the left or to the right. On long wheel base recumbents usually the steering pushrod is on the left side, and therefore the maximum steering angle of the front wheel to the left is bigger. On low racers the chain is usually running on the right side of the front wheel and there also the steering angle to the left is bigger. According to Bram Moens the approximate diameter of the turning circle of his low racer is 7 meters to the left and 10.5 meters to the right (Ref. 9) He claims that cornering is good enough in order that he could have ridden the low racer on the narrow lanes - sometimes in the order of less than 3 meters - in the around-the-block-race at the European Championships 1993 in Farum, Denmark, but that finally he did not race due to other safety reasons.

The dependence of the turning radius on velomobile speed (centrifugal force) is not measured due to lack of time and for the sake of simplicity. The chosen speed for the test is low. Therefore in the races the riders should take care and ride around corners with reduced speed (warning signals in very sharp corners would be a good safety feature). During the measurement of the turning radius all wheels should contact the ground to exclude artistic manoeuvres.

| Class | range of turning circle diameter [m] |
|-------|---|
| 1 | < 4 |
| 2 | 4 to 6 |
| 3 | 6 to 8 |
| 4 | 8 to 10 |
| 5 | 10 to 12 |
| 6 | 12 to 14 |
| 7 | > 14 |

Table 1 Classes for measurements of turning circle diameter

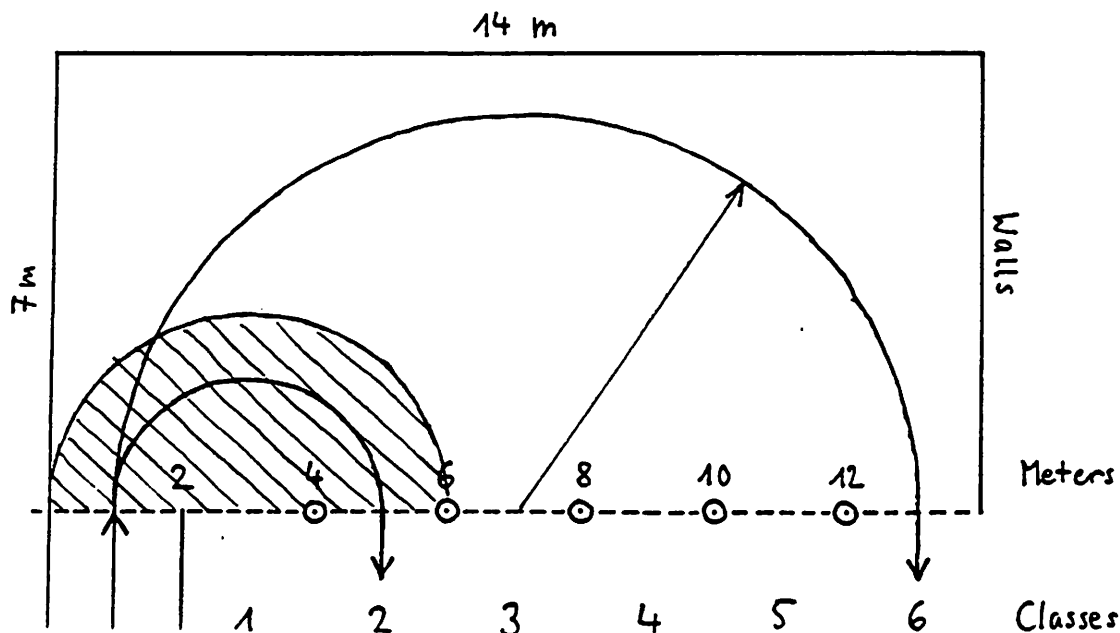


Fig. 2a Setup of the area used to measure the turning radius.

II.d. The side forces on wheels of multitrack velomobile in corners can be quite high due to the centrifugal force. The wheels should therefore be stiff enough. Glued on racing tires will slip off the rim and large wheels (e.g. 27") with ordinary hubs and spokes will fail if used for fast cornering.

III.a. Two independent brakes are needed in case of failure of one (eg. breakage of the actuation mechanism).

One could think of air brakes but these work efficiently only at higher speeds. Therefore two independent brakes stopping the wheels are required. Aerodynamic brakes may be used in addition.

III.b. The shorter the stopping distance (> braking distance) the safer the velomobile if it remains stable while slowing down. Therefore a minimal deceleration is defined.

On dry pavement and on level road the deceleration should be better than 3 m/s² (Ref. 10, BAV, "Bau und Ausrüstungsverordnung", a part of the swiss law on traffic rules and velomobiles, called SVG, "Strassenverkehrsgesetz").

With only one brake, according to BAV the acceleration should still be at least 2 m/s².

On wet pavement and on level road the deceleration should be better than 1.4 m/s² (Ref. 11 citing corresponding DIN-regulations and Ref. 12).

These decelerations are very low compared to the 5m/s² required by swiss law (Ref. 10) for cars (Lightweight cars). Thus bikers have no chance not to crash into a car if that car starts to slow down suddenly and if the bikers follow it closely (Ref. 13 and 14). The developement of highly effective braking systems (hydraulic and disk brakes) and the application to velomobiles with low center of mass and medium or long wheel base (long wheel base recumbents start to slip before they start to lift the aft wheel) is therefore highly recommended.

According to D.G.Wilson (Ref. 15) the US regulations requires maximum 15 feet braking distance at a speed of 15 mph. This is equivalent to 4.92 m/s² braking acceleration which

is high compared to the technical status of today's bicycles.

Since it was not known what braking accelerations usually are achieved under practical conditions (Ref. 16 and 11) some measurements of typical braking accelerations were done by the author and Paul Rudin:

| Type of bike | Actuated Brakes | Braking decelerations and std. dev. [m/s ²] | |
|-------------------|-----------------|---|------|
| Normal bicycle 1) | front | 2.34 | 0.12 |
| | rear | 1.94 | 0.07 |
| | both | 3.85 | 0.10 |
| MTB 2) | rear | 3.33 | 0.06 |
| | both | 3.80 | 0.17 |
| LWB 3) | front | 2.18 | 0.21 |
| | rear | 4.20 | 0.27 |
| | both | 5.10 | 0.50 |

1) Normal bicycle with sidepull brakes

2) MTB: Mountain bike with cantilever brakes

3) LWB: Long wheel base recumbent with cantilever brakes

The measurements were done with the test described below. It should be noted that if the brakes are not adjusted well the braking decelerations might be much smaller than theoretically possible → table 3 (example: LWB recumbent with front brake only).

Table 2 Typical (measured) decelerations on flat dry pavement

It is important to note that braking with the front axle is much more effective than braking with the rear axle alone. For stability while braking the rear wheel should never be locked (it should roll so that adhesive instead of slipping friction is predominant).

The maximum theoretical deceleration can be calculated with formulas given in Ref. 17.

| Type of velomobile | Approx. theoretical max. deceleration (no slippage) [m/s ²] |
|-----------------------|---|
| MTB or normal bicycle | 5 |
| Leitra trike | 6 |
| Lightning MWB | 9 |
| Peer Gynt LWB | 14 |

MWB: Medium wheel base

Table 3 Theoretical maximum braking accelerations. If the braking accelerations are higher the velomobile will start to lift the rear axle if the slip-limit is not already reached (velomobiles start to slip if the braking acceleration is higher than 2 to 5 m/s² for wet surfaces and 6 to 10 m/s² for dry surfaces).

| Class | Decelerations dry | | wet | | Braking distance | |
|-------|------------------------------|------------------------------|------------------------------|------------------------------|---------------------|---------------------|
| | lower [m/s ²] | upper [m/s ²] | lower [m/s ²] | upper [m/s ²] | dry lower [m] | wet lower [m] |
| 1 | < 3 | 3 | < 1.4 | 1.4 | | |
| 2 | 3.0 | 3.5 | 1.4 | 2.0 | 4.17 | 8.93 |
| 3 | 3.5 | 4.0 | 2.0 | 2.5 | 3.57 | 6.25 |
| 4 | 4.0 | 4.5 | 2.5 | 3.0 | 3.13 | 5.00 |
| 5 | 4.5 | 5.0 | 3.0 | 3.5 | 2.78 | 4.17 |
| 6 | 5.0 | 5.5 | 3.5 | 4.0 | 2.50 | 3.57 |
| 7 | 5.5 | 6.0 | 4.0 | 4.5 | 2.27 | 3.13 |
| 8 | 6.0 | 7.0 | 4.5 | 5.0 | 2.08 | 2.78 |
| 9 | 7.0 | 8.0 | 5.0 | 6.0 | 1.79 | 2.50 |
| 10 | 8.0 | 10.0 | 6.0 | 8.0 | 1.56 | 2.08 |
| 11 | 10.0 | 12.0 | 8.0 | 12.0 | 1.25 | 1.56 |
| 12 | 12.0 | > 12 | 12.0 | > 12 | 1.04 | 1.04 |

Table 4 Classes used to measure decelerations after an initial speed of 18 km/h (= 5 m/s)

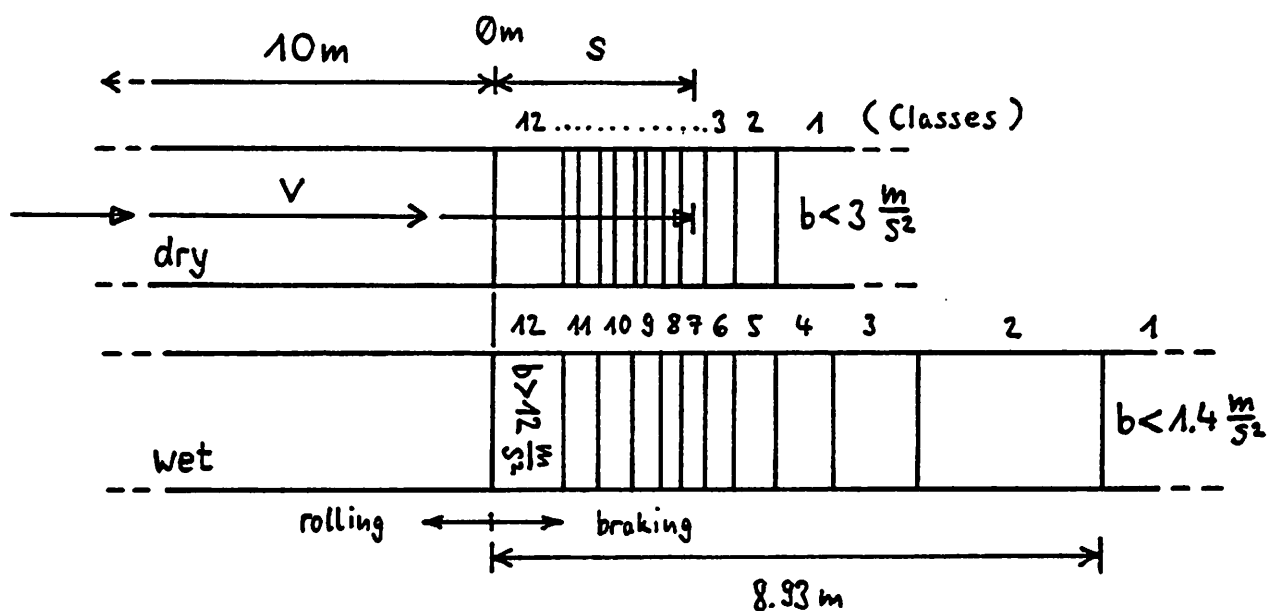


Fig. 2b Setup of the area used to measure the deceleration.

On a 10% down slope the technical braking acceleration is reduced to the effective braking acceleration due to a component of the force of gravity by nearly 1 m/s². This is up to approximately 70 % (!) less deceleration for wet braking since wet braking is less effective than dry braking. Therefore, for dry braking the reduction is typically between 30% and 20%. Since at a given speed stopping distance is inversely proportional to deceleration, this enlarges the stopping distance of typically a few or several meters by

between 25% and more than 200%!

Form. 2
$$S = \frac{v_o^2}{2b}$$

S = braking distance [m]

v_o = speed [m/s]

b = deceleration [m/s²]

In the velomobile test, for simplicity the braking accelerations are determined from measurements of the braking distance (< stopping distance) and of the speed prior to braking.

Even though the braking accelerations required are such that even a standard bicycle should not overturn, wearing a helmet is required.

The test procedure is as follows: The velomobile rolls over a distance of 10 meters (no pedaling) and the time to travel these 10 meters is measured. At the end of these 10 meters the brakes are actuated and the braking distance is measured. If the velomobile needed less than 2 seconds to travel the 10 meters and if the braking distance on dry pavement was below 4.17 m (wet: 8.93 m) then the deceleration was more than 3 m/s² (wet: 1.4 m/s²).

The method used was the one explained above. For scientific purposes this method is not accurate enough, but for rough estimates of practically achieved decelerations the method is perfect due to its simplicity and because the test is very similar to a real braking manoeuvre.

Other possible methods, using accelerometers (a decelerometer with pendulum resting at its maximum elongation is easy to build) or filming real time sequences are either too complicated and thus not feasible to test a big batch of velomobiles in little time or cost too much for non-professional organisations.

Error estimates showed that it is the braking distance that should be measured as precisely as possible. Therefore maximum quality of the results is achieved if the rider concentrates on actuating the brake levers. Thus no pedalling is recommended. Bad series of measurements with the same vehicle and rider can be detected by calculating the correlation of initial speed and deceleration. If the correlation coefficient is far from 0 then the measurement should be repeated. If braking distance does not depend on velocity then the series of measurements can be considered good.

III.c. On multitrack velomobiles the wheels on the axles with two wheels need to be braked symmetrically to avoid spontaneous and uncontrollable turns when slowing down. This task is achieved with braking force dividers.

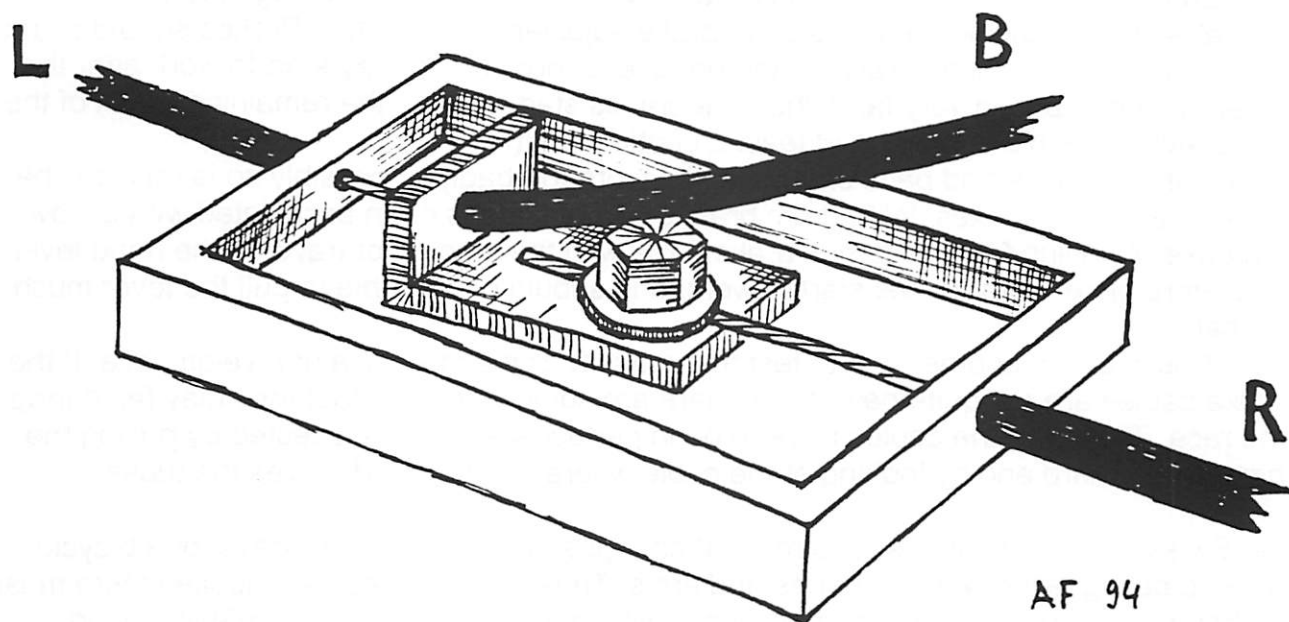


Fig. 3 Simple braking force divider. It works well if the friction on the brake cables and the levers of the braking system is minimal. B: From the hand lever. L and R: Braking cables to the left and the right hub respectively.

Hydraulic brake force dividers are possibly the ones which will need the lowest amount of maintenance.

On slopes, multitrack velomobiles can only be parked if they are equipped with a parking brake.

IV.a Helmet. Wearing a helmet has to be demonstrated in the velomobile safety test: It should fit well (Ref. 18).

In the narrow fully faired velomobiles a traditional bike helmet is the absolute minimum of protection since a thin walled fairing does not cushion upon impact at high speed.

Riders of unfaired or partially faired velomobiles need to wear a modern bicycle helmet approved by SNELL, ANSI, BFU (Bund für Unfallverhütung, CH), or an other renowned standardisation organisation.

IV.b Points, sharp edges and uncovered chain wheels (mainly on SWB and MWB-designs) may hurt badly upon impact. Therefore either these dangerous features have to be altered or at least cushioned and or covered. Covers of chain wheels should stay intact and in place when the velomobile crashes at typical velocities.

A safe interior of a velomobile contains mainly structures that are tangential to the riders body and not radial to prevent penetration during an impact.

V.a. It is of course difficult to judge if a joint will stand the loads possibly encountered during a race. But in this qualitative check absolutely poor craftsmanship will be detected and consequently the risk of racing velomobiles disintegrating at high speed should be somewhat smaller than if there is no judgement of the overall quality of a velomobile.

V.b. This check is included to test the intensity of maintenance of a velomobile. If a tire is not totally new, the possibility of a blowout due to false mounting is minimal, but if a tire is

too old it may not stand sharp cornering or bumping into holes that may not have been recognized by the rider. The optimum age of a tire is therefore "not brand new".

V.c. Braking is very important for safe riding so no failure of the braking system is tolerable. In this check the precision of brake adjustment is tested. Brakes should start to work neither at very small travel of the hand lever nor should they start to work after the lever has been pulled very far. When the brakes start working the remaining travel of the hand lever possible should be at least 2 centimeters (Ref. 19).

The brake surfaces and pads should not be worn too badly. If possibly so is easy to check with rim and disk brakes. With drum brakes bad braking is often associated with a slow increase of pulling force and thus brake force with the amount of travel of the hand lever. Therefore once drum brakes start to work, one should not be able to pull the lever much further.

V.d. This check is another one to test the intensity of maintenance of a velomobile. If the brake cables are not quite new (say if there are some worn threads) they may fail during the race. Therefore the cables have to be in perfect shape. This is tested by pulling the hand levers hard and by looking at the cable where it enters and leaves the tubes.

I.e. Swiss traffic regulations requires that changes in the direction of travel of a bicycle have to be signalled with the hands and arms. Thus in fully faired velomobiles there must be holes or doors or at least open windows which allow to give signs. In Switzerland blinkers are not allowed on bikes but Future Bike does not force the riders to take them off for only one race. But it is forbidden to use them during the races even though it is believed that blinkers would be a nice safety feature.

I.f. Bumping into holes might be catastrophic and therefore it is required for CV's that the rider sees as much of the surface of the street in front of the velomobile as possible. The measure of at most 3 meters in front of the velomobile-nose shaded to the view of the rider was taken from the rules for the GT class (Ref. 6) of the 1993 International Human Powered Speed Championships (10 feet).

Through the windscreen of his Leitra the author is able to see the street 1.45 meters in front of the velomobile nose.

I.g. To have a bell on a velomobile is primarily practical.

I.h. Today there are numerous lighting systems on the market that might simply be strapped onto a bicycle. To avoid that too many racing velomobiles will be transformed to pseudo-CV's just to win titles Future Bike chose not to allow strapped-on lighting systems in the CV class: The headlamp and the tail light have to be tightly mounted to the velomobile. Additionally, often these battery driven lights are forgotten at home and then are not available to the rider if she or he is late and has to ride in twilight. Since in Switzerland the power of bicycle lighting systems luckily is no longer limited to 3 watts Future Bike does not require that a generator is mounted. Battery packs are allowed if they are shown connected to the lighting system during the velomobile test.

I.i. Fenders are an important feature on practical vehicles since these should work perfectly also on rainy days.

I.j. Bags, racks and other forms of luggage compartments are without any doubt an integral part of CV's.

II.e. To enter parking lots a small turning radius is required. CV's should be able to do an 180 degrees turn on a street (between walls) that is 6 meters wide.

The extra large (long) Leitra of the author needs 5.2 meters of space (between walls) to do a 180 degrees turn. Without fairing, less space is required. Long wheelbase recumbents like a Fateba L2 and an Easy Racer clone need 4.5 meters with no pedalling and up to 6 meters when moving the pedals forward and backwards and pushing them

only when near vertical position.

Criteria that originally were taken into account but that were finally omitted or that are difficult to test

First a planned criteria to CV's was rider eye level height. 90 centimeters seemed to be an appropriate measure because at this height there is the lower boundary of car windows. Since the center of mass of faired single track velomobiles should be as low as possible for safe travel in mixed traffic in gusty wind finally no such lower limit of eye level height was added to the criteria for practical velomobiles.

It would be important to test if the braking system stands braking for long times. Tires may blow off if rims are heated excessively (Ref. 21) or drum brakes may lock at any hard-to-predict time. Unfortunately, such tests are complicated to perform if they are to be repeatable and therefore at the moment it is impossible to add them to velomobile tests prior to races.

Please note: Wind-cooling of brakes is not very efficient in faired velomobiles.

Test procedure

A lot of velomobiles have to be tested in a short time. Additionally, the number of helpers and the amount of money is limited. Therefore not every interesting detail is tested at the HPV EC 1994, but a lot is asked with a form. The riders need not to fill in that form if they do not want to do so. This will guarantee the quality of the data which could eventually then also be used for scientific purposes.

Parameters asked with a form:

0.1. Rider/Builder

1. Name, address, country, phone
2. Race number
3. Category

0.2. Basics

1. Name of the velomobile
2. Year the prototype was built
3. Commercial product: 1994 price
4. Number of seats and pedals
5. Position of the rider(s): Recumbent, Upright, Prone
6. Material of frame and fairing
7. Mass (empty and max. mass of payload), max. mass of rider, weight distribution with rider on the seat
8. Overall length, width, height
9. Wheelbase (SWB, MWB, LWB) in centimeters, track width
10. Number of axles, number of wheels per axle, diameters of wheels
11. Type of brakes
12. Steered wheels, driven wheels
13. Gearing (number of gears, gear range, gears in meters)

0.3. Ergonomics

- 1. Type of steering (above the seat, under the seat, joy stick, ...)**
- 2. Eye level height, seat height, bottom bracket height, angle between backrest and vertical**
- 3. Horizontal distance between front wheel and hip joint**

0.4. Fairing

- 1. Unfaired, partially faired (front, rear, front and rear, 3/4 or head free), fully faired**
- 2. Entering, starting, stopping and exiting the fairing without help?**

0.5. Field of view

- 1. Field of view in degrees; mirrors**
- 2. Material & angle of front view window, wipers**
- 3. Front- and taillight?**
- 4. Battery pack or generator? Generator remote control?**
- 5. RV but nevertheless with lights?**

0.6. Visibility

- 1. Colour of fairing**
- 2. Reflectors**
- 3. Flags**

0.7. Safety

- 1. Sharp edges in the interior of the vehicle?**
- 2. Fairing hard (fibreglass) or made from tissue (soft)?**
- 3. Roll bars; seat belts**

0.8. Comfort

- 1. Partial or full weather protection**
- 2. Fenders and chain guards**
- 3. Suspension/travel of suspension/suspended seat**
- 4. Type of dampers (polymer/springs/hydraulic/pneumatic)**
- 5. Seat: width of seat/backrest. Ventilation of back possible?**
- 6. Inclination of backrest variable?**
- 7. Armrests**

0.9. Specialities

- 1.**

Filling in that form as well as the velomobile test should be interesting and educative (about safety) for the riders (as well as for the spectators).

The criteria essential for safety I.a. to V.d. are tested in a queue of specialized posts. On each post, only few criteria are checked by experienced bikers or by professionals. The testers stay at that post during the whole test to ensure first a high volume of tested velomobiles per unit time and second a fair comparison of all the velomobiles.

To test 120 velomobiles in approximately 3 hours two such queues each of five posts are needed. A velomobile stays at a post for only 3 minutes.

be documented on two photographs, one from the front and one from the side (rider on or in the velomobile).

Remarks and Thanks

Thanks to Paul Rudin for helping with the deceleration measurements and thanks to Theo Schmidt for reviewing the paper and his valuable hints.

This paper was finished in July 1994, well before the HPV EC 1994 August 26 to 28.

Therefore the actual test done in Laupen may be slightly different from the one described in this text.

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Leonard M. Brunkalla

Safety... Crashing... and related debris

People of the world have been riding upright bikes for a considerable time. Most of you know the basics of "Over the Bars" and "Nose to the Pavement" that crashing a common diamond frame bike can provide. Even the "high tech" track bikes, only increase the rider's chances of vaulting over the handlebars when they are equipped with a smaller front wheel. None of this is news. What is news, is that the recumbent market is beginning to take-off. For this reason, I would like to relate some of my own observations and experiences with recumbent bikes, and trikes.

There are many recumbent designs in production today. If you really look at recumbents as a whole, however, you will see that there are only a few different configurations for two wheeled recumbents. There are long wheelbase designs (LWB), short wheelbase designs (SWB), and medium wheelbase (or compact long wheelbase) recumbents (CLWB). Of these basic configurations, there will be other variables such as, high or low bottom bracket, above or below leg steering, and using different or matching wheels front and rear. Since three wheeled recumbents can vary in different ways from two wheeled recumbents, I will come back to discussing trikes later.

Currently the most common recumbent design, at least in America, is the long wheelbase recumbent with above leg steering. The familiar handlebar position provides a sense of security for first time riders while the relaxed handling characteristics build confidence easily. If any start-up problems are encountered, it is quite easy to put a foot down since most recumbents of this type have a relatively low bottom bracket position. As speed increases, however, the ability to catch yourself, before falling completely, is reduced. Since the riding position is low, and the rider's legs are extended forward, the rider's legs cannot be brought under the rider's body (compare to an upright where the legs are always under the rider) as quickly to prevent a fall. Add to this the leverage disadvantage when you try to lift your body with your leg extended in front of, or to the side of your torso. If you consider that an upright rider's body is seated about 34-40 inches above the ground, and many recumbents seat the rider at a height between 18 and 24 inches, you will see that the recumbent rider starts any fall, closer to the ground. Falling a shorter distance means falling for a shorter time, and leaving less time to react. This falling time will vary as seat height varies from design to design. Short wheelbase recumbents, which have inherently more agile

handling, usually have higher bottom brackets, which increase the time needed to get a leg under the rider to avoid a fall.

A short wheelbase recumbent, with above-leg steering, in my opinion, is probably the toughest situation for a “crashing” recumbent. Almost invariably, the above-leg steering short wheelbase, positions the rider straddling the steering column/post and the front wheel. This type of steering arrangement is also usually in close proximity to the rider's face and chest, leaving the rider closely “contained” or trapped, in the event of a crash. During a crash, this configuration also makes it difficult to get a leg down on the side that the rider is falling to, as well as making it impossible to get the other leg off of the vehicle since the leg on the high side is on top of both the steering column and the front wheel. My own experience with this configuration resulted in a feet up landing, and a sharp impact on the tailbone. Imagine if I had been using clipless pedals! It would have been impossible to get the foot on the high side of the fall, out of the pedal since the wheel would have impeded its release. Even a long wheelbase bike, with above-leg steering, can encumber the rider in the event of a spill, hampering a clean clear departure from the bike.

I have found no “ideal” configuration, or at least not universally ideal. My own personal preference for safety, comfort and reduced fatigue, is under-leg steering. Since there is no bar or steering column to straddle, it is easier to depart the vehicle when necessary, and whether intentional or not. Cable routing is shorter – a desired situation on most recumbents. Fatigue is reduced simply because your arms naturally hang by your side.

Weight distribution can vary drastically between different recumbent designs. Some generalizations can be made for the three basic configurations that I mentioned previously (LWB, SWB, CLWB). The long wheelbase recumbent will tend to have a smaller percentage of the total rider/vehicle weight on the front wheel. Although braking action would tend to shift some of the weight toward the front, most long wheelbase bikes will still be light on the front wheel. A common result of this light loading of the front wheel, is a tendency for the front wheel to skid to the outside in hard cornering or loose surface conditions (i.e. sand, rain, or gravel). This will cause the rider to fall to the leading side (or ahead) of the bike. A short wheelbase recumbent on the other hand, usually positions 50% or more of the total rider/vehicle weight on the front wheel. This situation tends to make rear wheel braking less effective, and could in fact increase the tendency for the bike to nose over in a panic stop. With the heavily loaded front wheel, the short wheelbase machine will usually skid the rear wheel out in over exuberant cornering, causing the rider to fall to the trailing (behind) side of the bike. Although I've had some experience on both long and short wheelbase machines, I can only comment on my expectations of the compact long wheelbase configuration. A compact long wheelbase recumbent (a rather recent designation) tends to combine

the best traits of both short and long wheelbase designs, to obtain the most widely appreciable characteristics. The weight distribution can be more even, than either the LWB or the SWB. This should result in better all around braking performance. The more evenly distributed weight should also alleviate most of the tendency to skid either the front or the rear wheel in a hard turn.

Wheel sizes for recumbents are as diverse as the designs themselves. Just try walking into your average bike shop and asking for a 16" x 1 3/8" tube or tire. Even 20" sew-ups are not everyday fare for your typical bicycle retailer. Those of you that already do extensive riding on recumbents probably know that feeling of dread that comes over you when you puncture a front tire. Why the front you ask? There are several reasons why that smaller, odd size tire gets so much attention, abuse, and consequently replacement. Many recumbent designs use a smaller diameter front wheel to achieve a lower profile and hence better aerodynamics. On many short wheelbase designs, the rider must be able to straddle the front wheel and, let's face it, not all of us can reach our legs around a 700c. On long wheelbase designs, a smaller front wheel keeps the profile low, and gives sufficient foot-to-wheel clearance without making the overall length of the bike unreasonably long. Unfortunately, the front wheel is the first wheel to hit debris, bumps, or other road hazards. With the smaller diameter comes the reduced ability to climb over bumps. That is to say, that it is easier to ride over a 2" bump with a 27" wheel than with a 20" wheel. Along with this reduced ability to go over bumps, there is greater impact force on the smaller diameter wheel. This greater impact force affects the handling of the bike as well as the life of the tire. Imagine riding on a short wheelbase machine, with the higher front wheel loading, fitted with a small diameter front wheel, hitting a substantial bump (remember – reduced ability to get over the bump, along with increased impact force) and having a blowout. This could be the start of a real bad day! Without the addition of some sort of shock absorption, short wheelbase machines, in my opinion, are for smooth surface rides, and definitely not for off-road use. The larger rear wheels that are commonly found on recumbent bikes (usually the driven wheel) allow the use of commonly available drive components, whereas a small drive wheel would require higher gear ratios to attain the same speeds. Some recumbent designs use two small wheels that are the same. This keeps the height of the vehicle lower, and can aid in cornering performance since the main mass of the rider is closer to the ground.

I would like to briefly touch on the subject of recumbent tricycles, since I have had some experience in designing, building and riding trikes. There are two common configurations for tricycles. There are designs that have one wheel in the front and two wheels in the back. Some of these single front wheel designs, drive the front wheel while steering the two rear wheels. Rear wheel steering, to the best of my knowledge, has not

been very successful either in inherent stability, or controllability. Some rear-steer designs suffer from self generating oscillations at high speed. Enough said about rear-steer. Trikes with a single steering front wheel, and two driven rear wheels, is a fairly common arrangement. This configuration, however, often times requires a differential to avoid a tendency to scrub a tire when negotiating a turn. By driving only one of the rear wheels, the tendency to scrub a tire is alleviated, although turns in one direction will be easier than the other when the drive wheel is on the outside of the turn. My experience, and my preference is two wheels in front, and one driven wheel in the rear. This seems to be the most stable tricycle configuration. Steering geometry is the same as a car, as are the direction of the forces on the wheels. Driving one rear wheel is as simple as any two wheeled recumbent, plus, you never have to put your feet down when you stop! A real advantage of the recumbent trike design, is the ability to drop the rider's position down between the wheels. This results in the lowest possible profile of any recumbent design. This also results in an inability of motorists to see you on the street. Most two wheeled recumbent designs put the rider at nearly the same eye level as motorists. A recumbent trike, on the other hand, is about as high as the door handle on most cars. For this reason, I always do any street riding with a 6 foot flag on the back of my trike.

I experienced a rather severe collision with an immovable object – in this case a cement curb – while riding my recumbent tricycle. My tricycle is very low, with two 20" x 1 1/8" wheels in the front, and a 700c in the back. Just by chance, I had converted the steering from a fold-down above-leg steering column and handlebar, to an under-leg handlebar, only two days before a race in BayCity, Michigan. My intention was to allow more clearance for my knees. During the race, efforts to shadow another racer and force him to overshoot a turn, and allow me to pass on the inside, failed. Instead, I had to turn wide, too wide, at which point I hit the concrete curb, at about 20 mph, with the right front wheel. Although the tricycle did a complete end-over-end flip, I was able to bail out unimpeded by any handlebars or steering column. Even though the tricycle suffered a crushed right front wheel, and a loosened seam in the rear wheel, I emerged unscathed except for a very red face. Had I not changed the tricycle from the above-leg steering, I would not have been able to successfully bail out of the cartwheeling trike. OUCH!! It hurts to think about it.

For those of you that might be considering building or purchasing a recumbent, I hope that I have given you some insight on safety considerations, or design characteristics. For those of you whose opinion cannot be swayed, or are "hard nosed" about your choices...wear a helmet when you ride...the ground is harder!

EVALUATION OF THE HANDLING CHARACTERISTICS OF A HUMAN POWERED VEHICLE WITH A MIRROR-SYMMETRIC FRONT-WHEEL GEOMETRY

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1 INTRODUCTION

This evaluation was part of a test-series that has been carried out to improve handling characteristics of a single-track HPV. The front-wheel geometry has great influence on handling characteristics of such a vehicle. Aim of this evaluation was to find the best combination of head-angle and track in order to get:

- * Good handling quality (similar to conventional bike)
- * Safety of vehicle handling
- * Less strain due to the task of steering

It was necessary to carry out a new evaluation because:

- * Evaluation of the relation between steering-geometry and handling characteristics of single-track-HPV with scientific methods are not known. Existing designs are based on experience following the concept of trial and error
- * Front-wheel geometries used in conventional bicycles are not useful for recumbent bicycles because the diameter of front-wheel is smaller and the distribution of load is different (center of gravity more in front)
- * For the new mirror-symmetric front-wheel geometry used in DESIRA II there have been no preceding tests

2 THEORETICAL ASPECTS

The most important parameters of the front-wheel geometry are head-angle and track under the condition of fixed wheel loading and front-wheel diameter. Both parameters together decide the magnitude and development of steering torques which have a big influence on handling characteristics. The theory concerned is common and there is no need to repeat it here. This investigation was done on a single-track recumbent bicycle with mirror-symmetric front-wheel geometry (see figure 1).

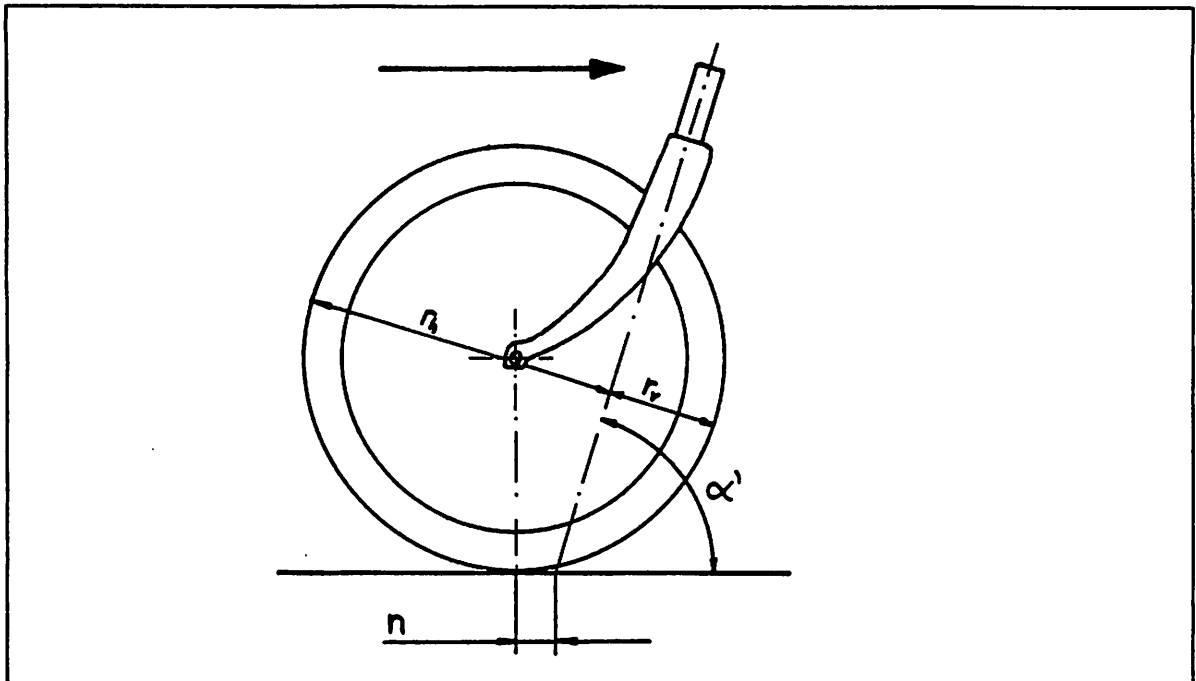


Figure 1: Mirror-symmetric front-wheel geometry

n = track

α = head-angle

Main points of difference to a regular front-wheel geometry are:

1. Reduction of collision between front-wheel and feet during crank rotation in narrow curves
2. Increase of steering torques because in a curve the center of gravity is lifted (and not lowered!). As a result steering forces caused by this effect change their sign (from - to +). This causes an increase of stabilizing steering torques.
3. Destabilizing torques appearing while crossing an obstacle are reduced
4. Aerodynamic forces caused by sidewinds do not obstruct steering activity as strongly as with conventional geometry and disc wheels

Asuming all points it can be predicted that a vehicle with the modified geometry has a better dynamic and static stability (ROHMERT/GLOGER, 1993).

3 METHODS OF MEASUREMENT

Numeric solutions to improve steering parameters are rarely known. This is caused by the difficulty of finding a mathematical form to exactly describe the dependence of track, head-angle, steering angle, velocity and steering torques. That is the reason, why experimental methods were used. In the experiments subjects were asked to drive a recumbent bike several times through a special test-track. Physical and physiological signals as well as subjective ratings were picked up and recorded in order to get data as

driver characteristics, stress, driver action and strain.

| Stress | Driver | Action | Strain |
|-------------------|--------------------|--------------------------------------|----------------------------|
| test track | sex | Steering angle | Heart rate and variability |
| design-parameters | age | Electromyogram of M. vastus medialis | Electromyogram of abdomen |
| driving task | body height | Video recording | Blink activity |
| | driving experience | | Subjective Rating-Scale |

Table 1: Measurement concept

For vehicle handling evaluation a two-level sequential judgement rating scale designed by KÄPPLER and PITRELLA (1988) was used. Subjects had to do their ratings in seven categories on an 11 point rating scale with psychologically scaled descriptors.

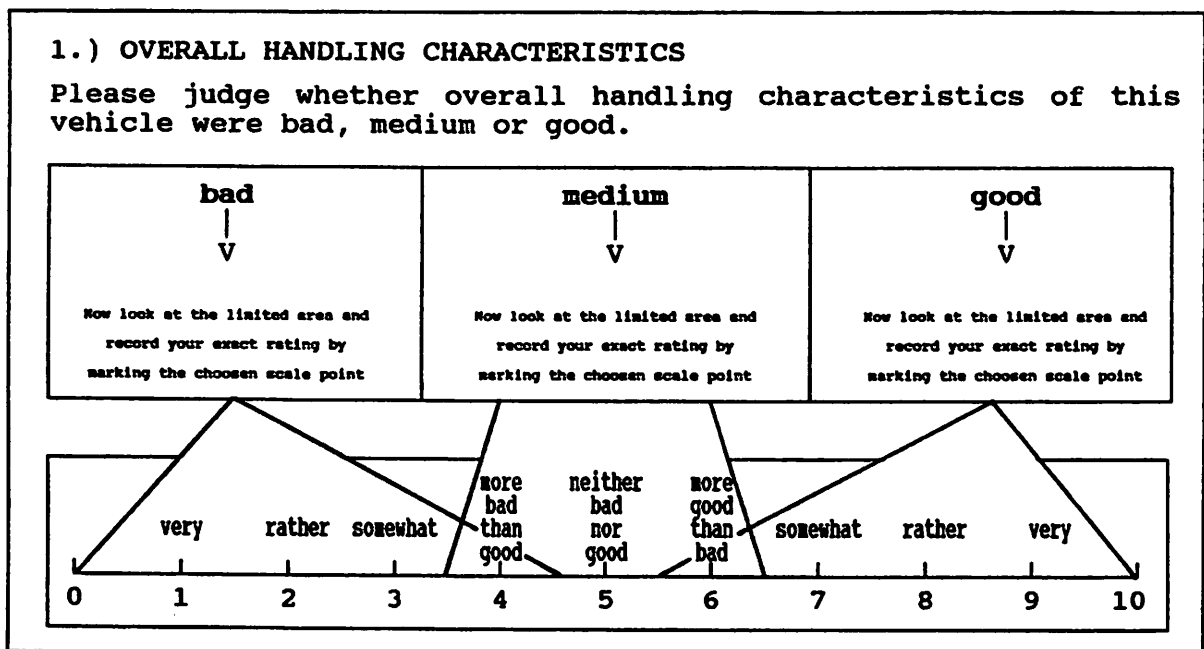


Figure 2: Example for the two-level sequential judgement rating scale

The workload for the subjects was reduced by using a two-level scale requiring two ratings in sequence from the raters, the first being rather coarse (3 steps) and the second being a fine one (11 steps - see figure 2). The advantage of this design is that raters do not have to deal with more than 5 scale points. The final rating was precise without passing over the rating capacity of the subjects.

Categories of judgement were:

1. Overall handling characteristics
2. Steering characteristics
3. Strain caused by stabilisation
4. High-speed stability
5. Subjective feeling of safety
6. Maneuverability
7. Assessment of task difficulty

4 PERFORMANCE OF VEHICLE HANDLING EVALUATION TEST

The test vehicle was a single track recumbent bicycle called MULTILAB with mirror-symmetric front-wheel geometry. It was built at the Technical University of Darmstadt especially to perform different handling evaluations. Several technical parameters can be varied and many parts of the technical equipment (handlebars, suspension) are interchangeable.



Figure 3: test vehicle MULTILAB with equipped experimental subject

A detailed description of this vehicle can be found in the article of ROHMERT/GLOGER (1993).

The handling tests were made on roads and car parks of the University. Subjects were asked to perform several driving tasks marked on the road. Aim of these driving tasks was to simulate typical driving situations which occur during the daily use of a bicycle.

- * Frequent situations: driving slowly, fast and without cranking
- * Typical maneuvers: U-turn, crossing of an obstacle, lane change
- * Difficult tasks: slalom and combination of narrow curves

Experimental subjects were 19 persons in total; 10 experienced with recumbent bike, 9 unexperienced, 5 female and 14 male subjects.

The two parameters of the front-wheel geometry were determined in a way shown in table 2.

| CONFIGURATION : | 1 | 2 | 3 | 4 | 5 | 6 |
|---------------------|------|------|-----|------|------|------|
| HEAD-ANGLE α | 90° | 85° | 80° | 89° | 89° | 89° |
| TRACK [mm] | 41,5 | 41,2 | 41 | 89,5 | 59,5 | 34,5 |

Table 2: Tested parameters of front-wheel geometry and abbreviations

Head-angle was modified 3 times with fixed track (from 80° to 90°) and track was changed 3 times with fixed head-angle (from 34,5 to 89,5 mm). In total there were 6 different combinations of both parameters. For an easy identification of each combination they were given abbreviations (p.e. conf.1 - see table 2) which will be used in the following text. Due to the theory it can be expected that front-wheel geometries with long track and flat head-angle will have higher steering forces than those with short track and steep head-angle.

Testing procedure

Subjects of the experiments had enough time to get familiar with the test vehicle before starting the measurements. This was necessary in order to reduce effects of training and to get a higher reliability of results. After being equipped with all measurement equipment subjects were instructed about test procedure and driving task. They had to drive 6 times through the prepared test track. After finishing each test ride subjects made their ratings about the present configuration. Meanwhile the recorded physical and physiological data were transferred to a fixed computer and technical parameters of the front-wheel geometry were changed. To prevent any sort of influence drivers did not exactly know what was changed. After the last ride subjects were asked to make a final ranking of the best configurations and to answer some additional questions.

5 RESULTS AND DISCUSSION

The first important result was that everyone participating in the test (even unexperienced) was able to operate MULTILAB safely after a very short time (ca. 5 minutes) or even immediately. This is a basic requirement for acceptance of HPV.

Subjective rating scale

Ranking

Finishing the last test track subjects had to choose the best 3 configurations and classify them in a ranking scale. The best got 3 points, the second 2 and the third 1 point. Figure 4 shows results separately for experienced and unexperienced drivers.

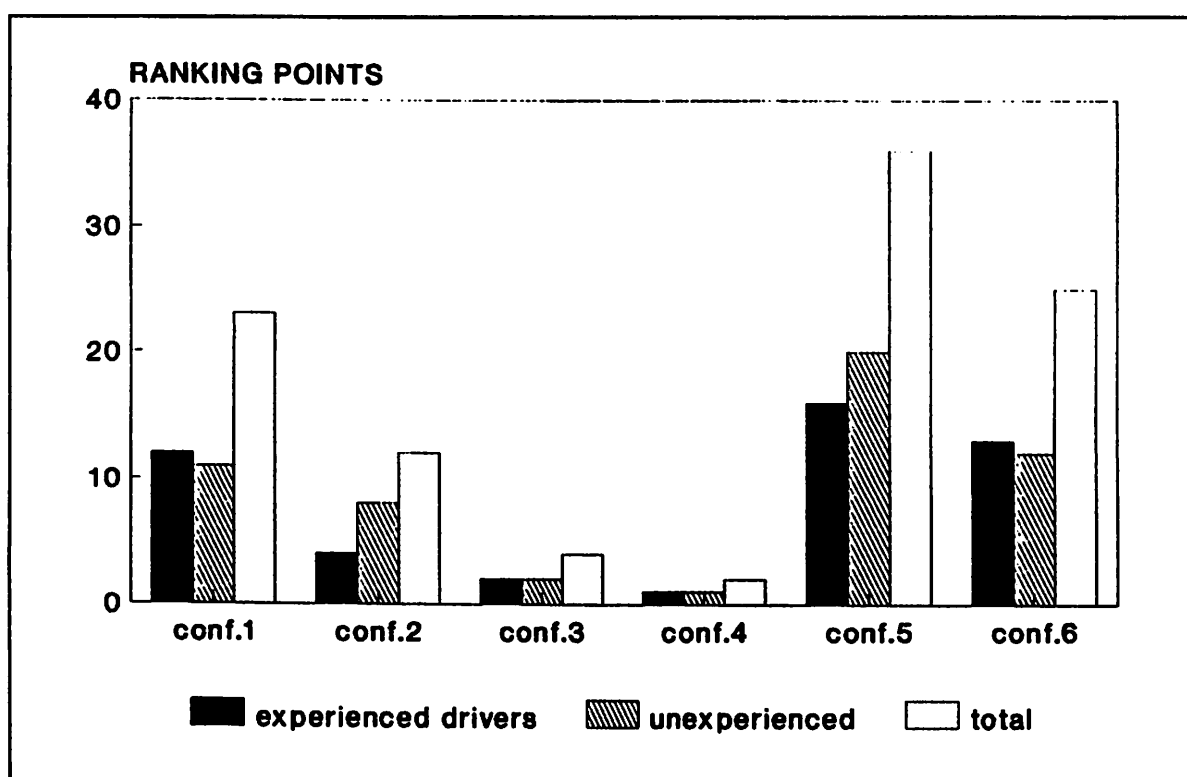


Figure 4: Ranking of experienced and unexperienced subjects

Both groups classified configuration 5 to be the best. A tendency can be observed that geometries with low steering forces (conf.1, conf.6) get better rankings than those with high forces (conf.3, conf.4). Ranking of experienced and unexperienced raters are similar. That allows two conclusions:

1. One of the tested front-wheel geometries is able to accomplish the demands of both groups of drivers
2. Similarity of ranking proves that the results are conclusive and not accidental

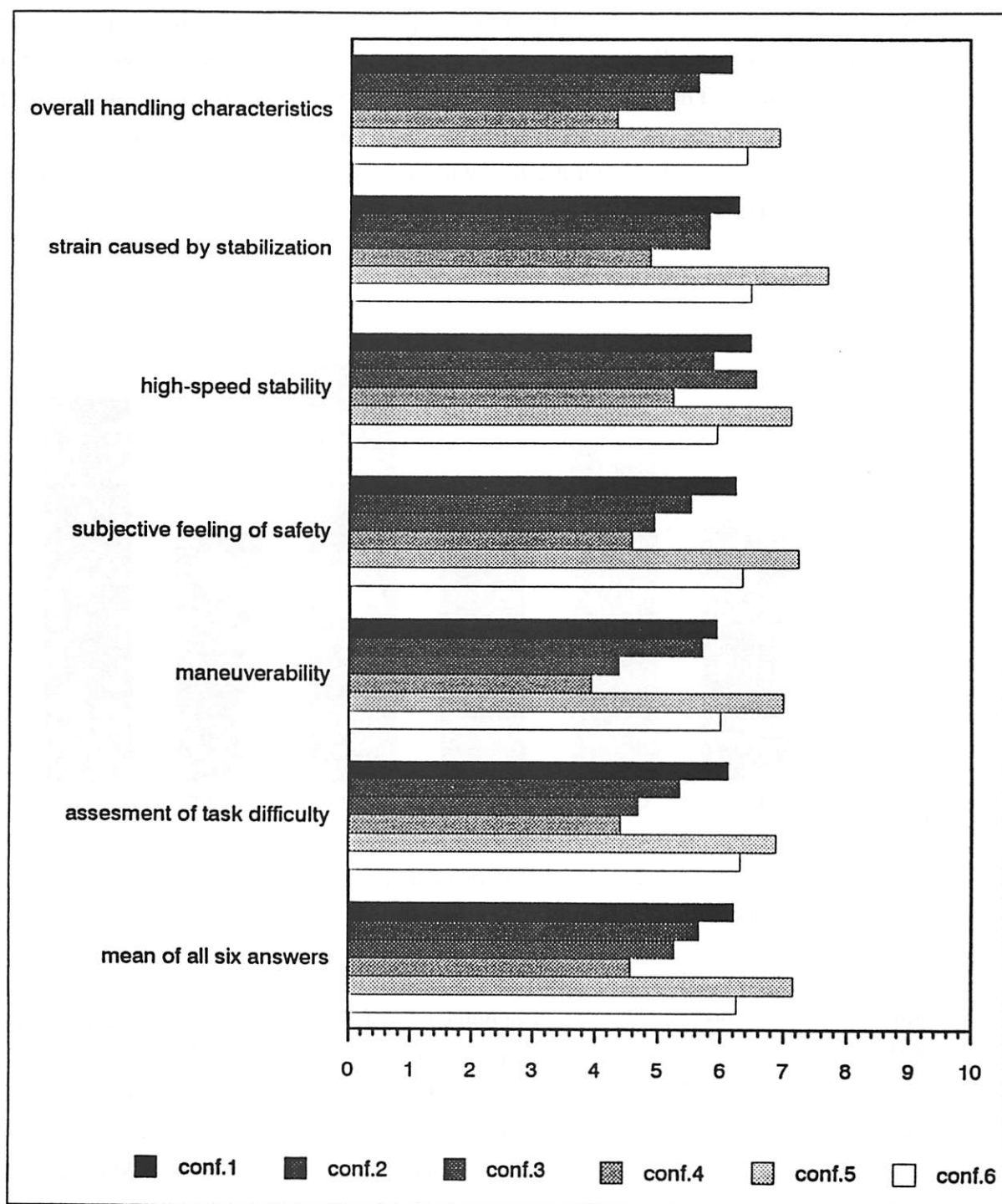


Figure 5: Subjective ratings of the 6 different vehicle configurations
(Means of 19 subjects in 6 categories)

All rating scales except the second one were basically designed following the same principle. The better a valuation was the more scale points were reached. Only in the second rating scale - concerning steering characteristics - the best judgement was correlated with the middle of the scale (5 points - "neutral"). High or low values indicate a worse classification. For all 7 questions concerning 6 configurations scale points of all subjects were summed up. Results of the calculation of Means are shown in figure 5 and of Standard Deviation (SD) in figure 6.

Overall handling characteristics as well as the average of all questions (except No.2 - 'steering characteristics') show the same sequence of ratings. This sequence correlates exactly with the overall ranking (see figure 4). In all questions configuration 5 reaches the highest ratings. This combination of head-angle and track seems to be the best. Even in contrary attributes as 'maneuverability' and 'high-speed stability' it gets the best classification. Front-wheel geometries with low steering forces get better ratings than those with higher forces.

