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MASTER OF SCIENCE THESIS

The Velomobile as a Vehicle for more Sustainable Transportation

Reshaping the social construction of cycling technology

Frederik Van De Walle

Supervisor: Christer Sanne

STOCKHOLM, SWEDEN

Abstract

Transportation has a very important influence on the future of society. Cycling as transportation is recognised as beneficial and sustainable means of transportation and is increasingly included in transportation policies in nations around the world. Nevertheless, there is almost no future vision for technological innovation and improvement for cycling as a transportation system; cycling as transportation has remained conceptually the same for more than a century.

This paper goes through the history of cycling technology up to today from the perspective of the social construction of technology theory. This theory can help explain why certain cycling solutions developed, and why others did not. Moreover, it becomes clear that the solutions that did develop can obstruct further development. One of the cycling technologies that has been latently present is the human-powered, weather protected ”velomobile”. Using the social construction of technology theory, an appropriate framing of the velomobile concept is proposed, giving the velomobile a place as a mode of individual transportation in our current context. A velomobile is about as different from a bicycle as, taking a parallel for motorised vehicles, an automobile is different from a motorcycle. From this frame of reference, the potential of the velomobile concept as a mode of transportation is discussed. Moreover, it is pointed out that, even if the velomobile concept does not become a widespread mode of transportation, the new understanding of individual transportation that emerges from its presence can contribute significantly to more ecologically sustainable transportation solutions. Moving away from a hierarchic ordering where one mode is ‘better’ than the other, to the conceptual understanding that a greater diversity in individual transportation can serve the differing transportation needs of society in a better, more ecologically sustainable way.

The concept of the velomobile can thus play an important role to offset the unsustainable transportation patterns in the post-modern world and its development as a technology of transportation is a unique opportunity to be seized.

Keywords (not included in the title): bicycle, HPV, recumbent, innovation, pedal, car, automobile, history, STS, SCOT, vehicle categories, sociotechnical frame, socio-technical frame, technological frame.

About the author

Frederik Van De Walle lived in Belgium up to the age of 23 and graduated there as a mechanical engineer with a specialization in aerospace technology. As a youth with a fascination for all kinds of vehicles and motivated by the Dutch magazine 'Fiets', he ended up building a velomobile from a kit at the age of 15. Having some talent for cycling, a few years later he took up racing recumbent bicycles and came into close contact with the fascinating world of alternative bicycle and velomobile design. For his engineering education thesis work, Frederik decided to design and build a velomobile in which he, with some delay in the actual building, succeeded. After his courses in environmental engineering and sustainable infrastructure at KTH Stockholm, he more clearly recognised the role for velomobiles in the context of ecologically sustainable transportation and the need to spread the unique knowledge he once took for granted on this subject, not only in a purely technical approach as before, but also by exploring the social and sustainability dimensions.

Contact: favdw@yahoo.com

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Eventually, all honour goes to the creator of all who keeps us in his endless love, even if we do not always love him and all his creation back.

Stockholm, June 2004,

Frederik

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List of acronyms

KTH: Royal Institute of Technology
SCOT: Social Construction of Technology
HPV: Human Powered Vehicle
UCI: Union Cycliste International
IHPVA: International Human Powered Vehicle Association
STF: Sociotechnical Frame
FRP: Fibre Reinforced Plastic
DIY: Do It Yourself
NGO: Non-governmental Organisation

1 Introduction

Innovation in transportation is today a very relevant topic. More than ever before we understand that transportation has a key influence on how societies form and develop over time. A close interaction exists between transport and infrastructure, the way human settlements develop, and the way we affect our natural surroundings. Every mode of transport represents a certain technology, knowledge of how to do things. These technologies are easily taken for granted, making it harder to objectively question them and to seek improvement and new paths of development.
There is indeed an acute awareness that society would benefit a lot if transportation became more ecologically sustainable, yet at the same time society is very dependent on transportation for its functioning; this makes change in transportation all the harder. This paper is about the most widespread personal transportation technology, cycling, its social construction, and its relevance in the bigger picture of transportation technology for the future. Cycling, if considered as a transportation system, is usually closely associated with the bicycle, which has remained conceptually the same for more than a century. This paper will argue for a widening of the cycling transportation spectrum that includes the so-called velomobile.

A velomobile is a closed vehicle powered by an abundant, sustainable energy source that, especially in recent times, is not used enough: human power. The concept of velomobiles is not new at all: conceptually it has gone under the names of pedalcar, cyclecar, Velocar, pedalmobile, and modern velomobiles are today often described as practical, streamlined recumbent cycles. Modern velomobiles usually have an aerodynamic, streamlined body resulting in a high efficiency — giving the possibility to reach higher speed, also providing weather and crash protection and an overall practicality on a different level from the bicycle. The concept and the ideas of velomobiles have been around for a long time, and may be rationally very convincing; many fine prototypes have been built and a good number of academic papers have been written, yet velomobiles have not had a breakthrough as a more widespread proposition. There is more to it than engineering and face value considerations of the velomobile.

The first supposition of this paper is that cycling functions as a transportation system and that it is a desirable system as such. This transportation system consists of the user, the vehicle technology and the infrastructure technology. Because it is a desirable system, the consequence is that there should be a constant need to improve this system of transportation. This is a very reasonable proposition, but in practice it is, depending on the geographic locations considered, seldom or simply not the rationale in place. Cycling technology for transportation is at a virtual standstill and thus looses ground to fast evolving motorised modes. The reasons for this disregard of cycling as a transport technology is rooted in the way we perceive technology. There is a tendency to simplify technology to the level of the properties of the technical object already taken for granted in its existence, inconsiderate to the origin and the greater implications on and interactions with society. It is of principal importance to understand where transportation technology comes from since, as stated above, our transportation technologies strongly influence our society. It also works in the other direction: we, members of society, are the ones shaping our transportation technology. It is tempting to say that transport solutions we use today work because they are the best technical solutions currently available, but the true nature of our choices to embrace a certain technical solution for its proliferation is far more complex than that. This paper is an attempt to understand cycling technology as transport, and the past and future role of the velomobile therein.

1.1 Goals

The goals of this paper are:

- To introduce a theoretical foundation on which to situate cycling history, and to build ideas and concepts around the velomobile.
- To describe how cycling developed and how there remains large potential for transportation innovation in cycling technology, even if there has been over 100 years of technical development of the bicycle.
- To describe the historical and social context on why the velomobile has not developed, and how this relates to the general attitudes to individual transportation and cycling over the last century.
- To appropriately reframe the velomobile concept as a mode of individual transportation, within the context of the assumptions and attitudes to individual transportation in general.
- To discuss the role of the velomobile as a mode of individual transportation, from this new perspective.
- In general, to contribute to a more comprehensive and rational approach to cycling as transportation technology, which in its turn will contribute to a more ecologically sustainable future.

1.2 Method

The approach used for the study of cycling technology and the velomobile is adapted from the theory of the *social construction of technology*, or SCOT in short. This was not so from the outset; the initial intention was to give a case study of the velomobile concept as sustainable transportation, with a more traditional engineering approach and the accompanying rational argumentation. It became apparent, however, that the positioning of the velomobile as a technical object in the current transportation context is very difficult and that there are many non-technical barriers to its adoption. What started as a side step into the social construction of technology — to explain the positioning of velomobile technology as transportation — actually started such profound insights that it was decided to rewrite the whole paper from this perspective. The velomobile no longer consists of the technical object per se, but of the meaning and interpretation given to it in a larger context of society. This context is given by using historical description of cycling technology, treating differing aspects from literature starting at the beginnings of the development of cycling, to the modern form of cycling technology as individual transportation. SCOT is used for a conceptual discussion of meaning of the velomobile among other vehicles for individual transportation, the basis for a more comprehensive discussion of the role of the velomobile as an individual mode of transportation. All this is based on extensive study of a variety of literature related to this subject, both from libraries and from Internet resources. Also, (informal) interviews with various actors have been done, from visiting velomobile manufacturers, attending seminars and meetings on cycling, to a small research with questionnaire and general discussion of the subject.

As such, the approach is different from typical literature about transport. Studies of new vehicle designs tend to have a dominantly technical approach with an unquestioned socio-economical context. On the other end, mobility studies contain models for human behaviour, traffic and infrastructure planning and management, and the interaction with more general spatial planning, yet the transportation technologies themselves are usually unchallenged. As a result, the deeper understanding that society and (transportation) technology are intimately interdependent finds little place for development in these classical approaches. I hope this paper addresses these issues effectively.

1.3 Organisation of contents

The social construction of technology (SCOT) theory as the theoretical basis for the rest of this thesis, is introduced in **chapter 2**.

In **chapter 3** this theory is then applied onto the history of technology of the bicycle. This will bring an understanding on how bicycle technology, its perception and use as transport grew throughout time, already introducing some developments that hint at the velomobile. At the end of this chapter, the current transportation context is also explored.

In **chapter 4,** the velomobile is treated in detail, how the concept has been latently present all this time, how it emerged and disappeared again in the first half of the 1900s, and how the current modern velomobile arose. In addition, some properties of modern velomobiles are treated.

The pièce de résistance comes in **chapter 5,** where the concept of the velomobile is evaluated in its social construction and a social mechanism of change is introduced to effectively frame its concept to its fullest possibilities in the current mix of vehicle concepts for individual transportation. Additionally, some consequences are highlighted, as the reframing also changes the perception of all individual modes of transportation.

Finally **chapter 6** treats the role of the future velomobile, both as a transportation preposition by itself and how it affects the larger context, reshaping society. It is discussed how all this brings us closer to ecological sustainability in transportation.

The text is multidisciplinary, technical explanations will be mixed with social theory, history and culture. I will only cover technical details if it is appropriate in increasing the understanding of the bigger picture.

2 Theory of the Social Construction of Technology

According to Bijker and Law (1992), complex trade-offs that mirror the society shape our technologies. Technology does not evolve from some internal technical logic or some inherent self-contained momentum, but reflects professional, economic, and political realities in the compromises chosen by the engineers. Models for successful technology that focus mostly on the economics only show part of this picture. A key realisation is that technology we use does not necessarily represent the best technology. As society gets used to the convenience of a certain technology, widespread acceptance obstructs even better technology. If certain technology lasts for a longer time, we get used to it and lose reference of their true origin, creating a bias towards alternative technologies.
Contributing factor is that common historical accounts present technological history in an overly simplified manner. Conventional narratives tend to represent the development of a technology as a pure and logical progression, tracing back the history of success as the ultimate explanation for success itself, commonly assigning the honour of success to a single genius invention, event or person. However, the deeper nature of success is that these key events or persons are just one part of a complex whole of many big and small happenings. The complex nature of the social and technical reality necessary for technology is not readily recognised, as there are many other actors interacting in the larger social, political and economic context.

These two realisations, taking technology for granted and simplified technological history, can obstruct our understanding of the trade-offs made that shaped the technology of today. Not understanding how societies built up the technologies of today makes it harder to improve them. Technology easily becomes a goal of itself, rather than being a means to fulfil the greater goals of society. However, when one does grasp the forces that formed technology, one gets a realisation that things could have gone or been made differently and, most often, better (Bijker and Law, 1992:3). Again, the goals become clear and the technology questioned.

The above rationale is adapted from the theory of the Social Construction of Technology (SCOT), as proposed by Pinch and Bijker (1984), and improved by, amongst others, Bijker and Law (1992), Bijker (1995) and Rosen (2002). They have developed a theory with concepts that make it possible to grasp the different elements of the social construction of technology.

2.1 Basic elements of the SCOT theory

From Bijker (1995), we can distinguish four key concepts to build up the social construction of technology: relevant social groups, interpretative flexibility, closure and stabilisation.

A technical object by itself has no meaning, but it becomes a technological artefact through the meaning that relevant social groups[1] give it. These meanings are not static; they develop as the relevant social groups change the artefact or their perceptions of it. Interpretative flexibility is the basis of how social groups construct different meanings for the same — novel — technological object and change these artefacts according to the different meanings they give to it: *"Each problem and each solution, as soon as they are perceived by a relevant social group, changes the artefact's meaning, whether the solution is implemented or not."* (Bijker 1995:52). This is the social construction; the meaning given to the artefact is in fact the *true* artefact. That is, the technical object will be changed to suit the meaning given to it. Because there are different interpretations, we can speak of 'pluralism of artefacts', there are as many artefacts as there are meanings, and every meaning corresponds in principle to at least one relevant social group.

The process of closure in technology is when the interpretative flexibility reduces. Closure is reached when consensus emerges between the relevant social groups about the dominant meaning of an artefact[2]. The 'pluralism of artefacts' reduces, i.e. some — meanings of — artefacts disappear. (Bijker, 1995:86)

The process of stabilisation is just the 'other side of the coin' of the closure process; it describes a different part of the same happening. Closure has more to do with interpretative flexibility between all relevant social groups, while stabilisation is about how the understanding of an artefact evolves within one social group. The more an artefact becomes stabilised, the less need there is to use a description, short elucidations or adjectives to point out about what artefact one is talking about (so-called semiotics). The more accepted an artefact, the easier it is to make clear what one is talking about without using many qualifying terms.

As long as there is a consensus or one dominant perspective on the meaning of an artefact, there is, in Bijker's terms, a technological frame associated with it. A technological frame is like a worldview, a certain perspective on an artefact and its context.

Bijker (1995:125) gives a tentative list of elements of a technological frame:

- *Goals*
- *Key Problems*
- *Problem-solving strategies*
- *Requirements to be met by problem solutions*
- *Current theories*
- *Tacit knowledge*

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[1] For a discussion on how to identify relevant social groups and their 'relevance' to the analyst, see (Bijker 1995:46-50)

[2] Similar as in theory of science, controversy ends when the interpretative flexibility of e.g. an observation statement reduces and scientists reach consensus on one interpretation, a 'scientific fact' is constructed. This kind of closure can have far reaching consequences as it reshaped the participants' world and rewrites history. It can be very hard to trace back the factual flexibility that existed during the controversy. (Bijker 1995:85)

- *Testing procedures*
- *Design methods*
- *User's practice*
- *Perceived substitution function*
- *Exemplary artefacts*

One can notice that the list does not include relevant social groups. For every dominant artefact, there is in principle a technological frame associated with it. Since there are many different technological frames, relevant social groups overlap and are 'shared' between different technologies. That is, one social group can be relevant to different technological frames. Similarly, one technological frame can actually hold many artefacts, as new artefacts may be created to produce, service, improve or accompany the artefact of initial interest[3].

There are interesting parallels between a technological frame and the concept of 'scientific paradigms' by Kuhn used in the theory of science (Pinch and Bijker, 1984). However, a technological frame is not purely cognitive, it is also social and physical. A technological frame applies to all relevant social groups and related artefacts, not just the scientists/engineers. A technological frame is not characteristic of one group, rather characterises the relations between and within the relevant social groups, and these actors' relation to the artefact. It is a network of practices, theories and social hierarchy.

The actions following from these relations uphold the meaning of a certain artefact. The relative stability of these relations upholds the meaning of the artefact — that is, the artefact itself —, and the other way around, the fixity of meaning is a building stone to enable effective relations. An artefact with low interpretative flexibility — with fixity of meaning — is also called an *obdurate*[4] artefact. A certain amount of obduracy provides stability and structural power, needed for technologies to become widespread.

Development within the framework of the technological frame can be characterised by what is known as functional failure (Constant, 1980). If the artefact fails to function properly for a certain purpose, improved variants are conceived to fit the new challenge. However, this kind of innovation tends to be very conservative and incremental. Innovation is usually restricted to a rearrangement of existing variants, improvement of details and/or the re-invention of old solutions in a modern jacket. No radical changes succeed.

Development outside the framework of a technological frame can be characterised by the identification of presumptive anomalies. A presumptive anomaly "occurs in technology, not when the conventional system fails in any absolute or objective sense, but when assumptions derived from science indicate that under some future conditions the

[3] Problems with multiple artefacts are addressed in the next paragraph.
[4] *Collins' dictionary*: **Obdurate** *adj.* Stubbornly resistant, rigid, inflexible

conventional system will fail (or function badly) or that a radically different system will do a much better job" (Constant, 1980:15; quoted in Bijker (1995:278))[5].

2.2 Sociotechnical frame

There are however limitations to the technological frame, addressed by Rosen (2002). The technological frame has problems dealing with multiple related artefacts, where it becomes difficult to delineate which artefact is to be associated with a technological frame (Rosen 2002:19-20). Maybe the main shortcoming is that, although Bijker makes plenty of considerations of cultural aspects in his texts, the technological frame concept tends to focus too much on technical concerns (Rosen 2002:17-18).

Rosen made a useful refinement of the SCOT model, which builds closely on Bijker's concepts. Rosen made the change from *technological* frame to *sociotechnical* frame. Although Bijker (1995) discussed sociotechnical ensembles and implicitly included the non-engineering social groups and user's practice in his technological frame model, the technological frame model does not really provide for their development. Rosen's so-called sociotechnical frame allows this; see Figure 1.

A sociotechnical frame (STF) includes the elements of a technological frame but encompasses "also the groups of artefacts that have meaning for those involved, the significant events in the construction of the central artefact, and related technical processes and technologies" (Rosen 2002:22).

The sociotechnical framework puts more emphasis on the surrounding culture that fosters and performs the key function in structuring the relations between the social groups and the technology. Alternatively, stated otherwise, the 'invisible social relations' that hold together the notion of the technological frame —the relevant social groups and artefacts — has now received an appropriate concept, which is culture.

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[5] Constant used this concept on aerodynamic theory, from which one could expect that propellers would be non-suitable for the airplane speeds that could be reached in future by proper streamlining, so predicting the feasibility of gas turbine engines. (Bijker 1995:278).

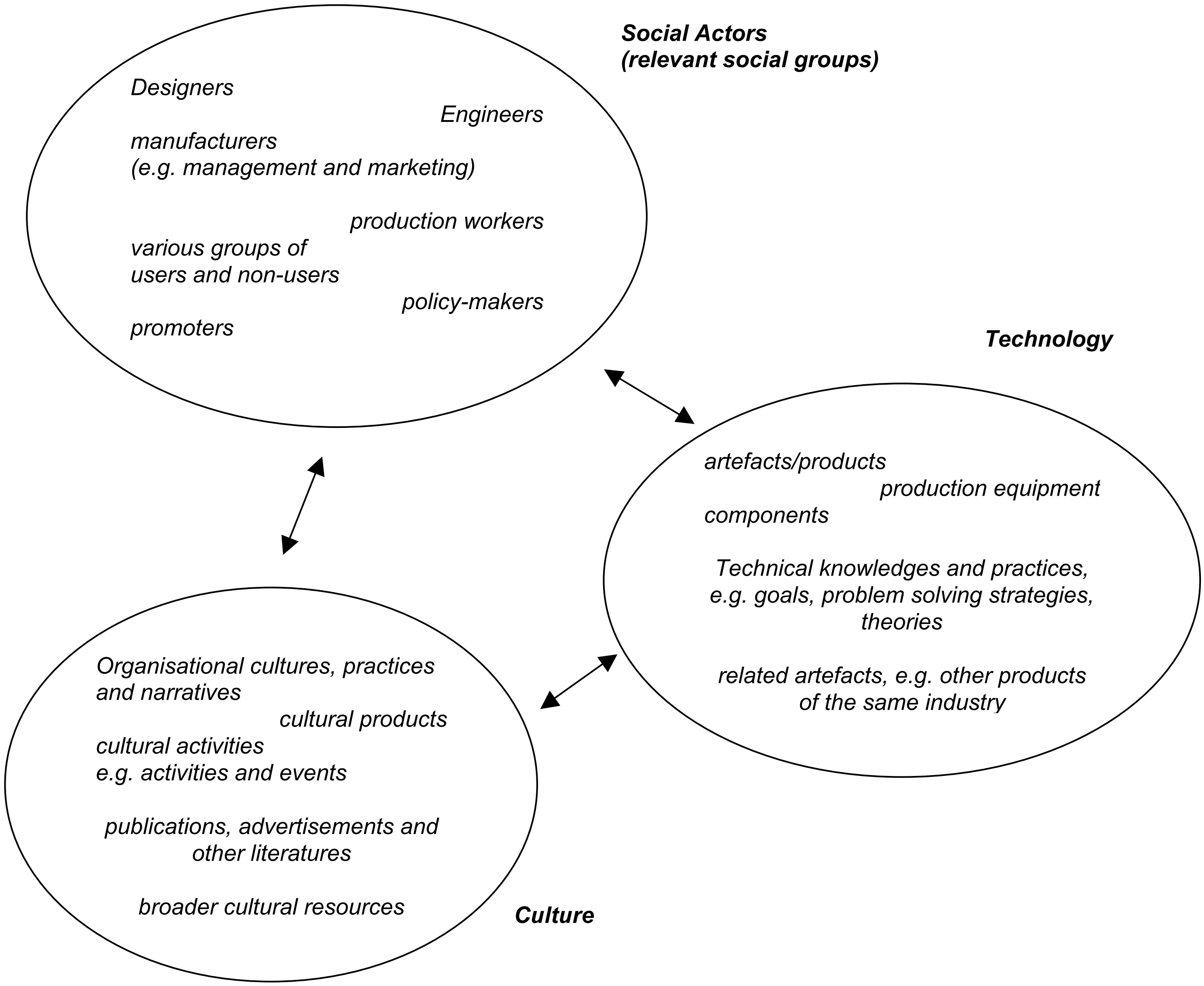

Figure 1: Elements of a Sociotechnical Frame
(Figure adapted from Rosen 2002:21)

2.3 Modelling change

The theory behind the sociotechnical frame would have little significance if there were no model for change. Bijker employs three ways in which a new technological frame is established as the result of change. The first is when a new technological frame emerges where there was none before, e.g. the case of the bicycle in Bijker (1995). The second is where an actor with low inclusion manages to find a radical solution impossible in the established technological frame, resulting in a new technological frame that truly supersedes the established technological frame, e.g. the case of Bakelite in Bijker (1995). The third is where actors of two technological frames with competing interests compromise, giving rise to a new artefact that pleases both sides and giving rise to a new technological frame, e.g. the case of the high-intensity fluorescent lamp, the last case study in Bijker (1995). These models of change are sufficient for technological frames where there is only one technology and one dominant artefact, but they are insufficient where there are multiple artefacts, overlapping technologies and several levels of interaction (i.e. market, sports, culture). "Changes to the meanings, the constructions, or even the material basis will not necessarily bring about a transformation of the ***entire*** sociotechnical frame in which it is located" (Rosen 2002:23, emphasis added). Rosen's model for change that allows change without the creation of a completely new sociotechnical frame is presented in Figure 2. Several different marginal actors from an alternative frame interact with the established frame. The marginal actors are the carriers of their culture and their technology. If this is accompanied by an appropriate cultural discourse, this can lead to the acceptance of the marginal actors in what then amounts to a new sociotechnical frame.

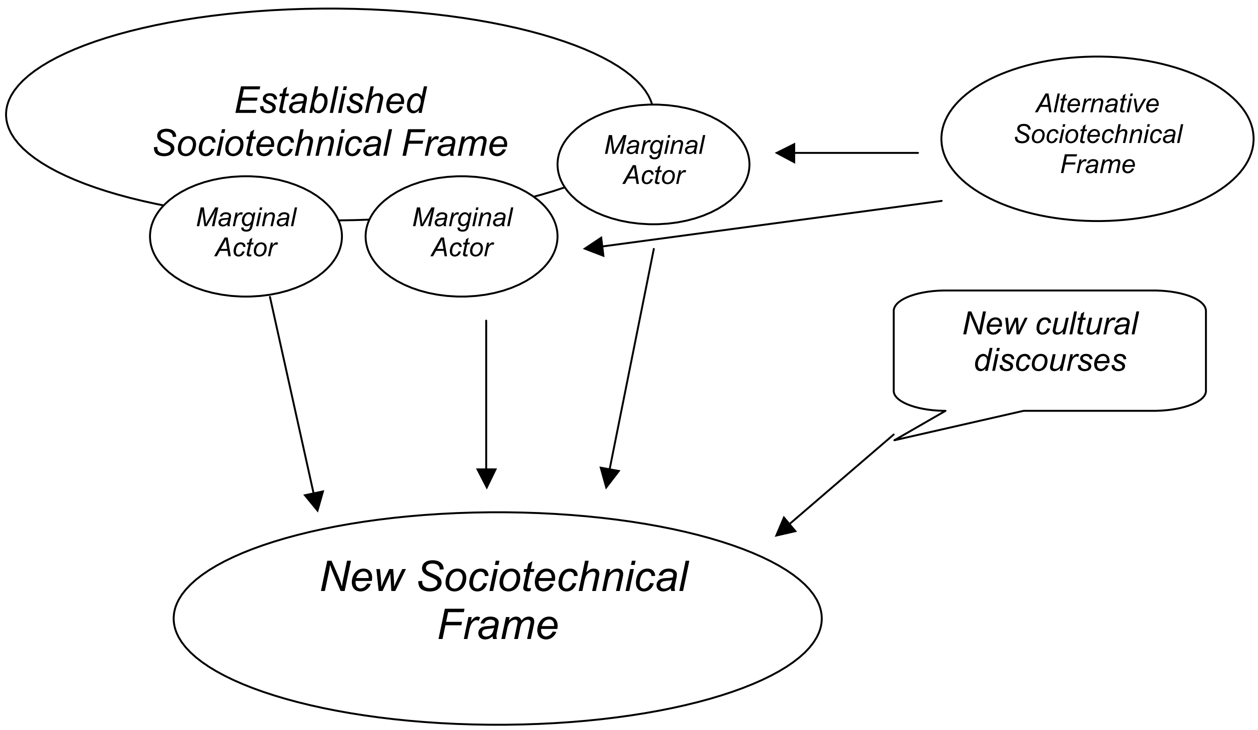

Figure 2: "How marginal actors establish a new sociotechnical frame through encounters with alternatives"
(Figure adapted from Rosen 2002:25)

The 'new sociotechnical frame' that results from change is thus not necessarily completely new; rather it is modified. Change in a sociotechnical frame can happen "when the three components of a [sociotechnical] frame (the social, the cultural and the technological) get out of step with one another — more specifically, when the cultural components' mediating role between technology and society is no longer effective" (Rosen 2002:24). This model of change is more powerful than Bijker's, because apart from technical change and the resulting change in meaning, the theory accounts more effectively for changes in society and/or culture (or even related technologies) as the initial reason of change in technology.

A sociotechnical frame is thus an effective way to frame the reality and shall be applied to our subject of cycling technology and the velomobile.

3 History of Bicycle Technology

In this chapter, we will look back at the history of the bicycle as it is an essential part in understanding cycling technology which will later also incorporate the velomobile, which is discussed in the next chapter. Emphasis is on the relationship between the technology and society, on the 'why?' and 'how?' of development of the bicycle, not 'what?' and 'who?'

The Safety Bicycle, the archetype of the present bicycle, was already a massive success in the beginning of the 1900s, both as leisure, and as transport bringing mobility to millions who could not afford a horse or an automobile. In the first half of the 20th century, the bicycle was in many cities without doubt the king of the road. The bicycle opened up communities from rural isolation, stimulating communication, education and development, and it continues to do so in many parts of the world. "For women the bicycle became a vehicle of their liberation from domesticity and isolation" (McGurn, 1987:100). Fashion for women also changed forever because of the bicycle. Young men could venture outside their own village to look for a spouse[6]. The bicycle was also a means to escape daily life, bringing into life tourism and leisure activities. (McGurn, 1987; Bijker, 1995; etc.).

