SUBSTITUTION OF TRAVEL DEMAND BETWEEN
CAR AND PUBLIC TRANSPORT:
A DISCUSSION OF POSSIBILITIES.

P.H.L. Bovy
J. van der Waard
A. Baanders

Dutch Ministry of Transport and Public Works
Rijkswaterstaat
Traffic and Transportation Research Division

1. INTRODUCTION

Forecasts made with the Dutch National Model System (NMS) for evaluation of the latest long term policy (the 2nd Transport Structure Plan 1990-2010) showed very little effect on public transport patronage of the measures proposed to discourage car use. Measures aimed at improving the public transport system also showed to produce less change from car to public transport than expected (or hoped). These findings gave rise to a lot of discussion about the validity of the demand models as a long term forecasting instrument as well as about the effectiveness of the policy measures proposed in the 2nd Transport Structure Plan.

This paper tries to clarify this issue, both with respect to the plausibility of the National Model results and the effectiveness of the proposed 'push' and 'pull' measures. 'Availability' and 'relative quality' of alternative travel modes play a central role in this discussion. The relative position of both car and public transport in these two dimensions of travel behaviour are presented by means of a number of recently performed examples of empirical research and transportation modelling studies.

2. ARE CAR AND PUBLIC TRANSPORT 'COMMUNICATING VESSELS'? 

It is surprising to see that very often the assumption is made as if the car and public transport are 'communicating vessels'. However, that image is very misleading. There are big differences between car and public transport both with respect to availability and comfort in use. These differences make that car and public transport constitute only partially overlapping segments of the total travel demand market and, therefore, there is no unconstrained 'communication' between the 'vessels'.

There is, for instance, the difference in availability by time. The car is at our disposal during the full 24 hours; public transport usually only operates during a limited part of the day. There is also a difference in availability
Substitution of travel demand

Bovy, et al.

in space. In the major cities there is a dense public transport network. Also on the connections between the major cities there is a high standard in supply of public transport (rail)services. However, in the rural areas and between smaller towns and villages the public transport system is inadequate. In that case the car is superior. Furthermore there is a difference with respect to travel purpose. For certain travel purposes the preference for the car is for instance quite clear, considering the specific need to carry luggage. Just think about the people who do their shopping once a week, sales representatives and maintenance mechanics in business travel with their samples and tools, and of course campers with their tents, surfers with their surfboards, etc.

All these and other differences cause the 'communication' between the two transport 'vessels' not to be perfect. However, to keep using the metaphor: there are a lot of other travel 'vessels' with which 'communication' is possible. For instance, over shorter distances the bicycle is a good alternative. Often with an even higher availability with respect to time and place than the car. Also the activity pattern, the driving force of mobility, can be adjusted; trips can be made less frequent or a destination closer to the origin can be chosen. Furthermore one can decide to drive together with someone else or be willing to let others drive with you.

Given all these alternatives to the use of the private car it is still possible that at certain moments and places, for some travel purposes, for some individuals, and under certain circumstances public transport is indeed an attractive alternative. If and when this is the case then there is a clear case of 'communication' between 'vessels'. Although such spatial relations are still a minority, the mode share for public transport can easily reach over 50%. These are the outstanding examples of spatial relations that are regarded as the potential of public transport.

There exist spatial relations where travel time by public transport is competitive to that by car (e.g. the train over long distances and LRT to city centres). There are also routes where congestion is high and public transport can use special independent infrastructure. There are also specific spatial relations in which egress times are short (e.g. offices near to a railway station), or where there are major parking problems. Furthermore, there are spatial relations in which most of the travellers do not carry any heavy luggage and are all in good health (e.g. the daily commuter flows). Although the total number of such spatial relations in The Netherlands is only modest, the high public transport shares prove the potential competitiveness of public transport under such circumstances.
Hereafter, the concept of 'availability of travel modes' is defined as the absence of limitations to use a certain travel mode (in this case usually public transport) for a certain trip (in this case usually by car). As mentioned above, these limitations can take on any form; not being available in time or place, individual circumstances, etc. Some of the studies mentioned hereafter use a more limited definition of availability, however, in which car availability is e.g. the same as car ownership, or in which the availability of public transport is considered to be the same as the physical presence of a public transport connection.

