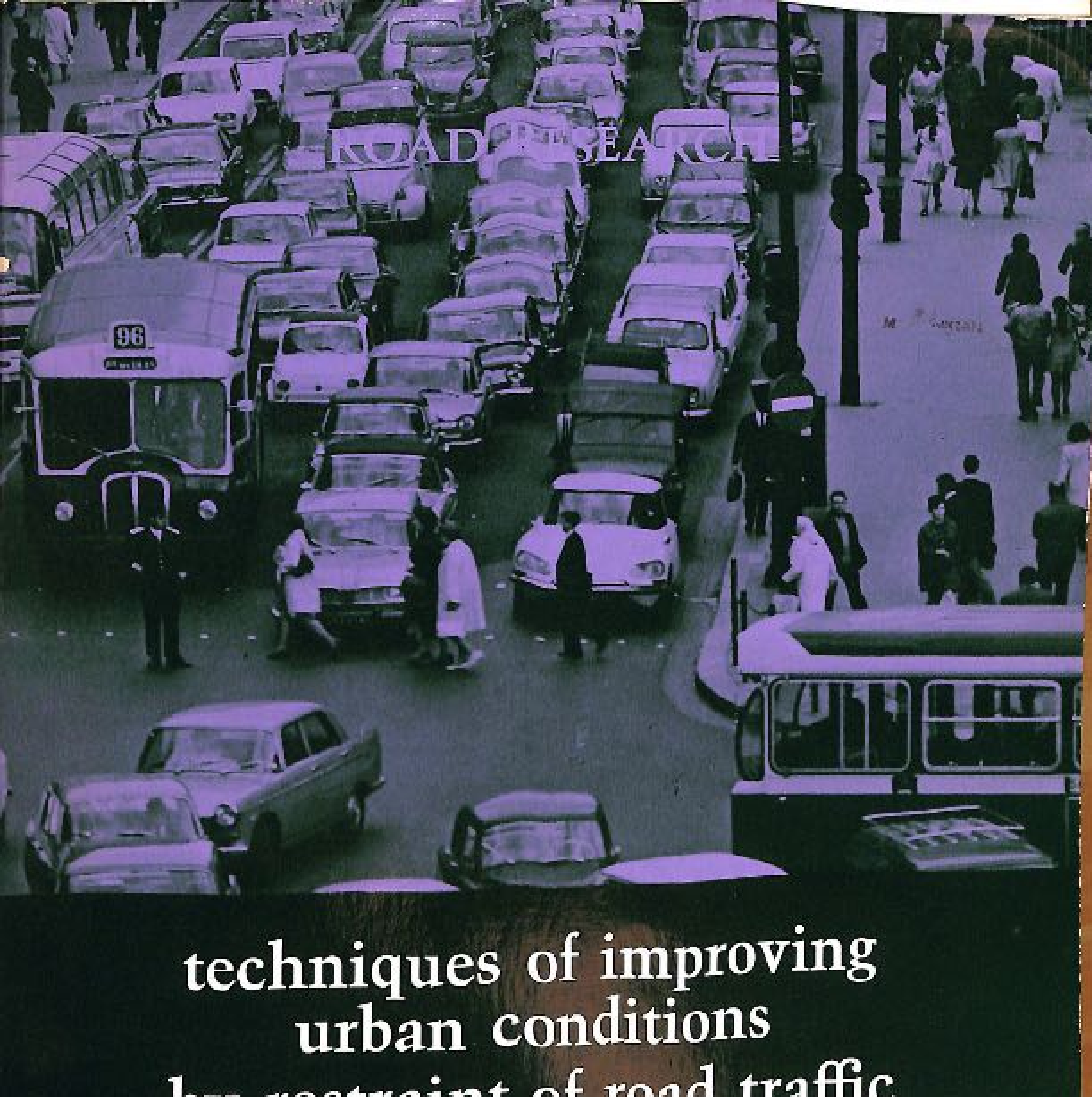
ROAD RESEARCH



techniques of improving urban conditions by restraint of road traffic

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METHODS OF EVALUATION OF TRAFFIC RESTRAINT TECHNIQUES

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Introduction

The common objective of traffic restraint policies is to make the best use of available resources, and the work 'restraint' enters as a result of current situations wherein traffic takes up too many of the constrained resources of environment and space. Restraint policies work by changing the observed behaviour of travellers in making modal choice, routing, and other travel decisions, including the decision to make the trip at all. Physical restraint schemes operate by prohibition or restriction of some or all classes of traffic in a given area whereas fiscal schemes operate by imposing extra monetary payments on traffic using road or parking space in a given area. Either type of policy will alter the balance between modes of travel, and may also affect the numbers of trips made.

In order to determine the 'best' level of restraint to achieve optimal use of a given resource, it is necessary to decide on the objective function to be maximised (or minimised). As restraint operates by affecting behaviour, such a function must include valuations of the changes in behaviour observed. A measure of consumers' surplus must therefore be included and valuations obtained for comfort, convenience, and similar variables affecting behaviour. We can illustrate this approach to such an evaluation of restraint systems by two pieces of work carried out by the TRRL.

Average link model

The first example considers a homogeneous urban area as represented by the average major road in the area under study; such a model is referred to as an average link model. The total flow of car and bus travellers along this average road is fixed, though present car travellers change their mode of travel when the relative travel costs alter due, for example, to the introduction of a road pricing charge.

Peak period and off-peak period conditions have been modelled separately and combined to obtain an all-day travel cost for all travellers and vehicles (cars, buses, taxis and goods vehicles). A minimum overall travel cost was then computed by optimising items such as bus loadings, bus-stop frequency, relative density of bus routes and amounts of private car restraint.