Besides a massive boom in the use of bicycles on a personal basis, bicycle racing became immensely popular as spectator sport. Authorities and sports clubs built many velodromes — round/oval (indoor) racing tracks — and many bicycle-racing schools emerged (Schmitz, 1999). It was a sport of the people; anyone could become a famed racer if he (or she[7]) was fast enough. Today we fail to grasp how big cycling was, both as a society changing mode of transportation and as a sport in the early 1900's. Bicycle champions were national heroes on the covers of the papers.

3.1 Origin of the bicycle

Where did this bicycle come from, how did it develop? Any history about *cycling* is usually about the bicycle, inadvertently neglecting other forms of cycling. However, the bicycle is indeed in the dominant perspective, so I will start from this perspective with a short account from an encyclopaedia, and widen the subject into our field of interest as things progress:

> *Early bicycles*
> *The bicycle's first direct ancestor was the* ***Draisine*** *(pronounced dray ZEEN) or draisienne (pronounced dray zee EHN). This scooter like vehicle, made about 1817 by Baron Karl von Drais of Germany, had a steering bar connected to the*

[6] The start of globalisation?
[7] E.g. Hélène Dutrieu, one of the first women bicycle racers who later also became one of the first women aviators.

> *front wheel. A Scottish blacksmith named Kirkpatrick Macmillan added pedals to the Draisine in 1839, thus producing the first bicycle. Pierre Lallemont, a French mechanic, took out the first U.S. patent on a pedal bicycle in 1866.* [Called Velocipede].
>
> *About 1870, a new bicycle called the **high-wheeler**, Ordinary, or penny-farthing appeared. It had a huge front wheel and a small rear wheel. The front wheel of these bicycles was up to 5 feet (1.5 meters) high. Each turn of the pedals turned the front wheel around once, so the bike travelled a long distance with a single turn of the pedals. The high-wheeler and other early models had solid tires made of iron or rubber.*
>
> *About 1885, J. K. Starley, an English bicycle manufacturer, produced the first commercially successful* [Rover] ***Safety Bicycle**. This bicycle had wheels of equal size, which made it easier and safer to ride than a high-wheeler. It also had a chain-and-sprocket system. By 1890, wheels made of air-filled rubber tires had replaced solid wheels. The coaster brake and adjustable handlebar also came into use around this time.*
>
> *By the late 1800's, millions of people rode bikes. But during the early 1900's, the rapid development of the automobile caused many people to lose interest in cycling.*
>
> *From: World Book, 2003 (emphasis added)*

The above account is obviously very short, a compact example of how history textbooks tend to reconstruct a simplified linear story line, presenting development of technological artefacts as a logical uninterrupted succession of development, 'survival of the successful'. The problem lies in that traditional accounts — even long ones — look back into history to explain success by tracing it back in history, when success itself, as a social construction is actually what needs to be explained. Success is an interpretation of a relevant social group and can coexist with another — possibly negative — interpretation of another relevant social group. Success as such is not absolute, but a demonstration of interpretative flexibility. Success is a result of the social construction of technology, not the origin[8]. Therefore, although there is an impression that traditional accounts *explain* the origin of the bicycle, it actually just sums up some memorable happenings related to it. The tendency to regard accounts like the one above as an acceptable way to retell history hides the notion that there is much more to technological development.

In the 19th century, cycling was at the forefront of technological development in the dawning industrial era, but it was only after the Safety Bicycle that cycling became truly very widespread. Bijker (1995) in his case study of the bicycle treated the history of the bicycle with great insight as an exemplary study for the social construction of technology. From his work, we can summarize the main points of interest of the history of bicycle

[8] Therefore it is also very subjective to claim that success proofs that a certain technology is 'the best', the 'natural winner', as SCOT theory has already shown that this is very rarely the case (Rosen, 2002:15)

development, both for a better understanding of cycling and as an example on how the social construction of technology (SCOT) explains technological development.

The unsafe High-wheeler

One of the things that Bijker (1995) sought to explain was the success of the Ordinary or High-Wheeler, first commercialised by W. Hillman and J. Starley as the Ariel[9]. When presuming technical evolution with a logical uninterrupted linear succession of development, the High-wheeler clearly does not fit in. From our present day perspective, the High-Wheeler is a difficult and dangerous to ride contraption. *"The technologies needed to turn the 1860 low-wheelers into 1880 low-wheelers, such as chain and gear drives, were already available in the 1860s."* (Bijker 1995:97). None withstanding, the High-wheeler emerged successfully anyway.

The key to understanding the success of the High-wheeler lies in the realisation that technological development is a social process, carried by relevant social groups. When considered from the perspective of the actors, the process of development starts to make sense. The makers of the first bicycles were also the first cyclists, attempting to draw attention to the possibilities of their designs with stunts and races[10]. With the first commercial success of the velocipedes in the 1870s, clubs were established and races were organised on famous English roads, the first probably on Brighton road. There they had relay races against the four-horse coach (Bijker, 1995a). W. Hillman and J. Starley, makers of the fist High-wheelers demonstrated their capacity by riding from London to Coventry in one day, contributing to the sports image of their product. The public soon recognised the High-wheeler as the racing machine of choice — e.g. it was the fastest — and the sports clubs proliferated.

The users of the High-wheeler were primarily the young, male daredevils who could afford the pastime of racing with each other. The rider's high point of gravity just behind the front wheel made it prone to spectacular and notoriously deadly falls when any unforeseen obstacle on the road was hit. It is hard to imagine why anyone would want to ride such an impractical and dangerous device. Yet, the fact that it was dangerous and difficult to master starting and stopping only increased the bravery of those who could and wanted to ride them. When not racing, the riders showed of their wheels at the local park, seated high above the crowd and associating themselves with the elegant aesthetics of the beautifully crafted machines. For them the High-wheeler was the 'Macho Bicycle'. This social group of young males is one *relevant social group*. For them the High-wheeler was an artefact that 'worked' for their purpose. One of the practices that illustrate this purpose is that racers-builders tried to make their wheels as big as was physically possible. They did this so that they could reach higher speeds, since the big wheel of the high-wheeler increased distance per pedal revolution. However, for people who did not or could not use the High-wheeler, the relevant social group of non-users, the High-wheeler

[9] In the above quoted account there is no inventor named for the High-wheeler, rather, it 'appeared'. W. Hillman and J.Starley patented the Ariel high wheeler in 1870. The latter's nephew was J.K Starley, the now recognised inventor of the famous Rover Safety Bicycle.

[10] Already Von Drais in the 1820s made demonstration rides with his Draisine and raced stagecoaches against the clock, proving to be faster and hoping to receive attention. He did not receive a lot of response at that time. (McGurn, 1987)

was in effect the 'Unsafe Bicycle'. In addition, contrary to the 'Macho Bicycle', the 'Unsafe Bicycle' was a nonworking machine.

Figure 3: High-wheeler
(Photo by H. Van der Borght)

This is what Bijker (1995:76) called "demonstrating the interpretative flexibility of the Ordinary [or High-wheeler]", deconstructing the High-wheeler in two artefacts, the 'Macho' and the 'Unsafe' bicycle, as the respective relevant social groups constitute them[11]. Thus also demonstrating that meanings are not static but meanings develop as the relevant social groups change the artefact or their perceptions of it.

Manufacturers became aware of the problem of the 'Unsafe Bicycle' and resulted in a search for solutions backed up with important research investments. A great diversity of bicycles emerged with very different layouts: "*The new designs from the mid-1880's clearly show that all elements of the basic scheme of the Ordinary had been called in question*" (Bijker 1995:71). The basic scheme of the High-wheeler was thus only obdurate for the 'macho Bicycle' interpretation. Besides the modification of High-wheelers — the 'unsafe bicycle' — and more radical reordering of the two-wheeler designs, also three and four-wheeled cycles re-emerged as a solution to the safety problem. Although they did exist as singular prototypes before, they were now successfully commercialised because of the interest in cycling generated by the 'unsafe bicycle'. Of quite diverse designs, these sometimes surprisingly large vehicles were quite

[11] Manufacturers and designers can be considered part of both relevant social groups with varying degrees of inclusion in each of them.

popular, especially when the aristocracy accepted them[12]. They fell into the liking of elder people and also made it possible for 'ladies' to participate in cycling[13], making cycle manufacturers very aware of the potential in these markets.
Now in hindsight we know that the cycle that overcame the 'unsafe bicycle' was the Safety Bicycle whose design we use today. This makes it easy to overlook the significance of all the other designs that existed in the 1880s and 1890s that were also quite successful and are part of the social shaping of cycling. For instance:

An ***1886 catalogue of all British cycles available described 89 different bicycles and 106 tricycles*** (Bijker, 1995:57).

So there was a very large diversity indeed, development was almost unrestricted by convention and tricycles were successful. "*Many people were convinced that it would just be a matter of time before the tricycle was the only commercially available cycle."* (Bijker 1995:57). However, most tricycles and quads had some safety problems of their own: they had no good braking systems, were especially dangerous on downhill slopes and the large, elegant spoke wheels on the sides of the rider became 'less attractive' in an incident that would throw the rider of his/her seat (Bijker, 1995). Therefore, tricycles were not free from danger either. With the proliferation of diversity and the success of other cycles as solutions to the safety problem, it is clear that the original artefact, the 'macho bicycle' High-wheeler, was loosing ground to the 'unsafe bicycle' High-wheeler interpretation.

The Safety Bicycle and the air tire
One of those other cycles with a more radical reordering of the two-wheeler layout was 'Lawson's "Bicyclette", patented by H.J. Lawson in 1879. It was unsuccessfully promoted but had all the ingredients of what would make the later 'Safety Bicycle' a safe preposition: a low seat way *behind* the front wheel and pedal and chain drive to the rear wheel. The large front wheel shows its derivation from the High-wheeler (Bijker, 1995:68). 'The Rover', designed in 1884 by J.K. Starley and W. Sutton, was the first 'dwarf safety' with a diamond like frame, see figure 4. This design did receive a following and more dwarf safeties came on the market. However, they were far from replacing the 'Macho Bicycle' High-wheelers, rather they complemented the High-wheelers together with the tricycles, hence the slightly denigrating 'dwarf' name. To the cycling public the 'safety dwarfs' had several perceived problems: splashing of water on the feet, energy loss from the chain transmission and the vibration problem[14] caused by the smaller wheels, and to many they lacked the elegance of the stately High-wheeler. Because of the vibration problem, manufacturers used a diversity of hinges and springs built into the structure to counter the problem. From 1888 to 1890, most dwarf safeties had some anti-vibration device[15]. However, these only partly solved the problem and introduced unwanted complexity. The true breakthrough of the Safety Bike came with the

[12] Very much helped by the fact that the Queen Victoria ordered two Salvo Quad's from J. Starley, the model was immediately renamed Royal Salvo after that event. (Bijker 1995:56)
[13] Making a significant contribution to the beginnings of the women emancipation.
[14] Smaller wheels tend to follow road imperfections more, resulting in more vibration, as roads were rough.
[15] They remained available until the late 1890s (Bijker 1995:83). Today anti-vibration devices are known as a wheel suspension systems.

introduction of the air tire. The air tire was supposed to reduce or end vibration of safety dwarfs on the bad roads. Air tires were expensive, very impractical to repair and its success was all but certain. The anti-vibration tire was not what changed the course of history. That happened on the race track: after initial laughter at the strange sight, Safety Bikes equipped with air tires convincingly beat the 'Macho Bicycle' High-wheeler in races. This happened the first time in May 1889, where a big financer was so impressed — as were many others — that he started a company to mass-produce air tires. As a result: *"Within a year no serious racing man bothered to compete with anything else than air tires."* (Bijker 1995:82). As an artefact, they had redefined the air tire's meaning from 'anti-vibration device' to 'high-speed air tire'. The newly founded tire manufacturers saved no effort to widely promote their high-speed tires at races and advertise this towards the public. While in 1890 air tires were an exclusivity at exhibits, they were standard practice just 4 years later on almost all exhibited cycles. The 'dwarf safety' became a success as a result from the racing achievements. Parallel to the air-tire's redefinition, the sport cyclist and the public had 'redefined the problem' of vibration to a 'low-speed' problem of the safety bicycle, as if previous cycles were too slow. Although 'the high-speed tire' interpretation for safety bikes seems a logic proposition, its social construction becomes obvious when considering that a more scientific explanation for most of the speed advantage compared to the High-wheeler is the reduced air resistance and better gearing of the Safety Bike, not the air tire per se[16]. (Bijker, 1995).

Figure 4: J. K. Starley on his Rover Safety Bike 1885
(Science Museum, London/ Science & Society Picture Library)

[16] One can imagine that air tires were not exclusive for dwarf safety bicycles per se; tricycles, quadricycles and High-wheelers could in principle also use them. Therefore, the introduction of the air tire on dwarf safeties due to the vibration problem had the unexpected side effect of emphasising the inherent speed advantage of the dwarf safeties. The social construction of the air tire is that, when this happened, it was redefined as if this had always been the main reason for using air-tires.

Concerning the High-wheeler, the ‘unsafe bicycle’ interpretation became dominant over the ‘macho bicycle’, as the ‘macho bicycle’ was abandoned by its adherent social groups as the high-speed air tired Safety bike took over the racing scene and, somewhat slower, the market. Since the ‘unsafe Bicycle’ meaning is a non-working artefact, this spelled the end of the High-wheeler. Similarly, the ‘anti-vibration device’ air tire artefact became obsolete to the ‘high-speed air tire’ interpretation because of success in the races. Simultaneously in a process of closure, the ‘dwarf safety’ interpretation— just one of many safety (bi)cycle solutions — became reinterpreted as THE ‘Safety Bicycle’ interpretation among all relevant social groups, an eventual closure which shaped what is today simply *the* bicycle.

Nevertheless, this eventual closure did not happen immediately, and the process of stabilisation can highlight this. The method used by Bijker to trace the stabilisation of the Safety Bicycle is to consider the semiotics used to describe the Safety Bicycle. Bijker used the journal ‘The Engineer’ to trace the stabilisation of the safety bicycle, so having a consistent context of the social group in which the artefact is traced.
After the racing success that made the High-wheeler obsolete, there were several kinds of ‘safety bikes’[17]. According to Bijker, the safety bicycle stabilised in its interpretation about 1897, when it became clear that with a ‘bicycle’, one meant a diamond frame, circular pedalling and chain driven safety bicycle. Once the bicycle had stabilised and closure happened, change became more difficult, the artefact of the bicycle became obdurate. So the whole process of closure on the meaning of the safety bicycle took about 18 years, from Lawson’s “Bicyclette” 1879 until the final stabilisation of its meaning around 1897. In the bigger picture, from Draisine to bicycle, we can say it took about 82 years for the bicycle to develop.

It is only with hindsight that we can say that J.K. Starley’s Rover was the archetype of the present day ‘Bicycle’, because during its conception this was far from obvious, it could have been any other of the varieties. J.K. Starley himself confirmed this when he reconsiders how things turned out in confirmation of his design choices (quoted from a paper presented at the Society of the Arts in 1898):

> *'...my aim was not only to make a safety bicycle, but to produce a machine which should be the true Evolution of the Cycle, and the fact that so little change has been made in the essential positions, which were established by me in 1885, prove that I was not wrong in the cardinal points to be embodied to this end'* (Science museum London, 2002).

Indeed, development did not prove Starley wrong in his choice of ‘essential positions’[18], in the 13 years from the conception of the Rover until he made this statement. The time

[17] It took quite some time before there was agreement that a diamond frame construction was better than a cross frame. Neither was there agreement on the best pedal movement: circular or linear (up and down). In addition, there were many different drive systems that were competing for the favour of the customer: chain drive, ellipsoidal chain wheels, shaft drive, steel belt drive, linear drive etc.

[18] Actually, the true archetype of the bicycle is very recognisable in the bicycle presented in 1890 by Humber & Co (see figure 5). Its longer than usual wheelbase made it possible to use straight tubing for the diamond frame, which is the dominant frame shape up to today. In fact, bicycles with the exact same

of this statement happens to coincide with the period Bijker (1995) identifies as closure and stabilisation of the bicycle.

Yet, it is not so hard to imagine that another course of events in the complex web of society could have produced different or more artefacts than the present day bicycle. Technology is not of self-contained by technical logic, but events, people and their relations mould it.

Figure 5: The Humber bicycle (1890)

Today, the bicycle is still the same in 'essential positions', 107 years after the stabilisation and closure of its meaning. The sociotechnical frame of the bicycle is a fact. Contrary to the High-wheeler, the bicycle was very much a practical mode of transportation, could carry much larger amounts of luggage than a High-wheeler, and was thus very successful. It was this success of the bicycle that spread its meaning into societies all over the world and cemented its obduracy. Most history narratives of transportation indeed fail to mention the important role of the bicycle and its influence in many important issues, as the main mode of transportation, in the development of industry, on social and gender related issues and even as an important factor in warfare (Bijker, 1995; Rosen, 2002; McGurn, 1987:9-). Attention usually tends to shift to the emerging automobile technology, e.g. the story of Henry Ford and the first mass produced car is a standard practice in introducing the history of the modern era. Yet, on the social level the automobile was still irrelevant at that time[19].

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technical details in transmission, brakes and even the saddle are still manufactured in large numbers today, something almost unthinkable for any other technology. This is truly the archetype then.

[19] After the introduction of the automobile in the beginning of the 1900's, interest for cycling did not die off as one could wrongly assume. Maybe the main effect of the automobile was that the elite, also the first bicycle customers, gradually switched over to the automobile for their transport, but they were a minority at this time.

3.2 Pushing the limits of bicycle obduracy

After the stabilisation of the bicycle, the racing forum remained an important place for technical improvement of the bicycle and bicycle racing quickly became one of the largest sports around the turn of the century. Already in 1900 the international federation of cycling was founded, the Union Cycliste International (UCI). The UCI is until today an NGO representing all national associations worldwide, playing an important role in the organisation of the bicycle sociotechnical frame. Sadly, the UCI has kept its historical records poorly, so the newspapers are almost the only available sources of information on happenings from this period (Schmitz, 1999). Cycling was not only big as a sport in Europe, but also in the USA, where until the 1920s bicycle races were bigger than any other sport, including major league baseball and American football (Nye, 1988).

> *"In 1920, eleven football teams that would eventually form the National Football League went on sale for $100 each. One could have bought the entire NFL for $1,100. The better bicycle racers made almost that much - $700 to $1000 - in a good week."* (Nye, 1988)

Already very early in the 20th century, velodrome racing was big and the bicycle was the unquestioned machine of choice.

It speaks for itself that the idea of racing is to go faster than your competitor does. Thus, there was an active search to increase speed. One obvious way was to train the body better and improve the pedalling technique and ergonomics. As for the machines, this was a motivator to the improvement of every aspect of the bicycle. There are four main areas for optimising bicycle performance (simplified): increasing mechanical efficiency (bearings, efficiency of power transfer i.e. stiffness of frame), reducing rolling resistance (tire technology), weight (for acceleration and climbing) and air resistance. Air resistance is in fact the most important barrier to increase speed for racing bicycles (see also Box 2 on page 46 and 47). The most obvious way to reduce air resistance was to take a crouching position on low handlebars, which very soon became typical for the racing bicycles. Air resistance, even today, plays an important role beyond the individual speed: the earliest racers already discovered that the racer riding behind another can take advantage of the lower air resistance from the forerunners wake. This is called drafting or pacing. To this day racing cyclists (e.g. in the Tour de France) have perfected the use of this drafting effect to create the high speeds of group riding, the so-called ‘Peloton’. This effect gives road bicycle racing its main character, keeping the riders together in cooperating groups, making exciting races with spectacle and tactical teamwork possible[20, 21].

[20] Without team tactics and teamwork (possible because of the drafting effect) the races would have been pretty dull and unattractive as a (TV-) spectator sport. And, thus, they would have been non-existent today?

[21] Another practice resulting of the pacing effect is racing behind motorbikes, a sport variant widely practiced in the past practiced but today almost no longer existent. In 1995 the Dutch Fred Rompelberg rode 268,8 km/h on his bike on the Bonneville Salt Flats, in the slipstream of a modified race car with about three orders of magnitude the horsepower of Fred and a large windscreen at the back. Amazing indeed, but not very relevant to the daily cyclist.

Ideas about the science of aerodynamics were spreading and soon the innovators went even further. As a first result, in Paris 1913, Marcel Berthet rode 10km with an average speed of 57km/h in the Velo Torpille, one of the first streamlined bicycles (see Figure 6). Berthet also established records on the 1 and 5 km with this machine. The UCI decided to not recognise these records and to ban streamlining from regular racing. Marcel Berthet was not just anyone; he was a leading professional racer holding the UCI hour record on the classic race bicycle, with 43.775 km/h in 1913.

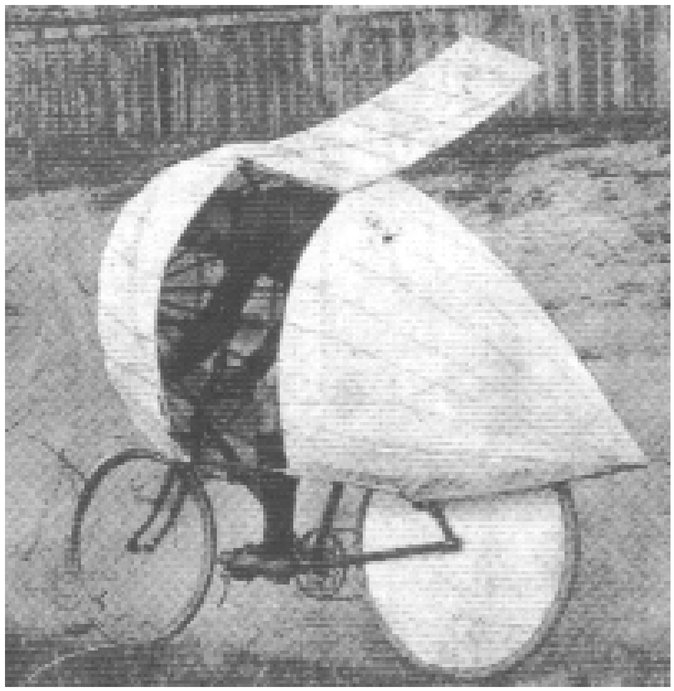

Figure 6: 'Le Velo Torpille', November 1913.
(Archives P. Berthet)

Several streamlined bicycles followed in the next 20 years. Although they were obviously faster and popular attractions with many demonstration rides, they had little chance to replace regular racing: their design was expensive — state of the art aircraft technology was needed to build the streamline — and was unsuitable for creating the racing spectacle that regular bicycle racing in groups did. Speed was important, but spectacle was even more important and regular racing provided this in plenty.

Indeed, the streamlined bicycle failed to become an established discipline of bicycle racing. Besides the individualism, another important consideration is that, contrary to the air-tire safety bicycle that took over the racing scene from the High-wheeler, there was no apparent practical aspect about the streamlined bicycle that could be commercialised. Thus, there was no entrepreneurial interest to commercialise and promote the streamliners in races, as the public had little personal interest in the idea. The streamlined bicycle racing was no more than a special act[22].

[22] In 1933 Berthet improved the hour record with another high-tech streamlined bicycle, the Velodyne, to 49,922 km/h, just short of the magical 50km/h barrier. This speed (49,922 km/h) is already higher than the

The streamline failed to change the artefact of the bicycle and even made it more stabilised, as the UCI decided to excluded the use of streamlined or aerodynamic aids from regular racing. From the SCOT perspective, this rule is a first clear demonstration of the structural power of the bicycle sociotechnical frame.

Reducing air resistance with the recumbent riding position

In 1932, a new design emerged[23] in France in the quest for racing superiority. Its name was Velo Velocar or VV in short and was designed and built by automobile constructor Mochet. The Velo Velocar is what we would today call a recumbent bicycle. Unlike the Velo Torpille, the Velodyne, and the likes, this design was within the then regulations of the UCI as it was shorter than 2m, narrower than 75 cm and had no streamlined body. Consequently, UCI allowed the recumbent bicycle to compete in all races and to attempt to improve bicycle speed records.
After the constructor found a suitable rider, Francis Faure[24], new records soon followed. On the first attempt, the 5 km and the half hour record were broken. A little later, in his second record attempt, the 10, 20, 30, 40 and 50 km records were broken, together with the hour record, up from 44,247 km to 45,55 km (Schmitz, 1999). The Velo Velocar was faster than the classic racing bicycles because of the aerodynamic advantage caused by a smaller frontal area than the classic racing bicycle, aerodynamic drag being the main resistance at the speeds they ride.

Figure 7: Francis Faure has just beaten Henri Lemoine, February 1934
(Archives A. Schmitz)

Newspaper articles reflected how the public received the Velo Velocar. Some recognised its speed, ease of riding and comfort[25] superiority over the bicycle, and its potential to again make revolution in cycling. Others ridiculed its unusualness and made denigrating comparisons and stupid jokes. Disappointing was that the French, instead of being proud

current (2000) 49,441 km/h hour record on a race bike conforming to official UCI rules (Union Cycliste International, the international governing body for cycling races). However, by 1933, the novelty was already faded and the UCI had already decided not to recognise any records ridden with aerodynamic aids, so this performance was hardly noticed in the routine of every day racing events.

[23] How it emerged will be recounted in the next part about Velomobile history.

[24] Francis Faure was unique in that he had no air, no 'attitude' that was typical for racers in those days. So he saw no problem in racing something different.

[25] A classic argument sounds: is a bar chair not less comfortable than a sofa?

of this new French invention and the French record, reacted decidedly lukewarm. The following quotation gives an idea of the scene.

> *It seems that Mochet and Faure had stirred up a hornet's nest. On the surface, it is all sport and fair play. But what do those who make their living from bicycle racing* ***really*** *think – sports magazines, bike factories, officials, managers and racers?* (From Schmitz, 1999)

Despite the fact that the Velo Velocar complied with UCI regulations, it was 'discussed' during the UCI congress before the world championship in 1933. Most seemed positive, but when the UCI representatives decided to make a vote, they rejected the Velo Velocar in the voting. This vote was unfair and illegal, and the president of the UCI, aware of the political sensitiveness of direct confrontation, gave the Velo Velocar a 'provisional' approval and demanded a technical definition of the French Cycle trade organisation for the next congress. (Schmitz, 1999)

Figure 8: Plassat, Lemoine and Faure on the 20th of February 1934.
(Archives C. Mochet)

For the next congress held on the 3rd of February 1934, Mochet distributed a leaflet to the members, addressing the fact that his bicycle complied with the rules and that it would be a travesty to call a slower rider a winner just because the bicycle is older. His lobby worked and the UCI acknowledged the Velocar and its records. The Velo Velocar was allowed to race. In a direct confrontation with top racers as Plassat and Lemoine, the 'mediocre' Francis Faure defended himself well; see Figure 7 and Figure 8. He also beat the 'unbeatable' sprinter Ricard in the pursuit. (Schmitz, 1999)

However, the Velo Velocar success story soon ended. On the 1st of April 1934, the committee advised by the bicycle industry published its definition of a racing bicycle. Non-surprisingly, their definition excluded the Velo Velocar, by stating that the pedalling axis (bracket) cannot be more than 10cm in front of the tip of the saddle. They invalidated all the records of Faure's and even deleted the records completely from the listings

(Schmitz, 1999). Especially the latter contributed to the fact that very few are aware of these historic happenings; even at the UCI headquarters today most are oblivious[26,27].