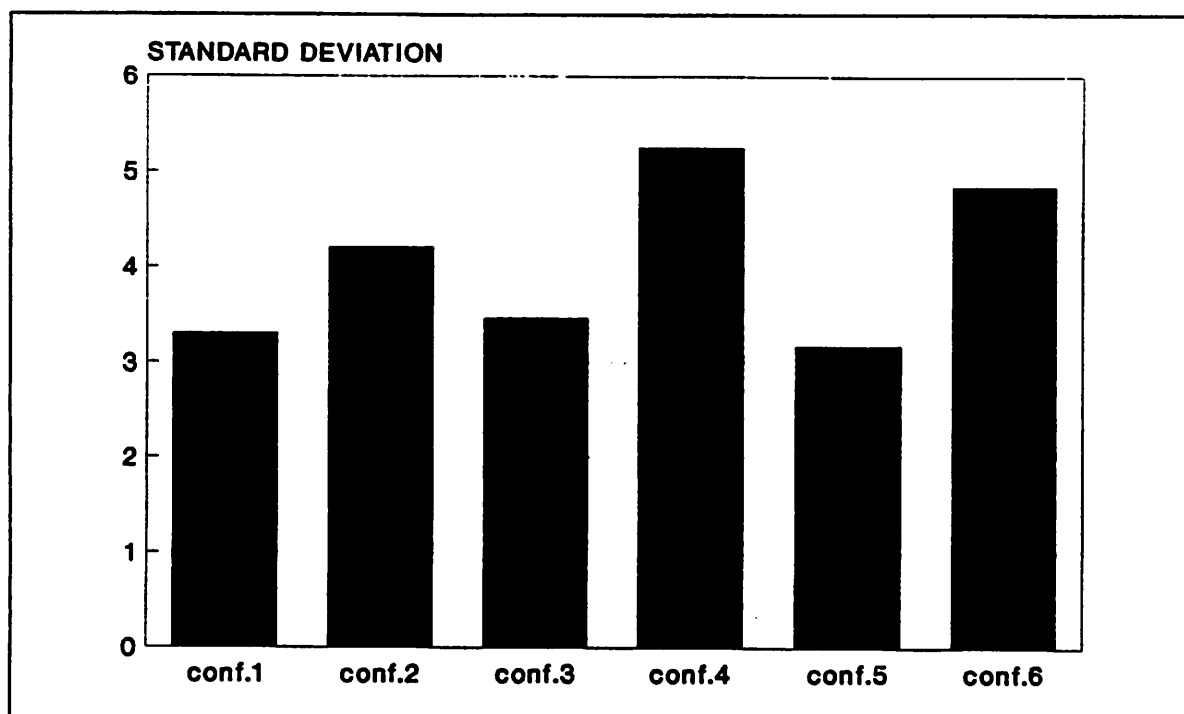
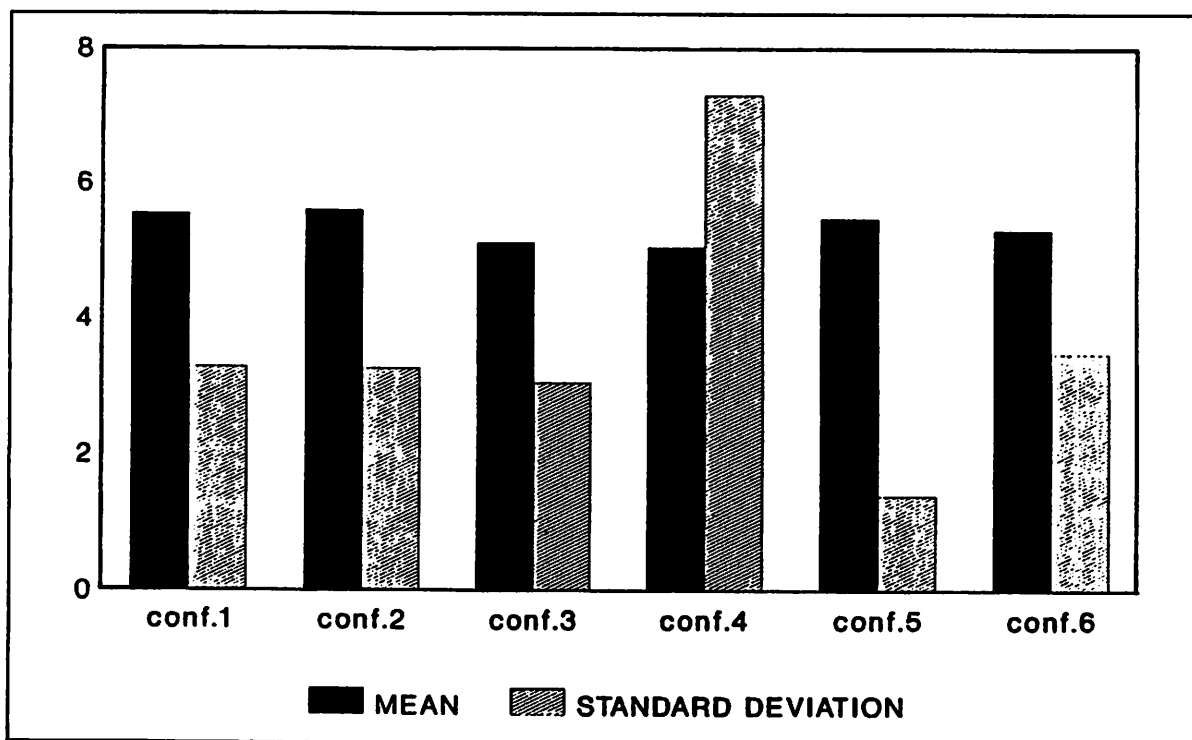


Figure 6: Subjective ratings of different vehicle configurations
(Standard Deviation of 19 subjects)

Standard Deviation SD can be seen as a standard to qualify the range of ratings. A high uniformity is important for the acceptance of a vehicle because it demonstrates that differences between ratings are small. Comparing the addition of SD over all rating scales configuration 5 has the lowest SD standing for the best acceptance of all tested geometries. A majority of subjects uniformly classified the handling characteristics of geometry 5 to be good. Configuration 4 has the highest value for SD indicating big differences between the ratings. Some subjects had problems to accomplish the driving tasks with this geometry.

Results for Means in the rating scale about steering characteristics were too close to derive a statement (see figure 7). Only SD can give more detailed information. The appearance of low values for SD as noticeable for configuration 5 ($SD=1,39$) indicates a uniformity of ratings. A high SD as appearing for configuration 4 ($SD=7,31$) demonstrates that in this case Mean is a result of extreme low and high ratings. Although Means of conf.4 and conf.5 are close, interpretation is very different.



**Figure 7: Subjective ratings concerning steering characteristics
(Means and Standard Deviation of 19 subjects)**

To avoid influences caused by training subjects drove through the test track with different sequences of configurations. A special investigation proved that there was only a small influence from the first to the second ride.

6 RESULTS OF PHYSICAL AND PHYSIOLOGICAL MEASURINGS

With regard to the questions of this investigation the results were less significant than those of the rating scales. One reason is a dominating activity of the body when riding a vehicle which is humanly powered. Compared to this body activity (muscular demands) the influence caused by mental or emotional strain due to the steering task is much smaller. Performance of this evaluation under condition of natural environment caused some disturbance variables.

Two methods of evaluation were used:

1. Statistic calculation of measured values
2. Graphical representation of the measured values in charts.

For each set of values representing one test track ride or one configuration, four measuring quantities (steering angle, electromyogram of abdomen (EMG-abd), electromyogram of lag (M. vastus medialis), blink-activity) were figured one upon another in their transient behaviour. The idea was, to point out the dependence and relationship between objective values and coincidence with the results of the subjective rating scales.

Statistic evaluation - statements

- * Fastest ride through the test track with the configuration which was best in the ranking
 - * Less driving faults with preferred front-wheel geometries
 - * Electromyogramm of abdomen is higher when configuration is scaled "good"
 - * SD of steering angle is a measurement instrument for control deviation
 - *unexperienced drivers*: SD is small when driving a configuration with average steering forces
 - *experienced drivers*: small steering forces --> small SD
high steering forces --> high SD
- Ratings for handling quality are better when SD is small or average.

Evaluation of measurement charts

Information obtained by interpretation of charts is more detailed and specific than statistic calculations. Even the subjects' reaction on the single driving task can be observed. The relationship between values may explain results of the statistic calculation.

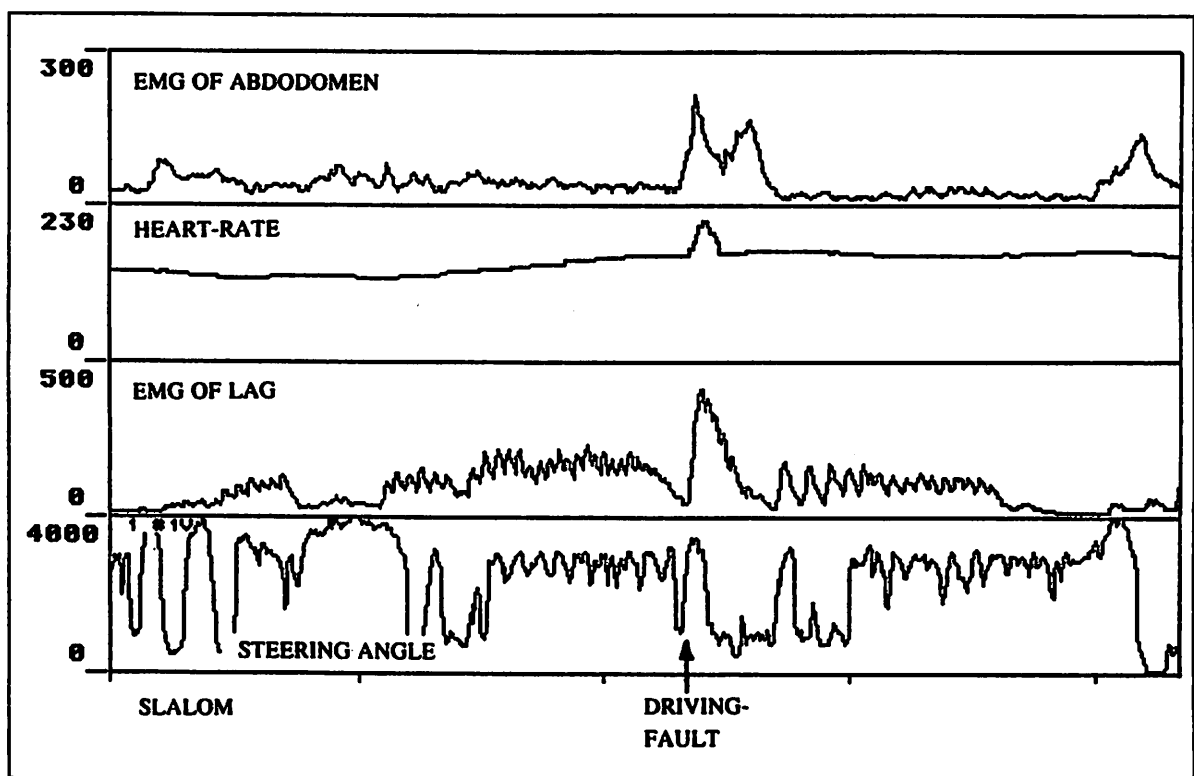


Figure 8: Chart of four measuring quantities showing part of the test ride of Subject JZ

Figure 8 demonstrates as an example physiological reactions of subject JZ after a driving fault. She drove too fast into a curve and began to loose control over the vehicle. A correcting maneuver in order to regain control can be recognized in the steering angle. The short shock caused by this event can be observed as a peak in the measurement quantities heart-rate and EMG-abd. Unfortunately only few emotional reactions were

quantities heart-rate and EMG-abd. Unfortunately only few emotional reactions were registered so clearly.

The chart of the steering angle allows the identification of the exact position of the subject in the test track. In figures 8 and 10 several different driving tasks are marked. Dependency between steering angle and driving mode (fast, slow, rolling) are obvious.

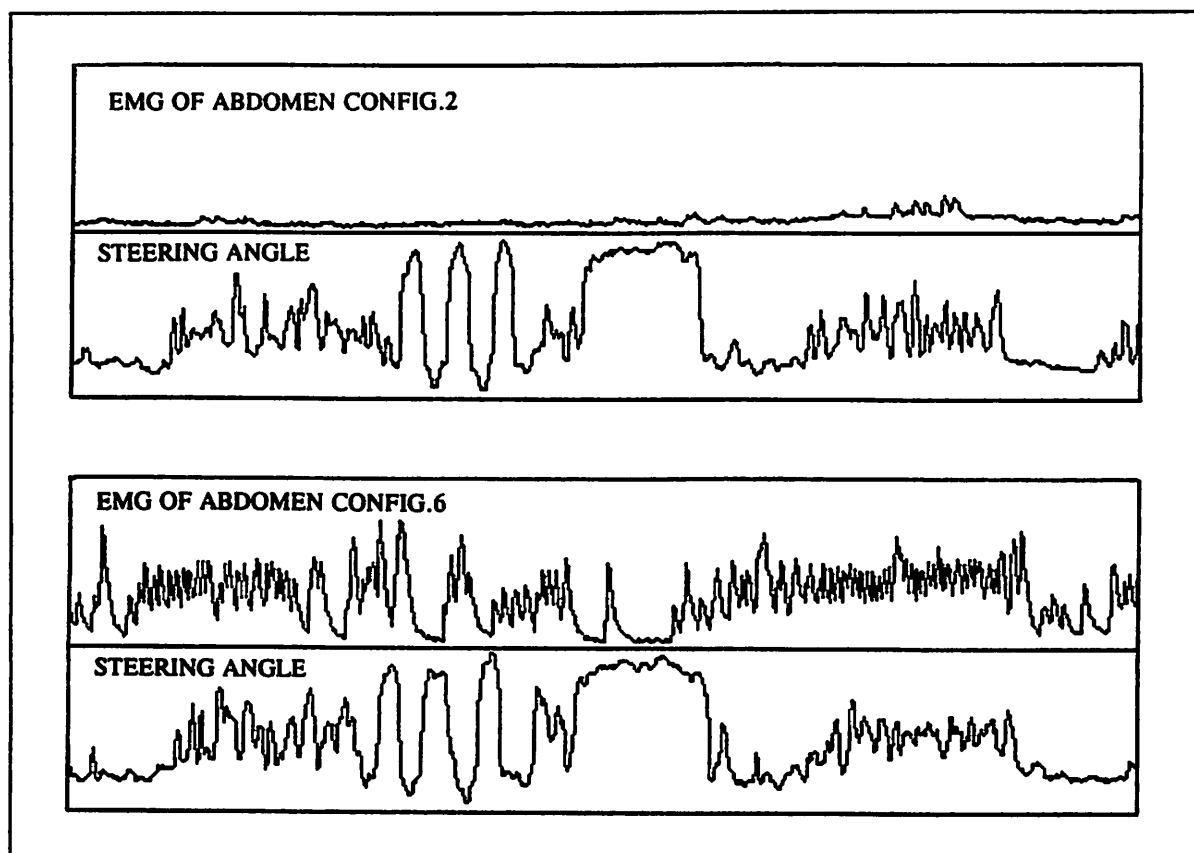


Figure 9: Steering-angle and EMG of abdomen indicating body activity due to steering and stabilising the vehicle (subj. DG)

For one subject the level of EMG-abdomen differed very much depending on the configuration. High values characterize movements of the body in order to operate the vehicle taking over steering and stabilization activity. This is correlated with good ratings in handling quality. The steering characteristics of these front-wheel geometries seem to be predictable and adapted to the requirements of drivers.

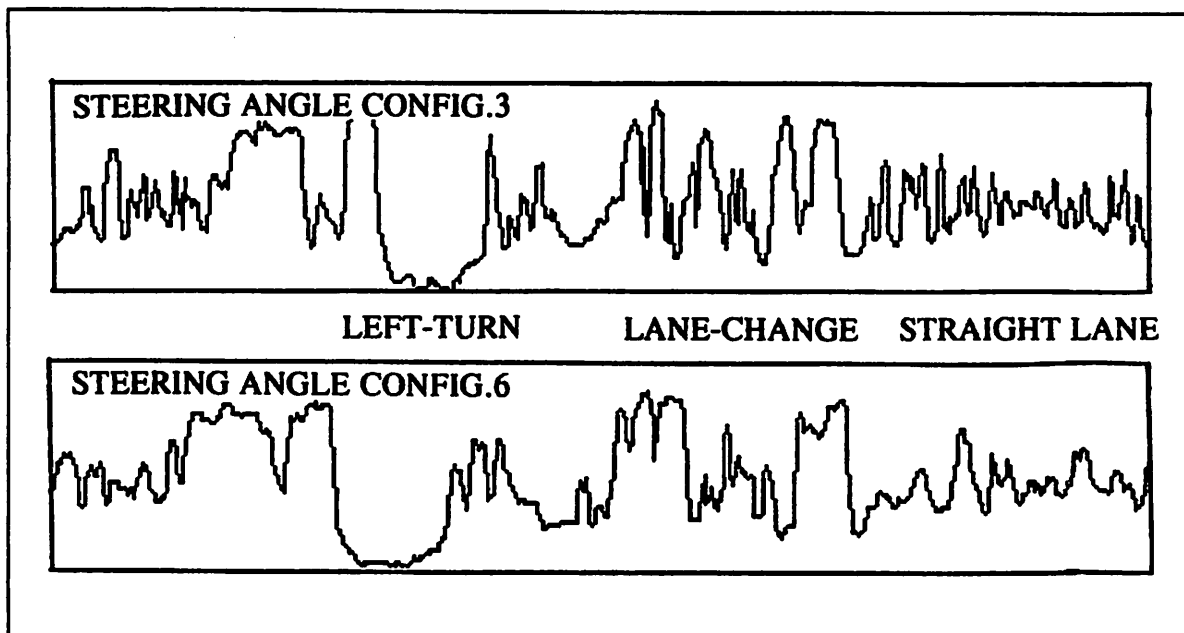


Figure 10: Difference between steering angle due to different front-wheel geometries (subj. BS)

The upper part of figure 10 shows the steering angle of configuration 3 which had a flat head-angle (80°). Frequency and amplitude of steering movements are much higher than in the lower part of the chart. 'Overall handling quality' of this configuration was scaled 'rather bad'. The lower part of the chart shows configuration 6 with short track and steep head-angle. Performance of steering angle is quite smooth in comparison with conf.3. 'Overall handling quality' of this configuration was scaled 'somewhat good'. Subjects had less difficulty in operating the recumbent bike with this front-wheel geometry. Strain caused by the driving task was reduced.

7 CONCLUSION

The results of this handling evaluation are definite: configuration 5 has the best handling qualities of all. In all categories that had to be rated, like 'feeling of safety', 'maneuverability', etc. and the final ranking it got the best ratings. Standard Deviation as measure for the range of ratings is the smallest in this test. This combination of head-angle and track is able to accomplish with the demands of most drivers. Strain caused by the operation of a single track vehicle is reduced.

The following parameters should be used for the design of DESIRA II:

head-angle: $88^\circ - 89^\circ$
 track: 40 - 60 mm

A change in the wheel loading causes the need of an adaption of track.

The two-level sequential judgement rating scale used in this evaluation was an accurate and relatively simple tool for measuring vehicle handling qualities. Driver raters' ability of rating and discrimination was provided by the design of the scale. Results were conclusive rather than accidental. The use of a properly designed rating scale is a good means of evaluating vehicle handling characteristics helping to find design solutions.

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Impacts of Suspensions on Recumbent Bicycles

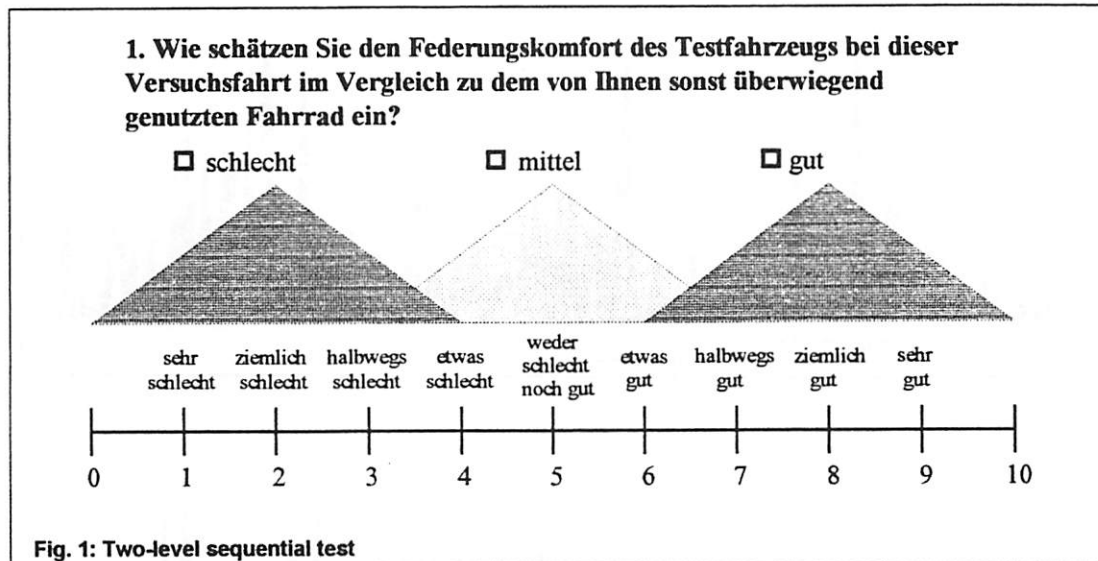
Suspension on mountainbikes has been gaining popularity during the last couple of years. For some people it has become important to have a fully suspended bike simply because it is being the most sophisticated system of mobility. On the other hand there is still a big number of HPV-owners who think full suspension is not necessary for them although their possibility of changing their seating position on the bike is a lot smaller than for riders of mountainbikes.

Within a research project at the Darmstadt University of Technology the impacts of front and rear suspension on a recumbent bicycle were analysed. This analysis was to lead to a recommendation for the suspension-system of the project DESIRA 2. In detail the different effects of front and rear suspension, the different impacts of suspension on comfort and strain and the change of the handling characteristics by installing a suspension system had to be analysed.

Choice of the Important Factors

For this project it was necessary to have suspending elements which are easy to handle and easy to adjust, therefore Elastomer-material was chosen. For a first phase of testing three subjects solved a city-route of about 25 minutes five times with a suspension ranging from rigid to very soft. It turned out that front suspension has to be harder than rear suspension. These findings were used for the main phase of testing.

In the main phase of testing each of nine subjects had to pass the city-route three times, equipped with controls and sensors for heart rate, strain of abdominal muscle and thigh muscle (by electromyograms) and the vibrations of the bicycle. The applied suspension configurations were rigid (for reference), very soft in the rear and soft in the front, soft in the rear and medium-soft in the front. After every lap the subjects had to fill in a questionnaire containing personal questions (Tab. 1) and a two-level sequential test (KÄPPLER, PITRELLA, 1989; Fig. 1) about the qualities of the bike.



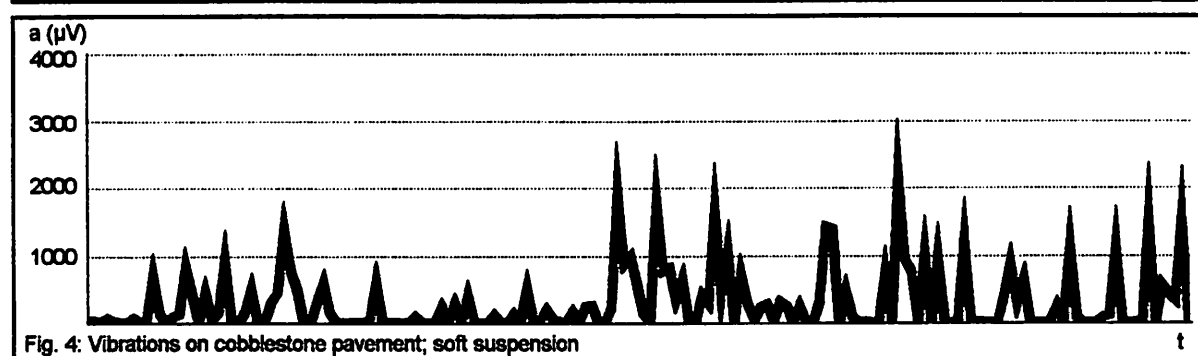
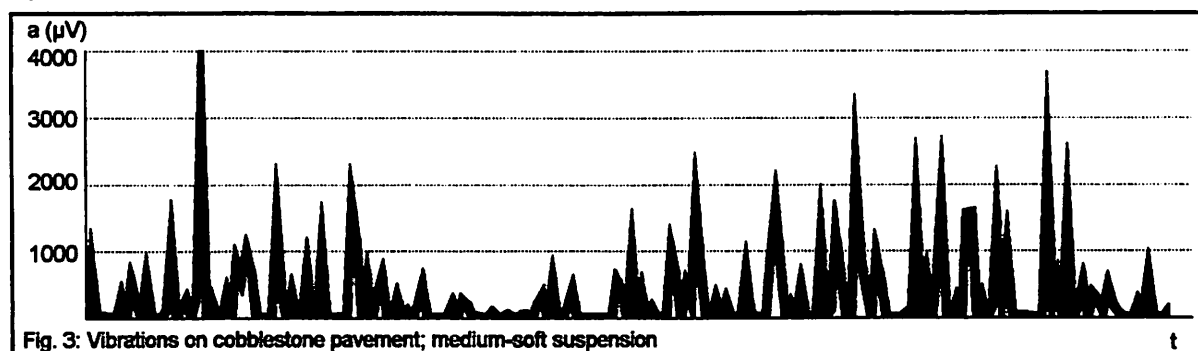
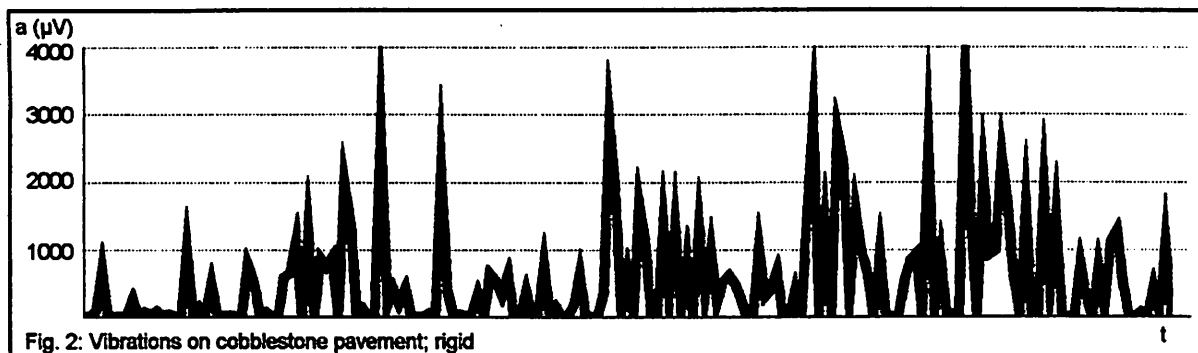
| | |
|------------|--|
| question 1 | Quality of vehicle's suspension compared to a conventional bicycle |
| question 2 | Rating of the elasticity of suspension |
| question 3 | Impression of the differences between good and bad road surfaces |
| question 4 | Rating of the bicycle's ability of going straight |
| question 5 | Rating of the manoeuvrability |
| question 6 | Impression of the safety |
| question 7 | Rating of the bicycles' overall qualities |
| question 8 | Rating of the stress of the abdominal muscle |

Tab. 1: Questions of the questionnaire

With the statistical analysis a great number of interesting results was observed. This was done by a correlation test (HARTUNG, 1987).

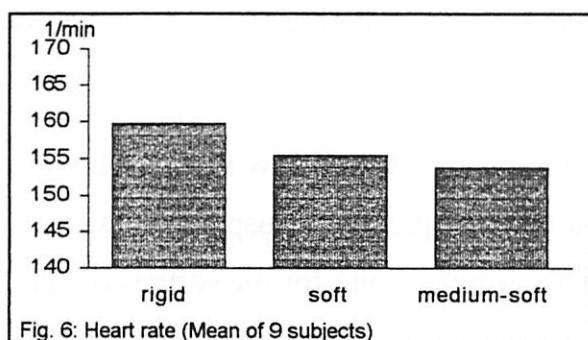
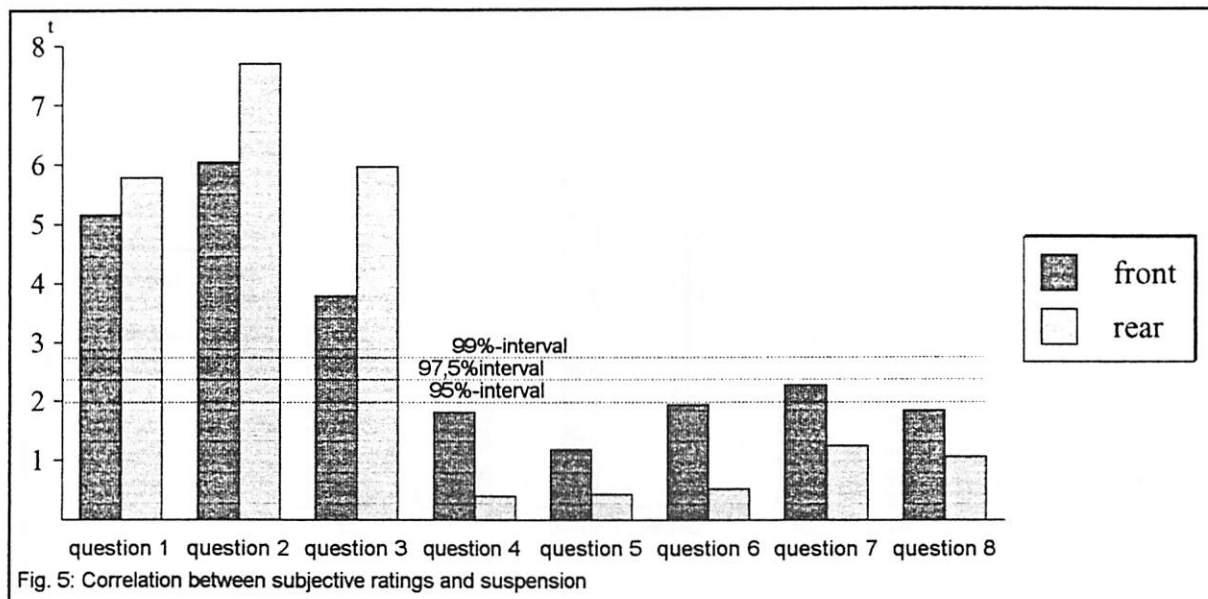
The Reduction of Vibration

The readings recorded at the first lap of the subjects (rigid suspension) were very high (Fig. 2). After the installation of the elastomers the readings of the vibrations on the bicycle were lower. The soft suspension was lowering all vibrations including the peaks. This was very obvious especially on cobblestone pavement which is the worst road surface you can find in the cities (Fig. 4). The medium-soft suspension also worked quite well. Compared to the soft suspension the peaks were higher (Fig. 3).

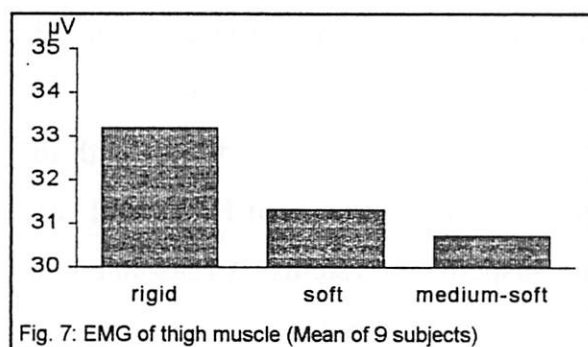


The Impacts of Suspensions on Man

According to the results of the questionnaire the impacts of front and rear suspension were different (Fig. 5). Rear suspension is very important concerning comfort aspects like the difference between good and bad road surfaces (question 3) or the suspension compared to the comfort of an ordinary bicycle (question 1). In contrast to this the front suspension is important for the judgement of aspects like safety on the bicycle (question 6) and the quality of the bicycle in general (question 7). For other questions as manoeuvrability, safety in general or the stress of the spinal column (questions 5, 6 and 8) there may be differences depending on front or rear suspension but no significant results could be found.



The impact of the suspension on the heart rate Mean (Fig. 6) was a change from an average of 160 beats per minute without suspension to 155 beats per minute (soft configuration) or 153 beats per minute (medium-soft configuration).

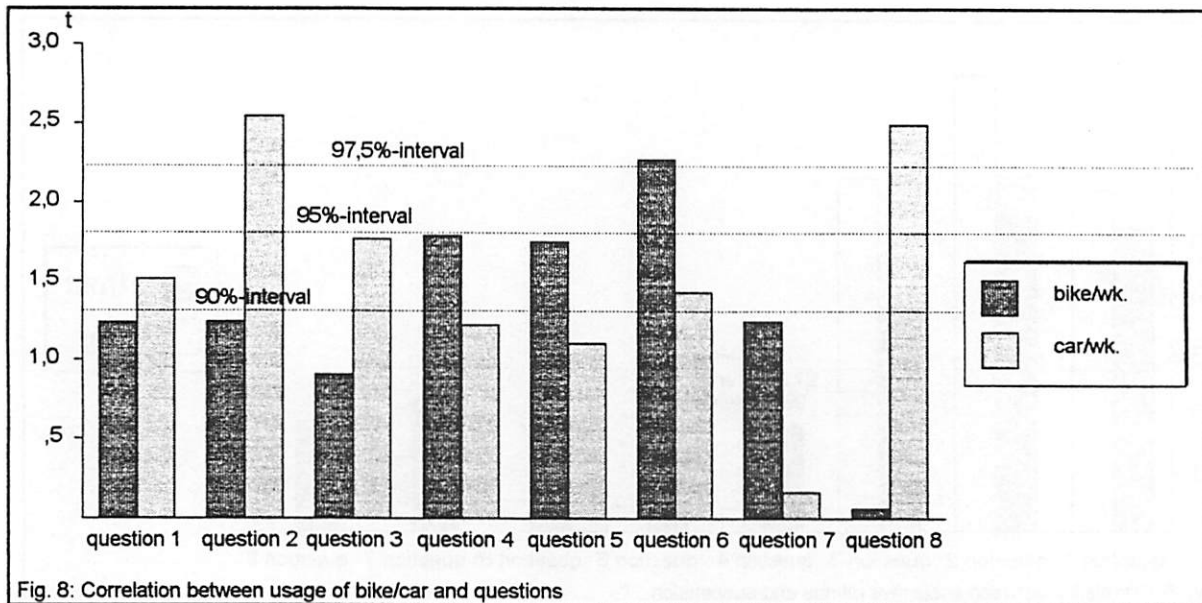


The Mean of the thigh muscle strain could also be lowered by using suspension (Fig. 7). Again it was obvious that the suspension may not be too soft when the best results shall be obtained.

Group-specific Reaction

According to the subjects' most favoured vehicle some people behaved significantly group-specific.

Subjects who prefer bikes for transportation are very critical regarding safety questions (handling characteristics, manoeuvrability and safety in general). The more kilometres were driven weekly the less was the rating given for these questions (Fig. 8).



This is because they do know how a bicycle has to react and so at first they are confused by the reactions of a fully suspended bike.

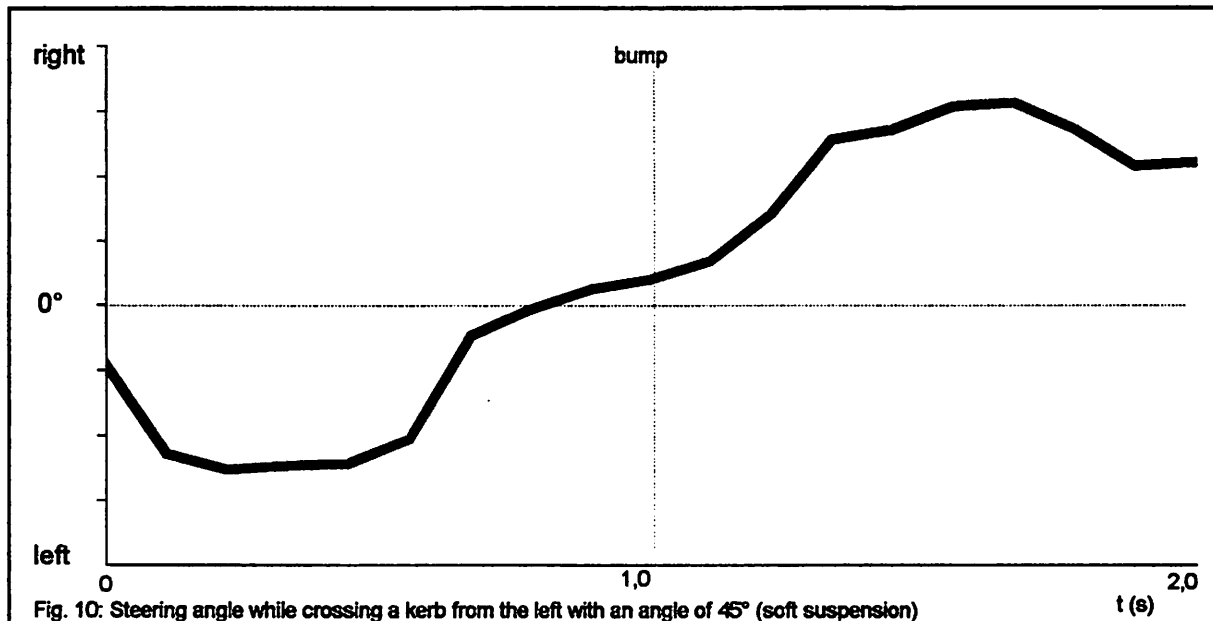
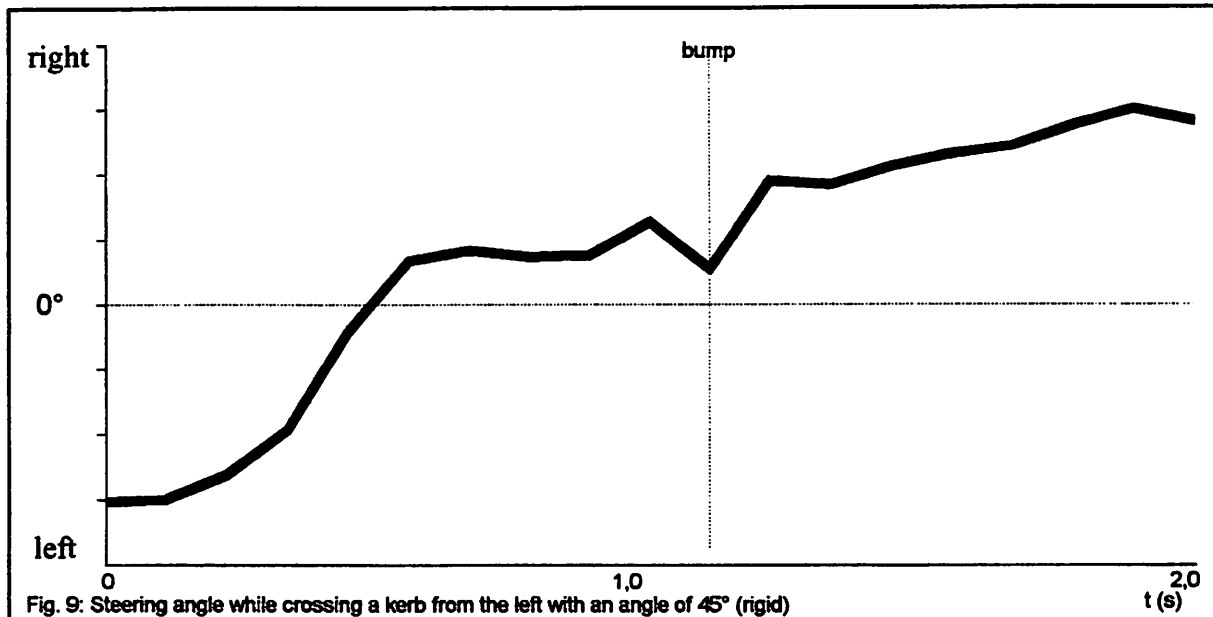
People preferring the car for transportation - the target group for new types of low or zero emission vehicles - show different behaviour. The quality of suspension is rated very good, a lot better than by other subjects. This group's rating for the softness of the suspension was better than from other groups in all cases. The difference between different road surfaces is always rated smaller than by other groups. Obviously they do not know how good bicycles can be because they never ride them. The sensitivity for the stress of the spinal column is getting less the more kilometres are driven with the car weekly. The reason of this might be the similar seating position of HPVs and cars. Users of cars are satisfied with relatively simple suspension systems. A reasonable alternative for the car has to be solid, lightweight and easy to handle.

The users of public transportation did not show a behaviour significantly different from the average in any of these questions.

Interesting results were observed by asking for the readiness of the subjects to pay a certain amount of money for a new (conventional) bicycle. The people who are ready to pay more money for a new bicycle expect a higher level of manoeuvrability and their ratings for the safety of the bicycle are worse than the ratings from other people. They demand very high standards because they do know that bicycles do not belong to the lower level of technology anymore.

Manoeuvrability

More detailed informations were obtained by measuring the steering angle while crossing a kerb with an angle of 45° . Without suspension the driver has to react on a bump on the front wheel coming from the side with the readjustment of the steering angle (Fig. 9).



When the front wheel touches the kerb a strong beat can be observed.

As soon as the vehicle is equipped with a suspension system the driver is not disturbed by the bump anymore (Fig. 10). The suspension system flattens the curve and takes away the bump.

This is not necessarily an advantage because the same effect causes inexactness of the steering unit so that small readjustments of the driver are necessary even on a straight course.

It is obvious that the main principle of suspension systems should not be "as soft as possible" but rather "as safe as possible" because the manoeuvrability of the bicycle is getting worse as soon as suspension is too soft. If these principles are observed the installation of a suspension system is a big step towards a good transportation alternative to cars in city traffic.

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KÄPPLER, W.-D. / PITRELLA, F. D.: Evaluation of Vehicle Handling: Design and Test of the Two-Level Sequential Judgement Rating Scale. Forschungsinstitut für Anthropotechnik, Wachtberg-Werthhoven, 1989.

Subjective Speed as a Major Safety Factor

Theo Schmidt

Introduction

As is well known, speed is one of the most important factors relating to vehicle safety. The probabilities of not seeing something, of errors in judgement, of actual driving errors leading to loss of control, and of actually colliding with something all increase greatly with speed. As the vehicle's momentum is proportional to the speed, and its kinetic energy to the square of the speed, the severity of a collision and the degree of injury are also sensitive functions of speed. According to Ref. [1], accidents occur about proportional to the square of average driving speed, injuries about to the third power, and deaths even to the fourth power of average driving speed, i.e. very small changes in speed make all the difference between life and death.

Therefore the reduction of driving speed is one of the most effective and traditional methods of increasing vehicular safety. This is in conflict with the fact that almost everybody loves speed and that this is a highly emotional and political issue. Even the HPV movement was born out of a racing context where the aim is to increase speed, and the annual competitions of the International Human-Powered Vehicle Association are still called Speed Championships. A large number of IHPVA members are also primarily interested in racing and not in practical vehicles or safety.

HPVs have the great advantage that in general their speed is intrinsically limited to more or less safe speeds by the limited supply of human power. Problems do occur going downhill but here another characteristic of most HPVs prevents things from getting out of hand completely: the lightweight and often unsprung construction transmits the feeling of speed directly to the rider who is at least made aware of the danger of going too fast. However as HPV construction improves, suspensions are developed, and hybrid vehicles with motors appear, speeds will increase and it is important to pause and reflect on ways of preventing a decrease of safety. The following remarks are formulated in a general way because they are valid for all vehicles, and for true HPV safety we must prevent speed excesses of not just the velomobiles themselves, but of all automobiles and other vehicles likely to hit them on the road.

What is speed?

When you ask someone why they have a fast car, why they overtake on the road even when it is risky, why they are against tighter speed limits, they will tell you that they need to go fast in order to get from A to B quickly. Except in very exceptional circumstances, this is nonsense, as the amount of time which can be saved is quite minimal, on the order of seconds or minutes for average trips. For example, someone who drives 90 km/h instead of the allowed 80 km/h on a main road (in Switzerland) will save about 3 minutes on a 40 km trip. As it is rarely possible to drive such speeds without having to slow down frequently for other traffic or in towns, the actual time saved will be even less. Even on motorways where consistent high speeds are more easily possible, the time saved between going "fast" and going "slowly" is only a tiny fraction of the total journey time.

Contrary to what people tell you or even to what they believe themselves, the actual speed is quite unimportant, what matters is the *feeling* of speed. Fanatical motorcyclists or teenage racers are more honest and admit openly that they want to go as fast as possible just for the thrill of it. However the same principle applies to everyone, even to people who are very safety or energy conscious; given a choice they will drive at precisely the speed that they *feel* best with. Furthermore this principle isn't restricted to cars: it applies universally to all vehicles and even to people walking or just living, one could say to life itself. People walk at 6 km/h or so because this is most comfortable, even though they could easily run at twice the speed. But forced to slow down behind someone walking only very slightly more slowly, most people get nervous and try to overtake. If this is not possible, they get upset. Riding in a bumpy bus, a scenic mountain railway, or an urban tram, 30 km/h feels quite adequately fast. The same speed in an intercity train kept up for any length of time has people getting nervous wondering what the matter is. Flying in a small airplane or glider at 100 km/h over land is quite interesting, flying at many times this rate in a commercial airliner high above the clouds is not very exciting and the airlines try to counteract this boredom with food, comfortable seats, video, etc.

The principle is always the same: no matter what you do or how you travel, there is always a rate which is felt to be comfortable and any variation from the expected or from the choice is met with apprehension. The expected speed or preferred speed not only varies widely with the type of vehicle but also with other factors such as surroundings or acquired behaviour patterns. Driving in western USA is for example slower and much less stressful than the typically hectic driving in Europe.

In a given situation (vehicle type and condition, road type and condition, surroundings, weather, time of day, etc) a driver will have a personal preferred speed. Having to drive below this speed, the driver will become increasingly bored, nervous and uncomfortable and given any choice he will go faster. He will also have a subjective feeling for danger and will increase his speed until the speed-induced feeling of exhilaration is balanced by this *feeling* of danger coming from the *perceived* risks.¹ Other factors which influence the chosen speed in one way or the other are the momentary state of mind and body, an unusual or especially pleasant environment, amount of traffic, and very importantly, interactions and communications with other road users.

What is a safe speed?

Unfortunately, the chosen speed is very often higher than the speed which could be defined as safe in the given situation. Here we will define a safe speed as the speed which will result in a chosen number of casualties in a particular set of conditions. If this number is zero as one might hope, the safe speed might however also be zero, so this isn't very helpful. A more useful definition might be that the chosen number of casualties should be less than that due to any single natural cause, which would mean a several-fold reduction compared to the situation today, where traffic accidents represent the greatest of all not self-inflicted risks. If this reduction is the goal, then today's vehicular speeds are (by this definition) in general too high. In fact it is the policy of every European country to reduce the present casualty rate by a large amount, but the policy-makers do not use proven and obvious methods like lower and strictly enforced speed or

¹ Perceived risks have little to do with actual risks: travelling on the road today is very much more dangerous than flying or using a cable-car, yet many people who drive quite happily are frightened of using these.

alcohol limits because the auto lobby has so successfully swayed public opinion toward an uncritical acceptance of a transport system which is emotionally successful but rationally an unmitigated disaster for all mankind. The benefits of using an automobile and in particular of driving fast are obvious, individual, and short-term. The disastrous side-effects are less obvious, long-term, and affect everyone.

Even if imposed, lower speed limits would simply not be adhered to except in strict police states, as people will drive their chosen speeds at almost any cost. The key must therefore lie in working on the chosen speeds, i.e. these must be reduced to below the defined safe speeds. If this can be done, vehicles so designed will be automatically driven at safe speeds with less need for speed limits, surveillance, traffic police and legal bureaucracy.

Shifting towards safer speeds

How can we reduce the chosen speed? The most effective way well known to the participants of this seminar is the use of human power. Riding a bicycle at 20 km/h or a fully-faired HPV at say 40 km/h is pleasant. Except when racing or training, there is not much incentive to go faster, as a great deal more exertion produces only relatively little extra speed. Cyclists try to find pleasant routes where they can benefit from being able to look at the scenery. Put the same cyclist in a car and he will drive much faster than 40 km/h in most situations. If forced to stick to 40 or some lower speed for any length of time, the same person who can happily cycle at 20 will become upset. Although there are differences between car types, drivers and even nationalities, all cars made today have in common that the chosen speeds are in general higher than any speeds definable as safe, unless one is satisfied with today's enormous loss of life on the roads. This has occurred because car manufacturers have not been able to — or have not even wanted to — use human factors knowledge in the correct way. Cars drivers are isolated too much from the road and the world and do not feel the physics acting on their vehicles. In a car we get so little sensory input at low speeds that we must go faster in order to increase the rate of the optical input we do get, otherwise we get bored and inattentive, which is bad as well. The speed we do end up at is usually too high. It may be okay for 1000 km or even 1'000'000 km. But the average car driver travels several million kilometers and it only takes one mistake for one split second to kill oneself or someone else.

Positive factors influencing subjective speed

As noted above, the subjective to objective speed ratio is better for cycling or velomobiling than for most motor vehicles. Why is this? Apart from simply not being able to go faster, why are we satisfied with much lower speeds? Is it simply the acceptance of the unalterable? Is it the song of the tires on the road or the wind in our faces? Is it the immediate acceleration felt on a very light racing bike at each push of the pedals? Is it the endorphins, natural body drugs which are produced under muscular activity? Is it the rapid consumption of other speed-induced, stress-producing chemicals such as adrenalin, which lead to extreme stress and irrationality in car drivers who are not able to use their muscles?² Or is it the feeling of being free, having as little vehicle as possible and yet going faster than without a vehicle at all, feeling a bit like superman?

² Schmidt's Law: "Conciliatory driving is inversely proportional to the kinetic energy of the vehicle."

It is probably a combination of all these in varying degrees. The last point, the superman effect, is a conjecture of mine which applies to a large part of the population, mainly young and active people: such people love sports where it is possible to move their bodies in a way which simulates speed and/or flying like a bird, but without using a huge contraption. Such sports are paragliding, skiing, skating, surfing, sailboarding, canoeing, sub-aqua and springboard diving and indeed cycling itself.

With all of these, the feeling of speed is much greater than the speed itself, as is typified by subaqua-diving: gliding effortlessly over the sea bottom or amongst the wildlife of a marine wonderland feels as much like flying as anything else even though the actual speed is only very few km/h.

Getting back to practical transportation, we see why the TWIKE³ has kept its pedals: even though this three-wheeler has a powerful electric motor and a battery with more energy than you could generate in a week, even though the fraction of the human power drive is very small in comparison, even though the pedal drive imposes an extra cost on an already expensive vehicle, the pedals are kept because it simply feels better to be able to pedal than forced to sit still. Other people besides myself and the TWIKE group also propose this principle: Michael Kutter with his electric bicycle VELOCITY, Alan Abbott, who says that exercise even in a very heavy vehicle is better than no exercise (think of all those people who drive their cars to a fitness club and then pedal away on a stationary exerciser!), Jim Kor with his Solos and Ulo Gertsch with his TRIMO (both described in these proceedings). So, even if the pedals increase the actual speed of such vehicles by only a small fraction, they increase the driver's subjective speed by a large amount. The driver can thus actually travel at a lower speed than if he had a pure motor vehicle and still be happy. Or to put it simply, driving a vehicle which feels fast is just as fun as driving one which is fast, but usually safer! (The extreme would be the person who works at home yet drives to work every day while stationary at 200 km/h via the Indianapolis Circuit or the Nürnberg Ring on his "Cybervelo".)

There are other positive factors which increase subjective speed (not the subjective speed limit), making the driving experience more attractive with more sensory input and mitigating the desire to go fast. Most measures for this also influence other safety aspects and must be chosen carefully.

- A low driving position increases the perceived angular speed at which the road goes by. This is also good for vehicle stability, but gives the driver a poor overview and reduces the quality of communication with other road users.
- An open vehicle improves communication with other road users and lets the driver feel the vehicle's speed and wind influence, but decreases passive safety and weather protection.
- Strong acceleration is exciting but is usually achieved with powerful motors giving the possibility of highly excessive top speeds. Properly designed light electric vehicles however can achieve strong acceleration at low speeds even with motors with quite low power ratings. If the motor is controlled by the pedals as in a servo mechanism, such a human power amplifier gives a terrific feeling when accelerating, invoking the "Superman effect" mentioned earlier. It is my opinion that incorporating this principle in a vehicle could be a major factor in making it a commercial

³ The TWIKE is a two-person human/electric hybrid tricycle soon to go into limited production.

success. Vehicles without motors must be as light as possible even in areas without hills: really light vehicles such as racing bikes have extremely good acceleration from standstill, better than most cars, and this not only feels good but is a safety factor in city traffic. There is less hesitation in braking when using a vehicle which accelerates easily. Cumbersome vehicles are more likely to be run over red lights, etc. Most bicycle gearing systems are poorly suited to easy acceleration.

Much of the above also applies to manoeuvrability: A small and nippy vehicle is not only very practical but great fun to use. This is one of the reasons for the continued popularity of upright bicycles and the unsuitability of long-wheelbase recumbents for congested cities.

- Large windscreens and windows (or indeed open vehicles) give a better view, increase the perceived angular velocities, improve communication with other road users, but can decrease passive safety.

Negative factors influencing subjective speed

Besides the positive factors mentioned above, there are many negative factors which decrease the driver's subjective safe speed limit: hard suspension, poor damping of noise and vibrations, tires and components with a fragile appearance, purposely missing information about actually implemented safety components, etc. All of these have a negative connotation, so that vehicles equipped like this are not likely to be popular unless especially cheap or having other special advantages. Vehicles which really are cheap may have the desired low subjective speed limits but are likely to be lacking in basic active and passive safety components. A solution toward this problem is to equip the vehicle with the best safety components yet arrange for special active mechanisms to become effective when an unsafe condition is approached, such as a suspension which is comfortable at moderate speeds and hardens up at high speeds, or steering which is normally smooth but begins to vibrate when excessive cornering forces are applied. The controlled introduction of noise and warning lamps or even voices are also possible. Such solutions are only very partial and are likely to be expensive and perhaps misinterpreted by customers.

Cars are dangerous precisely because developers have managed to remove most of the negative factors but have not been able to incorporate enough of the positive factors leading to driving at safe speeds. Velomobile developers must not make the same mistakes but must incorporate enough positive factors before removing the negative factors.

What speed in other traffic?

So far we have only looked at the simplified case of a single vehicle. In most traffic situations there are many vehicles and the interactions between their drivers are complex and very important.

