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Biking and Walking: The Position of Non-Motorised Transport Modes in Transport Systems

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BIKING AND WALKING;

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Abstract.
Long run developments such as income growth and urban sprawl lead one to expect a continuous decline of the contribution of non-motorised transport modes to the performance of transport systems. In terms of the total number of trips, non-motorised transport modes have retained high shares, however. The potential of non-motorised transport modes to contribute to the urban quality of life is increasingly being recognised. In this paper the possibilities of substitution between non-motorised and motorised transport are discussed. In addition, attention is paid to the issue of complementarity between motorised and non-motorised transport modes.

Keywords: bicycle, pedestrian, green transport, multimodality, urban transport.

1. INTRODUCTION.

Biking and walking are rather neglected transport modes within transportation research. In terms of their contribution to the total number of kilometres travelled, their share is indeed small in most countries. However, their share in the total number of trips made is substantial almost everywhere. In less developed countries walking and biking are the natural transport modes for low income households, but also in many countries with higher incomes they are considered important transport modes. Walking and biking remain attractive transport modes for a number of reasons:

-they provide door to door transport

-biking and walking infrastructure usually have a very high spatial penetration

-biking and walking do not lead to waiting times compared with waiting at public transport stops

-walking and biking have a favourable environmental performance

-they are cheap transport modes

-biking and walking are essential elements in multimodal transport chains.

-biking and walking are healthy activities (see for example Hendriksen, 1996, Hillman, 1997)

Among the negative aspects of non-motorised (or slow[1]) transport modes are:

-their low speed (although in heavily congested areas their speed may be comparable to other transport modes),

-relatively high accident rates

-low level of comfort (susceptibility to weather conditions)

-the physical efforts that are required (depending among others on wind, temperature and gradients)

Walking has been the dominant transport mode for many centuries in all countries. Before industrialisation took place there were some alternatives such as riding animals, horse drawn carriages and water transport, but walking must have been by far the most substantial transport mode. The Roman roads of 2000 years ago were predominantly used by pedestrians. Conflicts between pedestrians and wheeled traffic did occur, however, especially in urban areas. For example Hass-Klau (1990) mentions that Julius Caesar banned chariots from the streets in Rome between sunrise and sunset to offer space to the pedestrian. Since the nineteenth century the development of railway and highway systems have led to dramatic changes in travel behaviour towards motorised transport modes. In addition, the bicycle became available as a possible substitute for the pedestrian.

The bicycle started its development at the beginning of the nineteenth century, and it took about 80 years before reaching a level of quality and comfort that allowed massive adoption. Important steps towards the large scale use of bicycles were the use of the inflatable rubber tyre, the introduction of the ‘safety’ type which was much easier to use as well as the construction of extensive road networks of sufficient quality. It is interesting to note that the bicycle started its career as a means for sport and recreation of the upper class in the last part of the nineteenth century (Veraart, 1990, Dutch Ministry of Transport, 1999). Later on it developed into a transport means for a much larger public for many transport motives. Filarski (2000) mentions the bicycle and the tram as the main transport modes in Dutch cities during the period 1910-1950. During the first and the second world war the bicycle has played a very important role in military operations. For example, the French and the Germans were reported to have a total of 150,000 bicycle troops. Similar numbers have been mentioned for the British, Germans and Turks. Bicycle troops played an important role in Japanese military operations in China and the Malay Peninsula in the 1930’s and 40’s. In the Vietnamese war the bicycle was an essential element in the logistical operations of the Vietcong.

The car has become the dominant transport mode since 1950 in most industrialised countries. Since then bicycle use has decreased substantially. In some countries it has returned to its marginal role where it is mainly used for recreational purposes, but there are exceptions, especially in Northern Europe. In the mean time, in several major developing countries including China and India the bicycle continues to play a very important role in transport.

There are a number of long run trends that pose a threat to non-motorised transport modes. For example, with an increase of per capita income leading to higher values of time and an increasing priority for comfort a shift might be expected towards fast and comfortable transport modes. Also the trend of urban sprawl and low density construction provide a set-back to non-motorised transport modes. Another trend is the increasing use of ICT in motorised transport that may increase the quality gap between motorised and non-motorised modes. However, some studies indicate a rather stable position of non-motorised transport modes and even tendencies towards expansion. For example, OECD (2000) mentions a remarkable stability of the number of kms walked by Europeans of about 1 km per person per day during the last decades. In addition, a renaissance in bicycle use in a number of European countries has been mentioned (Pucher, 1999, Dutch Ministry of Transport, 1999, OECD, 2000) implying that the life cycle of the bicycle would take an upward turn.

At the world level the bicycle appears to be an extremely vital transport mode. Its annual sales volume was of a comparable size with that of the car during the 1950's and 1960's but since then the total sales have increased at a faster rate than that of the car. This also holds true for the total stock. There are two main reasons why nevertheless during the past 50 years the car has become a much more dominant transport mode than the bike during the past 50 years in Western countries. First, a major part of the growth in bicycle stocks took place in developing countries (see also section 6). Second, the increase in ownership of bicycles does not necessarily mean that the bicycles are used more often. In the USA the share of the bicycle in transport is very low, but a large share of the households own at least one bicycles. This illustrates the position of the bicycle in several high income countries where it is only used occasionally as a medium for recreational purposes. Nevertheless, the figures presented in Table 1 demonstrate that the bicycle plays a much larger role in the world than is usually thought. Assuming that there are about 2 billion households in the world, Table 1 implies that there is on average 1 bicycle per two households in the world.

