16th INTERNATIONAL SYMPOSIUM ON
THEORY AND PRACTICE IN TRANSPORT ECONOMICS

BUDAPEST, 29-31 October 2003

50 YEARS OF TRANSPORT RESEARCH:

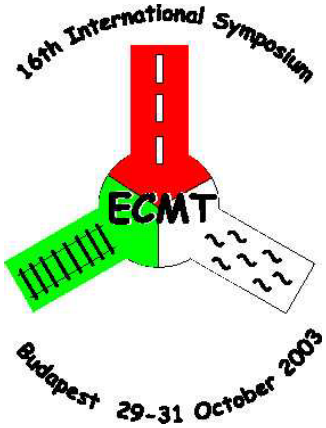
EXPERIENCE GAINED AND MAJOR CHALLENGES AHEAD

Topic 3:

Sustainability of transport: The roles of modal split and pricing

a) The role of modal split

Hermann KNOFLACHER
Technische Universität Wien
Vienna
Austria



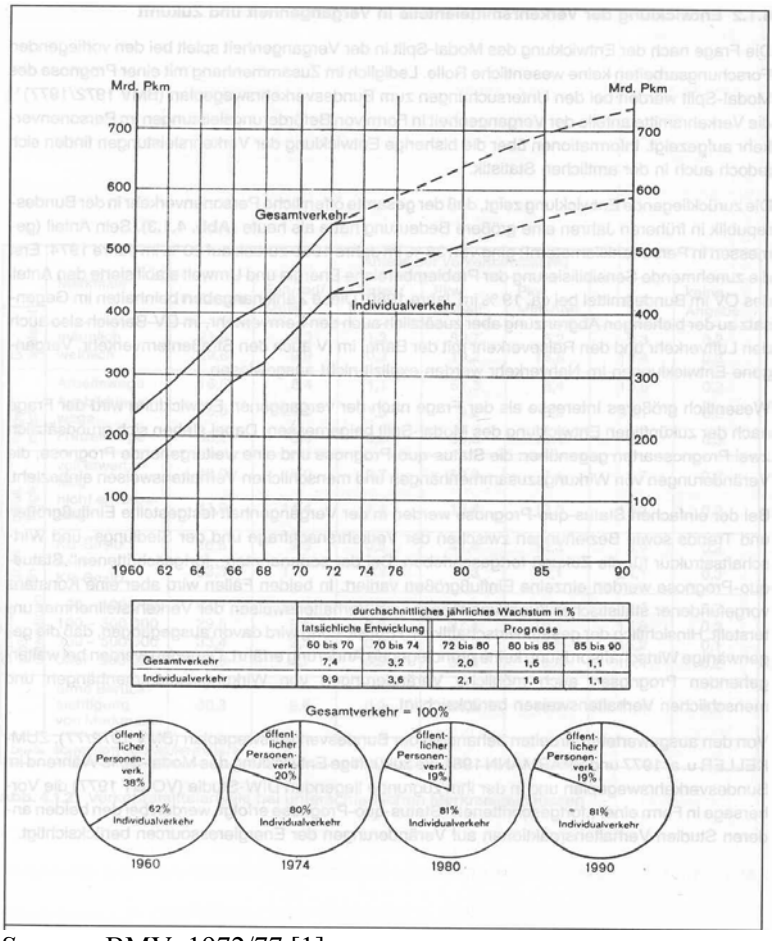
SUMMARY

Vienna, February 2003

1. HISTORICAL BACKGROUND

Modal split is a fairly new technical term in traffic engineering because, for most of history, the majority of people generally had no modal choice. Even in earlier times, transport in some parts of the world was not sustainable; for example, Venetian ship-building caused deforestation around the Mediterranean. With the invention of new transport technologies such as the railway and the aeroplane, transport scientists had to address the problem of modal choice. To describe the phenomenon, they devised a "modal split" indicator. The term "modal split" was primarily used to describe the "mobility shares" of the various means of transport -- car and public transport. Figure 1 shows a typical forecast from 1972.

Figure 1. **Forecast of person-kilometres**
[the modal split is shown in the circles at the bottom of the figure]



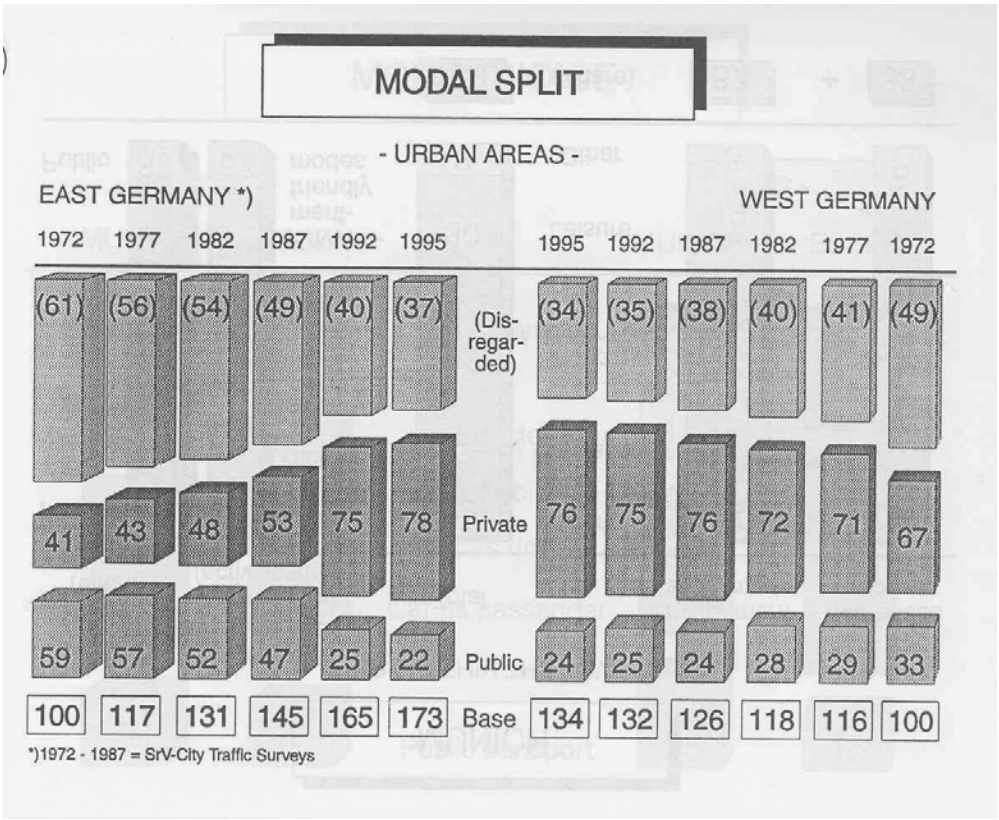
	durchschnittliches jährliches Wachstum in %				
	tatsächliche Entwicklung		Prognose		
	60 bis 70	70 bis 74	72 bis 80	80 bis 85	85 bis 90
Gesamtverkehr	7,4	3,2	2,0	1,5	1,1
Individualverkehr	9,9	3,6	2,1	1,6	1,1

Source: BMV, 1972/77 [1].

This rather restrictive definition of modal split was mainly used by traditionally educated transport engineers who were totally focused on mechanical transport systems. The use of this indicator gave the impression that mobility was increasing. The unit of scale was usually the number of person- or tonne- kilometres for each of the two modes. Sometimes the number of trips made with the two modes was also used [2].