Figure 9: Paul Morand leading the pack
(Picture from Le Miroir des Sports, No.787, 28th of August, 1934. Schmitz, 1999A)

Obduracy of the bicycle and innovation in cycling technology

Why did the cycling world not embrace the comfortable and fast Velo Velocar as the superior bicycle design and drop the Safety Bicycle? Like the Safety Bicycle succeeded the High-wheeler and the High-wheeler the velocipede? We already saw that races and competitions provided and important forum in the acceptance of new developments in cycling technology, a forum that provided for the social links that led to the development, commercialisation and acceptance of the Safety Bicycle.
The Ban of the Velo Velocar and the regulation of accepted bicycle design effectively blocked this mechanism in mainstream racing. When we analyse these events with the help of the bicycle sociotechnical frame, it becomes clear that this ban is not a real surprise. First, these events happened more than 35 years after the stabilisation of the Safety Bicycle and Safety Bicycles had been dominant in races for almost 45 years. The interpretative flexibility of the racing bicycle was very low and its meaning confirmed

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[26] Even up to today, critics aware of the Velo Velocar history were convinced that the Velo Velocar would not have done well in a professional road race, the true real world test of new developments, knowing that this never happened in the time the Velo Velocar was still 'legal'. Schmitz has recently published a new find that the Velo Velocar raced in road races. Although there was a ban, one Velo Velocar, ridden by the Spaniard Paul Morand, rode about 15 professional road races with distances between 250 and 350km in 1934 (see Figure 9) (Schmitz, 1999A). Morand achieved admirable results, showing the inherent superiority of the design, leading races for long stretches, but he was completely alone and could not oppose the team tactics of sometimes 50 or 100 cooperating competitors for final victory. Before rumours of the start-up of a complete Velo Velocar team to take victory — even it were to be unofficially — became reality, the racing organisers banned Velo Velocars completely from starting at road races. (Schmitz, 1999A)

[27] Personal communication of Marc Tauss with the UCI, in Geneva, Switzerland, where the UCI is seated today.

endless times. The racers were perfectly happy with the speed of the bicycle, there was a strong bicycle culture. The Velo Velocar emerged very suddenly and gave actors of the bicycle sociotechnical frame little time to interpret its design. The Velo Velocar was certainly a 'strange bicycle' at its introduction, something that quickly changed into a 'Problem Bicycle' when it claimed the speed records, threatening the vested interests by claiming attention. The Velo Velocar brought a solution to a problem that did not exist: there was no 'Slow Bicycle', and apparently, there was no sufficient room for a 'faster bicycle'. Instead of adopting the Velo Velocar, the dominant group of racing organisers adopted rules to protect their artefact from the intruder.

Not only was the Velo Velocar a racing machine; contrary to the streamlined bicycles, the Velo Velocar did have practical transport aspects, although at this time these aspects did not get the chance to come forward properly, Mochet sold only about 800 Velo Velocars commercially. Therefore, the Velo Velocar in daily use had very little impact of the fixity of the bicycle. The imminent Second World War probably also did its part in diminishing the memory of the Velo Velocar as there were other worries then.

Division of cultures

The ban of the recumbent bicycle from the recognised racing forum is a signifier of the end to more radical developments within the bicycle sociotechnical frame. In the first decades, the relevant social groups accepted by consensus the dominant shape of the bicycle. The Velo Velocar showed that there was no longer consensus everywhere that the Safety Bicycle is 'best'. The rulings of the UCI put on paper the dominant interpretation of the bicycle. A new relevant social group became manifest here, a group that thinks outside the dominant interpretation of the bicycle: the group that stands behind the streamlined bicycles and the Velo Velocar. They are radical innovators, identifiers of *presumptive anomalies* with a low inclusion in the bicycle frame. The UCI and those who are nonchalant or ignorant to the radical innovations have a high inclusion in the bicycle frame; where development becomes characterised by functional failure. The concept of high and low inclusion is part of the technological frame theory of Bijker (1995). Under the SCOT theory of Rosen, we can say there is a division in culture that the Mochet case clearly illustrates. On one side, there is the mainstream bicycle culture associated with the bicycle sociotechnical frame, the subject of this chapter; and there is the seed for an alternative culture, the subject of the next chapter.

3.3 Modern bicycle history

From the above history and examples, it is clear that innovation and its acceptance in cycling is very strongly influenced by racing and since 1934 demonstrable by the rule makers of this racing[28]. Attention goes to racing heroes, not to the unknown, anonymous bicycle commuter or cycling tourist. Commercial interest follows the attention. Although the bicycle for daily and transport use is not regulated by the UCI, racing culture does continually confirm the definition and the understanding of what a bicycle is. Many are unaware of these early roots of alternative bicycle development, a confirmation of the obduracy of the bicycle sociotechnical frame.

Bicycle use after World War II

The massive success of the bicycle took a turn after the Second World War. The average European started to be able to afford an own automobile. Europe experienced its automobile boom from the 1950s onwards, where the automobile interpretation transformed from a luxury for the affluent, to a democratic good and transport for the masses, accompanied with massive investments in road infrastructure for the automobile — and, in most cases, the neglect of bicycle planning. This success of the automobile also coincided with the decline of popularity of the bicycle. "The total number of kilometres travelled by British cyclists dropped steadily from about 23000 million in 1952 to just under 4000 million in 1974, at which point it began to rise" (McGurn 1987:164). This decline in bicycle use in some European cities is visualised in Figure 10 [29]. In many other European cities besides those in Figure 10, bicycle declined to a level of almost no use at all today.

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[28] It is in this time of the Velo Velocar that the UCI (Union Cycliste International) started their habit of regulating the actual shape and configuration of the bicycle. As the only international cycling organisation body grouping national organisations, the UCI has allowed itself to strictly enforce their restrictive rules on technical innovation. Just recently, in September 2000, the UCI released a controversial press release, announcing the division into two categories of the historical hour record. In effect, this was the annulation of the highly sought after and admired hour records ridden in the last three decades by the greatest athletes of our times: Francesco Moser, Miguel Indurain, Greame Obree, Chris Boardman and Tony Rominger. Their bicycles were deemed too advanced to relate to daily racing. Until today, anyone who attempts to produce something better for the 'good old racing' bicycle, subjects him/herself to a highly political game; approval of a modification is like a licence to sell as racers are happily buying anything that gives a perceived advantage. This is far from the ideal innovation climate. But of course development is not restricted to racing only. Producers of practical and leisure bicycles develop their products to get a competitive advantage on the commercial market.

[29] In addition, the use as transportation of mopeds and light motorcycles also has this decline in use because of the automobile, albeit at a later time. Perhaps the subject for a future analysis.

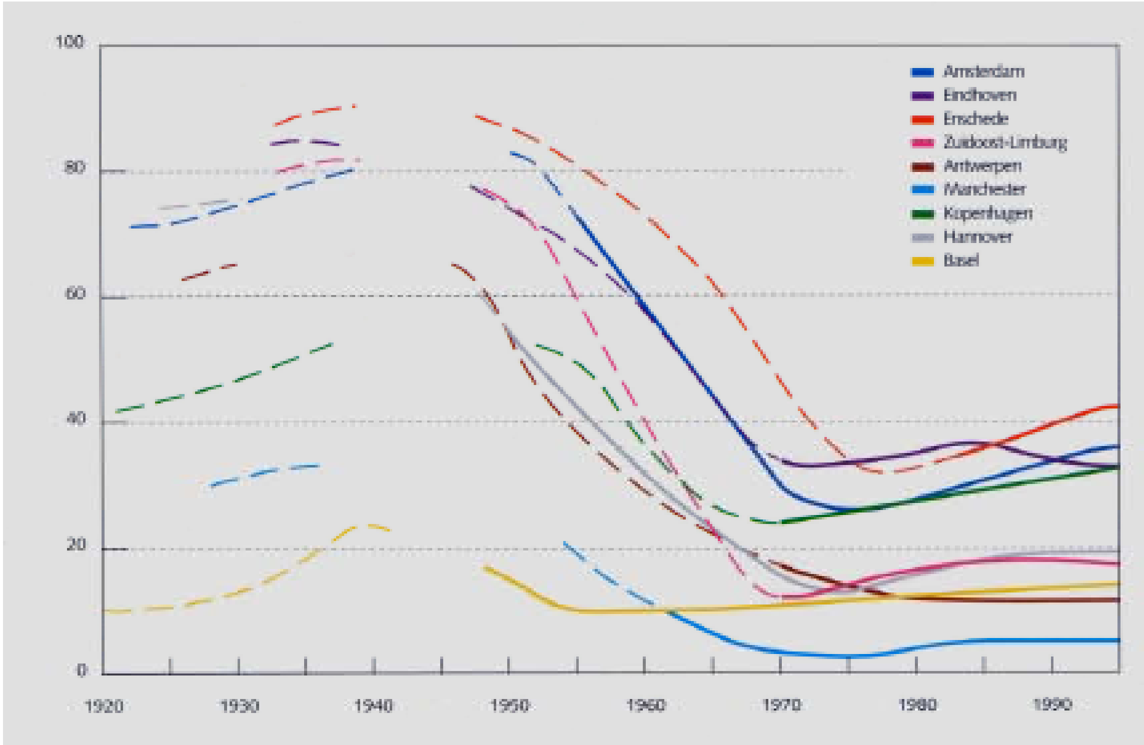

Figure 10: Reconstructed trends of the percentage of bicycle use — modal split[30] — from 1920 to 1995 in some European cities[31] (Ministerie van verkeer en waterstaat, 1999)

Only in the seventies did the decline in bicycle use turn around into a timid rise in bicycle use. However, bicycle use in Europe never recovered to the levels of use when the bicycle was king of the road[32].
Similarly, freight bicycles — differing bicycles and tricycles for carrying loads — started to disappear as vans and trucks replaced them.

Bicycle industry

Today, the bicycle is without doubt very developed and refined as an evolved, modern Rover Safety Bike in several variants. A lot of development has gone into refining geometry and all the components: looking for better functionality, efficiency, lower weight and lower cost. Over the time, some typical variations have formed: besides ‘regular’ bikes, there is the racing bike, mountain bike and some hybrid forms[33]. When looking outside Europe, bikes conceived to transport goods and people (taxi) have (or

[30] Other modes in the modal split are the automobile, the moped/motorcycle and public transportation.
[31] The top four cities are the Dutch cities Amsterdam, Enschede and Eindhoven, and the fourth is the Danish Copenhagen.
[32] Bicycle use during the Second World War was probably very high indeed, although there are no official figures for that (of course).
[33] Folding bikes are popular here and there, but are not mainstream nevertheless (as they ‘should’ be in a transport sense).

had) a large following mostly in Asia. Nevertheless, most of them still use most of the construction, drive and seating position of the bicycle.

Over the last century, production of bicycles changed from craft production, over mass production to today's globalized flexible system (Rosen, 2002). In this production sense, there has been a real change in the bicycle sociotechnical frame.

Today, bicycle brands have become tools of the management and the marketing department; most production of the actual parts takes place in specialised Asian countries. True bicycle design only happens for high-end models, and average models consist mostly of just another recombination of an enormous choice of standard bicycle parts, copying whatever is fashionable. For most market players — except for the few top innovative companies who manage to create extra value — the absence of other real technological differentiation makes price competition one of the few ways to obtain a competitive advantage in the market. The price range for a new bicycle is larger than ever: a new bicycle can cost anything between 50 EURO and 5000 EURO or more. Changes in the bicycling industry have indeed made low-end bicycles very inexpensive, but the lack of quality norms — legislative and industrial — also made it possible that a huge amount of basically awful bicycles can be sold. Some of these are sometimes barely functional. Not to mention that they can be very dangerous. The cycling industry is aware of this problem, which in the end is decidedly contra-productive. Changing these trends and creating value in the bicycle transport market is one of the biggest challenges of today.

The success of the mountain bike

The mountain bike or MTB is the most successful development within the bicycle technological frame of recent time. The mountain bike revitalised the sluggish bicycle culture from the 1980s onwards.

Usually presented as a great innovation, the actual question is: why did it take such a long time to develop the mountain bike? From a designer point of view, the upright position of the Safety bicycle layout is optimal for off-road riding. It is basic knowledge that a greater gearing range, thick, knobbed tires on strong wheels and a tough build will do better in off-road riding, especially considering dirt motorbikes/motocross bikes that have existed much longer. These motorcycle variants already developed after the Second World War. Similarly, the developments of suspension systems on mountain bikes are inspired by the development of motorcycle suspension systems in the past[34]. Not a surprise then that — especially downhill versions — mountain bikes today resemble motocross motorcycles very well: long travel suspension, disk brakes, wide handlebars, impressive frames etc. See Figure 11 for an example.

[34] First, the development of front suspension, later on the introduction of rear wheel suspension on the complete range, using similar techniques.

Figure 11: Downhill mountain bike[35]
(Picture from Specialised)

New mountain bike developments heavily rely on the sport of mountain biking and its surrounding culture. So, one can wonder if it is the invention of the mountain bike SPORT and associated culture that lies at the basis of the invention of the mountain bike. They go hand in hand.

Good marketing of innovative industry players made it possible to create value, status and desirability, using the mountain bike to get a competitive advantage. New brands became dominant and old ones disappeared. It is not so much the concept of a mountain bike by itself that makes it better, but the renewed interest in innovating the details and parts of the bicycle. The difference between a good bicycle and an awful one indeed lies in the details; a truth every cycling enthusiast knows. The mountain bike added value and stimulated many innovations within the new forum of development, i.e. off-road biking.

The mountain bike image furthered the change of meaning of the bicycle from a mode of transportation to a leisure vehicle, suitable for recreation/tourism and sport, massively expanding the latter's market. At the same time, the mountain bike became a fashionable accessory for the automobile's roof rack. Indeed, the bicycle is increasingly becoming a leisure vehicle, a trend that already set in the 1950s[36]. The sports culture makes true enthusiastic users willing to invest in their vehicle, and the leisure industry has indeed become the most interesting niche for the industry. Mountain bike innovations also trickled down to other bicycles, but accomplished bicycles for transportation use remain hard to sell compared to leisure and sports bicycles. The bicycle as transport has a status problem.

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[35] Specialised Big Hit Expert, model 2004

[36] This trend is generally acknowledged in industry and shown in studies, e.g. the industrial developments with English bicycle manufacturers (Rosen, 2002), the trends of bicycle use in France by Papon (1999), McGurn (1987), Whitt and Wilson (1982).

3.4 The bicycle in the context of individual transport technologies

When considering the bicycle as transport, it is important to see it in the larger context of individual transport technologies[37]. As such, it can be said that there are four categories of individual transportation today: the automobile, the motorcycle[38], the bicycle and walking. These categories are presupposed throughout society whenever individual transportation is considered. Although these categories are widely accepted and unquestioned, they lack a strict definition, i.e. they are socially constructed. Their meaning lies in the assumption of their normality; they are obdurate. Each of these categories popularly represents the reality of their sociotechnical frames.

In the case of walking, this taken-for-granted mode of transport has led to its neglect for a long time in transportation planning; although it has improved now. In this paper, we are mainly concerned with vehicle technology, so walking will not be mentioned further.

In the case of vehicle categories, the fixed meanings — these taken-for-granted categories of existence — represent structural power. This structural power makes it possible for these technologies to function, the meaning keeps together the complete socio-technical frame: relevant social groups, culture and technology. Just as with the bicycle, the relevant social groups in the motorcycle and the automobile sociotechnical frames enforce the obduracy of meaning so that there is stability and security of their interests.

Just as individual transport technologies by themselves are defined by socially constructed categorisations, there is a tendency to order the three dominant modes relatively to each other in our common awareness about them. It fits the narrative of evolutionary progress and it resembles the following Figure 12:

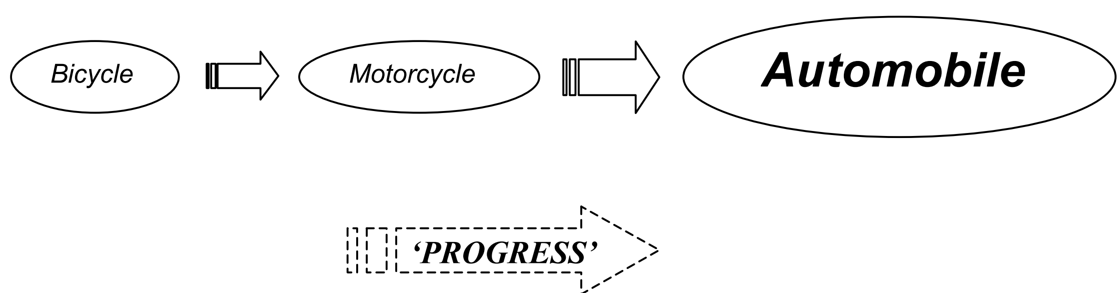

Figure 12: Linear, evolutionary organisation of individual transportation (evolinear sociotechnical frame)

[37] Public transportation is thus not included in this picture.
[38] Including mopeds. Today, the motorcycle as transport is especially popular in warm countries and in developing countries.

This representation embodies many of the present day perceptions of transport technology, and it stands for (these are of course generalisations):

- The exchange value or status of the respective modes: the bicycle has the lowest status, the automobile the highest. The moped and motorcycle lie — when considered as a mode of transportation — somewhere in between.

- The individual path of upgrading: in need of individual transportation, 'everyone' can afford and use a bicycle. The eventual ambition is to be able to afford and to have the legal position (i.e. age and driving licence) to have an automobile; as such, the bicycle functions as a stopgap solution for those who cannot afford an automobile. Going in the other direction, changing from automobile to motorcycle or bicycle almost automatically incurs some perception of downgrading.

- Absolute monetary value: for transportation, a (new) bicycle is not supposed to cost more than a (new) motorcycle, which in its turn is supposed to be cheaper than an (new) automobile. Breaking this convention is considered suspect behaviour in most cultures.

- The perception of progress and the evolutionary narrative of how we perceive the development of transportation technology through history. The motorcycle superseded the bicycle and the automobile superseded the motorcycle as individual transportation. The previous ones become old 'less-functional' technology, receiving development and innovation for specialized applications that exploit their 'inferior transport attributes', like recreation and sports (Cox, 2004).

- The perceptions of the bicycle as an inferior mode of transportation. Considered by planners more as a 'rolling pedestrian' that should be protected *from* traffic, instead of *constituting* traffic that also demands effective infrastructure in the transportation sense (Forester, 1992).

- Finally, yet importantly, it represents how we envision the future of transportation. Solving mobility problems, increasing quality of life and clearing the road to sustainability, the answers lie first on the shoulders of massive technological innovation of the automobile. More adoption and use of the bicycle (and motorcycle?) is incorporated in that strategy, but only when the automobile options have been exhausted. Great expectations of technological innovation are not included in future visions for the bicycle (or motorcycle).

In short, the linear, evolutionary representation reflects the (western) automobile-centred perception of individual transportation technology. These vehicle categories are organised in a manner resembling the above, and are a hierarchic ordering. This is n assumed and not a conscious ordering. This fits the bill of a sociotechnical frame of unquestioned, obdurate meaning of socio-technological ensembles. Therefore, it is my conjecture that the linear, evolutionary ordering of the three individual modes of transportation could together also be considered some sort of sociotechnical frame. Its meaning lies not just in the meaning of each vehicle's sociotechnical frame, but also in how these relate to one another; it is the socio-technical frame of all individual transportation technologies. I will refer to this as the ***evolinear* sociotechnical frame** (imagine a big circle around Figure 12). It encompasses the technology, relevant social groups and culture of the e respective established sociotechnical frames, as well as additional social groups with their culture and technology[39] (e.g. planners and institutions) that (inadvertently?) keep the evolinear assumptions in their place[40].

The evolinear sociotechnical frame thus puts into context the attitudes towards cycling in its larger transport context. Cycling advocacy is about countering the evolutionary assumptions of the evolinear frame that promotes the automobile-centred society. A prime example of dominance of the evolinear assumption are the developing countries where almost without exception the bicycle — together with transport tricycles and bicycle taxis etc. — is regarded as a sign of under-development. As such, bicycle usage has been discriminated, banned or even been destroyed by governments ambitioning to upgrade to the automobile era (see e.g. McGurn 1987:188). China is another typical example of a bicycle nation, having 6 million registered bicycles in Beijing alone (Feng, 2003). Although they are the main mode of transportation in the city, most people see them as a nuisance to the development of motorised transportation and they are largely ignored in future planning for improved transportation (also by Feng, 2003). Producing, owning and using automobiles seem to be *the* goal for China.

"While the obduracy of the automobile is embodied materially in infrastructure, it is the culture of the automobile that secures its hold over us" (Rosen 2002:176). Most western societies, if not all, are automobile-centred where the car 'naturally' gets all attention and, not always, the bicycle gets some goodwill attention on the side, usually hard won by cycling activism. In the evolinear sociotechnical frame, the car culture dominates the bicycle transport culture. The spirit of automobile-centred society is that only when the automobile shows strong signs of failure (chronic congestion and in your face pollution), only then is the bicycle considered as an 'alternative' transportation. Consideration for the bicycle as an equal mode of transportation in constant need of improvement is not part of this perspective[41].

As such, different countries are in different stages of 'progress' in the evolinear frame. Most of the western countries have already progressed to the automobile, leaving the two-wheelers[42] behind as budget transportation and recreational modes. On the other hand, China is in the process of exchanging bicycles for automobiles, mostly skipping over the motorcycle as a mode of transportation[43]. Other developing countries on the other hand have been or are in the process of exchanging the bicycle for the light utility motorcycle, while the automobile remains unreachable for many.

[39] E.g., computer-modelling programs that only include motorized modes.
[40] The additional groups that keep up the evolinear assumption most likely belong to the automobile STF.
[41] This is also valid for the cycling activists that have a distinct utilitarian vision of a cycling future.
[42] Some three- and four-wheeler *bi*cycles aside of course.
[43] Motorcycle use is administratively restricted in Beijing, at least when I visited in 2000.

4 The Velomobile Story

The history of velomobile development is parallel to the previous chapter because it is also about *cycling technology*. The first cycling vehicles that resembled an automobile — or better, what would later be recognised as an open automobiles —, already appeared before the Rover Safety Bike emerged in 1885. These were three or four wheelers, with a sitting or semi-recumbent rider position, sometimes with luggage compartment and occasionally a roof; they are the tricycles or quadricycles discussed before as a solution to the safety problem of the High-wheeler. In the 1880s, they were at least as popular as the 'dwarf safeties' and they continued to exist well into the 20th century, albeit increasingly in the shadow of the massively successful Safety Bicycle, which emerged as the most preferred vehicle in this period. After the stabilisation of the bicycle, radical innovation became much harder. Many engineers involved with the bicycle continued to become innovators in other areas, like Henry Ford building automobiles and the brothers Wright developing the first aeroplane.

The same period was also the beginning of the car era; the difference between a horseless carriage, a motorised tricycle and the first automobiles was in the eye of the beholder. During the first commercial successes of the automobile in the early 1900s, pedal driven derivatives were purposefully made for those who could not afford a motorised version. By this time, the bicycle sociotechnical frame was firmly established and no one took in consideration these pedalcars as serious transport — they were probably very slow compared to the safety bicycle[44] — and they clearly existed as derivatives of the automobile. With the application of industrial series production, the automobiles and engines became cheaper, and most pedalcars were later equipped with an engine. Although the pedalcars were not very appreciated as transport, they were surprisingly popular with the upper class, who used them for their amusement. This interpretation of the pedalcar survives until today as popular toy-versions of real cars, or as attractions for amusement[45].

It seems that all modes of individual transportation have their origins in the similar period, the late 1800s. In this large diversity of inventions, almost every thinkable concept was thought of. In hindsight we can now trace back the ideas that stabilised in that period: the bicycle, the motorcycle[46] and the automobile. However, the vehicle concepts that were preferable *then* are not necessarily so at a later time, as conditions and technologies change and improve. Nevertheless, the obduracy of already stabilised technologies is very real. The evolinear sociotechnical frame is thus the frame of reference for the continuation of the velomobile history in this chapter.

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[44] In fact, the earliest automobiles were also slower than the bicycle.

[45] Pedalcars are a traditional amusement at the Belgian coast, together with the bicycle probably the origin of my fascination for wheeled vehicles.

[46] The very first motorcycles emerged very early, while stabilisation happened quite late (after the bicycle and the automobile).

4.1 Early velomobiles

Any streamlined human powered vehicle could be a velomobile according to a very free interpretation[47]. This makes the Velo Torpille from the previous chapter a potential velomobile. However, the meaning of the word velomobile as used today also implies a practical vehicle.

The Velocar

The first well-documented pedalcar/velomobile is the Velocar. Produced from 1925 to 1944, Mochet made about 6000 of them. The Velocar was indeed made by the same manufacturer of the later Velo Velocar discussed in the previous chapter, Mochet. Most of the information under this heading comes from the son of the founder, Georges Mochet, as recorded by Schmitz (1999).

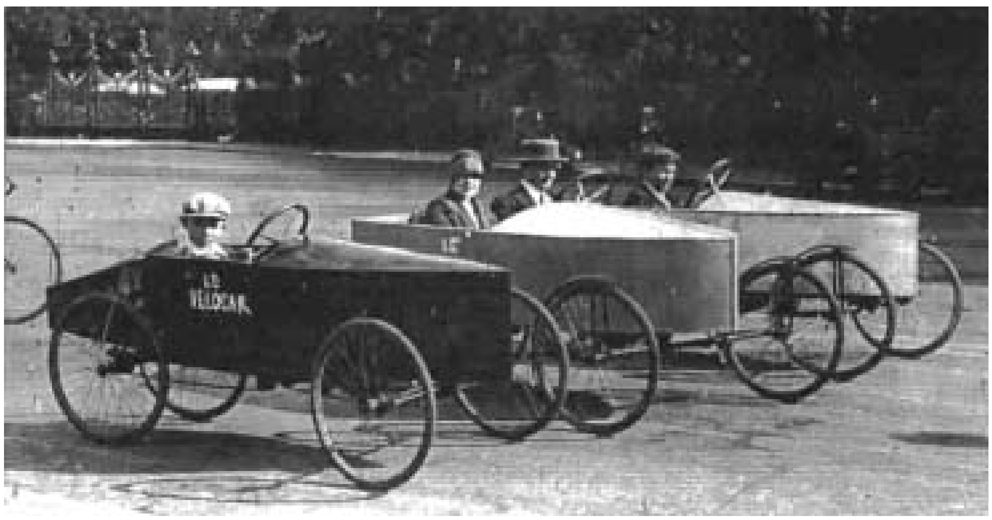

Figure 13: The first Velocars, with young Georges Mochet on the left, Paris 1925 ***(Archives G. Mochet)***

Mochet's primarily ambition was to be an automobile producer, and his last name was associated with the 8th largest automobile producer in France, specialised in building small, lightweight cars, from 1920 to 1960. According to Georges Mochet, many producers in France made pedalcars commercially, but very little is known of them today.

