M Longhrgs

Planning & Transport Research & Computation Co Ltd

PTRC

SYMPOSIUM PROCEEDINGS

Models of traffic outside towns

12-15 NOVEMBER 1970. AMSTERDAM

A MODEL FOR THE STUDY OF MODAL CHOICE IN INTER-URBAN TRAVEL

by D.A. Walmsley and M.R. Wigan, Transport Research Assessment Group and Road Research Laboratory

Objective

A model has been developed to predict market shares of traffic flow on each mode over a multi-modal inter-city network. The present status of the work is that a modal-split model exists which will allocate a given number of people travelling between a pair of zones to the various modal links between the two cities, and which takes some generation effects into account. The model is geographically specific; i.e. it does not attempt to predict the form of a city with its distribution of origins, destinations, and main mode terminals, but uses data from real cities.

The main feature of the model is that it takes into account the terminal journeys by considering the available routes from origin to destination as being a combination of access, main, and egress modes. Money costs, together with travel and waiting time penalties, are incurred at each stage, resulting in an overall cost and journey time for the journey. Figure 1 shows a typical simple network consisting of two modes, each with one terminal in each city, linked to origin and destination zones by single urban mode. In the more general case there will be many such urban modes linking each terminal to each zone, and many such zones in each city.

Mathematical Description

The mathematical basis of the model is the theoretical analysis by Wilson (1) which gives results which are consistent with those of Quarmby (2) in his discriminant analysis of modal choice in an urban situation. Let the number of people travelling from zone i to zone j by main mode k be T_{ijk}. Wilson's analysis produces a relation of the form:

$$T_{ijk} = A_{ij} \exp(-\alpha C_{ijk}),$$

where C_{ijk} is a representative generalised cost of travel between zones i and j by main mode k, α is a constant whose significance is explained below, and A_{ij} is a multiplicative constant characteristic of the pair of zones. This leads to a modal split equation of the form:

$$\frac{T_{ijk}}{T_{ij}} = S_{ijk} = \frac{\exp(-\alpha C_{ijk})}{\sum_{n=1}^{N} \exp(-\alpha C_{ijn})}$$

where T_{ij} is the total number of travellers on all modes, S_{ijk} is the proportion who choose mode k, and the summation is taken over all available modes n (total N) between i and j.

Now there may be several routes r (i.e. combinations of access, main and egress modes) involving each main mode, and on each of these a generalised cost is perceived; this may be taken as the linear sum of the money costs plus money equivalent of the time spent on the journey. The generalised costs C_{ijr} on the separate routes must be aggregated to form a snigle representative cost C_{ijk} for travel by each main mode. A way of doing this is to define C_{ijk} by

$$\exp(-\alpha C_{ijk}) = \frac{1}{R} \sum_{r=1}^{R} \exp(-\alpha C_{ijr})$$

where R is the number of routes r involving main mode k. This is consistent with a later version of Wilson's formulation.

The constant α which appears in the formulae is a parameter depending on person-type, and the modal split calculation is performed for each person-type separately. Different person-types in this context are those who have different sets of modes available to them; the main categories are those who have a car available for their journey and those who do not. The numerical value of α is determined by comparing model predictions with a known modal split and adjusting α to give the best fit: this being the calibration process. α can be thought of as representing the importance of cost differences between the modes. For large values of α, all travellers tend to travel by the mode of least generalised cost. For small values the travellers are distributed equally between the available modes. Different groups of travellers who value their time differently may of course perceive a different mode or combination of modes as having the least generalised costs.

A model of this general type has been applied in the SELNEC (South East Lancashire and North East Cheshire) Transportation Study (3). The novel feature of the model described in this paper is the way in which the very large problem posed by the description of movement between large numbers of places has been cut down to give a small and tractable model. This has been done without losing the detailed representation of the locations of the start and end of each desired movement.

Single Zone Model

As an initial exercise, some calculations were done using a two-zone network, consisting of a single zone in the centre of each of two cities. The results gave a good fit to present travel between the cities, but they proved to be rather sensitive to the value of α and the valuation put on travel time.