The traditional concept of modal split and transport planning disregards non-motorised transport users such as pedestrians and cyclists. City planners and social scientists, but also traffic engineers with a more holistic view, tried to construct an indicator that would also include these modes. Transport scientists from various disciplines replaced the extremely narrow definition of modal split by the "common standard of today", which includes all modes i.e. non-motorised transport users as well. The problem was to define the correct unit of scale. Kilometres were not appropriate any more and the "trip" unit also had to be specified since many trips are made with different modes. Every trip by car or public transport also has at least one pedestrian trip at either end. Usually, the main mode used during the trip in terms of distance or time is considered to be the dominant mode. Depending on which definition is used, the results differ. For example, in the City of Vienna the split between car, public transport and non-motorised modes is 37 : 34 : 29, or if all trips in public space are counted separately, 16 : 14 : 72. In freight transport, up to now, the dominant role of non-motorised users has not been taken into account.

Figure 2. **If the definition of modal split is restricted to mechanical transport modes only, then the large share of non-motorised modes is disregarded**



Source: W. Brög [3].

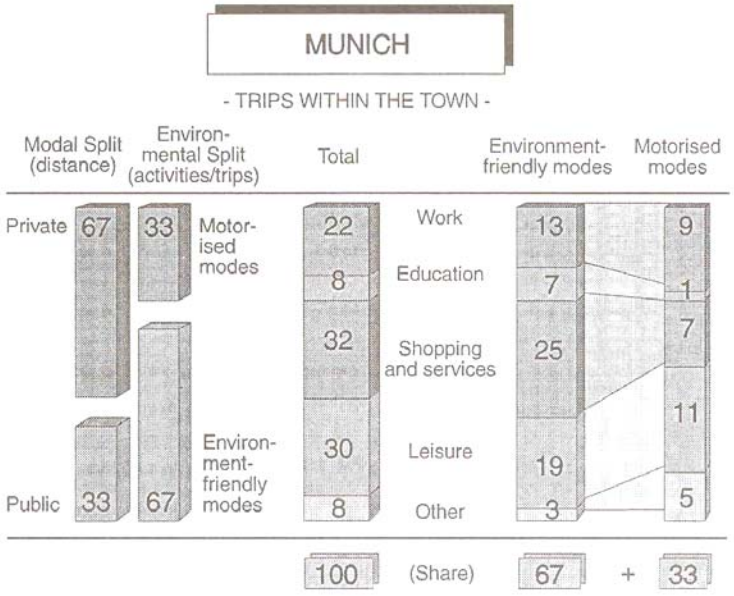
2. INDICATORS THAT GIVE A BETTER UNDERSTANDING OF MOBILITY

The "person-kilometres" or "tonne-kilometres" unit became obsolete with the change in the way mobility was understood. Surveys showed that increasing speeds in transport systems were not reducing travel time, an observation already found in Lill's law of 1889 [4]. The analysis of worldwide surveys by Schaefer *et al.* [5] also confirmed this important finding. On the other hand, the average number of trips for person per day has not changed with increasing car use.

These two findings had an important impact on the modal split definition. The traditional definition does not satisfactorily reflect the actual state of affairs. The constancy of all mobility indicators (except for distance) has to be taken into consideration. The modal split indicator requires another standard of comparison [6][7]. As Brög has shown in his comparative studies of East and West Germany, a substantial part of mobility was ignored by the traditional definition of modal split.

Furthermore, only the number of trips is taken into consideration and not the number of kilometres (Figure 2). The differences between the definitions are clearly visible in Figure 3. Using distance as the basis for calculating modal split no longer makes sense. This applies to all the various modes (non-motorised: pedestrian, cyclists; motorised: mopeds, cars and coaches; public transport: bus, tram, metro, rail and even air). The purpose of the trip also has to be taken into consideration.

Figure 3. **Distance- or trip-based calculations give different results for the modal split**



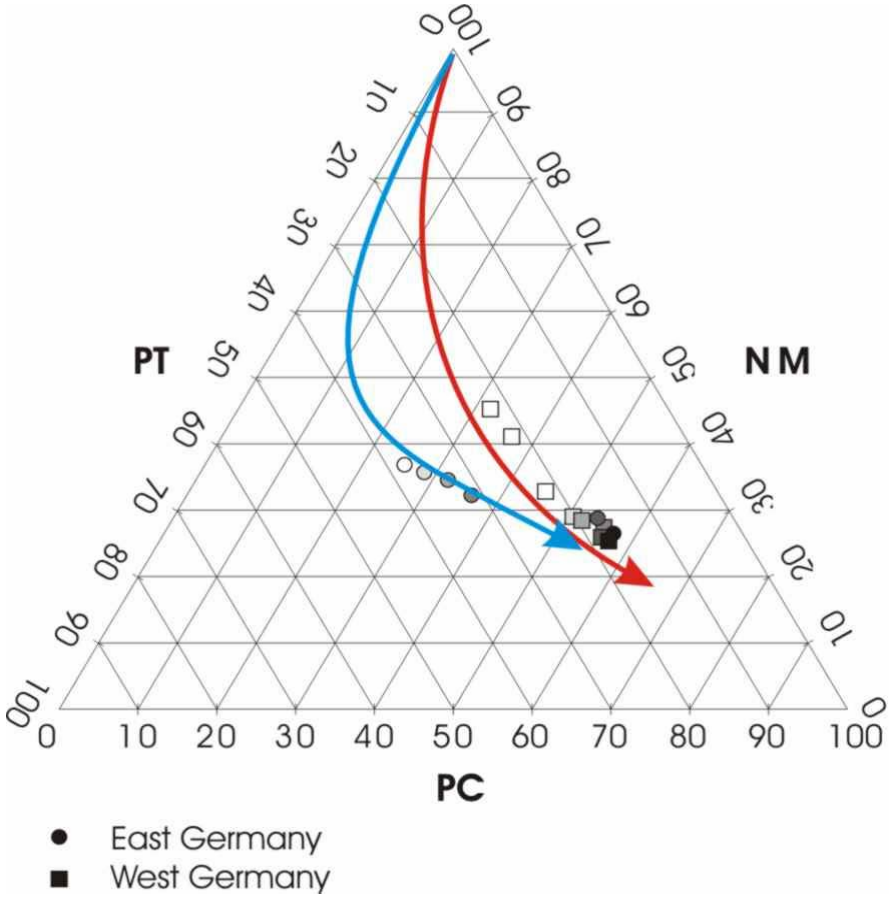
Source: W. Brög [3].

3. TRENDS IN MODAL SPLIT

The dominant trend in transport over the past hundred years has been the growth of car traffic.

Cars, as they are used today, cannot be considered a sustainable mode. Car travel requires much more space, material resources and non-renewable energy than any other land-based mode. The rising trend in car use is unsustainable. Figure 4 shows the path of modal split in a Modal Split Triangle, from the uncomfortable but sustainable area to the present comfortable but unsustainable transport system. If we want to develop a sustainable transport system, we must escape from the bottom right-hand corner. One way of doing this, which is often discussed in the literature, is by pricing.

Figure 4. **The path of modal split runs from sustainable modes (top left-hand side of the diagram) to the unsustainable modes in the bottom corner**



West Germany: red line; East Germany: blue line
(PC = private car, PT = public transport, NM = non-motorised mode)

4. A LOT OF EFFORT, MANY ATTEMPTS BUT FEW CONVINCING RESULTS

With the increasing awareness of the down side to comfortable mechanical transport, countless efforts have been made to change the trends in modal split. Urban transport took the lead in this development. The growing volume of long-distance road haulage in the Alpine valleys has been a problem since the 1980s. Future-oriented transport policy concepts propose a change in the modal split [8].