The origin of the idea to build Velocars came when Mochet's young son Georges wanted a bicycle. However, his mother said no because it was too dangerous in the Paris traffic. Instead of a bicycle, his father built him a lightweight pedalcar. Young Georges was very happy with his sturdy, big machine and he soon noticed that he could overtake any cyclist he encountered on the streets (of his own age of course). Mochet started to produce Velocars commercially in 1925, as the commercial potential for a fast[48] Mochet Velocar was apparent to him. The price was about the same as a motorbike to purchase, but it

[47] The meaning of velomobile is not very stabilised yet. More about the velomobile definition in the next chapter.
[48] The Velocar was more aerodynamic than a classic bicycle, despite its large appearance

needed no fuel, was more practical than a motorbike — most Velocars were 2-seaters[49] and had luggage room —, and could be maintained by a bicycle mechanic at a cost similar to two classic bicycles. Most also appreciated the healthy additional exercise. For these reasons, the Velocar, in several variants, was a relatively large success for the small automobile constructor.

This story is remarkable that again the idea of 'unsafe bicycle' led to a new development. In this case, low inclusion in the bicycle sociotechnical frame and construction knowledge of lightweight automobiles lead to a very functional reinterpretation of the pedalcar. The Velocar was at least equalled to the classic bicycle as a non-motorised, human powered mode of transport. The decisive factor that made the Velocar a more serious preposition to previous pedalcars was its potential for speed.

Mochet indeed promoted the possibilities of the Velocar in street races, but most races (and public) were in the Velodrome where the four-wheeled Velocar was impossible to race. Therefore, he decided to make two-wheeler, principally 'half' a Velocar[50]. For commercial reasons, he called it Velo Velocar[51]. The rest of this story we already know (see p.29).

During the Second World War, the Velocars were very popular, as the Germans had rationed most goods and the people appreciated efficient and cheap transport. The Germans reportedly laughed at the Velocars, but in the mean time the Parisians did have transportation[52].

Cyclecars

The Velocar was not alone. During the end of WW2 and the years after, many individuals built pedalcar-like vehicles by themselves as almost no one could afford to buy an automobile. In Sweden and Finland there were several DIY building plans available for cyclecars ('cykelbilar') that were very popular. E.g., the Swedish Pilot CB 101 drawings by Ulf Cronberg were popular in the whole of Scandinavia. He also had similar plans and kits for lightweight automobiles. G.C. Rasmussen (1993:9) speaks about "…some of the designs were very successful, … [the Cronberg design was] built by many people in Scandinavia — including myself". Rasmussen appreciated the weather protection and the speed, but was not so happy with the weight of his Cronberg design (42 kg) and the lousy bicycle gearing. Rasmussen turned to airplane engineering, only to return to velomobiles again later on.

Another popular — at least on paper — cyclecar was the Fantom, as an estimated 100 000 drawings have been sold up to today. However, it was hard to build — the drawings lack any measurements — and even harder to ride and only ten or so successful builds could be documented by Johansson (2003). Nevertheless, there are plenty of

[49] Even with a passenger bench for two more.
[50] Word is that Baron von Drais discovered the Draisine (the first 'bicycle') by cutting a 4-wheeled horse-carriage into two. History repeated…
[51] French for 'Bicycle *from* Car-bicycle'
[52] E.g. Georges Mochet used the 2-seater Velocar to bring his pregnant wife to the hospital.

indications that the cyclecars that existed were functional and used; much probably depended on the quality of execution by its builder. Between 1942 and '49 races were organised between pedalcars (see Figure 14) and the best of constructors reportedly managed to build a machine weighing only 28 kg[53] from the experience of building better pedalcars after every racing year (Lahtinen, 2004). According to Rasmussen[54], the numbers of used velomobiles must have been a few hundreds in Scandinavia.

Figure 14: A Swedish 'Bikecar' race, tandem category
(Picture from Lahtinen, 2004)

Like the first pedalcars, the cyclecars from the 1940s was very much a substitute for a real automobile. Surely many appreciated their vehicles, but in the end, they were wannabe members of the automobile sociotechnical frame. Out of imagination and fascination, they tried to build their dream themselves — even if most lacked any technical training and failed. It was a folkloric subculture, festively remembered in the book of Johansson (2003), although he seemingly has no ambition to reinstate the basic idea of a cyclecar today. Johansson's personal practical experience with the 'Fantom' is indeed not very positive, and from an engineering point of view, it is not hard to understand that he found this cyclecar not a very attractive proposition[55].

After World War II

After the Second World War, it became harder to sell Velocars. Because the financial situation was already bad because of the war, the Mochets had to refocus on their main activity of building cars. When years later a new law was passed in France that limited the speed of small cars without licence to 40 km/h, sales dropped heavily and the Mochet factories had to close as a result. A similar fate was probably destined for many other small pedalcar and micro-automobile manufacturers (Schmitz, 1999). This coincides with

[53] Other cyclecars could easily weigh more than 60 kg.
[54] Personal communication.
[55] I.e. the Fantom was in most of its implementations terribly slow and bulky as a transportation proposition.

the previously discussed European automobile boom, and the massive decline in bicycle use after the war. In the period between 1950 and 1970, there apparently was very little interest in cycling innovation, and most of the history of (alternative) cycling technology was forgotten. The post-war automobile boom gave little reason to prefer pedal to an engine in an automobile. Only after the oil crises of the 1970s, there is a revival.

BOX 1: An Incredible Story

A very memorable feat of these cyclecar phenomena was the crossing from Helsinki to Stockholm with a home built amphibious velomobile by Finnish Reino Karpio and his friend Matti Näränen in July 1949. On land, the Amphibike was faster than a bicycle, but especially the crossing over open sea surprised many when they succeeded. They received a great deal of attention and became national heroes. The Swedish papers Aftonbladet and Expressen competed for the news story scoop of their arrival in Stockholm by respectively sending out a fishing boat and a seaplane to search for them (see Figure 15). Aftonbladet won with old technology.

Figure 15: The Amphibike amphibious Velomobile in Stockholm waters
(Photo by Expressen, Stockholm 1949, published in BCQ (1999))

4.2 The revival

The breakthrough for the sociotechnical frame alternative to the bicycle came in the 1970's with the **International Human Powered Vehicle Association** (IHPVA) when innovation started to become organised and awareness of the history of the recumbent bicycle increased.

The main idea was to gather people that were interested in building human powered vehicles[56] that could set new records without any rule restrictions on design (except basic safety), inspired by straightforward scientific realisations of these possibilities. The association organised competitions that soon became very successful; they had created a new racing forum for innovation and development. Top universities became involved and prize money from sponsoring companies speeded up the efforts. It was the start of a long succession of records. IHPVA members keep setting new records with their newfound fundamental understanding of cycling efficiency and speed, an understanding that is still increasing. This scientifically inspired record searching has resulted in the absolute records purely by human power, presented in Table 1: compared to the restricted UCI records in the same discipline (2003).

[56] Under the IHPVA, there were also categories for human powered boats and airplanes. After the setting of some major and very noteworthy records at the end of the 80s, activities in these categories lessened, as there was little practical application, yet they remained present in the background. The water and air records are held by the famed Massachusetts Institute of Technology university (MIT). In 1991 MIT Professor Mark Drela reached an average speed of 18,5 knots (34,3 km/h) over a 100m race course with the 'Decavitator' human powered hydrofoil boat. In 1988, Kanellos Kanellopoulos flew the Daedalus 88 human powered airplane between the islands of Crete and Santorini, covering 130km in 3h54. Since these events, science teachers no longer have any grounds to say that humans cannot fly on their own power (which was previously conceived impossible)…

Table 1: Absolute speed records according to the UCI and IHPVA

	UCI (www.uci.ch)	**IHPVA** (www.ihpva.org)
1 Hour record (Standing start)	**49,441 km** [57] Chris Boardman (GB), 2000	**82,601 km** [58] Lars Teutenberg[59](D), 2002
200m flying start	**72,985 km/h** [60] Curt Hartnett (USA), 1995	**130,33 km/h** [61] Sam Whittingham (CAN), 2002

Keeping in mind that records within the UCI get broken with margins usually below 1km/h (0,01 km/h in the above Boardman case), the records of the IHPVA are mind blowing[62]. This is obvious also when the IHPVA 1 hour record is almost 10 km/h above the UCI sprint record!

The knowledge — technology — to build high-speed cycles has been actively gathered by the IHPVA and is available in proceedings from the several technical seminars that have been held on the subject. Key concepts to reach the phenomenal speeds are the importance of aerodynamics and the relative unimportance of weight, the latter tends to be very much emphasised in UCI racing bike development. For example, the constructors of the Varna Diablo managed to reduce air resistance of the vehicle (A x Cd) to about 5% of an UCI racing bicycle[63], while it weighs 27 kg (see Figure 16). This does not mean that there is no knowledge to build extremely light HPVs, for instance the streamlined Nillgo II weighs 13 kg, and non-streamlined road racing recumbent bicycles can be as light as 7 kg.

[57] Ridden on a UCI track bicycle on Manchester velodrome, GB.
[58] Ridden in the Whitehawk streamlined recumbent bicycle on Opel test centre in Dudenhofen, Germany
[59] Lars Teutenberg is a professional UCI racer, and Sam Whittingham is also a regular UCI racer. It is a question of diversity, not mutual exclusivity.
[60] Ridden on a UCI track bicycle, during the Track Olympics 1995, Bogota, Colombia
[61] Ridden in the Varna Diablo streamlined recumbent bicycle, in Battle mountain, Nevada, USA. In November, 2003, he also rode 83.71 km/h in a one hour record attempt, not sure if it is an official record.
[62] For some it seems hard to grasp that in cycling, you cannot keep putting in a bigger engine and increase the scale, as with car speed records with sometimes seemingly infinite budgets. This results in a rather nonchalant way of quoting speeds, ‘take or leave 10 km/h’. Cycling records are great achievements in athletic performance and (especially in the IHPVA cases) vehicle development. This is really about pushing the laws of physics and here every digit, even after the comma, counts.
[63] A typical racing bicycle+rider has about a Cd x A = 0,9 x 0,4 m^2 = 0,36 m^2. The Diablo has a Cd x A = 0,11 x 0,18 m^2= 0,019 m^2. Because it takes a long time to accelerate to the very high record speeds, the maximum peak (anearobic) power of the Diablo rider is lower as the human engine maximum power decreases quickly with prolonged duration

Figure 16: The 130km/h Varna Diablo ready to start at Battle Mountain

The IHPVA originated in the USA, but from the start, there were members also from the UK and Germany. Soon the idea spread to other countries with strong bicycle cultures[64].

Already quite early, there was a spin–off from the pure record vehicles in the form of practical vehicles. The first probably were mostly training vehicles, but soon became purposeful developments by themselves. In the 80s these practical vehicles were mostly home built and of a very large diversity. The interpretative flexibility was again very high in this social group, and actors marginal to the bicycle sociotechnical frame became inspired to become their own personal manufacturers, modifying existing products, building their new ideas. Almost every possible configuration was built, small or large wheels, 2,3 or 4 wheels, single or many riders; recumbent, prone or upright seating positions, partial or full streamlining etc. Mostly in the search for speed but with many practical considerations in mind as well.

The innovators tried and tested almost any conceivable rider position and again the recumbent position emerged as the preferable posture, both for pure speed and for practical and comfortable road bicycles/vehicles. Soon human powered vehicle (HPV) became almost synonymous to recumbent bicycle. HPV is now a specialist term, while recumbent bicycle is much better known. This is a demonstration of the unpredictable semiotics of stabilisation. Therefore, I will refer to this alternative sociotechnical frame o fall the HPVs as the *alternative sociotechnical frame of the recumbent bicycle*.

[64] Today the IHPVA embraces the national member clubs of North America (USA+Canada), UK, Germany, Netherlands, Australia, Switzerland, Sweden, Belgium, France, and Finland. There is also quite some activity in other countries like Italy, Lithuania, Czech republic, Russia, Canada, South Africa, Taiwan, Norway and Japan.

Previous inventions of the recumbent bicycle

Looking back into cycling history, I have already discussed the Velo Velocar, the most remarkable development that clearly signified the beginnings of an alternative sociotechnical frame to the regular bicycle. However, there are more examples of recumbent bicycles. Fehlau (1994) shortly describes examples like the Swiss Challand from 1896, the US Brown recumbent (1901), the French series produced Peugeot recumbent of 1914, and several models[65] that existed around the time of the Velo Velocar. In the 1950s, Paul Rinkowski was an innovative recumbent bicycle inventor in the DDR (former East Germany) (Fehlau, 1994). These artefacts of recumbent bicycle inventions were not necessarily inspired by each other; a tendency for constant reinvention exists as developments become obscured by distance and time, ready to be reinvented. Before the IHPVA, it would have been easy to regard small production runs of recumbent bicycles as single events when a larger context was lacking. The odds for a breakthrough were as such very much against the 'presumptive innovators', especially as with time the bicycle became even more obdurate, indeed manifested in the UCI practice of issuing technical definitions of the bicycle. Only after the IHPVA, these innovations were rediscovered in the past and gathered as the prehistory of a now organised alternative culture.

Although the recumbent position in itself emerged quite quickly as the preferred rider position under the IHPVA success, this did not mean that the artefact of the recumbent bicycle stabilised into one typical configuration, as did the Safety Bicycle. Recumbent bicycles are, till today, of many different configurations including three- and four wheelers, long or short, high or low, small wheels or large wheels etc. depending on which purpose they are to serve. So there is some form of stabilisation in the configuration in the commercial recumbent bicycles, even if there is no uniformity per se. Figure 17, Figure 18, Figure 19, Figure 20, Figure 21 and Figure 22 show some examples of different types of recumbent bicycles.

[65] E.g. Cyclo recumbent, Cycloratio, Triumph Moller, Kingston-recumbent, Danish Sofacykle.

Box 2: **Some Basic Human Powered Vehicle Physics**

The human engine:
The human engine cannot be quantified in the same way as a combustion engine. The amount of power a human can produce decreases in time, while a combustion engine can, in principle, hold its maximum power continuously. The amount a human can deliver differs between different people, from almost nothing (e.g. 25W) for the truly terrible unfit to approx. 2000W peak for Olympic sprinters. Luckily the human body can be trained and then things level out a bit. Then it is reasonable to make a typical example that a healthy adult person can produce around 100W, for a reasonable long time, e.g. a commute distance (Whitt and Wilson, 1982). In comparison with a modern automobile engine that can produce about 100 000W continuously, the discrepancy with the automobile becomes clear: the average automobile continuously has 3 orders of magnitude more power at its disposal than an average fit cyclist. The pedal frequency for effective power delivery ranges from approx. 70 to 110 rpm. Appropriate gearing systems make it possible to maintain the desired pedal frequency at a wide range of speeds.

Level road cycling:
The **power** needed to overcome air resistance of any vehicle increases to the third power of the speed {(Vehicle speed + wind speed)^2 x vehicle speed}. Therefore, if one goes twice as fast, the power needed to overcome air resistance increases eight times. Power needed to overcome rolling resistance increases only proportionally with speed. A rule of thumb is that for an average cyclist on a regular bicycle riding on a flat road with no wind, air resistance becomes dominant over rolling resistance above 15 km/h. Although many cyclists experience rolling and mechanical resistance as the main resistance as they feel little force of the wind, it is actually the exponential growth of the air resistance that makes the subjective barrier that prevents further acceleration to higher speeds. This rule of thumb is, however, only valid with the already low rolling resistance of a well-inflated air tire and with a well maintained bicycle. Almost flat tires and rusty chains and bearings can easily slow down the cyclists to speeds so low that air resistance has hardly any significance at all.
In fact a regular cyclist has terrible aerodynamic properties. One can quantify air resistance of a vehicle (+rider!) with the product of the frontal area (A) and the drag coefficient (Cd). The Cd x A of a male adult on a regular utility bicycle is about 1,2 x 0,5 m^2= 0,6 m^2. For a small automobile, this is about 0,35 x 2 m^2= 0,7 m^2. So the air resistance is of the same order of magnitude! So even if an automobile is frontally four times larger than a cyclist, the drag coefficient is about 3-4 times lower. The recumbent position reduces the frontal area. The ‘trick’ of the velomobile is to combine the frontal area of a regular bicyclist (+- 0,4 - 0,6 m^2) with the drag coefficient similar to that of an automobile body (Cd = 0,25 – 0,4). Thus the air resistance becomes much lower, enabling significantly lower power requirements compared to the bicycle at the same speeds (sometimes only a third), or for higher speeds for the same power.

Upphill riding

Uphill riding resistance can be equalled to lifting oneself + vehicle over the height difference. When speed drops significantly on steeper slopes the uphill resistance increasingly becomes dominant. It such a situation, speed can be related proportionally to the power delivered by the rider and the total mass of the rider vehicle combination. This is why cars manage hills easily compared to cyclists; they have much more power/weight available. The mass of the bicycle — strongly emphasised in the established UCI racing culture — is not so important if related relative to the total mass of rider + vehicle, although in a racing situation it of course can make the necessary difference. What usually makes the big difference in climbing speeds between different cyclists are differences in power delivered; appropriate gearing to make power delivery possible at low speeds is also a condition for successful uphill riding. People with low power output or inappropriate gearing would in some situations indeed be better off to walk uphill. In general, hilly living areas usually have much less cyclists; assistance engines could be a solution for those to whom hills are an almost unconquerable barrier to using the bicycle or velomobile as transport.

Head wind

Head winds can last for a whole journey and the regular cyclist on a safety bicycle is affected in large degree because of the high air resistance. A steady and brisk head wind can easily reduce cycling speed to walking speeds. Recumbents and especially velomobiles are much less affected and make cycling in such situations much more pleasant.

Acceleration

Weight also plays a role in acceleration. Velomobiles are indeed heavier than bicycles, but as soon as speed rises, the better aerodynamics of velomobiles start working, so that acceleration at higher speeds can actually be better, depending on the balance of all other variables.

Some practical speed examples are treated later in the heading about speed of velomobiles (see Table 2, page 57).

Figure 17: A USA long-wheelbase recumbent bicycle
(from www.easyracers.com)

Figure 18: The Windcheetah, one of the pioneering recumbent tricycles[66]
(Photo from 'Bicycle', September 1983)

Figure 19: European short-wheelbase recumbent bicycle
(Photo from HPV France)

Figure 20: Cruising in style
(by Felter)

Figure 21: Low racer racing indoor[67]
(Photo by A. Vrielink)

Figure 22: Rowing bicycles[68]
(Photo from www.rowingbike.com)

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[66] Designed by Mike Burrows, one of the most well known bicycle designers. His work includes winning Olympic UCI bicycles.

[67] Observe the 'hand down', parallel to the 'knee down' from motorcycle racing. Indoor circuits are originally indoor go-kart circuits. Low centre of gravity and possibility to pedal in curves makes high curve speeds possible.

[68] The recumbent position combines well with the rowing motion; not faster per se, just different and a good workout for the whole body.

4.3 Establishment of the recumbent bicycle

The culture of the IHPVA movement unambiguously structures the alternative sociotechnical frame of the recumbent bicycle. This culture includes the initial ideology of the HPV movement and that of diversity, the organisation of events and competitions, exchange of knowledge and information in publications and on the Internet, the racing culture, the 'culture' of innovation and production etc. It also — in principal — includes the regular bicycle and its variants, showing the close connection with the established sociotechnical frame of the bicycle. Hence, when we adopt Rosen's model of change, the place for the recumbent bicycle is quite straightforward.

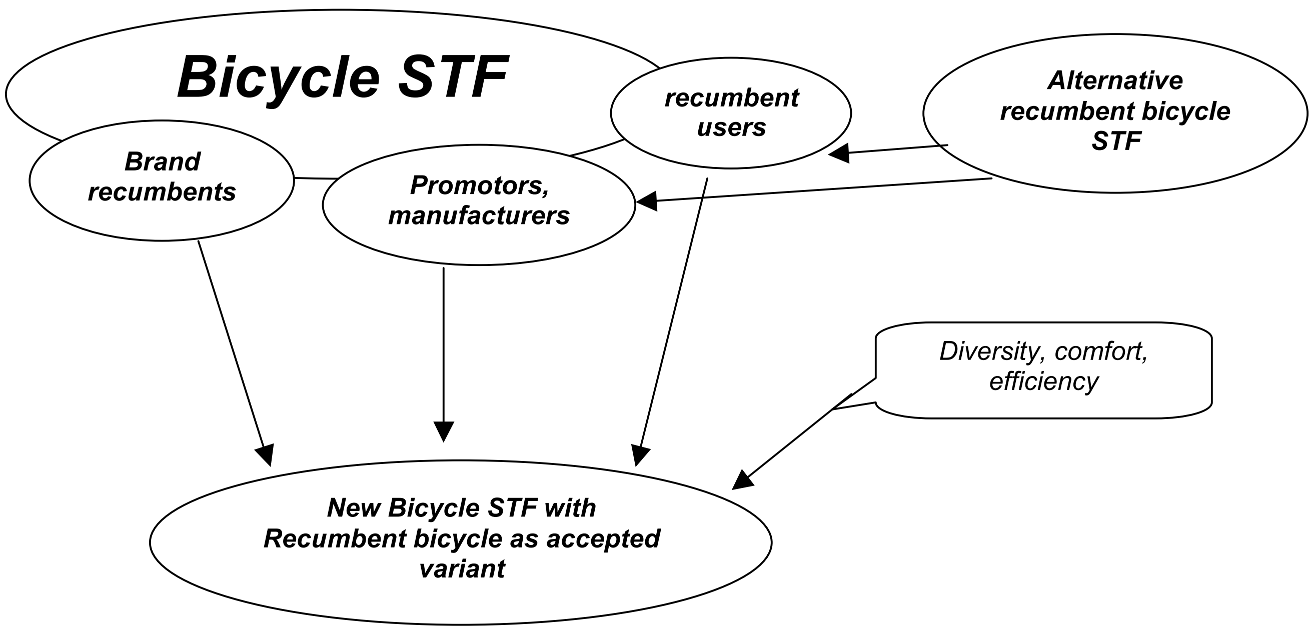

Figure 23: The social mechanism of change for the acceptance of the recumbent bicycle. (STF = sociotechnical frame)

The recumbent bicycle market and culture is relatively well organised and forms an alternative sociotechnical frame to the established sociotechnical frame of the bicycle. The various actors involved in recumbent bicycles, not in the least their users, usually have some straightforward connection to the established bicycle i.e. they are marginal actors to the bicycle STF. The presence of a significant number of recumbent bicycle users deconstructs the traditional notion of what the artefact of the bicycle constitutes. Likewise, the recumbent bicycle producers are marginal actors to the bicycle industry for parts, and promoters at times organise events in close relation to a regular bicycle events (exhibitions, touring rides etc.). The cultural discourse consists of arguments for comfort, speed, range, diversity, etc. As people increasingly recognise recumbent bicycles as legitimate bicycles, come into contact with recumbent bicycles on a daily basis and as prestigious MTB manufacturers start marketing (semi-)recumbent bicycles, it is apparent that the process of creating a new sociotechnical frame is ongoing; a new framework

where the recumbent bicycle is an accepted variant of the bicycle[69]. This is a transition in happening, with large local divergence; in places like ‘recumbent valley’ Dronten in the Netherlands it is almost completed, while in many other places where even the bicycle is hardly used, it is non-existing[70]. There remain economic and social barriers primarily caused by the low valuation of cycling as transport; and a seeming incompatibility of recumbent bicycles and regular bicycles in the traditional distribution channels, necessitating the slow process of setting up a separate distribution network.
That large industry manufacturers as Giant — one of the three largest bicycle manufacturers in the world — are actively pushing the boundary of acceptable artefacts is very positive for future bicycle technology (see Figure 24)[71].

Figure 24: Giant Revive, an semi-recumbent bicycle, marketed on large scale
(Picture from www.giant-bicycles.com)

Summing up, the recumbent bicycle is in the process of being accepted as a variant of the (safety) bicycle in the bicycle sociotechnical frame. For the time being, the recumbent sociotechnical frame remains in a marginal position in respect to the established bicycle sociotechnical frame. Moreover, since the bicycle itself is, at large, in a rather marginalised position as a mode of transportation, the recumbent bicycle remains a very marginal phenomenon as a mode of transportation.

[69] Except in UCI racing, although for instance HPV Belgium is a branch of the national UCI.
[70] Alternative tends to be strong where there also is a very strong ‘regular’ cycling cuclture.
[71] Cannondale, Trek, and Batavus and Gazelle are some other large bicycle producers that have (semi) recumbent bicycles in their line-up.

4.4 The birth of the modern Velomobile

While the early pedalcars/velomobiles were inspired mostly from automobiles, the modern velomobile emerges more from the recumbent bicycle and the streamlining idea. Ideas for designs of practical streamlined bicycles re-emerged in a few international design competitions to improve on human powered transport and bicycle design, e.g. the one organised by the journal *Engineering* in 1967-68 (Whitt and Wilson, 1982:335-341). The actors involved with this design competition also lay at the basis of the IHPVA. The IHPVA embodied the alternative culture that was the feeding ground for the resurrection of the streamlined bicycles and, deduced from these, velomobiles.

The Leitra

The first commercial velomobile of the new generation emerged around 1980. It is the Danish Leitra, designed and built by Carl G. Rasmussen, the same who once built a cyclecar in his youth (p. 42). He succeeded in building a lightweight (as little as 25 kg), very practical vehicle for daily use in all weather. It uses a space-frame built around the rider for safety and lightweight strength. The outside shape is made very aerodynamic, so it is much more efficient — or faster —than the best regular bicycles made for commuting.


Figure 25 and Figure 26: the Leitra, an efficient individual mode of transport ***(Pictures from www.leitra.dk)***

The Leitra remains until today a competitive model on the velomobile market[72]. It main drawback is a high price because of the low production volume by hand, mostly by Rasmussen himself. Despite this, Rasmussen has sold several hundreds Leitras since 1980 and these have been ridden for many millions of kilometres without major injuries. The fact that his vehicles are used so much is the best proof that this is a functional mode of transportation and not some futuristic dream vision.

Rasmussen was very early with his velomobile as he personally bridged the period from the cyclecars of the late 1940s to the revival of the IHPVA. Even for the alternative

[72] The LEITRA has separate luggage space, full weather protection with a glass windscreen and rain wiper, an ingenious ventilation system, independent full suspension, 21 gears, easy entry and access and the possibility to be disassembled so that it can be more easily transported.

recumbent bicycle culture, his vehicle was quite radical and for more than a decade, the Leitra was the only velomobile on sale[73].

The Leitra slowly restarted a process of wider acceptance of the idea of practical, closed vehicles for personal individual transportation. Even though many innovators under IHPVA ambitioned velomobile like vehicles, making the streamlined 'bicycle' a practical proposition was indeed a challenge.

The 365-day FIETS prize

In 1993 a design competition was organised in the Netherlands by the Dutch national HPV association, the respected bicycle magazine FIETS[74] and the Technical University of Eindhoven. Financial support came from the Dutch government's cycling promotion program[75].