	Annual bicycle sales	Annual car sales	Bicycle stock[2]	Car stock
1950	11	8	65	53
1955	15	11	100	73
1960	20	13	150	98
1965	21	19	190	140
1970	36	22	230	194
1975	43	25	360	260
1980	62	29	500	320
1985	79	32	630	374
1990	94	36	840	445
1995	107	36	1000	477

Source: Worldwatch Institute, plus own estimates

Table 1. Annual sales and stocks of bicycles and cars (millions), world level.

2. DEMAND FOR NON-MOTORISED TRANSPORT MODES.

Most markets of transport services are studied in terms of demand and supply. In the case of walking and biking this distinction is not very helpful, however, since here the supplier and the consumer coincide. The consumer is usually producing the transport service himself. There are some exceptions in developing countries (palanquin, rickshaw), and these will be discussed in some detail in section 6, but in industrialised countries non-motorised transport services are always self produced.

The fact that supplier and consumer coincide means that there are no monetary costs involved in the trip and that waiting for the transport service does not play a role. Thus, their cost structure differs strongly from that of most motorised transport modes. Factors which have an impact on the use of non-motorised transport modes include individual features, physical conditions, socio-cultural factors and infrastructure. Also the availability of other travel alternatives and government policies play a role. Figure 1 provides a schematic representation.

Insert Figure 1 here

Figure 1. Factors having an impact on the use of non-motorised transport modes

Relevant *individual features* are age, income, and physical abilities. For children and youngsters non-motorised transport tends to be relatively important. People having low incomes may not be able to afford a car so that non-motorised transport modes are important alternatives. Students of high schools and academic institutions are known to be frequent bike users. In the USA university towns score relatively high in terms of the share of bicycle trips (see Gordon and Richardson, 1998, Pucher et al., 1999) In addition, *physical conditions* (gradients) play an important role. Dimitriou (1995) mentions that bicycles are not convenient with slopes higher than 4 per cent. Of course *weather conditions* (temperature, wind, rain, snow) are another group of determinants of modal choice. This holds true both at the strategic level and at the level of daily varying travel patterns (Golob et al., 1996, Khattak and De Palma, 1997). *Infrastructure* is also frequently mentioned as a factor: bicycle paths may be quite instrumental to improve the convenience and safety of bicycle trips (see also Pucher et al., 1999). In addition, detour factors in networks for motorised versus non-motorised modes play a role. The choice for non-motorised transport modes is further a matter of the *composition of choice sets.* In rural areas without public transport these modes will be chosen more often since the car alternative is not available. Another factor is *urban spatial structure:* in areas with high densities where trip distances tend to be short, non-motorised alternatives often perform well (Tolley, 1997). Finally, *social and cultural factors* should be mentioned: non-motorised transport modes tend to be associated with low status (Dimitriou, 1995), but this is not always true. As we saw in the historical excursion in section 1, the bicycle started as the transportation means of upper class citizens, and present bicycle manufacturers do their best to develop fashionable models that are attractive for higher income consumers. At a cross-country level, there appear to be large differences between the USA and Europe in the appreciation of bicycle use (Pucher et al., 1999). Within Europe, a clear distinction can be observed between Northern and Southern countries (high versus low status, cf., OECD, 2000)

Some data on the use of non-motorised transport modes in various countries can be found in Table 2. The table shows consistently high shares of these transport modes in terms of the number of trips (between 31 and 47 per cent). Given the ways the questionnaires have been carried out, it is quite plausible that these shares are underestimated. The design of many travel surveys lead to a neglect of short trips like walking with the dog, bringing a letter to the mail box or calling at somebody nearby. In terms of total number of kilometres travelled this neglect will not have a large impact, but in terms of number of trips and travel time this may lead to a substantial underestimate.

Non-motorised transport modes tend to have high shares in countries such as the Netherlands and Switzerland. Low values are found in the Nordic countries (Norway, Sweden and Finland)[3]. Table 2 demonstrates that there seems to be a substantial substitution between non-motorised transport modes and public transport, leaving car use rather unaffected. This suggests that policies aiming at an increasing share of non-motorised transport modes do not necessarily lead to a decrease of car use. In this table non-motorised transport modes are treated as a combined mode. A more detailed treatment of the two modes reveals that the two are to some extent substitutes. For example, Gerondeau (1997, p.322) shows that countries with a small share of bicyclists tend to have a large share of pedestrians and vice versa. Thus, substitution between the two modes should be taken into account in the assessment of policies to stimulate one of the two modes. A more detailed picture of the mobility needs that are satisfied by the two non-motorised transport modes can be found in Table 3.

Country	Year	Non-motorised share (trips)	Public transport share (trips)	Car share (trips)	Non-motorised share (kms)	Public transport share (kms)	Car share (kms)
Austria	1983	40	19	42	8	34	58
Finland	1986	31	12	57	6	19	75
France	1984	41	8	51	8	17	75
Germany	1982	41	14	45	8	25	67
Israel	1984	37	31	32	-	-	-
Netherlands	1987	47	5	47	16	12	72
Norway	1985	35	11	54	6	31	63
Sweden	1983	38	12	50	5	20	75
Switzerland	1984	46	12	42	10	20	70
UK	1986	37	14	49	9	19	72

Source: Orfeuil and Salomon (1993), adjusted

Table 2. Shares of transport modes in various European countries (in %).

Table 3 presents a more detailed view of the share of walking and biking in trips as a function of distance travelled in the Netherlands. The table shows that trips up to 1 km are dominated by pedestrians. Between 1 and 3.7 km, the bicycle is the most frequently used transport mode. Up to distances of 7.5 km, the non-motorised transport modes play a substantial role. In terms of the total number of trips, the share of the pedestrian is 18 per cent and of the bicyclist 28 per cent implying a total modal share of slow transport modes of slightly less than 50 per cent. It is also interesting to note that the average number of bicycle trips per person per day equals 1.01. Since a standard tour includes two trips, this means more or less that every day 50 per cent of the average Dutch residents uses his/her bike. The table also demonstrates the potential for substitution between the two slow transport modes. If bicycling would not be feasible for some reason, the share of pedestrian trips in the range up to 2.5 km might easily be much larger. For longer trips such a substitution would be less easy to imagine.