One of the core measures proposed is pricing, i.e. using financial mechanisms to induce people to adopt more sustainable transport modes. In [9] Rothengatter wrote, *"There is no contradiction between economic roles and sustainability if the prices for environmental goals are clearly set and rationally expected for the future. But the problem is the key issue: to convince people, because they are also voters and buyers."* He thus called for more analysis in regard to the following objectives:

- To convince people that environmental objectives and internalisation measures are scientifically -founded and feasible;
- To simplify and clarify the scientific reasoning and results, so people can understand the message;
- To construct scenarios for different measures if environmental actions also have some negative impacts, e.g. the redistributional effects of CO_2 charges;
- To develop bonus and refund systems if environmental pricing generates high tax revenue, so such measures are not perceived as being designed to balance public finances.

Rothengatter called for a transport system with a more effective feedback mechanism. In regard to priority infrastructure in Europe and its funding, he states: *"Additional capacity must be rapidly provided in response to Europe's new commercial geographical structure. A European infrastructure master plan is required that will both cover the main routes in inland rail, road and waterway transport, in sea transport and in air transport, and co-ordinate measures for the development and creation of infrastructure."*

There is a certain contradiction involved in trying to achieve more sustainable transport without a basic change in existing structures. A clear systemic analysis is therefore necessary.

5. DATA AND THE UNDERPINNING METHODOLOGY

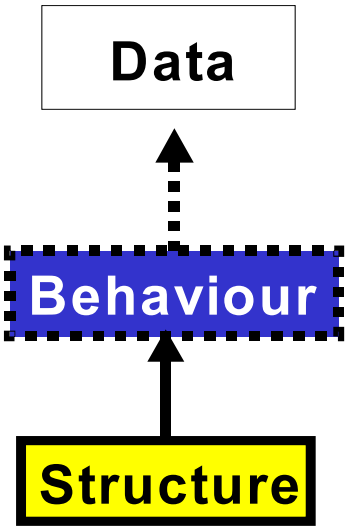
The modal split is an indicator (regardless of the base unit used) which is based on data. Data are the reflection of a given perception of reality. The traditional definition of the modal split -- between car and public transport -- reflects the way in which traditionally-educated transport engineers perceive reality. The kilometre unit expresses their "world view". The definition of modal split, based on the

number of trips or tonnes and including non-motorised transport, is not used but embodies another world view. The nature of the indicator and its definition is thus shaped by a certain methodology which, in turn, produces the data. Data are the result of behaviour, in the case under consideration, the behaviour of people or goods activities -- as well as of experts. Modal split is thus an indicator which reflects the behaviour of society and people's world view.

6. WHAT INFLUENCES BEHAVIOUR?

If we want more sustainable transport, it is necessary to change people's behaviour. But the question is how? The technological problems of the past were compatible with and driven by individual egoism (Rothengatter [9]). This statement is correct and will remain so in the future. Why should people change their behaviour?; and is it possible for them to do so anyway? Better understanding of human behaviour is thus required if we want to shift modal split in a more sustainable direction (by pricing). We have to understand what pricing can do and cannot do. For this purpose, it is necessary to understand human behaviour in the transport system, not only on the functional level but also in relation to its causes. Basically, behaviour is always structurally determined (Figure 5). Examples of those structures are building structures, financial, social, value and economic structures, etc. Currently, modal split is an indicator with a car bias. As long as such structures exist, it will be difficult to change the trend, since behaviour is the effect of such structures and the modal split is the result of behaviour.

Figure 5. **Basic relationship between structures, behaviour and data**



7. IS PRICING EFFECTIVE ?

Pricing is the use of monetary measures to influence human behaviour. A comprehensive review of pricing mechanisms can be found in the ECMT Round Tables Nos. 7, 10, 13, 22, 46, 56, 67, 79 and 80. Pricing covers public transport fares, rail tariffs and fares, road pricing, tolls, fuel taxes and parking charges. Several studies have been carried out which confirm the widely-observed weakness of the price-elasticity of demand for car use under prevailing conditions. It is commonly acknowledged that elasticities increase in the long run. This means that individuals require a certain period of time, given the constraints arising from their lifestyle, to modify their behaviour in response to price changes.

Pricing is a financial tool used to make one mode less attractive and to make another one (such as public transport) more so. Experiments with transport pricing have been confined to very specific cases from which it is difficult to generalise. There are a few examples (mainly involving parking charges) of pricing producing a substantial change in modal split. A certain amount of price elasticity -- at least in the short term -- exists, but long-run elasticity, which has been analysed in several theoretical studies [10], has not been observed in practice so far.

The question remains as to whether pricing can modify the prevailing trend in modal split and redirect it towards a sustainable transport system. Analysis of the available empirical studies shows that there is a deeper driving force influencing human travel behaviour than pricing systems. Pricing is a financial structure. This structure is (in general) not permanently present compared with other structures. Built structures, for example, are always present and effective and they have a direct influence on human behaviour and thus on modal split.

Figure 6. **Reduction in commuter trips resulting from daily parking charges**

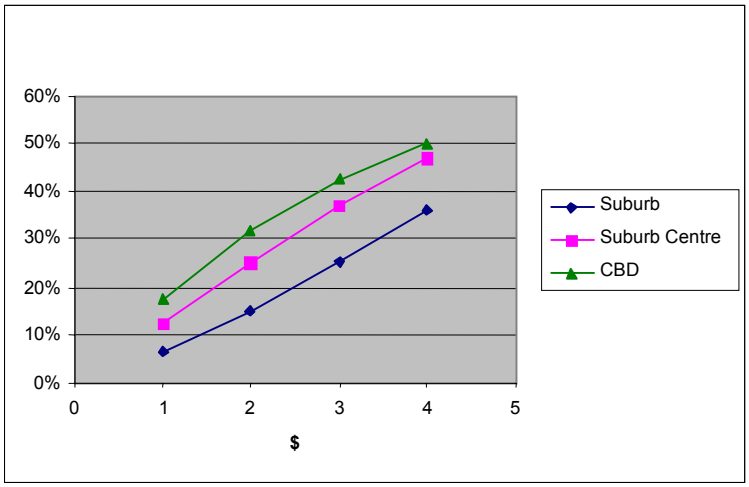


Figure 7. **Impact of fuel tax increase, year 2010**

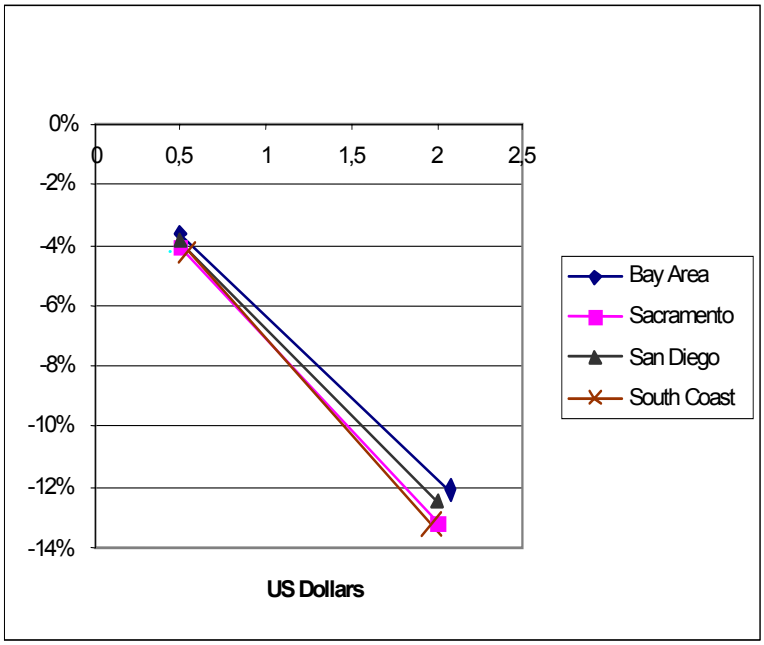
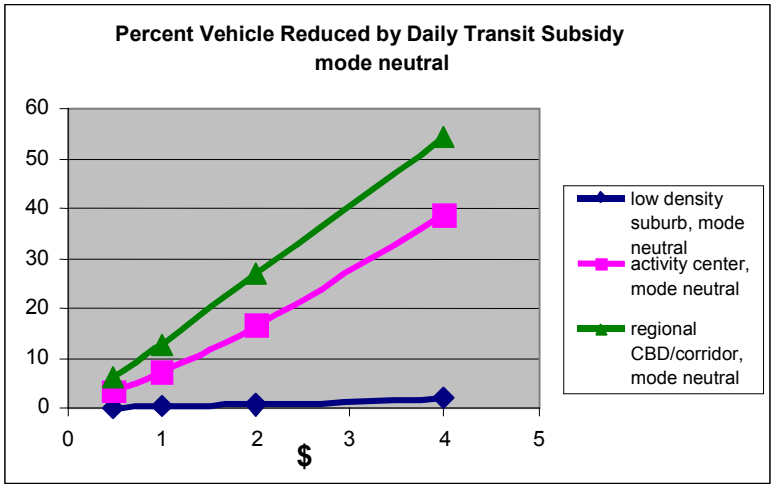