Earlier we have said that most motor vehicles are consistently driven too fast and should be slowed down. Although mixing slow vehicles with fast ones will reduce the average speeds, this should only be done very gently, as the frustrated drivers who would like to drive fast and are hindered by slow vehicles tend to take great risks, and thus create dangerous situations. It is an axiom of traffic engineering that safety increases the more similar the vehicular speeds are. As there are always vehicles which are considerably slower than others, e.g. velomobiles going uphill, or faster than others, e.g. bicycles in congested traffic, such vehicles should be built to be easily overtaken or overtake: they must be narrow and short. Although it may seem unfair that HPVs in Switzerland should not exceed 1 m width, it is desirable from a traffic point of view. This also has an other extremely important safety effect: it is plausible to suggest that small vehicles are less likely to hit something or be hit by something, than large ones. This is probably one reason cyclists are not even more endangered than they are, and automobiles (most of which are much larger than necessary) are so often involved in collisions.

To sum up: make the design speed of your vehicles just slightly less than average, thereby bringing the average traffic speed down slowly without upsetting anyone but the maniacs. As your vehicles get more popular, the average speed can be decreased further. Make the width of the vehicle some function of the speed. A narrow vehicle is easily overtaken on almost any road and is hardly a hinderance no matter how slow. A wide vehicle should be able to keep up with the general traffic flow.

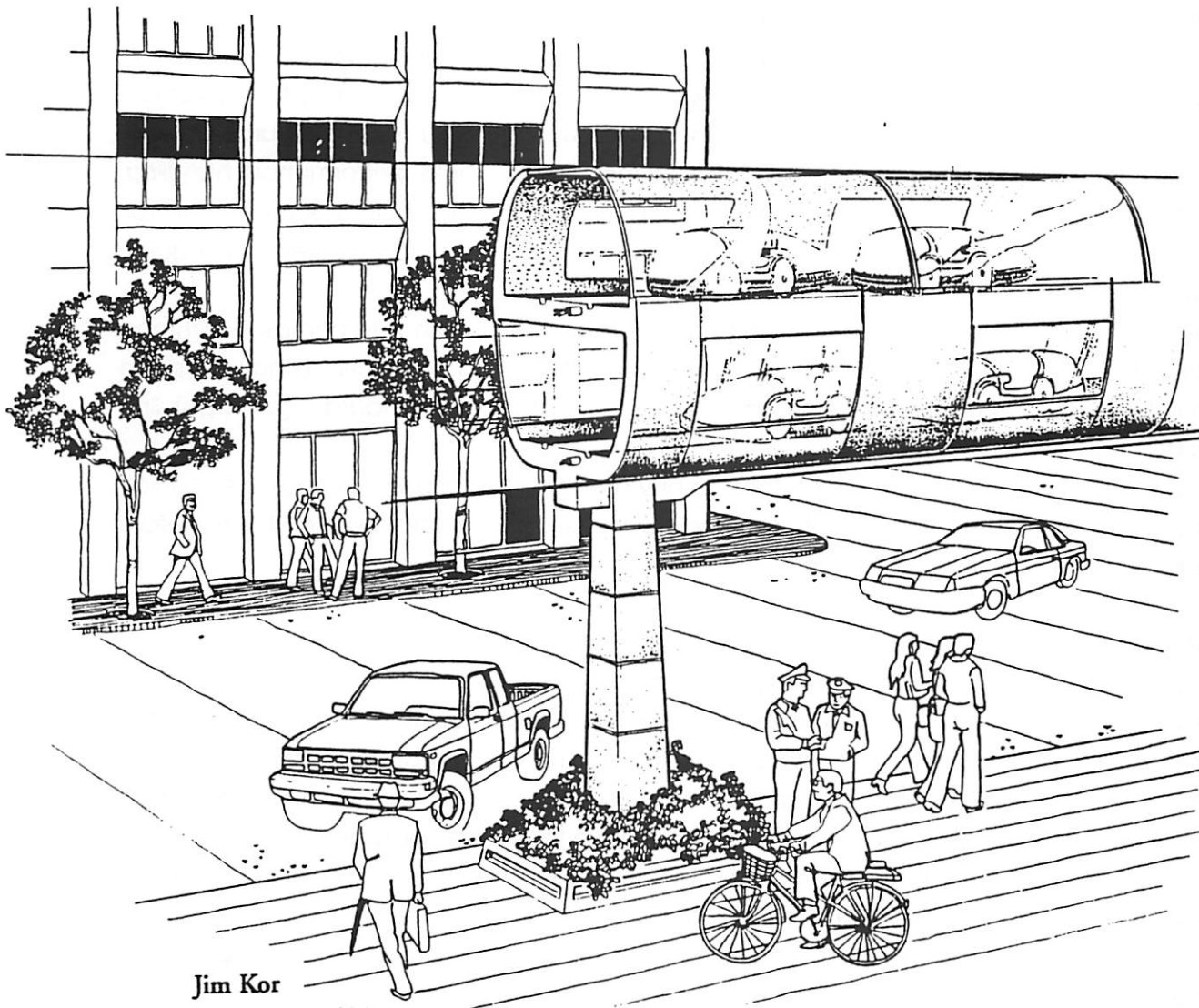
Conclusion and Summary

Traffic speeds are in general too high, resulting in an enormous loss of life. This has happened because motor vehicle designers do not correctly use human factors engineering or vehicle psychology knowledge. HPVs are inherently better in this respect because of the lack of power and the necessity of lightweight construction. As velomobile designers attempt to make their vehicles more popular, e.g. making them more comfortable with springing and faster by adding motors, safety will decrease unless it is possible to compensate for the removal of "negative" speed-reducing factors by the introduction of "positive" speed-reducing factors, that is subjective speed enhancers.

References

- [1] "Die Verkehrssicherheit in der Europäischen Gemeinde", Grondeau C., Zeitschrift für Verkehrssicherheit 2/92
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DESIGN



Jim Kor
Solos Personal Transit

Bare Necessity – Design for HPVs

Target

If your aim is to build a HPV for yourself, your friends or for some insiders, the following thoughts might not be of any bigger interest to you. But if your goal is to construct vehicles that are taken seriously as a product, also by a vast majority neglecting technological finesse, this essay might give you some hints.

Acceptance problems of the Velomobile

Ever since the recumbent bike has been banned from the official racing scene in the 1930's because it was too fast and therefore a threat to the bike industry, it had to make and prove its way on alternative stages. The reasons why it hasn't found broad acceptance yet are numerous. Many of them are interlinked and bike-specific. If you take a recumbent bike naked, it will immediately be compared to a "normal" bike by looks, performance, handling. The diamond frame has burnt its image into people's heads over a period of more than 100 years. Therefore you can't expect neutral, objective opinions. Prejudice also reigns in judging technical innovation.

If, on the other hand, you show a HPV with fairing, its **appearance** has to compete with cars or at least with motorbikes. Unfortunately it is exactly these two products, along with some consumer products like walkmen or sports-equipment, that set the standard regarding styling and design.

You will never get an "average consumer" to buy a vehicle that makes him look like an idiot. This decision is unconsciously emotional and happens within a split second, it is therefore much stronger than rational arguments.

How to deal with these problems

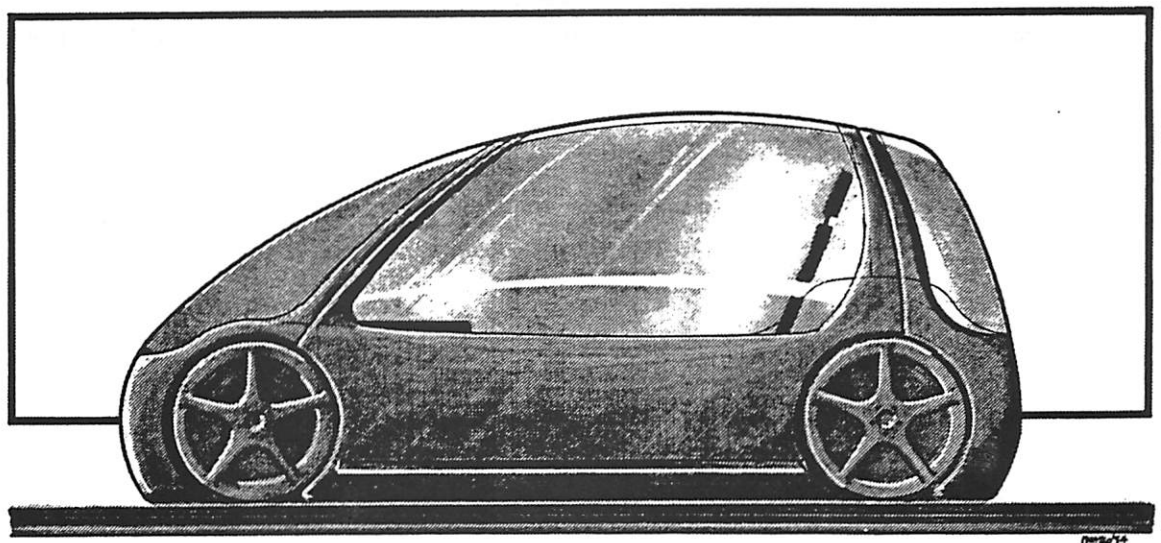
Fighting prejudice on a rational base is much harder than convincing on an emotional base. The aim should be to create HPVs showing their functional and technical qualities to the outside. Just by looking at it anybody ought to know immediately that he or she is standing in front of a high-tech, fast, passionate product. Don't make an everyday-use recumbent **look** like "everyday-use" – but give it the race image world records provide. If your concept doesn't work with sleek, aggressive styling, or you want to push other qualities, go for a fun, rascal-like character. In any case, the proportions, surfaces and graphics have to be perfect and emphasize each other. Whenever working together with an industrial or transportation designer, one should always involve him/her right from the start of the project. A good designer will not only work on concepts, ergonomics, consumer needs and styling, but also keep a close relation with the engineer to make sure manufacturability is maintained and production costs are low. To realize these points, the HPV-scene has to go more professional. It's amazing how big a knowledge there is technologywise and how little there is design- and marketingwise.

Engineering, design, marketing and production are the main ingredients one needs to succeed. None of these parameters should be underestimated.

A paper presentation
of the Second
European Seminary
On Velomobiles

solos

PERSONAL TRANSIT



Written by: **Jim Kor, P. Eng.**
Senior Designer

to start ...

"The thing that seems to come out most clearly is that there are technological solutions to many of our contemporary human problems, but in no field that we stumbled into (possibly excepting communications) did we find them being used in any significant way, or any indication that they might be in the next three decades."

Why aren't currently available technologies being used?

We suggest that the imposition of institutions - governmental, religious, educational, corporate - which were formed in agrarian and rural times, simply do not allow a technological society to function at anywhere near the efficiency that it could. And by efficiency we mean the least "heat loss" in any energy transaction.

Through their vast bureaucratic waste, most existing institutions dissipate much of the human and ecological benefits that could be enjoyed if the institutions adapted themselves to the post-industrial-age realities of the contemporary technological era.

This is not to say that technology, as usually defined, can solve all our problems. We don't believe it can. We feel that it might help to solve some of them.

For example, there is no reason to continue the 19th Century transportation systems we have today.

There is no reason. No reason at all."

Quotation by Don Fabun in "Dimensions of Change", 1971

"All life is roads, for all life is movement. Animals began it; then primitive man, then caravans, armies, ships. With them went fabulous wares, rubies, and gold for the eyes' delight. Bronze for the helmet, tools for the hand, cedar timbers to build the house - rainbow silks of Samarkand. Ahead of each went the idea. The true roadmaker."

Quotation by Madge Jenison in "Roads", 1948

This paper relates to ultra-light and super-efficient passenger vehicles and transport systems integrated into a mass passenger transport. Called solos personal transit, this transportation system addresses the need to move people efficiently within any vibrant city, and the growing necessity to reduce the congestion and pollution now common in car-based urban centers around the world.

Solos is a system of personalized vehicles moving within weather-protected corridors. These corridors are permanent, glass-enclosed structures that are erected along high density traffic routes that warrant this investment. The complete solos network consists of corridors connecting off-line stations spaced approximately 1/4 mile apart. The vehicles provide personal space similar to the car, the inherent safety and non-attentive requirement of the train, and the direct non-stop trip of the freeway.

Solos is a public system where the vehicles can be accessed and used by any member of society. Solos has been designed to not just be wheelchair accessible, but to accommodate all of the physically challenged as well as the traffic-vulnerable or fragile groups within society (estimated to be between 30% and 50% of the population).

Within solos, the size and weight of the vehicle has been dramatically reduced, in comparison to present mass transits (buses, trains, etc.). Also, the integrated vehicle/corridor design has been optimized regarding energy use, and has reached such a low requirement that the vehicles can be powered by a combination of electric and human power. When not utilizing any electricity, vehicles can maintain the line speed of 25 kph (15 mph) with an energy input from the rider similar to that of walking (0.1 horsepower). It is not essential that riders provide assistance, as the journey can be accomplished on electric power alone. However, the rider's incentive to do so is that the journey is accomplished slightly faster, and that the required leg movement provides a comfortable and healthy form of mild exercise. The over-all electrical demand of the entire solos system is low enough to make feasible the generation of on-site, non-fossil-fuel-based electricity.

Capacity and range of solos addresses city center applications. Due to its holistic approach and over-all appeal, solos is able to effectively compete for ridership with existing modes of transport. Being a small mass transit system, solos promotes a built environment more in line with the human scale, allowing for a more livable cityscape.

Solos contributes to the greening of our modern urban landscape.

➤ Introduction

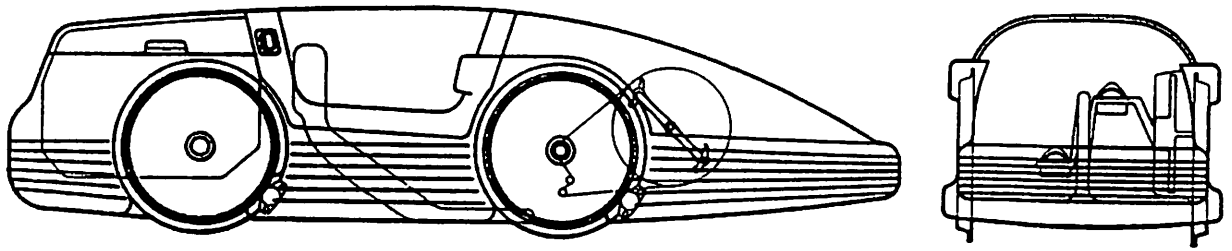
Solos is a grouping of existing technologies. With that said, to best understand and appreciate solos, one should realize how this system evolved; its beginnings and its inherent philosophies. My purpose, in this paper, is to describe these to the reader, while placing emphasis on how solos relates to the focus of this velomobile conference. Due to space limitations, I will only briefly initiate the reader to the exact workings of solos. If interested in technical details on this transit, beyond those basics found in this paper, I encourage the reader to contact our company directly. We will be pleased to send you a comprehensive technical package on solos. Send inquiries to: KOR Product Design Inc., 866A King Edward St., Winnipeg, Manitoba, Canada R3H 0P7, phone (204)783-3348, fax (204)786-2972.

➤ History of the Idea

Solos is not just an idea that has been put on paper all at once, in a single sitting. It is a solution that has emerged after extensive research, and after having undergone several major iterations. Far from being the idea of a single inventor, solos is a solution that has been arrived at by the careful attention of many professionals in rather varied disciplines (mechanical and civil engineers, industrial designers, architects, physiotherapists, marketing, business administrators, etc.).

The solos project commenced in the summer of 1989, during a period when KOR, a consulting design/engineering firm, was in-between projects. Fueled primarily by interest in transportation and the environment, KOR undertook research in the area of urban commuting. Every working day, in the USA alone, approximately 40 million people climb into their cars in the morning, drive by themselves an average of 7 miles to work, and return the same way at the end of the work day. This continuous cycle, repeated to a lesser extent all over the world, utilizes the earth's non-renewable energy resource in an extremely inefficient and potentially damaging manner. KOR's research, documented under the code name DSS (Department of Supply and Services unsolicited proposal section), took over 4 months to complete, and focused primarily upon the problem at hand and placed it in a historical context. Being product designers, KOR did offer, within the final document, a glimpse of a rather idealistic commuting system as an example of what could be.

As KOR became busy with consulting work, this document was temporarily shelved. No further work proceeded until KOR decided to send a copy of the research document to Bicycling magazine. Scott Marten, the associate editor of Bicycling, was interested in doing a story about the ideal commuting system. He requested that KOR give this area more thought, and that KOR create visual images of this system. In March, 1992, the story "Cycle City 2000" appeared in Bicycling magazine, in which Skyway was described. This article, which included KOR's address, created a swell of interest. Over 700 requests for further information were received by KOR, from avid cyclists as well as transportation planners, academics, and professionals from around the world.



This interest motivated KOR to produce a slide presentation around Skyway. This was presented at various environmental conferences and universities (Globe 92, IHPVA Championships, University of Washington, etc.).

Dave Shaw, from the Seattle Bicycle Exposition organizing committee, asked KOR if a display could be made of Skyway, to be featured at the 1993 Seattle show. KOR was postured to begin an industrial design study, which was then modified into a 30 feet by 10 feet display. This display showed the Skyway vehicle in full scale moving along a section of enclosed, elevated corridor.

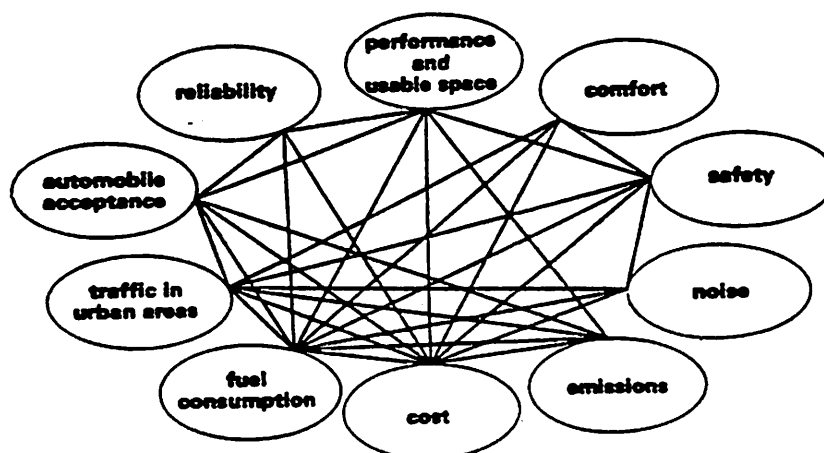
After Seattle, KOR presented the project to various levels of Canadian government (municipal, provincial, and federal). Financial assistance was acquired, and KOR embarked upon an 11-month research program, starting October, 1993. This program included extensive technical as well as market research, and transformed Skyway from a story of personally owned vehicles in enclosed passageways into solos, a true public transit accessible to all. The Forks, a potential site within Winnipeg, was used as a focus for the study, and as a typical application for solos. A prototype solos vehicle was built and tested under this program.

To date, over \$500,000 (Canadian) has been invested in the entire solos project.

Next steps include more engineering and marketing, as well as the construction of a test track facility, that includes a station, a switch, and a bend in the section of track. After further testing and verification, a demonstration and pilot installation will be undertaken.

It is important to keep in perspective the basic philosophies that have molded DSS, Skyway, and solos since their inception in 1989. From a very idealistic beginning, over the years solos has come closer to the real world while maintaining these ideals relatively intact.

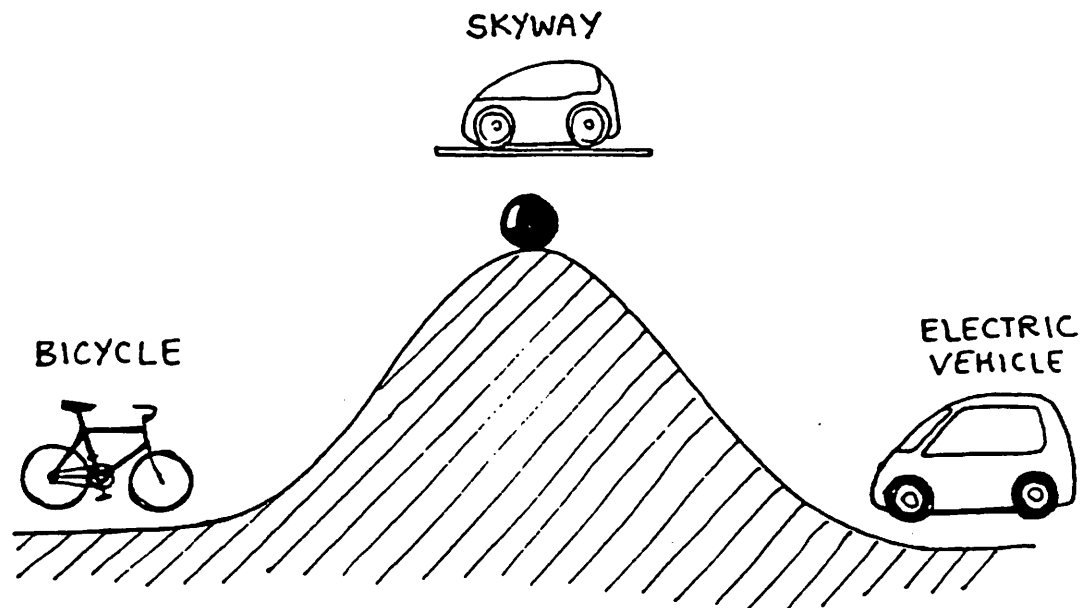
The present solos solution, molded over the last eleven months, is a very carefully crafted compromise of many competing elements (see chart used in the automotive industry, as a guide to the competing elements involved). The designers of solos have attempted to find a balance between ease of accessibility and compactness, light weight and durability, low energy and performance, and low cost and trip quality, among other mutually exclusive criteria.



The interrelationship between requirements an automobile has to fulfill.

This careful balance that was sought is a metastable situation, and can be visualized as a ball sitting at the very top of a hill. Everything remains stable and static unless the ball is moved slightly in any direction. Then a runaway situation develops, a cascading sequence of necessary, technical consequences. Relating this to solos; consider if, for example, the frontal area increases, or if more people need to be carried, or if line speed needs to be faster, then more horsepower will be required, which means a larger motor, which means more or larger and heavier on-board batteries, which means even more horsepower to move the vehicle, which means an even larger motor, more batteries, and on and on. Until finally we have a typical 3000 pound, battery-operated "automobile" traveling on rails, instead of the super efficient, light, electric/human powered hybrid vehicle that was envisioned. On the other side of the coin, if items, weight, and features are dropped from the solos system, the solution will cascade down to something similar to the bicycle, and lacking adequate comfort, accessibility, cargo capacity, performance, durability, and so on in that direction.

The most important point to realize about this "metastable" design is that it is a very rigid specification, intolerant to changes. An indiscriminate change in basic specification percolates throughout the design and pulls it "down the hill" into an area where the original elegance of the solution is diluted or lost altogether.



➤ From Private to Public

Solos came from very idealistic beginnings over 5 years ago. Initially, solos was depicted as a personally owned, super-aerodynamic, ultra-light (80 pound), human powered vehicle that offered dramatic performance for very low input (30 mph with 0.1 horsepower).

Over the past 8-month program solos has changed significantly. Now a public system, the vehicles are of necessity accessible to all people including the young, the elderly, and the physically-challenged. The solos vehicles are also extremely durable, with anticipated mileage up to 50,000 miles/year. And lastly, the speed of these vehicles is no longer as dramatic because the vehicles are now larger and heavier than before. However, solos performance is still more than adequate for movement about any city center. The vehicles are now a hybrid; primarily electric supplemented by human power.

From its very idealistic, futuristic beginning, solos has come down to earth. In its present form, a carefully crafted mixture of existing technologies, solos is capable of providing reliable urban transportation in an affordable and sustainable manner.

Philosophically, a great deal of the original idea has remained intact within solos. The basic principles integrated into the present solos system are as follows:

- Environmental
- Non-Fossil Fuel Based
- Minimizing Energy Use
- Placing the Power Where It Is Needed
- Integrating the Vehicles and Pathway as a Holistic Unit
- Adhering to Appropriate Technology
- Designed for People
- Relieving Congestion
- Safety Considerations
- Promoting a Healthy Lifestyle
- Providing Affordable Transportation

Following are these sections described in more detail.

➤ Environmental

Solos started as a designer's personal journey in envisioning an urban transportation system that was completely environmental. This was motivated primarily by interest (not money), and by a genuine concern for our children and upcoming generations, and the degrading ecology that we will all have to live with, and somehow deal with.

The basic premise was that no way to "clean up" the environment exists. Pollution or environmental degradation must be stopped at source. Also, a "cradle-to-grave" approach must

be taken in evaluating potential solutions. In this light, environmental issues are: waste, soil contamination, water contamination, air contamination, energy consumption, noise, and local habitat. During the product's life cycle, which should be as long-term as possible, instead of justified purely on short-term financial gains, the following stages are carefully evaluated for environmental impact:

- supply
- production
- distribution
- use
- disposal

Designing a truly environmental solution is an emerging field. It is a very complicated area that requires tremendous depth of knowledge in technical, scientific, and social areas.

Solos, in its present form and level of technological development, cannot hope to drastically reduce the pollution presently caused by the movement of people around our cities; pollution created primarily by private automobiles. However, since solos has been created by a small, dedicated group of people that endeavor to be part of the solution instead of part of the problem, the present solos solution does point in a direction that society should pay some attention to.

➤ Non-Fossil Fuel Based

Burning of fossil fuels, aside from the poisons generated, produces carbon dioxide. (Cleaner burning technology addresses the generation of certain regulated poisons to some extent.) Carbon dioxide is essentially harmless to animal life, and plants breathe it and need it for survival. However, carbon dioxide is a greenhouse gas. Its steady increase in our atmosphere, due to unprecedented liberation of million-year-old oil reserves over the last century, results in global warming. The effect of this may be a dramatic rise in ocean water levels that would affect the majority of the populations that are living in coastal areas. Global weather changes would drastically affect food production, with desertification proliferating in huge land areas.

Some estimates point to depletion of the accessible oil reserves in around 35 years; or by the year 2030. According to *Automobile Technology of the Future*, by Ulrich Seiffert and Peter Walzer, "The long-range influence of the carbon dioxide problem might, on the other hand, necessitate a departure from fossil fuels as primary energy sources even before these reserves are exhausted. In this connection, electrically driven automobiles that are emission-free and noiseless offer advantages at least in densely populated areas if their electrical energy is obtained from non-fossil sources."

Solos is a hybrid vehicle; electrical supplemented by human power. What differentiates solos from present day electric vehicles is that its electrical demand is low enough that it can be provided by non-fossil means using today's available technology in solar and/or wind electrical generating equipment. The primary reason for this is that on-board energy demands are

low (small batteries), and off-board energy is kept as low as possible due to the fact that heavy on-board batteries are not being moved around. Realize that battery weight is usually 30% to 50% of the total weight of present typical electric vehicles.

➤ Minimizing Energy Use

With any of today's technologies, energy use causes some form of pollution. Generally, minimizing pollution means minimizing energy use. Also, energy costs money. Reducing energy consumption reduces society's costs, a fact that will be much more significant in the near future as fossil-fuel resources become harder to recover from the ground, and costs of oil escalate.

Other than a very brief energy crisis in the seventies, the past has been a period of cheap energy. "If you need more energy, just go and get it", has been the over riding philosophy of most of western society. Regarding vehicles, "If you need to go faster, put a bigger motor in it." was once the norm, and is still followed to some extent in many companies today.

Solos has been designed with the intent of using a minimal amount of energy. Solos was originally conceptualized as attaining almost all of its power from humans. In the present solos, vehicle weight and size have increased to make that unlikely, and necessitated the addition of an electric motor. Even with this shift, a delicate balance had to be arrived at in the design of solos in order to maintain at least partial input from human power. The solution is truly hybrid, as the vehicles can perform under purely electric power, purely human power, or a combination of the two. This combination should be the norm when the system is operating as expected.

Of all the known transportation systems, solos uses the least energy to move people, individually and under complete weather protection, within an urban center.

➤ Placing the Power Where It Is Needed

Typical present day battery powered electrical automobiles fail because of the low power carrying capacity of the on-board batteries. Batteries just do not have anywhere near the punch of gasoline, either by weight or volume.

Using lead-acid batteries compared to gasoline:

- 5300 kg of battery equals 46 kg of gasoline;
- 2040 liters of battery storage equals 67 liters of gasoline;
- 0.25 MJ/L energy in batteries equals 32 MJ/L energy in gasoline.

What the above figures show is that the "gas tank" in electric vehicles has to, out of necessity, grow until it is almost 1/3 to 1/2 of the vehicle (by weight). Even then, the limitations of the electric car are still great. Quick recharging and running the auxiliaries (heater, air conditioner, lights, etc.) have still not been resolved. Also, the problem of pollution and energy required is not solved, but merely transferred to the electrical generating station.

The electric car industry is desperately in need of a better battery, and an enormous amount of research is going into this area. To date, batteries around 1.5 times better than

➤ Integrating the
Vehicles and Pathway
as a Holistic Unit

the lead-acid battery have been developed. However, cost and complexity still limit their widespread use. Also, this performance gain is negligible to the enormous leap in performance demanded, if battery powered electric vehicles are to effectively compete with the gasoline powered vehicle.

Solos differs significantly from the electric automobiles in that the vehicles receive their high-power requirements for acceleration and hill climbing from the powered rails within the passageway. These powered rails are strategically placed only where they are needed, at stations and up gradients. This eliminates the complete electrification of the solos system, with its inherent expense and power losses due to the lengthy electrical lines. Within solos only low-demand power is achieved from the on-board batteries. This minimizes the grossly inefficient movement of very heavy batteries around the solos system. Solos vehicles have standard lead-acid batteries on board.

When designing an automobile, one designs for existing roads. When designing roads, one designs for existing automobiles. This situation, common to most present transportation systems, forms a design "grid-lock" which severely limits the possible solutions available.

Solos has been designed from essentially a clean sheet of paper. The only real limitation imposed upon solos is that it must co-exist with all other transportation systems within an urban landscape.

This design flexibility has allowed the solos designers to create a system whereby the vehicle and pathway are an integrated unit. It also allowed easy transfer between the vehicle and the pathway. For example, when it made sense to put a component or system on the pathway instead of the vehicle, this was done. The logic followed was that if a component did not have to be on the vehicle then it would be placed in the pathway. The pathway was stationary. The vehicle was mobile. Keeping anything on the pathway prevented its movement, and the associated cost of energy, maintenance, etc. Some systems transferred from the vehicle to the pathway include:

- weather protection (no heaters, air conditioners, windshield wipers, etc. on vehicle);
- ride quality (no suspension on the vehicle; the pathway is maintained to accurate tolerances);
- accessibility (the "stepped station", where the vehicle seat rests at standard chair level in the station, has reduced vehicle frontal area by approximately 30%, by allowing easy access into a very low vehicle);
- electrical power (all high-demand power, for accelerating and inclines, is provided by the powered rails on the passageway).

This design methodology has resulted in a system in which the vehicles are ultra-light, and where the majority of the energy is utilized to move people, and not the containers for the people.

Appropriate technology is a school of thought that promotes the application of the level of technology that is appropriate to the task at hand. This is distinctly different from low-technology typified by "third-world" solutions, and high-technology typified by the latest in developments, usually introduced in the computer industry, the aerospace industry, or the electronics industry.

Appropriate technology proponents are not "hungry" for newness, as is the case in high-technology. By the same token, appropriate technology utilizes existing, known technologies, and is not into those that are desperately seeking a breakthrough prior to their successful implementation.

Appropriate technology proponents are knowledgeable of older technologies, but are not inflexible regarding traditional methods, as occurs in low-technology philosophies.

A survey of solos shows that many well established areas of technology have been studied and adopted. Among others, these include the following:

- railways; over 100 years of development
- fiberglass/balsa-core composite construction; now utilized in modern railcars to achieve a high strength-to-weight ratio
- modern bicycles
- existing PRTs
- present battery-powered electrical vehicles
- existing sonar distance detection devices
- modern civil engineering; modular, off-site construction, on-site erection techniques

Utilizing appropriate technology means that the technical risk for the successful completion of the solos project is very low. Solos will work technically. The uncertainty surrounding solos revolves around its acceptance and use by the general public.

Virtually all transits in the past were designed for normal people. Normal meant an able bodied, unencumbered person with good eyesight and hearing, paying undistracted attention. That definition excludes children under 12 (perceptual studies suggest they cannot adequately judge traffic risks) and many people over 50 (normal aging effects include loss of hearing and visual acuity, slower reactions and less agility). It was just too bad if your leg was in a cast or you were carrying a suitcase or heavy box or shopping bags. "Wheeled pedestrians" in wheel-chairs, or pushing baby buggies are even more affected by difficulties of access into most transit systems that were designed in the past.

In effect it is those who are most dependent on walking and least likely to have access to their own car - such as the elderly, children and women - who are disproportionately affected by the unnecessarily demanding standards of "normal" accessibility that are assumed.

Moreover, the Disabled People's Transport Advisory Committee estimates that one in seven of the population at any time will be suffering some form of mobility handicap (England, 1988).

Therefore, a transit should not be viewed as being designed solely for "wheelchairs" or the "physically-challenged". These are, percentage wise, a rather small section of the potential user group (some 12% of the population in Britain is registered disabled, with 4% of this group being chairbound). If, however, one thinks of the number of "traffic-vulnerable" or "fragile" people that are in need of mobility, the percentage of the potential users is large and truly significant (The Greening of Urban Transport, edited by Rodney Tolley, estimates the traffic-vulnerable or fragile group to be between 30% to 50% of the population, in Britain). To this "fragile" group, which includes the wheelchair-bound, the blind, the deaf, the elderly, children and women, among others, a well-designed transit can well make the difference between being housebound and dependent or being able to live independently.

Solos originated from and was developed by a product design/engineering firm. Inherent in this type of company's methodology is a user oriented approach. Although designed with ergonomics integrated into the solution, solos may still get resistance on purely psychological grounds. Solos, from its beginning, has been described by some as more of a social problem than a technical problem. It remains to be seen if society will accept and use solos, because the smallness of the vehicles will require some getting used to, as will the weather-awareness inherent in the system.

As environmental issues increase, and as economics catch up to the true cost of fossil fuel usage, the solos solution will make more and more sense. On a global scale, this maturity will not happen all at once, but will initially become apparent in a few cities.

Conditions that need to emerge within a city include:

- lots of visible pollution (smog)
- a general environmental awareness (global warming)
- intolerable congestion (grid-lock)
- an awareness of the negative aspects of a car-based transportation system
- a will to change
- the economic capacity to afford to change (a budget)
- the willingness to risk attempting a pioneering system.

With the above conditions, it should be possible to sell the idea of a solos system within their city. Without the above conditions, an installation of a solos system turns into an educational awareness program of environmental and/or congestion issues. While this might lead to eventual acceptance of this transportation system, it would undoubtedly prove too lengthy a process to be economically viable for those developing solos.

Design is a social act. Since its onset, solos has been designed for society in general. It remains to be seen which society chooses to be the first to attempt a solos system. What can be said at this time is that conditions within Europe, where environmental and urban pressures are some of the highest in the world, appear to be the most favorable for a solos installation. The countries of Germany, Holland, and Denmark are particularly well suited.

Relieving Congestion

Congestion in city centers is reaching intolerable conditions, with predictions pointing to ever-worsening conditions, and no clear solutions sighted by these analysts. Without question, for any solution to prove successful in reducing congestion, it must reduce the use of the automobile.

The present solos is a PRT (Personal Rapid Transit) system. It attempts to combine the desirable qualities of the personal automobile with the advantages of a public transit system.

Only time will tell, when a pilot installation is actually in operation, whether solos is successful in displacing car usage in the urban center. All that can be said at this point is that solos has been carefully designed to accomplish this end.

Safety Considerations

Railed vehicles are inherently safe, statistically far safer than loose projectiles controlled in close quarters solely by the skill of the trained operators as, is the case with automobiles.

Driverless railed systems are now in use throughout the world, and have proved to be safe. The control of these vehicles has been relinquished to a computer, utilizing on-board and station sensors.

Solos is a railed vehicle with on-board electronics that controls vehicle movements through automatic distance-sensing and braking. The rider of solos is not expected to "drive" the vehicle, but rather to ride in the security of total computer control. Dual on-board systems, as is common in aircraft, assure a virtually fail-safe control system within solos.

Also, solos speeds (maximum of 15 mph) are slow by transportation standards, but adequate for rapid transit about most urban centers. This slow speed is inherently safer than higher speeds.

Promoting a Healthy Lifestyle

Maintaining the human powered element within solos makes it a truly unique transit system: a transit system that promotes mild exercise and the only transit system that can actually be good for your body. The fact is that mild exercise is good for everyone, no matter what age or level of physical condition. This is proven by numerous studies. The real question is how this feature of solos will be received and utilized by the general public.

➤ Providing Affordable Transportation

The cost of transportation today is escalating at an alarming rate. Several factors are involved, including the following costs of:

- labor
- materials used in civil structures
- equipment (the rolling stock)
- right-of-way
- adhering to regulations, necessitated by the liability aspect of operating a public transit system

As mass transit costs have escalated, society's costs related to gasoline and automobile-usage have been kept low, receiving large and essentially hidden subsidies that make other transportation options appear outrageously expensive in comparison. This unfair playing field makes it almost impossible for any transit system to compete economically with the private automobile.

Solos has attempted to provide affordable transportation along urban corridors that warrant the erection of a permanent structure; in other words, along travel paths where steady movement of people is anticipated well into the future. This long-term usage with low operating costs, sustainable energy demands, and minimal pollution damage justifies the initial expense of installation. Solos targets those paths connecting destinations that are too far to walk, but too short for the convenient use of the car.

Solos strategy for affordable transportation include the following:

- minimize moving weight
- minimize over all energy usage
- minimize operating personnel to approximately one person per station
- minimize maintenance; design for durability
- utilize understandable, appropriate, and essentially available technology.

As the actual costs emerge during the solos Feasibility Study, the economic viability of solos will be better understood.

➤ In Conclusion

The basic design philosophies behind solos have been responsible for molding the numerous detailed specifications that make up the present solos system design. It is important to understand them in order to appreciate the many tiny details that are now part of the design of solos.

➤ Some Brief Technical Details

Two Types of Solos Vehicles

Solos consists of two types of vehicles operating within a common passageway. The two vehicles are:

➤ the Standard solos vehicle

➤ the Van solos vehicle.

In a typical installation, we would anticipate a ratio between 10:1 and 20:1 of Standard vehicles over Van vehicles (if 100 Standard vehicles are required, from 5 to 10 Van vehicles would be appropriate). This is based upon typical potential users of the solos system, and an anticipated ridership level of 1.1 to 1.2 people per vehicle. Certain locations may demand a different mix of vehicles.

➤ Space Utilization

Each type of solos vehicle uses its internal volume to the maximum capability. The diagrams illustrate the space utilization of each vehicle.

➤ Usage Variations

The Standard solos vehicle is roomy for one person, and cozy for two. The ample storage space can be put to varied use, and can accommodate other people (babies, children, or adolescents) or cargo.

The Van solos vehicle can accommodate various combinations of people and cargo. Some typical examples are illustrated below and on the next page.

➤ The Stepped Station

The stepped station is a unique feature of solos. This solution allows for a very small vehicle to be easily accessible by the majority of users.

The final seating position in a Standard solos vehicle is very similar to that of an English sports car, with the person's back gently reclined and the legs almost horizontal. However, a sports car is very difficult to enter and exit. This is not because of the final seating position, but due to two factors:

➤ the seat is very low to the ground, which means that a user must raise or lower his/her body dramatically while entering or exiting the sports car

➤ the door is relatively small, which means that the leg must be fully bent at the knee as one pivots about the seat while entering or exiting the sports car.

The solos vehicle is significantly different in that the seat is located much higher, due to the stepped station, and the door is much larger, allowing the legs to be swiveled into or out of the vehicle without bending at the knee. Entering or exiting a solos vehicle is identical to sitting on a sofa and putting one's feet up on a foot stool, or to getting up onto a bed in a sitting position. These operations can easily be accomplished by most people, including the vast majority of the elderly.

The advantages of utilizing a stepped station are:

- the frontal area of the vehicle is dramatically reduced, compared to a vehicle with similar seat height sitting on the ground, by approximately 30% less area; this is very significant in reducing air resistance of the vehicle
- the center of gravity of the vehicle is very low, without sacrificing ease of accessibility
- the stepped station offers a natural barrier to the users; a barrier that they are unlikely to cross unless an open door vehicle awaits them.
- The illustrations indicate some of the finer points of the entry and exit into the Standard solos vehicle.

Entrance and exit into the Van solos vehicle is via an area where the floor is the same level as the vehicle floor. This is necessary to allow wheelchairs and other rolling devices ease of entry. By necessity, the seat cushions of a Van solos vehicle are located higher to allow easy seating of regular passengers. This more traditional layout means that the Van vehicle has a higher frontal area and higher center of gravity than a Standard solos vehicle. Within the Van vehicle, a person in a wheelchair is able to position the chair facing forward. This has been found to be important in PRT studies (Anderson).

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Projekt MOVEO: ein neuer Entwurf für ein alltagstaugliches, vollverkleidetes Liegedreirad

Ein Beitrag zum Zweiten Europäischen Velomobil-Seminar "Sicherheit und Design"

Project MOVEO: a Novel Design of a Fully-Faired Recumbent Tricycle for Everyday Use

A Contribution to the Second European Seminar on Velomobiles "Safety and Design"

Laupen, CH, 25. August 1994

von Michael Gronau und Markus Hampe, Studenten der Konstruktionstechnik an der Technischen Universität Hamburg-Harburg, Deutschland

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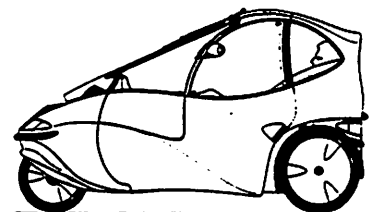
Zusammenfassung

Die erdrückende Verkehrssituation in den Großstädten, die zu einem Großteil durch schlecht ausgelastete private PKW verursacht wird, veranlaßte uns, darüber nachzudenken, warum auch auf kürzeren Strecken, die ohne weiteres mit einem Fahrrad zu bewältigen wären, meistens das Auto benutzt wird. So gut wie jeder Autofahrer besitzt auch ein Fahrrad und die meisten Autofahrten sind kürzer als zehn Kilometer. Dennoch wird das als Personen-Transportmittel für Kurzstrecken sehr gut geeignete Fahrrad meistens nur als Sport- und Freizeitgerät genutzt.

Der Ansatz für unsere Arbeit war die Herausarbeitung einiger schwerwiegender Nachteile des Fahrrades gegenüber dem Auto, einmal abgesehen davon, daß man die eigene Muskelkraft zur Fortbewegung einsetzen muß. Diese Nachteile betreffen vor allem einen nicht vorhandenen Witterungsschutz (Radfahren im Regen ist bekanntlich kein Vergnügen), mangelnde passive Sicherheit (ein Kriterium, das heute im Automobilbau sehr groß geschrieben wird: Airbags, Seitenaufprallschutz...) und mangelhafte Transportmöglichkeiten (man vergleiche die Kapazität und Funktionalität eines Fahrrad-Gepäckträgers mit der eines abschließbaren Kofferraumes!).

Das Ergebnis unserer Bemühungen ist ein Gesamtentwurf für ein dreirädriges "Velomobil" mit konventionellem Rundtretantrieb, geschlossener Verkleidung und höhenverstellbarer Sitzposition, der im wesentlichen unter den Entwicklungsschwerpunkten *Ergonomie, Alltagstauglichkeit, Sicherheit und Design* gestaltet wurde. Er bietet dabei viele neuartige Detaillösungen, die bei uns bekannten bereits gebauten Velomobilen bzw. "HPVs" noch nicht in ähnlicher Form realisiert wurden. Der Bau eines Prototypen soll in den nächsten Monaten begonnen werden.

Inhalt dieses Artikels ist, nach der Erläuterung unserer Motivation und der Darstellung des Fahrzeugkonzepts die nähere Beschreibung unseres Entwurfs im Hinblick auf die genannten Schwerpunkte.



1 Intention

Der ständig zunehmende Individual-Autoverkehr in den Städten der Industrienationen verursacht neben großen irreparablen Umweltschäden eine starke Beeinträchtigung der Lebensqualität für die Bewohner durch Luftverschmutzung, Lärmbelästigung und einen unverhältnismäßig hohen Flächenverbrauch durch Straßen und Parkplätze [1]. Da das Bedürfnis und auch die Notwendigkeit individueller Mobilität in Zukunft noch weiter zunehmen wird, müssen heute verstärkt Anstrengungen unternommen werden, alternative Konzepte der Personenbeförderung voranzutreiben und neu zu entwickeln. Neben dem öffentlichen Personennahverkehr und den - in ihrem ökologischen Nutzen beim gegenwärtigen Stand der Technik umstrittenen - Elektro-Kleinfahrzeugen könnte das *Fahrrad* als die zweifellos umweltfreundlichste Alternative bei der Abwicklung des täglichen Kurzstrecken-Personenverkehrs eine weit größere Rolle spielen, als das heute der Fall ist [2].

Die Vorteile des Fahrrades im Vergleich zum Auto sind augenfällig [3]: Es fährt ohne Fremdenergie und damit emissionsfrei und geräuscharm. Es beansprucht wenig Platz; sein geringer Herstellungsaufwand schont Ressourcen und erlaubt einen niedrigen Anschaffungspreis. Geringe Unterhaltskosten und die Förderung körperlicher Bewegung sind weitere Vorteile.

Unserer Meinung nach liegt die viel zu geringe Nutzung des Fahrrades als *Transportmittel* (als Freizeit- und Sportgerät ist es dagegen sehr beliebt - der Mountain-Bike-Trend spricht für sich) weniger an der geringen Bereitschaft des potentiellen Benutzers, die Muskelkraft für die eigene Fortbewegung aufzubringen (viele "Büromenschen" klagen im Gegenteil heutzutage über Bewegungsmangel) als vielmehr an einigen entscheidenden Nachteilen, die das herkömmliche Fahrrad gegenüber dem Automobil aufweist: Es bietet keinen Schutz gegen Wind und Wetter, die passive Sicherheit im Straßenverkehr ist katastrophal, da der Fahrer keinerlei "Schutzhülle" um sich hat, die Transportmöglichkeiten für den größeren Einkauf sind schlecht (schon ein Getränkekasten bereitet große Schwierigkeiten) und der Sitz- und Federungskomfort auf längeren Strecken ist unzureichend.

In diesen Punkten ist das Auto dem Fahrrad überlegen. Nicht zuletzt deshalb hat es einen so hohen Gebrauchswert und erfreut sich entsprechender Beliebtheit.

Unsere Aufgabe sahen wir nun darin, ein Fahrzeug zu konzipieren und zu entwerfen, das eine möglichst gute Synthese der spezifischen Vorteile des Fahrrads einerseits (einfache Konstruktion, Leichtbauweise, keine Fremdenergie zum Antrieb, geringer Platzbedarf, Wendigkeit, Nutzung von Radwegen) und des Automobils andererseits (Rundum-Witterungsschutz, Sitzkomfort, gute Transportmöglichkeiten, Abschließbarkeit, hohe aktive und passive Sicherheit) darstellt. Mit diesem Fahrzeug soll dem Autofahrer eine brauchbare Alternative für die typischen Kurzstreckenfahrten bis zu etwa 10 km zum Arbeitsplatz oder zum Einkauf angeboten werden. So kann er auf diesen Strecken - immerhin 70 % aller Autofahrten [4]- auf sein Auto verzichten.

Umgesetzt wurde diese Aufgabenstellung in dem Projekt "MOVEO"¹, das wir als gemeinsame Studienarbeit an der Technischen Universität Hamburg-Harburg im Arbeitsbereich "Arbeitswissenschaften" seit Oktober 1992 bearbeiten.

¹ lat.: "ich bewege"

2 Anforderungen

Die Idee des MOVEO, Vorteile von Fahrrad und Auto optimal zu verknüpfen, bedeutet jedoch nicht, daß sich alle Vorteile der beiden "klassischen" Fahrzeuggattungen uneingeschränkt in das neue Konzept übertragen lassen. Sieht man beispielsweise einen brauchbaren Witterungsschutz und Elemente zur Verbesserung der passiven Sicherheit vor, so sind das geringe Gewicht und die einfache Konstruktion eines "normalen" Fahrrades nicht zu erreichen. Andererseits erlauben der Verzicht auf einen Antriebsmotor und die dadurch bedingte Leichtbauweise nicht die hohe Fahrgeschwindigkeit und Sicherheit eines Automobils.

Unsere Arbeit soll zeigen, daß es dennoch möglich ist, ein Fahrzeugkonzept zu entwickeln, das einen guten Kompromiß zwischen beiden Fahrzeugarten darstellt und das - vor allem bei den an Komfort, Sicherheit und ansprechendes Design gewöhnten Autofahrern - eine hohe Akzeptanz erzielen kann. Daher haben wir uns folgende Anforderungen gestellt, die im wesentlichen unter vier Themenschwerpunkten zusammenzufassen sind:

- **Ergonomie:**
Variable Tretposition, optimale Tretfrequenz, Anpaßbarkeit an Körperabmessungen, Fahrbedingungen und Umweltbedingungen, Fahr- und Sitzkomfort, effektive Kraftausnutzung, einfache Handhabung des Fahrzeugs, bequemer Ein- und Ausstieg
- **Alltagstauglichkeit:**
Wirksamer Witterungsschutz, gute Transportmöglichkeiten, An- und Abschließbarkeit, Kompatibilität zu Radwegen, Wendigkeit, Wartungsfreundlichkeit
- **Sicherheit:**
Passiv: gute Sichtbarkeit, Rundumschutz
Aktiv: gute Bremsen, stabiles Fahrverhalten, gute Sicht
- **Design:**
Anlehnung an Automobildesign, modernes, dynamisches Erscheinungsbild, harmonische Verbindung der Fahrzeugelemente

3 Konzipierung und Entwurf

Ausgehend von diesen Anforderungen wurde ein grundsätzliches Fahrzeugkonzept erarbeitet. Ein wesentliches Merkmal dieses Konzepts ist eine allseitig geschlossene Vollverkleidung, da nur diese die als besonders wichtig angesehenen Forderungen nach einem effektiven Witterungsschutz und einem Rundumschutz bei Kollisionen hinreichend erfüllen kann [5]. Weitere damit verbundene Vorteile sind bei geeigneter Gestaltung:

- Gute Aerodynamik (\Leftrightarrow gute Kraftausnutzung)
- Abschließbarkeit des Fahrzeuginnenraumes

- Automobilähnliches Design

Die Gewährleistung der Fahrstabilität (eine Vollverkleidung ist seitenwindempfindlich) und auch der Standsicherheit im beladenen Zustand machte eine mehrspurige Radkonfiguration erforderlich. Eine Ausführung mit vier Rädern wurde wegen des damit verbundenen zu hohen Aufwandes und Fahrzeuggewichts verworfen. Somit entstand ein dreirädriger Entwurf mit zwei angetriebenen Hinterrädern und einem gelenkten Vorderrad. Dieser erweist sich gegenüber der - häufig bevorzugten - Anordnung mit zwei Vorderrädern vor allem in folgenden Punkten als vorteilhaft [6]:

- Geringerer Aufwand für die Lenkung
- Bessere Lastaufteilung und niedrigerer Schwerpunkt bei Beladung
- Höhere Bremsstabilität

Akzeptable Kurvengeschwindigkeiten lassen sich bei einem Dreirad über eine große Spurbreite - die aber wegen der üblichen Radwegebreiten begrenzt ist - und eine möglichst geringe Höhe des Fahrzeugschwerpunktes erreichen. Letztere wird bei gleichzeitig angestrebtem geringen Fahrzeuggewicht hauptsächlich durch die Sitzhöhe des Fahrers bestimmt. Einen niedrigen Schwerpunkt ergibt die für das MOVEO vorgesehene *Liegerad*-Sitzposition, die auch noch weitere Vorteile gegenüber der konventionellen Fahrrad-Sitzposition hat:

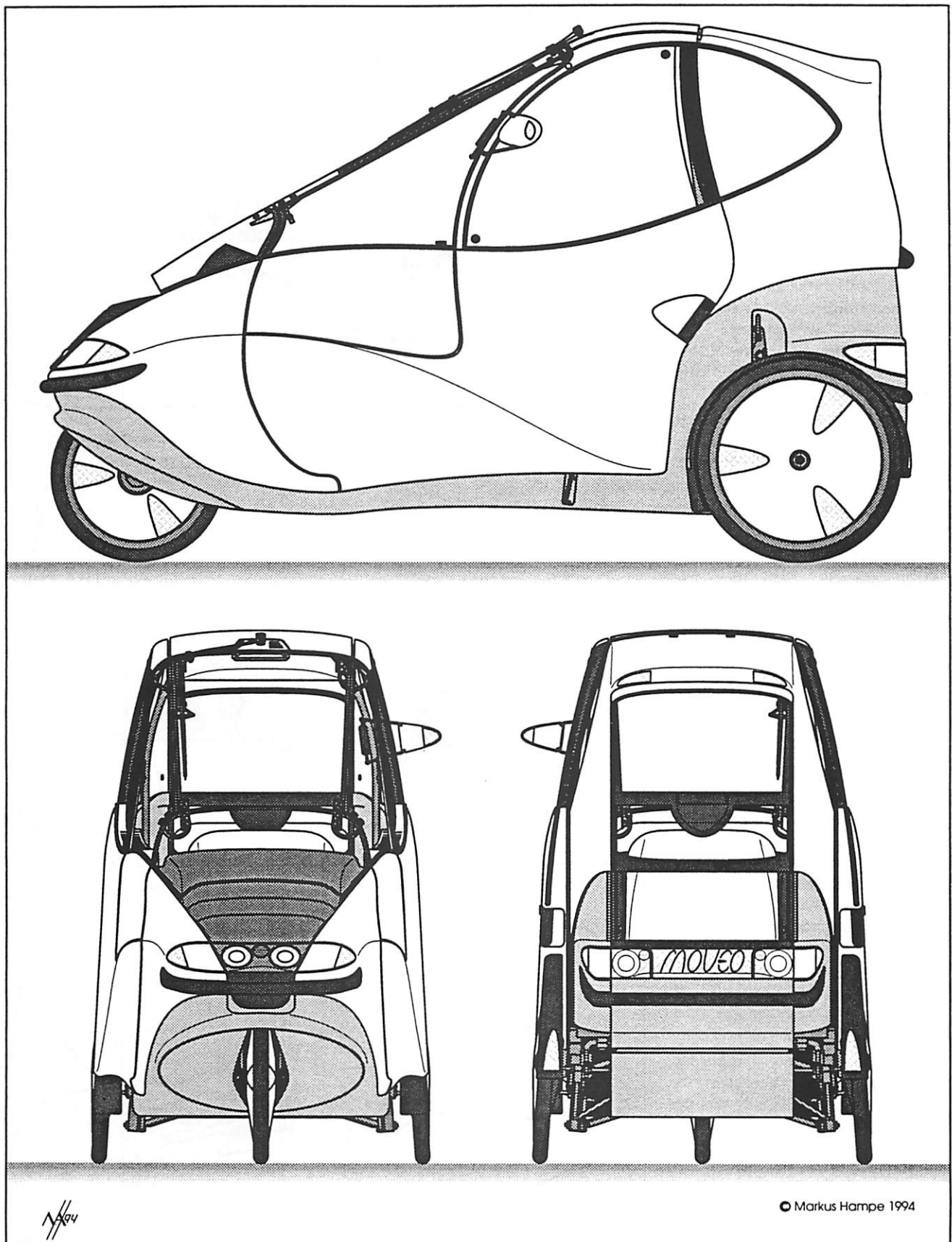
Neben einem durch die kleinere Fahrzeug-Stirnfläche verminderten Luftwiderstand ergibt sich durch die große Sitzfläche und Rückenlehne eine komfortable, entspannte und kraftsparende Körperhaltung [7].