Multizone Model

The model presented in this paper is basically a multizone one, and all but the initial runs have been performed using a network of several zones in each city, linked to the terminals by several urban modes. Fig. 2. shows a simple form of such a network. The dotted lines linking the terminals in each city represent intermode interchanges: for example, a traveller from city 1 bound for city 2 may find it more convenient to travel by air from city 1 to city 3 and complete his journey by rail, rather than travel directly by rail from city 1 to city 2. This facility has not yet been incorporated in the model.

The model calculates the modal split for travellers between a pair of zones, and assigns them to the inter and intra-city links. The calculation is repeated for all zone pairs and the numbers in the links are accumulated. This means that data are required on the number of people wishing to travel from each zone in the origin city to every zone in the destination city, and the lack of such data is one of the greatest difficulties in the application of the model to practical cases.

Calibration of the Model

The model has been used to predict present day travel on two routes in the UK, labelled A and B.

Some people are prepared to pay more than others in order to save time on a journey, and this can be expressed by assigning to each traveller a time coefficient which is used to convert journey time into an equivalent cost. The time coefficient may of course not be linear (i.e. a three minute saving may not be valued at three times as much as a one minute saving) but we shall assume here that it is. The time coefficient may also be different for different modes, but again we shall assume it is not.

In view of the many studies into time valuation

FIG. 1. SINGLE ZONE, TWO MODE NETWORK

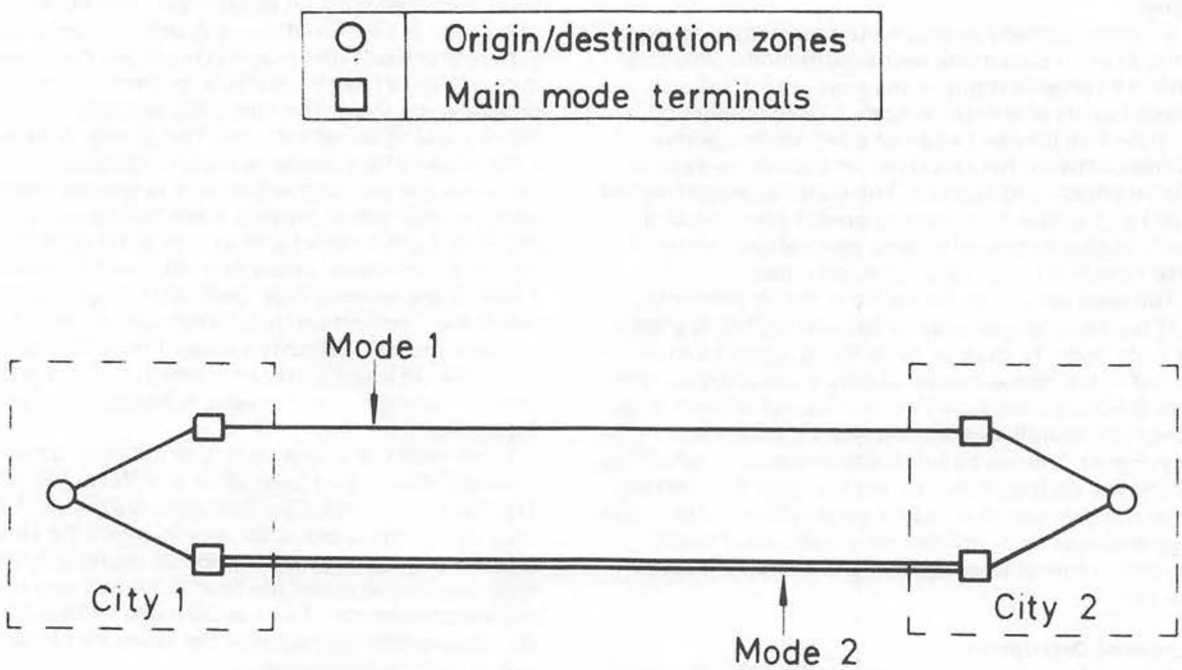


FIG 2 : MULTIZONE NETWORK

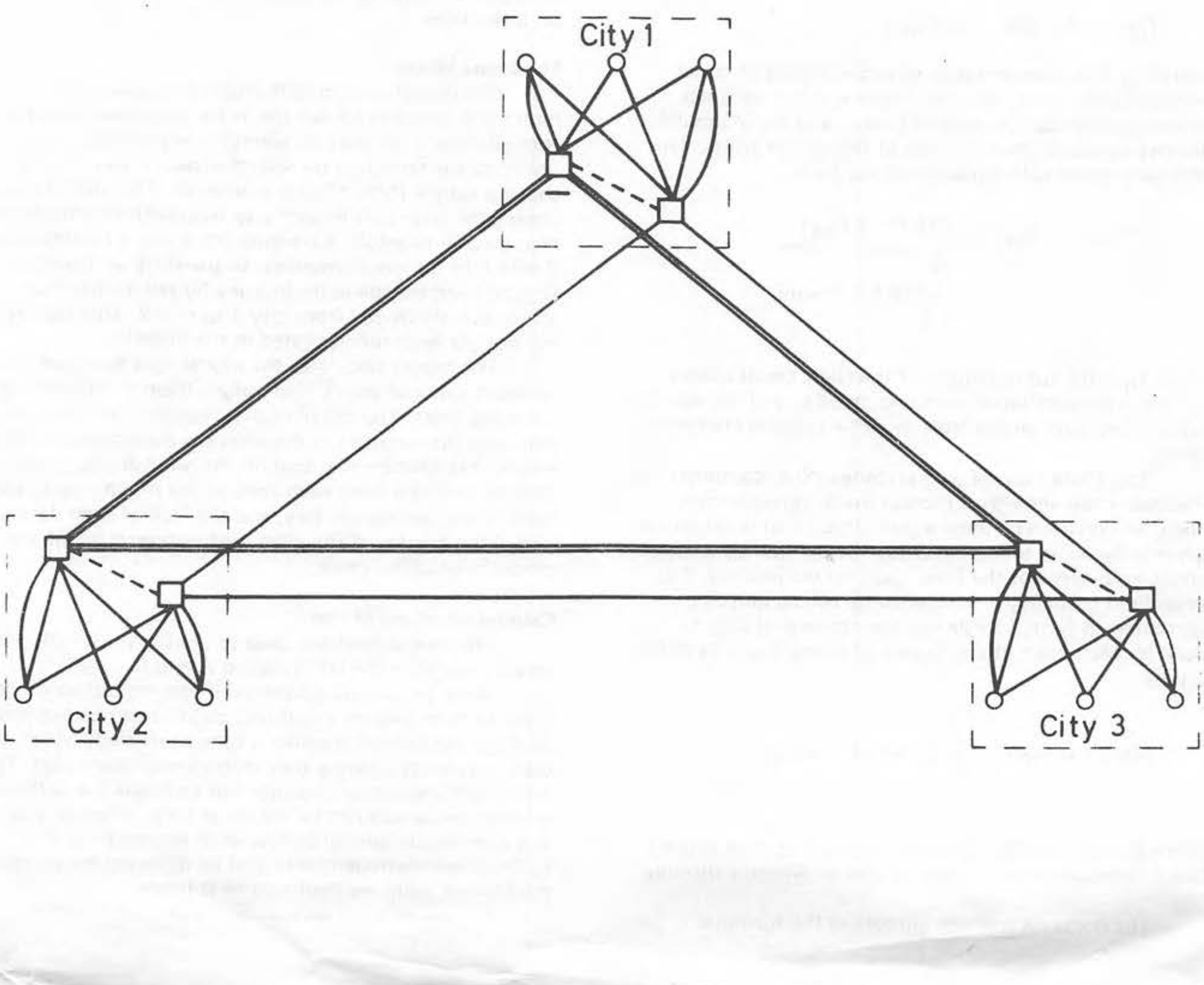
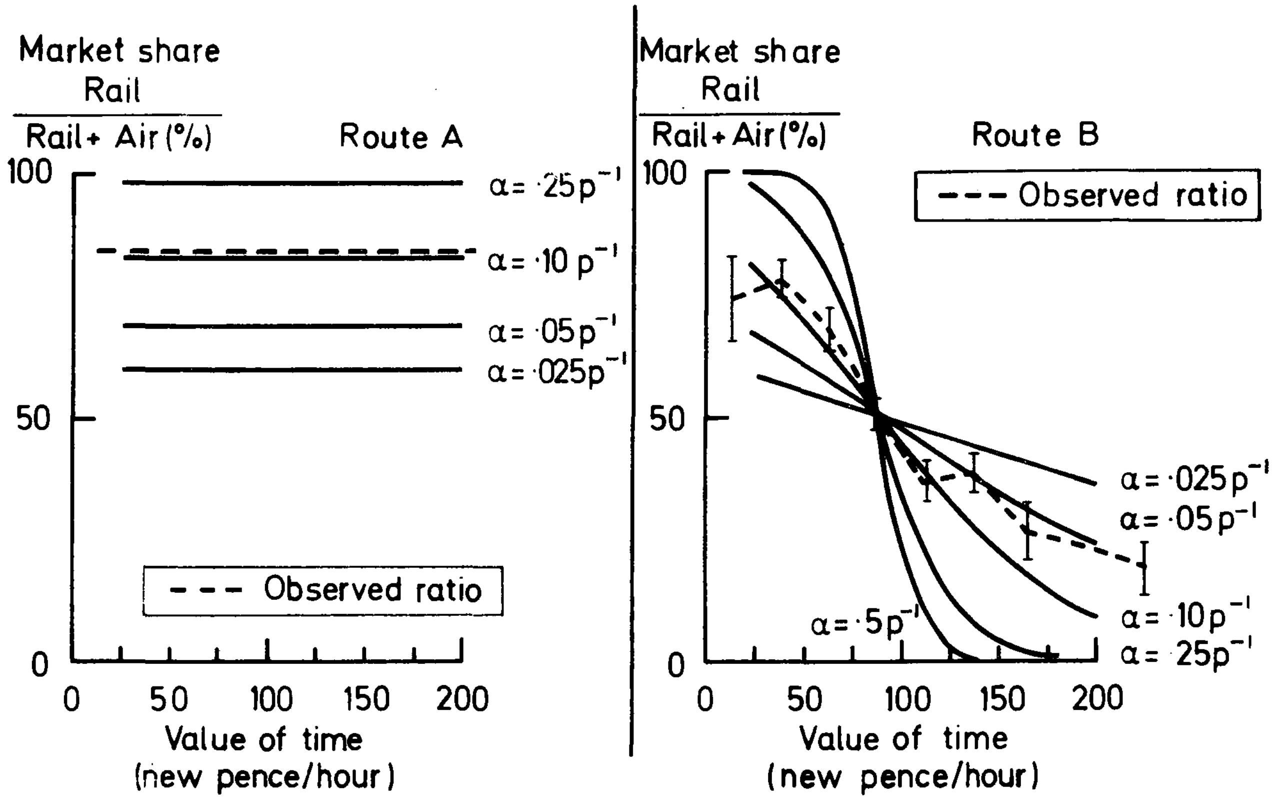