This design competition — the 365-day FIETS prize — was a competition for practical cycles for all-year round use, and it was unique in that in order to qualify, one had to build a working prototype. The requirements of the competition were not biased towards 'safety bicycles only' as most modern design competitions and the rules were very practical. In order to qualify for the competition, the working prototype had to ride 35 km in one hour in an outside track during early spring (it was windy and slightly rainy that day, typical so-so weather), while carrying 15 kg of ballast in a minimum 80-litre luggage space. After the qualification, a jury composed of the competitors would judge the designs on 7 points: usability under all weather conditions, general riding properties, usability in traffic, comfort, luggage capacity, maintenance and repair. A separate professional jury assessed the possibility for mass production (price).

As it turned out, most designers grossly underestimated the seemingly low 35 km/h qualification target and the majority of the competitors failed to reach it, including all regular safety designs. Only nine of the 26 competition entrants qualified and all of them were streamlined recumbent vehicles[76]. The target was set so that the vehicles would not compromise too much in efficiency (speed/pleasantness/power requirement of use) in search for practicality and also because it was a simple measure for quality of execution of the prototype. Even if 35 km/h is far below racing speeds of regular bicycles (and professional riders for the qualification test were encouraged), their failure to qualify illustrates the difference between racing speeds in group competition or in ideal record

[73] In the USA, there was a velomobile on sale by the name 'Cyclodyne' between 1979 and 1982 when 14 were built. Probably too revolutionary for its time and place, it was also a bit 'over-engineered' and too complicated. In Lithuania, a whole velomobile movement emerged in the 1980s under the inspiration of V.Dovydenas, building over a hundred prototypes, yet no commercial machine emerged.

[74] 'Fiets' is Dutch for (bi)cycle. For a long time main editor Guus van de Beek was a driving force for 'no-rules' technical innovation in this open-minded magazine, providing a great media forum and several initiatives. When he retired however, the magazine producers decided that, for commercial reasons, it would be better to ignore recumbent bicycles and velomobiles and focus on UCI-regulated bicycles. Similar things happened to other bicycle magazines that first reported freely about innovation during the beginning of IHPVA. The Bicycle technological frame kicks in again.

[75] 'Masterplan Fiets': a large scale research effort financed by the Dutch government to improve cycling and to reduce car use, from 1990 to 1997.

[76] Not only did the competitors overestimate their own capabilities, so did the organisers that expected regular bicycles to qualify for the final. This is probably a contributing factor to why the competition was not organised again.

circumstances and the real world speeds attainable when riding alone on practical bicycles for daily use. So cycling as transport is not about cycling to work at '130 km/h!', but rather at 30 km/h in a comfortable, pleasant and efficient manner.

This design prize was among the first and up to now the last of its kind. It was one of the few efforts to stimulate development for human powered vehicles as primarily modes of transport that was covered by mainstream media. Most people present at the symposium organised after the design contest were very positive to all the developments and achievements that existed in this novel world[77].

The Alleweder concept

The winner of this 365-day FIETS Prize competition was a velomobile called the Alleweder (see Figure 27). Originating from a design by Bart Verhees[78] first realised around 1985, the Alleweder is different from the Leitra because of its self-supporting, monocoque construction. This monocoque construction signifies that the body is one structural part, carrying the loads the vehicle is subjected to[79]. This self-supporting structure resembles modern automobile concepts. Also the front suspension design, McPherson struts, remind us of automobile construction. The body itself was built from aluminium body panels riveted together, similar to the building method of airplanes. This self-supporting design made the outer body less flimsy than the body of non-monocoque vehicles, adding sturdiness that is welcome for a practical vehicle, without necessarily adding extra weight.

Figure 27: the Flevobike Alleweder
(Photo by Dries Callebaut)

Largely because of the success resulting from the exposure of this design competition, the design was commercialised by the Dutch Flevobike[80]. The Alleweder was relatively

[77] Initiatives that arose from this are not easily traced, certain is that the whole design competition has not been repeated.
[78] Designed as his undergraduate work. He continued to also build small airplanes.
[79] Instead of a separate frame that carries the loads and a body that does not participate in this function.
[80] Today, a modified design of the Alleweder is still available at Alligt.

popular in the Netherlands, Germany and Belgium: 90% of the 500 sold between 1992 and 1999 were DIY kits[81]. Not only was the Alleweder relatively successful, it created enthusiasm for the concept of the velomobile especially in the Dutch and German HPV culture, something that the Leitra concept did not invoke. The culture of the IHPVA is thus fundamental in structuring the emergence of the modern velomobile.

More velomobiles

The concept and layout of the original Alleweder proved inspirational for new designs commercialised today. This means: monocoque design, McPherson-like front strut suspension and one driven rear wheel (also with suspension). The body material for most of these velomobiles changed from aluminium to fibre reinforced plastics, so-called composites[82]. These materials are more expensive, but give more freedom in body design and allows for better aerodynamics. See Figure 28

Figure 28: Some modern velomobiles gathered
(Photo by Dries Callebaut)

[81] One could buy 4 Alleweder kits for 1 LEITRA
[82] Fibres: carbon, aramide, glass. Matrix: epoxy, polyester or even thermoplastics.

Together with the Leitra and a modernised variant of the Alleweder, there are now about nine velomobiles commercially available[83]. The companies that commercialise them are very small and most of the production is manual labour. Production runs are small and comparable to the smallest sports automobile builders. These companies are small, but they are very innovative and have already accomplished quite a lot of progress in developing their velomobiles into more attractive vehicles. Better, cheaper production methods, better finish, less maintenance, better efficiency, more comfort and better looks are already of their making. There is certainly an ideal that drives their development, although it is not, for example, environmental considerations or anti-car ideologies per se as one might suspect, but more a passion for cycling and the awe of transporting oneself seemingly so effortlessly over large distances. The builders are usually the most avid users themselves. As such, the producers are very accessible, assuring a healthy market interaction — much sought after in large industries — between producer and consumer, as well as between designer and user.

[83] The companies are from the Netherlands (Alligt Alleweder, [Limit], Velomobile.nl Quest and Mango, [Flevobike Versatile]), Germany (Cab Bike, Go-one3), Denmark (Leitra), Belgium (Fietser.be Waw), Australia (Tri-sled Sorcerer) and Switzerland (Birk Butterfly).

4.5 Properties of modern velomobiles

The idea of the velomobile exists in many places and in many forms, but in the end, there is of course a need for a real vehicle and real development to put these ideas in practice. This heading highlights some more practical aspects of the concept of the velomobile, using examples from commercially available velomobiles.

Speed, efficiency and range

Above it was discussed how competition and speed played an important role in the development of the Safety Bicycle and recumbent bicycle. The realisation with velomobiles is that speed is also important for human powered transportation. A modern velomobile can be much faster than a regular bicycle, see Table 2.

Table 2: Comparison[84] of speed is differing conditions[85] between typical bicycles and velomobiles

(Speed in km/h)	(Neglected bicycle[86])	Good, regular bicycle[87]	*Standard velomobile (Flevobike Alleweder[88])*	Racing bicycle UCI compliant, deep racing posture[89].	*Best Practice velomobile (Velomobiel.nl Quest[90])*
Flat road, 250W	(23,5)	**29**	***41***	**37,5**	***50***
Flat road, 100W	(15)	**20,5**	***28***	**27**	***34***
5% uphill, 150W	(6,5)	**9,7**	***8,6***	**11,6**	***9***
2% downhill, 100W	(25)	**29,5**	***50***	**38,5**	***63,8***
Strong head wind[91], 150W	(3,9)	**5,5**	***12,1***	**9,3**	***17,4***
Power required to ride 30 km/h	(444W)	271W	*115W*	137W	*79W*

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[84] The background to these results (formula, variables used) can be found in the appendix A.

[85] 100W is the power an average healthy adult person can uphold for a longer time (e.g. 1 hour), while 250W is approximately that of a well-trained, sportive cyclist. The best racing cyclists can pedal 400W or more during several hours.

[86] Typical 'cheap' bicycle used for short distance transportation with rusty chain, underinflated tires, bad riding position (too low), no gearing. The latter two are *modelled* as bad efficiency, to reflect the lower power output than would have been possible with the same 'effort' on a good set-up. Included only as a very rough indication of the big difference between a neglected bicycle and one in good condition.

[87] For transportation use: including fenders, luggage rack, upright rider position.

[88] See Figure 27

[89] The rider wearing typical tight cycling clothes. Overall, a pure racing configuration that slows down considerably when equipped with practical accesoires that are inherently there with velomobiles.

[90] See Figure 29

[91] 13,88 m/s or 50km/h against riding direction.

In comparing the vehicles in the above table, one needs to realise that contrary to all the other vehicles, the UCI racing bicycle is not a practical configuration. Equipping this racing bicycle with practical accessories slows it down considerably. Therefore, as a practical vehicle proposition, velomobiles are faster than practical bicycles. Most obviously, a faster mode of transportation decreases travel time or increases the distance travelled in certain amount of time. However, a *fast* human powered vehicle is also *by definition* a very efficient vehicle. This means that when the properties of a velomobile are not used for speed, it is used for efficiency, requiring much less pedalling power than the classic bicycle (see last row in Table 2)[92]. This enables an increased range or simply tires the rider less. The latter can be interpreted as a form of comfort, because even if an important motivation to cycle as transport is to use the human need for physical exercise in a productive way, there is no reason to be wasteful when the demands on individual transportation are only rising.

Figure 29: Velomobiel.nl Quests on their way

The most obvious examples of *efficiency* comes from Velomobiel.nl that makes effort to register and demonstrate the capabilities of their Velomobiles in the hands of their customers in everyday practice. Almost all customers use their velomobiles (the Quest and the Mango) primarily as a mode of transportation, not as a recreational or sport device. The customers on average[93] cover about 5000 km/year, although 15000 km+ per year is not exceptional; of course most riders are dedicated cyclists, but nevertheless this is a simple demonstration that the velomobile is used accordingly. During Cycle Vision 2002, a yearly cycling event in Lelystad (NL), 16 daily users rode their Velomobiel.nl Quests (see Figure 29) in the one hour time trial. With the 365-day FIETS prize in the back of our mind — where the target for practical vehicles was 35 km/h (see p. 55), the demonstration of *efficiency* was very convincing: the *slowest* rider rode 43 km in one

[92] Also worth mentioning: the aerodynamic efficiency of bicycles further reduces with additional loose (rain)clothing and luggage panniers, contrary to velomobiles that in these situation increase their aerodynamic advantage.
[93] Of customers that register their kms, a majority.

hour while the fastest rode 60,9 km in one hour[94]. These speeds are completely unthinkable with a regular bicycle! In combination with all the other practical aspect of velomobiles, this demonstration of efficiency is a kind of relative advantage that is very alluring for the transport cyclist. Even if practical circumstances have no use of such speeds[95], the efficiency matters, increasing the transportation function dramatically. Assist engines, as mentioned before, can help overcome the hurdle of uphill riding, which is maybe the largest barrier of all to cycling for transport in hilly regions[96].

Design and production

Up to now, individual innovators have driven velomobile development. They already have a lot of experience in designing and building velomobiles, also experimenting with production techniques. Expectation and future visions have carried the ideas of velomobiles for a long time, but there needs to be a real object to actually demonstrate what is possible. As such, the modern velomobile already shows some stabilisation in the form of the Alleweder type of velomobiles. Other velomobile design principles have the possibility to emerge if the market is healthy, open to innovation and useful products. I will try to remain as general as possible, so not to impose a limited focus on existing design concepts of velomobile like vehicles.

Apart from mechanical parts that need their own share of design effort, velomobile design differs from other vehicle technologies especially concerning the body. The body is what makes a velomobile, as much or even more as the frame makes the bicycle. The body is also the source of practicality that makes the velomobile such an interesting transport solution. Supplementary to the aerodynamic function that the streamlined body had in racing under the IHPVA, the velomobile body performs several more functions and likewise needs to live up to several more demands. These demands have some similarity to the automobile body, but because of the different scale and strict low weight requirement, the velomobile is a unique engineering challenge. A list of such demands is:

Weather protection, protection against dirt
Crash protection
Luggage space
Easy accessibility for the rider, good ergonomics
Good visibility for the rider and towards other road users
Internal climate management: ventilation and radiation properties
Low noise and vibrations
Appealing, dynamic, pleasurable aesthetics
Good aerodynamic properties
Low weight
Protecting mechanical parts from environmental wear and tear
Accessibility to parts for maintenance

[94] And in the 3 hour time trial, the fastest Quest averaged 57km/h, i.e. covered 171 km distance in 3 hours of cycling.
[95] A fast vehicle is of course NEVER a license to speed and to endanger other people's lives.
[96] Assisted bicycles and velomobiles can be found in Velomobile design (1999).

Integration of the above functions; integration of secondary functions such as: lighting, electronics, security, other accessories, etc.
Low cost[97] production
Etc.

Especially the strong demand to keep total weight of the whole vehicle down as much as possible, as well as cost considerations, make body design and production definitely a high-technological challenge. Compared to motorised vehicles, only the engine does not need to be constructed, but the power source — the rider — must most certainly be taken into account in the design in detail. Therefore, there is no reason whatsoever to regard the velomobile as a 'low-tech' engineering[98].

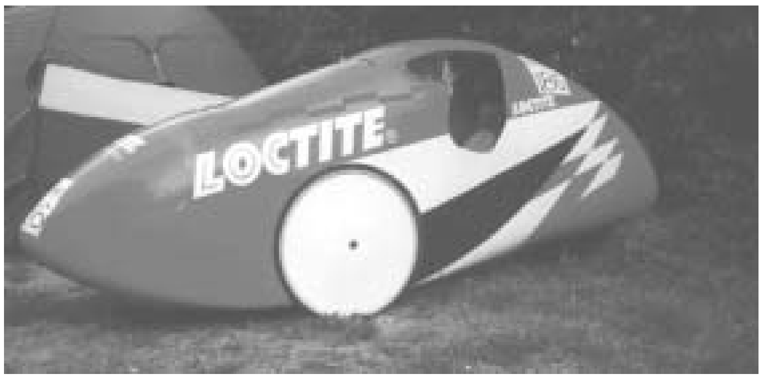

Figure 30: Windcheetah lightweight racing velomobile

It was already mentioned that some designers of velomobiles have backgrounds in designing aeroplanes, obviously relevant to velomobile body design. Before them, Mochet was an automobile builder, from the time that building a lightweight automobile was still an art.

The existing velomobiles already show what is possible in a more absolute sense. Considering lightweight, the Leitra is still one of the lightest practical velomobiles, weighting between 25 and 30 kg depending on the level of equipment. If comparing velomobiles with racing bicycles, which typically weigh between 8 and 10 kg, the Windcheetah racing velomobile (built without practical or comfort considerations) weights in at a very moderate 16kg (see Figure 30). Considering that a conventional bicycle for practical use weighs somewhere between 14 and 20 kg[99], the weight penalty for the velomobile is remarkably small considering how much more 'vehicle' is concerned here. In perspective the total weight of the vehicle *and* rider, the weight penalty amounts to approx. 10-20%.
Improvement in design for production has also led to important improvements of cost reduction using existing methods of small-scale production. For instance, between the

[97] Quite obvious that high cost is, in most consumer products, not a demand.
[98] Here we have yet another indication why velomobiles are not widespread and are in need of a performant sociotechnical frame for its development.
[99] Utility bicycles as used in third world countries easily weigh 30 kg or more.

Limit and the Mango, respectively the first and the third design of Allert Jacobs, there is a price drop of 37% [100]. See Figure 31 and Figure 32.

Figure 31: The Limit[101]
(*Picture from www.ligfiets.net*)

Figure 32: Velomobiel.nl Mango
(Picture from www.velomobiel.nl)

Production technology

In order to be able to make a breakthrough, the costs of velomobiles need to become lower. This requires larger scale production of velomobiles. Series production is a technological challenge that should not be underestimated, as there is no such thing as a velomobile series-production culture; especially the body of velomobiles is a unique technological challenge.

The typical fibre reinforced thermoharder polymers[102] that are used today are a proven material used for small-scale production, but for large-scale production, other methods might be preferable. The other body material that right now is the least expensive proposition is aluminium panels (0,8-1,0 mm) riveted together to form a rigid box structure as on the Alleweder. These panels of the Alleweder were previously laser cut at Fokker, the former Dutch aeroplane constructor. With some ingenuity and design for production, production with this material, in an expanded, robotised form, could be a relatively low cost high volume production method[103].

[100] The Limit (formerly known as the C-alleweder when first commercialised by Flevobike, a Dutch recumbent manufacturer) was the first monocoque composite velomobile. The body was produced by Tempelman using hand lay-up laminting of epoxy and carbon/aramid fibre weave and its retail price was 7100 Euro. It was sold between 1997 and 2002. The Mango is a more recent velomobile from the same designer, who now started a seperate company, Velomobiel.nl. The Velomobiel.nl Mango is still produced with the same basic manuel method of hand lay-up, but by reviewing the total design for optimised production, the Mango now costs a much more reasonable 4500 Euro, while retaining performance similar to the Limit.
[101] The former Flevobike C-alleweder.
[102] A combination of mostly glassfibre and also carbonfibre and aramid weave in a matrix of epoxy.
[103] In the past there has been a test project with TNO, one of the worlds largest research institutions, to see if it was possible to deep draw the thin aluminium plates in more attractive 3D shapes, but results showed this was a scenario not worth pursuing (Vrielink, 2003).

Box 3: **Case of the Versatile**

The most advanced velomobile concerning production technology today is the (semi-protoype) Versatile by Flevobike Technology. Although Flevobike is principally the same company, in 2000 they sold all their models and model licences (including the Alleweder and C-Alleweder velomobiles) in order to refocus their activities on product development and prototype for third party industry customers, mostly from the cycling industry (e.g. Giant Europe).

The Versatile velomobile (Figure A and the front velomobile in Figure 28) is from the Alleweder type and is now Flevobikes only own product. It functions as a showcase for their competence as technology development company. The Versatile is the first velomobile to be designed 'the automobile' way, completely on computer (CAD), while manufacturing of the various moulds is done by applying the CAD 3D designs directly in the machining equipment (CAM). The whole project helps Flevobike Technology to gain experience designing complete assemblies for possible series production. However, the family company does not have the resources to move to a series production. Anyway, the design has been very well received and integrates all the functions of the velomobile in an unprecedented way with purposeful, aesthetic design. Designing an improved version with expertise from e.g. the automobile industry could be the breakthrough to the first truly series produced velomobile.

Figure A: Flevobike Versatile at cruising speed

The materials used for the body are thermoplasts, a first for velomobiles. The black lower half is the structural part and is made from Twintex, a continuous glassfibre reinforced polypropylene weave. This weave is vacuum bagged and heated in an oven for a short time, so that the PP weave melts and impregnates the glass fibres. This method allows for cycle times that are much shorter than the traditional hand lay-up method. According to Flevobike, 10 bodies could be made a day with one mold, and 20 bodies if there are two moulds and one oven (Vrielink, 2003), not a huge number but already a huge improvement over the current small production rate. Mechanical properties of Twintex are similar to a polyester-galssfibre body, except for a much higher impact resistance and higher durability. Moreover, thermoplast are much more environmentally friendly and can be recycled, contrary to thermoharders. The upper, non-structural part of the Versatile is also a thermoplast, a vacuum moulded PET (future ABS) which is painted from the inside. Most of the remaining parts are made from aluminium.

The fact that such a small development company can design such an accomplished velomobile is telling and lifts up a little bit of the possible future that could be… A dozen pre-series protoypes have been sold at 6000 EURO. According to Vrielink (2003), it would take about 10 miljon Euro investment and 3 or 4 persons from the automobile design world in cooperation with the existing team (3 people) to develop the Versatile concept towards a model ripe for successfull series production. It is only in larger production numbers that the high CAD/CAM investments start paying off by dramatically reducing development costs and production costs. A full-featured velomobile, similar to the Versatile, would then cost about 3000 Euro for the consumer if about 10 000 a year would be made (Vrielink, 2003). Higher production rates would further reduce the price. Likewise, Rasmussen, the designer of the Leitra says that industrial production would reduce the price of a Leitra to a similar level. One can only imagine if there were much more models than now and what could emerge from a strong competitive market.

The current trend in the velomobile world is to move towards FRP[104] bodies, which are more expensive but can be shaped in 3D, achieving more appealing and aerodynamic shapes. For future perspectives, the polymer industry is a very dynamic and innovative, with many developments of advanced production methods for high performance polymer structures. The velomobile is a suitable application of these innovations. The scale of the velomobile body and its high structural demands (strength/weight) are an interesting technological challenge; research can determine what methods exactly are possible for the specific requirements of velomobiles (body design is also strongly determined by the production method and materials used). Once large-scale production is in place, the cost of the velomobile body can become very low, as material cost becomes the main cost factor in large series. Because the weight of a velomobile is so low (body should be not much more than 10 kg), the material of choice can be quite high cost (i.e. high performance) compared to bulkier applications. In the future, another possibility may be the use of ecological composites with natural fibres, as these are these are innovations on their way in the industry[105]. In appendix C, there is a more in-depth description of possible production methods.

Besides the plastics industry, other industries can also contribute a lot to velomobile development. For instance, advanced lightweight electronics could play a significant role

[104] Fibre reinforced plastics
[105] One could even make attractive, lighweight velomobiles from advanced plywood.

in providing some modern comforts as lightweight communication, entertainment and navigation; but also more elementary functions like lightweight, integrated lighting and electronic theft prevention. In addition, electronic controlled gear changing and suspension developments are possible[106] and assisted velomobiles can benefit from better electric engine control for e.g. regenerative braking, battery technology etc. The velomobile is a platform where most lightweight engineering innovations can find their niche in producing attractive, reliable, light and cost-effective parts, e.g. thixomolded magnesium parts (Vrielink, 2003).

Infrastructure

There is also the question of material infrastructure. There are two sides to this infrastructure question: legal aspects and practical aspects.

National or federal laws usually struggle with new vehicle concepts. In the motorised categories for instance, the four wheeled motorcycle — also known as quads or ATVs[107] — were classed by authorities sometimes as motorcycles, sometimes as automobiles and sometimes even as agricultural equipment. This led to regulations applying that were obviously ridiculous or impractical and thus not particularly supportive of this vehicle type.
Concerning non-motorised vehicles, most authorities have quite liberal regulations, and usually there are already some laws in place that regulate non-motorised vehicles that are not bicycles (with some criteria to determine this, e.g. based on number of wheels or width of the vehicle). These regulations tend to be inconsistent across different countries and even across local authorities in the same country. It is obvious that for every new vehicle concept, goodwill from the authorities is needed to allow for reasonable regulations. Compared to other existing modes of transport, velomobiles are certainly not more threatening. Things as appropriate lighting and vehicle dynamics suitable for the speeds of the velomobile are just common sense requirements. For the time being, luckily no laws have yet made it impossible to use a velomobile.

Concerning practical infrastructure, most velomobiles are quite narrow (about 80 cm) so that they can ride on cycling tracks without little or no additional problems[108]. The space velomobiles take on the road is of the same magnitude of mopeds, which usually also are allowed on cycling paths — even if mopeds tend to be much faster than bicyclists are. Anyhow, in terms of width, most velomobiles can mix with two-wheelers on existing cycling paths without any problem. The velomobilist behaves in traffic the same way as regular cyclists[109]. Both cyclists and velomobilists benefit of more and better cycling infrastructure[110]. In practice, velomobilists — just as experienced cyclists — tend to

[106] These are already applied in limited extent in some technological bicycles. These features can be of extra use in velomobiles as they all use suspension and have more use in gear changing as the speed range is much greater.
[107] All Terrain Vehicles
[108] Many velomobiles even fit through standard doors, so that storage in the house is possible.
[109] Or hopefully a bit better, as some cyclists have very low traffic moral.
[110] Cycling paths tend to be designed with total disregard to the travel speed of the cyclists. Serious planning recognises that even cyclist have certain speed requirements, and that route choice very much

choose the most appropriate place — road or cycling path — depending on traffic conditions and the own desired travel speed.

The similarity between mopeds and velomobiles also extends to storage (parking) places. Parking space suitable for mopeds and motorcycles[111] is also suitable for velomobiles. Given that they take little space compared to automobiles, it is relatively easy to plan for them. A secure parking place is very important for the adoption of any individual mode of transportation.

Last, commuting to work either bicycle or velomobile becomes a much more attractive option if there is a possibility to freshen up/shower and change clothes at the working place. This measure is non-specific to velomobiles and already promoted by cycling advocacy, but maybe it is worth mentioning an incentive that can make a big difference in willingness to commute using human power. This cycling promoting measure is also good for other purposes of course, and this accommodation is usually already present in larger companies.

Safety

Making statements about 'objective' velomobile safety now is maybe premature, as there is no material for a deeper, statistical analysis and attitudes can still change a lot as time progresses.

Concerning passive safety, one can say that the structure around the rider has done a good job in protecting velomobile riders from serious injury in velomobile accidents until now (Velomobile Design, 1998; 2004). There are many ways to design a vehicle crash safe 'despite' its low weight[112], for both the rider and the other party. Kinetic energy can be dissipated by diverting the direction of the vehicle (which is promoted by the rounded shape of the body), by energy absorbance of the vehicle structures and, additionally, even by the legs of the rider, which can take up a considerable amount of crash energy in a frontal crash[113] without injuring the rider[114]. Future developments can of course further increase the passive safety.
However, it should be obvious that in collision with a much heavier vehicle, a velomobile is the underdog. Just like bicycles, velomobiles are preferably kept separate from heavily trafficked roads and crossings with effective and attractive cycling infrastructure.

Concerning active safety (the ability to avoid accidents), the narrow and lightweight velomobiles are quite agile and quick in changing direction. This is usually quite surprising to most people that are used to the bulk of automobiles. All this presuming that the rider has taken the time to become acquainted with the road handling behaviour of

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depends on the average speeds. Concepts accommodating for these needs are projects such as 'cycle highways' where the cyclist has priority.

[111] Two-wheelers usually also lack designated parking space.

[112] A lighter vehicle has of course also less energy that needs to be absorbed in the event of a crash.

[113] Crashes where the front of the vehicle is involved are the most common type of crash for automobiles and cyclists (except falling) and most probably the same is valid for velomobiles.

[114] The recumbent rider position is 'Feet First' in a frontal collision, contrary to 'Head First" for the bicycle, hence the importance of a helmet for the latter.

his/her vehicle. Good visibility for the rider is also crucial, and usually velomobiles use light body colours to increase their visibility towards other road users.

In the end, one cannot be explicit enough in the importance of an attitude with all road users (including cyclists themselves) that considers the bicycle and the velomobile as a ‘real’ mode of transportation with the same rights and responsibilities in traffic as motorists, creating healthy and responsible traffic interaction between the different modes (Forester, 1992).

5 The Place of the Velomobile in Transport Technology

Visions for a future with more velomobiles is a part of the culture of the velomobile sociotechnical frame, even the recumbent sociotechnical frame by extension. Simply because there is an overall belief that appropriate cycling technology can make a sociable, equitable, healthy and ecologically sustainable future. So presuming that widespread velomobile use could have a positive influence on future society, I will discuss how the now unimportant velomobile sociotechnical frame and society relate to each other and how they can change towards mutual benefit.

5.1 Prejudice towards cycling technology

Although the velomobile is different from the bicycle, it still remains in essence a *cycling* — referring to the human powered drive — technology. In the perspective of the evolinear frame, there are many technological aspirations for even better automobiles in the future. Combined, the automotive industry receives billions in government research grants to improve and innovate automotive technologies. A corresponding vision for the bicycle (or motorcycle), *for transportation,* is virtually non-existent. However, a precondition for any possible success of the velomobile is that there is a visionary perception of its future, as there is still need of a lot of development of the velomobile to come up to the level of development of other modes of transportation.