Aufbauend auf diesem prinzipiellen Fahrzeugkonzept entstand unter Berücksichtigung der oben aufgelisteten Anforderungen folgender Entwurf:

Das MOVEO ist ein pedalgetriebenes Liegedreirad für eine Person. Besondere Merkmale sind ein höhenverstellbarer Sitz und eine geschlossene Verkleidung mit integriertem Gepäckraum.

Das vollständig gefederte Fahrwerk weist ein gelenktes Vorderrad und zwei einzeln aufgehängte Hinterräder auf. Der Antrieb erfolgt konventionell über Tretkurbeln und eine Kettenschaltung. Die Kette dient gleichzeitig als Transmission zur Hinterachse; die Lastaufteilung auf beide Hinterräder erfolgt über ein selbst entwickeltes Differentialgetriebe mit integriertem Rückwärtsgang.

Die Fahrzeugkonstruktion besteht aus einem geschweißten Aluminiumrahmen und daran aufgehängten Kunststoff-Verkleidungselementen. Durch diese Leichtbauweise soll ein Fahrzeuggewicht von ca. 25 kg erreicht werden. Eine Weiterentwicklung des MOVEO zu einem Großserienprodukt soll zu einem Kaufpreis zwischen 4000,- und 5000,- DM angeboten werden können. *Bild 1* zeigt den Gesamtentwurf des MOVEO in drei Ansichten.



NSV

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Bild 1 Der Gesamtentwurf in drei Ansichten

4 Ergonomie

Das neuartige Fahrzeug wird vom Fahrer nur dann gern (anstelle des Autos) benutzt, wenn er das Fahren als angenehm, komfortabel und wenig anstrengend empfindet. Ein Schwerpunkt bei der Entwicklung des MOVEO war daher die Gestaltung unter *ergonomischen* Gesichtspunkten. Der Fahrzeuginnenraum wird hierbei gewissermaßen als Arbeitsplatz angesehen, der so zu gestalten ist, daß der Mensch durch seine Arbeit (in diesem Falle hauptsächlich die körperliche Arbeit des Tretens, aber auch das Wahrnehmen des Verkehrsgeschehens und das Lenken des Fahrzeugs) möglichst wenig beansprucht wird.

Eine wesentliche Grundidee bei der ergonomisch orientierten Entwicklung des MOVEO ist seine flexible *Anpaßbarkeit* an die individuellen Bedürfnisse und Vorlieben des Fahrers.

Da das Treten die hauptsächliche Arbeit darstellt, sind die *Tret-Geometrie*, die *Tret-Frequenz* und das im Fahrzeuginnenraum herrschende *Klima* die wichtigsten ergonomischen Parameter [8], deren individuelle Anpassung besonders wichtig ist:

1. Bezüglich der Tretgeometrie erachteten wir es für besonders sinnvoll, die *Sitzhöhe* individuell einstellbar zu gestalten, so daß eine Variation der Tretposition in weiten Grenzen ermöglicht wird. Je nach persönlicher Vorliebe kann so jede Lage zwischen einer bequemen Sesselposition mit einer eher nach unten orientierten Trettrichtung und einer flachen Liegeposition mit nach vorne gerichteter Tretbewegung gewählt werden. Die manuell zu betätigende Verstellung geschieht stufenlos (*Bild 2*).

Der Oberbau der Verkleidung bewegt sich bei Verstellung der Sitzhöhe entsprechend mit (vgl. auch Bild 9), und die Spurbreite wird automatisch entsprechend vergrößert bzw. verkleinert, so daß in jeder Position eine ausreichende Kopffreiheit und hinreichende Kurvenstabilität gewährleistet ist.

Die Anpaßbarkeit der Tretgeometrie wird ergänzt durch weitere vielfältige Möglichkeiten

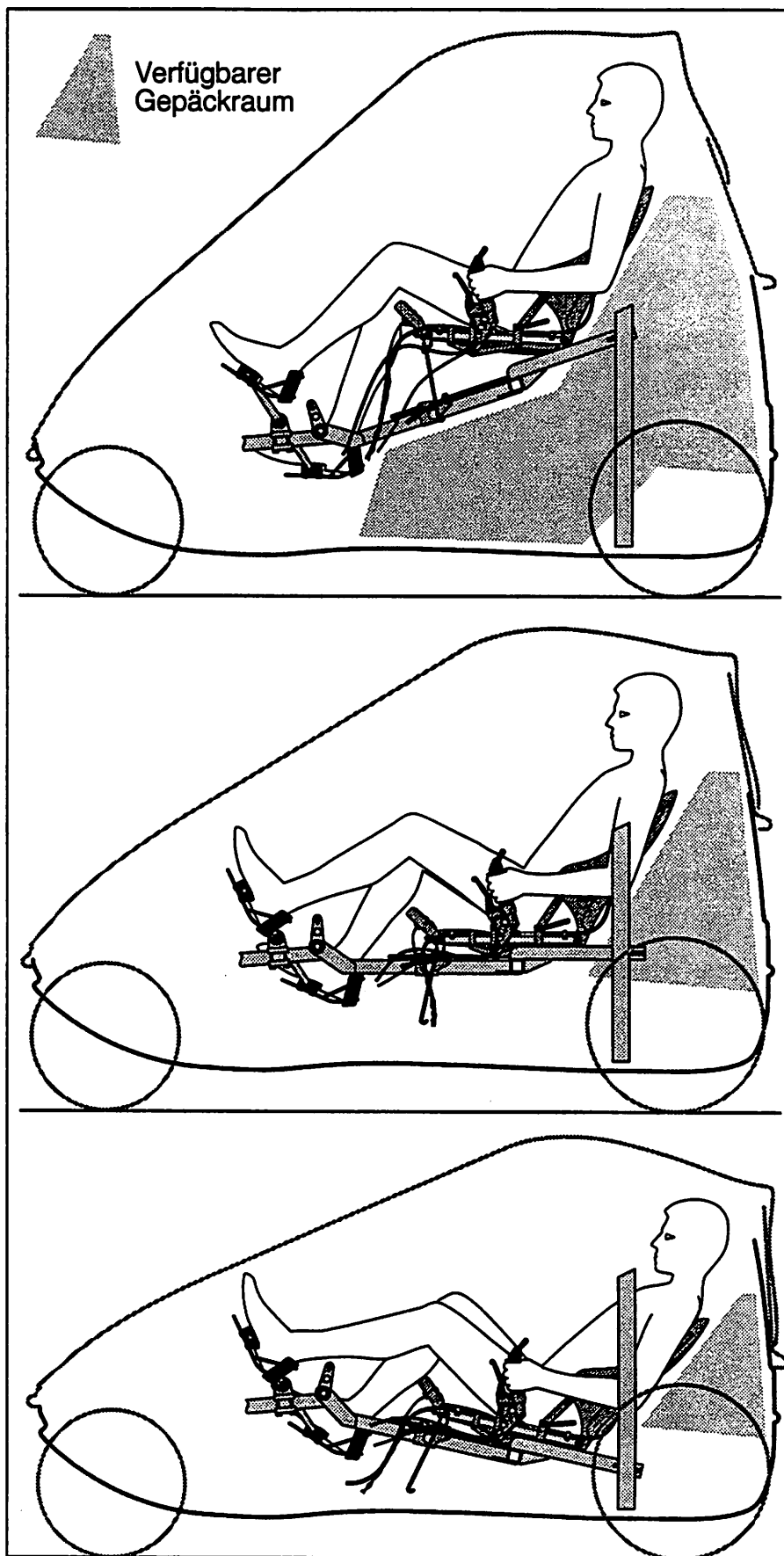


Bild 2 Anpassung der Sitzhöhe an individuelle Bedürfnisse

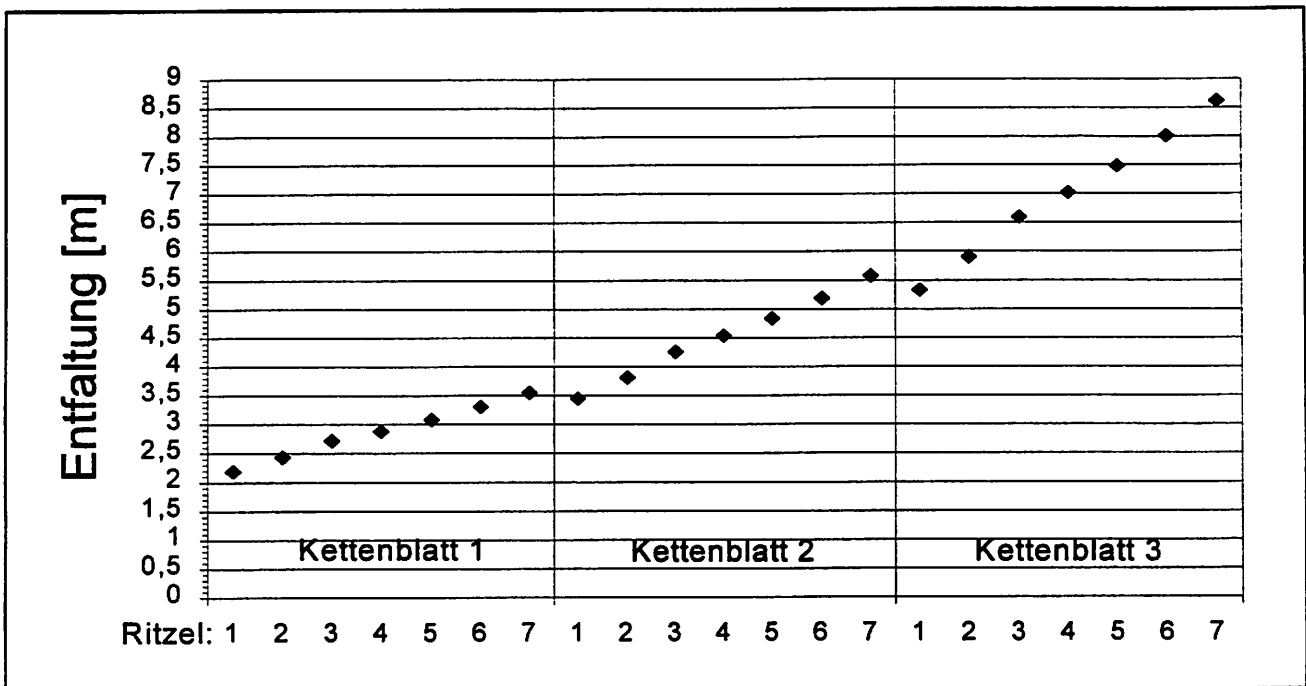


Bild 3 Entfaltung in Abhängigkeit vom eingeschalteten Gang

der Sitzeinstellung wie Sitz-Tretlager-Abstand, Sitzneigung und Lehnenneigung. Die Verstellbereiche (1. - 99. Perzentil² der signifikanten Körperabmessungen [9,10]) sind so groß gewählt, daß unabhängig von der Körpergröße eine optimale Einstellung ermöglicht wird. Für die Bemessung und Gestaltung der Sitzgeometrie und der Innenraumabmessungen wurden die "Kieler Puppen" nach DIN 33408 [11] eingesetzt.

2. Um unter den meisten Fahrbedingungen möglichst angenehme Tretfrequenzen zu erreichen, ist die ansonsten konventionell gestaltete Kettenübersetzung auf einen weiten Übersetzungsbereich ausgelegt worden. Bild 3 zeigt die Entfaltungen der 21 schaltbaren Gänge.
3. Zur Gewährleistung eines angenehmen Klimas ist eine gute, variable Innenraumdurchlüftung durch großflächige, verstellbare Belüftungsklappen und einen elektrischen Lüfter (Bild 4) vorgesehen. Ein modular gestalteter Aufbau der Verkleidung mit abnehmbaren Komponenten erlaubt außerdem die flexible Anpassung an unterschiedliche Witterungsverhältnisse (Bild 5).

Auch weitere ergonomische Überlegungen flossen in die Gestaltung des MOVEO ein:

- Entspannte Armhaltung durch Positionierung von Lenker und Bremsgriffen in Hüfthöhe (vgl. Bild 2)
- Griffgünstige Anordnung von Hebeln, Schaltern und Türöffnern
- Leichter Ein- und Ausstieg wahlweise links oder rechts durch große, weit heruntergezogene Flügeltüren und gute Beladbarkeit durch niedrige Ladekante (Bild 1)
- Hoher Fahrkomfort durch großflächigen Sitz und Fahrzeugfederung und -dämpfung durch einzeln

aufgehängte, mit PU-Feder-Dämpfer-Elementen abgefederte Räder

- Weites Raumgefühl trotz des relativ engen Innenraums durch großzügige Fensterflächen
- Niedrige Fahrwiderstände durch Direktübersetzung, hochwertige Wälzlagerungen, Hochdruckreifen und aerodynamische Verkleidung für eine hohe Ausnutzung der menschlichen Leistung.

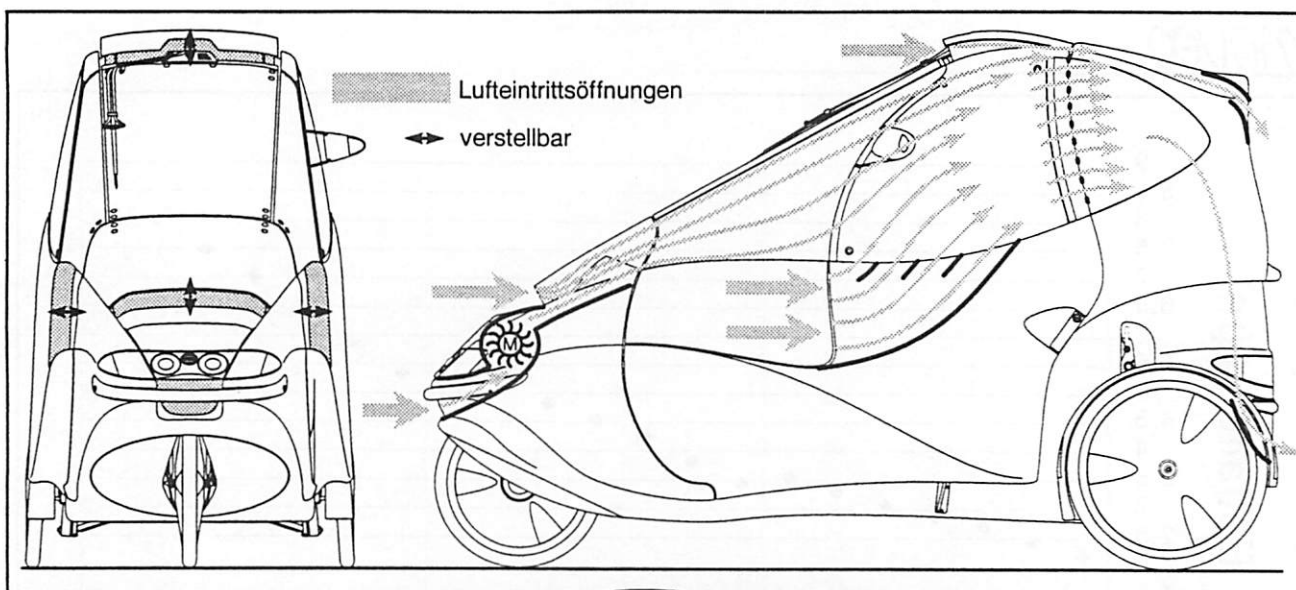
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Bild 4 Die Innenraumdurchlüftung sorgt für angenehmes Klima und verhindert das Beschlagen der Scheiben

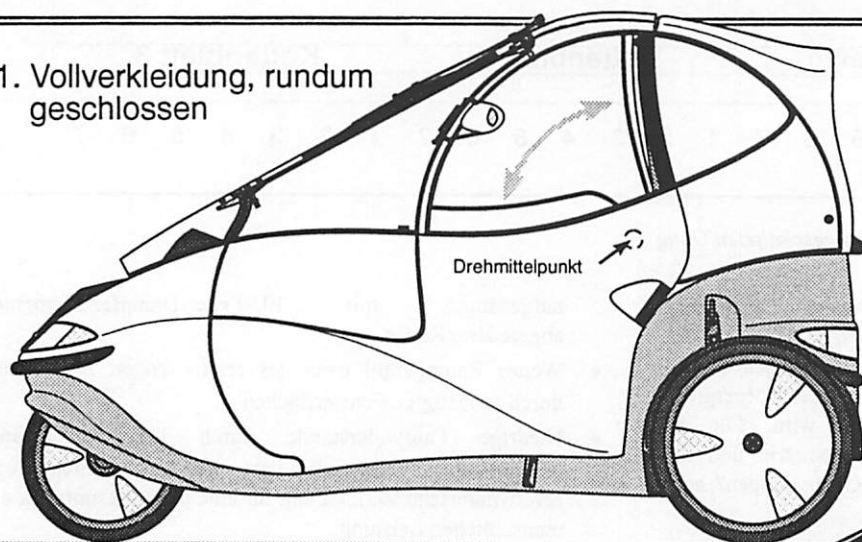
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Bild 5 Anpassung an Witterungsverhältnisse durch Variation der Verkleidungselemente

² Summenhäufigkeit der Körperabmessungen von erwachsenen Männern und Frauen nach DIN 33402

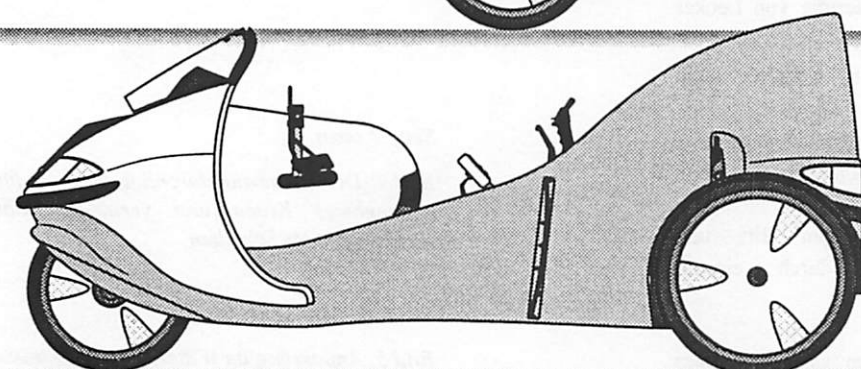
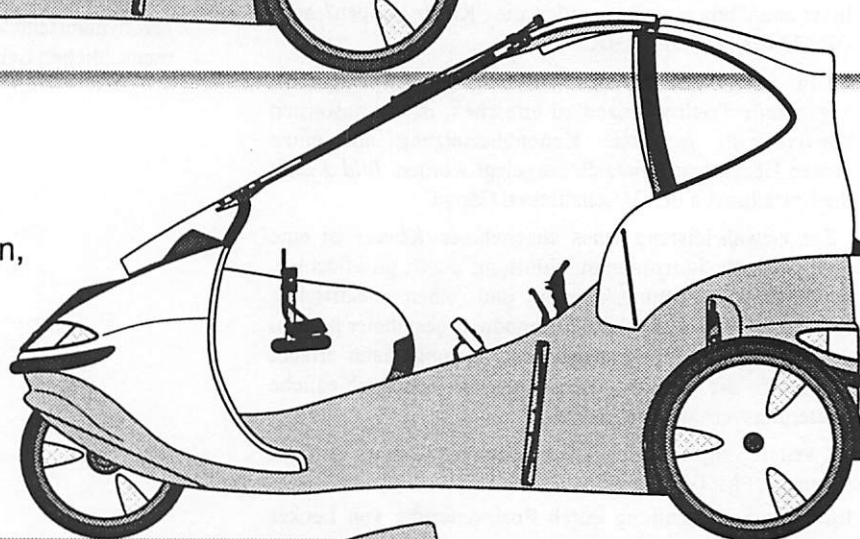


1. Vollverkleidung, rundum geschlossen



Seitenfenster nach vorne oder hinten zu öffnen

2. Seitentüren abgenommen, Schutz gegen Wind und Regen



3. "Cabrio" für den Sommer

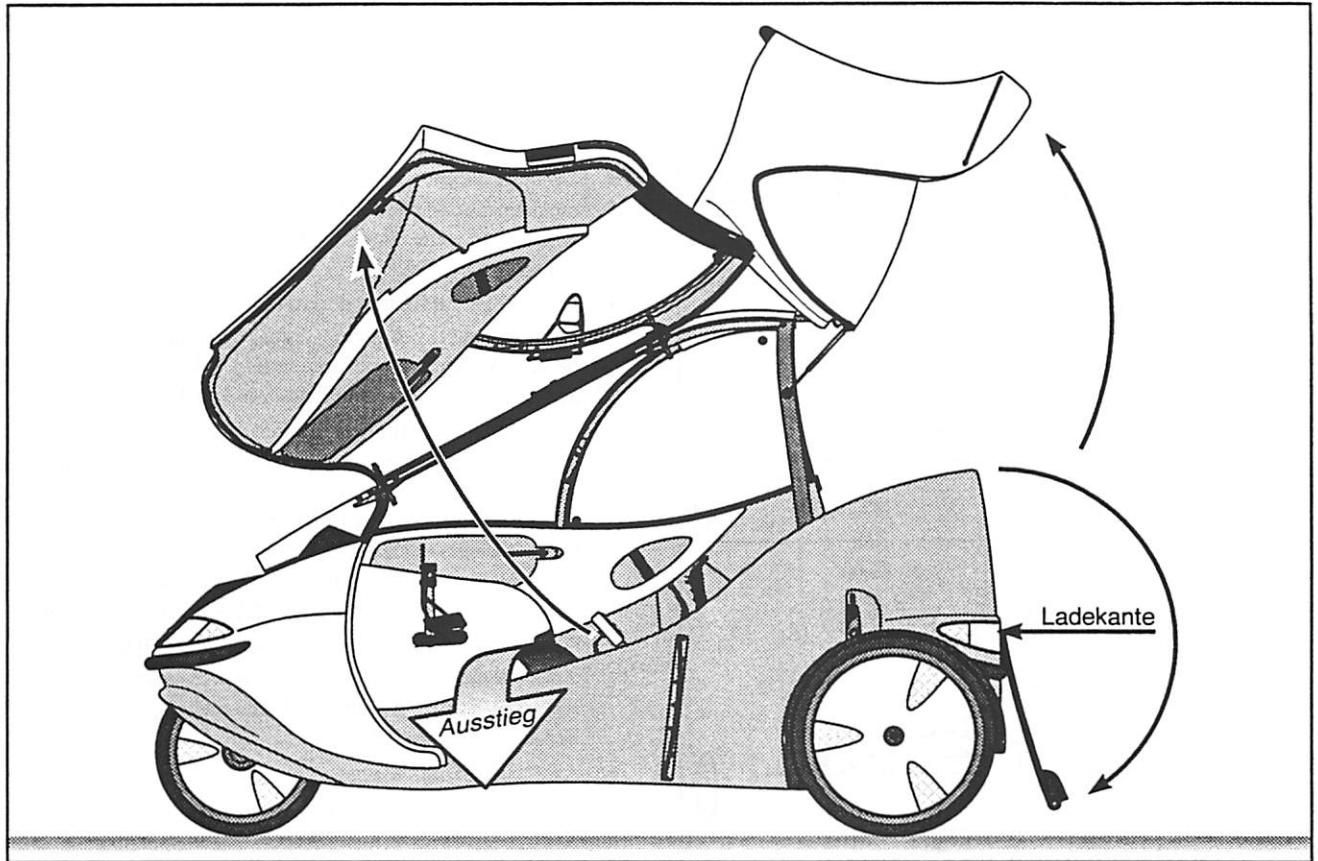


Bild 6 Weit heruntergezogene Öffnungen zum Ein- und Ausstieg und zum Beladen

5 Alltagstauglichkeit

Neben der Berücksichtigung ergonomischer Kriterien stellt auch die Alltagstauglichkeit wichtige Anforderungen an die Gestaltung des MOVEO [12]. So muß es die vorgegebene Radfahr-Infrastruktur nutzen können und besonders für den alltäglichen Einsatz geeignet sein (v. a. Berufspendelverkehr und Einkaufsfahrten).

Der geforderte Witterungsschutz wird durch die Vollverkleidung erreicht, die bei Regen selbst bei geöffneten Belüftungskappen kein Wasser in den Innenraum dringen läßt und auch vor Spritzwasser von der Fahrbahn schützt. Daneben bietet sie einen Wind- und Kälteschutz.

Der Gepäckraum, dessen Volumen von der eingestellten Sitzhöhe abhängt (vgl. Bild 2), ist so bemessen, daß größere Lasten (z.B. Getränkekisten) mitgeführt werden können; stattdessen finden auch eine weitere Person oder zwei kleine Kinder im Innenraum Platz. Die Einfederung der Hinterachse kann durch eine stufenlos verstellbare Hinterachs-Federung an den Beladungszustand angepaßt werden.

Um den alltäglichen Gebrauch des MOVEO zu erleichtern, wurden außerdem folgende Funktionen realisiert:

- Feststellbremse zur Sicherung des abgestellten Fahrzeugs gegen Wegrollen
- Abschließbarer Fahrzeuginnenraum durch Schlösser an den beiden Seitentüren und an der Heckklappe (vgl. Bild 1)

- Stoßstangen an Front und Heck, die gleichzeitig als Tragegriffe und Anschließbügel dienen, zur Vermeidung von Beschädigungen an der Verkleidung (vgl. Bild 1)
- Kleiner Wendekreis (ca. 4 m) für eine gute Wendigkeit
- Ausstattung mit einem selbst entwickelten Differentialgetriebe, das auf Leerlauf oder Rückwärtsgang umgeschaltet werden kann (Bild 7). Der Leerlauf ermöglicht einen Gangwechsel im Stand trotz Kettenschaltung. Der Rückwärtsgang erleichtert Wende- und Einparkmanöver.
- Kompatibilität zu Radwegen durch moderate Fahrzeugabmessungen, v.a. in bezug auf die Spurbreite (840 - 1000 mm)
- Wartungsfreundliche Konstruktion: Komponenten sind gut zugänglich durch einfache Demontage und Montage von Verkleidungselementen. Für den Fall von Radpannen sind die Räder durch eine Schnellspannachse vorn bzw. nur je eine zu lösende Schraube an den Hinterrädern sehr einfach zu lösen. Integrierte aufklappbare Stützen verhindern bei demontiertem Rad ein Aufliegen der Verkleidung
- Verschleißarmer Antrieb (Ritzel und Kette) durch Unterbringung innerhalb der Verkleidung

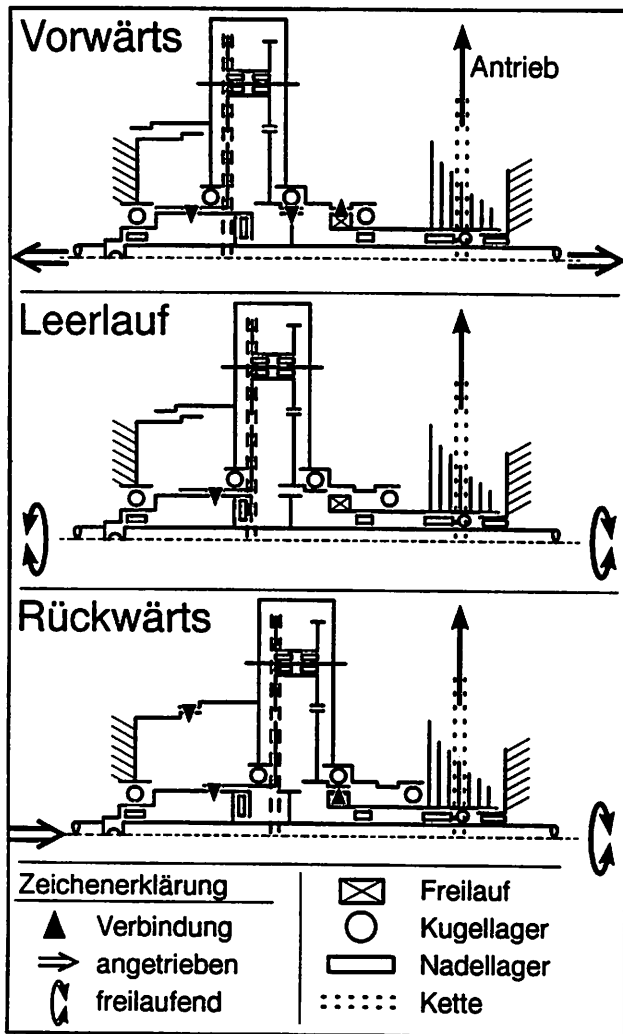


Bild 7 Differentialgetriebe mit schaltbarem Leerlauf und Rückwärtsgang

6 Sicherheit

Eine weitere wesentliche Anforderung an das MOVEO ist die Gewährleistung einer ausreichenden *Sicherheit* des Fahrers im Straßenverkehr [13]. Vor allem im Autoverkehr sind die *Sichtbarkeit* des Fahrzeugs und - für den Fall einer Kollision - ein wirksamer *Aufprallschutz* die wesentlichen Elemente der passiven Sicherheit:

Für eine gute Sichtbarkeit sorgen eine leistungsfähige, ausfallsichere Lichtanlage mit zwei Halogenscheinwerfern vorn, Standlichtfunktion, Fahrtrichtungsanzeigern und Bremsleuchten sowie große allseitige Reflektorflächen (vgl. Bild 1)

Beim herkömmlichen Fahrrad ist der Fahrer bei einer Kollision praktisch ungeschützt [14]. Dagegen kann die Vollverkleidung des MOVEO (Aluminium-Schweißrahmen, Überrollbügel, Verkleidungselemente mit Schaumkernen) einen ausreichenden

Rundumschutz bieten. Der Aluminiumrahmen, der wegen der hohen plastischen Verformbarkeit des Werkstoffs zur Absorption großer Stoßenergien geeignet ist, umgibt den Fahrer allseitig.

Die *aktive* Sicherheit findet beim MOVEO in folgenden Punkten Berücksichtigung:

- Leistungsfähige hydraulische Felgenbremse vorn und mechanische Trommelbremsen hinten. Die Bremskraft wird über eine Zwischenrolle gleichmäßig auf beide Hinterräder verteilt.
- Stabiles Fahrverhalten durch Viergelenk-Radaufhängungen vorn und hinten mit exakter Kinematik (querbewegungsfreie Einfederung ohne Änderung von Spur und Sturz) und Stabilisator an der Hinterachse
- Gute Sichtverhältnisse durch großzügig bemessene Fensterflächen (vgl. Bild 1); kratz feste Verbundglas-Frontscheibe mit elektrisch angetriebenem Scheibenwischer sowie linksseitigen Rückspiegel, der von innen verstellbar ist. (Für den Scheibenwischerantrieb könnte ein neuartiger, kompakter Piezo-Wanderwellenmotor eingesetzt werden, der die Wischbewegung elektronisch, also ohne zusätzlichen Kurbeltrieb, erzeugen kann.)
- Vermeidung des Beschlagens der Fenster durch eine Führung der Innenraum-Luftströmung entlang der Fensterflächen (vgl. Bild 4)
- Akustische Signalanlage

Die vorgesehenen elektrischen Komponenten machen eine leistungsfähige Elektrik erforderlich, die einen Nabendynamo und einen ausreichend dimensionierten Akkumulator beinhaltet.

7 Design

Alle bisher aufgeführten Funktionen sind in einen Gesamtentwurf integriert, der durch ein modernes, dynamisches Design dem potentiellen Benutzer die Identifizierung mit dem neuartigen Fahrzeug erleichtern soll. Dafür sind stilistische Elemente aus dem heutigen Automobil-Design übertragen worden (vgl. Bild 1):

- Aerodynamische Keilform mit langer, schräg ansteigender Windschutzscheibe und steil abfallendem Heck
- Harmonische, geschwungene Linienführung entlang von Kanten und Fensterbändern
- Glatte Verkleidung mit bündigen Fugen zwischen den Verkleidungselementen
- Großflächige Beleuchtungselemente und Reflektoren, die bündig in die Verkleidung versenkt sind

Es sind jedoch auch Elemente enthalten, die an ein herkömmliches Fahrrad erinnern, womit zum Ausdruck kommen soll, daß das MOVEO eine Synthese aus beiden Fahrzeugarten darstellt: die nicht in die Karosserie integrierten Hinterräder mit separaten Schutzblechen und die Lenkhebel und Bremsgriffe.

MOVEO

Um alle Komponenten des MOVEO harmonisch zu integrieren, werden gleiche Formelemente an verschiedenen Komponenten wiederholt (vgl. Bild 1):

- Eine charakteristische Parabelform findet sich z.B. an den seitlichen Blinkern, den Radreflektoren, dem hinteren Auslauf des seitlichen Fensterbandes, verschiedenen Griffmulden und am Außenspiegel wieder (auch der MOVEO-Schriftzug enthält solche Parabelformen).
- Die zwei runden Frontscheinwerfer mit integrierten Reflektoren finden ihre formale Entsprechung bei den Heckleuchten.

Eine besondere Schwierigkeit bei der Gestaltung der Verkleidung ergibt sich aus der mit Sitzhöhenverstellung gekoppelten variablen Höhe des Oberbaus. Damit die Verkleidung stets geschlossen bleibt, umgreift der obere Teil den Unterbau teleskopartig. Das Erscheinungsbild des MOVEO wandelt sich in Abhängigkeit der gewählten Sitzhöhe vom großräumigen Stadt-Vehikel zum flachen Rennmobil (Bild 8).

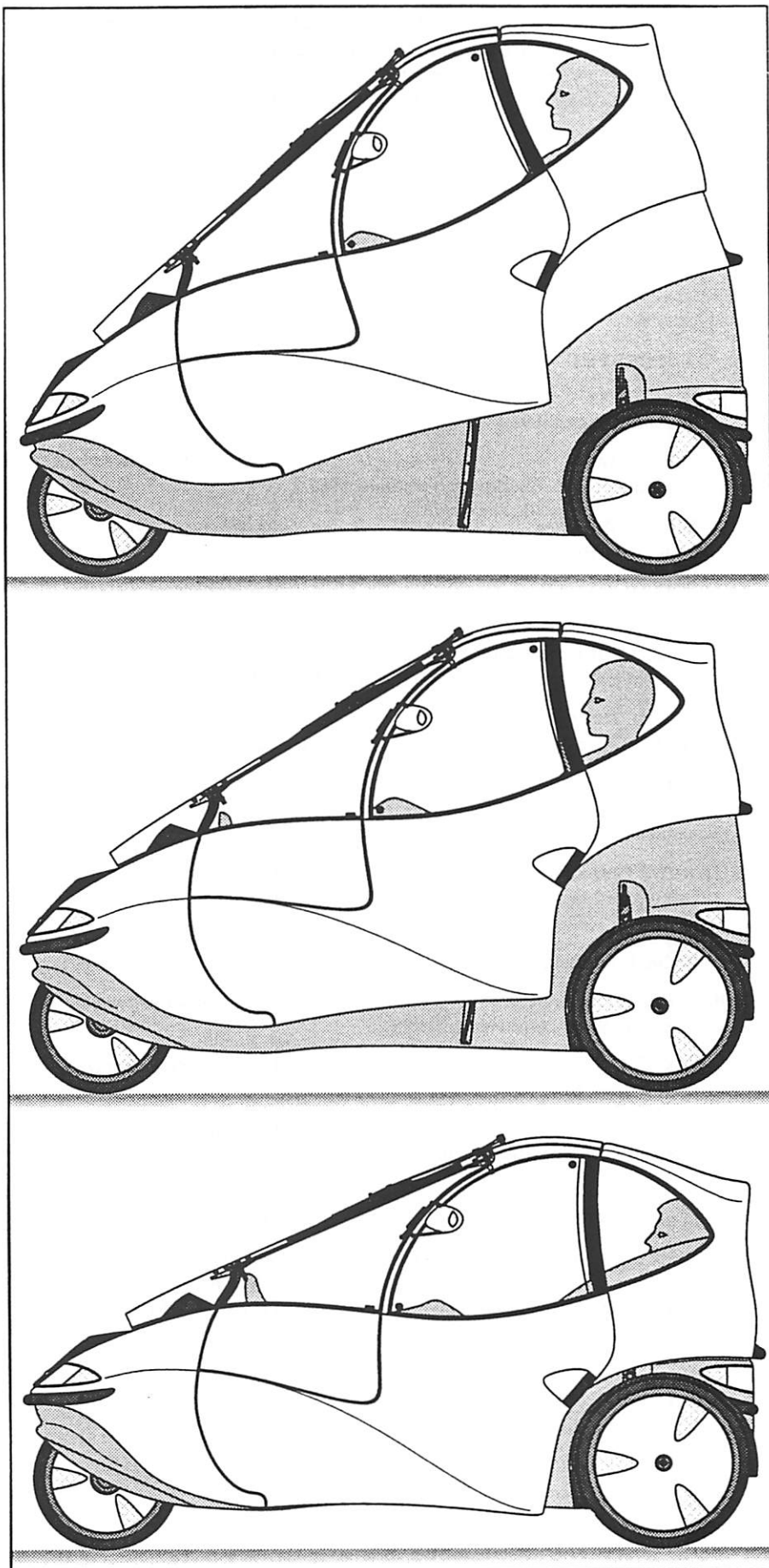


Bild 8 Veränderung des Erscheinungsbildes je nach Sitzhöhe

Der dargelegte Entwurf des MOVEO zeigt nach unserer Auffassung, daß es möglich ist, ein zugleich anwender- und umweltfreundliches muskelkraftgetriebenes Fahrzeug zu konzipieren, das wesentlich besser als ein übliches Fahrrad

geeignet ist, das Auto auf kurzen bis mittleren Strecken zu ersetzen.

Wir hoffen, daß unsere Arbeit einen Beitrag dazu leistet, daß sich wieder mehr automobilverwöhnte Menschen "aus eigenem Antrieb" fortbewegen werden.

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Anhang: Technische Daten

| | |
|----------------------------|---|
| Fahrzeugabmessungen | |
| Gesamtlänge | 2240 mm |
| Gesamtbreite | 875 - 1035 mm |
| Gesamthöhe | 1260 - 1683 mm |
| Innenraumbreite | 572 mm |
| Spurweite | 840 - 1000 mm |
| Radstand | 1700 mm |
| Rad- und Reifengrößen | vorn: 16 x 1 ³ / ₈ ", hinten: 20 x 1 ³ / ₈ " |
| Tretgeometrie | |
| Kurbellänge | 170 mm |
| Sitz-Tretlager-Abstand | 850 - 1300 mm (Rückenlehne bis vorderes Pedal), Aufteilung in Tretlagerverstellung (120 mm) und Sitzverstellung (330 mm) |
| Tretlagerhöhe über Boden | 520 mm |
| Sitzhöhe über Tretlager | ± 250 mm (bei mittlerem Sitz-Tretlagerabstand) |
| Lenkung | indirekt auf das Vorderrad wirkend, Übertragung über Bowdenzüge, Lenkhebel in Hüfthöhe angeordnet |
| Bremsen | vorn: hydraulische Felgenbremse, hinten: Trommelbremsen, über Bowdenzüge und Bremskraftdifferential betätigt Feststellbremse über Sperrklinkenrastung des Hinterrad-Bremshebels |
| Fahrzeugrahmen | geschweißte Aluminium-Tragstruktur mit Profilrohren in Leichtbauweise |
| Verkleidung | zweischalige GfK-Bauteile mit PU-Schaumkern (Sandwich-Struktur), am Rahmen aufgehängt Radverkleidungen aus Textil |
| Fahrwerk | Viergelenk-Radaufhängungen vorn und hinten, Federung und Dämpfung über PU-Federelemente, hinten Stahlrohr-Stabilisator und Spurweitenverstellung, über Gewindespindel und Zahnriemen mit Sitzhöhenverstellung gekoppelt |
| Bodenfreiheit | min. 120 mm |
| Verglasung | Verbundglas-Windschutzscheibe, sonst Macralon [®] -Formteile |
| Elektrik | Stromversorgung von Beleuchtung, Blinker, Bremsleuchten, Scheibenwischer, Lüfter und Signalhorn über Nabendynamo und Akkumulator |
| Antrieb | Kettenantrieb über konventionelle Tretkurbel, Kettenschaltung, Differential, Kardangelenkwellen auf beide Hinterräder; Sperrklinkenfreilauf, Leerlauf und Rückwärtsgang im Differentialgetriebe integriert |
| Zähnezahlen | vorn: 28, 44, 68 hinten: 13, 14, 15, 16, 17, 19, 21 |
| Gesamtgewicht | angestrebt: 25 kg |

The future of Velomobiles - Design-concepts for individual necessities

by Prof. Dr.-Ing. W. Rohmert and Dipl.-Ing. S. Gloger

1 Introduction

The idea of velomobiles is now about 20 years old. The early pioneers dreamt of high speeds and of a widespread substitute of automobiles. But nowadays there are only a few velomobiles (HPV with weather protection and transport capacity) on the market. To reach substitution of automobiles the design concepts of practical velomobiles such as the *LEITRA*, *ALLEWEDDER* and *DESIRA-2* are based on the idea of universal properties such as automobiles. The major drawback of these vehicle-concept is the relatively high price, e.g. the production cost for the *DESIRA-2* is about 6.500 DM with respect to the conditions of a sailplane manufacturer. From questionnaires (ROHMERT/ GLOGER, 1992) we know, that only a few people would pay such a high price. The other way is to produce vehicles not for universal but for typical necessities. Four examples for the technical realisation of those vehicles will be described.

2 DESIRA-2

The *DESIRA-2* (Figure 1) is designed for universal necessities, such as commmuting, shopping, children's transportation and touring. It is build of a monocoque composite structure. The technical data are shown in Table 1. As all other *DESIRA* types it can be used by people of different body height (150-200 cm) by adaption of the variable seat and handlebar.

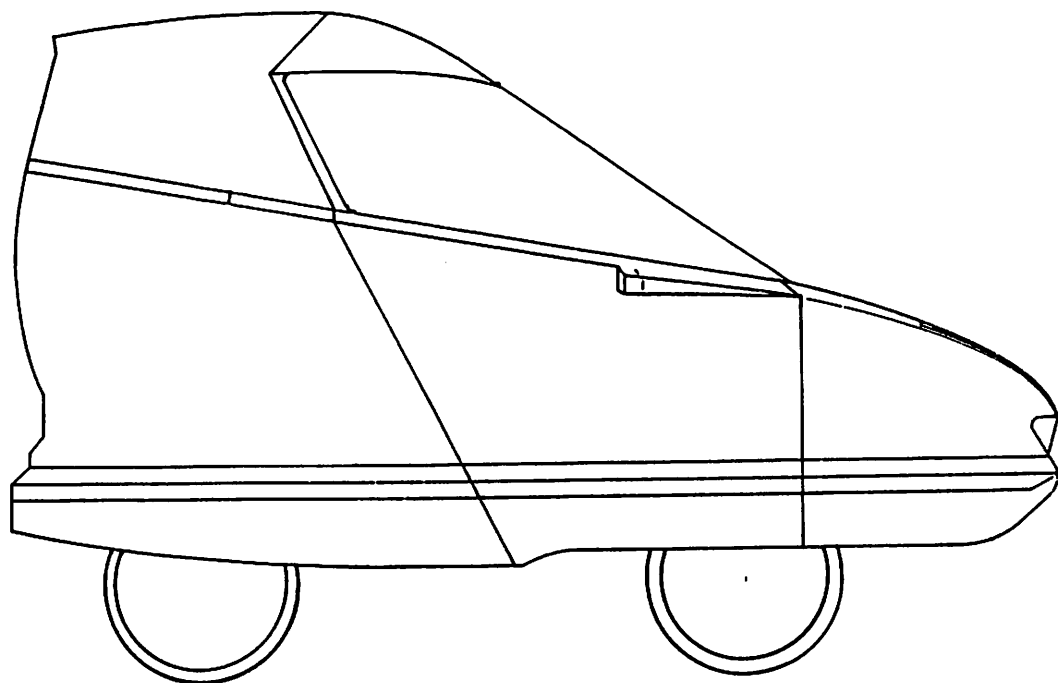


Figure 1: DESIRA-2

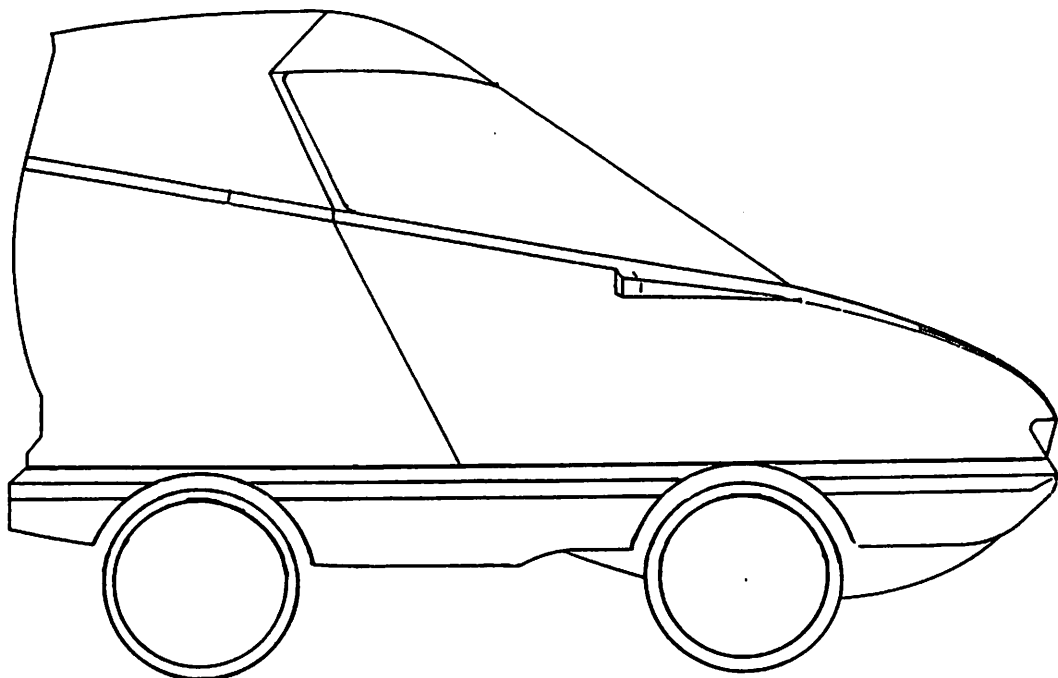


Figure 2: DESIRA-quattro

Body

- Fully closed monocoque composite body structure ("May-Bug-Principle", Side-Impact-Protection)
- Variable air-conditioning
- Luggage compartment with 225 l volume, (Child seat available)
- Visor for stepwise opening with wiper and anti-fog-finish
- multiple adjustable seat for body-heights from 150-200 cm
- ergonomically optimized *Epsilon*-handlebar
- length/width/height: 2150/950/1450 mm
- gross vehicle weight: 23-29 kg

Chassis

- rear wheel with elastomer suspension (150 mm)
- mirror-symmetric front wheel geometry with elastomer suspension (80 mm)
- wheel-size: 16x1,75 (high pressure tire), disc-wheels available
- wheelbase 1080 mm
- track 40-50 mm
- head-angle 88°

Components

- Gearing: 4x7 gears with additional control shaft (Sachs-ARIS)
- Brakes: MAGURA-hydrostop rim brakes
- Lamps: Halogen front-light, double rear-light, 4 turn indicators

Table 1: Technical description of *DESIRA-2*

Body

- Fully closed monocoque composite body structure ("May-Bug-Principle", Side-Impact-Protection)
- Variable air-conditioning
- Luggage compartment with 265 l volume, (Child seat available)
- Visor for stepwise opening with wiper and anti-fog-finish
- multiple adjustable seat for body-heights from 150-200 cm
- ergonomical optimized *Epsilon*-handlebar
- length/width/height: 2150/950/1450 mm
- gross vehicle weight: 25-30 kg

Chassis

- rear wheel elastomer suspension (100 mm)
- front wheel with elastomer suspension (50 mm)
- wheel-size: 16x1,75 (high pressure tire), disc-wheels available
- wheelbase 1000 mm
- track 30 mm
- head-angle 88°

Components

- Gearing: 3x7 gears (Sachs-ARIS)
- Brakes: MAGURA-hydrostop rim brakes (rear)
SACHS drumbrakes
- Lamps: double Halogen front-light, double rear-light,
4 turn indicators

Table 2: Technical description of *DESIRA-quattro*

3 DESIRA-quattro

For people who do not like the stabilisation tasks of single track vehicles, especially those of fully faired recumbents, the *DESIRA-quattro* (Figure 2) was designed. It is a rear driven four wheeler with a car-like handling characteristic. All wheels are suspended. In comparison to the *DESIRA-2* there is a bigger luggage compartment and a more difficult and heavier chassis. This concept is particularly suitable for motor assistance.

The technical data are shown in table 2.

4 DESIRA-light

People who have to store their vehicle inside the house (e.g. the cellar) will like the *DESIRA-light* (Figure 3). Its design is nearer to the bicycle. It has a rollable soft-shell fairing and the luggage case is optional. The chassis and the operating position are the same as in the *DESIRA-2*. The passive safety has decreased especially if the fairing is not mounted. Because of the turn-over-frame, the passive safety is nevertheless better than that of other unfaired HPV's. The *DESIRA-light* is relatively light and cheap. The technical data are listed in table 3.

5 DESIRA-classic

The additional functions of velomobiles in comparison to standard bicycles (weather protection and transport capacity) are not necessarily coupled with the recumbent position. For many years we have seen Eggert Bülk with his "Camping-rad" at European Championships with a standard riding position. The advantage of this position is, that every one, who can ride a normal bicycle, will be familiar with the driving characteristics and there will be no psychological reservations. With a look to this idea we have designed the *DESIRA-classic*, which is not a complete vehicle but an extension board for a normal mountain bike (Figure 4).