3. ARE THE RESULTS OF TRAVEL DEMAND MODELS PLAUSIBLE?

3.1 How does the National Model work?

The National Model System estimates current and future national mobility characteristics of the Dutch population on an average working day. It offers the capability of estimating the impacts of a wide range of policy measures on future travel behaviour. The calculated mobility characteristics include: numbers of trips, passenger kilometres, travel hours, travel costs, etc., split by travel mode and time of day.

The kilometrage by travel mode results from the simultaneous changes in mode and destination choice. The effects of proposed policy measures are calculated by disaggregate interrelated choice models using purpose and group-specific choice parameters as well as relation-specific values for the quality characteristics of the alternative transport modes (distance, time, cost, transfers, parking, etc.).

The overall effect results as a weighed average over all spatial relations and all travel purposes. This average is therefore also dependent on the relative proportion of each travel segment. Depending on the type of policy measure evaluated, substantial effects on a few specific spatial relations can therefore 'drown' in the bulk of spatial relations that do not undergo any significant change as a result of the measure.

There is a strong relationship between the effect of a measure and the presence and availability of travel alternatives in each market segment. For instance, for short distance trips the train is usually not available, while the bicycle is no real alternative over a longer distance.

The proportion of each market segment and its composition in terms of travel alternatives determines the potential for switch between transport modes due to a certain measure. From several investigations a rather good insight has been developed into the availability of different travel modes within the different segments of the travel market and the potential for switching between different travel modes, with the emphasis on the switch from car to public...
transport. This public transport potential seems to be limited, especially due to the presence of competition in the form of the bicycle and ride sharing.

The effect of a measure also depends on the quality ratio between the competitive travel modes (see sec. 4.2). Analyses show that the quality of the public transport system that is necessary to be a competitive alternative for a substantial amount of car kilometres is not supplied in most of the spatial relations in the short and medium distance classes (< 25km). This market segment however contains the bulk of all car trips.

Both these factors in the relationship car / public transport, combined with the types of measures proposed, explain why the switch from private car to public transport is still so limited.

3.2. Some elasticities for the substitution from car to public transport

The effect of car costs on public transport use, as derived from the National Model, appears to be relatively small (see table 1); The average cross-elasticity of public transport kilometrage for the fuel costs is +0.14 (Van der Waard, 1990). This is the national average over all travel purposes and all types of spatial relations (with and without good public transport). Comparable figures result from other studies, when the market segments to which they apply, are taken into account. The Long Distance Travel Model (LDTM; public transport = train only) for the longer distance (> 40 km) shows a somewhat higher value of +0.22 (MVA, 1987). The non-captives in commuting appear to be a bit more sensitive: +0.26 (NVI, 1983). These two higher elasticities are due to the fact that within these specific market segments the availability of public transport alternatives is higher.

According to the National Model results, the cross-elasticity of the travel time by public transport on car use appears to be very low (about +0.03). The Long Distance Travel Model (trips > 40 km) shows a value for the travel time cross-elasticity on car use of + 0.17 (MVA, 1987), which is comparable taking into account the difference in market segments. Especially over longer distances (50 km and more) the train competes very well with the car with respect to travel time and therefore shows a substantial modal share of appr. 15%. However, the largest contingent of all trips take place on the short and medium distance range, where public transport does not (yet) offer a competitive travel time. In both these distance ranges there are of course exceptions to these rules.
Table 1. Cross-elasticities given by several modelling studies

<table>
<thead>
<tr>
<th>Measure</th>
<th>Car use all com-purp. mute</th>
<th>P.T. use all com-purp. mute</th>
<th>Source</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PRICES</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- variabele car costs</td>
<td>0.22</td>
<td>0.39</td>
<td>LDTM (1) &gt; 40 km</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.62</td>
<td></td>
<td>TRRL (2) in major cities</td>
<td></td>
</tr>
<tr>
<td>- fuel</td>
<td>0.14</td>
<td>0.26</td>
<td>NM (3)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.04</td>
<td></td>
<td>NS (5) train</td>
<td></td>
</tr>
<tr>
<td>- fare of public transport</td>
<td>0.05</td>
<td>0.14</td>
<td>LDTM (1) &gt; 40km</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.16</td>
<td></td>
<td>TRRL (2) in major cities</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.02</td>
<td></td>
<td>NM (3) train</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>P+R (4) non-captives train</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>QUALITY</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- travel time car</td>
<td>0.30</td>
<td>0.74</td>
<td>LDTM (1) &gt; 40km</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.50</td>
<td></td>
<td>NM (3)</td>
<td></td>
</tr>
<tr>
<td>- travel time P.T.</td>
<td>0.16</td>
<td>0.17</td>
<td>LDTM (1) &gt; 40km</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.03</td>
<td></td>
<td>NM (3) train</td>
<td></td>
</tr>
</tbody>
</table>