	Car (driver)	Car (passenger)	Train	Bus/tram/ metro	Moped	Bicycle	Walking	Other	Total
0 - 0.5 km	0.01	0.00	0.00	0.00	0.00	0.05	0.18	0.00	0.24
0.5- 1 km	0.03	0.02	0.00	0.00	0.00	0.14	0.17	0.01	0.35
1 - 2.5 km	0.19	0.11	0.00	0.01	0.01	0.44	0.23	0.01	0.99
2.5 - 3.7 km	0.11	0.06	0.00	0.01	0.00	0.17	0.03	0.01	0.39
3.7 - 5 km	0.07	0.04	0.00	0.01	0.00	0.06	0.01	0.00	0.18
5 - 7.5 km	0.16	0.09	0.00	0.02	0.01	0.09	0.02	0.01	0.39
7.5 - 10 km	0.06	0.03	0.00	0.01	0.00	0.02	0.00	0.00	0.13

10 - 15 km	0.12	0.07	0.00	0.02	0.00	0.03	0.00	0.00	0.25
15 - 20 km	0.10	0.05	0.01	0.01	0.00	0.01	0.00	0.00	0.19
20 - 30 km	0.09	0.04	0.01	0.01	0.00	0.01	0.00	0.00	0.16
30 - 40 km	0.04	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.09
40 - 50 km	0.03	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.05
50 km <	0.07	0.04	0.03	0.00	0.00	0.00	0.00	0.00	0.15
Total	1.07	0.59	0.07	0.10	0.03	1.01	0.63	0.06	3.57

Source: CBS (1998)

Table 3: Average number of trips per person per day according to distance class and main travel mode (The Netherlands, 1997).

Shares of non-motorised transport modes vary according to the objective of a trip. In many countries non-motorised transport modes are over-represented in leisure trips and trips to educational institutions, whereas in shopping trips and commuting they are underrepresented (Gordon and Richardson, 1998, OECD, 2000). However, there are exceptions. For example, in the Netherlands an above average share of non-motorised transport modes is observed for shopping (the share of non-motorised transport in shopping trips is 51 per cent).

Given the orientation of slow transport modes towards short distances one may expect that high population densities are favourable. This is indeed confirmed by Dutch data (see Table 4), although the impact is smaller than one might expect. The share of walking is indeed declining consistently with density. However, the link with bicycle use is much less clear. The reason is that in higher density municipalities the quality of local public transport makes it a competitor of the bicycle. We conclude that our expectation of a clear link between urban density and non-motorised transport modes is confirmed for the pedestrian, but not for the bicyclist, a possible explanation for the latter being the competition by public transport (see also OECD, 2000).

Degree of urbanisation	Car	Public transport	Bicycle	Walking	Other	Total
Very high	1.26	.36	0.95	.82	.09	3.48
High	1.63	.16	1.04	.67	.09	3.60
Medium	1.75	.13	1.04	.61	.09	3.62
Low	1.81	.10	1.07	.54	.09	3.61
Very low	1.84	.09	0.93	.52	.09	3.48
Total	1.66	.17	1.01	.63	.09	3.57

Source: CBS (1998)

Table 4. Average number of trips per person per day according to degree of urbanisation and main transport mode (The Netherlands, 1997).

Given the rather direct link between degree of urbanisation (measured via urban density) and city size, one may expect patterns as described in Figure 1. Information of this type is important for municipality governments that want to apply bench-marking approaches to non-motorised transport.

In the above presentation non-motorised and motorised transport has been presented in terms of competing modes. However, in addition to substitution, complementarity of transport modes has to be considered. This aspect will be discussed in the next section.

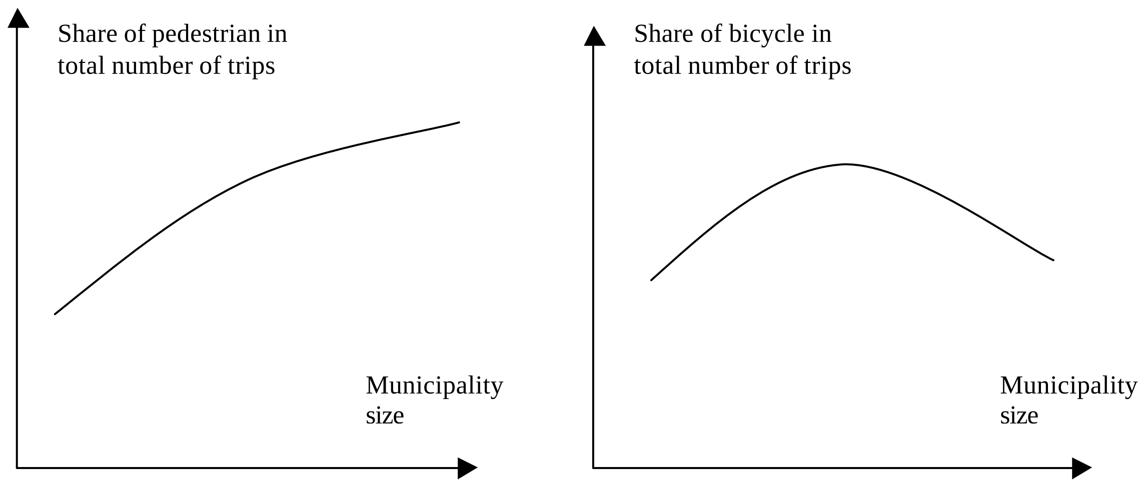

Figure 2. Share of non-motorised transport modes as a function of municipality size

3. THE ROLE OF NON-MOTORISED TRANSPORT MODES IN MULTIMODAL TRANSPORT CHAINS

Transport statistics are usually formulated in terms of 'main' transport mode. This leads to a systematic underestimation of non-motorised transport modes. Even in the case of car trips, walking to and from the parking place is an inevitable element of the chain. The same holds true for walking and biking to the bus stop or the railway station. A consequence of this complementarity is that when the various trip elements are considered, the share of bike and walking is much higher. An example of a systematic inventory is given in Table 5.