Figure 8. **Percentage reduction in vehicle use resulting from daily transport subsidy, mode-neutral**



If we go back in history, tariffs were always related to travel time. Such tariffs go back a long way in the case of public transport. But there are also other kinds of pricing, for example, road infrastructure pricing, as in the case of the traditional toll road.

From the traffic engineering point of view, pricing is a device to restrict travel. Transport engineers and planners have removed all barriers and restrictions to car traffic by widening roads, building excellent connections and providing enough cheap parking places. City planners have designed city structures with a view to optimising car traffic. This has an influence on people's behaviour. The existing trend points towards an over-capacity of car-oriented infrastructure. Financial barriers are now being proposed or implemented to try to bring this development under control. If pricing is necessary to correct this trend, it shows that the over-capacity of car-oriented infrastructure must be widespread.

8. UNDERSTANDING HUMAN BEHAVIOUR

Engineers and economists work with distances or time, as measured by a machine (clock) or a scale, and with costs. But does human behaviour conform to these physical units?

8.1. Modal split -- the result of deeply-entrenched behaviour, conditioned by evolution

The issue paper of the EST Workshop in Berlin in 2002 [11] provides an excellent review of how human behaviour in transport is understood today. *"There are almost as many views about how human behaviour is maintained and how it changes as there are people who hold the views."*

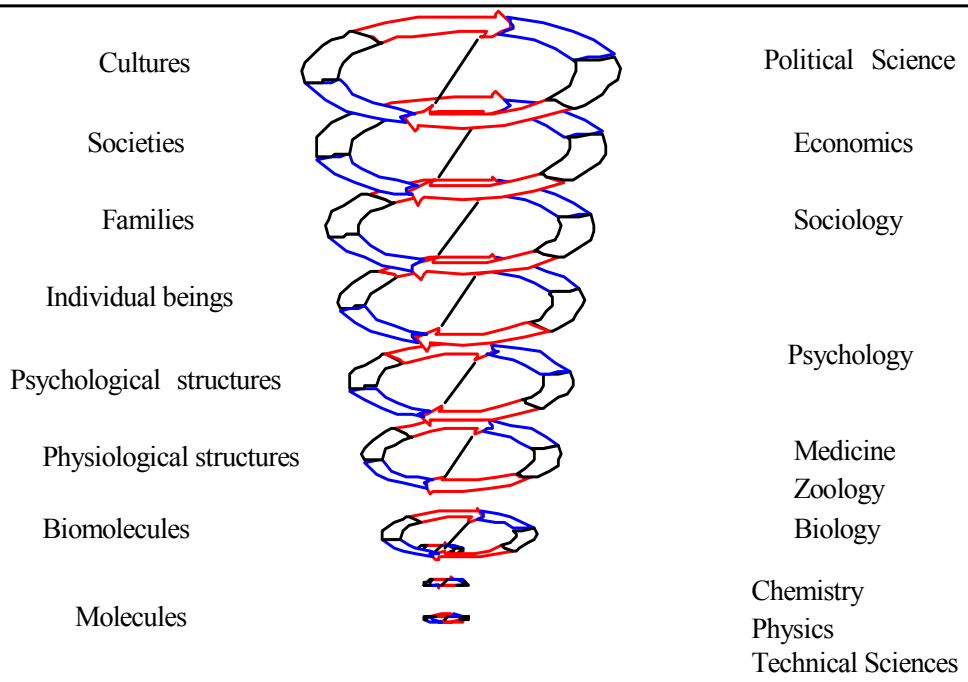
The paper distinguishes five different approaches:

- Interior construct;
- Brain activities;
- Heredity;
- Antecedent external causes;
- Consequences of behaviour.

The paper comes to the conclusion that the best way to change transport behaviour may be to change the milieu in which it takes place.

This confusion is a result of cross-sectional problems, which are not obvious and span several disciplines. First, it is necessary to analyse the five approaches. Afterwards we should be able to understand whether the conclusion derives from strict logical necessity or amounts to only vague recommendations. The tools that will be used are based on evolution and epistemology. They have their roots in the 19th century (Darwin) and have been further developed and popularised by Konrad Lorenz, Rupert Riedl, Bertalanffy and others [12][13][14]. Riedl has published a "hierarchy" of disciplines based on levels of evolution. This hierarchical order, ranging from the basic elements of matter and the structures that emerge from atoms, molecules and bio-molecules to the more complex structures of animals, man, family and society, civilisation and cultures, is mirrored by a parallel order of disciplines (Figure 9).

Figure 9. **Levels of evolution and scientific disciplines**



Source: Rupert Ried.

The basic problem is the lack of an holistic view. Each discipline is more or less considered in isolation from the others. However, if effects occur on one level, they can also affect other levels and therefore other disciplines. This means that each discipline attempts to find an explanation in its own particular realm and ignores the other level where the problem actually came from. Explanations may also reflect concerns specific to a discipline and may not be related to the processes on the levels in which the problem occurs. At the lower, molecular level of the evolutionary process, human behaviour in a technical environment is usually not a core issue.

According to this distinction, the *interior construct* approach pertains to the upper levels, and ignores the fact that a new kind of transport system may also influence the more basic levels that are remote from human consciousness.

The second approach, which focuses on *brain activity,* addresses part of human behaviour but is not adequate to deal with behaviour as a whole .

In this paper, *heredity* is understood as the part of the process that lays down the preconditions of behaviour. It can be understood as a result of useful behaviour in response to a particular context or the human environment. However, more research is needed to understand human behaviour in an artificially-built environment.

Antecedent external causes do, of course, play a role in the system but cannot explain behaviour as a whole.

Finally, the *consequences of behaviour* are only one part of the equation, the other being the feedback that connects experience with expectations.

8.2. On what level does the car interact with the driver?

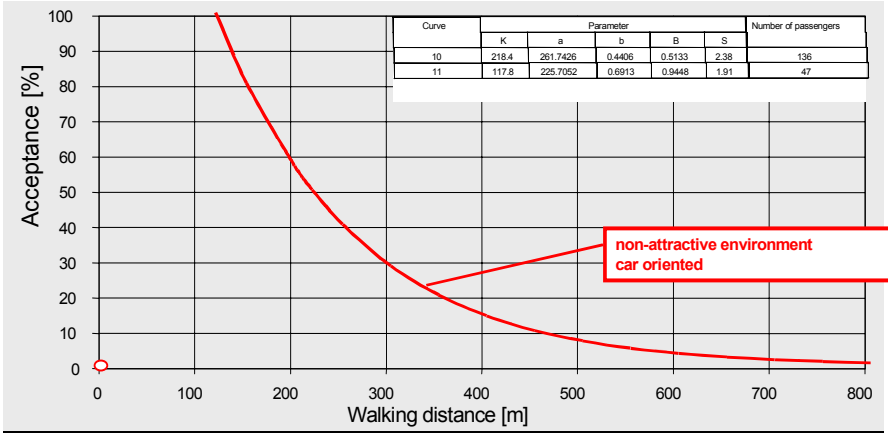
In 1974, Walter published a study about the different time perceptions involved in walking and riding a bus.