The velomobile, as a technology, is not just a variant of the bicycle. It is not the result of incremental development — because of functional failure — for which there is a market niche *within* the established bicycle market. This should already be obvious. For the velomobile to succeed, it needs a place, a new market[115]. Of course, wherever this market is — as a complete system of producers and consumers and everything in between, it can obviously borrow expertise from other fields, as the technology and knowledge behind the velomobile is not completely alien.

The current place of the velomobile in the evolinear sociotechnical frame

Experience from velomobile users is that, on first sight, most people think a velomobile is a little electric automobile, especially if they saw a velomobile at speed. When they find out it is driven with pedals, the observer either is disappointed that it is not a little automobile, or exclaims: “oh, it’s a bicycle!” They place the velomobile in the evolinear sociotechnical frame as not-an-automobile-but-a-special-bicycle.

Now ‘velomobile’ as a term is very well accepted and used in the alternative sociotechnical frame. Nevertheless, even the people closely involved with velomobiles cannot accurately define a velomobile and there are plenty of discussions on what exactly constitutes a velomobile. Although a velomobile is very different from a bicycle, enthusiasts usually describe a velomobile in relation to the (recumbent) bicycle. For

[115] A parallel from the automobile world: the hydrogen automobile would also never emerge incrementally from the combustion engine paradigm, it has to be pushed seperatley of course.

instance, in my mechanical engineering thesis on a design for a velomobile, the title was (translated from Dutch): ‘Design study for a three-wheeled streamlined recumbent bicycle’. In Wikipedia (2004), we find the following description/definition:

> “*A velomobile is a human-powered vehicle, fully enclosed for protection from weather and possibly from collisions. They are virtually always single-passenger vehicles. They are derived from bicycles and tricycles, with the addition of a full fairing (aerodynamic shell)*”.

For actors of the alternative sociotechnical frame of the recumbent bicycle, it usually suffices to describe a velomobile as a practical, streamlined recumbent, although the meaning of ‘streamlined’ and ‘practical’ remain open for wide interpretation and discussion.

Thus, in almost all cases, in the alternative sociotechnical frame of the velomobile, the velomobile is described as a ‘special’ bicycle; several descriptive attributes and qualifications tell what kind of special bicycle it is. This is semiotics, analysing the meanings of words. And as we understand from SCOT theory, the interpretation — the given meaning — is the actual socially constructed artefact. The deduction from this is that the velomobile is a ‘sub-category’ of the bicycle, existing in relation to, and derived from, a sociotechnical artefact that has a fixed, established meaning in society, that is: the bicycle[116].

These semiotics of meaning, wanted or not, determine the position of the velomobile in the evolinear sociotechnical frame of individual vehicle technologies. It also makes sense from a historical perspective as discussed in the previous chapter: the modern velomobile indeed emerged from the HPV movement, the alternative sociotechnical frame of the recumbent bicycle. It would be fairly correct to state that the sociotechnical frame of the velomobile is itself alternative to the sociotechnical frame of the recumbent bicycle (in its turn alternative to the bicycle sociotechnical frame): velomobiles are different from the simple understanding of a recumbent bicycle and often perceived as expensive, unwieldy and overcomplicated in relation to ‘normal’ recumbent bicycles. Thus even if the velomobile did emerge from the recumbent bicycle alternative frame, it is not automatically part of it. Or as Dr. Peter Cox (2004) expresses it, “*Within the existing framework of transport options, the velomobile has a heavily circumscribed market as a symbol of the social elitism amongst cyclists.”* We can say that the velomobile is marginal to the recumbent bicycle; the recumbent bicycle is marginal to the bicycle; and as a mode of transportation in the evolinear frame, the bicycle is itself marginal to the automobile. In the end, the velomobile is in a very marginalised position in the evolinear sociotechnical frame, especially for a vehicle technology that has ambitions to have some sort of substitute function for the automobile. Cox (2004), with his approach from the consumption perspective, comes to a similar understanding: “*If the velomobile is itself a marginalised form of cycle, then it is difficult to envisage a greater future role than its current limited market.”*

[116] Bicycle or bike, cycling, HPV, whatever: it is all exisitng in relation to the meanings in the Bicycle sociotechnical frame.

The apparent failure of the velomobile

The social construction identified above explains why a velomobile has a feeding ground in the Netherlands: it has both a strong bicycle culture[117] and, relatively, a strong recumbent bicycle culture; velomobiles are today to a large extent accepted as rational recumbent bicycle variants.

However, as a starting point for true widespread velomobile development, the current marginal position in the evolinear sociotechnical frame is nevertheless hopeless. It is hopeless because it is very unlikely that societies would go through all the changes in transportation technology so as to reproduce the strong cycling culture present in the Netherlands[118].

Another often heard argument is that the main barrier to velomobile acceptance is high cost. Of course, to increase the chances for success, the velomobiles need to become as economically viable as possible, but as the *only* strategy for commercial acceptance, it holds little promise. As long as the velomobile is compared directly with a bicycle, the velomobile will obviously always be an expensive proposition, as it by its very conception is a more complex vehicle.

The actors of the velomobile sociotechnical frame have a deep understanding and vision when it concerns the velomobile as a source for attractive and appropriate mobility for the future, yet by their cultural discourse they unwillingly acknowledge the velomobiles marginal place in the evolinear sociotechnical frame every time the velomobile is described or defined in reference to the bicycle. If the velomobile is to be given a fair chance to develop, it is crucial that the meaning of the velomobile changes its place in the evolinear sociotechnical frame, out of the shadow of the bicycle.

Indeed, despite the presence of a large body of knowledge[119], it seems that the knowledge about velomobiles that exists has a very hard time to permeate into mainstream academic considerations. Rational, scientific arguments apparently only reach a public with low inclusion to the bicycle sociotechnical frame. Cox (2004) said, "*Potential consumers who do not adopt velomobiles are not being perverse or blind to the perceived advantages, but what is rational for one group may not be for another. Further, perceptions of relative advantage are highly context specific*." Beyond the theoretical appreciation of the velomobile concept, the rational-scientific arguments about the advantages of velomobiles only seem to be effective for the few people who already have very malleable and flexible interpretation of the automobile and the bicycle. For the majority who uses the classical modes, those who are involved in their industries or, on the other extreme, have no interest in personal transportation, the opposite is the case and the

[117] In parallel, we can note that the peak of success of the Mochet Velocar also coincided with the peak of bicycle use in the previous century, see Figure 10.

[118] This is a progressive scenario consistent with development because of functional failure (see heading 2.1)

[119] 'Velomobile Seminars' (Velomobile design, 1993, 1994, 1998, 1999, 2004) have been organised. Papers presented there discussed almost all possible related subjects: how to design velomobiles, user aspects, safety studies, calls for better infrastructure, sustainable cities, economical analyses, attitudes to velomobiles, how to advertise, how to market, hybrid-powered solutions etc.

meaning of automobile and bicycle are very fixed, obdurate in meaning. In the context of the majority, the transportation options under consideration are already set.

We are dealing with a unique situation; if we want to understand the apparent failure of the velomobile, we need to understand it in a larger framework of the existing technologies of transportation. Only then can we start to understand how the apparent failure of the velomobile can be overcome. The obduracy of the existing sociotechnical frames is of course a significant barrier to any new or radical innovation, but it should of course not be an excuse to discard any possibility of future change.

5.2 Expanding the evolinear sociotechnical frame

The velomobile is not unique as a 'marginalised' alternative sociotechnical frame relative to the evolinear sociotechnical frame (representing all individual transportation technologies). There are other vehicle concepts marginal to the three established socio-technical frames of the bicycle, motorcycle and automobile. The latter concepts can be scrutinised to see how their obduracy is built up and how they relate to each other and other marginal vehicle concepts.

The difference between a bicycle and a motorcycle

The first motorcycles were motorised bicycles. Today, this transition remains just as straightforward: if it has an engine, it is a motorcycle, if not, it is a bicycle. If someone disagrees with this statement, than this person is probably a marginal actor who thinks further than the social construction of taken-for-granted categorisation. There is indeed an alternative sociotechnical frame of the assisted bicycle, a bicycle with a small engine complementing the pedal motion. Its sociotechnical frame is alternative to both the bicycle and motorcycle sociotechnical frame. National laws usually regulate these motorised categories, in the EU countries this means that the assisted bicycle is considered a bicycle if the engine has a power that does not exceed 250W[120] and the engine assist only when pedalling up to the maximum speed of 25 km/h. If not, the law will decide if it is a moped, a motorcycle or just plain illegal. No need to say that the law itself is a social construction and that its existence on paper does not equate its existence in social practice. As such, practice tells us that the users of 'assisted bicycles' remain marginal actors to the bicycle sociotechnical frame. The assisted bicycle is in a similar process as the recumbent bicycle to become accepted as legitimate variant of a new bicycle sociotechnical frame, modified from the old established one that excluded the assisted bicycle.

Legal constructs effectively draw a definite distinction between the bicycle and the motorcycle sociotechnical frame. Notice that if there was no motorcycle sociotechnical frame, the social construction of the assisted bicycle could be very different; purely hypothetical it would much more likely become a separate sociotechnical frame, maybe an 'assistcycle' sociotechnical frame instead of becoming included in the bicycle

[120] In the USA, it is a much more generous 736W or 1hp and a maximum speed of 20 mph (32km/h).

sociotechnical frame. This is relevant to our subject because there are also assisted velomobiles (see Velomobile Design, 1999).

The difference between a 'bicycle' and an 'automobile'

The assisted velomobile is an interesting case, both from the evolinear sociotechnical frame and from the perspective of the alternative sociotechnical frame of the velomobile. For many velomobile enthusiasts, putting an engine in a lightweight, streamlined velomobile is close to a heresy; assisted velomobiles 'open the road' to the automobile mindset and the vicious circle of 'want-more-engine-power…'. I call this the 'purist' position. To others, a mild assistance is a key concept for the widespread acceptance of the velomobile, because the human is indeed a weak engine and not everyone has the fitness necessary to move a velomobile at an attractive speed, especially uphill[121]. The latter is a 'realist' position. More than a disagreement between velomobile minded people, this discussion points to a discontinuity in the meaning of the velomobile. The 'discontinuity' in meaning is that the velomobile, by adding an assist engine, transforms:

- Purist: from a fast 'bicycle' into an slow *'automobile'* in need for more power
- Realist: from a heavy 'bicycle' into a more attractive, fully practical *'assisted bicycle'*

It is acceptable to describe a velomobile as a specialised 'bicycle', but most agree that direct association with the automobile sociotechnical frame is something that needs to be avoided. Yet, the very possibility to have a direct association between the velomobile and the automobile sociotechnical frame shows that the current 'special bicycle' place of the velomobile in the evolinear sociotechnical frame of individual transport technologies is flawed.

In the history of the early velomobiles, the family relation of the velomobile and the automobile is obvious. The Velocar (see p. 41) was relatively popular, in spite that it was a 'lesser automobile', what would be today considered a downgrading by almost any automobile user. The difference between a Velocar and a Mochet automobile was very small, and Mochet indeed equipped his Velocars with small engines and sold them as (micro) automobiles. There existed a natural relation between pedalcars and automobiles and the transition was indeed no more than exchanging pedals for a combustion engine[122].

[121] Uphill riding is of course a big barrier for an increase in all bicycle use in hilly areas.
[122] The velomobile can as such also be perceived as an automobile that is so light and efficient, that the human power is sufficient to power it forward effectively.

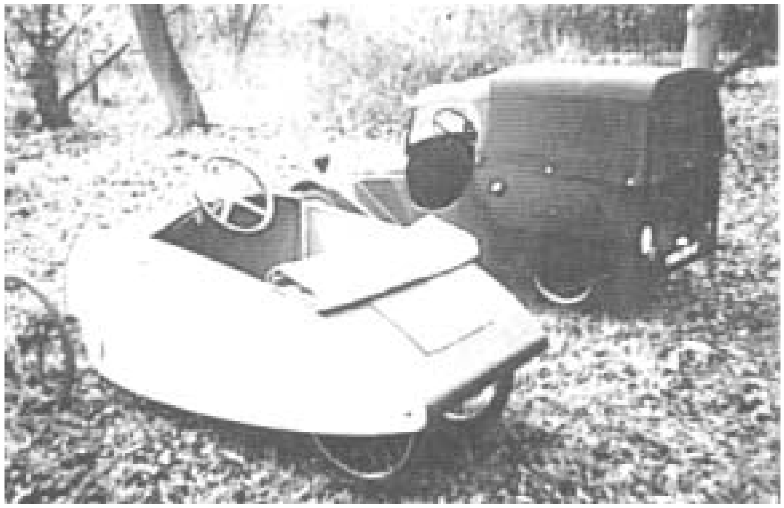

Figure 33: A 1936 Mochet Velocar next to a 1952 Mochet Microvan automobile
(Archives G. Mochet)

With the speed limitation law of light automobiles without license to 40 km/h in France and the subsequent demise of Mochet and other micro automobiles manufacturers, the era where pedalcars and small, light automobiles existed side by side ended rather abruptly, see Figure 33. From this time on, the light automobile variant became uninteresting and the automobile sociotechnical frame developed towards the heavyweights of today. With these happenings, the idea of a serious pedalcar logically emerging from the automobile sociotechnical frame became very unlikely, if not impossible, as the weight gap from automobile to potential velomobile grew too large. This situation is illustrated by Figure 34: one of the smallest 'regular' automobiles available (Daewoo Matiz, +-800 kg[123]) is today about 25 times heavier than a velomobile[124] (+-32 kg).

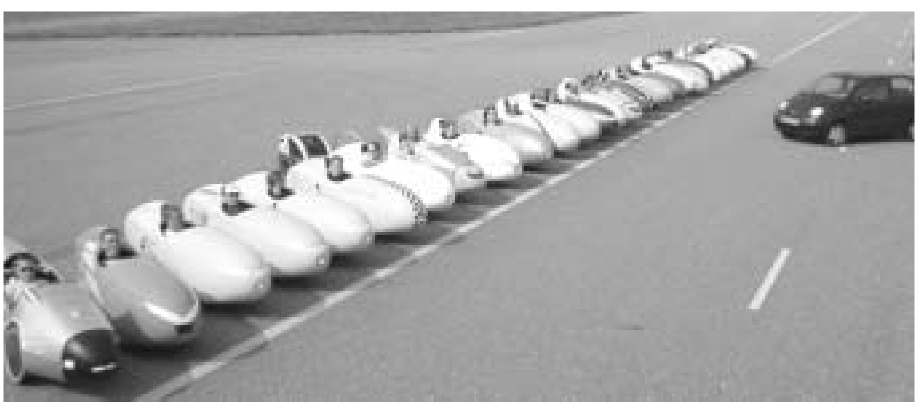

Figure 34: twenty-seven velomobiles are comparable in mass to one small car
(Photograph by author)

It is thus understandable that the modern velomobile relates more to the lightweight bicycle than to the modern automobile. At the same time, the idea of a lightweight

[123] The popular high-end Volkswagen Touareg, an SUV, weighs 2400 kg (thus the weight of about 75 velomobiles).
[124] Surely it evens out more reasonably when there always would be 5 occupants in a car; yet the reality is quite different, with an average of about 1,5 occupants/car in the EU.

automobile is very hard to sell in the established sociotechnical frame of the automobile. 'Moped' automobiles only have a very limited niche market — e.g. for those who for some reason cannot have a drivers licence, and small lightweight ecological automobiles are popular as prototypes and public relation tools, but are virtually impossible to market successfully.

Motorcycle or automobile

In the motorised world, the categorisation of the motorcycle and the automobile are very obdurate. For the relevant social groups the difference between them is obvious. However, inquiring further can easily challenge this taken for granted difference, exposing the social nature of the distinction between these two sociotechnical frames. A small research into the subject is in appendix B.
There are of course archetypes of both automobiles and motorcycles that can be described technically, but describing the actual difference is very hard. Likewise, it is nearly impossible to define the automobile vehicle concept in such a way that is inclusive of all vehicles recognised as such and exclusive of all motorcycles, and the other way around. Rather, the socially constructed meaning makes the separation between the two categories. A few examples of motorised vehicles that fall outside the cultural understanding and therefore challenge the social construction of vehicle categories are presented in Figure 35, Figure 36, Figure 37 and Figure 38. These alternatives then struggle for recognition by modifying the established sociotechnical frames for their acceptance. Big budget advertising campaigns often have limited effect and in some examples, a seemingly constant flow of advertising is needed to keep the alternatives in the options list of the buyers, e.g. the Smart car[125]. Changing the social and cultural infrastructure of large established sociotechnical frames as that of the automobile is very hard indeed.

[125] Which already challenges the very strong automobile culture just by being short.

Figure 35: BMW C1: Motorcycle with roof, seat belts and no helmet, or just something completely new?

Figure 36: Peraves Ecomobile: Who said that closed vehicles are automobiles?

Figure 37: Vandenbrink Carver: motorcycle or automobile?

Figure 38: Quad or ATV[126]: Four wheels are not exclusive for automobiles. Must motorcycles have two wheels then?

[126] All Terrain Vehicle

Summary analysis of the evolinear sociotechnical frame

From the above analyses of the evolinear frame, we can expand the evolinear frame with some alternative vehicle concepts. A symbolical representation is in Figure 39:

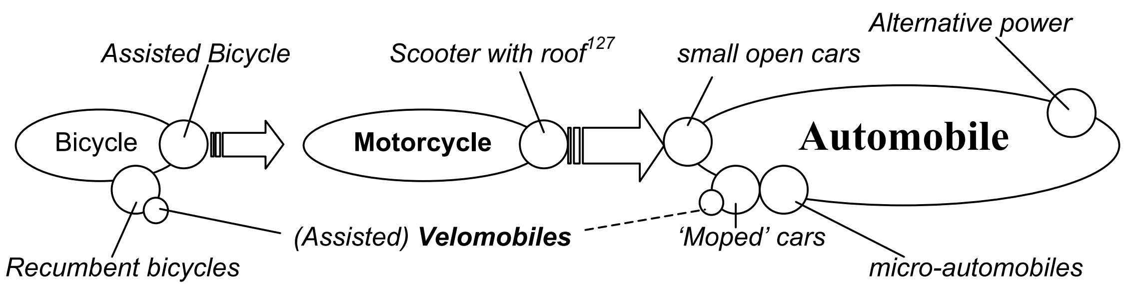

Figure 39: Relative position of marginal vehicle concepts in the evolinear sociotechnical frame

The above figure is a symbolic representation of how a more complex reality does not fit the simplified perception of the evolinear sociotechnical frame. The alternative sociotechnical frame of the velomobile does not fit within the linear sequence. That is, the places that exist are inconsistent. Historically seen, we can position the velomobile in two positions in the evolinear sociotechnical frame. First as a 'downgraded' derivative of the automobile — now obsolete, and second, as a very marginalised, special variant to the bicycle sociotechnical frame[128]. The velomobile, as a transportation preposition, is confusing from the evolinear perspective. It has no place and is thus easily ignored in the existing perceptions about transportation. Alternatively, as in the experience of velomobile promoters, the idea is welcomed with enthusiasm, but at the same time, the ideas are very volatile.

In addition, the other alternative sociotechnical frames appear 'downstream' to the automobile sociotechnical frame and thus have a harder time coming out of their 'social marginal position'[129]. Because the meaning of bicycle, motorcycle and automobile are so dominant, the only mechanism for acceptance and development of alternative vehicle concepts within the evolinear framework seems to be modifying one of the existing sociotechnical frames to accept the alternative technology as a legitimate variant, a process that only few manage to fulfil.

[127] E.g. picture 1 in Table 3: BMW C1

[128] Attempting to place the velomobile meaning conceptually between the bicycle and motorcycle does not make sense and does not work either.

[129] One can also wonder if people feel 'socially marginalised' when they choose to use alternative modes of transportation, especially in the consumption paradigm where products are perceived as a reflection of the social standing or as an extention of the person who uses it.

5.3 Adding the velomobile to the larger context of individual transportation

'Making' a new sociotechnical frame for the velomobile within the evolinear sociotechnical frame is not a very realistic option as the traditional modes are already very dominant. In the end, the evolutionary assumption in the evolinear sociotechnical frame is not more than a non-rational assumptions serving the automobile sociotechnical frame, where the automobile is the goal of transportation[130], instead of (sustainable) transportation itself being the goal and the automobile just one of the means.

The backbone of the evolutionary assumption is linearity, the one-dimensional continuum of transportation modes; the evolinear frame is not designed, rather it is assumed. Therefore, I propose 'bending' the established evolinear backbone by differentiating between the 'true nature' of the two relations between respectively the bicycle and the motorcycle, and the motorcycle and the automobile. The transition between the bicycle and the motorcycle is the transition between human power (pedal power) and motorisation, while the transition between the motorcycle and the automobile is the transition between '–cycle' and '–mobile', i.e. the social constructed conceptual difference between a motorcycle and an automobile. As such, the evolinear frame would no longer be linear, but two-dimensional. This 'bending' makes sense in the light of the velomobile concept.

The rational relations between the established sociotechnical frames can be applied in parallel to frame the concept of the velomobile.

The 'bending' is done by modifying the evolinear sociotechnical frame according to Rosen's model of change (p. 16), with the alternative sociotechnical frame being that of the velomobile. Velomobile users are marginal actors to the evolinear sociotechnical frame (of individual transportation technologies); there is no place for them within. Yet, by their very existence, they challenge the established evolinear frame. Instead of building the meaning of the velomobile as a specialised bicycle, a new cultural discourse can be employed. This discourse uses the relations within the evolinear sociotechnical frame in parallel to the velomobile concept, building meaning for the velomobile. This strategy would both break the weak evolinear assumption and create a logical place for the velomobile in a new sociotechnical frame of individual transportation technologies, where the sociotechnical frame of the velomobile has room to develop. Simply and logically, the velomobile would become the fourth 'vehicle category'. This resulting new sociotechnical frame I will refer to as the '**new matrix sociotechnical frame**'.

For a symbolic representation of this transition, see Figure 40.

[130] a.k.a automobile dependance and the industrialised world's 'addiction to oil'.

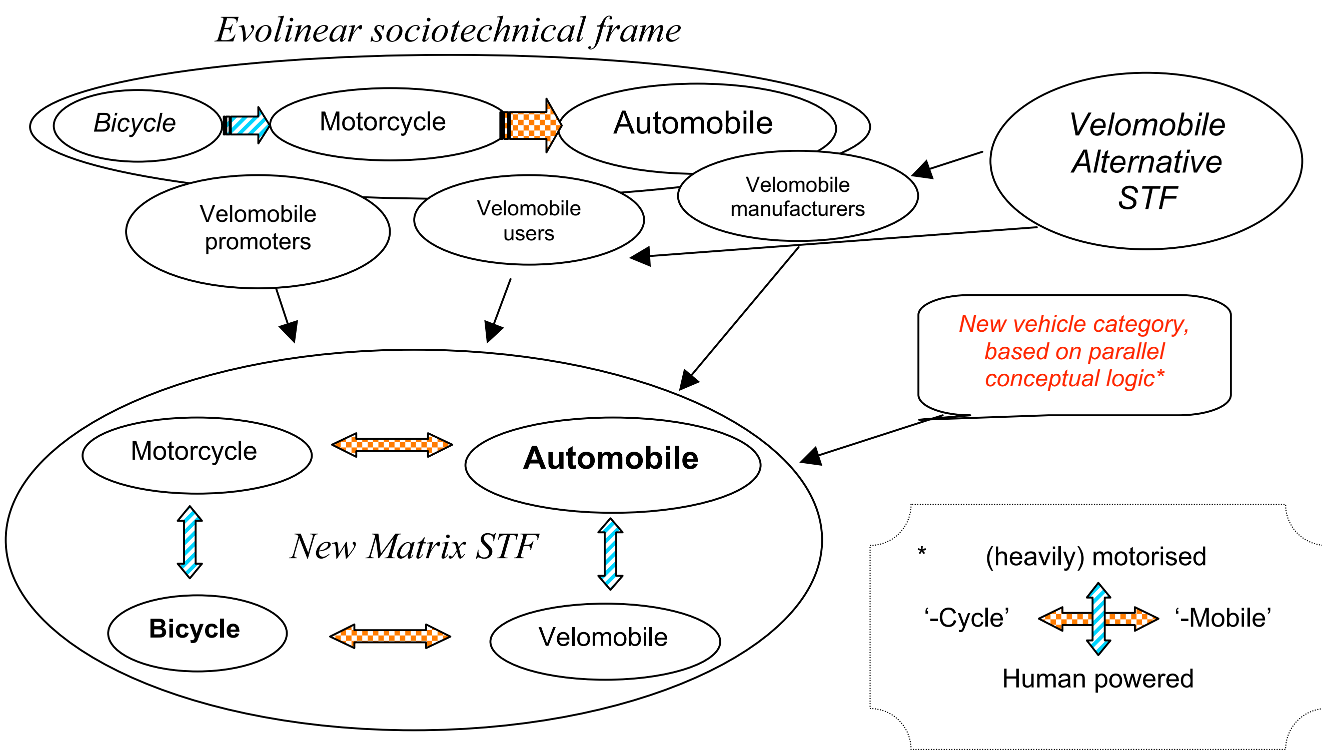

Figure 40: Rearranging the evolinear sociotechnical frame[131]

Presently, the actors of the sociotechnical frame of the velomobile define the velomobile in relation to the bicycle sociotechnical frame. This is rhetoric; a cultural discourse arguing effectively that the velomobile should join the bicycle sociotechnical frame. Discussed before, this — unconsciously — ambitioned social construction is very problematic. The now proposed cultural discourse avoids altogether these problems.

However, why would it be easier to modify the whole evolinear sociotechnical frame instead of the bicycle sociotechnical frame?

The assumptions of linearity and evolutionary 'hierarchy' *between* the established vehicle sociotechnical frames *within* the evolinear sociotechnical frame are relatively weak and not rationally defendable. Therefore the key for the new cultural discourse is defining/describing/explaining the *meaning* of velomobile using the same arguments that *logically* make up the relations between the three established sociotechnical frames (='vehicle categories'); then the very acceptance of this velomobile definition plants the seed of logic that deconstructs the evolinear frame.

Instead of relating to a velomobile as a bicycle, we can thus relate to it as the fourth vehicle category. A new definition could be something along these lines:

[131] The new matrix sociotechnical frame is modified from the evolinear because it still contains the same unchanged established sociotechnical frames.

"*There are today three vehicle categories: the bicycle, the motorcycle and the automobile. The velomobile is the fourth one: the difference between a bicycle and a velomobile* ***is like*** *the difference between a motorcycle and an automobile (-cycle to –mobile dimension); and the difference between an velomobile and an automobile* ***is like*** *the difference between a bicycle and a motorcycle.*"

Alternatively, in short, a velomobile is about as different from a bicycle as, taking a parallel for motorised vehicles, an automobile is different from a motorcycle.

Because the concept of the velomobile is actually very straightforward, it should be enough to point out that a velomobile is not an automobile, nor a bicycle, but a category of its own that logically fits in with the other three concepts.