Mode of transport	Main trips	Transport on foot before/after	Transport by bicycle before/after	Total transport before/after incl.
On foot	0.67			4.37
Bicycle	1.05			1.09
Moped	0.03			0.03
Car (driver)	1.13	2.26		1.13
Car (passenger)	0.60	1.22		0.60
Train	0.07	0.05	0.03	0.07
Bus/tram/metro	0.10	0.17	0.01	0.10
Other	0.06			0.06
Total	3.71	3.70	0.04	7.46

Source: CBS (1998), Voetgangersvereniging (1998), adjusted

Table 5. Total number of trips per person per day made for various transport modes taking into account multimodality (The Netherlands, 1997).

The average number of trips made per person per day in the Netherlands is 3.7. Taking into account that for car trips and public transport trips walking or biking elements have to be included in order to give the trip a door-to-door character the total number of trip elements rises to 7.5 per person per day. In terms of total distances travelled this has a rather negligible consequence. But in terms of total travel time, its consequence cannot be ignored. It leads to low travel speeds for short distance motorised trips.

Although table 5 indicates that pedestrians dominate the scene of multimodal chains, there is one subset where bicycles are also rather important: train related public transport trips. As indicated by Rietveld (2000), the bicycle is the dominant access mode at the home end of trips by train (modal share of bicycle about 35-40 per cent, of pedestrian about 25 per cent). At the activity end these shares are 10 and 45 per cent, respectively. These figures underline the complementarity of train and slow transport modes. They also point at the importance of co-ordination of physical planning and infrastructure planning. Concentration of new residential construction in zones up to some 3 kms from railway stations offers favourable opportunities for train based public transport chains. A similar point holds true at the 'activity end' of train based chains, but there is a difference. Since the bicycle is not available at the activity end, concentration of destinations within a 1 km radius is important to make train based chains attractive. The high share of slow transport modes in rail based chains means that many travelers prefer the use of slow transport modes above bus, tram and metro. The reason is that on relatively short distance trips to railways stations, slow transport modes are often faster than bus or tram, especially when aspects like rescheduling costs and uncertainty costs are taken into account: because of their time-continuous character, the slow modes do not give rise to the risk of missing a connection in a chain. For railway companies an important lesson to be drawn is that real estate developments in the immediate proximity of railway stations are of eminent importance for the patronage of railway services. In addition, investments in local infrastructure for slow modes such as safe and convenient pedestrian routes towards railway stations and parking facilities for bikes near railway stations are necessary ingredients for a successful exploitation of a railway line.

The discussion thus far has focused on non-motorised transport modes for passenger transport. However, in *freight* transport they are also relevant. In many countries walking and biking are part of logistical chains to provide customers with the goods they need. Major examples are the post man and the paper boy who provide an essential contribution to distribution in fine meshed networks in urban areas: non-motorised transport modes often appear to be essential elements of chains dominated by motorised modes. Also in the sector of express service deliveries the importance of the bicycle has been recognised. Firms such as Fedex observed that the bike is the fastest transport mode in some congested urban centres and shifted their express delivery system to that mode. In Amsterdam barges are used for garbage collection to avoid blockades of the narrow streets. More on non-motorised transport can be found in section 6, where the case of developing countries is discussed.

4. COST COMPARISON OF TRANSPORT MODES.

Non-motorised transport modes are considered to have a favourable energy performance. This is based on their low direct energy input needed per passenger kilometre. For a more complete comparison between transport modes indirect effects also have to be taken into account (the use of infrastructure and vehicles). Results on average costs per passenger kilometre (pkm) are given in Table 6.

Transport mode	Space used for infrastructure (10^{-2} m^2/pkm)	Direct + indirect energy use (MJ/pkm)	Average costs paid by traveller (Euro/pkm)	Travel time (min/pkm)
Petrol passenger car	0.55	1.79	0.170	1.34
Train	0.21	0.98	0.075	0.94
Bus, tram, metro	0.51	1.11	0.085	1.92
Bicyle	0.71	0.04	0.045	5.40
Walking	1.7	0.03	0.000	10.77

Source: Bouwman (2000)

Table 6 Comparison of costs of various transport modes (1998; based on average trip length of each mode)

The table shows zero monetary costs of walking, but the costs of biking are not as low as one might expect, because it includes the costs of interest of the bike plus maintenance. Note that Table 6 is in terms of average costs, the marginal costs of modes where the user owns the vehicle (car and bike) are much smaller than the average costs. The table further underlines the slow nature of the non-motorised transport modes and their favourable energy performance. Somewhat surprising may be the high levels of space consumption for the non-motorised transport modes because these are often reported to be highly space-efficient given their low demands for parking space. The reason of this outcome is that sidewalks and bicycle paths occupy substantial surfaces but are not used in a very intensive way. Given the low speed of pedestrians the space needed per km travelled annually is relatively high. The same holds true to some extent for bikers. One must be aware, however, that side walks also fulfil other functions in residential areas: they function as buffers between motorised traffic and residences, they provide playing ground for children, provide space so that light can enter the houses. In shopping areas the sidewalks provide space for café pavements and traders; in addition, they allow consumers to walk along the shopping windows to inspect the goods on offer. Sidewalks can be interpreted therefore as inputs in a multiple-output production function so that the space requirements in the table are overestimated by this figure.