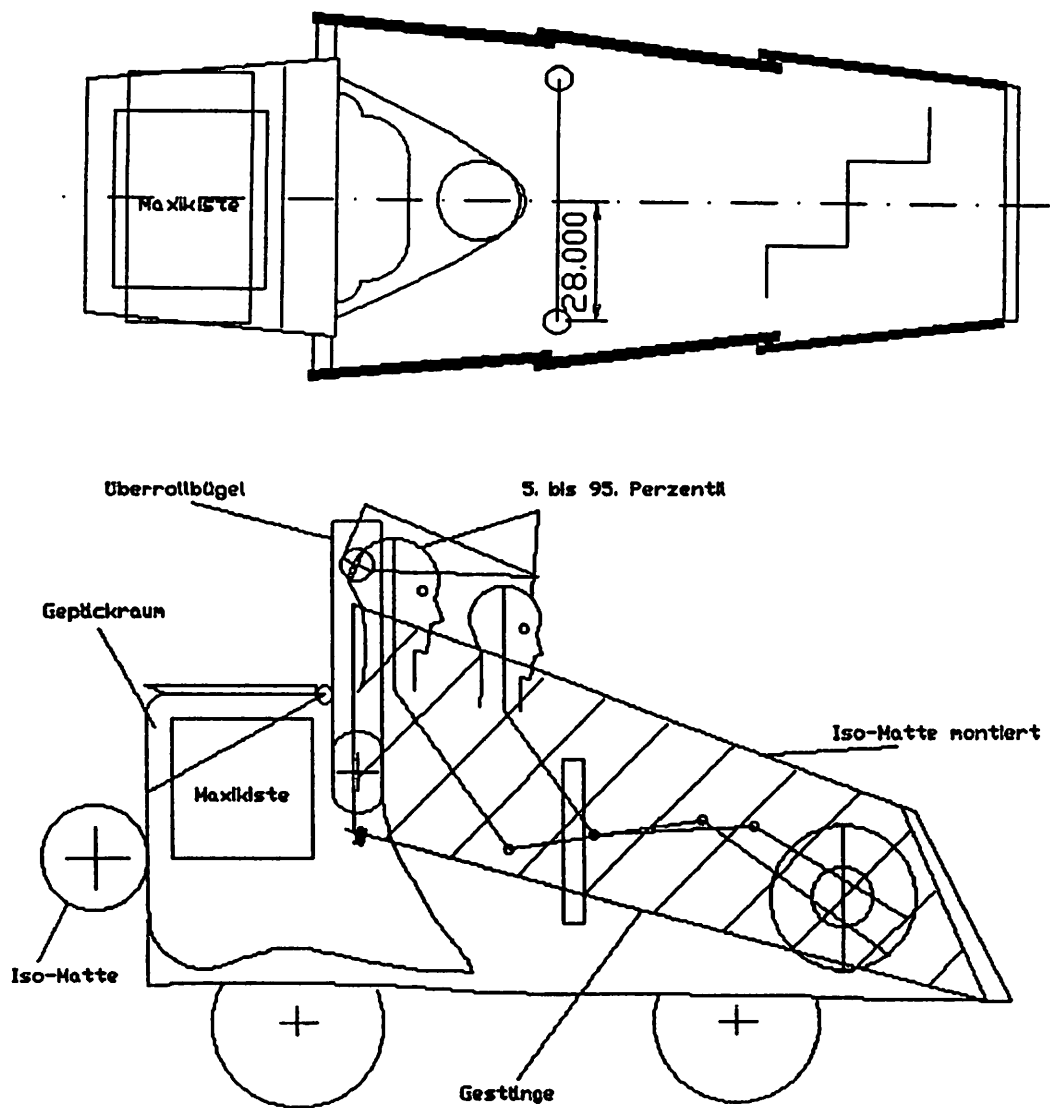


Figure 3: DESIRA-light

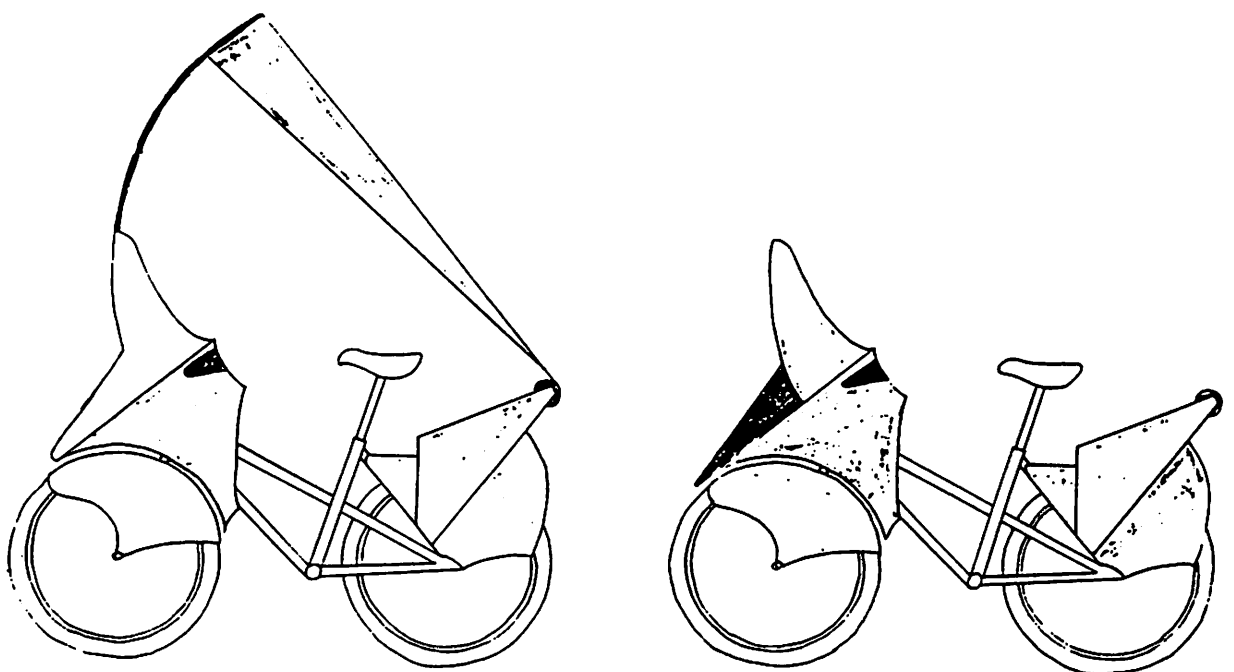


Figure 4: DESIRA-classic

Body

- Variable soft-shell polyurethan fairing
- turn-over-frame
- big radiator grill
- removable luggage compartment with 120l volume,
- Visor for stepwise opening with anti-fog-finish (umbrella principle)
- multiple adjustable seat for body-heights from 150-200 cm
- ergonomical optimized *Epsilon*-handlebar
- length/width/height: 2150/650/1450 mm
- gross vehicle weight: 15-20 kg

Chassis

- rear wheel elastomer suspension (150 mm)
- front wheel with elastomer suspension (50 mm)
- wheel-size: 16x1,75 (high pressure tire), disc-wheels available
- wheelbase 1080 mm
- track 40-50 mm
- head-angle 88°

Components

- Gearing: 7 gear-hub (Sachs-Super 7)
- Brakes: MAGURA-hydrostop rim brakes
- Lamps: Halogen front-light, rear-light

Table 3: Technical description of *DESIRA-light*

Body

- Front-fairing with variable adjustable visor and integrated luggage compartment (20 l)
- rear luggage compartment (80 l) with additional fabric cape on a batch roller; additional child seat or standard box mountable
- Gross weight: 7,5 kg

Chassis

- Standard mountain bike (e.g. TREK Mountain Track 820, lady-style-frame)

Components

- Lamps: Halogen front light, rear light

Table 4: Technical description of *DESIRA-classic*

The attaching parts are built to fit with the most frame geometries and with suspension forks. The front and the rear part provide space for luggage. The weather protection is realized as a telescopic shield in front and a fabric cape on a batch roller at the rear part. They are attached with press buttons. Mounting of a child seat is possible. Besides familiar driving characteristic the other advantage of this configuration is the low price in comparison to a complete velomobile. The disadvantages are lower comfort and less passive safety. (Technical Data)

6 The Future of Velomobiles

Due to the fact that acceptance of velomobiles is not only estimated by the technical and ergonomical design but also by the price, the step into the market in the near future will be easier with designs for special necessities such as the DESIRA-light and DESIRA-classic as with universal machines such as the DESIRA-2 or the DESIRA-quattro.

7 Summary

The design concepts of practical velomobiles such as the *LEITRA*, *ALLEWEDDER* and *DESIRA-2* are based on the idea of universal properties such as automobiles. The major drawback of these vehicle-concept is the relatively high price. As we all know the universal properties of the automobile are not used by everyone on every day. So the other way is to design vehicles for individual necessities. This is possible by the diversification of functions. Four examples for the combinations of functions for practical velomobiles -*DESIRA-2*, *DESIRA-quattro*, *DESIRA-light* and *DESIRA-classic*- are described.

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Typical design-problems of Velomobils - Solutions for the DESIRA-2

by Prof. Dr.-Ing. W. Rohmert and Dipl.-Ing. S. Gloger

1 Design-concept of DESIRA-2

In this paper we want to describe some solutions for typical design-problems of velomobiles, that we have found for the *DESIRA-2* prototype. We wanted to create a practical HPV for city traffic with universal qualities. The range of application is commuting, shopping, childrens transport and touring. While it is not designed for sports it can be used for transportation of sports equipment.

2 Typical Design-Problems

All velomobiles that are designed for those purposes have to deal with problems for the climate inside the fairing (especially in summer), the conspicuousness in city-traffic, getting-in, getting-of and loading. Besides the stability, controllability and passive safety these are the most important parameters for the acceptance of practical velomobiles (RETZKO et al., 1994).

2.1 Climate inside the fairing

Besides the effects of convection, heat conduction and thermal radiation, the heat production of the rider has to be considered, because the human power generation by pedaling has a physiological efficiency of 25-30% (SPITZER et al., 1982). The result is that driving with an average performance of 150 Watts produces 450 Watts of heat. That is half of the maximum performance of a fanforced heater. Imagine this fanforced heater in the little, closed and well isolated cabine of a fully faired hard-shell HPV! The other important effect is heat radiation, that is reinforced to a greenhouse effect by the transparent area of the fairing. Anyone who has ever sit in a sailplane on a sunny summer day waiting for the take off clearance will know what we are

going to talk about.

For cooling the driver the effects of convection and sweating are available (WENZEL/PIEKARSKY, 1982). Because sweating can be an acceptance problem for some purposes we should focus on convection. Conduction effects (by metallic surfaces) will lead to additional heating in summer and to additional cooling in winter. In both cases the reinforcement is unwelcome.

Because only the rider is able to influence the heat production by choice of speed the designer has to minimize radiation and to maximize convection.

The *DESIRA-2* shows a relatively small transparent visor to reduce radiation. In addition to this a sunshade inside the roof can be pulled out when the visor is opened (Figure 1).

To maximize convection on the body surface the air speed near the driver should be as high as possible. Therefore the gradient of pressure between air inlet and air outlet should be high and its direction should be parallel to the body surface. Because of the losses inside the fairing the outlet should be bigger than the inlet. The solution for the *DESIRA-2* is shown in Figure 1.

The permanent air-inlets are located along the two impact pressure lines whereas the outlet is in the area of atmospheric pressure behind the vehicle. The variable inlet is the visor and the variable outlets are the rear doors. Both can be adjusted continuously. Additionally the main spar element is formed as a cooling baffle and the protective cover of the trunk can be used as its elongation. The main area of the bucket seat is made from an aluminium net.

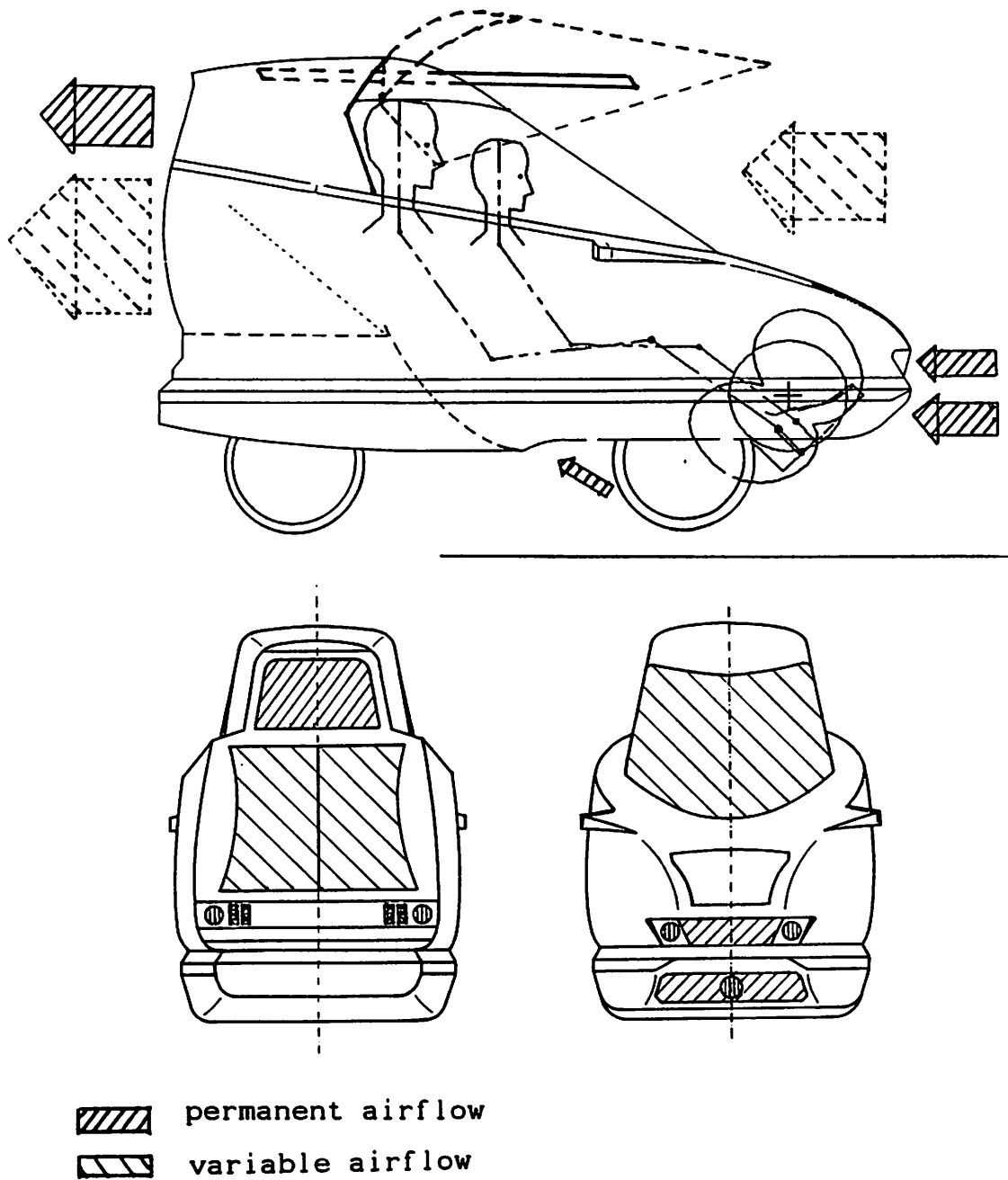


Figure 1: Solutions for the regulation of climate inside the fairing of DESIRA-2

2.2 Visibility in traffic

A fully faired practical vehicle must guarantee visibility under all conditions. There must be no fog on the wind-screen, no raindrops and no snow. In contrast to automobiles there is no heat energy to prevent fog, and the aerodynamic form of the visor (windscreen) is in conflict with a rotational wiper. The solution for the *DESIRA-2* is a polycarbonat windscreen with an anti-fog coating inside together with the ventilation described above. The outer surface of the visor is coated hydrophob ideally so that drops of a definite size will roll down. The linear, manually controlled wiper has only to be used at night to prevent dazzle source. The wiper (Figure 2) consists of two parts: the handle on the inner side and the wiper blade outside. They are connected by two strong samarium-cobald magnets on every side. There is no need of an extra guideway because of the curvature of the visor.

The attempt of using the capillary action of black nylon nets on the visor or alone as a "drop-brake", coated or uncoated, were insufficient. Even mechanical vibrations (activated by an electrical 50 Hz razor) were not sufficient to reach a clear sight through the visor on rainy days.

2.3 Getting in and off

The time needed to start is important for the acceptance of a vehicle. Especially in city traffic with short distances and several driving goals this time is essential for the time that is needed for the whole trip. So it has to be easy and comfortable to get in and to get out. The solution consists of two parts. The first part is the continuously variable visor, and the second part is a door on the right side of the vehicle (Figure 3). So the driver only has to step over the inner frame. A solution with a movable hud like the *LEITRA* was tested, too. In this case the driver would have to step over the outer and the inner part of the monocoque structure. The emergency exit after a crash is the visor.

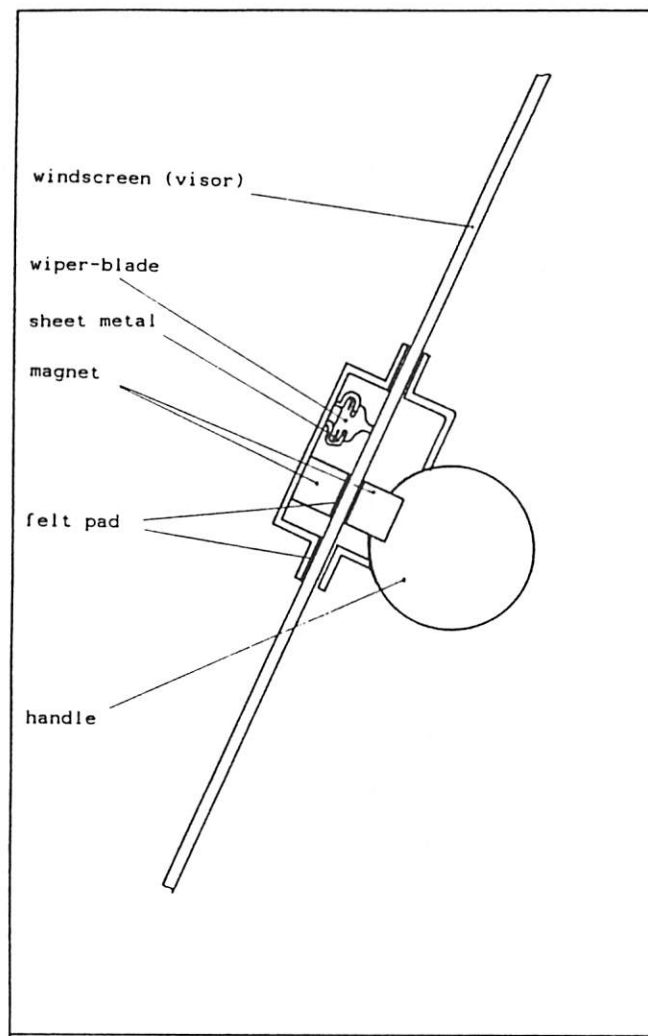


Figure 2: Windscreenwiper of the DESIRA-2



Figure 3: DESIRA-2 with opened door and visor

2.4 Loading

Most of all fully faired vehicles have no special solution for the loading of goods. Unfortunately, the typical boxes and cases (e.g. for beverages) cannot be transported. The *DESIRA-2* is equipped with a large plane surface over the rear wheel. Under that plate there is a lockable space left and right of the rear wheel for smaller goods. Instead of this a child-seat can be assembled. The luggage compartment can be loaded through two large doors at the rear end of the vehicle (Figure 1).

3 Summary

For the typical design-problems (climate inside the fairing, visibility, getting-in, getting-off and loading) the solutions are shown that were found for the *DESIRA-2* prototype.

3 Zusammenfassung

Für die typischen Konstruktionsprobleme Innenraumklimatisierung, Sicht, Ein- und Ausstieg sowie Beladen werden die für das Fahrzeug *DESIRA-2* gefundenen Lösungen erläutert.

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Characteristics of a Practical Velomobile Fairing

by C. G. Rasmussen, LEITRA ApS

Summary

Unlike streamlinings for racing vehicles, where low air resistance and lightweight are the sole optimization parameters, the practical fairing should meet a wide range of additional specifications, which make them suitable for city transport, commuting and/or long distance touring, day and night the whole year round.

Moreover, practical velomobiles are not ridden by young sportsmen/women only, but rather by ordinary cyclists, who want a safe bike with full weather protection, better comfort and an appropriate transport capacity.

This paper summarizes the most important characteristics of a practical fairing and illustrates, how they have been realized and tested in a LEITRA velomobile.

Another kind of record

Considering that the success of different HPVs has so far been closely associated with the ability to brake speed records, I appreciate very much that the European Seminars on Velomobile Design now tries to set new trends for the design work by focusing on safety.

Speed is, indeed, an important factor to make the velomobile attractive as an alternative to the motorized vehicles, but we should not forget to develop the full potential of velomobiles as very safe vehicles, for the rider and for other road users as well.

Wouldn't it be an attractive new object for a record: To reach the highest mileage in normal traffic without any injuries of significance. Only a vehicle, which at the same time is fast, reliable and safe, can hold such a record.

But safety is not enough. A practical velomobile should also be comfortable to ride under different weather conditions the whole year round, and it should be adaptable or convertible to different applications to meet the different transport needs of the owner, such as commuting, shopping, recreation and long distance touring.

The more versatile it is, the more will it be used as a substitute for a car and the more kilometers will it cover.

Safety should, therefore, be considered in relation to other design parameters.

Why do bicyclists get hurt ?

People working with statistics of accidents tell us, that if you ride on an ordinary bicycle in normal traffic you are exposed to a higher risk of being hurt than any other kind of road user. In Denmark one of the leading groups for the analysis of accidents is based at the casualty department of Odense hospital.

About 2000 cyclists are brought in every year for treatment after accidents, and this corresponds to 60 % of all treatments of traffic injuries. The rest are motorcycle- or car-drivers or pedestrians.

An analysis from 1992 shows, that 72 % of the bicycle accidents were solo-accidents, where the cyclist hits a fixed obstacle, falls due to road and/or weather conditions or due to wrong and careless loading and manoeuvring of the bike, or because the bicycle had defects and faults.

In 25 % of the cases the cyclist were more or less under influence of alcohol.

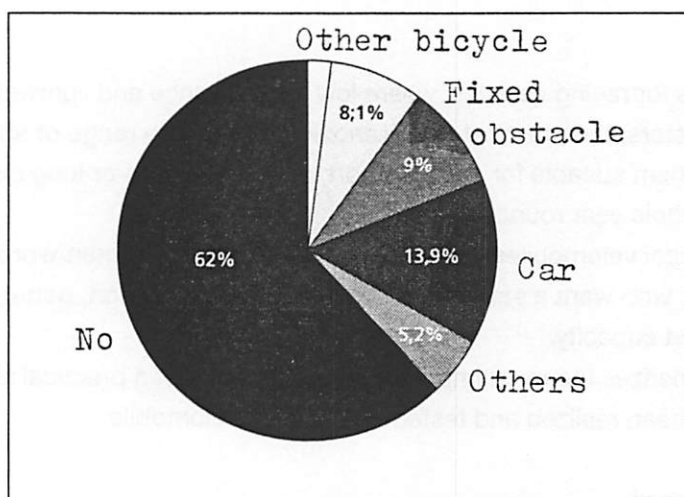


Figure 1. Distribution of bicycle casualties according to collision partner. Odense hospital 1992.

Only 14 % of the accidents were caused by collisions with cars, but they let to the most severe injuries and death. Broken bones and skin abrasions are very common.

Using the fairing as a shield

It seems like ordinary bicyclists are getting more and more consious of the risk they take, when riding in the traffic without any protection.

In the last 10 years intensive campaigns through out the World has let to extensive use of bicycle helmets.

Also the use of elbow guards and gloves are quite common in cycle sport, which sometimes makes the rider look like an American football player.

A velomobile with a full hard-shell-fairing offers a much better protection, because it covers the whole body, including the head. Therefore, you need no helmet.

The design of practical velomobiles is still at an early stage, and very few HPVs on the market to-day offer a reasonable crash protection.

Very cheap and light fairings can be made of thin fabric.

They may provide sufficient weather protection and reduction of the air resistance, but they do not protect the rider in case of a fall.

In order to function as an effective crash shield the fairing should be tough and flexible, so that it stays integrated in case of a collision and protects the rider against direct contact with the obstacle or collision partner.

If the collision partner is another bicyclist, he/she will also be better protected than in a normal bicycle collision, because a flexible and partly elastic fairing will absorb the kinetic energy and cushion the impact.

Many solo-accidents happens because of a wrong manoeuvre, which results in a fall or overturn. In that case the fairing should protect against direct contact with the road surface.

Experience has shown, that provided the surface of the fairing is smooth and coated with a tough and hard lacquer with excellent wearing qualities, sliding on the side on asphalt will only leave a few scratches in the lacquer.

The LEITRA fairing is a glass-fiber/epoxy shell with a wall thickness of 0.7-0.8 mm and a polyurethane coating of 0.2 mm

It has carbon fiber and extra glass fiber reinforcement along the edges for stiffness and stability.

The fairing has proven to give a very good protection in case of collisions as well as overturns. Only in a few extreme cases, sliding on the side has worn small holes in the fairing.

A glass fiber fairing is damage tolerant and easy to repair, which is another important characteristics of a practical fairing.

In relation to safety the choice of material is an important factor. Very thin/light and tough/flexible shells can be made of glass fiber and/or kevlar fabric in an epoxy matrix. Carbon fibers are stiff and strong, and they are very well suited for build-in of extra stiffness in the structure, but the use of 100 % carbon fiber fabric for the fairing shell is dangerous. When a carbon fiber shell brakes, it produces very sharp edges, which can cut through a human body like a knife.

Weather protection and comfort

Next after crash protection and aerodynamic streamlining a practical fairing serves as weather protection.

The specifications for an all-weather-velomobile will, of course, depend on the climatical operation conditions. In South Europe and North Africa protection against the sun radiation is essential for the riding comfort, while protection against the cold wind and precipitation is more important in Scandinavia.

The LEITRA fairing has been tested at air temperatures up to 35-40°C. It is still possible to maintain a good comfort under such conditions, provided the air humidity is not too high and the fairing has

- a white top coating to reflect the sun radiation, and
- good ventilation to cool the rider, and
- a seat padding, which is open enough in the structure to let the transpiration through.

With a white top, the surface temperature of the fairing is kept at about the air temperature, and there is no heat radiation to the inside. If the fairing is painted in dark colours or black, the surface temperature may rise to about 80-90°C in the sun, and the poor rider feels like being baked in an oven.

The author has been riding several days quite comfortably at a high air temperature and in direct sun shine, just wearing bathing trunks or T-shirt and shorts.

The fairing has a big adjustable air inlet in both sides, and as long as the vehicle moves, a nice cooling air flow is let through the fairing.

The only problem is, that by stops and slow drive the cooling is insufficient, because the

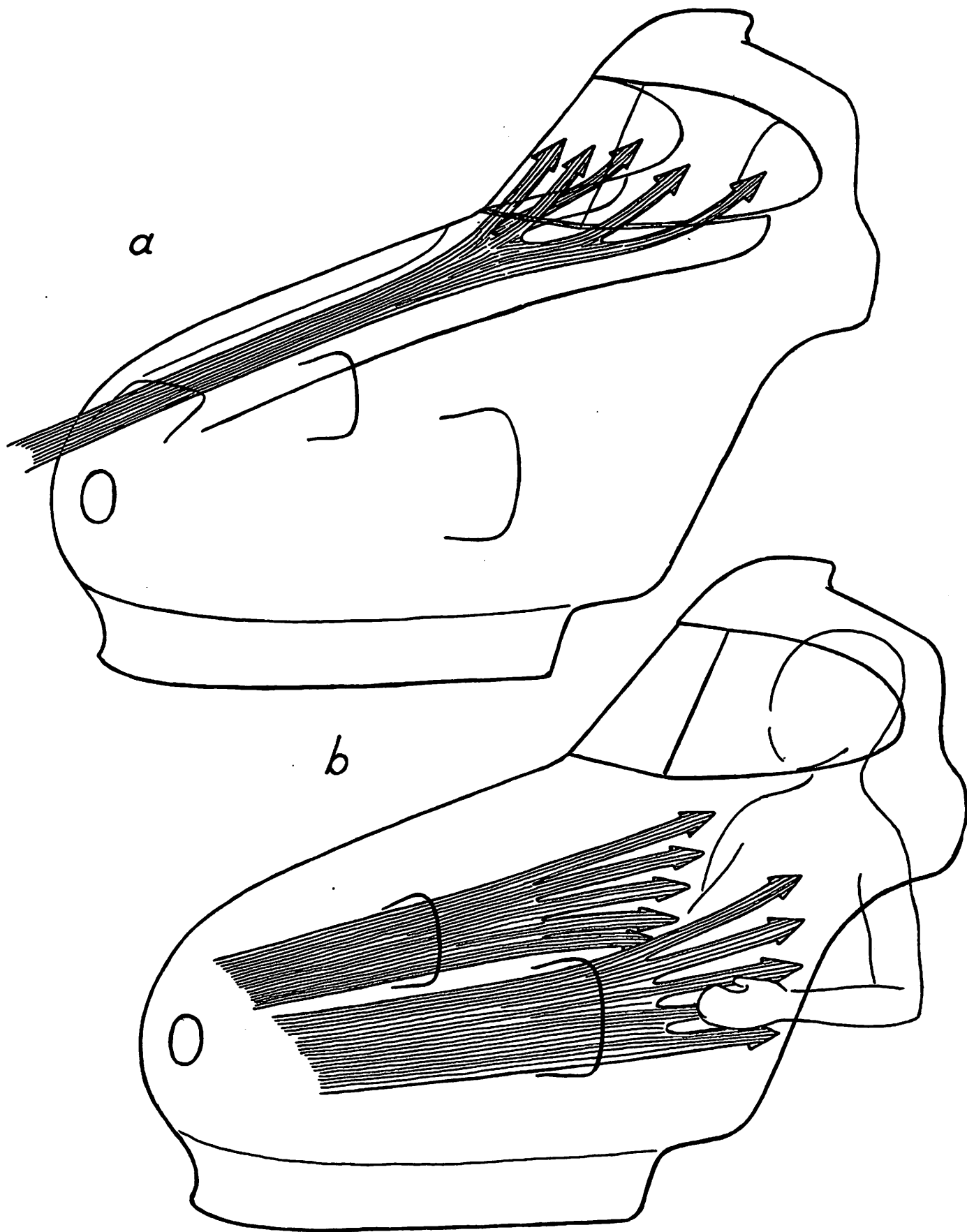


Fig. 2. Ventilation systems in a LEITRA fairing:
 (a) for the wind screen to prevent formation
 of dew and ice on the inside, and
 (b) for the cyclist to provide maximum comfort.
 The latter is adjustable.

ventilation is driven by the dynamic pressure only. A forced ventilation, powered by solar cells, would be nice to have when riding on steep hills in hot weather, because that is when you need cooling the most.

The best seat patting, for hot as well as cold weather, is a lam skin or a material with a similar woollen structure.

It permits the transpiration to get away without being wet itself.

Extremely hot days with strong sun shine are rare in North Europe and Scandinavia. What is really appreciated in the north is the protection against the cold wind, rain and snow, which makes winter cycling possible.

An all-weather-fairing for the winter period should meet same additional specifications:

- (1) Full wind protection of the whole body, including the head
- (2) Prevention of dew and ice formation on the wind screen,
- (3) Wind screen preferably of glass and with a wiper.

Ad (1): The full wind protection is important because the combination of wind and low temperatures has a strong cooling effect on a cyclist. This is illustrated in *Table 1*.

| Beauforts scale | Wind speed m/sec | Cooling effect in equivalent Celsius-Degrees | | | | | | | | | |
|-----------------|------------------|--|-----|-----|-----|-----|-----|-----|-----|-----|--|
| 0 | 0 | +10 | +5 | 0 | -5 | -10 | -15 | -20 | -25 | -30 | |
| 2 | 2.2 | +8 | +3 | -2 | -7 | -12 | -17 | -23 | -28 | -33 | |
| 3 | 4.5 | +4 | -2 | -8 | -14 | -20 | -26 | -32 | -38 | -44 | |
| 4 | 6.7 | +2 | -4 | -11 | -17 | -25 | -32 | -38 | -45 | -52 | |
| 5 | 8.9 | 0 | -7 | -14 | -21 | -28 | -36 | -42 | -49 | -57 | |
| 6 | 13.4 | -2 | -10 | -17 | -25 | -33 | -41 | -48 | -56 | -63 | |
| 7 | 15.6 | -3 | -11 | -18 | -26 | -34 | -42 | -49 | -57 | -65 | |
| 8 | 17.9 | -3 | -11 | -19 | -27 | -35 | -43 | -51 | -59 | -66 | |
| 9 | 22.4 | -4 | -12 | -20 | -28 | -36 | -44 | -52 | -60 | -68 | |

Table 1. Equivalent cooling effect of the wind on a cyclist

For example at a wind speed of 10 meters per second and an air temperature of 0°C a normal cyclist riding in head wind at a speed of 5 meters per second (18 km/h) will experience a cooling equivalent to -18°C.

The LEITRA-fairing can be completely closed, except for the bottom of the front fairing. There is no noticeable draft from below thanks to the special front spoiler.

Experience shows, that it is possible to ride the LEITRA many hours (200 km per day) at a wind speed about 10 m/sec and an air temperature around -10°C just wearing a woollen sweater and normal in-door winter dress with a light overcoat around the shoulders. But do not forget to keep your drinks and food in thermos!

It is, however, a problem to keep the feet warm during long rides at low temperatures, even with battle boots and two pairs of socks. The author has tested the LEITRA-fairing at air temperatures down to -29°C.

Ad (2): In order to prevent the formation of dew and ice on the inside of the wind screen due to condensation of the riders respiration and transpiration, the LEITRA-fairing is furnished with an air duct, which takes air from an inlet in the nose and leads it to a slit-nozzle placed along the lower edge of the wind screen on the inside.

The system works well except in case of stops or in special situations with tail wind, where the dynamic pressure at the inlet vanishes.

Ad (3): When the wind screen is close enough to the eyes, it is normally not a great problem to look through a plastic screen in rain at day light. But in the dark and with the front lights of cars against you, it is absolutely necessary to use the same kind of screen and wiper as in cars, otherwise you will get totally blinded.

The LEITRA-fairing has a flat front section, which can be covered by an ordinary laminated glass pane. The wiper is also taken from a car, but is hand-operated instead of electric.

Using a wiper on a polycarbonate or other plastic screen is not practical, because the screen very soon gets scratches.

Therefore, it is necessary to use safety glass, but the penalty for this is an additional weight of approx 750 grams.

However, with this outfit you have a vision just as good as the car driver, in rain, fog and dark.

Accessibility and versatility

We now come to some points, which are equal important for the comfort as for the safety. Accessibility is usually not given a high priority in the design of streamlinings for racing vehicles. Those who have tried to enter a fully faired racing bike, supported by helpers, may confirm this.

A complicated entering and alighting is not acceptable for a practical velomobile. It should be as easy to enter and to get out of as a car.

The LEITRA-fairing is hinged at the front spoiler and can be opened to a vertical position. The rider has then direct access to the seat and plenty of space to get in and out.

In strong wind it is necessary to take special precautions before opening the fairing. A clever rider will either choose a place to stop, where there is a shelter for the wind, or turn the nose against the wind before stepping out.

Do not forget, that a velomobile is an extremely light vehicle, which can easily fly away with the wind, if the rider leaves it without a mooring.

The hinge for the front fairing is at the same time a snap coupling, which can release the fairing in one second. This feature is very useful in many practical situations:

- The tricycle can be converted from faired to unfaired in one second.
- The front fairing can be carried separately, when the LEITRA-velomobile has to be moved up- or downstairs or loaded in a train, a car or an airliner.
- When the velomobile is parked outside in the winter, it may be covered by ice and snow.

Unlike a car driver, who must first scrape the ice off the windows and clean the body

before starting, the velomobile owner just snaps off the front fairing and puts it indoor, where the temperature is above 0°C, for a short moment. The ice and snow melt off at once, because the fairing shell has a very low heat capacity.

A practical fairing should fit the rider just right in order to provide maximum comfort and safety. Some individual adjustment is, therefore, necessary. If the fairing is too big, it will be difficult for the rider to get a complete and unobstructed view in all directions, and if it is too small, it doesn't give sufficient space for free movement.

The LEITRA-fairing is available in two sizes: For people between 160 and 185 cm and between 185 and 210 cm respectively.

The mounting of the fairing is made individually to fit the riders body and leg length. As can be seen from *Figure 3*, there is very little correlation between peoples leg length and body size.

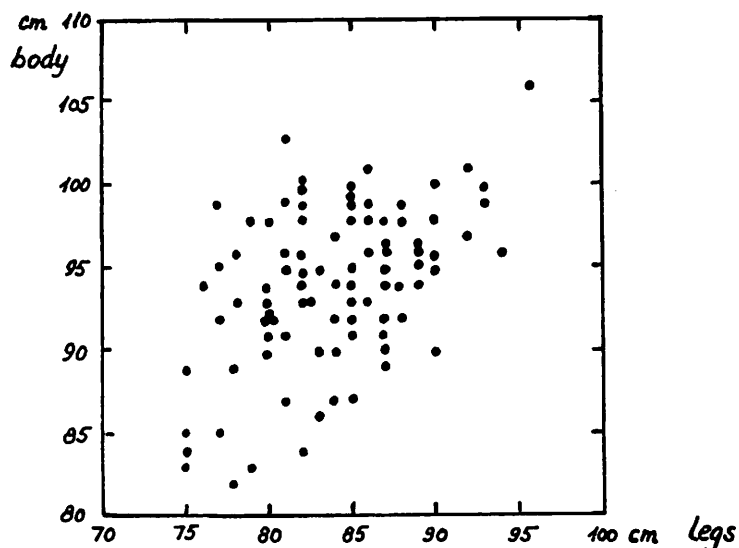


Fig. 3. Distribution of leg length and body size for a population of LEITRA test riders.

It demonstrates the need for large individual adjustments of the fairing.

The position of the front fairing varies with the crank position and the height of the roll bar. The rear fairing, including the head rest, is mounted on the roll bar and can be adjusted in height.

Accommodation of luggage

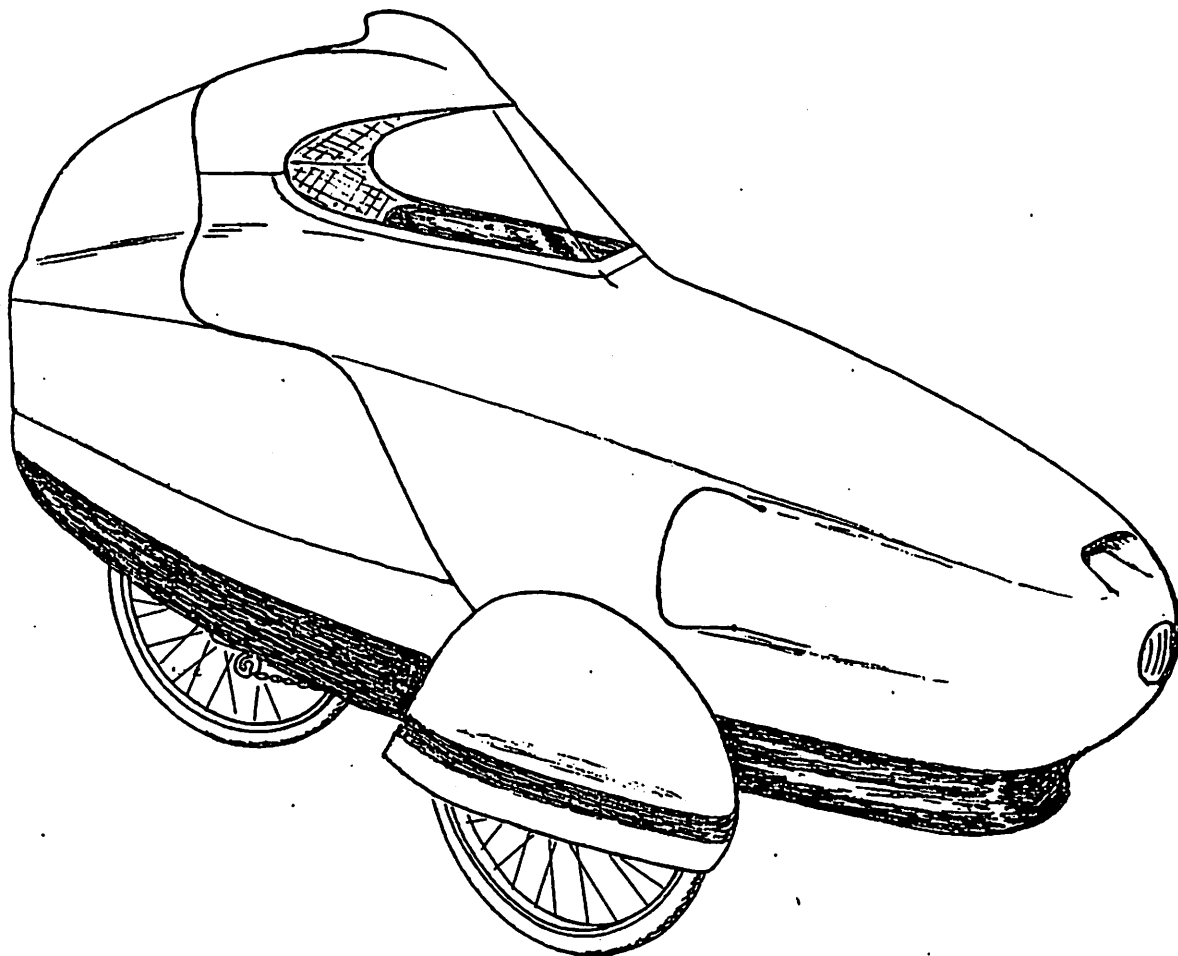
Heavy luggage should be carried as low as possible in order to maintain maximum stability.

The LEITRA velomobile is furnished with two long luggage compartments under the seat, each with a luggage capacity of 30 liters.

The weight of the luggage lowers the center of gravity of the vehicle and, thus increases the stability against overturns.

The added weight has no influence on the steering, as is often the case when a normal bicycle is loaded with bags and luggage carriers.

The luggage compartments form part of the total fairing, and they can be dismantled without screws or locks. The possibility of easy and quick disassembly is important in practical use, e.g. for the maintenance and repair of the tricycle.



Conclusion

To design a practical velomobile requires a considerable experience in the use of human powered vehicles. If you are not aware of the problems you may meet in the real life of a velomobile owner, you will not be able to build in all the necessary features to make the velomobile operational under different traffic- and weather conditions. The author has listed a number of specifications for a practical velomobile fairing, which he from personal experience has found necessary.

MUFA II - Design and Construction of a High Speed Velomobile

**Prof. Dr.-Ing. Gerhart Rinne, Prof. Dr.-Ing. Paul Wollschläger
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1 Introduction

Under the aspect of high traffic density and resulting emissions in overcrowded areas accompanied by the fact that fossil fuels are getting scarce and CO₂-problems are becoming alarming alternative propulsion or power sources for road vehicles are gaining in importance. For obvious reasons a sensible employment of the human muscle power should be taken into consideration because the additional health effect will be beneficial for the user of such type of vehicle. Muscle-driven vehicles have to follow the principles of ergonomic design, extreme light-weight construction, minimal resistance to rolling, and excellent aerodynamics in order to take advantage of the human working power in the most economical way possible. The development of the MUFA-concept is supposed to generate experiences in this technology which can be transmitted onto other projects of alternative power sources for vehicles as the minimizing of the necessary propulsive output results into a minimum of power loss.

At the time being there is not any vehicle in the market manufactured in series, except bicycles and some rare electric vehicles, which complies with the prerequisites of an optimal vehicle for inner-city traffic. This criterion does not only apply to the absolutely emission-free drive unit but also to the inner-city vehicle of minimum dimensions using a consumption- and emission-optimized combustion engine. In the cities of Japan, for example, only sub-compact cars of maximal 600 ccm capacity are allowed, and in California only zero-emission vehicles will be licensed to circulate in the city centres in near future. According to our experience it is to be expected that in the foreseeable future such regulations will become effective in Germany too.

For the inner-city the speed limit is 50 km/h. The safety concept of vehicles for this type of traffic consequently only has to be designed for this speed. If this principle is not the relevant construction feature, a lot of mass will be invested into the passive safety, which is detrimental to the efficiency of muscle-driven vehicles.

2 The MUFA I Project

Since 1983 committed professors, employees and students of the Fachhochschule Braunschweig/Wolfenbüttel have been working on concepts for muscle-driven vehicles. In 1985 the first prototype of a four-wheel road vehicle, named MUFA, in which two persons could be seated side by side, was presented to the public.

2.1 Objectives

The first draft originated from the concept of two diploma theses employing creative techniques and value-analysis methods. These means of evaluation belonging to the field of "systematic design" enable the design engineer to objectively record the factors of influence controlling the design process. This results into a safeguarded concept consequently leading to definite solutions. The favoured solution in this case was a four-wheel vehicle seating two passengers side by side with a removable cover all around - thus representing the principle of the car more than that of the bicycle. This aspect equally seems to be relevant for the image of the envisaged vehicle, as it is not expected to roll on the bicycle path but is planned to be a partner of equal rank in traffic and in contrast to the bicycle is clearly visible and in this way less in danger of getting into accidents. Furthermore this vehicle represents almost every advantage of the bicycle. The MUFA-concept avoids the following disadvantages of the bicycle:

- lacking stability against tilting
- susceptibility to weather conditions, influence of noise and exhaust fumes for the user
- limited transportation capacity for children and luggage
- inconvenient seating position

Sporadically you will find three-wheel-vehicles for 1 to 2 persons on the market. The four-wheel-vehicle, however, has a better stability against tilting than the three-wheeler. But the most essential aspect of decision for a three- or four-wheeler is, as shown above, the outer appearance. In order to guarantee a successful marketing of the MUFA an attractive body design is of vital importance. This effect is more easily to be achieved with a vehicle having four wheels instead of three. For this reason the disadvantage of designing a more complex steering mechanism was accepted.



Fig. 1: MUFA I - Velomobile for two persons sitting side by side [Photo: v. Graefe]

2.2 Realization

The prototype of the MUFA I consists of a self-supporting tube frame structure made of steel. This material was chosen because of its low costs, availability of differently shaped profiles and good manufacturing conditions in the workshop of the college. In a future development stage aluminium is planned to be used which will permit an anticipated weight reduction of 30 per cent.

Cost reasons are equally responsible for the use of as many mass produced bicycle parts as possible. These items were to a great extent donated by the bicycle industry.

The present engineering concept of the MUFA I is represented by the following features:

- self-supporting welded tube frame structure
- 4 wheels: rear 26", front 20"
- dimensions: length x width x height: 2250 x 1270 x 1480 mm
- 2 adjustable seats positioned side by side
- drum brakes at all four wheels
- three-speed gearbox with differential
- reverse gear
- free-wheel for the passenger
- front wheel spring suspension
- removable cover all around made of canvas
- weight fully loaded: 270 kg

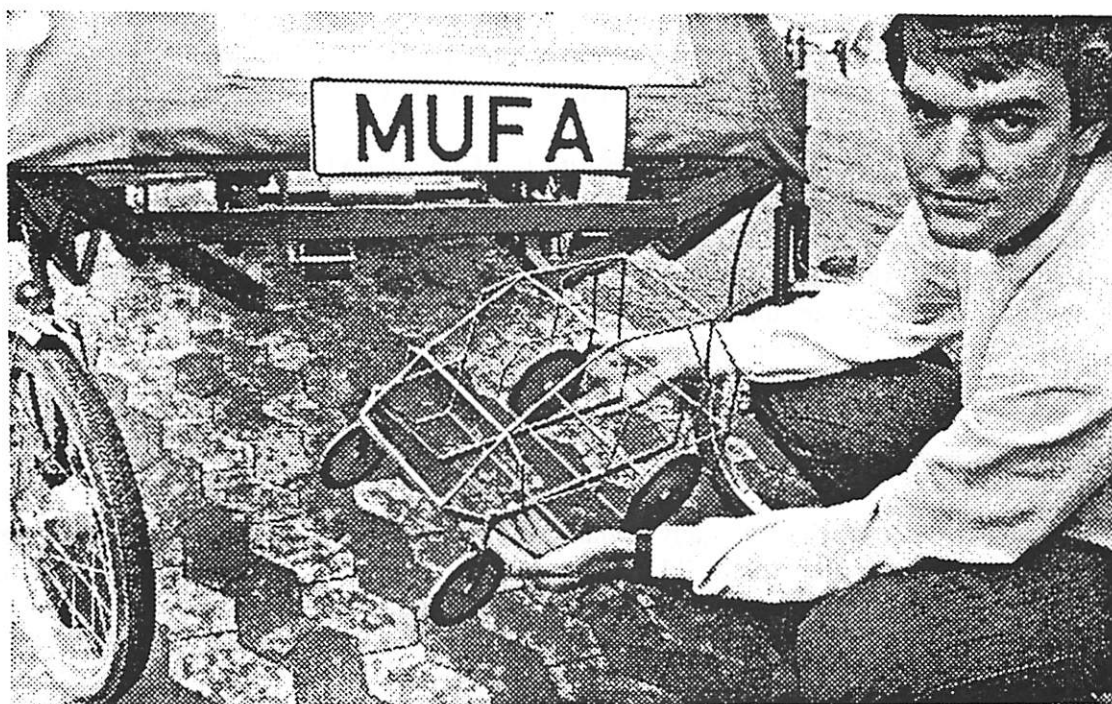


Fig. 2: MUFA I - Model of frame structure [Photo: v. Graefe]

2.3 Conclusions

It has to be noted that the MUFA I also presents a disadvantage compared with the bicycle. The bicycle is easy to handle, portable, foldable under certain conditions - in short: easily to be transported. These features do not apply to the MUFA I. It is not simply carried into the cellar or transported when travelling by car or by train. It might even be necessary to care for a parking area or a garage.

The "ecological efficiency", however, is undisputed. As with the bicycle only minimal efforts are needed for the ride, the vehicle and the infra-structure. On the other hand the health advantage in contrast to the car is considerable. It is obvious that hardly anyone would use his car for a pleasure trip after his working day just to cruise through the countryside. Especially this impetus for motion can be observed with numerous bicycle owners who exercise this activity as remedial exercises. In addition to this sportive training the seating position in the MUFA, sitting side by side, offers good opportunities for communication. Fun and pleasure become a vital factor.

3 The MUFA II Project

After the initial MUFA-enthusiasm there was a period of disenchantment. We doubted the marketability of the concept and temporarily stopped the development work after some changing experiments resulting from the prototype testing. After all a complete set of design drawings is existing representing the latest state of changes. There was no doubt about the fact that a drastic weight reduction had to be made in order to achieve acceptable properties for the utilization of the vehicle.

In 1988 the Institut für Fahrzeugbau (IFBW) of the Fachhochschule Braunschweig /Wolfenbüttel was inaugurated. This opened up a new dimension for the development process of vehicles: Computer Aided Design (CAD) was now available to us and our students. CAD does not only represent a helpful instrument of drawing. The generated CAD-geometry can furthermore be used as a basis for the tool and mould manufacturing in the subsequent production process. Additionally it may serve as a basic input for the CNC-manufacturing machines.

The CAD-system installed with our institute is of the ICEM.DDN-type and is used with work stations of Control Data Corp. This system is equally used by VW's research and development division. It is this lucky coincidence which enables our students of the IFBW to get acquainted with this design computer system at an early stage of their education. Moreover there is the opportunity to exchange data with VW - an advantage which equally helped us with the development of the velomobile MUFA II.

3.1 Objectives

The project MUFA II was originally initiated by Mr B. Busse, who developed and presented the concept in his diploma thesis [1]. In cooperative discussions with the Müsing Bicycle Manufacturer Ltd. at Braunschweig we evaluated the idea to design a muscle-driven single-track vehicle with full covering and lying position of the driver which was intended to beat the speed record of 105,36 km/h established by Fred Markham in the "Gold Rush" in 1985. (In the meantime, however, the record speed was improved to 110.59 km/h by Chris Huber in the "Cheetah" on 22, September 1992 [7]).

In this context the question was asked if record vehicles should be built at all. Is it not more reasonable to develop vehicles for the normal use which then can serve a large amount of consumers?

Generally record events are supposed to increase the popularity of a specific type of sports or a certain product. This public relation work would be very welcome for velomobiles as they normally are not in the limelight of publicity. Last but not least it is possible to prove the superiority of a concept or a certain design by an attempt on a record in a most spectacular way. All these reasons induced us to strive for a record run as an objective of our MUFA II Project. The experiences won from the record vehicle are then supposed to consequently flow into the development of velomobiles ready for use in everyday traffic.

3.2 Realization

3.2.1 Concept Phase

The concept we had in mind for the high-speed-HPV is meant to be orientated by the record vehicles "Vector" [6], "Gold Rush" [6] and recently "Cheetah" [7].

The following prerequisites of the concept were established [1]:

- single-track vehicle with rear wheel drive and front wheel steering
- chain drive
- frame material of aluminium connected by welding
- seating positions with legs performing work at a level above the location of the heart are to be avoided so that vascular congestions and a decrease of vigour cannot become effective.

A maximum speed of 30 m/s results into a pedaling frequency of 120 1/min and with a 27" drive wheel a transmission ratio $i = 7.2$ has to be employed. In order to keep the front surface as small as possible the seating position has to be low using a least possible total width. The >>manikin<<-Program developed by Mr B. Busse enabled us to generate the complete representation of a pedaling man by just a few inputs in the CAD-system. Dr. F. Rieß of the University of Oldenburg was friendly enough to contribute some very important hints concerning the ergonomic aspects and the steering geometry.

3.2.2 CAD/CAM-Application

All components necessary for the design have been generated in 3D-CAD or for simplification two-dimensionally including the correct depth. The program >>aeroform<< was created to produce a 3D-spline curve which is capable of drawing the aerodynamic shape in an adequate correctness by its curvature. The parameters of this curve are integrated in the program in the form of a set of data so that by the input of length and diameter of an assumed solid the shape can be depicted in any optional dimensions.

Using the program >>manikin<< first the seating position was exactly defined (Fig. 3):

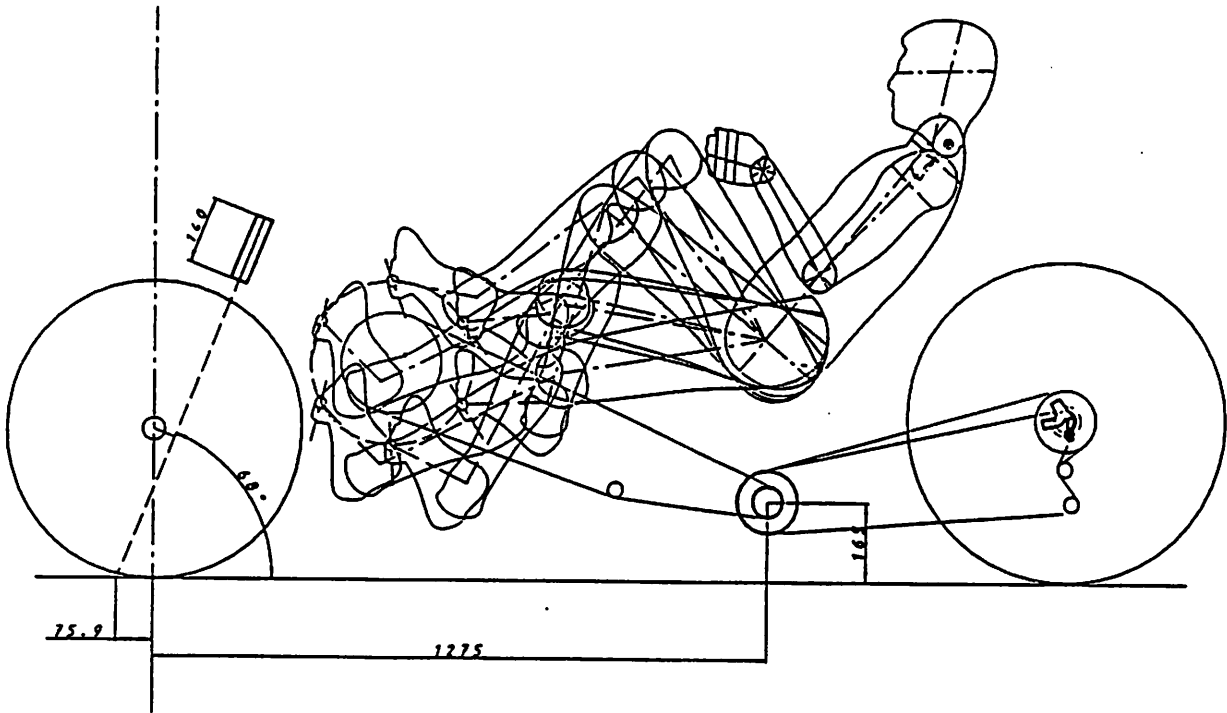


Fig. 3: MUFA II - Definition of seating position with >>manikin<< [1]

- distance bottom bracket bearing/hip joint centre 770 mm
- ground clearance of the bottom bracket bearing 449 mm
- ground clearance of the hip joint centre 503 mm
- inclination angle of the upper body 50°

This results into a total vehicle height of 1200 mm representing a very good value compared with the "Gold Rush". The following further design conditions can be based upon the seating position:

1. The chain strand has to be deflected at the tension side.
2. A direct steering is not possible. The position of the arm is responsible for the shape of the steering control handle.