Technical definitions

There is no need to get into technical details. In practice actors that are part of the existing evolinear sociotechnical frame, i.e. most people, are not conscious of the assumptions of the evolinear frame. If one logically accepts the velomobile as a new vehicle category as outlined above, they have, by definition, logically rejected the evolinear sociotechnical frame and accepted a place for the velomobile in the new matrix sociotechnical frame of all individual transportation technologies. This logical acceptance is of course only the beginning of the process that changes the social construction of individual transportation. However, the power of this simple and apparent logic should not be underestimated as the meaning given to technology is basis for its working. It is from a stabilised meaning that the social relations and institutions are built that make a technology 'working' as an established sociotechnical frame.

The fact that there is no agreement on a technical definition for a velomobile is actually to be expected for a new technology in development: the process of stabilisation and closure are still ongoing. As velomobile technology develops, the technological execution of the velomobile might very well develop in ways we had not imagined before because a new interactions with the consumers and society. Although current commercial velomobiles described in this paper are primarily of the Alleweder type, in the future different iterations could still emerge[132]. Then a limiting technical definition would only obstruct development. I have also already pointed out that there is no such thing as a conceptual technical definition when it concerns automobiles and motorcycles; the factual difference between a motorcycle and an automobile is not the subject to technical categorisation but to meaning. In like manner, the distinction between bicycle and velomobile will be in essence a social construction. In the mean time, velomobile as a fourth vehicle category is just a sensible, logical concept that creates and keeps a place for the velomobile in the larger context of individual transportation technologies.

[132] E.g. tandems or sociables, 4-wheeled, 2-wheeled, two-wheels back and one front (delta), assisted velomobiles, leaning velomobiles etc.

Avoiding conflict

The idea of modifying the evolinear sociotechnical frame instead of any vehicle sociotechnical frame is powerful because in essence, it leaves the established interest of the relevant social groups within the bicycle and the automobile sociotechnical frame untouched. The actors within the existing sociotechnical frames remain the same; the meanings of the respective artefacts[133] remain the same. The modification of the evolinear sociotechnical frame only affects the relations between the respective vehicle sociotechnical frames, and here the interest of the respective actors is vague. The velomobile category, conceptually speaking, is so different that it can avoid direct confrontation with the meaning of an automobile and bicycle. This is important because, besides modifying the evolinear sociotechnical frame to accept the meaning of a velomobile (i.e. the category), the new cultural discourse *at the same tim*e also needs to build up the socio-technical frame of the velomobile within the new matrix sociotechnical frame. The potent social mechanism that accomplishes this is **enrolment of new social groups** (Bijker, 1995:276). The more different social groups become involved with the velomobile, the more the meaning and function of the velomobile will become stabilised and accepted in society, in itself a dynamic and shaping process.

Practical frame of reference

The redefinition of the velomobile results in a new frame of reference — the new matrix sociotechnical frame — to fairly evaluate the conceptual differences between the established sociotechnical frames and the emerging velomobile sociotechnical frame. This is very relevant as future actors in the sociotechnical frame of the velomobile will usually already be part of the relevant social groups of one or several of the established sociotechnical frames.

The lack of this new framework has been frustrating to e.g. the designer who cannot make his product be understood and have it evaluated for what it is. Because that is exactly what happens when the velomobile is a 'special' bicycle, it is evaluated for what it is not. In the evolinear perspective, there is a big risk that a velomobile (subconsciously) is evaluated as an expensive, heavy, complex, large and difficult to park… bicycle with extra wheel(s) and a body on top of it[134]. The fallacy is obvious, it is like expecting an automobile to live up to motorcycle standards[135] or calling an automobile for a 'four-wheeled, streamlined, recumbent motorcycle'.

[133] Also all the associated artefacts.

[134] Hilarious situation sometimes emerge as onlookers are desperately trying to identify the bicycle that I supposedly hid 'under' the long, sleek, three-wheeled velomobile.

[135] Less common but also 'dangerous' perspective: the velomobile is a small, unsafe, slow, 'tiring' etc automobile (without an engine).

6 The Velomobile as a Vehicle for More Sustainable Transportation

That cycling as transport is an ecologically sustainable and a health improving means of transportation does not need much further explanation. With the increase of consciousness of environmental degradation and unsustainable, unhealthy societies, modern societies have put up many noble goals of 'sustainable development'. Nevertheless, especially the transportation sector is hard to change, and although a lot has changed relative to the 'no action at all' scenario, the overall situation does not seem to improve. Person travel keeps increasing, larger portions of the world's population are getting unhealthier and more obese, social segregation increases, air pollution and congestion in cities remain problematic, oil dependence remains as high as ever and the targets of the Kyoto protocol seem ever more out of reach.
No miracle technology is going to change these trends[136] and significant changes are needed to change the course of complete of societies towards true sustainability.

In principle, a velomobile is good for ecological sustainability, if it replaces unsustainable and unhealthy modes, but the larger public will most probably not choose a velomobile as their mode of transportation for that reason alone. It is possible to make a wide range of considerations on why and how the velomobile can be an interesting transport proposition. Therefore, the first parts of this chapter will deal with various approaches to velomobile adoption, ranging from the perspective of cycling advocacy, to rational and economic considerations, valuation and cultural aspects, and from the perspective of different social groups.

The last part of this chapter will deal with secondary influences of the velomobile concept on sustainable transportation, how, besides the direct effects of velomobile use, its very presence can play an important role in mitigating unsustainable transportation patterns.

6.1 The velomobile and the bicycle, partners in cycling advocacy

Up to the last few decades, governments and planners mostly ignored the bicycle as transportation. Not that its role as transport was not recognised as such, but it was taken for granted, as a second choice filling the openings in personal transportation that were not yet filled with motorised transportation. There are very few hard statistics on cycling as transport from the past century and so it is hard to understand the true impact cycling has had on societies. A lack of (scientific) understanding of this kind has without doubt contributed to the neglect of cycling as transport. Fortunately, things are changing and the bicycles' role as a mode of transport is more actively acknowledged, especially in Europe. Not just as poor man's transport, but also as the modern, short-range distance

[136] If there will come a miracle technology, so much the better, but we should not depend on it of course.

transport for 'active' people. Even though this results in some success stories in city planning for the bicycle (Bruges (B), Freiburg (D), Almere (NL), Groningen (NL), Erlangen (D), Strasbourg (Fr)), many other cities around the world have practically no cyclists whatsoever. Most worrying is that existing cycling societies are quickly disappearing in developing countries, where some governments still happily disregard or even ban cycling in the face of the promise of a new, prosperous era of widespread motorisation disregarding all dire consequences. The general world trend is that the use of cycling as transport is still declining, and the task for the pro-cycling movements is not getting any smaller.
This advocacy for cycling as transportation seeks to widen policy much beyond the painting of a bicycle path here and there. It includes cycling in the complete picture of traffic regulation and legislation, integrated infrastructure planning, fiscal policies to make cycling financially more attractive and extensive behavioural analysis and respective promotion campaigns to encourage the users[137]. The social creation of a 'cycling culture' for transport is indeed very important, as already emphasised by Finch and Morgan in 1985.

In essence, today's bicycling advocacy is directed to reverse the evolinear assumption; discourse is mostly centred on road infrastructure and attitude change, while technological development for the bicycle is rarely seen as an opportunity. It is here that the velomobile as a 'bicycle for transportation' suffers. Therefore, it is necessary for cycling advocacy — and in further consequence transportation planners — to be prepared to take up the velomobile as a separate vehicle category and strive for its development. When the velomobile comes out of the shadow of the bicycle, the velomobile concept serves the goals of bicycle advocacy by aiding in the deconstruction of the evolinear frame. In this way, the bicycle and velomobile combined make a strong argument for cycling as valid modes of transportation compared to the motorised alternatives, making their way as a synergetic, yet separate transportation proposition that appeal on a wider range of expectations.

More cycling use because of the velomobile will also make the bicycle more attractive as a mode of transportation, because cycling as transport as a whole will get more attention. Here the bicycle benefits from the velomobile in a practical sense too. Developments for velomobile technology can also serve bicycles, just as bicycle technology is now used in velomobiles. More cycling road infrastructure, possibly of a higher standard because of awareness caused by the velomobile[138], will consequently also benefit bicycle use.

[137] A compilation of knowledge in recent studies on cycling planning can be found in e.g. the proceedings of Velo-city (1999).
[138] One of the evolinear assumptions is that the bicycle is slow, resulting in cycling infrastructure that is touristic / unnecessarily slow for the transportation cyclist. Perhaps the idea of a fast commuting velomobile can change this. See also footnote 110.

6.2 The velomobile as a rational transport proposition

For cycling to be ecological, it must of course replace trips that otherwise would have been done with more polluting modes[139]. There are a several reasons why the velomobile has potential as a mode of transportation.
The velomobile is the most efficient[140] form of human transportation, more efficient than a bicycle. This means that the velomobile covers distance more easily than the bicycle. Now the bicycle, in transportation planning, is considered as a mode for short distance transportation. Promotion of bicycle use is directed to replace short ineffective trips of the automobile[141], because the average trip made by car is indeed only about 6 km in Europe[142] (EU transport figures, 2001). The bicycle is used for distances up to about 5 km; the average trip distance by bicycle is close, yet definitely below the average trip distance of the automobile.
Only a small increase in the average trip distance with cycling can thus potentially replace a disproportionate large amount of automobile trips.
The velomobile increases the appeal to cycle further[143]. Moreover, the weather protection of the velomobile makes it possible to appeal to more users over a wider range of weather patterns, as there is a strong seasonality in bicycle use as transport. Especially in areas that are not well served by public transportation, the velomobile can develop as an attractive alternative in overcoming automobile dependence over a wider range of trip distances.

Another factor that could inspire the use of velomobiles is safety. Not that motorised traffic becomes less threatening to the life of a velomobile rider than a bicycle rider per se, nevertheless the velomobile can inspire to some more confidence in traffic, as there is a greater sense of security of the external protective body. The stability of — usually — three wheels also gets rid of some major causes of injury in bicycle riding: falling over when hitting an obstacle or skidding in curves resulting in a fall. Riding on less than perfect surfaces, e.g. in winter, becomes less threatening.

The interior of a velomobile can be more accommodating than sitting outside, with less need to have all kinds of weather protecting clothing and the ease of taking luggage and stuff without having to worry about detachable bags, bicycle racks and straps. In the recumbent position, the seat supports the bottom and back of the rider, reducing the risk of painful sitting and much more forgiving to the back. The arms and neck are relaxed, overall an ergonomic, pleasurable and comfortable seating position[144].

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[139] Instead of inducing more use of polluting modes, as is often the case with cycling as a purely leisure or sports activity, even if healthy for the active nevertheless.
[140] In converting energy in distance travelled.
[141] In a lecture about new Urbanism, Prof. Douglas Kelbaugh from the University of Michigan mentioned that the average US citizen trades walking for driving if the trip is longer than… 300 metres!
[142] The distribution of this average trip distance is asymmetric, with many very short trips under the average and relatively few long trips above the average. For a more comprehensive analysis, using the median trip distance would shed extra light on this.
[143] For very short distances, it might be more trouble to take the velomobile than a bicycle, which is not a problem if one has the choice. But when the choice is between walking and a velomobile, use patterns might reflect the above footnote.
[144] Especially if the seat is well ventilated.

Last, there are of course the long list of health benefits and advantages to psychological well-being (less stress) that can be expected from cycling. Health can often not be bought back (just as non-renewable resources and biodiversity) and the decreasing health of western populations is indeed one of the most expensive problems of society. A cycling population is a healthier population.

6.3 Valuation of cycling and the velomobile

Even if velomobile prices would reduce considerably, in the perspective of the now dominant evolinear frame, a velomobile would remain relatively very expensive. The adoption of velomobiles is strongly linked to an increase of the status of *cycling* (bicycle and velomobile) as a mode of transportation.

Financial value of the bicycle

Bicycle retailers increasingly deal with customers who seem to expect a bicycle to cost next to nothing. This is incited by a trend of ever more inexpensive bicycles. Today it is common that supermarkets sell bicycles, where the most probable candidate purchaser is not a grown-up looking for transport, but parents looking for a 'toy' for their children. At the same time, many are willing to pay very high prices for sports equipment in the form of racing bicycles and mountain bikes. These trends are part of the process where the meaning of a bicycle as a functional mode of transport is fading. Rosen (2002:102-104) links this process with the global flexibilisation of bicycle production and the commercialisation of bicycles as a product rather than a mode of transport. This process started already in the 1950s (McGurn, 1987:162; Cox, 2004).

Table 3 is a comparison of the price of a new bicycle in the Netherlands and in the USA, countries that have respectively a high and a low use of the bicycle as a mode of transport.

Table 3: Average sales and retail prices of new bicycles according to distribution channel (2002)

<table>
<tr><th></th><th colspan="2">USA</th><th colspan="2">Netherlands</th></tr>
<tr><th></th><th>Average price</th><th>% of total sales</th><th>Average price</th><th>% of total sales</th></tr>
<tr><td>Average price of a new bicycle 2002</td><td>132$</td><td>100%</td><td>557 EURO</td><td>100%</td></tr>
<tr><td>Sold at:
-Specialty bike retailer</td><td>387$</td><td>16,2%</td><td>596 EURO</td><td>87%</td></tr>
<tr><td>-Mass merchant
(e.g. supermarket, discount, toy stores)</td><td>65$</td><td>74%</td><td rowspan="2">296 EURO</td><td>6%</td></tr>
<tr><td>-Other
(Sport shop, market, etc)</td><td>217$</td><td>9,8%</td><td>7%</td></tr>
<tr><td># sold/capita</td><td colspan="2">0,058</td><td colspan="2">0,0835</td></tr>
<tr><td>Total number bicycles/capita</td><td colspan="2">About 0,3</td><td colspan="2">1,1</td></tr>
<tr><td>(Source)</td><td colspan="2">www.nbda.com</td><td colspan="2">www.fietsrai.nl</td></tr>
</table>

We can see that the willingness to pay for a new bicycle of the Dutch average customer is high and that the difference is very remarkable with that of the USA. It also shows that the Dutch buy their bicycles at specialty bicycle retailers. These facts coincide with the high modal split of approximately 27% for bicycles in the Netherlands, i.e. the bicycle is used in about 27% of all trips done with the automobile, bicycle, motorcycle and public transportation.

Contrary to the Netherlands, the modal split in USA is less then 1%. Nevertheless, quite a lot of bicycles are sold, most of them in supermarkets at a very low average price of 65$, which equates to one tenth of the price in the Netherlands. This means that American use their bicycles mostly as sport/recreational or as toys. A recent news message on Bike-eu.com (2003) reported that more children bicycles are sold in the USA than ever before, mostly driven by extreme low prices (as little as 30$ in Wal-Mart), but that these bicycles are hardly used. There is a basic connection between bicycle valuation and bicycle use[145].

Bicycle and the automobile

The low financial valuations of the bicycle correspond with the prejudice from the evolinear perspective, where the automobile dictates value. Here it is normal or even 'esteemed' to pay on average 19100 EURO (incl. 25% VAT) and 21605$ for a new automobile in respectively Europe and the USA (eurocarprice.com, 2003; Department of Energy, 2002). Surely, the automobile by its very concept requires a larger investment than a bicycle. Nevertheless, it is clear that in a rational assessment, the difference in willingness to pay is very disproportionate[146] and to the disadvantage of the bicycle. No

[145] Sports and leisure cycling may influence more significantly this relation in demographies that have a less extreme high and lows in bicycle use as in our used examples, and should then be considered seperatly.

[146] This disproportionate scale remains also present in second hand values.

wonder that the automobile can technologically be so much more attractive, if one is willing to spend so much money on it.

User culture

In fact, the whole user culture characterises how much one values a mode of transportation. If taking in other aspects as maintenance, insurance, parking space, fuel costs, acquiring a drivers license, etc. the automobile user culture by far exceeds the dedication given to cycling as transportation in the evolinear frame.

More use of the bicycle as transport indeed demands attitude changes. Many people do not like to cycle because they have had bad experience with a neglected bicycle, many being completely unaware of the much-improved cycling experience a quality bicycle has to offer (see also Table 2). High quality bicycles for transportation can be hard to sell not just because of the low financial value per se, but also because other factors discourage investing in cycling, for instance the fear of theft. The problem of theft is widespread and can be traced back to a low appreciation of the bicycle as a mode of transportation resulting in neglect to lock bicycles decently, lacking of secure parking infrastructure, inaction of law enforcement etc. Attitude change and infrastructure improvements are issues continually on the agenda of bicycle activists and planners for good reasons. In the end, a low valued vehicle will usually be neglected, and a highly valued vehicle is taken good care of, on both the personal and the policy level.

Velomobile valuation

For the adoption of the velomobile to be possible, one needs to become aware of the prejudiced perspectives from the established user cultures. The first part is to identify that a velomobile should not be evaluated as if it were a special bicycle or automobile, but as a separate vehicle category, that needs separate attention (i.e. the framework of reference of the new matrix).

People spend relatively a lot of time in their lives to acquire the abilities to operate an automobile, and many experts would argue that a lot more time is necessary. Likewise, serious bicycle riding cannot be learned in five minutes and — again — many experts would argue a lot more education would be useful here too. Once one knows how to use a bicycle or an automobile decently, it is relatively easy to adapt to the velomobile, but an appropriate learning period should nevertheless be accredited to it. Otherwise, the user bias, the blindness for the effort needed to learn to use any new mode of transport, will definitely prevent integration as velomobiles can easily be perceived as strange and difficult, and accidents will be more likely to happen. Again, the importance of a change in meaning of the velomobile in the cultural discourse is exposed. Building up a user culture is a slow process that builds simultaneously with the technology and may lead development in often-unexpected directions, as users also influence the meaning of technology by their demands.

Relative to the evolinear perspective of the bicycle, a velomobile, as a special bicycle, is unacceptably expensive. However, in the new matrix perspective, it is mere logic that a velomobile will always remain more expensive than a bicycle of comparable quality, as it is by concept a more complicated vehicle.

In addition, there is of course more to the cost of transportation than the cost of acquiring the vehicle. In Velomobile Design (1998:43-48), Fuchs made a comparison of the effective speed of the bicycle, the velomobile and the automobile (using public transport for long distances for the cycling options), taking into account all individual costs and the time needed to earn this amount of money. Even with the assumption of the, at the time, very high investment cost of velomobiles, the velomobile turned out to be a viable economic proposition for the assumptions made with an average income. The lower the income, the more economic the bicycle becomes, and the higher, the more the automobile emerges as the mode with highest effective speed. The competitive position of the velomobile only improves as the purchase price of a velomobile drops (which already happened since the study was done).
Now by itself the economic argument is not very convincing, but it usually does have the last word in a rational approach[147]. Any economic analysis depends of course very much on the presuppositions and what is counted as a cost or ignored as externality. Discussing this in detail is not within the scope of this paper (and probably premature anyhow). But it is not so hard to understand that if a velomobile is used for its purpose, its seemingly high price becomes reasonable or even inexpensive spread over the time of use[148], as running costs are very low and modern (good) velomobiles are designed for little maintenance.

It seems that a realistic price range for velomobiles in the future, both from the consumer and producer perspective, ranges from 1500 to 3000 EURO[149] for a modern, attractive and valued velomobile. If there is a strong user culture with constant development, even much higher prices may be acceptable.

6.4 Production and planning culture

For the spreading of velomobiles to be possible, there is of course also a need for a supply of velomobiles and their development. Just as user culture for the velomobile is very important, there is more to production that the actual means of production. There is a need for a production culture, involving and organising different actors with velomobile production. This production culture will need to be quite different from that of the innovator culture of the pioneers that work mostly by themselves. An effective production culture will include a deeper understanding of velomobile production and properties that make effective communication and cooperation possible. With the redefinition and the framework from the previous chapter, these meanings can arise without conflict of interest with existing industries of transport, but rather cultivating symbiotic parallel relations and properties as opportunities for a new market and production niche. Besides enrolling individual material engineers, airplane engineers, automobile designers and production engineers, it is the enrolling of complete social

[147] In some strong user cultures, driven by status and image, the approach may as well be completely the opposite to rational.
[148] There are velomobiles that are still running well after 120 000 km.
[149] This is situated in a similar price range of modern, attractive mopeds.

groups that can bring a production culture along that can be fruitfully adapted to velomobile applications. This scenario will make it possible for the velomobile industry to become competitive and profitable relatively fast.
Logical candidates to partake in velomobile industry are the automotive industry, which has many plastics and advanced production expertise, and the aerospace industry that already have experience with production and design of lightweight and aerodynamic structures. Transportation/engineering companies already produce and/or market bicycles, motorcycles and automobiles simultaneously within the same concern or even under the same brand name, so there is no reason why, eventually, the velomobile vehicle class could not find its place here too in the future.

Planner culture

In a further consequence, the New Matrix also affects the complete perspective of transportation planning and the associated culture.
For a planner culture in the evolinear sociotechnical frame, the introduction of a new vehicle category of the velomobile is hard to defend rationally[150]. However, if the velomobile is already included in the planning culture, it becomes simply a question to cater for some specific needs of the concept. With the conceptual understanding of the new Matrix, it becomes clear that velomobiles shares infrastructure demands with existing modes very well and that only minor adaptations — in a planning perspective — might be needed when velomobiles becomes more widespread (see also 4.5, p.66). That is, beyond the need for more cycling friendly infrastructure in general, where the velomobile can easily be included.

6.5 Future Velomobile users

It was discussed above how the velomobile can be synergetic with bicycle advocacy, some rational arguments for velomobile use, the importance of valuation. And user, production and planner culture. However, what kind of people will be willing to use a velomobile?

The first group of people that buy radical new things are the so-called early adopters. Early adopters are trendsetters, open-minded people who have a social position that moves them to set an example, despite the possible social consequences of behaving different; or people who actually actively seek to be different and are willing to pay an elevated price to do so. A group of dedicated enthusiast emerges. Whether or not the velomobile will progress beyond this market of early adaptors, into a more mainstream market remains to be seen[151]. Nevertheless, if it does, the so-called ‘usual cyclists’[152] will probably not buy velomobiles at first. ‘Usual cyclists’ use the bicycle out of financial considerations or because they do not have a driver’s licences, traditionally the largest group of bicycle users (e.g. in student-cycling towns). Being a ‘Usual cyclist’ can of

[150] In parallel, the introduction of any new vehicle category that is not thought to have a right to exist is hard to defend rationally. Just imagine a world without an automobile and the planning nightmare to introduce it.
[151] Not that the market of early adopters is not worthwhile by itself.
[152] ‘Usual cyclist’ and ‘option cyclists’ are terms burrowed from Pappon (1999).

course can be a very desirable status and be a conscious choice. The status of an emerging velomobile culture as transportation can keep cycling an attractive option to 'usual cyclists' even when their financial situation improves or when they acquire driver's licences. This brings us to the group of 'option cyclists' — people that can choose to cycle or to use the automobile, where the velomobile will probably find its first customers.

This large group of 'option cyclists' are in principle willing to cycle, usually motivated by health and environmental arguments, but for various reasons do not always put their intention into practice. The choice is there and cycling is in direct competition with their 'second living room', the automobile. If they have the choice of the velomobile that receives status in an emerging velomobile culture, cycling can become a more convincing option. This is not about exchanging the automobile for a velomobile completely, but about it being the preferable option for shorter distances, replacing the unnecessary, inefficient use of the (second or third) automobile.

In either case, cycling that includes velomobiles does not only need attitude change in the form of goodwill for cycling, but also a user culture that builds up status and that spurs continuous development to keep the human powered option an attractive one. Of course, various marketing strategies can draw positive attention to the velomobile.

Table 4 summarises the above by visualising the space that the velomobile can fill up in the value range of cycling as transportation. Instead of an evolinear progression that inevitably goes to motorisation, this new perspective — that corresponds to the new matrix sociotechnical frame — shows the parallel between motorised and cycling modes, that both can appeal to different kinds of use.

Table 4: Velomobile as valued cycling transportation

User culture	**Motorised**	**Cycling**
Budget transport	Moped, light motorcycle, scooter.	Student-Commuting bike
Recreation-Sport; Occasional transport	Motorcycle	Racebike, mountainbike
Valued, status transport	Automobile	Velomobile

From the parallel in the above table, it comes forward that maybe another route to success of the velomobile exists that does not require a basis of a valued *bicycle* user culture. Perhaps the velomobile user culture can succeed as a transportation proposition where the bicycle has failed before, because the meaning of the velomobile can be disconnected from the low-status utility image of the bicycle and because, as a higher cost proposition, the velomobile gives its user status. In likewise manner, the user of the velomobile may receive more respect in traffic as a 'real' vehicle and as a mode of transportation than a bicycle. The absence of respect for the latter, coming from attitudes from both motorists and bicycle users, is a very important if not the most important source for cycling unsafety, an idea since long promoted by Forester (1992).

So while presently there is a need to appreciate cycling first before one can understand the velomobile as transportation, it might be possible that the understanding emerging from a velomobile user culture can lead to taking up the bicycle as transportation because of the velomobile example.

The velomobile has a place as a niche of valued transportation, one that the bicycle concept has difficulty to fill. It is not so difficult to imagine a valued velomobile user culture: valued cycling culture already exists in the leisure/sport category, i.e. mountain bike and racing bike culture, which has many parallels with the valued motorcycle user cultures. Likewise for the velomobile, there are parallels with the automobile user culture, quite apparent from the new matrix sociotechnical frame form the previous chapter. This valued transportation user culture goes much beyond the functional transportation function[153]; rather this transportation function emerges as the most important use simply because of the nature of the vehicle concept.

Different user groups

Today, the largest group of enthusiastic velomobile users, as with automobiles, are middle-aged men. However, the parallel between the velomobile and automobile user culture, as valued transportation, does not extend in all aspects. The automobile performs transportation and social roles that cannot be replaced by the velomobile. On the other hand, a velomobile is much more accessible as it is of much lower (variable) cost than an automobile[154] and does not have an age limit or require a driver's license.

As such, the velomobile can appeal to a wider group of users compared to the automobile, presuming that progressively a diversity of velomobiles becomes available that can address diverging needs, financial situations and preferences of differing groups in the population.

As such, there is a large opportunity to appeal to youth in search of mobility and freedom of movement. Although bicycle sales keep rising, bicycle use as transportation with young people is in decline. The bicycle has an image problem, but if a velomobile user culture develops that has status, a velomobile might become an interesting upmarket option, one similar to the role performed by mopeds today. A velomobile can be preferable to a moped for several reasons: besides environmental reasons, there is no restrictive speed legislation on velomobiles, and legal speeds can be more attractive[155].

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[153] Otherwise all would be satisfied with an automobile that manages to perform its utility function, and any new automobile much above 10 000 Euro would be hard to sell. Reality is different obviously.

[154] If there is a velomobile culture, a second hand market will also emerge that makes velomobiles financially much more accessible even if compared to second hand cars.