FIG 3: MODEL CALIBRATION RAIL / RAIL + AIR AGAINST TIME VALUATION



COMPARISON OF MODEL PREDICTIONS WITH OBSERVATIONS

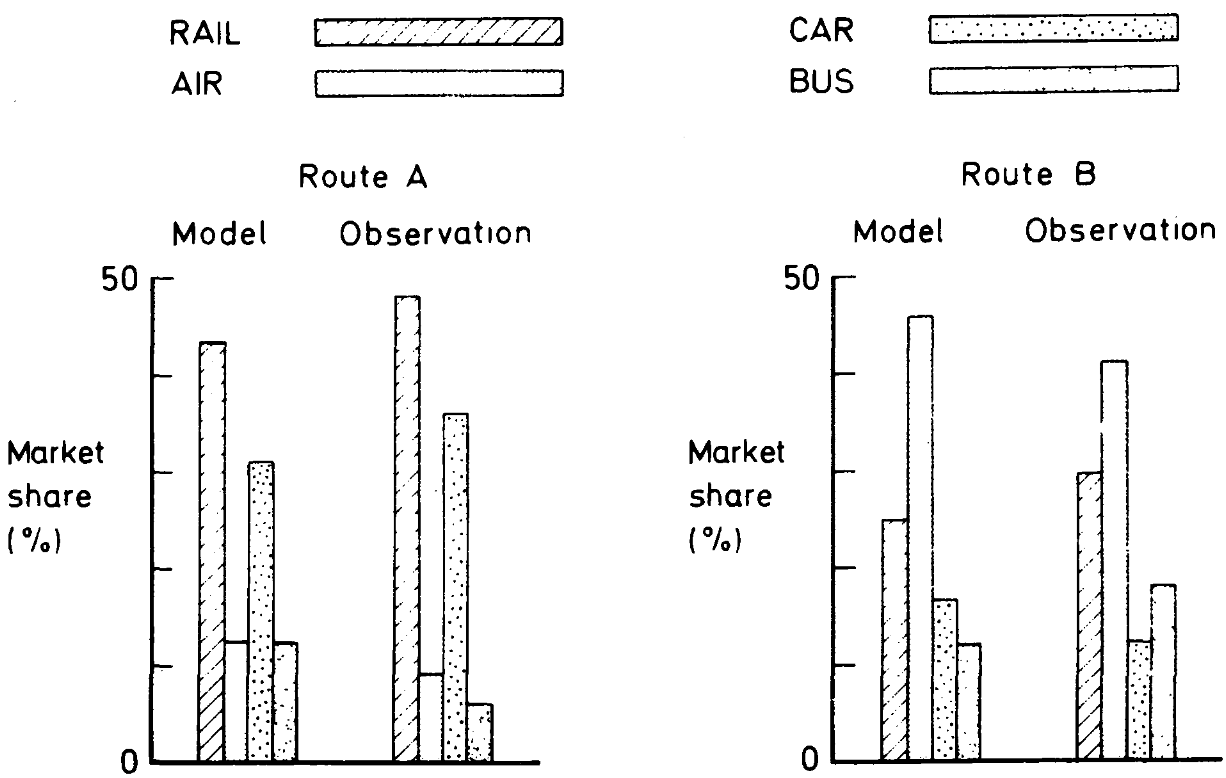