Compared to the time spent in the bus, the time spent walking to the bus stop was over-estimated exponentially with the distance; the reciprocal curve was called the "acceptance function" [15]. A similar observation was made by Karl von Frisch when he deciphered the language of bees. The frequency of a bee's dances shows the same mathematical function [16].

Conducting a "modal-split experiment for bees", Karl von Frisch (1956) discovered that the content of the information was body energy. Knoflacher (81) discovered the homology between these two experimental results. That discovery is now the crux of the explanation of human behaviour in the new transport system. Human body energy (physical and mental) is obviously the driving force for modal choice and determines behaviour and the modal split.

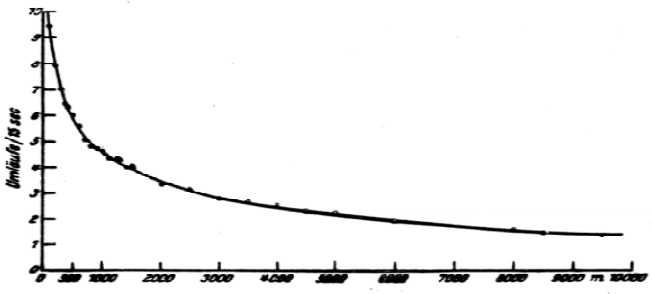
Figure 10.

a) Human "acceptance" function



Curve	Parameter					Number of passengers
	K	a	b	B	S	
10	218.4	261.7426	0.4406	0.5133	2.38	136
11	117.8	225.7052	0.6913	0.9448	1.91	47

b) Bees' "acceptance" function



Source: Walther, 1974 [15]; K. v., Frisch [16]; Knoflacher, 1981 [17].

Table 1. **Body energy demand for walking and driving a car, respectively**

Body energy	**Kcal per minute**	**In relation to car**
Walking 4 km/h	4.3	2
Walking 6 km/h	6.5	3
Running 12 km/h	12.6	6
Running 20 km/h	24.2	12
Driving a car	**2-2.9**	**1**

Knoflacher also applied Weber-Fechner's Law, a fundamental law of the relationship between human behaviour and the outside world, which describes the relationship between sensation, the trigger of our behaviour, and the intensity of stimulation of the physical indicators of the outside world.

$$\mathbf{S = \ln(I)} \quad \text{……..(1)}$$

S .... sensation
I ... intensity of irritation.

The inverse function:

$$\mathbf{I = e^{+/- S}} \quad \text{……..(2)}$$

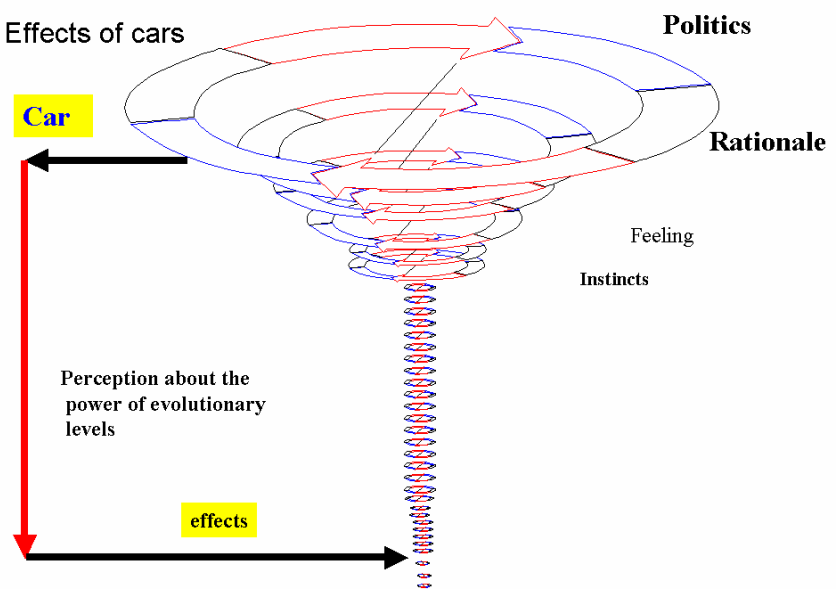
Equation (1) is Weber–Fechner's well-known law. Equation (2) is the inverse function and has the traditional form of the "resistance law" in transportation: $I = e^{-f(x)}$.

We see that sensation can have a + or a - sign. The + sign indicates an attractive sensation on an attractor. This has been shown in many studies by Knoflacher since 1981 [18].

8.3. A far-reaching effect

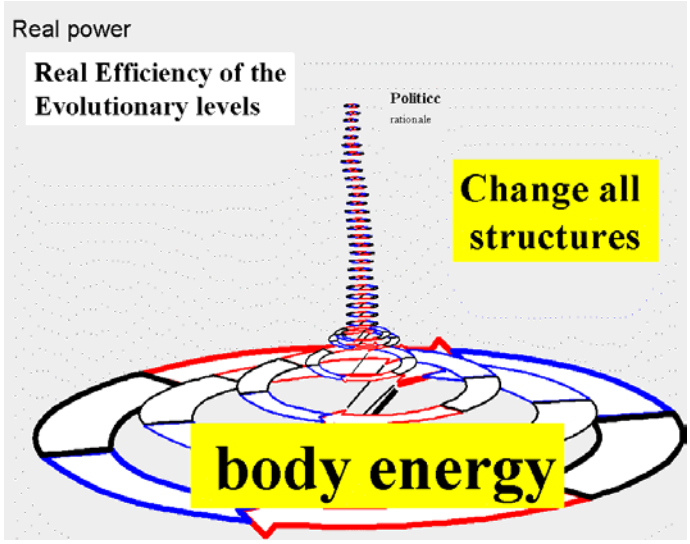
If body energy is the decisive factor shaping modal split, it means that cars move people and determine their behaviour at an extremely deep-rooted level in evolutionary terms (probably the deepest one), and this creates many problems.

Figure 11. **The most recent levels of evolution are the most important in our perception**



As a consequence, our society over-estimates the effect of the most recent evolutionary level, that which is related to politics and culture, and underestimates or neglects the effects of very old evolutionary levels that are embodied in new inventions, probably for the first time in human society.

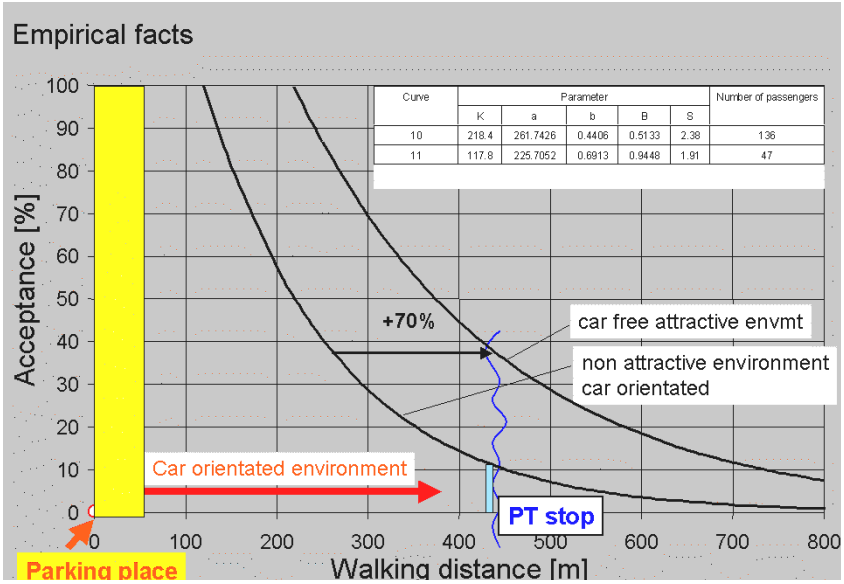
Figure 12. **The real power of evolutionary levels is related to their age**



This discovery has far-reaching consequences, since it can be shown that the point of leverage for changes in modal split is the place where man comes into contact with technical modes. For the car, this is the parking place. If we consider human behaviour as described by Weber-Fechner's Law, the decision as to modal choice takes place primarily at the origin and destination of each trip. If the

parking place is adjacent to human activities, as is usually the case today, all other modes trigger negative stimuli, due to the lack of space and lack of safety, environmental quality and accessibility.