The above figures give a comparison of transport modes per passengerkm given the average trip length per transport mode. If one wants to compare the suitability of the modes for a *given* trip length, these figures will change. For example, for very short distance trips the effective speed of car, train and bus will be rather low. This explains of course why slow transport modes are most frequently adopted for short trips.

Another point of importance when comparing costs of transport modes is that costs per km are not necessarily the most appropriate way of standardisation. For example, in the context of residential choice the appropriate comparison may be between a residence at 15 km distance (implying a 20 minute trip by car) and a residence at 5 km distance (a 20 minute trip by bicycle). In examples like this the adequate standard of cost comparison is the cost of the total trip, in stead of the per km cost. This tends to make slow transport modes more attractive, because their length is lower so that multiplication of cost per km times length in kms yields relatively low costs. Gerondeau (1997) emphasises that such a comparison on the basis of trips of equal duration in stead of equal length makes sense given the observed (quasi) constancy of travel budgets.

Traffic accidents deserve special attention when discussing non-motorised transport modes. As indicated in Table 7 the risks of a fatal accident per kilometre differ strongly among transport modes. The non-motorised transport modes in Europe have casualty rates that are much higher than that of the car, the difference being almost a factor 10. Also for the USA bicycling dangers are reported to be a major obstacle to bicycling. These figures vary strongly between continents. In Asia and Africa accident risks are much higher than the figures reported in this table.

Transport mode	Number of casualties per 100 million person-kilometres	Number of casualties per 100 million person-hours
Car	0.80	30
Train	0.04	2
Bicycle	6.3	90
Walking	7.5	30

Source ETSC (1999)

Table 7 Comparison of traffic casualties across transport modes (European Union, 1995)

There are two perspectives that lead to a different view on accident rates of slow transport modes. First, when the risks are computed per travel hour the differences are much smaller. As Table 7 demonstrates, risks per hour are quite similar for the pedestrian and the car driver. Thus when exposure is measured in terms of minutes in stead of in kilometres, slow transport modes perform much better. Second, the above figures relate to the *own* risk of the traveller. When risks for other road users are taken into account, non-motorised transport modes have a more favourable performance than the motorised ones because of the low degree of externalities involved (cf. Persson and Odegaard, 1995 and Dutch Ministry of Transport, 1999).

5. GOVERNMENT POLICIES

Governments have various means to stimulate non-motorised transport modes.
We will use the following classification:
-physical planning
-infrastructure planning
-regulation of transport
-technological development
-financial instruments
-organisational measures (stimulation of other actors)
-policies with respect to other transport modes

As indicated in section 3, *physical planning* is potentially important because spatial structure has an impact on the use of non-motorised transport modes, especially on walking. It is no surprise, therefore, that compact solutions are often proposed to arrive at green urban transport. Examples of such compact solutions can be found in several European countries where governments provide guidelines on minimum densities of residential construction and on the choice of locations where residential construction is allowed or not allowed.

Infrastructure planning is another field where governments can stimulate non-motorised transport modes by providing space for bicycle paths and sidewalks. This separation of motorised and non-motorised transport also strongly improves traffic safety. A historical account of transport infrastructure planning and traffic calming can be found in Hass-Klau (1990). When separation of fast and slow transport modes is included in the original design of transport networks it is often rather inexpensive to create an adequate quality level. Once infrastructure networks have been made without proper attention to the slow transport modes, the attainment of adequate quality levels tends to be more expensive.
An interesting development is the conversion of old railtracks to cycleways in countries such as the UK and the USA and the construction of special walking routes for pedestrians. These initiatives usually address leisure activities taking place in rural areas.
Some special elements that deserve attention in transport networks for slow transport modes is that railways, canals and highways often have substantial barrier effects on other transport modes, and in particular on non-

motorised transport. Tunnels and bridges may help to overcome this problem. For a review of options the reader is referred to Dutch Ministry of Transport (1999).

Another special point of attention is the lay-out of transport networks so that non-motorised transport gets a strong advantage above motorised modes by creating large detour factors for the latter. An example where the latter approach is followed is the city of Houten (30,000 inhabitants, The Netherlands). From residential areas to the city centre, slow transport modes typically bridge distances that are only one third of distances of car users. This leads to very high shares of these transport modes. The other side of the coin is that the detours lead to extra car kilometres. Thus, although the performance in terms of modal share looks quite good, the performance in terms of car kilometres generated is less favourable. The opportunities to create transport networks that are favourable for slow transport modes are usually favourable in new towns. This demonstrates the importance of an integrated approach to physical planning and planning of transport networks.

At a micro level the design of transport networks is important as well. Safety concerns call for a design of roads and crossings so that conflicts between fast and slow traffic is minimised. One of the means is the introduction of 'woonerven' and 30 km zones in residential areas. In addition to such safety oriented measures also convenience oriented measures are important for non-motorised transport modes. Examples are the quality of road surface of sidewalks and bicycle paths, protection against wind or sun, removal of snow and ice, preferential treatment at crossings for slow transport modes, etc. A nice example is given by Garder and Leden (2000) who mention that residents of the city of Helsinki (Finland) make extensive use of the bicycle, but only during the Summer period, an important reason being that winter maintenance procedures favour automobile traffic (see also Lahrmann and Lohmann-Hansen, 1998).