Fig 5. ROUTE B: EFFECT OF INCLUSION OF FAST RAIL

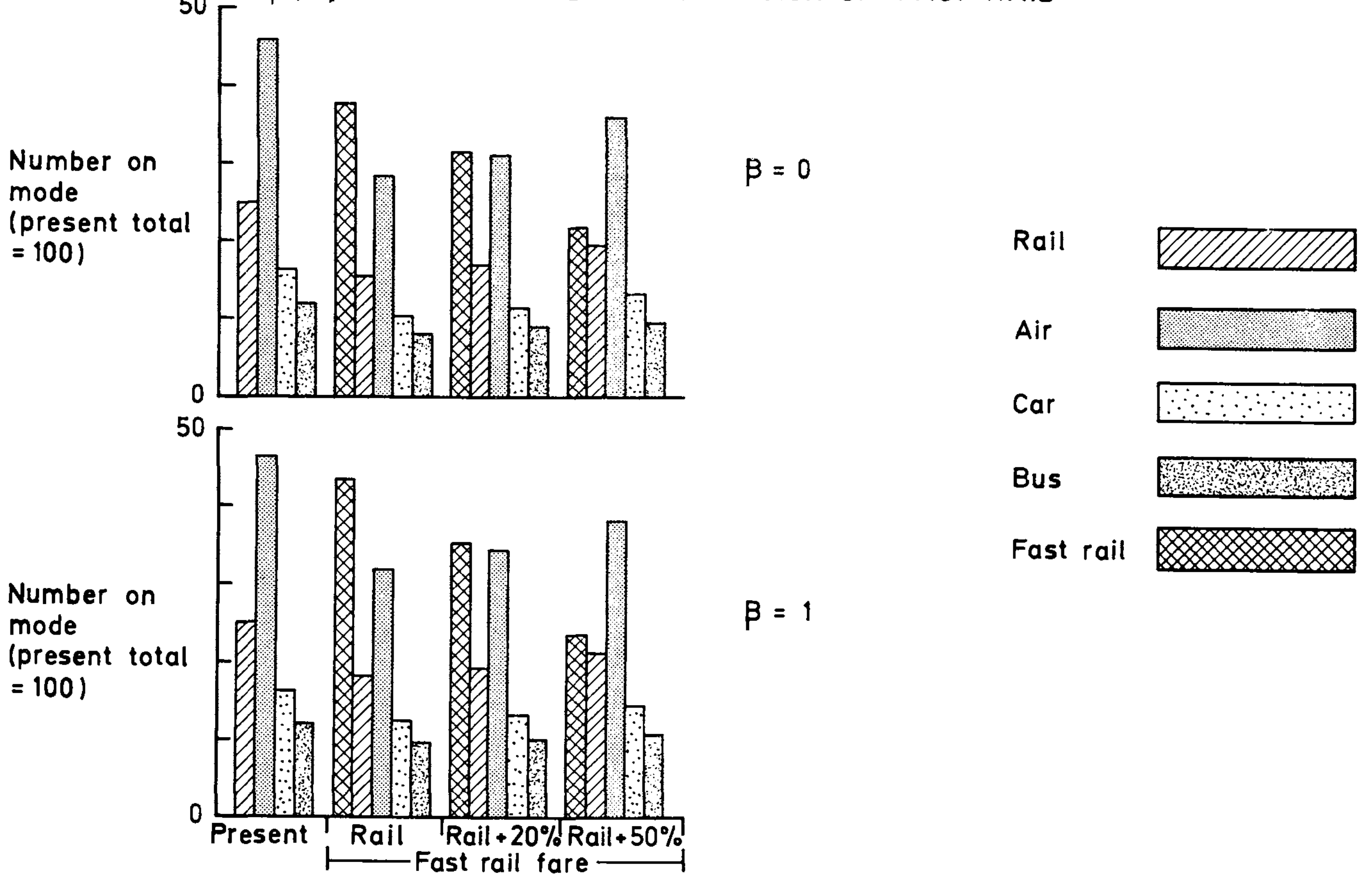
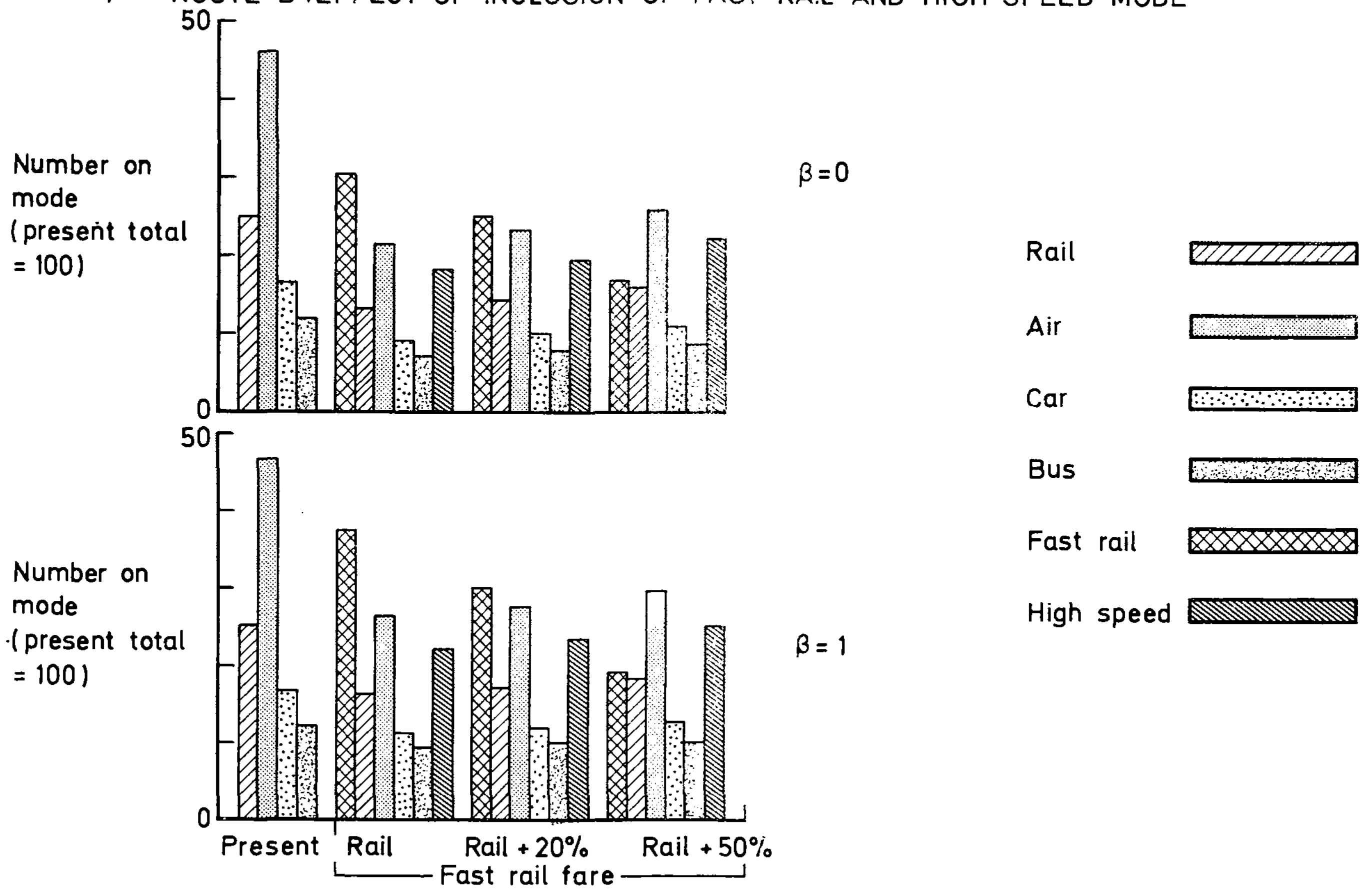