Figure 13. **Acceptance function for walking distance is the crucial factor**



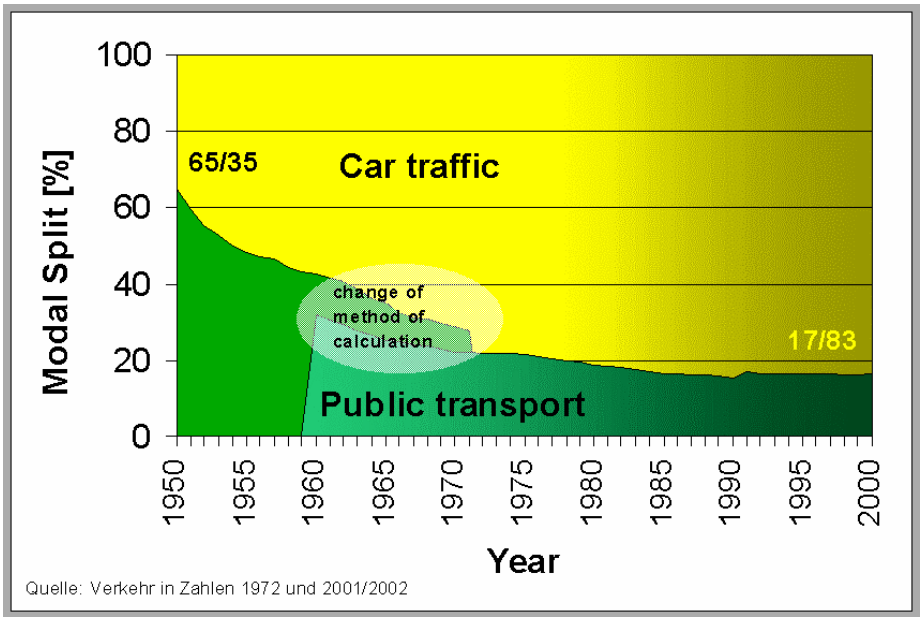
If a public transport stop is 300 or 400 metres away, 90 per cent of the modal split is preconditioned by a set of structural specifics. Man is caught in his own evolutionary trap if physical structures are organised in such a way.

9. EMPIRICAL PROOF

To show the validity of the theory, it is necessary to provide empirical proof. As an example, we will take the trend of modal split in Germany from 1960 to 2001 (Figure 14).

This figure and Figure 15 show increasing car use, and reflect the general trend. If we calculate the relationship between car availability and public transport use, we obtain a perfect reproduction of Weber-Fechner's Law (Figure 16).

Figure 14. **The share of public transport has been steadily decreasing for fifty years**



Source: Verkehr in Zahlen 1972 and 2001/2002.

Figure 15. **Increasing motorisation use goes hand in hand with decreasing public transport**

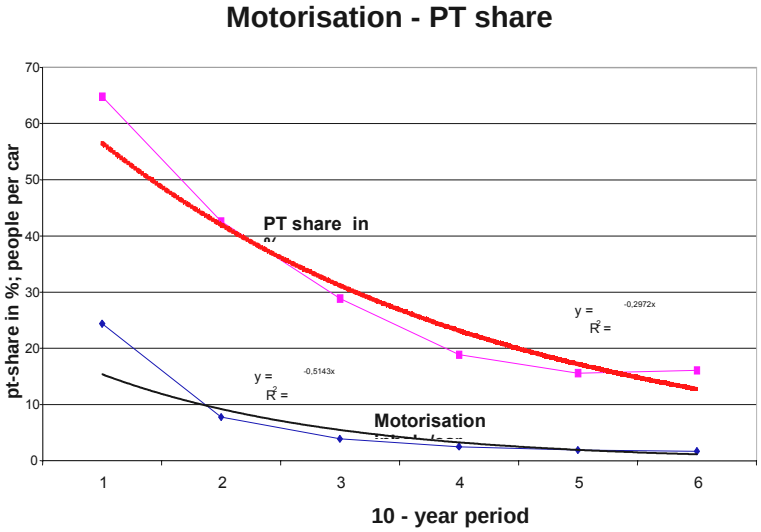
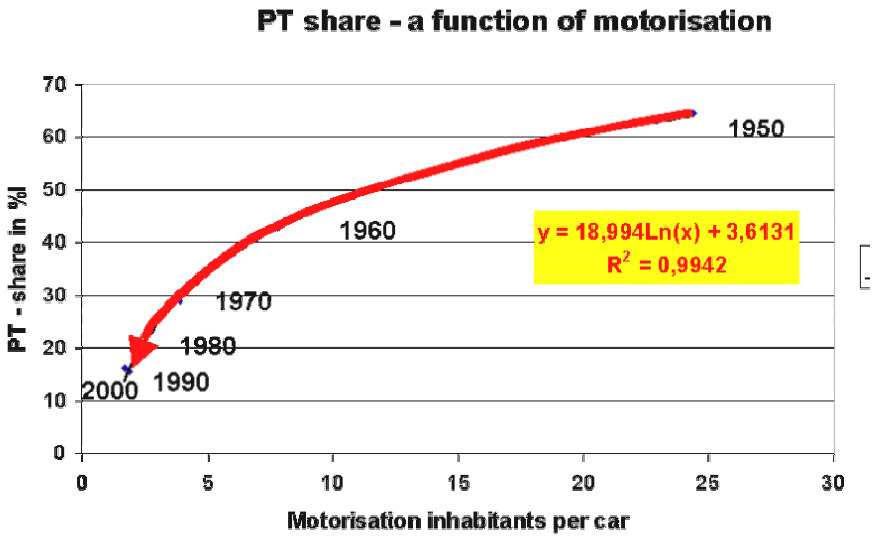


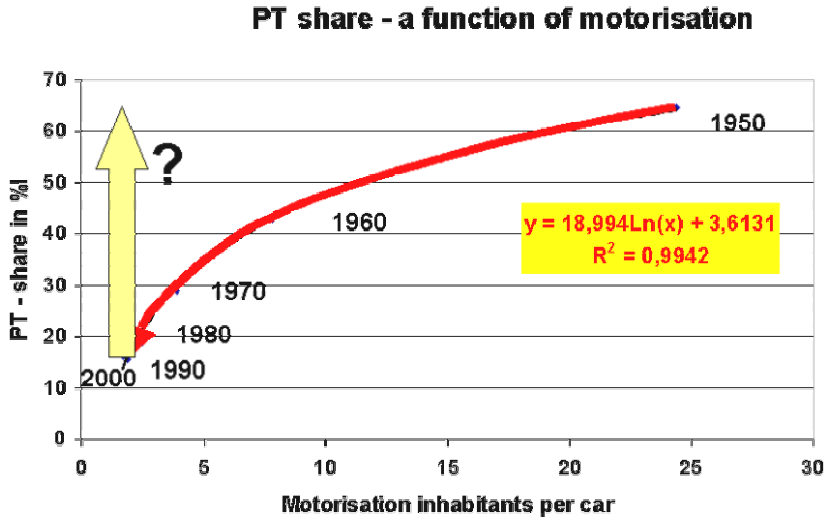
Figure 16. **The rate of motorisation and the share of public transport are connected by Weber-Fechner's Law**



If we want to use pricing to change behaviour, we have to bear in mind that money is a form of energy at the upper levels of evolution. Compared with physical power it is not sufficient to compensate for the effects of physical structures.