An interesting development is the *regulation of transport* via the introduction of pedestrian zones in urban centres. Well-known European examples are the cities of Freiburg, Nuremberg (both in Germany) and Groningen (The Netherlands).
In these historical cities relatively large areas have been made relatively car-free leading to networks of up to 10 km of pedestrian streets. A useful review is given by Monheim (1997). The concept has spread to many other cities. An important question is how the retail sector in these areas responds. This appears to depend on a number of factors such as government policies to allow development of large scale retailing at urban fringes, the existence of edge cities with their own retailing activities, location and pricing of parking places, public transport services for visitors from the wider region, etc. In general terms, however, it appears that in many cities these pedestrian zones did not hurt the position of the shopping area or even improved it. However, not all sectors will respond in the same manner; the more specialised a shop, the more it may be expected to benefit (see also Monheim, 1997). An important factor appears to be the overall quality of the city centre for the visitor. It is especially the cities with a historical character that are considered as attractive destinations for tourists and fun-shoppers. Making these city centres relatively car free will reinforce the perceived quality.

Safety is an important issue in policies to stimulate the use of non-motorised transport modes. This holds true in particular for children. Many parents function as private taxi drivers for their children to bring them to school or other destinations. Safer transport networks would yield opportunities for substitution towards non-motorised modes. As has been mentioned above, there are a number of ways to improve safety of transport networks by providing adequate infrastructure. Legal aspects also play a role. In some countries a tendency can be discerned where liability for traffic accidents is shifted away from non-motorised travellers to motorised ones. This will reinforce the legal position of non-motorised traveller and may induce a more careful driving behaviour from their side; a possible draw back being a more risky travel behaviour of the non-motorised traveller, prividing a clear example of risk compensating behaviour.
One of the means that is sometimes promoted to improve safety of bikers is the use of helmets. However, there are some concerns here because Australian research has demonstrated that requiring the use of bicycle helmets may lead to a reduced bicycle use (Finch et al., 1993). Wardlow (2000) claims that the health benefits of biking

are so large that they by far exceed the accident risks. Therefore, the requirement of the use of bicycle helmets leading to a decrease in bicycle use would have adverse health effects. Another potential problem is that bikers may be induced to take more risks given the protection of the helmet. Garder and Leden (2000) report figures about different rates of adoption of bicycle helmets in various parts of Scandinavia and conclude that much depends on promotion activities to support people that want to use a helmet.
Another means to promote safety of bicyclists is the requirement to equip the bike with of lights and reflectors. This is important because a relatively large share of bicycle accidents takes place at twilight and night time, one of the possible risks being collisions between bicycles.

In addition to traffic safety there is also social safety. In many cities the perceived lack of social safety discourages the use of non-motorised transport and of public transport. It is here that local governments can do much to improve the situation. Policies may range from increased police surveillance in general, special attention paid to black spots to improved lightning of bicycle paths and footpaths. Also, the introduction of social safety as a design criterion in the planning of infrastructure for non-motorised transport modes will improve social safety problems.

Bicycle theft and vandalism is a serious problem in some countries. For example, the probability that a bicycle is stolen is estimated to be 5 per cent or more per year in The Netherlands (Dutch Ministry of Transport, 1999). Among the solutions are insurance (but premiums are high), guided parking, police surveillance, and ICT applications as indicated below.

A point of special importance is the application of *advanced technologies* such as ICT in transport. ICT is gradually increasing the quality of motorised transport modes, making them more comfortable, and providing the traveller with information. An aspect that is easily overlooked concerns the potential contribution of ICT to improve the situation of non-motorised travellers. Governments have a responsibility in this respect because in the case of non-motorised transport there are no strong parties that have an interest in promoting ICT applications (in motorised transport car manufacturers and public transport operators obviously do have such an interest). Several opportunities exist to avoid a pro-motorised transport bias in ICT applications. For example, ICT could be used to impose strict adherence by car drivers to speed limits in residential areas. Similarly, ICT could also be applied at a larger scale to provide pedestrians and bicyclists a fair treatment at traffic lights. Also, ICT may be a promising solution to the problem of bicycle theft since it makes the tracing of stolen bicycles much easier.

One of the policy opportunities for governments is to *put non-motorised transport modes on the agenda of employers*. Bicycle use tends to be an exception by commuters in the USA (modal share far below 1 per cent). Yet even in a low density country such as the USA, the share of commuters living within a distance of 5 kms from the place of work is no less than 30 per cent, implying that for a considerable share of commuters the non-motorised transport modes would be feasible alternatives. Possible ways to stimulate bicycle use by commuters are: the provision of adequate bicycle parking facilities at the work place and a subsidy for workers that use the bike (it saves employers expenditures on expensive car parking space). Note that the provision of free parking space also implies a subsidy by the employer. Obviously such subsidies may have fiscal implications. Touwen (1997) surveys several case studies of policies by employers. In one case the share of the bicycle of commuters to a certain firm increased from 14 to 21 per cent after the introduction of a number of stimulating measures, despite the fact that in this case the number of employees having a company car was no less than 33 per cent.

Financial measures play a small role in policies to promote non-motorised transport modes. A relationship exists with the above issue of fiscal treatment of employers giving a bicycle to their personnel. Of marginal importance is a measure in The Netherlands where business trips that are made by bike yield an opportunity for a tax deduction of 6 Eurocents per km.

Of much more importance for the non-motorised transport modes are *policies with respect to motorised transport modes*. Some of them have already been mentioned above, such as traffic calming car traffic affecting their speeds or forcing cars to make large detours. Other measures to promote non-motorised transport concern parking policies. As the charges on parking increase (especially in high-density areas) non-motorised transport modes become interesting alternatives for short distance trips.