[155] When talking adolescent males, it is popular to illegally tune mopeds as one is very easily bored by the limited motorised speed. Velomobile riders are, on the road, bound by the general speed regulations, and fast velomobiles are thus allowed to reach higher speeds, e.g. 70 km/h if the rider is fit, giving also the satisfaction of self-accomplishment that a motorised mode cannot provide. On the other hand, cruising with a velomobile can also be very satisfying, something that the 'always full throttle' moped attitude lacks (an

Moreover, the riding experience of velomobiles is of a different nature than two-wheelers, and can be very entertaining. A group of teenagers in Belgium had the Alleweder velomobile as the 'cool' vehicle of choice, so this is certainly possible: a different kind of boy racer culture[156]. A velomobile racing culture can also emerge[157], where the social ordering is not as much determined by the most expensive machine, but also by the health and fitness of the rider.

As another social group, women can also become an important user group. Women react very positively to the velomobile idea and I see no reason why they would be less avid users then the men in the future[158] (e.g. Figure 41). Where the automobile user culture has a distinctive male macho connotation and women tend to use automobiles more out of necessity, the velomobiles appeal to a different, more friendly set of arguments, such as health and environmental care. As such, a distinct and enthusiastic user group can emerge here.
Finally, also the social group of the 'older' people can find their use in a velomobile. Actually, recumbent bicycles are most popular in this age group in the USA. Likewise, velomobiles could be a relaxing and peaceful way to keep mobile. Not all people have by default the possibility to cycle, but one must not underestimate how able 'older' people can be. In case pedal power indeed is restricted, an assist engine can increase the attractiveness of a velomobile here to a large degree.

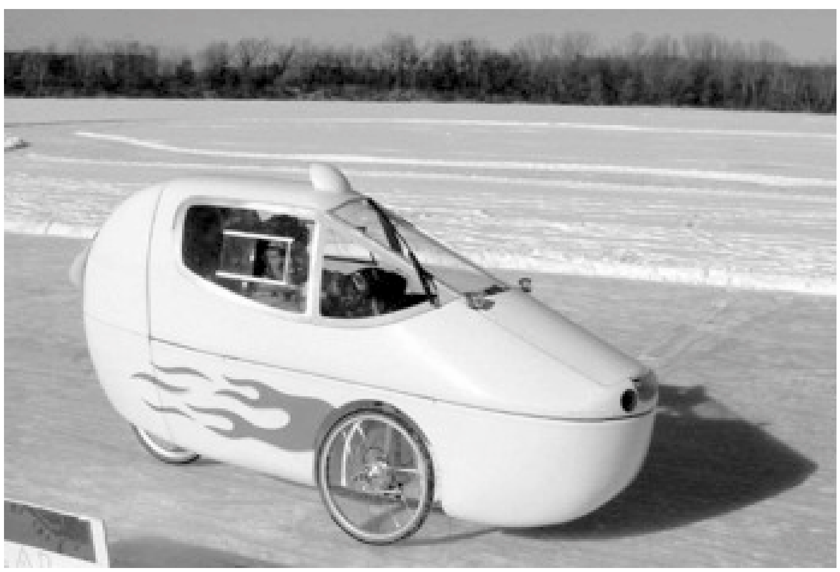


Figure 41: Mary Arneson from Minneapolis (USA) is an avid velomobile user, actively promoting velomobile use
(Photograph from www.cab-bike.com)

adolescent 'psycho-cultural issue', I have yet to see a young, male single rider of a flashy moped that takes it easy on the right wrist :-).

156 I should know, because during my youth I was part of such a group. Hans, Tim, Lex, Bart, Nico and Frederik all crossed around in their Alleweders together, short and long rides, and in the end it was very 'normal' to use velomobiles and a lot of fun.

157 E.g. a more advanced form of soapbox racing.

158 Current velomobile producers are already considering smaller models more suitable for women, as most current models fits person up to a lengthy 2m.

6.6 The new perspective on individual transportation because of the velomobile

If one succeeds in modifying the evolinear frame by introducing the velomobile, thus creating the new matrix sociotechnical frame, there are consequences that go beyond the acceptance of the velomobile per se.

Even the presence of a small[159] but persistent number of velomobiles — sufficient for everyone to have some personal experience with the phenomenon — can then work as a strong reminder to draw into question the current form of auto-mobility. When the velomobile concept, as a new vehicle category, can make the new matrix sociotechnical frame reality, the individual transportation modes relate more logically. This also includes the other marginal vehicle concepts, see Figure 42, which did not fit into the evolinear frame (Figure 39). There is no longer an 'upgrading' and a 'downgrading' but a more sensible organisation of individual transportation. Each concept position in the matrix has its advantages and disadvantages. Motorcycles are not 'better' than automobiles, they are just different. Likewise, cycling (human power), in the lower half of Figure 42, is a principal choice, not inherently better or worse than being motorised in an absolute sense, just different, serving another set of priorities.
This is a very basic, yet fundamentally new perspective on individual modes of transportation.

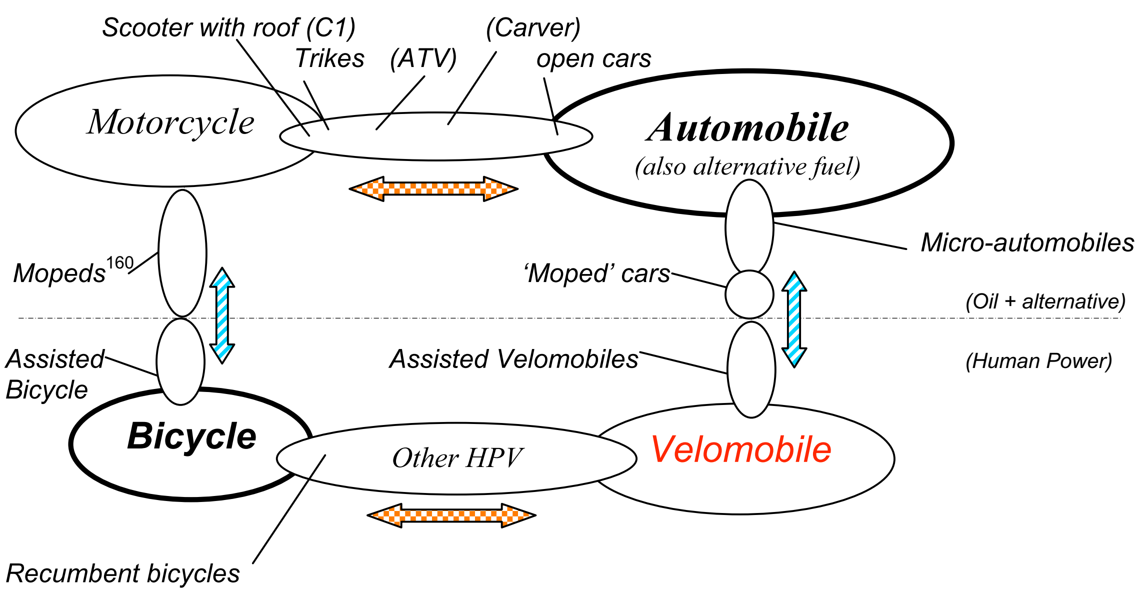


Figure 42: (alternative) vehicle concepts in their relative position to the new matrix sociotechnical frame

Future visions of transportation can incorporate a more balanced view where all sociotechnical frames deserve technological development. In the new matrix frame, it

[159] With 'small', I mean something like 1% of all trips, and not 0,001%.
[160] The moped is included in the Motorcycle sociotechnical frame but pictured separately here to 'meet' the assisted bicycle

becomes harder to defend the automobile as the *only* solution for all transportation demands. It works the other way too; the automobile itself is no longer the subject of hostility as it happens because of the automobile centered evolinear perspective. In the new matrix, it is more the inappropriate *use* of the automobile concept (and not the concept by itself) that comes more clearly to the attention.

More alternatives

The new matrix sociotechnical frame from Figure 42 does not make sense if there is no concept of the velomobile. Then the intermediates are in the current situation: the recumbent bicycle struggles to gain acceptance in the established bicycle sociotechnical frame, and automobile cultures find it almost impossible to move to lighter vehicles again and microcars and moped cars are in a very marginal position; they conceptually dangle in thin air. See Figure 43.

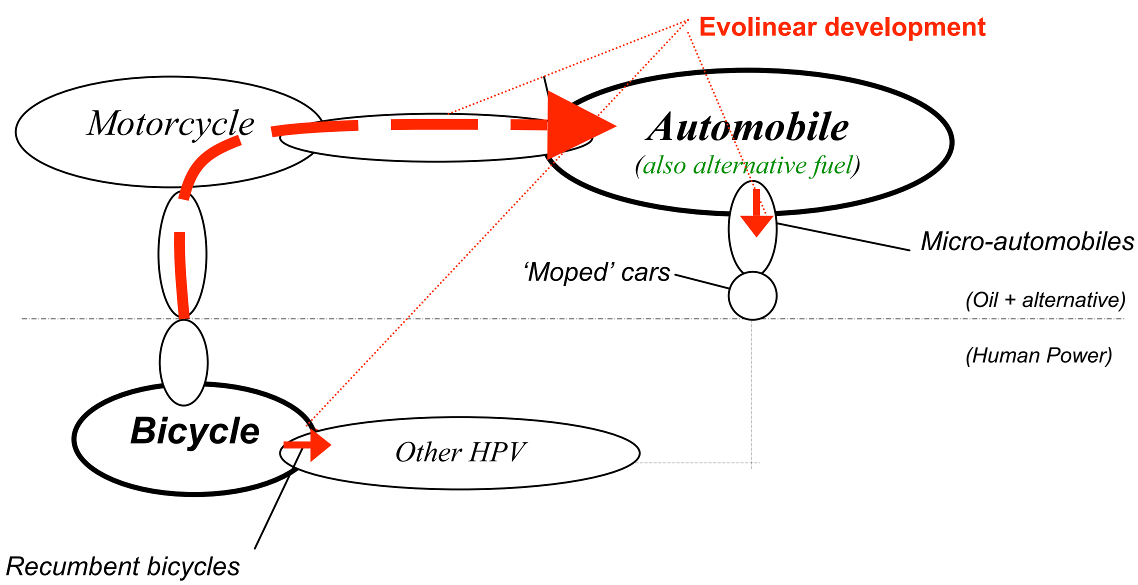


Figure 43: How development is inhibited in the present evolinear conception without the velomobile concept

The velomobile is, next to the existing motorcycle, the second concept that links the bicycle to the automobile. The velomobile frames more effectively the presently marginal concepts in this second link. Moreover, these intermediates in the second conceptual link are all, relative to the existing evolinear frame, *green* developments! See Figure 44.
However, if the velomobile sociotechnical frame becomes stabilised and the velomobile becomes accepted as a sensible mode of transportation, this also opens up the whole spectrum of other human power vehicles for acceptability. It also makes lightweight — and thus efficient — automobiles more credible again, as there is a concept that is even lighter and already credible.

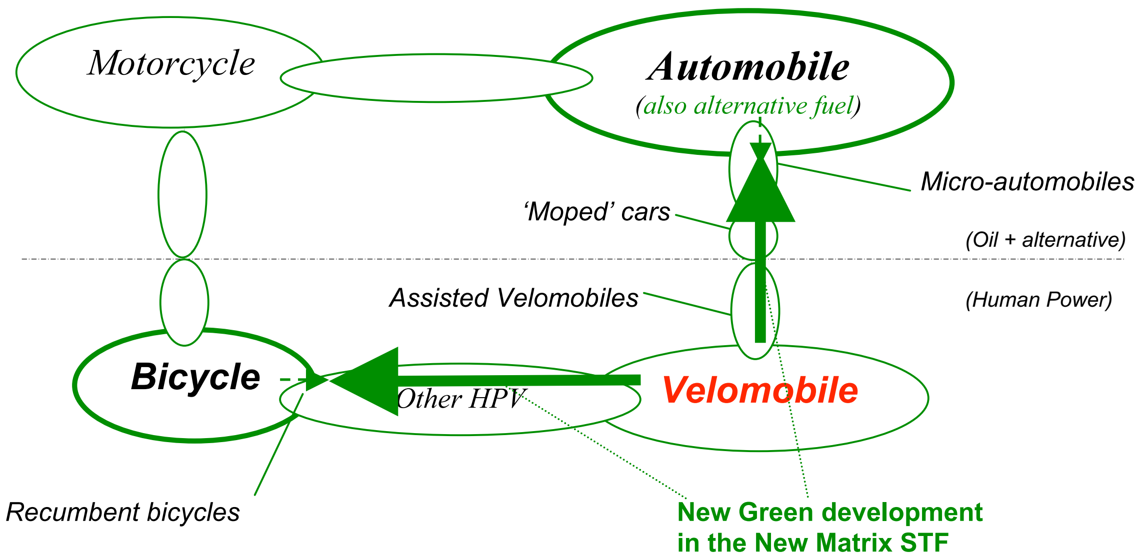


Figure 44: How the velomobile cornerstone inspires new green development away from its own concept

Even if the velomobile itself as a technology does not truly become widespread, the simple fact of its existence as a cornerstone concept facilitates the social and cultural acceptability of alternatives between the velomobile and the established ones. Lightweight automobiles and a large diversity of human powered vehicles today struggle to stretch their acceptability by trying to appeal as much as possible to the cultures of the established sociotechnical frames of the respective automobile and bicycle. This process is ambiguous as their respective concepts move away from the accepted standard; the whole is a difficult balancing attempt to stretch the acceptable. The meaning of the velomobile concept provides a counterbalance, pulling open a new spectrum of acceptability in the new matrix sociotechnical frame.

7 Summary

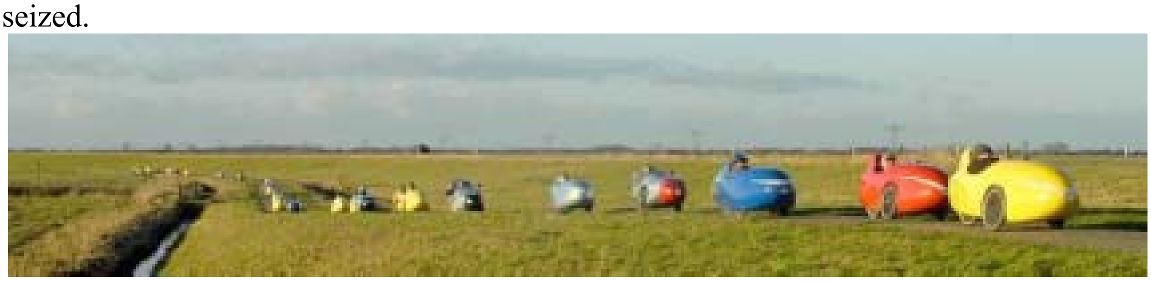
The goal of this paper was to give a comprehensive coverage of how cycling can continue to develop as transportation. I have introduced a theoretical foundation on which to situate cycling history and to build the ideas and concept around the velomobile.

By describing cycling history and using the social construction of technology theory, it became clearer why certain cycling solutions developed, and why others did not. Moreover, it showed how the solutions that did develop obstructed further development. The model of the evolinear sociotechnical frame was introduced to characterise this and the current attitudes to individual transportation. Introducing the velomobile as a new vehicle category in relation to this evolinear frame provided a social mechanism of change that transforms the velomobile from a marginal phenomenon of little impact into a cornerstone concept of individual transportation in the new matrix sociotechnical frame. This transformation includes a redefinition of the velomobile from a special bicycle to a mode of itself. The new matrix sociotechnical frame also has consequences on the complete perception on individual transportation. Moving away from a hierarchic ordering where one mode is 'better' than the other, to the understanding that a greater diversity in individual transportation can serve the differing transportation needs of society in a better, more ecologically sustainable way. It became clear what place the velomobile has in the larger perspective of individual transportation.

As such, I hope this paper brought us closer to what Cox (2004) sees as a solution for velomobile adoption:

> *The task of successfully marketing the velomobile, i.e. creating sufficient desire to justify expanded production, must be thought of within a wider revision of transport options in which the automobile does not have automatic recognition as the object with highest exchange value.*

The possibility to create a completely new vehicle category is unique yet inherent to the velomobile concept. Most vehicle concepts are predestined to try to assimilate with established sociotechnical frames, but not so the velomobile. Times are showing signs that, although the automobile continues to get the lion share of the attention and continues to become better and fatter (as do their drivers), there is a growing demand for alternatives to the automobile. The concept of the velomobile can play an important role to offset the unsustainable transportation patterns in the post-modern world and its development as a technology of transportation is a unique opportunity that should be seized.



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Appendix

Contents:

A Speed simulations of bicycles and velomobiles in different conditions.

B Qualitative questionnaire to understand how people distinguish between a motorcycle and automobile.

C Polymer production options for velomobile bodies

A Speed simulations of bicycles and velomobiles in different conditions.

Complete equation for speed simulation of land vehicles:

P x (n/100) = Vr x [{Mt x g x (Cr + (h/100) + a/g)} + {0,5 x rho x Cd x A x $(Vr + Vw)^2$}]

Where: P = Power delivered (at pedals) (W); n = power transfer efficiency to drive wheel(s) (%); Vr = Vehicle speed (m/s); Mt = Total mass rider + vehicle (kg); g = gravitational acceleration (m/s^2); Cr = Rolling resistance; h = slope (%); a = vehicle acceleration (m/s^2); rho = air density (kg/m^3); Cd = Drag coefficient; A = Frontal area (m^2); Vw = wind speed against riding direction (m/s)

Table A: Variables* used for simulating Table 2 on page 59

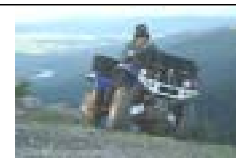
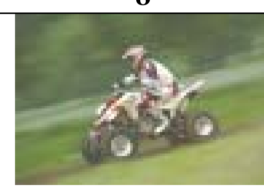
Assuming a rider 1m80 tall, 70kg	**n**	**Mt** (kg)	**Cr**	**A** (m^2)	**Cd***
Neglected safety bicycle with bad ergonomics/gearing (e.g. n_1=0,8), rusty chain (n_2 = 0,8), underinflated tires.	*0, 64*	*90*	*0,0100*	*0,5*	*1,20*
Good, regular bicycle for transportation use (fenders, luggage rack, upright rider position, well maintained and good inflated tires, normal loose clothing)	0,92	90	0,0050	0,50	1,20
Average velomobile (Flevobike Alleweder)	*0,90*	*106*	*0,0040*	*0,50*	*0,40*
Racing bicycle UCI compliant, deep racing posture, tight racing clothing.	0,96	80	0,0030	0,35	0,90
Fast, practical velomobile (Velomobiel.nl Quest)	*0,92*	*102*	*0,0040*	*0,46*	*0,24*

*These figures are deduced from testing done by the NVHPV, the Dutch national HPV association. The figures are deemed to be representative as average examples, however considerable variation is possible for true situations and between seemingly comparable configurations, especially for the non-streamlined configurations in the A and Cd values.

B Qualitative questionnaire to understand how people distinguish between a motorcycle and automobile.

A small experiment was conducted to better understand how people distinguish between a motorcycle and automobile, so not to impose too much of my own perspective. The test consisted of the following procedure: the interviewer asks the test person for a spontaneous reaction to a fixed sequence of 12 pictures of vehicles, the question being: ‘automobile or motorcycle?’ The test person could only see the following picture after the previous was answered. After this selection, the pictures sequence was repeated, but this time the test persons were asked to tell why they chose what they chose, i.e. which selection criteria did the test person use; they were also allowed to change their mind on the first question with the option to change to ‘I don’t know what it actually is’. Care was taken not to suggest new criteria during the interview. The last question was if they knew any of the vehicles showed specifically by make or model. The used pictures[161] are presented in Table :

Table B: Test pictures: “automobile or motorcycle?”

 **1**	 **2**	 **3**	 **4**
 **5**	 **6**	 **7**	 **8**
 **9**	 **10**	 **11**	 **12**

The pictures were kept small (approx. 6 x 8cm) so that the test persons would not look for clues in details[162] and only consider the ‘big picture’. Limitations are of course that the pictures only give one perspective of the vehicle and that the true dimensions are not always so easy to discern, if one is completely unfamiliar with the vehicles. In addition, the sequence can have some suggestive force that might influence the results, as the test persons ‘learned’ from their own criteria, but this seems unavoidable.

Twelve persons were interviewed, mostly (international) students and their answers are found below in the table. A larger group of test people is of course desirable to statistically represent the population, but as a qualitative research, the answers are useful

[161] Pictures courtesy of the respective manufacturer websites.
[162] E.g. brand names, small typical accessories etc.

nevertheless, especially since we actually do not expect a consistent answer to the research question in the first place. And, indeed, the test persons use the most diverse criteria to separate respectively a motorcycle (MC) from an automobile (AM). Here is the summary of criteria used:

- 'Looks' (look of front side is most relevant)
- number of wheels
- narrow or wide
- short or long wheelbase
- tandem seating or sociable
- short or long
- high or low seat
- handle bars or steering wheel
- leaning or not
- Automobile is stable by itself
- open or closed body
- 1 or 2 front lights
- no nose or long nose
- 'small' or 'large'
- no bumpers or bumpers
- sport or serious
- gas handle or pedal
- macho or family
- automobile has more than two occupants
- leisure or work
- small or large engine
- visible or invisible engine
- motorcycle or automobile like wheels
- front wheel directly steered or linkage system
- automobile has central rear view mirror

Etc.

Most of the used criteria were inconsistent with the answers the test persons themselves gave over the whole range of 12 pictures. This confirms that the sociotechnical frames ('vehicle categories') are socially constructed, and not technically defined. Concerning the third question, the only vehicles that were recognised by make by test persons were the BMWs in picture 1 and 3. A summary of the responses to question one and two is found below.

Some conclusions that appear reasonable to conclude from this limited experiment are presented here:

The most powerful selection criteria were associations with things know, i.e. 'looks'. Most obvious example is picture nr. 11 and 12: the former was many times called an automobile, the latter always (except for one) a motorcycle, even if technically seen, they have the same configuration.
There were many clues that motorcycles have a close association with leisure, sports, speed and macho connotations.
Noteworthy result was that all found picture 6 to be a motorcycle, despite most criteria used point to the opposite; there is a strong indication that any motorised vehicle on two wheels, leaning into curves is per definition a motorcycle.
Picture 7, the Vandenbrink Carver, was most confusing for all test subjects. According to the manufacturers, it is a special automobile.

In the end, most respondent were quite confused in their 'vehicle world view'[163]. The vehicles used are either marginal to the stereotypes of the motorcycle and the automobile sociotechnical frame or have already stabilised as rather unknown specialist variants. Which vehicle belongs in which sociotechnical frame according to the manufacturers can also be found in the below table.

Motorcycle or automobile? **(MC or AM)** Version 1.4

Answers of	Fig. 1	Fig. 2	Fig. 3	Fig. 4	Fig. 5	Fig. 6	Fig. 7	Fig. 8	Fig. 9	Fig. 10	Fig. 11	Fig. 12
Pers. 1	MC	AM	MC	AM	AM	MC	MC	MC	AM	MC	MC	MC
Pers. 2	MC	AM	MC	AM	AM	MC	AM	MC	AM	MC	MC	MC
Pers. 3	MC	AM	MC	AM	AM	MC	MC	AM> ??	AM	MC	AM> ??	MC
Pers. 4	MC	AM	MC	AM	AM	AM> MC	AM	AM	AM	MC	AM	AM> ??
Pers. 5	MC	AM	MC	AM	AM	MC	AM	AM	AM	MC	MC	MC
Pers. 6	MC	AM	MC	AM	AM	MC	AM> ??	AM	AM	MC	AM	MC
Pers. 7	MC	AM	MC	AM	AM	MC	MC> AM	MC> AM	AM	MC	MC> AM	MC
Pers. 8	MC	AM	MC	AM	AM	AM> MC	AM	AM	AM	MC	AM	MC
Pers. 9	MC	AM	MC	AM	AM	MC	AM	AM	AM	MC	AM> ??	MC
Pers. 10	MC	AM	MC	AM	AM	MC	MC> ??	AM	AM	MC	AM> ??	??
Pers. 11	MC	AM	MC	AM	AM	MC	MC> ??	AM	AM	MC	AM	AM
Pers. 12	MC	AM	MC	AM	AM	MC	AM	MC	AM	MC	MC	MC
Manufacturer's positioning	*MC*	*AM*	*MC*	*AM*	*AM*	*MC*	*AM*	*MC*	*AM*	*MC*	*MC*	*MC*
Make and model	BMW C1	Grinnall Scorpion III	Grinnall Trike	Reliant Robin	VW 1L proto	Peraves Turbo Mono Eco	Vanden-brink Carver	Yamaha Grizzly 660 '04	Renault Sport Spider	Hand-built?	Yamaha Grizzly 660 '04	Yamaha Raptor 660 '04

Legend: MC = Motorcycle AM = Automobile > = reconsidered in 2nd question round ?? = don't know

Test person specifics

	Nationality	Gender	Driv Lic	Age	Education
Pers. 1	India	m	MC, AM	24	Chemical engineer
Pers. 2	Zimbabwe	m	MC, AM	35	Engineer
Pers. 3	Sweden	m	AM	29	Law
Pers. 4	Sweden	f	AM	21	Logopedics
Pers. 5	Sweden	f	AM	28	IT
Pers. 6	Norway	f		22	orthopedics

[163] And afterwards, they were very understanding for the velomobile concept

Pers. 7	Ethiopia	m		28	Geologist
Pers. 8	Indonesia	f	AM	26	Environmental engineer
Pers. 9	Sweden	f		15	Music
Pers. 10	Nepal	f		31	Civil Engineering
Pers. 11	USA	m	AM	19	High school major Biology
Pers. 12	USA	m	AM	20	High school major sciences

C Polymer production options for velomobile bodies

The polymer industry players are certainly welcoming more applications for their state-of-the-art production technologies, as the overall world market demand for lightweight vehicles and structures is, relatively, behind the initial expectations. The polymer industry is an important contributor in the automobile industry especially in interior applications, but the more structural and larger applications like automobile bodies remain predominantly steel.

There are other thermoharder methods, other than open mould hand lay-up, exist, e.g. vacuum injection moulding (suitable for large parts) and RTM (Resin Transfer Moulding), but these methods are most probably not the most interesting because they do not allow much accelerated production speed (but more control and quality) and have a high investment cost (RTM) and it is doubtful that the desired thickness (i.e. relatively very thin) of the velomobile body can be achieved. If the latter is solved however, these methods can be used for medium scale production.

Probably the most suitable material for series production is a thermoplastic polymer, possibly reinforced with glassfibres or organic fibres. Injection moulding is the most common application of thermoplastics, materials being i.e. PP (Poly Propylene), PE (Poly Ethylene), PET, ABS, etc. Injection moulding something as large as a velomobile body, even in several parts, is quite uncommon, but it is possible. The tooling for large parts is very expensive, but because of very short cycle times, it makes very high productivity possible. It also gives a lot of freedom of shape. The newest methods even allow long strand glassfibre reinforcement, allowing high performing structural parts. The reinforcement can also be injected together with the resin, and Chrysler has already experimented with three prototype cars, which have a thermoplastic (PET with 15% glass) body and *structure* (Materials World, 1999). Not yet applied in production of automobiles, it might be ideal for velomobiles.

Rotomoulding is another possible production technology that could be investigated, and has already been used on the lightweight Cree electric three-wheeler prototypes.

Finally, a potential technique is thermoforming or hot press moulding of thermoplastics. A heated sheet of (reinforced) thermoplastics is formed in a mould by mechanical force or using vacuum. This also allows very short cycle times and structural parts, although surface finish is more problematic.