Fig 6: ROUTE B: EFFECT OF INCLUSION OF FAST RAIL AND HIGH SPEED MODE



carried out over the last decade the assumption is made that the time coefficient is proportional to the income rate, with the possibility of using different proportionality constants for different journey purposes. In the following analysis no distinction has been made between journey purposes, and the proportionality constant which best fits the available data appears to be about unity. The travellers have been divided into groups having approximately the same time coefficient, i.e. (with the assumption stated above) the same income.

In Fig. 3 the number of travellers by rail on routes A and B as a proportion of the total number by rail and air — i.e. a diversion curve between rail and air — is plotted as a function of time coefficient, for various values of α. Note that in each case the ratios are relatively insensitive to α.

For route A the modal split is also insensitive to time coefficient, since the journey times are more or less equal. The observed ratio of (rail) to (rail + air) is also shown, and from this we deduce a value of α of about $0.1p^{-1}$ (100p = £1). For route B, the modal split varies with time coefficient. A curve of the observed modal split against time coefficient (dashed line) has also been plotted on Fig 3 with the assumption that the time coefficient is equal to the income rate. Error bars have been included to give an indication of the relative accuracy of the samples in each income group, and the appropriate value of α can be seen to be in the region of $0.05 - 0.1p^{-1}$. A mean value of $0.085p^{-1}$ lies within the range of accuracy for both routes A and B, and has been used for both. This is consistent with our assumption that α is a parameter depending only on person-type.

Applying a time coefficient distribution for the travellers gives the modal splits shown in Fig. 4, and these can be compared with the observed values to check the agreement of the model with present data.