The results derived from the demand models are supported by completely different sources of information. Several before and after surveys show that the substitution effects of public transport service improvements on car users is only very small. In 'Afrekenen met Files (Combatting Congestion)' (McKinsey & C, 1986) some findings are presented with respect to three such research projects (the opening of the Zoetermeer- and Schiphol-line (both railway lines) and the opening of a exclusive busway near the town of Krimpen). A more recent example is the new railway connection between Amsterdam and the new satele town Almere (De Boer et al. 1989). In all these cases a strong increase in public transport patronage was apparent, but a decrease in car use on the spatial relations concerned could not be identified.
Analyses with the Dutch National Travel Survey data show that a simulated improvement of the service level of public transport on each spatial relation in The Netherlands to the highest level now supplied (e.g. in urban areas: bus, tram and metro services as in the four major cities; and for interurban trips: railway stations both at town or village of origin and destination) would reduce the total car kilometrage by 5% (Zondag & Schulten, 1988).

4. HOW EFFECTIVE ARE 'PULL' MEASURES?

4.1. Level of public transport availability

As already stated in section 2, there are spatial relations for which the 'vessels' of car and public transport are indeed 'communicating'. Among the total number of spatial relations, however, these are still a minority, although they are not unimportant.

Acceptable public transport services are at this stage only available on a limited number of spatial relations where both access and egress to the public transport system is good. For instance, only part of the Dutch population lives within an acceptable distance from a public transport stop; e.g. about 40% of the labour force lives in municipalities without a railway station. However, the supply is of a somewhat higher standard at the employment side.

Several investigations show quantitatively the limited market of the (current) public transport system. Zondag & Schulten (1988) calculated that roughly half of the total person kilometers in The Netherlands is travelled in spatial relations where there is no acceptable public transport.

The public transport availability for (both current and future) car trips is of special importance. According to Katteler and Roosen (1989) suitable public transport is basically available for only about 30% of the car kilometrage involved in regular car trips. For 2/3 of this kilometrage the local public transport is the available alternative and for 1/3 the train is. Regular car use was defined as trips by car that were made at least once a week between the same origin and destination. These regular trips by car form about 62% of the total number of trips by this mode. For the other (non-regular) trips by car a considerable lower percentage (about 11%) was found suitable for substitution by public transport. In the current situation the bicycle and ridesharing seem to be more important alternatives for car use than public transport. At this moment the percentages mentioned can be regarded as the upper limit for the potential reduction of car kilometrage by means of public transport 'pull' measures.
Substitution of travel demand

Also from the so called 'situational approach' analysis of trips in the corridor Breda - Rotterdam (Kropman & Kockelkoren, 1989) it appears that the group of car users with freedom of choice between train and car is only relatively small (17%). A substantial reduction in travel time by train (to or even below the level of the travel time by car) would lead to nearly doubling this specific group to 36%.

The question now is how the number of spatial relations with an acceptable public transport availability can be expanded, or how the quality of now available public transport can be raised to a competitive level.

4.2. Level of public transport quality

A frequently used measure for the quality of public transport relative to that of the car is the so called travel time ratio TTR:

\[
TTR = \frac{\text{Travel time by public transport}}{\text{Travel time by car}}
\]

Public transport is considered to become competitive if TTR is lower than 2. Figure 1, based on national data, shows how the mode share for public transport decreases with TTR. It appears that there are spatial relations with a public transport mode share of over 50%. At the same TTR-value the public transport mode share for longer trips (> 25 km) is much higher.