The wheelbase results from the necessary clearance of the front wheel when being steered and the distance to the rear wheel of 1905 mm. All dimensions are easily controlled and checked in the CAD-side view.

The steering behaviour of a bicycle is mainly defined by its steering geometry. This contains three parameters which can be varied: steering column angle, fork projection and caster. The optimization of these values, which was accomplished in cooperation with the University of Oldenburg, led to the following result:

- fork projection 45 mm (26" standard fork Tange 90C CrMo)
- steering column angle 22°
- caster 76 mm

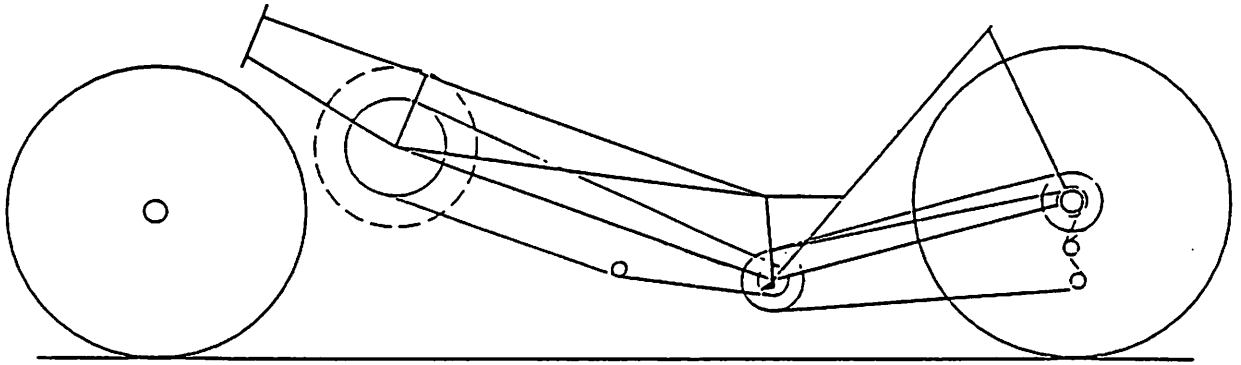


Fig. 4: MUFA II - Frame structure of lying position velomobile [1]

The concept and the seating position cause definite consequences for the design of the frame. The properties of the material Al 7020 and the welding method widely influence the shape of the frame. Equal diameters are butt-welded in a straight line or at an angle. Different diameters can equally be connected by the fact that the manufacturing process produces relatively broad welding seams. It is very important to care for a distortion-free design the stress analysis of which was checked by a FEM-calculation (finite element method, program ANSYS 4.4). The FEM-structure can be developed from the CAD-geometry by means of preprocessing.

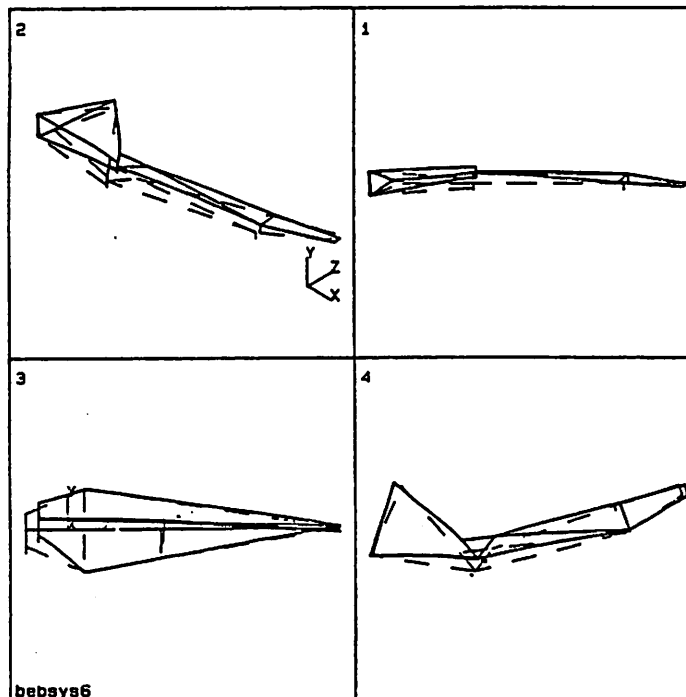


Fig. 5: MUFA II - Calculation of frame distortion by FEM system ANSYS [1]

Steering tube and bottom bracket bearing are standard components. Resulting from the seating position a chain strand deflection has to be provided. The deflection bearing is supposed to house a transmission gear in order to avoid the oversized sprocket wheel like that of the "Vector". ("Cheetah", by the way, has such a deflection with transmission gear!). The gearshift assembly is of the Shimano Dura Ace type using 5 sprocket wheels. A hydraulic calliper brake is mounted at the rear wheel.

The seat has to be adapted to the body shape of the driver. At the time being a plastic seat shell of a canoe is used which can be longitudinally adjusted. The backrest is formed from polystyrene and glued to the supporting bulkhead. In this way the backrest together with the handle bar represents an optimal support for the counteraction of the force.

3.2.3 Model Analyses

We had the opportunity to use the air-conditioned wind tunnel of the Volkswagen Company for the determination of the cw-value of a 1:1 model. This model was built by the students Mr J. Sander and Mr H. Wessel in the VW-prototype workshop [3]. The basis of the body was a 19 mm chipboard having the contour of the central longitudinal section. A vertical projection in a 1:1-scale was produced by the CAD-program in order to guarantee the exact shape. This plot was laid onto the chipboard and transferred to the timber surface. The wheels were formed to the model in one piece.

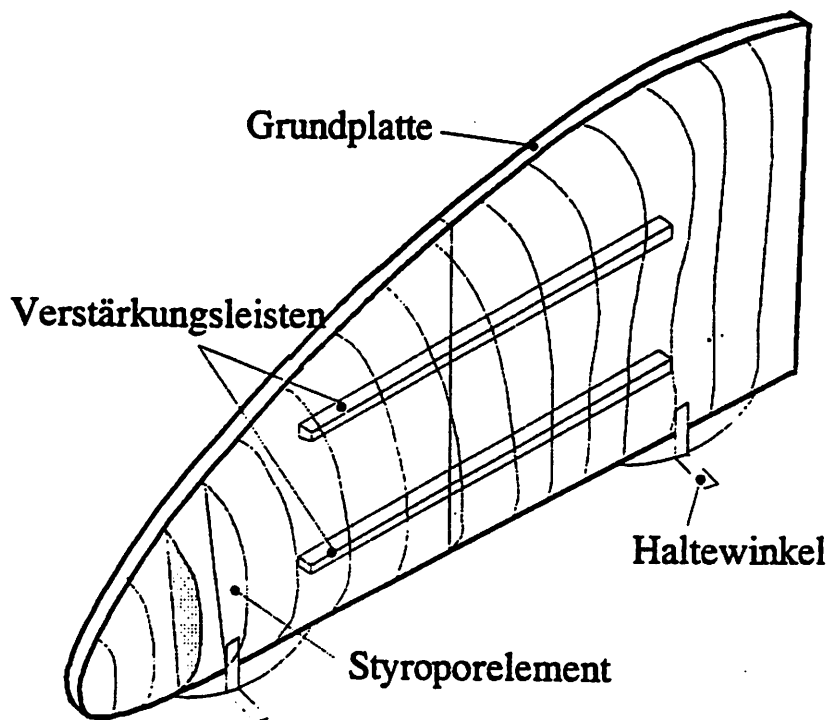


Fig. 6: MUFA II - Construction of wind tunnel model [3]

In order to be able to generate and check the contour of the surface, cross-sections were laid through the model by the computer in distances of 200 mm. Plots of these 16 cross-sections were printed to produce templates made of 6 mm thick plywood. Because of the symmetrical structure of the model only one set of templates had to be made for both sides.

The outer contour of the model was transmitted onto polystyrene plates of 200 mm thickness and then sawed out along the larger cross-section. After all the polystyrene elements had been carefully glued together by two-component adhesive the contour was worked out using an electric planning tool, a belt grinder and sand paper. Then the model was checked for accuracy by the templates. Finally it was finished by filler primer paint and another fine-grinding process.

Measuring showed an average cw-value of 0.07. The front surface is 0.56 m^2 so that the multiplication result of $c_w \times A = 0.039$. This represents a better value than that of the "Vector" (0.046) and the "Gold Rush" (0.041).



Fig. 7: MUFA II - Direction of streamlines on wind tunnel model [3]

3.2.4 Velomobile Frame

The frame based upon the concept study [1] and manufactured by Müsing was available very early already. The thesis of Brand/Kafara [4] was supposed to initiate the completion of the project and to concentrate on the design and construction of the steering mechanism and the seat.

From a choice of several steering variants finally a rod-and-lever mechanism of a 1:1.3 ratio was selected using a standard handlebar which, depending on driving test results, probably will have to be fitted with a damper (see "Cheetah" [7]). A steering mechanism placed underneath the seat, commonly found with a horizontal position of the driver, cannot be used with the MUFA II because the outer shape around the seat area is too narrow for aerodynamic reasons to accommodate the relevant device. For the force support, however, the chosen handlebar design is optimal (**Fig. 8**).

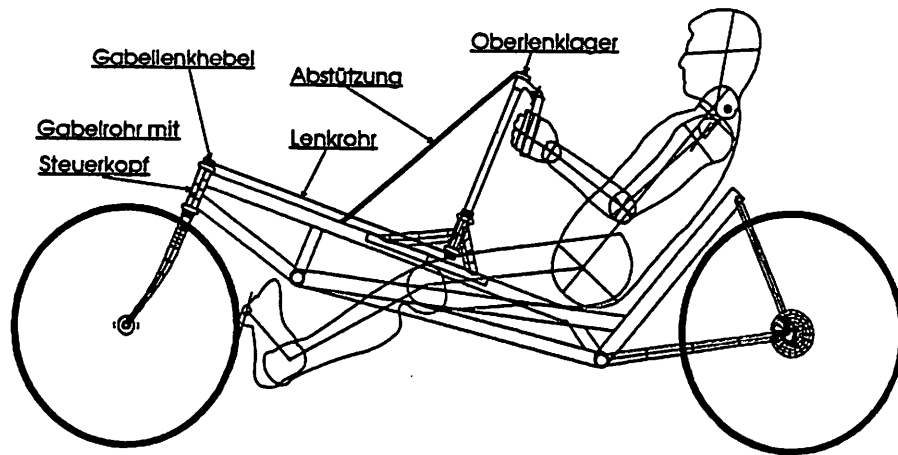


Fig. 8: MUFA II - Construction of steering device [4]

The seat concept was described above already. Good results were won from the installation of the canoe seat shell of the FES (Institute for Research and Development of Sports Kit, Berlin). The polystyrene backrest has to be adjusted to the requirements of the respective driver.

Without the fairing the frame structure can be used as a normal velomobile. The seating position is relaxed and when going uphill the human power is more effectively employed than with a normal bicycle. The long wheel base is somewhat disadvantageous when driving through bends. The low position of the centre of gravity, however, permits a good cornering stability compensating for the above disadvantage.

The connecting points for fixing the fairing to the frame are positioned near the steering head, the guide bearing and the backrest respectively. The clamping screws allow an easy disengagement of the connection (**Fig. 9**).

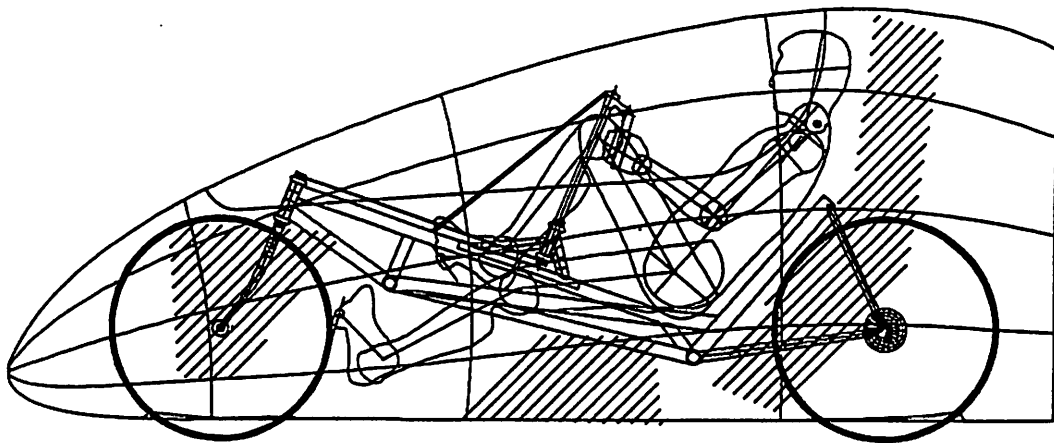


Fig. 9: MUFA II - Mounting of fairing [4]

3.2.5 Fairing

Professor Wollschläger, being an active glider pilot himself, contributed his experience to the aerodynamic shaping of the fairing. This led to an outer appearance similar to the cockpit of a sailplane. Further hints for improvement were given by Professor Scharnowski of the Design College of Halle, Castle of Giebichenstein and the DLR (Research Institute for Air and Space Travel) at Braunschweig as well as by the Volkswagen Company.

The 3D-CAD-geometry of the MUFA II-fairing resulted from the thesis of J. Sander and H. Wessel [2] (Fig. 10). The geometrical data were transferred to the VW-prototype workshop on a magnetic tape from which a NC-program (NC=Numerical Control) for the 5-axis gantry milling machine was generated. The openings of the wheel housings were designated with small grooves and the area above the front window marking was recessed by 2 mm to later accomodate the front view pane (Fig. 11) [4].

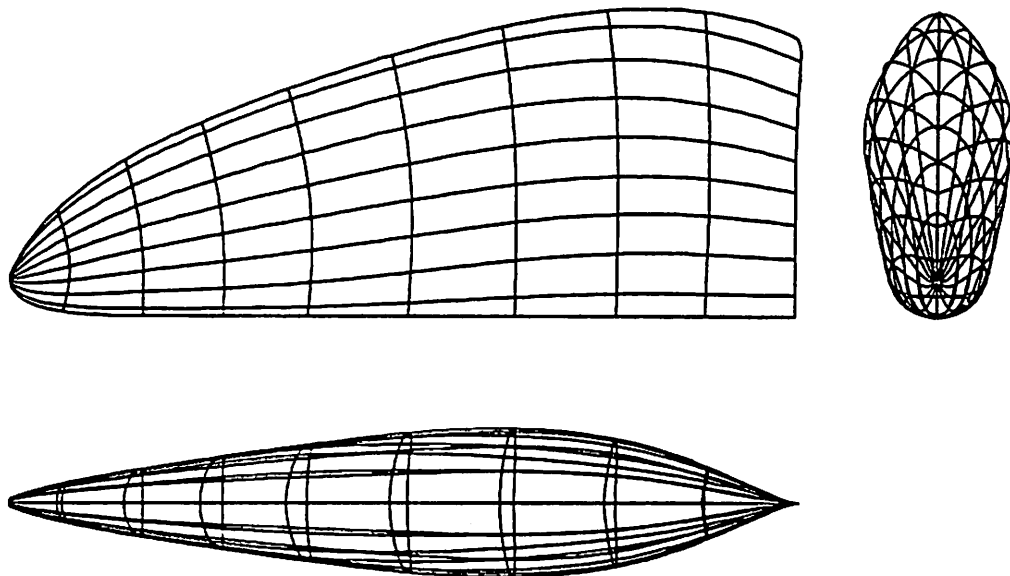


Fig. 10: MUFA II - Fairing 3D set of data [2]

The milling program was arranged in a way which offered the opportunity to generate a negative shape of the fairing by the action of a spherical cutter. The material of the mould was chosen to be polyurethane hard foam. The fine structure of this material resulted into a high quality surface finish produced by milling.

The front view pane was molded from a heated plexiglass plate over a positive model milled by VW after CAD-data. The edges of the pane were oversized so that final cutting guaranteed an exact fit into the fairing.

The fairing consists of two matching half shells made of Kevlar-sandwich (as with the "Gold Rush"), which were manufactured by FES in Berlin. For test purposes a GFK-fairing was made from the same model. This can be used for adjusting works and driving tests without running the risk of damaging the "race version". The main reinforcement is achieved by a transverse bulkhead

at the level of the backrest. Diagonal trussings at the steering head and at the guide bearing represent the other connecting points of the frame.

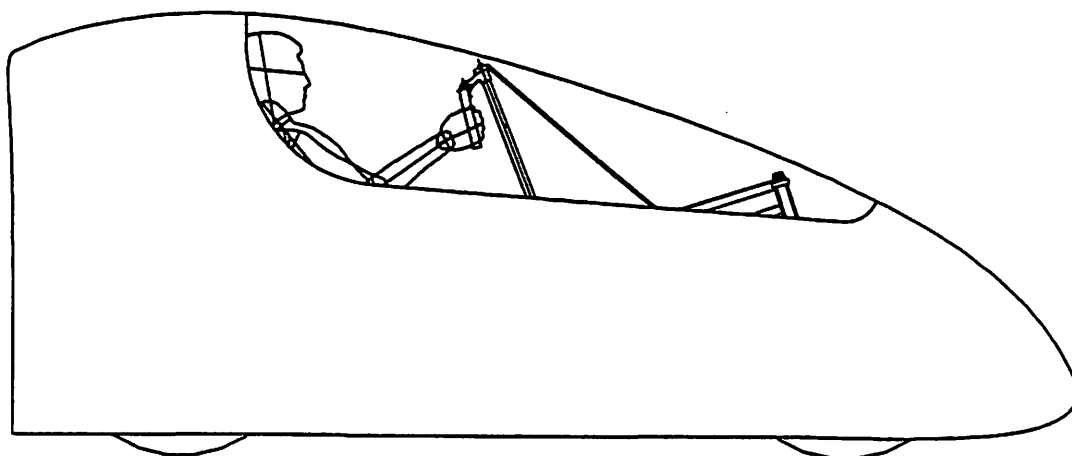


Fig. 11: MUFA II - Fairing with canopy [4]

Openings were cut into the GFK-fairing to enable the driver to support the vehicle with his feet. These features are missing with the race version so that the vehicle has to be given a shove when starting and it must be intercepted after the run.

3.3 Driving Tests

First the velomobile was tested without fairing. Professor Rinne rode the vehicle over a distance of 80 km on public roads in order to find out the advantages and disadvantages of the design. As the transmission ratio was not yet harmonized a top speed of only 45 km/h could not be exceeded.

The fairing was available in the winter of 1993. Driving tests, however, could not be started before the spring of 1994. During the test rides executed by our students on private roads near Wolfsburg using the GFK-fairing without top section a speed of 70 km/h was achieved at the first attempt.

In order to explore the potential of the vehicle a checking calculation concerning the necessary power of the cyclist related to the speed was carried out. The following base rates were assumed for the reckoning:

vehicle mass: 20 kg

cw-value: 0.07

air density: 1.226 kg/m³

driver's mass: 75 kg

efficiency: 0.95

bulkhead area: 0.56 m²

rolling friction: 0.003

The result of the calculation is shown in Fig. 12. It can be seen that for a speed of 110 km/h a propulsive output of 800 watts is needed. Good athletes should be able to apply this power over short distances.

It is remarkable that the rolling friction of about 100 watts compared to the aerodynamic effort which has to be accomplished in order to make the vehicle advance to high ranges of speed is of minor importance.

$$P(v) = \frac{fr \cdot M \cdot g \cdot v + \frac{\rho}{2} \cdot cw \cdot A \cdot v^3}{\eta}$$

$$Pr(v) = fr \cdot M \cdot g \cdot \frac{v}{\eta}$$

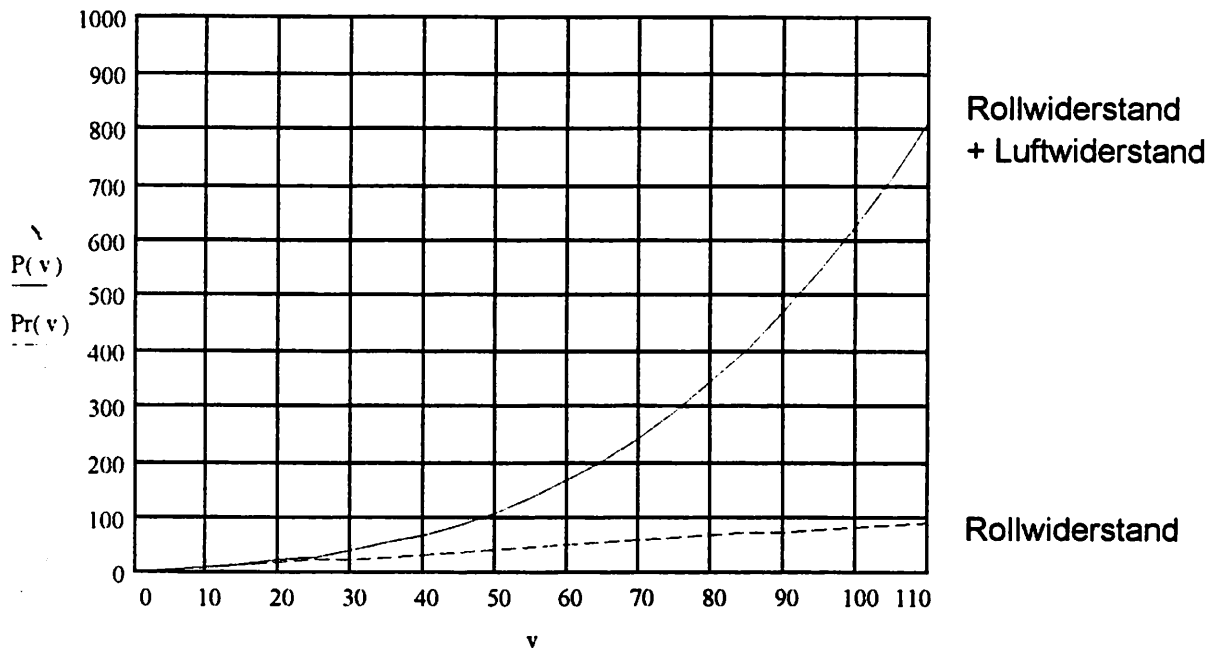


Fig. 12: MUFA II - Power P in watts as a function of driving speed v in km/h

3.4 Conclusions

The actual state of the MUFA II-development shows that it definitely seems to be possible to reach a speed of 110 km/h. If the record run, as with the "Cheetah", takes place at an altitude of 2400 m the air density will be reduced to 0.952 kg/m³. That means that the propulsive power at a speed of 110 km/h is decreased from 800 to 650 watts. On the other hand the efficiency of the cyclist equally will be reduced at an altitude like this (absorption of oxygen).

We do not intend to accomplish a record test at a high altitude. We are concerned to demonstrate that by light-weight construction and excellent aerodynamic design a muscle-driven vehicle is able to reach a speed of more than 100 km/h. The absolute level of the maximum speed achieved is of secondary importance in this context.

We furthermore are concerned to show that nowadays we are in the position of promoting the development of muscle-driven vehicles decisively by employing advanced engineering technology and tools (CAD/CAM, FEM, computer simulation, measuring technique).

4 Outlook

4.1 Safety Aspects

Velomobiles have to be regarded as legally equal partners in road traffic as long as they do not have the opportunity to use lanes which are separately reserved for their traveling purpose. As this condition is not consequently guaranteed, not only collisions among velomobiles alone have to be taken into consideration but, in a special way, also those which include faster vehicles of a larger mass.

Accidents between cyclists and motor vehicles mostly result into disastrous consequences: A chance of survival and a reduction of injuries are only given for the cyclist if the person is thrown over the car and the impact with the ground is a soft one. Normally the cyclist is badly hurt or even killed because of the lack of deformation distance on the side of his vehicle and the high speed and large mass on the side of the automobile. The recent tendency of offering bicycles and cyclist dresses in brilliant colours with a visual warning effect seems to reflect a small step into the direction of improving the passive safety for the otherwise unprotected person. Consequently it is necessary or advisable to provide the vehicles with visually warning features as to shape and colour, especially in that case when their silhouette is very low. Velomobiles with the cyclist in a lying position are therefore often equipped with small red flags fixed to bars at a height of 2 m above road level.

The safety of light-weight vehicles has been progressively stressed in relevant publications [8]. The reason for this development can be found in the fact that the introduction of "inner-city cars" will gain more and more importance in the future. These are the extremely small, light-weight vehicles having very low emission values and consuming very little fuel. They will exclusively be used in overcrowded areas and special traffic zones. The velomobile, however, is not included in this category. The results of the studies can be transferred onto the velomobiles, especially those evaluations which deal with plastic fibre compact materials [9],[10]. The relevant findings lead to promising aspects like, e.g., the prospective application of the "Rebound-Effect" of elasto-plastic frontal structures.

4.2 Future Developments

As already pointed out we expect an increase in production of small inner-city vehicles having an engine capacity of less than 1 litre (see Japan). In this category also hybrid and electric vehicles will play a certain part.

Concerning velomobiles we are hoping that two- and three-wheeled vehicles with the driver in a lying position will progressively be accepted which might lead to an increased application of fairings as a protection against bad weather. The price of a three-wheeler of DM 9 700 plus the price of the fairing of DM 5 000 (Radius, Münster) will definitely not promote the sales figures, but the development might go into the desired direction. Auxiliary small electric motors or Diesel engines will also be introduced. The power supply by solar cells will gain additional importance.

We ourselves are planning to develop a MUFA.III velomobile as a two- or three-wheeled vehicle which will be qualified for normal everyday use. For its design and construction we will be able to incorporate the experiences won from our MUFA II. Our program includes the installation of small auxiliary movers and concepts of energy recuperation. Any cooperation of other institutions will be greatly welcomed on our part.

5 Literature

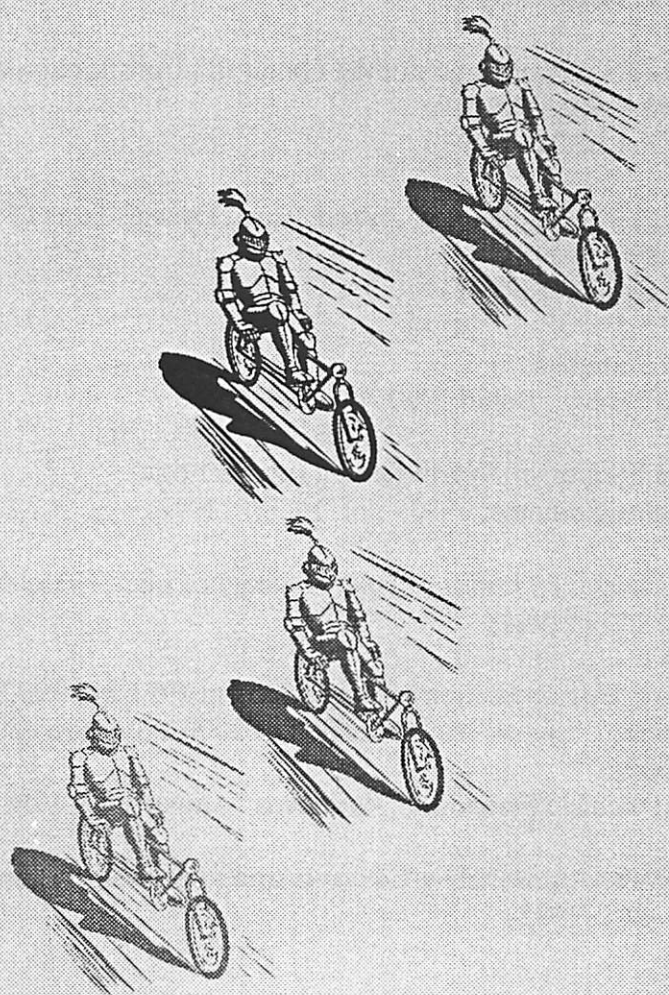
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DIVERSE SUBJECTS



BEING MOBILE WITHOUT A CAR: FIVE YEARS OF EVERYDAY LIFE AND HOLIDAYS WITH THE HUMAN POWERED VEHICLE

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There are a few simple reasons why I have never thought of getting a driving licence:

- Place of residence and work were nearly always close enough together for me to travel to work by bike.
- Up to now my employers have always permitted me to go on business trips by public transport.
- Our children never demanded to be taken from A to B, or C to D for that matter, by car, neither of me or my wife, who also cannot drive.

These, admittedly rather fortuitous circumstances, have always made it possible for me to combine work and fitness training and, moreover, to avoid the stress which is an inevitable part of weekend outings by car.

While I enjoy the privilege of not being able to drive a car more and more the older I get, I did not expect the added bonus of an increase in my sheer enthusiasm for living. At the International Bicycle and Motorcycle Exhibition in Cologne in 1988 I first made the acquaintance of people who had devoted themselves to the development of the HPV from the bicycle (Pict.1). A few months later, due to the wet and cold winter, I had to go through the tiresome routine of putting on extra layers of clothing in order to ward off the cold and not arrive at my destination wet through and chilled to the marrow. I recalled the Leitra and its designer, whose acquaintance I had made at the fair in Cologne, and I decided there and then to buy one of these velomobiles. My son Ivo followed my example and likewise ordered himself a Leitra.

In the workshop during the fourteen day construction period we were granted an insight into the Leitra's principal secrets, largely thanks to the excellent pedagogical abilities of the Leitra's designer, Carl Georg Rasmussen. After a longer test drive, we set out homewards, accompanied by Mr. Rasmussen, who stayed with us for about 50 km. Within a short time we had discovered one of the chief advantages of this comfortable means of transport: without any special training we were able to cover the 1150 km from Ganløse near Copenhagen to Rüsselsheim near Frankfurt, achieving an daily average of 165 km. The relaxed position and the comfort of the seat prevented us from getting tired too quickly.



Pict.1: C. G. Rasmussen, one of these people,
who has devoted himself
to the development of HPV



Pict.2: Riding on cycle paths in Germany

We would probably have achieved even longer daily stages had we not obeyed the Highway Code and ridden on cycle paths, wherever they were to be found. That this wastes a great deal of time over long distances is known to every cyclist in Germany (Pict.2).

On the journey home from Ganløse I discovered a whole new world of transportation through muscle power, and sorely regretted that I hadn't taken an interest in velomobiles earlier (Pict.3). To this day, my enthusiasm has not waned and I even feel that it is my duty to you, designers and manufacturers of velomobiles, to relay back a little of the joy that the simple beneficiary of

your ideas experiences in the everyday use of the velomobile.

In my opinion, there are four basic advantages that the velomobile displays over the ordinary bicycle, which, of course, in my case, applies almost exclusively to the Leitra.

1. I have excellent weather protection.
2. I am well secured in case of crash or collision.
3. I can concentrate my muscle power on propelling myself forward, without incurring excess strain.
4. The air resistance is clearly decreased.

I would like to concentrate on these four points and to talk about my experience in this regard.

Weather Protection

Let us start with weather protection. Only once have I managed to get wet in my Leitra. This happened when my son and I were riding through heavy rain near Quakenbrück in Northern Germany.



Pict.3: Pedal-power meets wind-power

Thrilled about the fact that the rain couldn't get to us, I went haring over a motorway bridge, straight into a huge puddle of unknown depth, without putting the cranks parallel to the ground. I never made this mistake again. The amount of water I ploughed up with my heel would have filled a bathtub.

However, the advantages of overall weather proofing are not confined to bad weather. As the fairing of my velomobile is predominantly white and the window area is no more than the necessary size required, only a comparatively small area of the interior is hit by direct sunlight. Since I have begun making tours by Leitra, I don't have to fear sunburn anymore. And since I am well past the half century milestone, I am, in any case, not too concerned about getting a suntan.

It rarely snows in Rüsselsheim. Therefore, until last year, I could do without a windscreen wiper. However, since I have been the proud owner of a front windscreen made of safety glass, which is unfortunately quite heavy (700 g), I have acquired a small windscreen wiper. Last winter I had the opportunity to test it. Its main advantage is that there is a significant reduction of dazzling caused by oncoming traffic in rain.

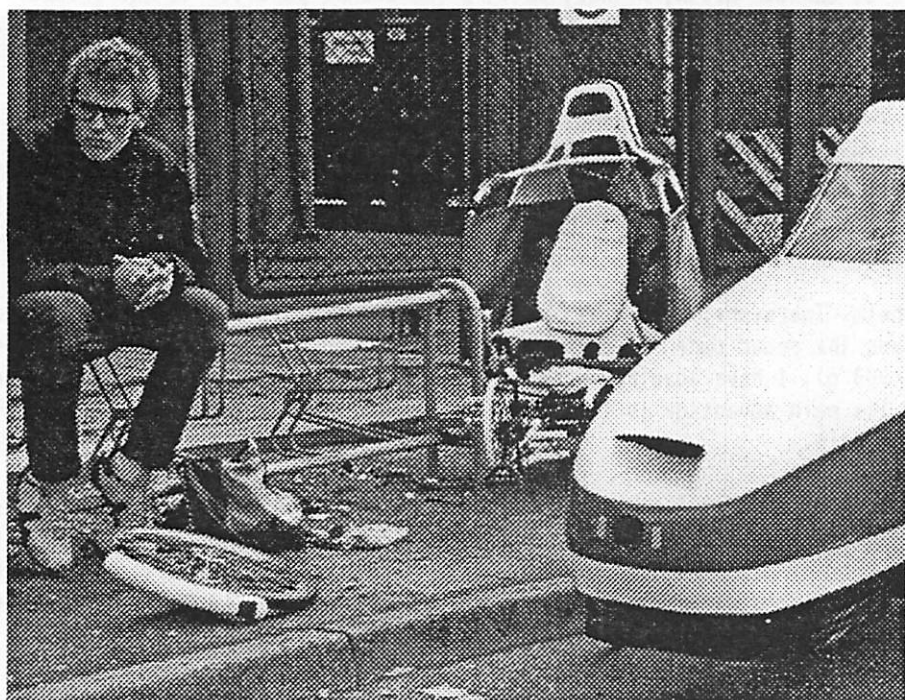
The daily trip to work (I am employed at the Rüsselsheim branch of the Wiesbaden Polytechnic) is unfortunately only 4,5 km, which means that it is not long enough to maintain peak fitness. But I can drive to work in any kind of weather, even, if necessary, wearing my Sunday best, and I can park my velomobile under the porch, whereas my dear colleagues have to hurry to work under their umbrellas, coming from their cars, which have usually been parked quite some distance away.

However, in 1990 and 1991, I had to work at Wiesbaden four days per week and travel a distance of 26 km. Although there were no showers at our main branch in Wiesbaden, thanks to the efficiency of my velomobile, I never worked up enough of a sweat to need one. A quick wash and change on arrival was sufficient.

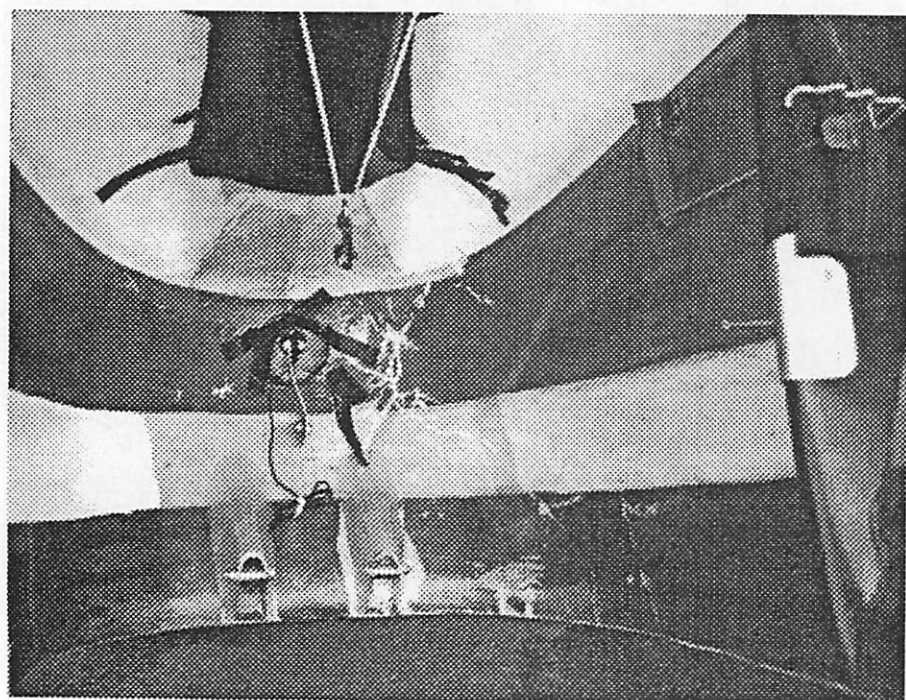
In the spring of 1992, our son built us an additional single track HPV, an unfaired, long wheel based recumbent to be used for forest and field paths (Pict.4). I used it for a 485 km three day tour from Rüsselsheim via Bonn, Gummersbach, Siegen and Wetzlar and back to Rüsselsheim, and, a few weeks later, made the same tour, only in the opposite direction, by Leitra, in order to weigh up the difference. The exhaustion was about the same, but I was a lot more frustrated on the unfaired recumbent after a 5 hour ride through the rain. I was soaked to the bone, although I was wearing Goretex clothes and gaiters. The time I needed for each stage was nearly the same both on the unfaired recumbent bicycle and in the Leitra, though I have to say, that I didn't try to get to my upper limit.



Pict.4: Comparative self-built single-track recumbent bicycle



Pict.5: On the ferry in Rødby Havn the first accident



Pict.6: The covering after the collision with a car

I would like to tell you about some of my experiences vis à vis accident protection. My lesson here was short, but impressive. On my way back to Rüsselsheim from Ganløse, whilst riding onto the ferry in Rødby Havn, my front-wheel got stuck in the groove of a rail and I toppled over. With a dry cracking sound, the two coal fibre springs of the right front wheel snapped off. It was a Saturday morning and I thought the journey was over (Pict.5). However, thanks to the lightning intervention of the stationmaster, Mr. Nielsen (I will never forget his name because of his spontaneous readiness to assist), and the Leitra Company, within five hours the conductor of an express train arriving from Copenhagen handed over a set of replacement springs, which Mr. Rasmussen had personally delivered to the station in Copenhagen, riding up from Ganløse in his Leitra.

I had a more serious, second, and so far last, accident on the last day of the same journey home when I collided with a Mercedes, whose driver hadn't looked in the rear view mirror when pulling out. At the time I was travelling at approximately 20 to 25 km/h. The Leitra hit the car at an angle of about 45 degrees, was knocked on its side and skidded off across the asphalt. It did not, however, overturn, because the wind

screen, which stands proud of the covering, prevented it from doing so. Uninjured, I was able to crawl out of my Velomobile. The front part of the covering was dented (Pict.6) and the suspension

of the covering badly bent. The rest of the impact was absorbed through my legs. It was only due to the fact that I had broken two further springs by falling over, that I had to wait another ten days before starting the last stage of my homeward journey.

To show just how mobile the rider of a velomobile can be without a car, I would like to tell you how I came into possession of the replacement springs: As I knew, that Mr. Rasmussen intended to go to South Germany by train where he wanted to deliver a Leitra, I called him in order to arrange a rendezvous for handover of the replacement parts, between 1.30am and 2.00am aboard the Münster-München express between Mainz and Darmstadt. I set out shortly before midnight with an old collapsible Bikerton bike, and bought a ticket to Darmstadt at Mainz station. Mr. Rasmussen and I had a very interesting half hour together on the train, until our ways parted again at Darmstadt and I had to ride home on the uncomfortable little bicycle. I finally got to sleep at 4.00am, eagerly anticipating the resurrection of my Leitra.

At the time of writing this report (May 1994) I had clocked up about 22,000 km on my velomobile and, so far, there have been no more accidents. I am bound to say that under the covering I feel safer than riding an ordinary bicycle. Car drivers usually give a wider berth (Pict.7) to the Leitra, than when overtaking ordinary bicycles, and, when there is oncoming traffic, often refrain from overtaking at all. Nevertheless, I try to appear as conspicuous as possible:



- Bright colours on the covering
- Battery operated lights (also when parked or stationary)
- Wristband reflectors to indicate by night

Pict.7: Car drivers usually give a wider berth

Having always only ridden bicycles, the next thing I had to get used to was that I could no longer look down on the car world, over the roofs of the cars from bicycle height. Meanwhile I have got used to being on the same level as cars and to looking through car windows. I even believe that this sometimes prevents me from attempting rash manoeuvres, which as an ordinary cyclist I couldn't resist.

There are two further features of my velomobile, which increase my feeling of safety. Firstly, the rear view mirror - which compared with that of an ordinary bicycle is very well secured - holds its position and gives a comprehensive view of the traffic behind me. Secondly, there is the comparatively noisy interior of my velomobile. The self-generated, pleasant rumble below the cover of my Leitra screens me from the aggressive noise of the traffic outside. Anyone who thinks this is a dangerous feature of a fully faired velomobile, should not forget that auto radios often boom at least at the same volume.

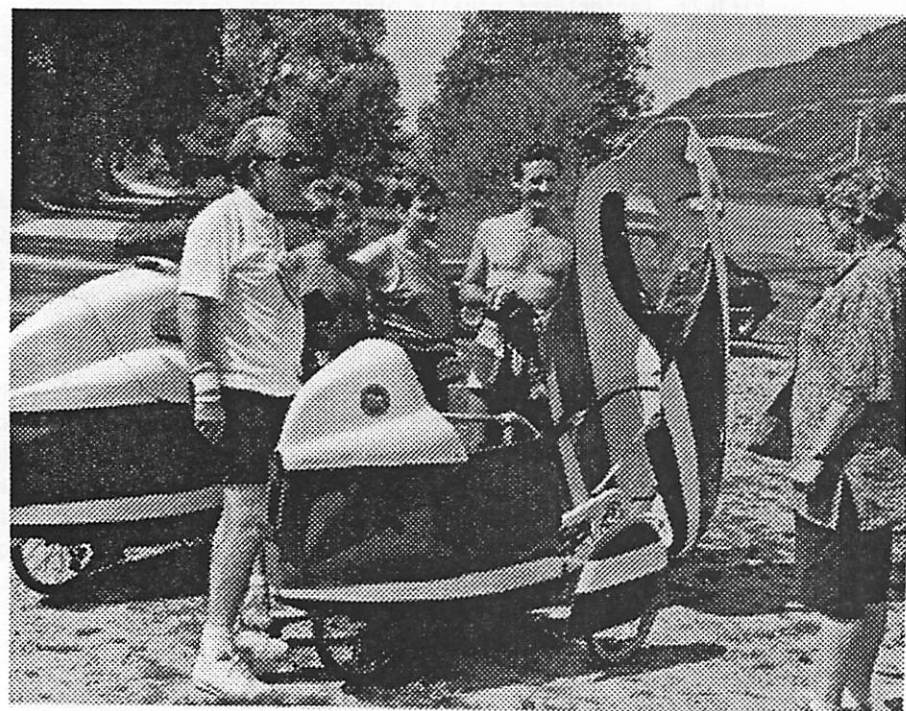
Freedom from useless physical Complaints



Pict.8: On the bank of the Rhine opposite the Marksburg

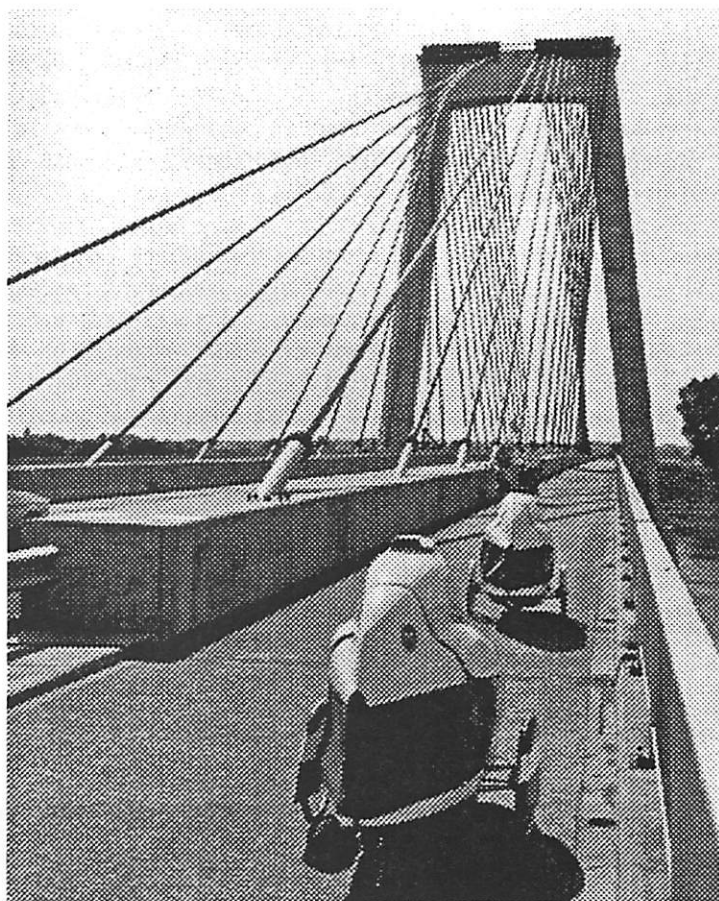
One of the most agreeable benefits of the transition from bicycle to velomobile is the elimination of physical complaints, which, when riding a bicycle, distracts one from the main aim - namely the pleasure of making progress by one's own physical power. In the summer of 1993, my wife and I rode along the Rhine to Holland and back by Leitra (Pict.8). Although my wife had used the velomobile for short, everyday trips, she depends on her ordinary bicycle, since our little dog prefers his seat in a basket on the bicycle and it is very hard to persuade him to sit in the Leitra. Meanwhile, our son's Leitra was in the possession of my wife (one could, in fact, say that my wife was acting as a pawnbroker in order to help out in a temporary financial crisis). Now, she felt like making a proper tour by Leitra and agreed straight away when I suggested Holland. The trip was thoroughly enjoyable, although it was very hot most of the time. We rode an average 94 km per day, and we included many daytrips and visits to museums in our programme, due to which we often didn't manage to ride as far as we had intended. We went through many a big city, rode through Arnhem in the

rush-hour, and visited the spectacular dice houses in the town centre of Helmond. We nearly always made contact with the nicest people - perhaps because of our Leitras (Pict.9). And even when it seemed as though we wouldn't succeed in finding space for them, landlords always managed to provide some small room in which to leave them.



Pict.9: British bikers stopped us to find out what a Velomobile is

The most important benefit was the absence of physical complaints, which meant we were able to cope with those not always very smooth cycle paths in Holland and on the banks of the Rhine (Pict.10). No complaints from sitting for long periods without training, and no neck aches, due to unusual head position, impaired our good health and well-being. We rode along in a relaxed way, until our legs got tired. We were often asked if we didn't miss being able to talk whilst riding. We were able to answer with a resounding "NO". And this is not because we have been married for 31 years and have nothing left to say to each other; touring with conventional bicycles also rules out long conversations since one has to ride in single file on country roads and cycle paths. One can, in any case, draw attention to points of interest in the landscape without necessitating the use of walkie-talkies. Leitra to Leitra communication is possible by means of pre-arranged signals.



Fit for everyday Life and still streamlined

Pict.10: Rolling relaxed and being open
for the impressions of the landscape

The low air resistance, which, at the time I bought the Leitra was only a secondary consideration due to my sparse knowledge of the history and development of HPVs, has become one of my favourite of the Leitra's qualities. I usually enjoy this advantage in the sense outlined by Martin Staubach in the magazine Pro-Velo, where he says: "An aerodynamically efficient vehicle affords a higher speed. But of course it permits you to ride at normal speed more comfortably." Last April, I had the opportunity to check on his comparison between the Leitra and a conventional bicycle in a practical verification. For



Pict.11: Decrease of air resistance by fairings
for the front wheels

the first time ever, I took part in a cycling tour organised by the Rüsselsheim Cycling Club, which included a small trip to the Odenwald. Up the hill I took it easy and saved my strength. Over the downhill stretch, I had to brake again and again (in spite of the fact that I was free-wheeling), in order not to disappoint a cyclist in professional race gear on a conventional racing bike with triathlon handlebars, who had overtaken me on the uphill ride and was now violently pedalling down the hill.

In the summer of 1993 the air resistance of my Leitra was further decreased by my acquisition, whilst in Denmark, of narrow high pressure tyres and fairings for the front wheels (Pict.11). On the way back to Germany, however, I first had to get used to the resultant increase in crosswind sensitivity. In particular, speeding HGVs oncoming or overtaking me on the Isle of Langeland, caused me some considerable anxiety. Whenever the wind hit me side-on I had to call to mind Andreas Fuchs' explanation at the first European Velomobile Seminar in Farum of the correlation between the angle of attack and resulting torque on multitrack velomobiles. I took care never to exceed 40 km/h on downhill stretches.

One of the most pleasing advantages of the fairing is the fact that an oncoming crosswind produces extra forward thrust, especially useful when swimming in the stream of cyclists, where I can glide comfortably along in high gear.

Some hopeful Requests of an Everyday HPV User



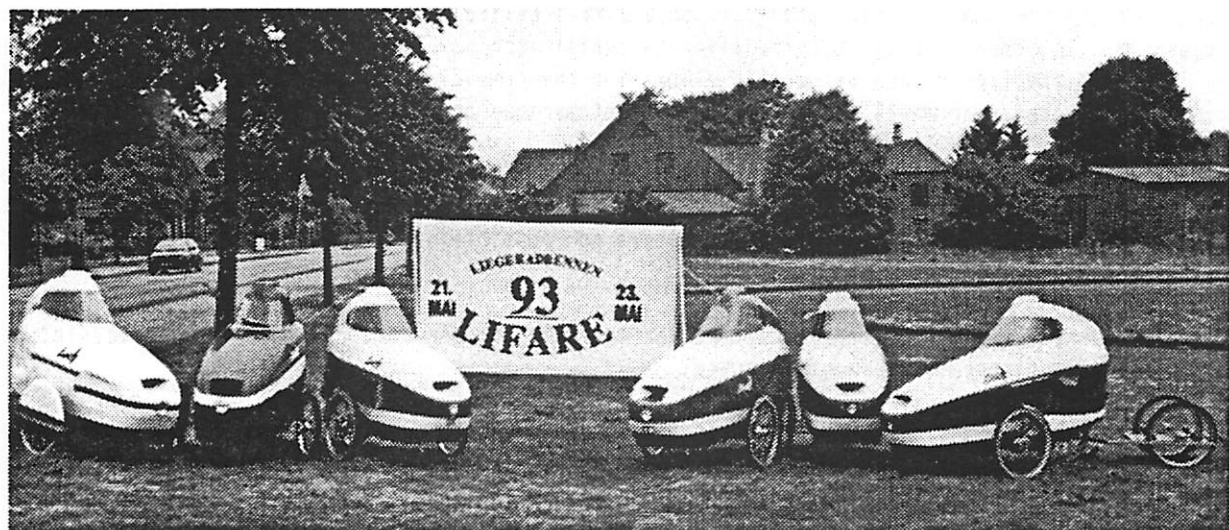
Pict.12: Desire for an obstacle free passage

Every increase in a person's level of enjoyment and perfection serves also to raise the level of enjoyment and perfection desired. And I am no exception. Both longer tours and my daily rounds in the Leitra certainly leave me ample time to contemplate insufficiencies.

As a velomobile rider, my dearest wish is for a smooth and obstacle free passage (Pict.12). However, so long as it remains the fashion to set roughly 1 to 1.5 tons of sheet metal in motion in order to transport approximately 120 kg of human flesh over long, short and even the shortest of distances, this wish is likely to remain unfulfilled. Until further notice, the wishes of all cyclists and velomobile riders will probably continue to be dismissed as unimportant by politicians at national, regional and district level, as well as by town planners and transport authorities.

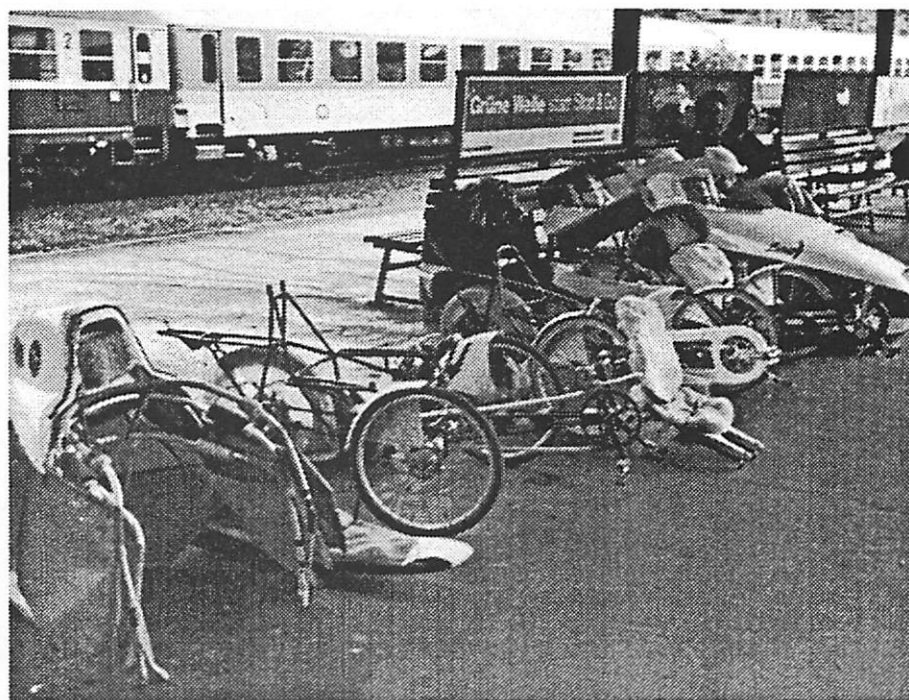
Another major item on my list of wishes is addressed to the European rail service. Namely, for more loading space on trains. In Germany at the moment "D-Züge" (a special elder type of express trains) together with their luggage waggons are gradually being withdrawn from service. Last year, when I wanted to travel to Farum to

the European HPV championships, I didn't have the time to get there by Leitra. Only after a considerable effort did I succeed in finding a "D-Zug" with luggage waggon that could transport me from Darmstadt to Hamburg-Altona without me having to change trains. By the end of the journey the waggon was crammed with bicycles. It is only thanks to the unrelenting pressure exerted by the ADFC (a German Cycling Association) on Deutsche Bahn that the so-called "Interregio" trains agree to carry conventional bicycles. But this is not a satisfactory solution to the problem of transporting fully faired HPV's, as the doors to the bicycle compartments are no wider than the doors to ordinary compartments.