The reason for limiting the calibration process to the rail and air modes is that these are the best documented. Car travel involves a perceived running cost and it is not clear what value should be assigned to this; a value of 0.78 p/km (3d/mile) has been used and gives good results. The results are insensitive to the range 3d-4d/mile, corresponding to approximately the marginal cost of the travel.

This process of calibration is simple and straightforward. The fitting process is not very precise but the low quality and paucity of the available data makes any more sophisticated procedure inappropriate.

Trip Generation

The model described so far has been for modal split only. The introduction of a new mode, or any other change in the network parameters, may cause the number of travellers to change. To take account of this we use a simple unconstrained gravity model of the form:

$$T_{ij} = D_{ij} \exp \left[-\beta f(C_{ij}) \right]$$

to predict the number of travellers between a pair of zones. The values of D_{ij} are obtained by taking the known number of travellers in an initial case and calculating the representative cost C_{ij} for travel between the zones. When the network is changed, the new number of travellers can then be obtained by using the new representative cost and the calibrated D_{ij}'s. A value for β, the elasticity of demand, must be obtained by calibrating against an observed change in numbers of travellers; in this case, the recent electrification of the London-Manchester railway will be used.

If we specify that the form of the function $f(C_{ij})$ (describing how generalised cost affects the number of trips made) is:

$$f(C_{ij}) = \log (C_{ij}),$$

i.e. $$\exp \left[- f(C_{ij}) \right] = 1/C_{ij},$$

then we obtain the simple, constant-elasticity, formulation:

$$T_{ij} = \frac{D_{ij}}{(C_{ij})\,\beta}$$

The representative cost of travel when there are K main modes available can be defined by

$$\exp(-\alpha C_{ij}) = \frac{1}{K} \sum_{k=1}^{K} \exp(-\alpha C_{ijk}),$$

using Wilson's formulism. The $\frac{1}{K}$ factor does not appear directly in Wilson's calculations but is an admissible free constraint in his calculations to which we have assigned this value. This produces reasonable results in most cases but can give rise to anomalies if, for example, the services provided by one mode are split into two and regarded as separate modes.

The implication of such a step is that each of the two new 'modes' produced is perceived to be different choice: while this is easily ruled out where it is merely a matter of separating white or green buses, it is not so clear when two very different services are offered by two bus companies with markedly different public image.

The second type of anomaly will occur if a 'new mode' is introduced that is far more expensive (in terms of generalised cost) than the existing modes: the effect here is that the representative cost of travel drops, but nobody uses this 'new mode'. A typical example would be the inclusion of 'walking' as a mode over distance of greater than a mile or two.

If these two extreme cases are avoided, this method of calculating a representative cost behaves in a sensible and useful manner. The modal split results of the model are unaffected by any of these anomalies, as the representative cost is used only to estimate changes in the total market size.

Results of Application to Hypothetical New Modes

The model is used here to forecast two hypothetical future situations: firstly, a speeding up of the railway to an average speed of 150 km/hr and secondly, the introduction of a new high grade mode with frequent services and the same terminal-to-terminal journey time as present CTOL aircraft services, but which benefits from having its terminals in the city centre. This might be a vertical take off aircraft or a high speed ground transport mode; it is not necessary to identify its precise form. The fares charged on these modes cover a reasonable range of possibilities; for the train, a range of values from the present 2nd class to the present first class fare has been used, and for the high speed mode, a fare of 25% above the present air fare has been used, on the assumption that people would be willing to pay more for a more convenient journey. The patronage of these modes has been calculated with elasticity of demand equal to zero (i.e. no generation of new trips) and unity and some results are shown for route B in Fig. 5 without, and in Fig. 6 with, the high speed mode

Summary

The model which has been described gives a good representation of present day travel on two routes. Further development to allow inter-mode interchanges, and to forecast total numbers of journeys, will continue.

References

1. Wilson, A.G., Journal of Transport Economics and Policy *3* (1) (1969)
2. Quarmby D.A., Journal of Transport Economics and Policy *1* (3) (1967)
3. Wilson A.G., Hawkins A.F., Wagon D.J., Regional Studies *3* (1969) pp 337-350.