However, these spatial relations with high public transport mode shares are a minority at this moment: about 80% of all travel kilometres take place in spatial relations with a TTR-value higher than 2. The average TTR-value now lies at about 3.2. Therefore, public transport is only really competitive for about 20% of all person kilometres travelled.

Designers of public transport systems use design standards for the TT-ratio that vary by distance (Van den Heuvel & Schoemaker, 1989). Figure 2 shows these design standards set against the current averages in the corresponding distance classes. It appears that the current level of quality strongly differs by the distinguished distance classes. At longer distances the current level is clearly below the average design standard of 2, so, on average, very little improvements seem to be needed. However, at shorter distances (where currently the bulk of the car kilometrage is made), the situation is still far from ideal. The graph suggests that for public transport over longer distances more factors than just travel time play a role.
Substitution of travel demand

Figure 1: Public transport market share at different TTR-values (Source: National Model, 1986)

Figure 2: TTR-values by distance class: target values and current situation (National Model, 1986)
4.3 Improving the relative quality of public transport

On which spatial relations can the relative quality of public transport be improved and how? One of the possibilities are express buses with exclusive lanes on roads with major congestion such as the so called 'Shuttle'-buses that are now in use to a few major employment centres. Where parking problems get worse, short egress times can be offered. In addition, the concentration of offices near railway stations could be increased through physical planning measures.

However, the presence of good public transport as such will not automatically result in attracting a substantial part of the car users. Substitution between travel modes can go both ways. And there are also some threats from within the car system.

Travel time is not the only factor affecting mode choice behaviour; especially not in commuting. There is more that the consumer takes into account. The problem is that public transport can not satisfy the needs of every customer; it can not offer a custom-made product. The preferences of the (potential) customers are very heterogeneous and to satisfy one customer sometimes means to lose another (e.g. being allowed to take dogs on public transport, tolerating music, etc.). This means that an ever increasing part of the non-captive market is not susceptible to any kind of travel time improvement what so ever.

The consumer who has a choice, compares alternatives. In order to have any effect, improvements in quality should be improvements relative to the quality of the future car system and not to the quality of present public transport! It needs to be considered that besides improvements in the public transport system, improvements in the car system will take place as well (e.g. less congestion, comfort, HiFi car stereo, car phones, introduction of electronics under the bonnet, in the passenger compartment as well as along the road (e.g. for route guidance)).

The spatial relations in which public transport is not a suitable alternative for the private car are numerous. Never-the-less, improving public transport in such cases can lead to an increase in patronage. These newly attracted travellers are not former car users, but the same type of travellers who were already using public transport in this spatial relation. They are, as it were, generated by the improvement, and can therefore be described as 'generation'. From a marketing point of view it is very understandable that public transport companies aim for this kind of increases in patronage. They can help to improve their profitability. In that case, however, the goal is different from reducing car traffic.
4.4 Effects of public transport fares

Changes in public transport fares only have a limited effect on the substitution of travel demand between car and public transport, as can be seen from several experiments (free public transport in several European cities [OECD, 1980; Baanders, 1978]), from surveys (Katteler, 1986, Kropman & Kockelkoren, 1989, McKinsey, 1989) and from model estimates (MVA, 1987, NVI, 1983, Van der Waard, 1990). A first possible explanation for this is the fact that changes in fares do hardly affect the availability of the different modes, as is for instance the case with changes in travel times. Besides that, further explanations can be the weight that travellers apparently put on quality, the low public transport fares relative to income, and the fact that the costs of business trips and also of trips to and from work are often not paid for by the employer.

The price elasticity of public transport (train) on car use (see table 1) is about +0.02 on average (Van der Waard, 1990); over longer distances (> 40 km) the value is more than doubled. (MVA, 1987). Commuting (+0.14) is more sensitive to changes than other travel purposes; and non captives in commuting again prove to be even twice as sensitive (0.28) to changes in public transport fares (NVI, 1983). However, the more sensitive segments of the travel population form only a small percentage of the total (see above).