A final point of importance concerns the *stimulation of non-motorised transport modes as access modes to public transport*. For pedestrians the construction of safe and convenient foot paths to railway stations and bus-stops is important. For bikers similar measures are needed and also the provision of adequate bicycle parking facilities near railway stations and bus-stops.

6. NON-MOTORISED TRANSPORT MODES IN DEVELOPING COUNTRIES

In developing countries, non-motorised transport modes often strongly dominate travel patterns. Also for freight transport they may play an important role. This holds true for both rural and urban areas. In rural areas in Indonesia infrastructure may be so bad and vehicle ownership so low that almost 100 per cent of the trips within the village take place by slow modes. For trips leaving these villages between 80 and 90 per cent of the trips are made with non-motorised modes (Rietveld et al., 1988). Similar figures are observed in African villages. Also within urban areas the share of slow transport modes is important. Although urban residents tend to have higher incomes than their rural compatriots, ownership of motorised vehicles is still low. In addition, the lay out of road networks in residential areas often does not allow mini-buses and cars to enter (Dimitriou, 1995).

China and India are examples of countries with a very strong presence of non-motorised transport in urban areas. Yang (1985) reports that in Chinese cities the share of bicycle trips generally varies between 30% and 60%. Average trip lenghts are considerable: for commuting the average bike trip length is about 9 km for males and 5 km for females in large Chinese cities. The popularity of the bike in the large cities leads to extremely large flows. Some intersections are reported to have flows of some 20,000 bicycles per hour. Speeds of busses and cars are not far above the speed of the bikes in the most busy parts of the cities. In Beijing policies of staggered working hours have been introduced to spread bicycle flows over time. For India, Pendakur (1988) reports bicycle shares of 10-20% for trips in large urban areas. The share of pedestrians varies between 15 and 45%.

An important difference between developing and industrialised countries is that slow transport modes play a substantial role in freight transport. Push-carts, horse drawn carriages and rickshaws are frequently used for this purpose. These transport modes appear to be suitable for the very small scale trading and manufacturing enterprises. For example, street vendors and small-scale food manufacturing have a large market share in the urban economy in low income countries. The narrowness of roads in residential areas gives non-motorised transport modes a natural advantage. Thus, in the marketing channels of inputs and outputs of small and medium scale enterprise within these countries non-motorised transport modes cannot be missed. Also bikes play an important role in freight transport in many developing countries, for example in transporting agricultural products from the villages to the nearby market places.

Another important difference between developing countries and industrialised countries concerns the degree of self-production of non-motorised transport services. Where in industrialised countries the producer and consumer of non-motorised transport services usually coincide, they are often different persons in developing countries. In some cities a substantial part of the working population earns an income as a rickshaw driver, or as a worker with pushcarts in market areas. The quality of these services is rather high: they provide flexible, personalised door to door service in very fine meshed transport networks, and given the large supply of these services the waiting times are usually low. The charge per km of these services is really high, however. A one way trip may be as high as the daily wage of a labourer (Kartodirdjo, 1981). In terms of charge per km, minibuses are much cheaper. Dimitriou, 1995 reports that per passengerkm rickshaws are 5-10 times more expensive than minibuses in Indonesian cities. This means that rickshaws and other non-motorised services are primarily consumed by higher income residents in these cities.

In rural parts of developing countries animals are often used extensively in freight transport. The tractor has not yet captured agricultural activity at all places so that in the rural parts of many countries one may still observe a large variety of animal traction. Examples are buffaloes, horses oxen, mules, donkeys and camels, all involved in various agricultural and transport activities. Also elephants are sometimes used in freight transport. It is good to remember that it was not too long ago that horses played a vital role in rural freight transport in Europe and North America (Ausubel et al, 2000).

Infrastructure problems have a strong impact on non-motorised transport in developing countries. The shortage of road infrastructure means that all transport modes make use of the same road. This leads to two problems. First, congestion in urban areas is very high. Separation of slow and fast traffic will be one of the means to make this problem manageable. Pendakur indicates that planning practices in Indian cities are havily biased in favour of motorised transport. One of the issues is the provision of 'proximity' allowing poor urban residents to find appropriate destinations of their trips within walking distance. The other problem relates to safety. The number of casualties per km driven in developing countries is extremely high. The fatality rates in transport per motorised kilometre may be a factor 100 higher in developing countries compared with industrialised countries. Separation of fast and slow transport modes will again be one of the tools to ameliorate this situation.

Given the strong presence of the bike in many developing countries it is no surprise that bicycle production is an important economic sector in several of them. The major world bicycle producing countries are located in Asia. Annual production figures in 1995 are 45 mln in China, 10 mln in India, 8 mln in Taiwan and 6 mln in Japan. The USA is the major producer outside Asia (8 mln), but a quite substantial share of the components (for example drive trains, hubs, brakes) of US and other non-Asian producers are imported from Asia. In addition to bicycle manufacturing also bicycle repair is an important economic activity in some of these Asian countries. In Africa, biking plays a much less important role than in Asia, but in certain countries such as Zimbabwe and Tanzania there are pockets of high bicycle use. Bicycle production is negligible in this continent. A major bottleneck for bicycle use in many African countries is the availability of spare parts.

7. CONCLUSIONS

With the increase of incomes in most countries, the share of motorised transport modes has increased, allowing people to travel longer distances. Thus, in terms of the contribution of non-motorised transport modes to the total number of passengerkms one can observe a continuous decline. In terms of the total number of trips, however, non-motorised transport modes have retained high shares, however (table 2 mentions shares of 31-47 per cent in a sample of European countries).