Pict.13: Leitras meet for a conference

In May 1993, three of us went to the HPV-meeting in Langwedel near Bremen from Mainz (Pict.13). The journey there wasn't a problem since we only had to change trains once. But on the return journey Deutsche Bahn had "forgotten" to attach the luggage waggon to the train coming from Rostock, which was packed with cyclists, although such a waggon was indicated in the timetable. The conductor loudly refused to let the train proceed because the halls and corridors were bursting with bicycles. Handlebars had been turned 90 degrees, flush with frames, in order to get the bicycles through the narrow passages. It cost the station master some effort to persuade the conductor to let the train proceed.



Pict.14: Rail transport service for velomobiles

I need hardly tell you we had no chance of boarding this train. We had to beg and plead (and imply that we had contacts with German television) to arrange for an extra waggon to be attached to the last train that day, in which we were allowed to stow the components of our dismantled Leitras. Had we not managed to take our Leitras apart (Pict.14) it would have meant spending the night at the station until the following day, in the hope of catching one of the few passenger trains scheduled with luggage waggons, and thus somehow to make our way back to Mainz.

Compared to the request for a velomobile friendly infrastructure, my wish for improvements to the velomobile itself are small, and could, besides, be fulfilled by next year. Above all, given the poor surface of many cycle paths, I would like a Leitra with rear wheel as well as front wheel suspension. A conventional bicycle offers a certain springy comfort and relief for the backside. If the construction of the velomobile allows for the removal of this disadvantage by installation of springs in the rear wheel suspension, as a customer one ought to have one.

In the same connection I would also suggest increasing the gear ratio. On numerous occasions, both on long and short tours in low mountain ranges, especially on steep stretches, I wished to take care of my knees. I've since heard that this is now possible, and I will gratefully take advantage of the development.

Even as I speak, I am looking forward to the increase in user comfort which the implementation of the measures mentioned above would produce.

I sincerely hope that every one of you creatively involved in developing the HPV for everyday use, will achieve the breakthrough for velomobiles, and will be motivated by your success to carry on. Then, perhaps, the future traffic on our streets may appear as in the last picture (Pict.15).



Pict.15: Vision of future traffic on our roads

The Draft of Biotransport Law of Lithuanian
Republic

Dr. Vytautas Dovydenas
Associate professor,

Vilnius Technical University, Lithuania

In pre-war Lithuania bicycle transport was very popular, but at present old cars bought now in Western Europe prevail. Traffic jams cause daily problems. Highly developed public transport is getting much more expensive. So the example of Danish towns is very attractive. But we want biotransport paths not only to serve transport needs, but to have more recreational qualities than those of traditional Danish bicycle paths. Most of them should be transformed into greenways or streets with beautiful architecture almost without any cars which have to move only on roads intended for their traffic.

In the passed General Law of transport of Lithuanian Republic biotransport is mentioned before motor and rail transport. The draft of the law presented below has been prepared to the order of Transport Ministry and discussed there.

The law was prepared by Dr. Associate Prof. Marija Burinskienė, the author of the monograph about bicycle traffic, the sociologist Alvydas Karalius, the chairman of the Vilnius development municipality committee, and author of this letter, as well as officials of Transport Ministry.

We hope that our Government will present this draft to the Seimas (Parliament) of Lithuania and it will be approved in this year.

BIOTRANSPORT DRAFT LAW OF LITHUANIAN REPUBLIC

ARTICLE 1. The purpose of biotransport law.

This law defines the position of biotransport of Lithuanian Republic in general transport system and the fundamentals of its organization and development.

ARTICLE 2. The law application sphere.

Biotransport is a generally used means of transport and it is stimulated by the state.

State institutions, juridical and natural persons using biotransport means and directing their development and maintenance must keep

the demands of this law.

ARTICLE 3. The main concepts.

Biotransport - the carriage of people and small loads by using biotransport vehicles.

Biotransport vehicles - devices for the carriage of a man (or people) and small loads driven by the power of the muscles of a driver or transported passengers. Bicycles, velomobiles and similar devices are biotransport vehicles.

Biotransport path - a belt of land for biotransport traffic. This concept also includes a greenway where traffic of motor vehicles and mopeds is prohibited. Such path is segregated from the roadway, has scenic qualities and is assigned to pedestrian use and biotransport traffic.

Infrastructure of biotransport - the whole complex of engineering equipment for the service of biotransport, ways for the organization of its traffic, storage and repair.

Zone of quiet traffic - a road with traffic and speed limitation for vehicles (up to 30 km/h) and priority for biotransport and pedestrians

ARTICLE 4. Biotransport system.

The system of biotransport contains biotransport vehicles the network of paths and their infrastructure. Biotransport has advantages over other means of transport in quiet traffic and recreational zones and residential areas of towns. The use of biotransport means is tax exempt.

According to their arrangement and interrelation with other means of transport there are the following types of paths in the network of biotransport paths:

- greenways,
- isolated paths.

Besides marked lanes on streets and roadways and marked lanes on footpaths and sidewalks intended for pedestrian use can be used for biotransport traffic.

Biotransport paths are constructed with proper attention to ecological conditions linking the main objects of attraction in the shortest possible way into one independent network.

According to their parametres biotransport paths are divided into separate categories which are defined by the standards and rules of design. The density of the network of biotransport paths must be designed and built no less than that of an arterial network.

The infrastructure of biotransport consists of parking and storage spots with equipment, enterprises for maintenance and repair and special structures and devices for biotransport.

Biotransport paths and objects of their infrastructure are being designed and constructed in accordance with the standards and rules confirmed by the Transport Ministry and discussed with the Ministry of Construction and Urbanistics.

ARTICLE 5. The development of biotransport system.

The development of biotransport system is maintained by the Transport Ministry and town (district) municipality. The money of juridical or natural persons devoted for the design, construction and maintenance of biotransport paths and infrastructure is not subject to taxes.

Enterprises and persons producing biotransport vehicles and equipment for local market and repairing and maintaining them are given privileges of taxes for this part of production by the Lithuanian government.

ARTICLE 6. The distribution of land for biotransport paths and their infrastructure.

The general development of biotransport system is defined in master plans of state, town or region which must foresee the network of biotransport paths and their infrastructure. In these plans priority is given to greenways.

The land for biotransport paths and other needs is granted in accordance with the laws of Lithuanian Republic.

ARTICLE 7. Property right to biotransport objects.

The network of biotransport paths and its infrastructure sited in master plans is the state property. State institutions carry out the functions of the owners of state paths and their infrastructure. The owners of private infrastructure are juridical and natural persons.

ARTICLE 8. Standard statements dealing with the problems of biotransport use.

Traffic rules define the movement of biotransport. Its maintenance is carried out according to technical requirements. These standard documents are confirmed by the Transport Ministry. Municipalities control the order of registration and accounting and the

fulfilment of technical requirements.

The Ministry of Internal Affairs controls the traffic of bio-transport vehicles.

ARTICLE 9. Financing of biotransport.

The state and municipality budgets determine the expenses for the development and maintainance of greenways, isolated paths and their infrastructure. Various funds can be used for this purpose according to the laws of Lithuanian Republic.

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Examples for the psychology behind the physics of Velomobiles

by Prof. Dr.-Ing. W.Rohmert, Dipl.-Ing. S. Gloger:

1 Typical Design Criteria

For every problem there will be working more than one solution, but for criteria given one can find one optimal solution. Designers of velomobiles mostly find physical and technical criteria for their decisions. Typical design criteria are the technology available, production costs, driving characteristics, functionality, reliability, simplicity and further criteria. The overall aim related to all those criteria is a smiling contentedly user. But often the user is not content although all those criteria being realized. Some examples will show possible subjective criteria of users.

2 Examples

2.1 Energy Storage

The idea of an energy storage using the braking energy for acceleration and hill climbing is as old as the bicycle itself (HERZOG, 1984). In questionnaires a recuperative-system is preferred instead of an assisted engine (ROHMERT/GLOGER, 1992). In the cause of technological development and changing technical circumstances of a Velomobile like the *DESIRA-2* in comparison to a standard bicycle (available volume, higher mass) we have investigated all possibilities of energy-storage that we know nowadays. Similar to the results of WHITT and WILSON (1978) we found that only a few technical components are useful for a velomobile: flywheel, rubber power (rubber spring), electrochemical storage (accumulator), brake-hill (DOVYDENAS, 1990) and freewheel. The first two principles have the need of a transmission and the third will lead to a motor assisted vehicle. The last two principles do not lead to any changes of the vehicle, but the brake hill would mean a very expansive construction for the administration of a city.

The money would better be spent into intersection-free bike lanes as we have seen in Farum, Denmark, at the last European HPV-Championships in 1993. The last principle is prepared free of charge in every bicycle, but is not often used by riders. Let's have a look on the objectives and the subjective.

Two bicyclists are driving with 7 m/s (25 km/h) and have to stop at a crossing. The first is driving constantly with 7 m/s and then brakes with 2 m/s^2 , the second lets his bicycle roll the last meters. Figure 1 shows the loss of time and the energy-saving of the second driver. At a rolling distance of 125 meters the energy-saving is 2,8 kJ, but the theoretical recuperative energy by braking with 2 m/s^2 is only 2,6 kJ (the technical efficiency of the recuperative system of about 50 % is not calculated). The loss of time is only 10 seconds. On a city route with an overall length of 6 km and 6 stops the loss of time would be one minute. The overall cruising time would be 19 versus 20 minutes, what is a difference of approx. 5%. Other calculations we have done show, that the difference of drivers performance needed to climb up a 500 meters long hill with a gradient of 10% with or without energy recuperation is about 20-25% in respect to the driving speed uphill and downhill.

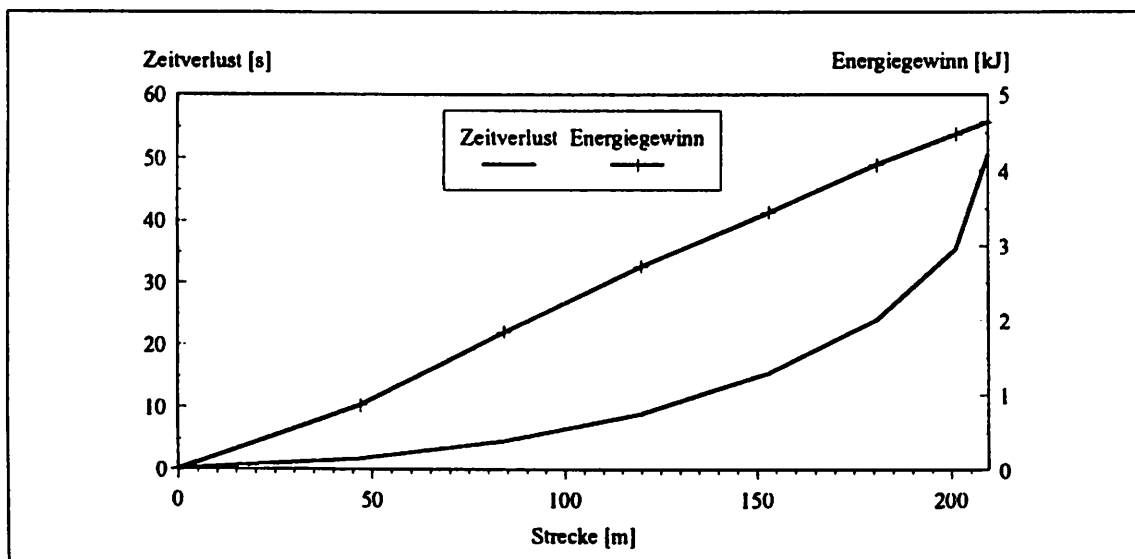


Figure 1: Energy gain and time losses by rolling

The subjective aspect is, that most people hope that the energy storage is something like a power harnessing equipment (normally called engine or motor) with zero ecological impact and more output than input. WHITT/WILSON (1974) expressed this in a few words: "In every bicyclist there is a desire, however suppressed, to leave the sports cars standing in a cloud of rubber smoke". What most bicyclists want is to drive as fast as possible but with zero ecological impact. This can only be realised by lower mass, better aerodynamics and smaller rolling resistance.

2.2 Weather Protection

Besides transport capacity weather protection is the most important reason to choose a velomobile instead of a bicycle (RETZKO et al., 1994). Unfortunately two new problems arise with a completely closed fairing: visibility in rain, snow and at cold days and cooling in summer. The last point is described in an article above, the first point will be discussed here. The typical car-solutions for those problems (electrical wiper and heating with energy-losses of the engine) are not practical for a velomobile. The principles we have investigated and finally chosen are described in the same article above. But the very best solution with respect to all objective criteria is the "umbrella principle". It gives 99% weather protection and the best visibility. Especially for those wearing glasses it fits better than a normal bike. The problem is, that the "umbrella" (e.g. a hud with a mounted visor) can not be seen by the observer if it is not activated. So the weather protection can only be seen at 10 % of the time. Additionally the possibilities for a nice looking vehicle outfit are restricted. But the acceptance of a velomobile is essential dependent on the visible existence of weather protection and the design impression. So we have to look for compromises and new design-ideas.

2.3 Fairing

If a fully closed fairing is designed around a recumbent bicycle and its rider in order to provide sufficient interior space, good aerodynamics, some space for luggage and a short length, one gets something that looks similar to an egg from the most points of view (e.g. the *DESIRA-1*). It is short, high and narrow. The problem is reinforced by single track vehicles with a short wheelbase. The often used synonym *cigar* for faired long-wheel-base recumbents isn't more complementary at all. In comparison to this we know that the most attractive automobil-designs are long, flat and wide. So we have to look for all design tricks and some compromises to get a long, flat and wide design impression of our velomobils. One possibility is the relatively bevelled body of the *DESIRA-2*. Perhaps the criterion design is the most important subjective criterion of all.

Driving the *DESIRA-2* through city traffic people often ask me, whether the stabilization of the vehicle is difficult or dangerous. It seems that most people are displeased by the combination of a single-track-vehicle and a fully closed fairing. Experiences with students of the *DESIRA*-team show, that even those students who are experienced with the *MULTILAB* are emotionally highly strained and feeling unsafe when they first ride the *DESIRA-2* in spite of the same operating conditions (front-wheel-geometry, seat, handlebar) of both vehicles. It seems to be that the existence of the fairing itself is a psychological hindrance. This effect even will be reinforced if the subject tries to ride the *DESIRA-2* without any experience with recumbents. But this is only a psychological problem, because after 10 minutes of riding those problems have vanished. Recognize that the same driving conditions without fairing on the *MULTILAB* are easy to control immediately for every unexperienced rider. On this background a monocoque structure is perhaps not the best solution for a start into the market.

3 Summary

For every problem there is more than one solution, but if criteria are given one can find one optimal solution. Designers of velomobiles mostly take physical and technical criteria for their decisions. Using the examples energy-storage, weather protection and form of the fairing it is demonstrated, that in some cases not those objective criteria but psychological criteria are defining the acceptance of the solution. Those examples show, that we have to add subjective criteria of the expected users to estimate the vehicle-concepts. The problem still unsolved is how to obtain the information from the potential user about individual subjective criteria he is preferring for the assessment of a velomobil.

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Verschiedene Sichtweisen auf Mensch und Velomobil

Beim Thema Velomobil und Sicherheit, so fällt mir auf, werden oft nur "äußere" Aspekte und Einzelheiten betrachtet. Seltener finden Gefühle, Beobachtungen, innere Beziehungen, und die Umgebung insgesamt Beachtung. Dabei tragen das allgemeine Wohlbefinden, unsere Wahrnehmung, die Reaktionszeit und -fähigkeit maßgeblich zur Sicherheit (nicht nur) von HPV-Benutzern bei. Ich empfinde hier ein großes Nachholbedürfnis.

Zu drei recht eng zusammenhängenden Themenkreisen möchte ich einige Anregungen geben und Fragen stellen. – 1) Der Mensch als Teil der Umwelt, die äußeren Einflüsse – 2) Innere Abläufe und Ausgeglichenheit des Menschen – 3) Unser Mobilitätsbedürfnis

1. Zu den äußeren Einflüssen auf den Menschen

Über Ernährung sind Regale von Büchern geschrieben, viele Ansichten werden vertreten über die Stoffe, die uns mit der nötigen Energie zum Bewegen versorgen. Erwähnt sei hier nur, daß Qualität wohl wichtiger ist als Quantität. Auch heißt es wohl zu recht: "Der Mensch ist, was er ißt."

Noch beständiger atmen wir die Luft um uns herum ein und aus. Nicht nur deren Zusammensetzung, sondern auch das lufterlektrische Ladungsfeld hat Einfluß auf den menschlichen Organismus. Wir sollten unseren Lebensatem genauer beobachten lernen, drückt er weit mehr als nur unsere momentane Stimmung aus.

Zu den physiologischen Aspekten ist einiges bekannt, vieles aber noch unerforscht. Erinnert sei nur an die Regel, die Gelenk- und Muskelbelastung durch eine hohe Trittfrequenz herabzusetzen, oder der berühmte "Runde Tritt". Noch keine befriedigenden Antworten gibt es beispielsweise zu anderen Antriebsformen – so halte ich die Diskussion nichtkreisförmiger Pedalbahnen oder Kettenblätter, Linear- oder Ganzkörperantriebe für lange noch nicht abgeschlossen.

Ergonomische Gestaltungsweisen finden zwar langsam mehr Beachtung, aber auch hier gibt es noch weite Betätigungsfelder. Es sei nur an die Frage von geeigneten Sitzformen erinnert, an optimale Bein-Oberkörperwinkel, die Armhaltung, das Verhältnis von Tretlager- zu Sitzhöhe. Statistisch relevante Untersuchungen sind mir nicht bekannt.

In seinem Buch "Die Kleidung unsere 2. Haut" schreibt Paulus Johannes Lehmann viel Wissenswertes über die Stoffe, die unsere allernächste Umgebung bilden. Zum Beispiel vermögen die tierischen Eiweißfasern Seide und besonders die Wolle viel Feuchtigkeit aufzunehmen, ohne sich naß-kalt anzufühlen. Auch besitzt Wolle die Fähigkeit, Schmutzstoffe und Schweiß von der Haut nach außen abzutransportieren, sowie an frischer Luft eine erstaunliche Selbstreinigungskraft. Dem natürlichen Wollfett werden zudem beachtliche Heilerfolge zugeschrieben. Pflanzliche Fasern wie z.B. Baumwolle besitzen diese Fähigkeit nicht in so starkem Umfang. Bei synthetischen Fasern kommt z.B. noch das Problem der elektrischen Aufladung hinzu. Die Träger stehen oft (unbewußt) permanent "unter Spannung", die Schweißaufnahmefähigkeit ist minimal. In einzelnen Aspekten vermögen Kunstfasern durchaus Vorteile aufzuweisen, entscheidend ist aber die Summe aller Trageeigenschaften. So besagt eine Untersuchung, daß sich durch das Tragen von Socken aus synthetischen Materialien die Reaktionszeiten verlängern, verglichen mit Naturfasern. Überträgt man diese Beobachtung, ergibt sich vielleicht auch ein neuer Blickwinkel bezüglich der Sturzhelmdiskussion.

Selbst die Farbe unserer Kleidung hat Wirkungen und beinhaltet Informationen für Körper und Geist. – Es wird sich also lohnen vor dem Kauf von neuen Radfahrer-Kleidungsstücken etwas intensiver darauf zu achten, in welche Sachen man sich hüllt.

Ein weiterer wesentlicher Punkt ist unsere Wahrnehmung ganz allgemein. Dieselben Tatsachen werden oft als sehr unterschiedlich empfunden und interpretiert. Sind sie einem Menschen angenehm, kann ein anderer sie als störend empfinden. Als Beispiel sei nur die Beurteilung einer bestimmten Verkehrssituation oder das subjektive Geschwindigkeitsempfinden genannt. Dies gilt nicht nur für die äußeren Einflüsse aus der Umgebung, sondern auch für die Wahrnehmung innerhalb von Körper und Geist. Häufig konnte ich schon beobachten, daß Streitpunkte nur mit individueller Wahrnehmung und Auslegung zu tun hatten.

2. Zu den inneren Abläufen

Wer Rad fährt, so heißt es in einer englischen Studie, denkt positiver und ist im allgemeinen lebensbejahender. Durch die gleichmäßige Bewegung setzt das Gehirn mehr vom Botenstoff Serotonin frei, steigert so Laune und Wohlbefinden.

In der westlichen Zivilisation sind wir darauf konditioniert, Intelligenz mit logischen, rationalen und wissenschaftlichen Fähigkeiten gleichzusetzen. Charakteristisch hierfür ist das lineare Denken. Ergänzend sind in den letzten Jahren immer mehr ganzheitliche Ansätze zu beobachten, die versuchen, sich Fragestellungen in vernetzter Betrachtungsweise unter Berücksichtigung vieler Blickwinkel zu nähern. Dabei sollen auch Gefühl, Intuition, Bewegung und Berührung, Form, Farbe, ja man könnte sagen das Wesen der Dinge mitberücksichtigt werden. Hierzu zählt auch die Beobachtung, daß das Ganze mehr ist, als nur die Summe der Einzelteile.

Ein Ansatz, der sich intensiv mit Bewegung und Energieflüssen beschäftigt, ist die Kinesiologie, einer sich auf alte chinesische Quellen und neuere wissenschaftliche Untersuchungen stützende Lehre, bei der die Integration der beiden Gehirnhälften angestrebt wird. Durch Meridiane bzw. Energiebahnen sind alle Körperteile verbunden. Akupunktur-Punkte und -Bahnen wurden ja mittlerweile mehrfach untersucht. Sind diese Meridiane nicht in Balance, kommt es zu Blockaden, Verspannungen, Streß, Allergie und Krankheiten, die durch gezieltes Einschalten bestimmter Muskeln wieder harmonisiert werden können. – Hierbei ist der Begriff "Energie" oder "energetisch" etwas weiter zu fassen. Die ganze Lebensenergie ist gemeint. Am besten könnte man sie so erklären, wie man sich fühlt, wenn man sie nicht hat.

Einige Eigenschaften der beiden Gehirnhälften

| <i>linke Gehirnhälfte</i> | <i>rechte Gehirnhälfte</i> |
|--------------------------------|----------------------------|
| <i>abstrakt</i> | <i>konkret</i> |
| <i>rational</i> | <i>emotional</i> |
| <i>zeitlich</i> | <i>räumlich</i> |
| <i>mental</i> | <i>intuitiv</i> |
| <i>logisch</i> | <i>gefühlsmäßig</i> |
| <i>introvertiert</i> | <i>extrovertiert</i> |
| <i>der Reihe nach – linear</i> | <i>Gestalt – simultan</i> |
| <i>angespannt</i> | <i>entspannt</i> |
| <i>auditiv</i> | <i>visuell</i> |
| <i>wissenschaftlich</i> | <i>künstlerisch</i> |
| <i>objektiv</i> | <i>subjektiv</i> |
| <i>analysierend</i> | <i>synthetisierend</i> |

Für die rechte Gehirnhälfte stehen dabei u.a. die Stichworte künstlerische und intuitive Fähigkeiten, Emotionen, Synthese, Gestalt, analog, simultan. Für die linke Gehirnhälfte stehen Analytik, Abstraktion, linear, rational, digital, logisch, zeitlich, mental. Dabei wird individuell eine Gehirnhälfte bevorzugt. Sind beide Gehirnhälften in Balance (integriert), fließt die Energie durch den ganzen Körper, sind die Muskeln im Gleichgewicht, wird das Universum als "Gestalt", als Ganzes wahrgenommen. Die Details sind weniger wichtig als die Wahrnehmung der Bedeutung.

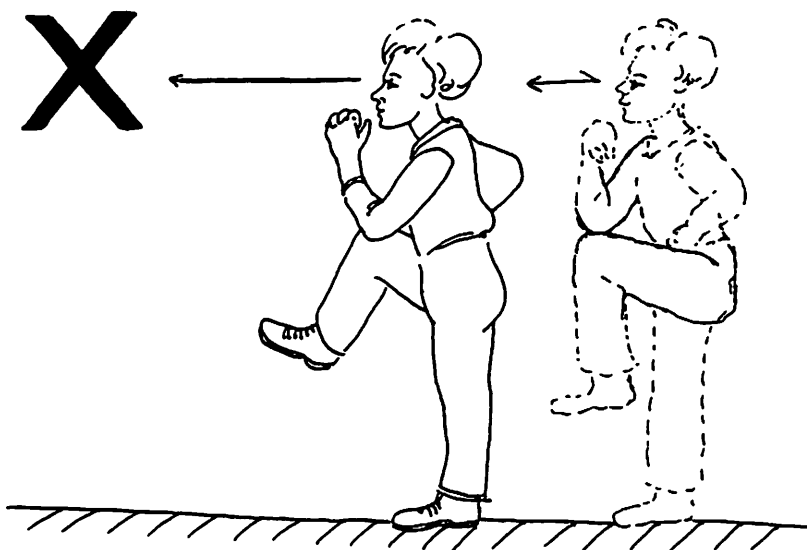
Als Diagnose- und Therapiemittel wird der Muskeltest benutzt, bei dem der Körper durch das Unterbewußtsein auf gestellte Fragen antwortet, indem ein isoliert getesteter Muskel ein- oder ausgeschaltet wird. Ob das geht, hängt mit dem ungehinderten oder blockierten Energiefluß vom Gehirn zum Muskel zusammen.

Werden so verschiedene Bewegungsabläufe getestet, so ist festzustellen, daß Überkreuz-Bewegungen energetisch stärken. Das Überkreuz-Bewegungsmuster kennzeichnet jede rhythmische, ausgeglichene Bewegung, die verlangt, daß man die rechte und linke Körperseite dynamisch in Beziehung bringt, während man sich zugleich des oberen und unteren Teils des Körpers bewußt ist. Die Überkreuzbewegung erfordert, daß das Gehirn die Muskeln zum richtigen Zeitpunkt arbeiten läßt. Das Kind erwirbt diese höchst komplizierte dyslaterale, also beidseitige, Integration in der Regel während der Kriechphase vor dem Laufen. Dieselbe Kooperation der Gehirnhälften ist übrigens auch für das Lesen und Schreiben notwendig. Dem Laufen ist ebenfalls die dyslaterale Bewegungsweise zu eigen, abgesehen von der energetischen Balance, die schon allein durch die Stimulanz der Fußreflexzonen-Punkte gefördert wird.

Testet man den Bewegungsablauf des Radfahrers, so wirkt er energetisch schwächend, wenn nicht beide Gehirnhälften vollkommen integriert sind. Warum? Weil es eine einseitige, also homolaterale Bewegungsform ist. – Interessant zu beobachten, daß dies nicht für das Freihändigfahren gilt. Offenbar reichen die kleinen Ausgleichsbewegungen der Arme und des Oberkörpers aus, um zu einem Überkreuz-Bewegungsmuster zu führen.

Hier sei kurz eine sehr einfache und wirkungsvolle Übung, die im Stehen durchgeführt wird, vorgestellt – der sogenannte Cross Crawl. Der rechte Ellbogen wird zum linken angehobenen Knie geführt und danach der linke Ellbogen zum rechten Knie. Verstärkend wirkt noch, auf zwei sich kreuzende Linien, also ein X, in Augenhöhe zu schauen. Diese Übung bringt nicht nur oben und unten in Beziehung, sie erfordert jedesmal eine Überquerung der Mittellinie der Körperhälften. Früh und abends, direkt vor oder in einer Pause während einer längeren Fahrt ist der Cross Crawl schnell 30 bis 50 mal geturnt, fördert die Gehirnintegration, schaltet ein.

der Cross Crawl



Interessant wären hier weiterführende Untersuchungen über die Wirkungen von einigen ausgleichenden Übungen, von anderen Antriebsbewegungen und von integrierenden Symbolen. – So stärkt es beispielsweise, auf ein X zu schauen, während zwei parallele Linien energetisch gesehen schwächen. Das liegende Kreuz symbolisiert die Koordination der beiden Gehirnhälften zur jeweils gegenüberliegenden Körperseite. Neben der Integration der rechten und linken Körperhälfte spielen die Dimension oben und unten, die für emotionale Zentriertheit steht, und die Dimension vorne und hinten, die den Vorgang an sich, den Fluß des Lebens beschreibt, eine Rolle.

Nicht unerwähnt bleiben soll auch der Einfluß unserer inneren Einstellung. Positive Gedanken werden zur Sicherheit im täglichen Straßenverkehr, und zwar durch Gesundung des Umganges miteinander und mit der Umgebung. Zur Sicherheit trägt dies mit Gewißheit mehr bei als eine aggressive, haßgeprägte Verhaltens- und somit Fahrweise. Ein Lächeln paßt eher zum Fahrrad und Velomobil als eine verkrampte Verbissenheit.

Wer hat Interesse, an diesen Fragen weiterzuarbeiten? Wer kennt evtl. bereits vorhandene weiterführende Untersuchungen und interessierte Fachleute?

3. Unser Mobilitätsbedürfnis

- Warum müssen wir einen derartigen Anspruch auf uneingeschränkte Mobilität entwickeln?
- Warum liegen die Arbeitsplätze oft so weit von den Wohnungen entfernt?
- Warum halten es die Menschen bei sich selbst zu Hause nicht aus, fliehen in der "Freizeit" Dutzende, ja hunderte Kilometer von daheim?
- Woher kommt die Faszination, ja der Rausch der Geschwindigkeit?
- Warum möchten wir über Kräfte gebieten, die schon längst nicht mehr für uns nachvollziehbar sind?
- Warum wird Entfernung zu einem schnell zu überwindenden Hindernis, statt zu einer Möglichkeit an "Erfahrung" reicher zu werden?

In einigen östlichen Sichtweisen heißt es: "Der Weg ist das Ziel". Ist es nicht eine große Gefahr, immer nur auf die Ziele zu starren und darüber die Mittel, also den Weg, zu vernachlässigen?

Zitieren möchte ich weiterhin Wolfgang Sachs, der schreibt: "Warum aber wird die Beschleunigung aller Vorgänge zur moralischen Pflicht? Das hat mit jenem Fortschrittsglauben zu tun, daß die Zukunft immer besser als die Gegenwart und Vergangenheit ist. Zeithetze entspringt nichts anderem als einem chronischen Defizitbewußtsein, nämlich dem Grundgefühl, daß man nie genug kriegen und erledigen kann, da die Möglichkeiten von morgen immer die Bedingungen von heute übergänzen. Damit ist jedoch ein Dauerkonflikt programmiert: das unbegrenzte Wollen stößt gegen die begrenzte Zeit. Schließlich ist, allem Fortschritt zum Trotz, der Tag in seiner konservativen Art immer nur 24 Stunden lang: weil die Stunden nicht vermehrbar sind, bleibt nur, sie unter Druck zu setzen und aus ihnen durch Planung und Eile mehr herauszuholen. Zeit zu verlieren wird deshalb fast zu einem Sakrileg, denn wenn die Zukunft alle Versprechen hält, bleibt der Gegenwart nur, sich zu beeilen. Gemächlichkeit versäumt daher die Zukunft, Beschleunigung ist Trumpf.

Das Fahrrad signalisiert, daß dieser Fortschrittsglaube, sowohl im Großen als Geschichtsentwurf, wie im Kleinen als Alltagsgefühl, am Bröckeln ist. Die Zukunft erscheint nicht mehr als Verheißung, sondern als Bedrohung, denn der Fortschritt, so hat sich gezeigt, beruht auf gigantischen Kostenverschiebungen, die das Morgen eher zur Falle werden lassen. Kurz, mit dem Fortschritt scheint auch der Rückschritt zu marschieren. Vor einem solchen Hintergrund wächst die Bereitschaft, die Gegenwart intensiver und genauer zu leben, anstatt einem vermeintlichen Optimismus nachzujagen, das Soll herabzusetzen, anstatt das Haben zu erhöhen. Und man erinnert sich, daß Eile einstmals nicht nur unhöflich war, sondern auch die Sprache immer schon Mißtrauen in die Ruhelosigkeit verriet, man denke an "übereilt", "voreilig", "eifertig" etc. Radfahren zieht eine Erfahrung in den Alltag, die gerade für die ökologische Bewegung wichtig geworden ist: daß Selbstbegrenzung ein Gewinn sein kann, daß mit Gelassenheit etwas nicht zu

tun, einem Konzentration und Souveränität verschafft. Selbstbegrenzung begründet Qualität des Lebens, privat wie auch öffentlich; so belegt die Renaissance des Fahrrades die Suche nach einer fortschrittsbefriedeten Gesellschaft.”

So ist zu merken, daß auch für unsere Mobilität gilt: eine Handlung ganz, bewußt, liebevoll und mit Ruhe getan ist erfüllender und fruchtbringender als drei Dinge gleichzeitig, gehetzt und mit verdrießlichem Gesicht. – In diesem Sinne laßt uns bei den vorstehen Rennen auch mal genauer in die Gesichter der Menschen schauen, ihre Gesten und ihr Wesen beobachten. Laßt uns vor allem nicht vergessen, daß es nicht um Konkurrenz und Gewinn gehen sollte, sondern um Menschen, um Kooperation und ein gesundheitsförderndes, positives, erfüllendes Maß an Bewegung, an Mobilität in einer menschlichen Gesellschaft, um Sein und Bewußtsein.

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Recumbents with rear wheel steering

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Abstract

It is considered that it is not possible to ride bicycles with rear wheel steering. Several attempts to build such bikes seemed to acknowledge this prejudice. But did the constructors choose an optimal steering geometry? We made a computer optimization with our dynamical bicycle model and with those results it should be possible to build a rear steered recumbent which is quite easy to handle. The advantages in contrast to normal recumbents could be the front drive with a short chain and the small length and weight.

Zusammenfassung

Es wird allgemein angenommen, daß Fahrräder mit Hecklenkung nicht fahrbar sind. Einige Versuche, solche Räder zu bauen, schienen dieses Vorurteil zu bestätigen. Aber haben die Erbauer eine optimale Lenkgeometrie gewählt? Wir haben einige computer-optimierte Lenkgeometrien mit unserem Dynamischen Fahrrad-Modell berechnet, und mit diesen Ergebnissen sollte es möglich sein, ein Liegerad mit Hecklenkung zu bauen, das gutmütige Fahreigenschaften hat. Die Vorteile gegenüber normalen Liegerädern wären der Frontantrieb mit kurzer Kette, kleine Abmessungen und geringes Gewicht.

Conventional recumbents

There are mainly two types of recumbent bicycles, which both have specific advantages and disadvantages. Recumbents with a long wheelbase (LWB) and the bottom bracket behind the front wheel are about 2.30 m long and therefore they are rather heavy. It's hard to tow them into a cellar or train and they are not very agile. Recumbents with short wheelbase (SWB) have the frontwheel behind the bottom bracket. While braking violently the rear wheel could lift off and the bike might tip over.

Advantages of rear wheel steering

To avoid these problems, the bottom bracket should be close to the front wheel. But then the riders feet or in worst case the pedals will interfere with the wheel. This dilemma was the reason to investigate the possibility of rear wheel steering, which could solve these problems and has further advantages:

- It results in a short chain because the bottom bracket is close to the driven front wheel. That means less weight not only because of the shorter chain, but also because of the lighter frame, which has not to stand the pulling chain forces on the whole length.
- The chain is not anymore in conflict with the front wheel, handle-bar, frame, seat and driver (as it is on LWB and SWB recumbents).
- The handle-bar mounted under the seat is close to the steered rear wheel. The steering direction has to be inversed, e.g. with an overcross mechanism or with separated handle-bars for each hand.

The physics behind the stabiplots

The equation of motion of a bicycle can be derived with Newton's mechanics. First the bicycle is reduced to five centres of gravity of wheels, frame, fork, driver and several moments of inertia. The state of motion of the bicycle is determined by the vektor \vec{Z} which consists of the velocity v , the lean angle κ , the steering angle ϕ and their derivations $\dot{\kappa}$ and $\dot{\phi}$. After an exact calculation of the positions \vec{x} of the bicycle parts as a function of κ and ϕ in a suitable and moving (fixed to the bicycle) coordinate system the equation of motion can be derived from an equilibrium of forces and momentum. The solution of that transcendent equation only is possible with numerical methods:

$$\begin{aligned} & \sum_c \dot{\vec{L}}^c + \sum_k m_k (\vec{x}^k - \vec{S}^{v0}) \times (\ddot{\vec{x}}^k + g\vec{e}_z) \\ & + \left\{ \frac{1}{L_F \cos \beta_H} \left[\sum_c \vec{e}_L \dot{\vec{L}}^c + \sum_k m_k (\vec{e}_L \times \vec{x}^k) (\ddot{\vec{x}}^k + g\vec{e}_z) + M_L - \mu_L \dot{\phi} \right] \right\} \vec{K} \times \vec{\omega}_1 \\ & + \left\{ \frac{\vec{e}_N \dot{\vec{L}}^{hi} + M_A}{R_H} - \mu_H v^h \right\} \vec{K} \times \vec{\omega}_2 + \left\{ \mu_v v^v - \frac{\vec{e}_N^v \dot{\vec{L}}^{v0}}{R_v} + \sum_k m_k \vec{e}_R^v \ddot{\vec{x}}^k \right\} \frac{\vec{K} \times \vec{e}_A}{-\sin \kappa \sin \phi} = 0 \end{aligned}$$

All terms are only depending from \vec{Z} , $\dot{\vec{Z}}$ and the geometry of the bicycle, although in complicated manner. By an implicit method $\dot{\vec{Z}} = f(\vec{Z})$ can be gained. For hands-off riding (steering momentum = zero) equilibrial states \vec{Z}_0 are calculated for which is $\dot{\vec{Z}}_0 = 0$. A linearisation of the system at \vec{Z}_0 leads to $(\vec{Z} - \vec{Z}_0) = \mathcal{J}_F (\vec{Z} - \vec{Z}_0)$. With the realparts λ_i of the eigenvalues of the matrix \mathcal{J}_F statements about the timing-behaviour of the system nearby the respective state of equilibrium and therewith about self-stability can be made.

So rear wheel steering has some good qualities and some people already built rear steered bicycles. Unfortunately most of these prototypes are not very succesful. None of them was rideable without extensive practising, some of them turned out to be unrideable despite of intensive exercise. Are rear steered bicycles really unrideable or does a steering geometry exist, which is as comfortable as at a normal bike? An approach to that question is to use a mathematical description of the phenomenon 'self-stability'. A normal bike which is standing upright is in an unstable equilibrium. That means that it falls down by the tiniest disturbance. But a moving bicycle is astonishing stable and easy to ride straight ahead as well as in turns. The moving bicycle has obviously the tendency to

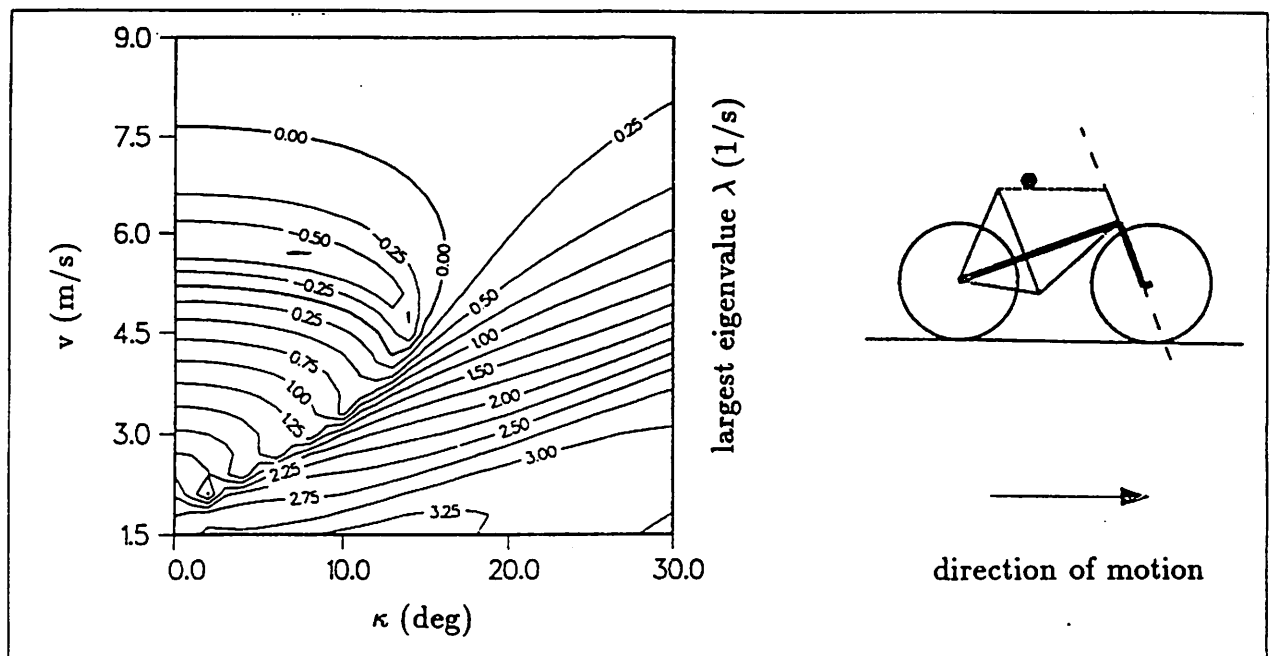


Figure 1: Stabiplot for a roadster bicycle. On the right: Drawing of the geometry. The hatched line is the steering axle, the point is the centre of gravity of the bike inclusive driver.

stabilize itself.

In a particular view it is quite complicated to understand self-stability. It is known, that the gyroscopic forces of the rotating steered wheel can change the steering angle if the bicycle begins to tilt. On the other hand trail causes the steered wheel to keep its direction. There are several additional effects which all work together, partly in opposite direction and it is not trivial how they really stabilize the bicycle.

Dynamical bicycle model

The dynamical bicycle model which has been developed several years ago at the University of Oldenburg helps to investigate all appearing forces exactly for different frame geometries, velocities, lean angles and steering angles. For hands-off riding and given lean angle κ (between the frame plane and the perpendicular) and velocity v for which the bicycle is in an equilibrial movement the displacement of the rider's centre of gravity u and a steering angle ϕ can be calculated. That means that the bike doesn't change the state of motion by itself.

For each state of equilibrium a so called largest eigenvalue λ can be calculated. The reciprocal $1/\lambda$ is the time after which a small disturbance of equilibrium is increased e-times (2.72-times). Small eigenvalues λ mean that the driver has enough time to compensate these disturbances by steering or displacing his centre of gravity. If λ is negative, then the bicycle is self-stable, that means that small disturbances die away without assistance of the rider. The calculation of λ in dependance of κ and v is intimated in the box and very extensive. The eigenvalues λ can be shown in a plot with contour-lines.

The plot for a typical roadster bike is shown in fig.1. It is self-stable between 5 and

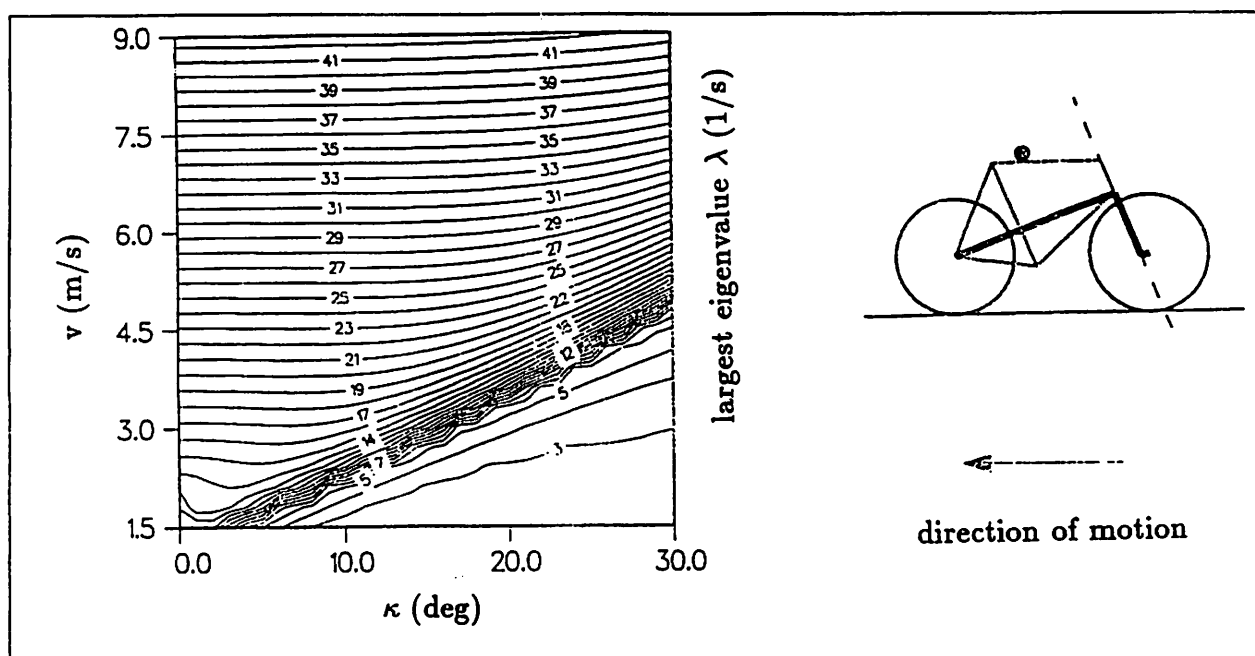


Figure 2: Stabiplot for a roadster bicycle with reversed direction of motion (emulated rear wheel steering)

7.5 m/s and if the lean angle κ is not too large ($< 17^\circ$). At higher speeds it is also rather stable what is in agreement with experience. The computed values λ are also acknowledged by measurements.

With a computer program it is possible to calculate the stability plot for the same bicycle but with reversed direction of motion (fig.2). This represents the case of rear wheel steering. At higher velocities the eigenvalues λ are getting larger and the bicycle more and more uncontrollable. Who ever tried to roll down a hill backwards will agree to this.

Optimization

To find out good steering geometries for rear wheel steering, a program has been written to vary the geometries in given ranges. The criterium for an optimal geometry is that the eigenvalues λ should be small for velocities of about 20 km/h, so that the driver doesn't need much effort and concentration for the handling. Unfortunately the action and reaction between human and machine during cycling is barely explored. Nowbody knows exactly how the driver forces his will upon the bicycle. Qualities like directional stability, manoeuvrability, steering precision can't be described physically until now. The following informations should only be understood as a clues, where one could search for an ideal frame geometry for a rear wheel steered bicycle for everyday use.

Our preconditions were:

- The driver's centre of gravity should be placed in a height of 90 cm to guarantee good view and visibility and 50 cm behind the front wheel to make a sufficient braking deceleration possible.
- The wheelbase was fixed to 120 cm to reach a sufficient front wheel load in all situations, especially for starting on a hill.

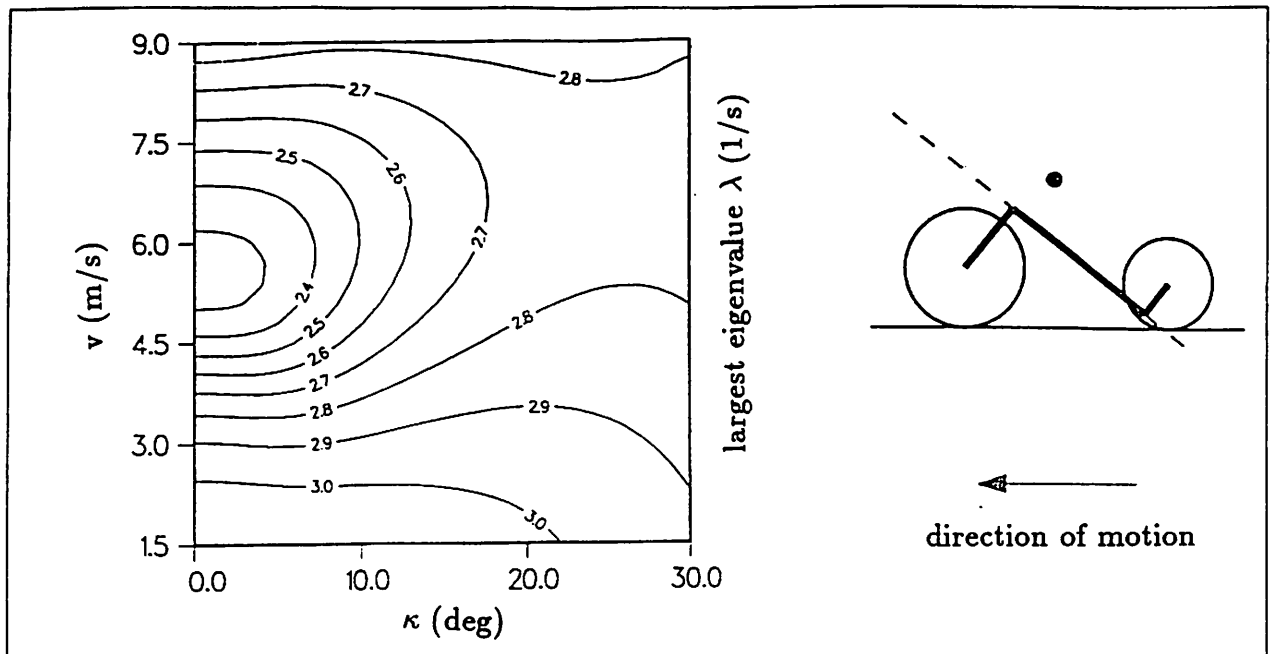


Figure 3: Stabiplot for the rear wheel steered bicycle which was the result of optimization (the frame is not drawn).

- There should not be used additional masses or springs at the steering system.
- The seat should be fixed to the front axle and only the rear wheel should be steerable; steering constructions like the 'Vlevobike' are not included.

With this constraints the remaining parameters (mainly trail, head angle and wheel sizes) have been varied independently from each other.

Results

- The moment of inertia of the steered rear wheel should — independent from the remaining parameters — be as small as possible to keep the gyroscopic forces low. If the bike leans to the right side, the rear wheel steering effects a turn to the left, so that the lean angle is increased further. This behaviour is of course undesirable.
- The optimal geometrie as calculated by the program is shown in fig.3. The angle between steering axle and perpendicular is 51.6° . The trail amounts to 3 cm.
- The front wheel should have a moment of inertia as high as possible, which means a big and heavy wheel. But this item is not so important.

The stabiplot shows that this rear wheel steered recumbent is not as stable as a normal bike. Especially there is no area of negative eigenvalues and therefore no self-stability. But nevertheless it is more stable in motion than at standstill, and it should be rideable without circus qualifications. Steering by displacement of the centre of gravity probably is not possible (as results from unshown plots).

A stabiplot for an already existing vehicle is shown in fig.4. This rear wheel steered bicycle was build by Hans-Ulrich Waldow (Berlin). The constructeur's experience is that after some exercise it has a pleasant driving behaviour and it is steerable by leaning.

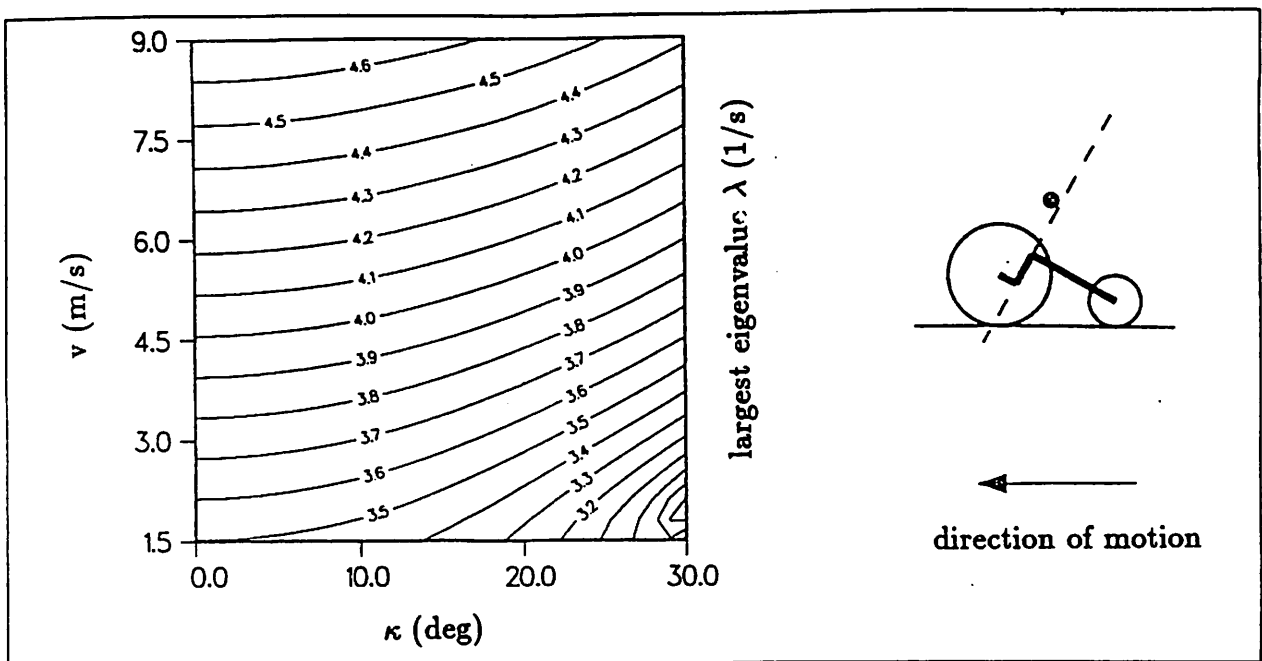


Figure 4: Stabiplot for the Waldow-bike.

Discussion

The computer simulation has shown that under the given conditions a rideable bike with rear wheel steering is possible. But the self-stable and effortless performance of a conventional bicycle presumably cannot be reached with rear wheel steering. Whether their good qualities will incite their disadvantages can only be found out by practical testing.

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HPV - ACTIVITIES AT A SECONDARY SCHOOL CENTRE IN BREMEN, GERMANY

by Joachim Franke, Alte Schule, D 27412 Buchholz

Bremen is the smallest Country of the Federal Republic of Germany. It is situated about 100 km to the West from Hamburg.

The SCHULZENTRUM IM HOLTER FELD is a secondary school which teaches graduating classes of a Gymnasium and a metal based vocational school. It runs a well equipped training workshop.