5. HOW EFFECTIVE ARE 'PUSH' MEASURES?

5.1. Effects of higher car costs

The effect of car costs on public transport patronage appears to be relatively small in the Netherlands (see table 1). The average cross-elasticity for the fuel costs is 0.14 (Van der Waard, 1990). Over longer distances (> 40 km) the value is slightly higher +0.22 (MVA, 1987). The non captives in commuter traffic are even more sensitive: 0.26 (NVI, 1983). These two higher elasticities are related to the fact that on average the availability of public transport alternatives is higher for these two groups of travellers.

Foremost the limited sensitivity is related to the availability of alternatives. A further role is played by the fact that the car user usually has a lot of other alternatives besides public transport to compensate for extra driving costs within the available budget. On short term these are for instance:
- receive higher compensation for travel costs,
- make less car trips,
- make shorter car trips by doing certain activities at locations nearer to the home,
Substitution of travel demand

- share rides with others,
- use the bicycle or walk,
- save on maintenance costs or other budget costs,
- postpone buying a new car.

On longer term these are:
- shifting to a cheaper car,
- shifting to a more fuel-economic car,
- changing work (location) and/or move to another house,
- increasing income.

The past has showed that sharp increases in fuel prices such as during the second oil crises in the eighties have no noticeable lasting effect on public transport use by non-captives. It also can be learned from several surveys (Katteler & Roosen, 1989, Kropman & Kockelkoren, 1989) that in case of increasing car costs there is only a limited willingness among car users to switch to public transport.

Does this mean that increasing car costs is a useless policy? Of course not! The purpose of such a measure is to reduce the growth in car use, not maximising public transport patronage. Differentiated toll levying by period of the day can cause a diversion from peak periods. Increasing fuel prices and toll levying will influence the destination choice behaviour, which in return will result in a reduction in trip lengths. Finally, an increase in fuel price will stimulate the consumers to more fuel economic driving behaviour and to buy more fuel economic cars. In return, this behaviour stimulates car manufacturers to put more fuel economic cars on the market.

5.2. **Effects of other 'push' measures.**

Parking measures are often referred to as the most powerful 'push' measures. Such measures as less parking space, restrictions in parking duration, paid parking, etc. prove to be effective in establishing a shift in modal split, as long as strict control is applied. Especially the commuter traffic appears to be sensitive to the availability of parking space. This is partly because restrictions in parking space can only be applied at locations where good public transport facilities are available. Again the problem here is that the total market for application of the instrument is only limited. Parking restrictions have only a very local effect: The instrument can only be applied efficiently in city centres and at locations with a high concentration of employment. In the McKinsey-study 'Vrijbaan in de Randstad' (1987) an inventory of such locations was undertaken. At maximum application of parking measures only 30% of all morning peak commuters in the 'Randstad' region would be confronted with them. When applied to all possible locations only a relatively small segment of the travel market can be influenced, and therefore the potential for a shift to public transport is only limited.
6. CONCLUSIONS

The volume of the shift from private car to public transport as a result of policy measures differs strongly by type of trip, by type of spatial relation and by distance class. This is a result of the big differences between market segments with respect to availability and the relative quality of public transport. Shifts do occur, but the relative volume of these market segments is such that under the currently proposed policy measures and expressed at a national level, as is the case with the National Model results, the substitution effect is relatively modest. The National Model results are similar to empirical findings and to results from other travel models. This does not take away the fact that in specific spatial relations or corridors with a high quality in public transport supply substantial shifts from private car to public transport can be expected.

The answers for the limited substitution of travel demand between car and public transport as presented in this paper amount to one common aspect; there are still too many spatial relations where the public transport supply is not a competitive alternative with respect to time, place and character among all the available travel alternatives.

The effectivity of PT-'pull' measures on car use can be increased by preferably applying them in spatial relations with high travel demand where the current competitiveness of public transport is still weak. 'Push' measures lead to substitution of car travel demand in situations where public transport is competitive; furthermore, both there and in other situations, they result anyhow in a decrease in car use.

If substitution of travel demand between car and public transport is to be the main objective of improvements in the public transport system, these should be aimed at (future) car users. Such an approach asks for public transport systems according to new design principles, with specific emphasis on elements which are perhaps less relevant to the present (captive) public transport user.

REFERENCES

A detailed list of references of sources mentioned can be found in:

Bovy, P.H.L. et al.
Substitution of travel demand between car and public transport: a challenge to policy makers.