If pricing were pitched at the level required to compensate for the effects of physical structures, it would be politically dangerous since it would create social problems (in other words, the rich can afford to pay, but not the poor) (Figure 17).

Figure 17. **The cause of this effect was (and still is) the change in physical structures over the period**



Modal split and pricing in the context of sustainable transport have to be conceived in the right order. Pricing can have a synergistic or prohibitive effect, but currently we have a synergistic effect between physical structures and prices that is counter to sustainable development.

10. THE DESTRUCTIVE EFFECT OF THE CURRENT PRICING SYSTEM

Today, national parking regulations require parking spaces to be provided close to activities, thereby encouraging car use to the detriment of public transport. Moreover, in many countries an additional fee has to be paid if private parking places are not provided. This is quite the opposite of what is needed to place both modes of transportation on an equal footing. Existing pricing arrangements are designed in an upside-down fashion and do not promote the behaviour required to attain a sustainable transport system. Also, the pricing of parking space is not conducive to sustainable behaviour.

11. THE PROPER USE OF PRICING AS A TOOL FOR CHANGING MODAL SPLIT

In a market economy, value and price should reflect desirable behaviour, but this is not the case today. A person pays less for a parking place with the highest value (at home) and society makes up the difference. A parking place at home has the highest value, but people do not pay for it as they should.

Fair pricing means that people have to pay for infrastructure and the consequences of their behaviour. They should pay for an extensive road network, longer pipelines and cable networks, as well as for the effects of their desire for personal comfort. They should pay for the deficit of public transport, in a certain amount for the damage to cities' economic fabric, and for local unemployment, etc. But at present they pay very little and society makes up the difference.

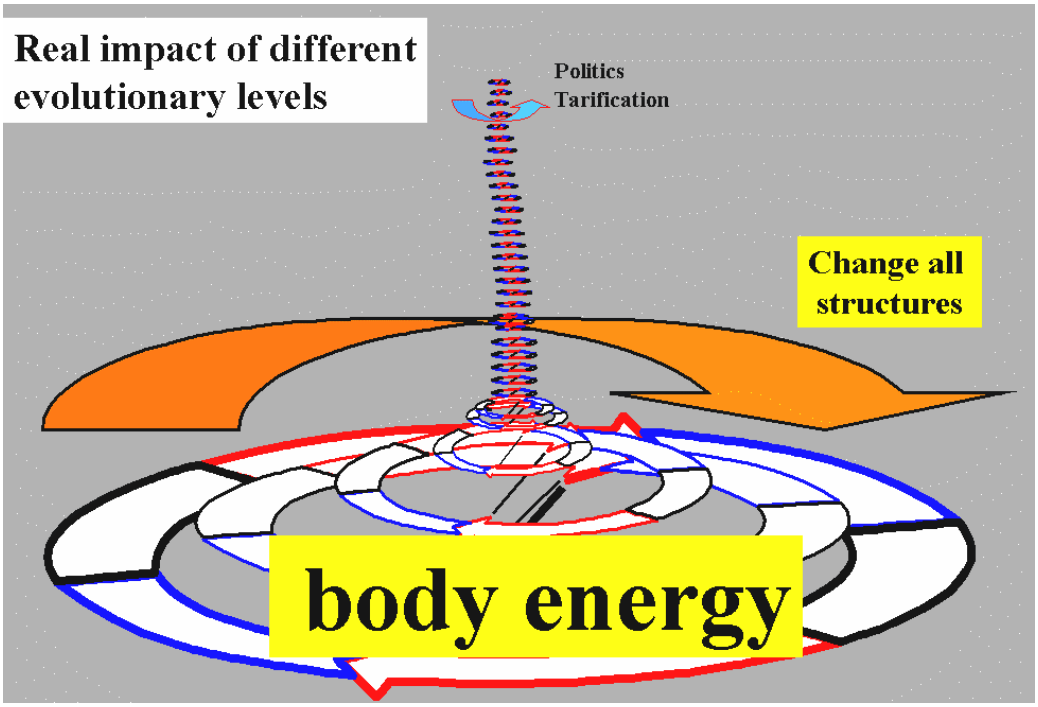
On the other hand, if they park in a place which minimises unsustainable transport behaviour, then they should pay less or nothing. If we accept political goals for public transport, the minimum distance between all activities and the parking place should be at least as great as that to public transport stops. This would change the parking regime totally: decentralised, individually-optimised parking would give way to centralised, system-oriented parking with central garages, which would have to be at least as far away from human activities as public transport stops. Such infrastructure would have to be supported by a fair pricing system.

The allocation of resources under existing pricing rules is totally wrong and counter to political and environmental goals. The structural set-up is such that we cannot expect human behaviour to change in the way it should. People's behaviour is determined by existing structures, but since built and financial structures are wrong, they cause the very problems about which we complain.

12. IS PRICING AN EFFECTIVE WAY FOR DEALING WITH THE PROBLEM?

Pricing deals with money and money is a unit of energy on the social level, which is one of the most recent levels in the ladder of evolution. The causal factor of unsustainable behaviour is also energy, but body energy on the individual human level, which is one of the oldest and most deeply-rooted.

Figure 18. **Pricing deals with money – the energy of our society – on the upper level**



[Please correct – **Pricing** instead of Tarification]

In principle, pricing may be regarded as an effective tool for changing the modal split, but its power lies on the upper social level, which is negligible compared with the individual effects of existing structures -- and the car, illustrating clearly the dilemma for policymakers. Under existing conditions, pricing is of secondary or tertiary importance. However, it will become a powerful tool if physical structures are changed in the way recommended above. Today, the pricing structure is the exact contrary of what would be needed to develop a sustainable transport system. If we introduced a pricing system based on actual human behaviour, anyone who parked at home or close to the shops or their workplace would have to pay accordingly. But, under the current pricing system, those who behave in a way that is conducive to sustainable transport and do not have a parking place at home are punished.

13. ROAD PRICING -- A PUNITIVE MEASURE?

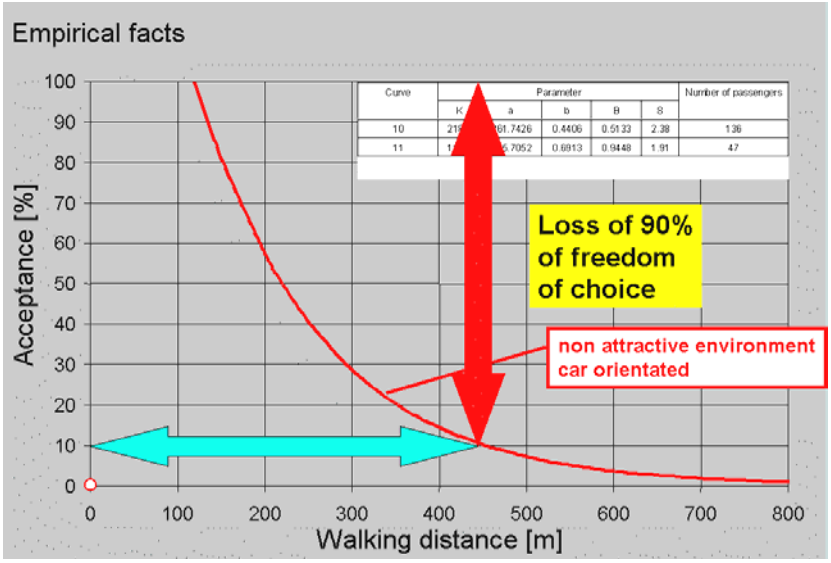
The application of road pricing to people and goods once they are already travelling in cars and trucks, respectively, is punitive for transport system users and is not an effective instrument for a human-oriented traffic policy. It is also unfair to the economy and industry. People and industry will behave in the right manner and optimise their benefits under given conditions.