For the quality of life in cities a substantial share of the non-motorised transport modes appears to be an unavoidable and essential element. Every trip contains non-motorised elements (for example, walking from the parking place to the final destination; biking to the railway station, etc.). The contribution of non-motorised transport modes to the urban quality of life is gaining increasing attention at the level of national and local governments in many countries (Tolley, 1997, Dutch Ministry of Transport, 1999, Pucher et al., 1999, OECD, 2000).

Among the factors that may stimulate non-motorised transport modes in the future are:
-improved image: health considerations are becoming more and more important in consumer behaviour and even limited use of non-motorised transport modes appears to reduce the risk of heart problems (Hendriksen,

1996). Health considerations were mentioned as the major reason for participation in a bicycle use programme in Denmark (Lahrmann and Lohmann-Hansen, 1998)
-introduction of new types of bicycles (for example the mountain bike led to an improved popularity of biking among youngsters)
-consistent government policies to remove barriers against non-motorised transport modes, traffic calming

Thus, there seems to be a potential for substitution of trips from motorised ones towards non-motorised ones. It appears indeed that in the range of trips with distances up to about 7 km where non-motorised modes are potentially attractive there is substantial room for substitution. However, a closer examination of data yields several indications that substitution between non-motorised transport modes and public transport is stronger than between non-motorised transport modes and the car. Thus, stimulation of non-motorised transport does not necessarily lead to less car use in cities.

An important implication of the above is that policies aiming at lower levels of car use in cities in order to improve the environmental quality by offering cheap or improved public transport may appear rather ineffective. The most notable effects that can be expected are 'new demand' (new public transport trips that do not replace other trips, and long public transport trips that substitute short public transport trips) and substitution of non-motorised trips by public transport trips. Both effects do not yield the anticipated target of green transport in cities.

The above discussion on substitution between transport modes should not lead one to forget that also complementarity is important. This paper has demonstrated the importance of non-motorised transport modes for the proper functioning of multimodal chains, both car oriented and public transport oriented ones.

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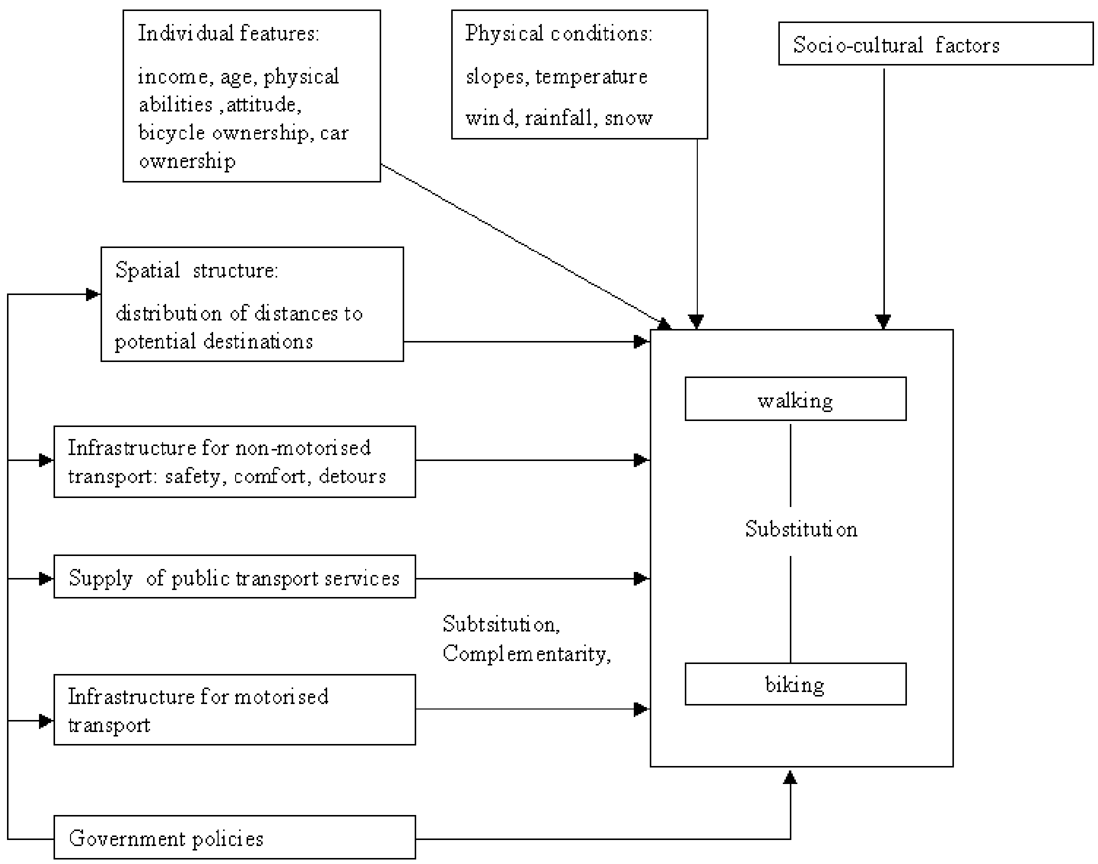
ENDNOTES

[1] We will use both terms interchangeably.

[2] These figures are estimates based on the assumption that the average lifetime of a bicycle is 10 years (Bouwman, 2000)

[3] The low scores for the Nordic countries are the result of very low shares for pedestrians and rather high shares for bikers, the first effect dominating the second.

Fig. 1.Factors having an impact on the use of non-motorised transport modes.


Individual features:
income, age, physical abilities ,attitude, bicycle ownership, car ownership
Physical conditions:
slopes, temperature
wind, rainfall, snow
Socio-cultural factors
Spatial structure:
distribution of distances to potential destinations
Infrastructure for non-motorised transport: safety, comfort, detours
Supply of public transport services
Subtsitution,
Complementarity,
Infrastructure for motorised transport
Government policies
walking
Substitution
biking