The Senate of the Free Hanseatic City of Bremen and the Ministry of Education and Science founded schoolcentres of secondary graduation in the eighties following the progressive idea of integration of academic and vocational education. This educational concept did not succeed due to manifold conservative resistance but created side effects which are still alive. To promote integration on a brand new schoolcentre of up to 3000 students, 160 teachers and 30 instructors Ministry of Education started STUDIO, a programme of voluntarily working groups in afternoon hours. Initially it was thought as a starting help for the cultural life of the school. A theatre group, orchestra, musical bands etc. may be a Third World group was thought of. Some few teachers of the vocational branch very soon recognized the potential possibilities of the workshop and therefore came up with new subjects in the field of energy, low cost housing, human powered transport, nutrition etc. Groups were also opened to the public: graduates, beltworkers and others joined the STUDIO - groups. Educational goals of these groups were: to work on innovations, to combine theory and practice, to do limited research work, to practice non formal education etc. The groups normally met for three or more late afternoon hours once a week.

Beside STUDIO the schoolcentre has developed cooperative courses with the Adult College (VHS) and Teacher's College of Further Education (WIS).

I have told you this background of my working place very briefly because I want you to understand how my activities became possible as a part of my teaching job. May be there are some opportunities at your working place? Check and tailor targets yourself which lead to more appropriate transport and a better future!

Let me now tell you about my activities in the field of human powered transport. At present I run four courses:

- | | |
|---|-------------|
| - recumbent bicycle design and construction (Liegeradbau AG) | since 1982 |
| - bicycle trailer construction (Fahrradanhängerbau, VHS) | since 1992 |
| - bicycle mechanic's toolmaking (Fahrradwerkzeugbau, VHS) advert. | oct. 1994 |
| - velomobile design (WIS) | since 1993. |

1. Liegeradbau AG

The recumbent bicycle design and construction group is one of the oldest STUDIO-groups of the schoolcentre. Here is an overview:

1982 The group started to build a recumbent very similar to the Avatar 2000. We copied a lot (even the nice hand-sewn leather-seat) because we had no experience in designing a recumbent. Work was successful.

1983 to 1985 the group produces a series of 12 copies for participants own supply.

1986 the group designs a tricycle velomobil model from 4 mm wire of appropriate size.

1986 first exhibition at schoolcentre "Week of the Bike" ("Woche des Rades"), local TV-report.

1986 to 1992 no activity of the group because I did development work in Ethiopia for 4 years including an assembly training for bicycle mechanics.

1992 the group restarts and designs its own recumbent prototyp (type 2) with these features:

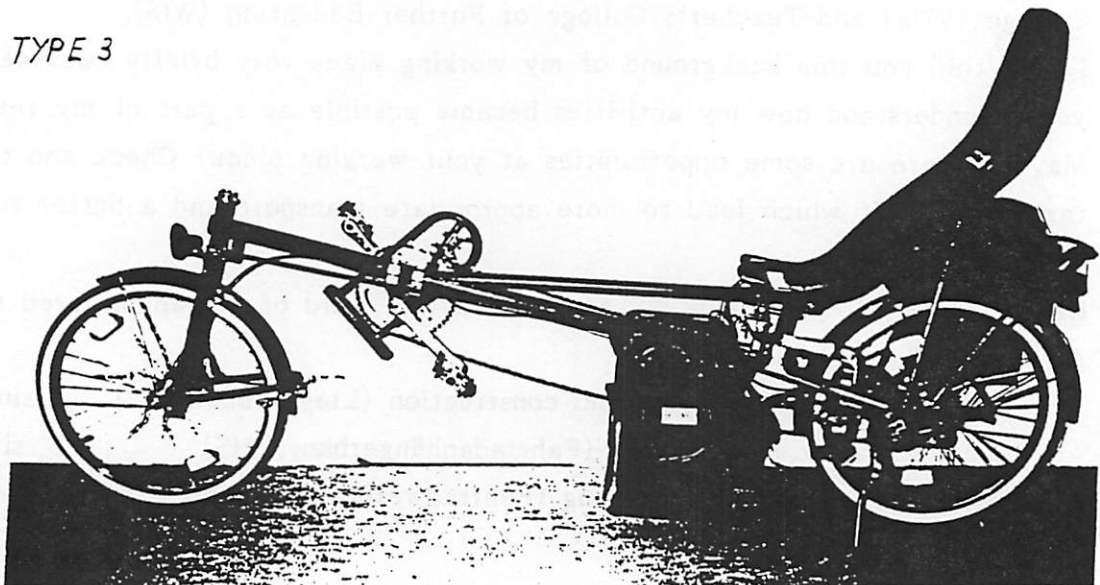
20" wheels front and rear, spring suspension (Rosta, swiss made) of the rear wheel, low and comfortable single square pipe frame, brazed, indirect steering by two corresponding controls instead of a handlebar, seat adjustable. The controls needed some training. The squarepipes are disliked. Spring suspension is appreciated.

1993 The group decides to build an alternative (type 3) with these features:

20" wheels front and rear, spring suspension front and rear, indirect handlebar steering under integrated moulded fibre-seat, bottom bracket shell adjustable. Long wheel base as short as possible.

1994 May. Typ 3 is shown to the public on a local exhibition at the City Hall. We have started to manufacture a series of 14 copies.

TYPE 3



2. Fahrradanhängerbau

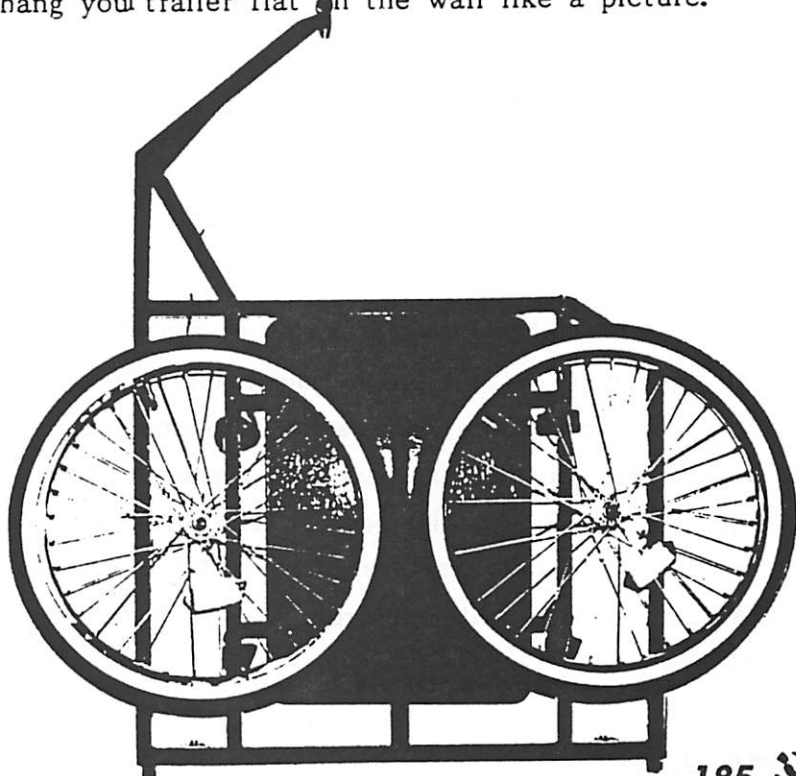
Another question was put to me to start a **bicycle trailer DIY-course** at the Adult College. Again I was released from my regular vocational teaching. In four successive courses we have now built some 40 trailers. The basic design is known as "Oldenburger Flunder" and was worked out by students of Oldenburg University under the lead of Dr. Falk Rieß.

My design is a smaller and specialized version of the original. These are the features: brazed, thin walled square pipe of normal steel (20/20/1 mm), 20" 1 3/4"-wheels with quick release axle, weight 6 kg, loading weight 40 kg, space for a newly normed banana box, outside width 69 cm, length with arm 107 cm, material costs DM 170 plus fee DM 90, production time 45 hours.

The trailer can be coupled on any bicycle with a 28" (26") wheel. There is a modified design for Leitra due to its 20" wheels.

There are some hardly perceptible improvements:

1. The **link** is a ball and socket joint. Its male thread is strong going because of securing disc springs and an adjusted locknut. The joint shall only spin around its thread in an emergency. Any normal action has to be taken by the ball.
2. A special **coupling** is fixed by the left axle nut which places the pivot behind the rear bicycle axle instead of inside the bicycle's rear stays. This is important because it allows a smaller trailer a larger angle (ca. 60°) between bicycle and trailer when the rider is curving to the right. You couple the trailer with an 8 mm Allen bolt which is a simple precaution against easy theft.
3. A **platform** from plywood which can be lowered solves the container problem. You need not necessarily have a special container: go empty for shopping, lower the platform, get a paperbox in, strap it quick released up and carry your goods home. After use you can hang your trailer flat on the wall like a picture.



3. Fahrradwerkzeugbau

This autumn I offer a special course in **bicycle mechanic's toolmaking** at the Adult College. We want to make professional truing stands and rigid repair stands. The course is designed for individuals, set up bicycle mechanics, teachers and youth group leaders which want to organize bicycle maintenance and service courses.

4. Velomobile Design

This is a group within the scope of Teacher's Further Education which started 1993, September and is now going in its second year. Teachers, instructors and students of education are participants; others are wellcome. The group meets every Monday afternoon for four hours. The final goal of this group is to prepare the manufacture of fully faired velomobiles in school workshops as object of practical vocational training. That means: working out a prototype, multiplying it for velomobile group members and their individual radical testing, drawing blueprints, designing devices, setting up an instruction scheme. This enterprise is supported as innovation with DM 4000 by the Senate of Bremen.

Despite the support this target is a tough matter: you have to convince authorities, instructors, fellows to support an idea which is completely strange and unfamiliar to them. My only argumentation help is my LEITRA. There is only one in the area of Bremen.

The LEITRA-idea must be multiplied.

Our **Velomobile Design Group** follows the goals of the LEITRA set up by C.G. Rasmussen and to be read in its technical details: safety in normal traffic, comfortable riding in wind, rain and cold, some loading space and reliability.

We supplement these further goals to our own design:

- easy service and repair, minimum maintenance,
- improving loading space: transport space for a small child,
- all wheels shock absorbed.

We dislike simply to copy a design and are eager to try our own, knowing that it is hard to compete the light weight LEITRA.

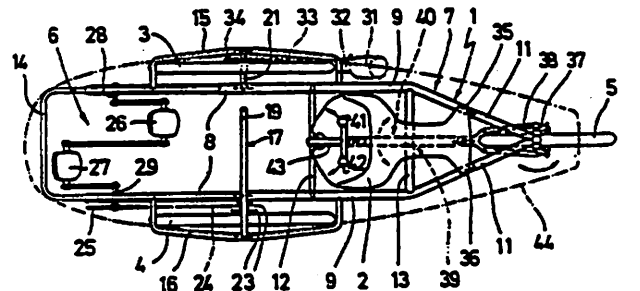
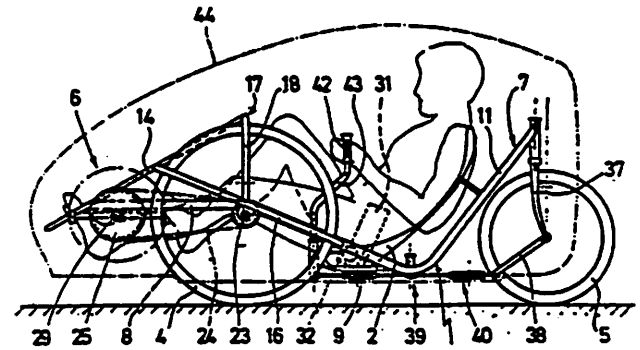
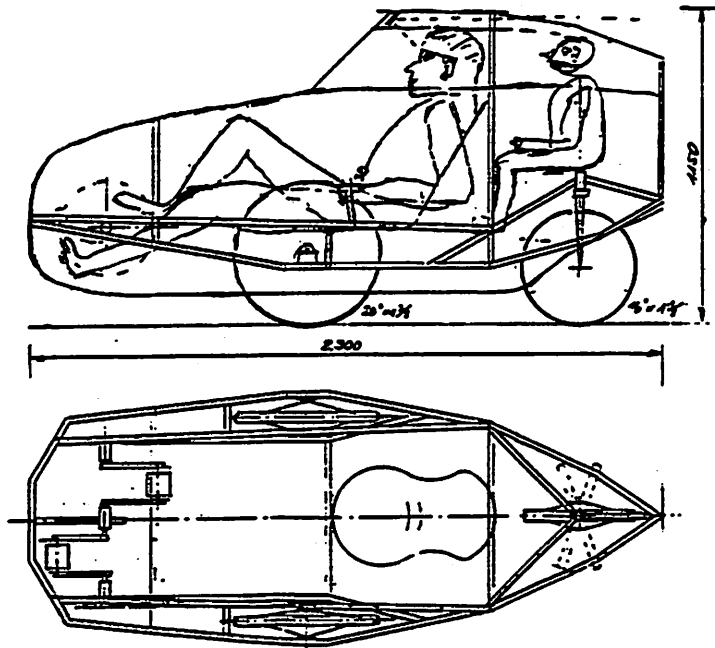
Thomas Liebich's systematization of tricycles from 1990 (see Pro Velo Magazin 22) is a big help for our group. The pattern front two wheels, front drive, single rear steering wheel attracts our interest: short chain, high manoeuvrability, loading space free from chain, easy tire repair of all wheels without black fingers etc.

Questions are: is a differential gear drive necessary? (No, it is not.) and: is at any rate a stable rear steering possible? (Yes, it is. See further down.)

A last question: will our group be the first one that builds a reliable rear steered HPV?

This is our very first sketch:

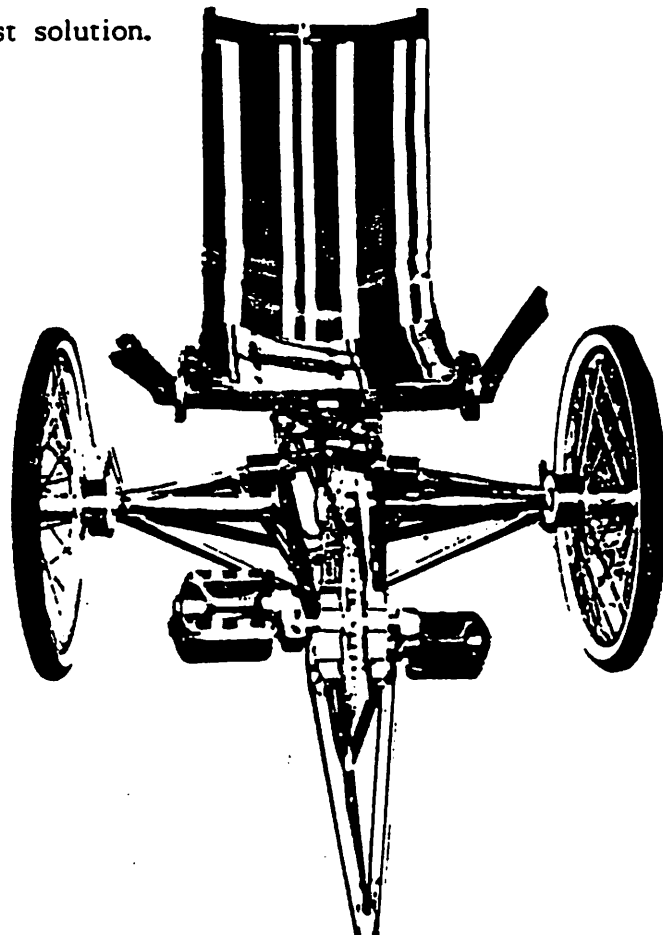
Nummer: 33 21 142
 Int. Cl. 6: 42 K 6/02
 Anmeldetag: 16. Juni 1983
 Offenlegungstag: 12. Dezember 1984



Upon the hint of a young engineer I go to the patent office to find out if there are patented tricycles. This is what I discover:

Herr Klaus-Dieter Geisert, Kiferstr. 48, 7148 Remseck 3
 HOEGER, STELLRECHT & PARTNER
 Patentanwälte in Stuttgart
 A 45 569 m

I have never seen a single example of this kind nor read from Mr. Geisert. The patent secures mainly the empty space in front of the seat. Therefore we have to alter our sketch in order not to copy Mr. Geisert's idea. We cancel our empty space and place the chain again between the legs. After all we feel the empty space not the best solution.



Let me sum up some features of our test tricycle:

chain drive: very short chain, stays clean, does not collect dust from road, lasts long, runs protected in the frame centre line, can be covered completely, does not make you dirty; chain runs separated from the wheels, no need to be touched in case of tire repair. (basic idea comes from F.Weber, Bremen)

wheels: all wheels 20", free access to one side mounted front wheels, rear wheel with quick release axle. Front wheels can run under fairing to gain aerodynamic advantages.

hubs: connected with shafts by parallel keys and fixed by Allen bolts.

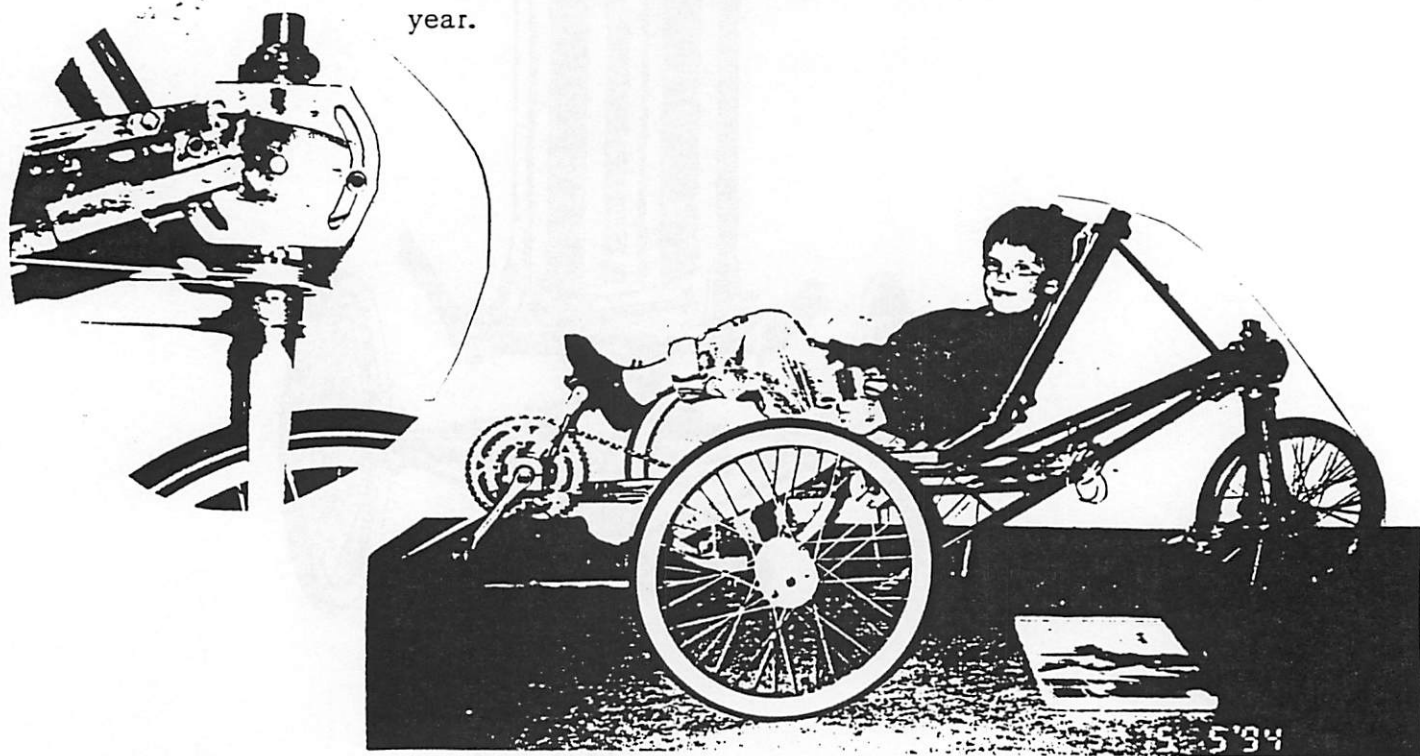
shafts: mounted in sealed ball-bearings which are placed inside the axle pipes; only left one is driven: we find it sufficient for driving.

brakes: drums are fixed with the aluminium hubs: heat from braking action will be removed easily by hubs, brake plates carrying the brake shoes (spare part of Fichtel & Sachs) are brazed on outside ends of axle pipes.

axles: left and right axle rest each in rubber hinges (Rosta) which are bolted to the "keel" of the frame and prop against shock absorbing rubber blocks at the top bars of the frame. We hope to absorb wheel noises inside the vehicle's later shell.

frame: frame is a brazed trellis work beam from square steelpipes with a triangle-shaped crosssection; can possibly be made from carbon fiber later.

seat and fairing: not yet at a final stage. We do still have a lot of design work ahead of us. So far we are lucky that our first experimental velomobile is rideable and promising. I am glad, too, that Authorities of Bremen allow me to continue this job for another year.

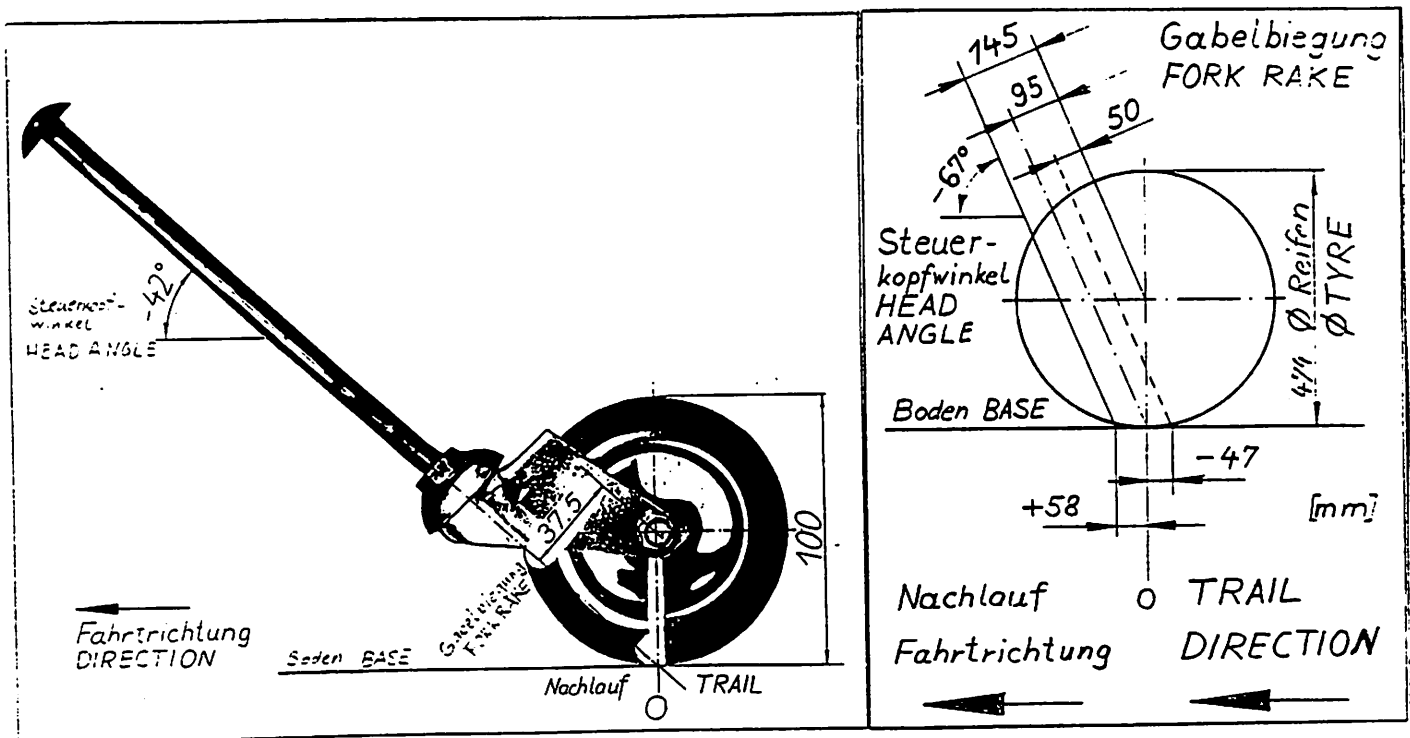


To end my report I like to give you some technical conclusions about rear steering of a tricycle.

Goal: you must be sure that the rear steering wheel adjusts itself to the straight-forward direction with hands off handlebar at any speed.

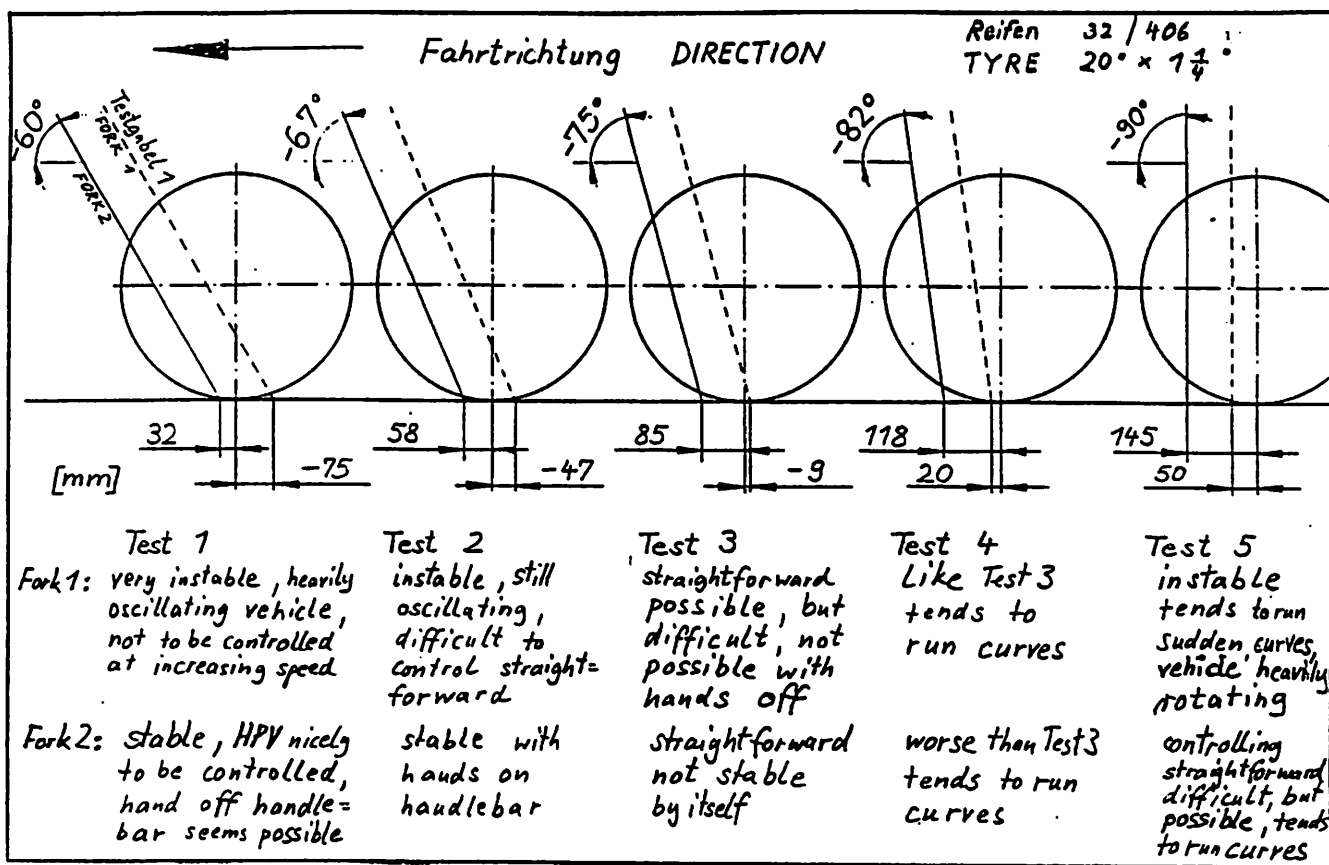
As you can see from the picture above we employed an adjustable steertube for testing the best "head"-angle. Attempts with our nice shock absorbing fork (fork rake 50 mm) did not show satisfying results and we got disappointed.

Contemplations of a castor led to success. We did some easy experiments: we fixed a longer bolt on a castor and simply pulled the whole thing by hand at different steering angles. We felt there were a range of positions in which the castor wheel stood up by itself when a little vertical force acts on the bolt. At a closer look we discovered a large fork rake of the castor compared to its tyre outside radius. Second simple experiment was to put on side forces at different head angles to see how they act on the wheel. We found out there was only one stable position. We measured the head angle. A sketch showed us trail 0.



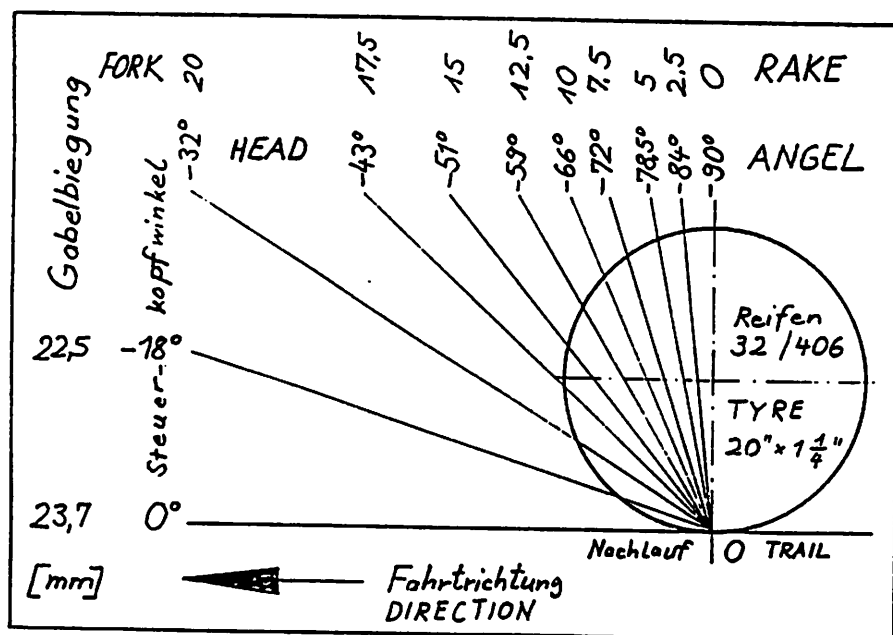
Definitions at rear steering: direction of vehicles is usually to the left. Therefore head angle becomes negative. Fork rake is the distance between fork centre line and wheel axle. Trail is positive if extension of fork centre line crosses the base ahead (left) of perpendicular axle centre line.

Now we wanted to know if it works the same way with a 20" wheel. A scrap metal fork was bended to a larger fork rake of 145 mm and these tests followed:

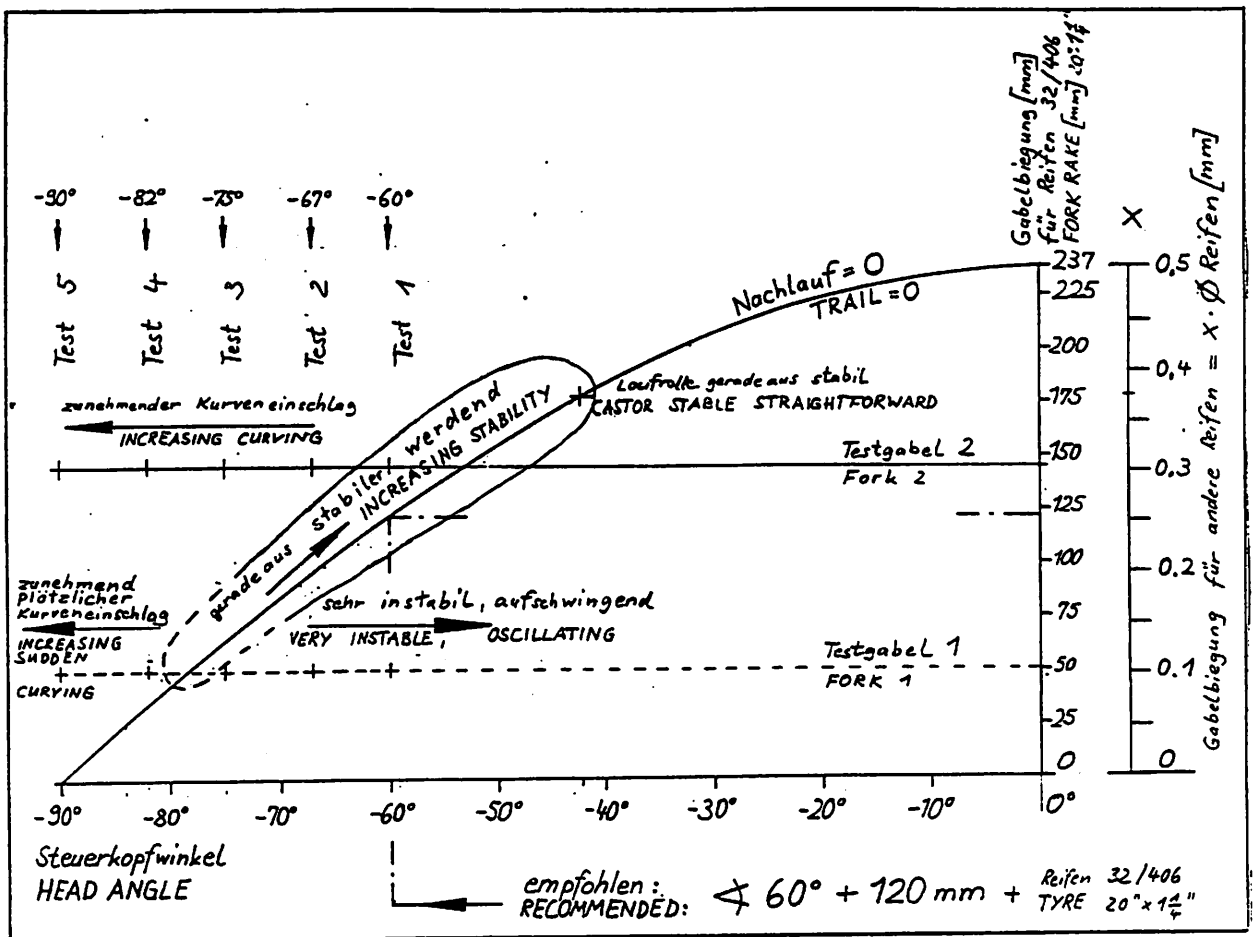


The test results show: rear steering becomes possible if trail is zero; a larger fork rake favours rear steering.

Coherence of tyre outside diameter, fork rake and depending head angle on condition trail zero is a simple geometrical problem:



Next step is to draw the graph of stability for a rear steered tricycle. It shows the coherence of any head angle, fork rake, and any tyre diameter on condition trail zero. Our 10 test results plus the castor are shown in the diagram.



Conclusions:

1. Trail:

- 1.1. A pulled steering rear wheel without lean of the head and with side and perpendicular forces should have a trail zero.
- 1.2. Is the trail increasing positive will the wheel increasingly burst into curves.
- 1.3. Is the trail increasing negative will the wheel increase in swivelling oscillation.

2. Fork Rake:

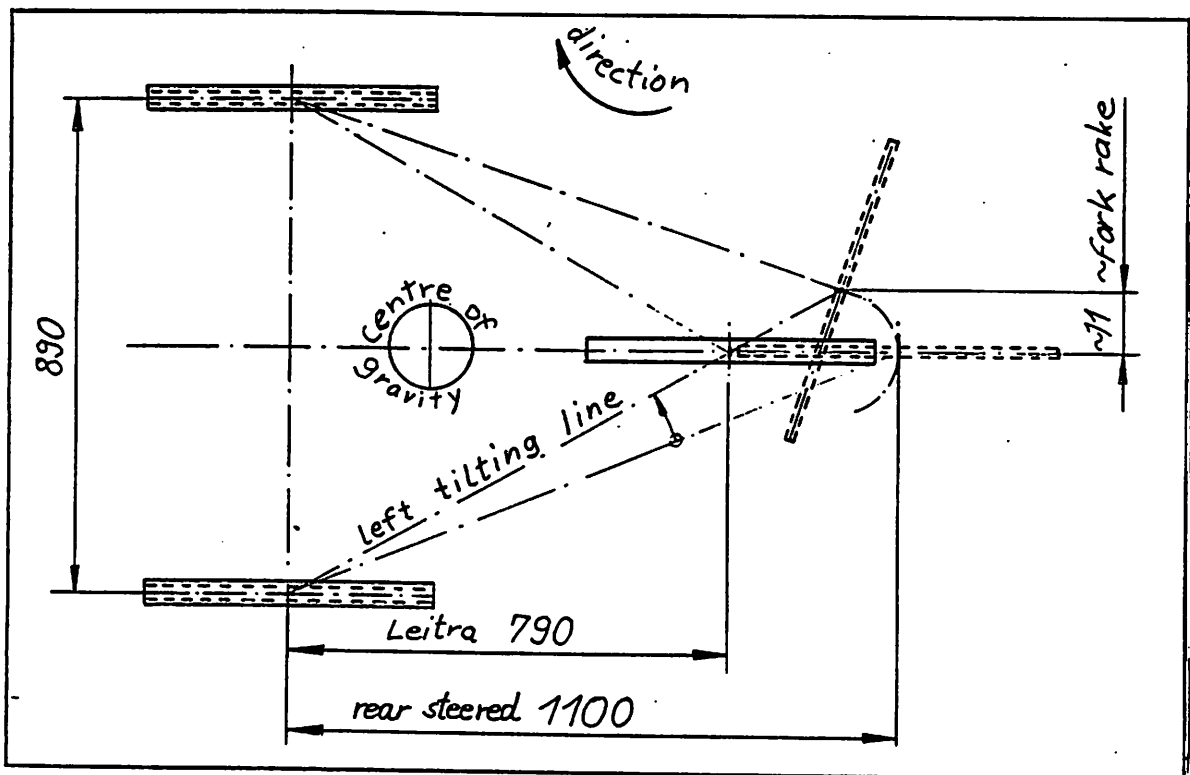
- 2.1. A smaller (towards 0) tending fork rake decreases the guiding abilities of the wheel.
- 2.2. A larger (towards tyre outside radius) tending fork rake lets the wheel simply fall aside.

3. Head Angle:

Due to the conclusions above head angles of -55° to -72° should be the recommended range for a stable straightforward rear steering of a tricycle. They result in acceptable fork rakes. Further tests are necessary.

4. Stability at Curves:

A larger fork rake decreases considerably the stability at curves. If you want to ride your tricycle to the right the fork needs to be turned to the right: the larger the fork rake is the more the rear wheel is moved to the side and therefore its point of contact with the base. The straight line between actual position of the rear wheel and left front wheel is the axle of tilting to the left. This line is moved closer to the centre of gravity and decreases the torque of resistance against tilting. There are some possibilities to compensate this disadvantage. We increase the distance of axles to achieve LEITRA-comparable properties. See our sketch:



Hot Ideas need Cool Heads

With the recumbent market on the upswing, at least in the United States, more and more entrepreneurs are anxious to get into the frenzy and produce a recumbent for the masses. Some very creative people spew out recumbent designs that, although their designs may be mechanically sound, lack of real world "bicycle know how" has resulted in over complexity, with costly machining and fabricating. The end result of these ventures is another dust collecting prototype at best, or for the more industrious, possibly a financial disaster with stacks of unwanted vehicles tucked away in some warehouse.

The venerable diamond frame upright bike has been around for a hundred years, with millions of faithful fans, for a handful of reasons. A bicycle is, on the average, a very basic or simple machine. Most of its workings are easy to understand for anyone with the slightest knack for things mechanical. There are relatively few parts required for the successful completion of its mission to transport the rider to his desired destination. Take a moment to take inventory of all of the moving parts integral to the typical bicycle. If you consider the chain a single part, then add the crank, wheel, freewheel, and headset bearings, the list of moving parts is quite short. Don't begin to think that the wheels are a moving part – as far as the spokes and the rim are concerned, they are locked to the hub which then turns on the bearings. This simplistic dissection is a good argument for the the bicycle's acceptance as the number one form of transportation worldwide, second only to your feet.

Many a good idea has been quashed by the public simply because they did not understand it. Even in this day and age where we are surrounded by computers and digital equipment that most of us couldn't begin to do physical maintenance on (I for one, couldn't wire-in a micro-chip), most of us would still feel capable of doing much of our own velocipede maintenance. When manufacturers use complicated assemblies, specialty parts, or custom parts that are unique to that particular product, the appeal of that product to the public will suffer. In the same way, the ability of skilled mechanics will be tested, when non standard parts or procedures are used in the maintenance of that product. Furthermore, with the use of non standard parts, comes the consideration of availability versus reliability. Is it worth putting a more expensive, hard to find part on the product? Is the pay-off longer more dependable service?

Or have all the practical aspects of human powered vehicles been abandoned in trade for a slight performance gain?

We'll assume that, when someone sets out to design a vehicle, they intend to produce a product that will perform its necessary function well, the public will purchase it, and production will continue and a business or dream or both will flourish. We will accept this assumption over the notion of someone trying to make money on a fad or short lived trend (i.e. elliptical chain rings). If you design with just yourself in mind, you may be the only one sold on your idea. To meet your production goal, you must please several people along the way. The product must be easy enough to produce so that production is efficient, and there is the least chance of snags throughout the process. If the product is to be sold through a dealer network, quantity breaks and cost considerations are of high priority, since you need to allow the retailer to mark-up your cost to him by 50% so that he may get his much needed 33% profit (1). If there are parts that are unique solely unto your product, you **MUST** have these SPARE parts available at the same time that the first completed vehicle goes out the door. If the public doesn't want or need the product, this could really dampen the outlook for sales. Building in reliability is one of the most important aspects of any product. Repeat customers, and customer loyalty are two of your best advertisements. In sales, there is a saying called the "20-200 Rule". If a customer is satisfied or happy with a product, he may tell some of his friends – perhaps as many as twenty. When a customer is dissatisfied or unhappy with a product, he will tell everyone he meets – possibly 200 people! Keep this in mind when designing, marketing, and selling a product for the general public.

When you consider designing a velomobile, velocipede, recumbent, whatever... let's call it an HPV (human powered vehicle), take stock in what is already available in the bicycle world. For instance, if you need bearings, but, you don't necessarily need cartridge bearings, consider using headset bearings if possible. Headset bearings are light, simple, adjustable, and inexpensive. In fact, common bicycle parts are made by the millions, as they have been for decades, and therefore they are cheap and widely available.

Let's look at the benefits of using a bicycle headset bearing set, as opposed to radial cartridge bearings. In the U.S., a pair of "light duty" cartridge bearings will cost about \$6–\$10. The cost for the bicycle headset bearings, which already come in pairs, can cost as little as \$1.50 for common grade. Extra benefits, from using bicycle associated parts, include lighter weight, and the ability of a typical bike shop mechanic to perform routine maintenance on familiar parts. My limited experience with bike shops found that most shops immediately tagged on higher repair costs to

exotic looking recumbents, simply because they knew they were on unfamiliar ground.

This does not mean that the use of bicycle industry components has to hamper creativity. The use of common bicycle parts does not mean that those parts must be used in common applications. I have seen several examples, on tricycles, where pairs of bicycle headsets were used in steering spindle pivots. I have seen fork blades used for the rear stays, or chain stays. Sometimes complete forks are used in place of the usual rear triangle. When contemplating the design of a new hpv, think in terms of common bike parts in uncommon positions or applications. A typical bottom bracket is the perfect position for a rear swing arm suspension. Let your imagination be your guide, and use the bike industries' parts like your own inventory. When you use parts that are standard to the industry, Retailers will be more receptive to selling your product, the buyer is not afraid to purchase the product, and most bike shop mechanics can perform necessary maintenance with common bike shop tools. Everyone is happy.

I hope that this information is helpful for those of you who, although you may have great design expertise, may lack any experience with bike dealers, the buying public, or the field of bicycles or related products. A couple of my favorite design principals are, the "K.I.S.S. Method" (keep it simple, stupid), and "the 6 P's". The "6 P's" are, proper planning prevents probable poor performance. Good luck!

(1) – The national average for profit margins on bikes sold in the U.S.A. is 33%, according to Bicycle Business Journal (1991), a trade journal for the industry. The profit margin is the amount of profit made compared to the final selling price of the bike. I.E. A dealer buys a bike from a wholesaler for \$100, he will mark-up the price to \$150 (or 150%), the profit of \$50 is 33% of the final selling price.

Announcement

Proceedings of the First European Seminar on Velomobile Design



The Proceedings of the First European Seminar on Velomobile Design July 8th 1993 at the Technical University of Denmark were compiled by Carl Georg Rasmussen, the organizer of the seminar ("Velomobile": European expression for HPV). The volume is 135 pages and contains a lot of drawings and b/w fotos.

The proceedings (ISBN 87-984875-0-7) are available from the Danish Cyclist Federation, Rømersgade 7, DK-1362 Copenhagen K, Denmark
Fax +45-33-32-76-83.

Price as of February 1994: Approx. 38 Swiss Francs.

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| Michael Kutter | VELOCITY – Elektrounterstützung für Velomobile Mixing of electric and human power at any ratio |

The Seminar Committee's Reading List

Literaturverzeichnis

General or classical literature about velomobiles

Vytas Dovydenas: Velomobile. Verlag Technik Berlin, 1990. ISBN 3-341-00790-3. Few remaining books available at the Future Bike CH Secretariat.

Gunnar Fehlau: Das Liegerad. Moby Dick Verlag, Kiel 1993. ISBN 3-922843-86-7

Gross, Kyle and Malewicki: The Aerodynamics of Human-powered Land Vehicles. Scientific American, December 1983

Gross, Kyle und Malewicki: Die Aerodynamik von Muskelkraft-Fahrzeugen. Spektrum der Wissenschaft, Februar 1984

Leufen, Möller: Das Fahrrad. Moby Dick Verlag, Kiel 1986. ISBN 3-922843-27-1

Eckhard Möller: Irre Fahrradtypen. Bauverlag, Berlin 1984. ISBN 3-7625-2242-1

The proceedings I, II, III and IV of the IHPVA scientific symposia by the IHPVA

Proceedings of the HPV Symposium by W.S.V. Simon Stevin, Eindhoven, The Netherlands, March 18, 1993. Studievereniging "Simon Stevin", W-Hoog 1.07a, Postbus 513, NL-5600 MB Eindhoven, The Netherlands

Karl Schubert: Das Tandem. Moby Dick Verlag, Kiel 1994. ISBN 3-922843-92-1

Archibald Sharp: Bicycles and Tricycles. Reprint by the MIT Press, Cambridge, Massachusetts 1982. -> IHPVA

F.R. Whitt, D.G. Wilson: "Bicycling Science", 3rd printing 1985, Massachusetts Institute of Technology Press, Cambridge, Massachusetts and London, England. ISBN 0-262-23111-5, ISBN 0-262-73060-X (pbk)

Specific literature about "Safety"

Please see the references of papers about Safety in this volume.

The proceedings of the "First European Seminar on Velomobile Design" contain several papers about safety (-> List of contents of the proceedings of the first European Seminar on Velomobile Design)

British Medical Association: Cycling towards health and safety. Oxford University Press, Oxford and New York 1992. ISBN 0-19-217783-4 and ISBN 0-19-286151-4 (pbk)

Uniroyal-Verkehrsuntersuchung "Radfahrer". No. 18 of a series of volumes about traffic and related problems published by Uniroyal Englebert Reifen GmbH, Öffentlichkeitsarbeit, Postfach 410, Hüttenstraße 7, D-5100 Aachen, Germany

Papers from the Oldenburg Bicycle Research Group [Arbeitsgruppe Fahrradforschung, Fachbereich Physik, Universität Oldenburg, Postfach 2503, D-26111 Oldenburg, Phone 0441-798-3527 and 0441-798-3540, Fax 0441-798-3326] from Universität Oldenburg, BIS (Bibliotheks- und Informationsdienst), Postfach 2503, D-26111 Oldenburg, Germany

Specific literature about "Design"

Please see the references of papers about Design in this volume.

*The proceedings of the "First European Seminar on Velomobile Design" contain one paper about design
(→ List of contents of the proceedings of the first European Seminar on Velomobile Design)*

"Future Special" in Bike 9/93, September 1993. Verlag Delius, Klasing & Co, Siekerwall 21, D-33602 Bielefeld or Postbox 101671, D-33516 Bielefeld, Germany

Christian Kuhtz: Entwicklung eines Langstreckenfahrrades unter Berücksichtigung ergonomischer und aerodynamischer Gesichtspunkte. Diplomarbeit in Industrie-Design 1984, Fachhochschule Kiel, Germany

F. Riess, R. Pivitt: Design Criteria for an Energy Saving Lightweight Vehicle for Commuting. First Experiences with a Prototype for Experimental Use, in: Human Power 7, No. 1 (1988), p. 1, 12-14

Specific literature about pioneer velomobiles

Carl Georg Rasmussen: "Testing a Vehicle Design for Safety: The Leitra Tricycle" in Human Power (Winter '85) Vol. 5 No. 1., Fotocopy available from the IHPVA (→ adresslist)

Rohmert, Gloger, Bier: Das Darmstädter Ergonomie- und Sicherheitsrad – Innovation für den Kurzstreckenverkehr. Spektrum der Wissenschaft März 91

Ralph Schnyder: Project 50/50, TWIKE. ETH Zürich Sommer 1987. ETH Bibliothek, Rämistrasse 101, CH-8092 Zürich, Switzerland
(or: Twike Ltd., Kirchrain 11, CH-4460 Gelterkinden, Switzerland)

John Schubert: "The Leitra M1 Recumbent: A Practical HPV" und
Carl Georg Rasmussen, "The Design of an All-Weather Cycle" in BIKE TECH (Feb. 83) Vol. 2 No. 1.
Fotocopy available from the IHPVA (→ adresslist)

Matt Weaver: The Cutting Edge streamlined bicycle, Cycling Science, Sept/Dec 1991

Lists of literature, producers and products

Future Bike CH, Jürg Hölzle, Spitzackerstrasse 9, CH-4410 Liestal, Switzerland

Source Guide: International Human Powered Vehicle Association IHPVA, P.O. Box 51255, Indianapolis, IN 46251-0255, USA

"Chopperfahrräder". Verlag Christian Kuhtz. ISBN 3-924038-30-9, Germany

Liegeraddatei: A. Pooch, Heidestraße 8, D-53840 Troisdorf, Germany. Phone Work +49-2241-105349, Fax +49-2241-83357

Bibliographie aktueller Fahrradliteratur, 2. Auflage. Allers, Bohle, Pivit. ISBN 3-8142-0269-4. Bibliotheks- und Informationsdienst der Universität Oldenburg: Universität Oldenburg, BIS (Bibliotheks- und Informationsdienst), Postfach 2503, D-26111 Oldenburg, Germany

Plans: Dipl.-Ing. W. Stiffel, Im Holderbusch 7, D-76228 Karlsruhe, Germany. Phone +49-721-451511

Encyclopedia (coloured catalog of specialty-bikes and of velomobiles from Europe): Open Road, 4 New Street, York YO1 2RA, England UK

Buyers Guide: Recumbent Cyclist, P.O. Box 58755, Renton, WA 98058-1755, USA

Magazines

Infobull. Periodical by Future Bike CH. Membership 40 SFr., Students 20 SFr.

"HPV News" (HPV: Human Powered Vehicle = Velomobiles), "Human Power" and "Source Guide" (List of vehicles and parts). Published by the IHPVA. Membership US \$ 30

Pro Velo. Pro Velo-Verlag, Riehtweg 3, D-29227 Celle. With "HPV-Nachrichten", the informations from HPV Deutschland e.V. 30 DEM per year

Bike Culture. Bike Culture Quarterly, Open Road, 4 New Street, York YO1 2RA, England UK. With Encyclopedia 25 £ per year

Organizations

Future Bike CH, c/o Jürg Hölzle, Spitzackerstrasse 9, CH-4410 Liestal, Switzerland

International Human Powered Vehicle Association IHPVA, P.O. Box 51255, Indianapolis, IN 46251-0255, USA

Electronic Information Systems (INTERNET)

Mailing lists: HPV@SONOMA.EDU

Archives: Sonoma HPV archive: zippy.sonoma.edu
York HPV archive: shiraz.ohm.york.ac.uk

In any event, there are three ways to gain access to the HPV mailing list:

(a) Via electronic mail – all messages sent to the list will appear in your mailbox.

To subscribe send a normal mail message to:

HPV-request@sonoma.edu

with the subject line e.g.

Subject: SUBSCRIBE fuChs@phil.unibe.ch (Andreas Fuchs)

The HPV list is maintained by Brian Wilson from the Sonoma State University in California, so you can also subscribe by sending him personal mail to the address:

Brian.Wilson@zippy.Sonoma.Edu

Then, to submit an article or a reply to the list, mail it to:

HPV@Sonoma.Edu

Do observe that the messages arriving from the list have headers set up in such manner that a Reply will be directed to the person that submitted the article, rather than to the list itself. In order for your post to become public you *have* to ensure that the reply message carries the 'HPV@Sonoma.Edu' address in its To: line.

(b) Via gopher access to the site zippy.sonoma.edu.

If you do not know what "gopher" is or are unsure if your mainframe allows 'telnet' access to the Internet then you should ask your network administrators about it. Test it first by typing

gopher zippy.sonoma.edu

at the command prompt. If you get an error message then obviously your site does not have gopher (yet; it should).

Gopher is a special kind of program that permits viewing of directory and file contents at all connected sites with a single, intuitive protocol which doesn't require learning it in advance. This method has the advantage over normal subscription that the messages do not get sent to your mailbox but can be read interactively in real time when *you* have the time. Brian has arranged it so that all traffic now sent to the HPV list appears automatically in gopher listings.

(c) Old traffic is archived at the FTP site shiraz.ohm.york.ac.uk

Date: Tue, 20 Oct 92 10:16:29 +0100 (BST)

From: rwt@ohm.york.ac.uk (Richard Taylor)

Subject: HPV Archive

shiraz.ohm.york.ac.uk 144.32.136.36

| | |
|-------------------|---------------------------|
| pub/HPV | – root directory |
| pub/HPV/mail | – mail from the HPV lists |
| pub/HPV/mail/1991 | – mail, April 91 – Dec 91 |
| pub/HPV/mail/1992 | – mail, Jan 92 onwards |
| pub/HPV/reviews | – reviews of machines |
| pub/submissions | |

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