But, under current parking regulations, people are also punished by virtue of the fact that their behaviour is determined by existing building and land-use structures, which can also be seen as a restriction of freedom of choice. This could be changed if people were able to obtain the right information at the right place, i.e. before they are forced (by inner and outer determinants) to use an unsustainable mode.

14. THE SAME PRINCIPLES SHOULD BE APPLIED TO GOODS TRANSPORT

The same principles should apply to freight transport. Building structures without direct access to the railway system should pay for being in the wrong location since they benefit from cheap sites. Today, these benefits are socialised and paid for by society. If the pricing structure took account of this, it would promote the right kind of behaviour and prevent people from making such structural mistakes. But there is a long way to go, since nearly everything that has been done in the transport system during the last fifty years has been in the opposite direction.

Figure 19. **If the walking distance at the origin and destination of trips differs according to the various modes, as it does today, body energy consumption becomes the decisive factor for modal choice**



15. CONCLUSION

Modal split is a key indicator for sustainable transport if it embraces all modes, from non-motorised users to mechanical transport modes. The invention of rail, cars, aeroplanes and telecommunications has fascinated society, experts and decisionmakers alike, and their consequences have not been recognised for a long time. The development of high speeds was an important step forward since it seemed to save time. But the overall outturn was quite different from individual short-term experiences. Spatial location, a stable entity for thousands of years, became a variable. "Invisible" travel time is a stable constant in the transport system. The myth of growing mobility has to be buried as well. More and more empirical findings from all over the world show the constancy of two very important indicators for the transport system: the average number of trips and the average travel time per person per day. What has changed are distances and fossil energy consumption, attesting not only to the decreasing sustainability of the transport system but also to a dramatic decline in overall efficiency. The indicator of modal split supports these findings, confirming a steady increase in car traffic.

Sustainable transport can be defined as transport systems that are highly efficient within the limits of ecological, social and economic capacity. Non-motorised transport users and, to a certain degree, mass transit systems, characterise such transport.

Pricing is a set of measures that can be used to encourage transport system users to behave in a sustainable way. Its effectiveness depends on the surrounding conditions. It is a measure that is socially very sensitive, which limits its theoretically possible effects. Money -- the tool of pricing -- is related to energy. To use this instrument in the most effective way, it must be applied at the most

appropriate point of leverage of the system, i.e. at the point of parking (or loading of goods) and not to traffic flows. Today, pricing takes the form of tolls, road pricing, congestion charging, etc. This is ineffective and unfair to users, who are forced to use their cars by existing structures. These structures are optimised for individual situations and not for the system. If the walking distance to a parking place is shorter than to a public transport stop, people will continue to use their car -- and to pay.

Pricing is a means of reducing car traffic in order to obtain a more sustainable transport system. The over-capacity of car transport is manifest; it shows clearly that the choices of the past were misguided. Taxpayers' money was used to remove barriers to car traffic at a very high cost. People use this expensive, artificial "limb", the car, more and more -- and then they are punished by road pricing. If they park near their home or close to their workplace, they are forced to use the car -- they become captive car-users. A fair system of pricing should give people at least the freedom of choice between modes. To this end, pricing has to be focused on parking management. Whoever parks near to home or uses parking facilities close to shops or the workplace should bear the cost of such facilities. Whoever parks his car where there is a freedom of choice between all modes, should pay less. If this balance is established, pricing will become a much more effective means of promoting sustainable behaviour.

BIBLIOGRAPHY

[1] Aufbereitung von Ergebnissen der Stadtverkehrsforschung. Pilotstudie: Sachgebiet Modal-Split. Forschung Stadtverkehr Heft A1. Herausgegeben vom Bundesminister für Verkehr. Forschungsgesellschaft für Straßen- und Verkehrswesen, Köln, 1983.

[2] Otruba, H., J. Gampe (1986), Untersuchung des Modal-Split im Ballungsraum Wien. Forschungsarbeiten aus dem Verkehrswesen, Band 3. Herausgegeben vom Bundesministerium für öffentliche Wirtschaft und Verkehr, Vienna.

[3] ECMT, Economic Research Centre (1996), *Changing Daily Urban Mobility: Less or Differently?, Round Table 102*, OECD, Paris.

[4] Lill, E. (1889), Die Grundgesetze des Personenverkehrs. Zeitschrift der Eisenbahnen und Dampfschiffahrt der österreichisch-ungarischen Monarchie. II.Jg., 35: 697-706 und 36: 713-725.

[5] Schafer, A. (1998), The Global Demand for Motorized Mobility, *Transportation Research A,* Vol. 32, No. 6, pp. 455-477.

[6] Bendtsen, P.H. (1968), Byplanleagning, Copenhagen.

[7] Knoflacher, H. (1986), Kann man Straßenbauten mit Zeiteinsparungen begründen? *Internationales Verkehrswesen*, 38. Jg., 6: 454-457.

[8] Klein, St. (1999), Beeinflussung der Verkehrsmittelwahl im Personenverkehr. Ermittlung des kommunalen Handlungsspielraums im Städtevergleich. Schriftenreihe für Verkehr und Technik, Band 88. Erich Schmidt Verlag, Bielefeld.

[9] ECMT, Economic Research Centre (1995), *Transport Economics: Past Trends and Future Prospects, Round Table 100*, OECD, Paris.

[10] Transportation Elasticities. How Prices and Other Factors Affect Travel Behavior. Online TDM Encyclopedia. Victoria Transport Policy Institute, Victoria, Canada. Updated 4 December 2002. Accessed: http://www.vtpi.org/tdm/tdm11.htm (09.01.2003)

[11] Knoflacher, H. (2002), Roles of Measures in Changing Transport and Other Behaviour. EST – Environmentally Sustainable Transport. OECD Workshop: Communicating Environmentally Sustainable Transport -- The Roles of Soft Measures in Achieving EST, 5-6 December, Berlin.

[12] Lorenz, K. (1983), *Der Abbau des Menschlichen*, Piper-Verlag, München–Zürich.

[13] Riedl, R. (1985), *Die Spaltung des Weltbildes. Biologische Grundlagen des Erklärens und Verstehens*, Verlag Paul Parey, Berlin and Hamburg.

[14] Bertalanffy, L. v. (1968), *General System Theory*. Tenth Printing 1988, George Braziller Inc., New York.

[15] Walther, K. (1991), Maßnahmenreagibler Modal-Split für den städtischen Personenverkehr Veröffentlichungen des Verkehrswissenschaftlichen Institutes der Rhein.-Westf. Techn. Hochschule Aachen, Heft 45.

[16] Frisch, K. v. (1965), *Tanzsprache und Orientierung der Bienen*, Springer-Verlag, Berlin-Heidelberg-New York.

[17] Knoflacher, H. (1981), Human Energy Expenditure in Different Modes: Implications for Town Planning. International Symposium on Surface Transportation System Performance, US Department of Transportation.

[18] Knoflacher, H. (1987), *Verkehrsplanung für den Menschen. Band 1: Grundstrukturen*, Verlag Orac, Vienna.