The losses in comfort and convenience associated with a switch from car to bus travel are estimated by considering the present situation and then imposing a rising road pricing charge. As such charges increase, travellers change to bus travel according to an assumed cross-elasticity of demand for car travel relative to bus travel (a value of one has been used in the present calculations). Using this method of representing comfort and convenience costs, an optimum level of private car restraint was obtained.

Applying this model to travel in a town of about half a million population (speed and flow data for Sheffield were used) suggested that the minimum overall travel cost would result after approximately one quarter of present peak-period car users had transferred to bus travel (Figure 1). The overall benefit for the whole of the town with this optimum amount of restraint was estimated to be just under £800 per hour of daytime operation or about £3m per year. This result was obtained for present-size 60-seater buses being used, but the model can also be used to optimise the size of bus. The model indicated that typical journeys (origin to destination) by bus in this area would never become as fast as present car journeys, though the smaller the bus the higher the direct journey speed (Figure 2).

A network approach

The second example is a model designed to reproduce the behaviour of travellers moving over a complex network (Figure 3). The evaluation of any specific fiscal policy is then a matter of applying the charges and tracing the behavioural effects through to the new situation produced: the evaluation is then carried out. Here travellers are offered a choice of routes for a given trip, over roads with widely different characteristics. The pattern of traffic flow produced is therefore a direct consequence of the balance between money, time, and distance that the average traveller can be observed to accept. Many different routes will be used for a given trip, and on any piece of road, journeys to a large number of destinations will compete for road space. A charge placed at any point on the road network will therefore affect traffic flow over a wide area, and raise the level of cost of journeys over an even wider area. In this network model, this is allowed to affect the number of journeys made, so that the process of simulating even a single charge at one place requires a search for new equilibrium of flows, trips, travel costs and journeys. Only at this point can a full evaluation be made.

The special case of a search for optimal road pricing charges is illustrative of the results obtainable from this supply-demand equilibrium model of travel behaviour (Figure 3). Such charges are aimed at equating the marginal private cost and the marginal social cost of travel on each individual piece of road, and are therefore a function of the traveller's behaviour in trading money for time over a given route and the actual characteristics of the road itself. A pattern of such charges can be generated over the network, and the consequent effects on altered traffic flow, travel demand and revenues enter the evaluation of the behaviour shown in response. As such charges are aimed at best resource utilisation, it is not surprising to observe that appreciable benefits can be achieved by the consequent rerouting effects even if the total number of journeys made is held constant.

The essential force driving the model is the behaviour of passenger car (or pcu) units in competition for road space as described by a behavioural cost function. To illustrate the results we could consider the behavioural cost-function as representing a unit of flow as a single pcu that is the average occupancy per pcu, taken over buses, cars, and all other types of vehicle. The high occupancy/pcu of buses gives a fairly high weighting to time savings, but the function will then represent all of the traffic flow in a consistent manner. Figure 4 could be interpreted in this way, although this approach implies bus fares that reflect road pricing charges.

The key features of these results are in the minimal effect of increasing the elasticity of demand for pcu travel above unity, and the rapid increase in potential benefits as the congestion level (defined as an overall factor multiplying the "off-peak" level of journeys) rises to represent peak hour (1.3 x matrix) or network saturation (2.0 x matrix) conditions. It is interesting to note that the known estimates for elasticities of demand based on generalised cost all lie above unity.

This special interpretation of the results of Figure 4 is useful only for illustrating the general effects of optimum road pricing, and more illuminating results are obtained by defining them as applicable only to non public-transport travellers, albeit with a higher value of time. If we now specify that public transport services are available over all links on our network, and pre-empt for their use a constant fraction of the capacity of each road with restraint or without, then we may use our model to analyse the behaviour of a single group of travellers with a single valuation of time savings but faced with the choice of two transport networks (car and bus) over which to make a given journey. If they use a car they will incur the operating costs associated with the simulated pcu travel. This is further simplified if we make the assumption that one traveller = 1 car = 1 pcu unit of flow. If they use the bus they will pay fare charges and some additional stopped time over and above the time costs that they incur in either case. This view of public transport as providing a network of service (where quality is linked to the car speeds on each road) allows us to model the behaviour of travellers who select their cheapest cost route through the bus services, and may also take full advantage of any changes produced by restraint policies altering traffic flows over the network.

The benefits derived from such adaptive behaviour are shown in Figure 5 as "changed routes", and "fixed routes" and show the benefits that would result from travellers being unwilling to change their route through the bus services. There is no compelling reason to suppose that the same travellers would display the same trip demand elasticity for both bus and car travel, and thus a number of "bus travel" elasticities are shown in Figure 5. It is, however, plausible to assume that one class of travellers would display a single elasticity demand for travel however satisfied, and Figure 6 illustrates the resulting net social benefit (and components) when the number of bus and car trips were equal in the initial unrestrained situation. The results shown in Figure 5 illustrate that if a flat fare rate/km is retained in the restrained situation the main benefits are received by those who were using the buses in the initial unrestrained situation. Further, the effect of different assumptions for the elasticity of demand for bus travel is not important, and is comparable with the difference between travellers taking up or neglecting the benefits to be gained by adapting their bus route after restraint.

Figure 6 is based on parameters comparable to those used for the first model described in this paper.

Conclusions

Equally, both models are closely concerned with valuations of behaviour and such valuations form a major part of the evaluation procedure. Although both models described here tackle the traffic restraint problem from quite different angles a comparison case for a particular town gave benefits from restraint within 15 per cent of each other, and the differences were in the direction one would expect from a consideration of the model types.

Figure 1

RELATIONSHIP BETWEEN TOTAL TRAVEL COST
AND AMOUNT OF PRIVATE CAR RESTRAINT USING A 60-SEATER BUS
(Data appropriate to Sheffield area)

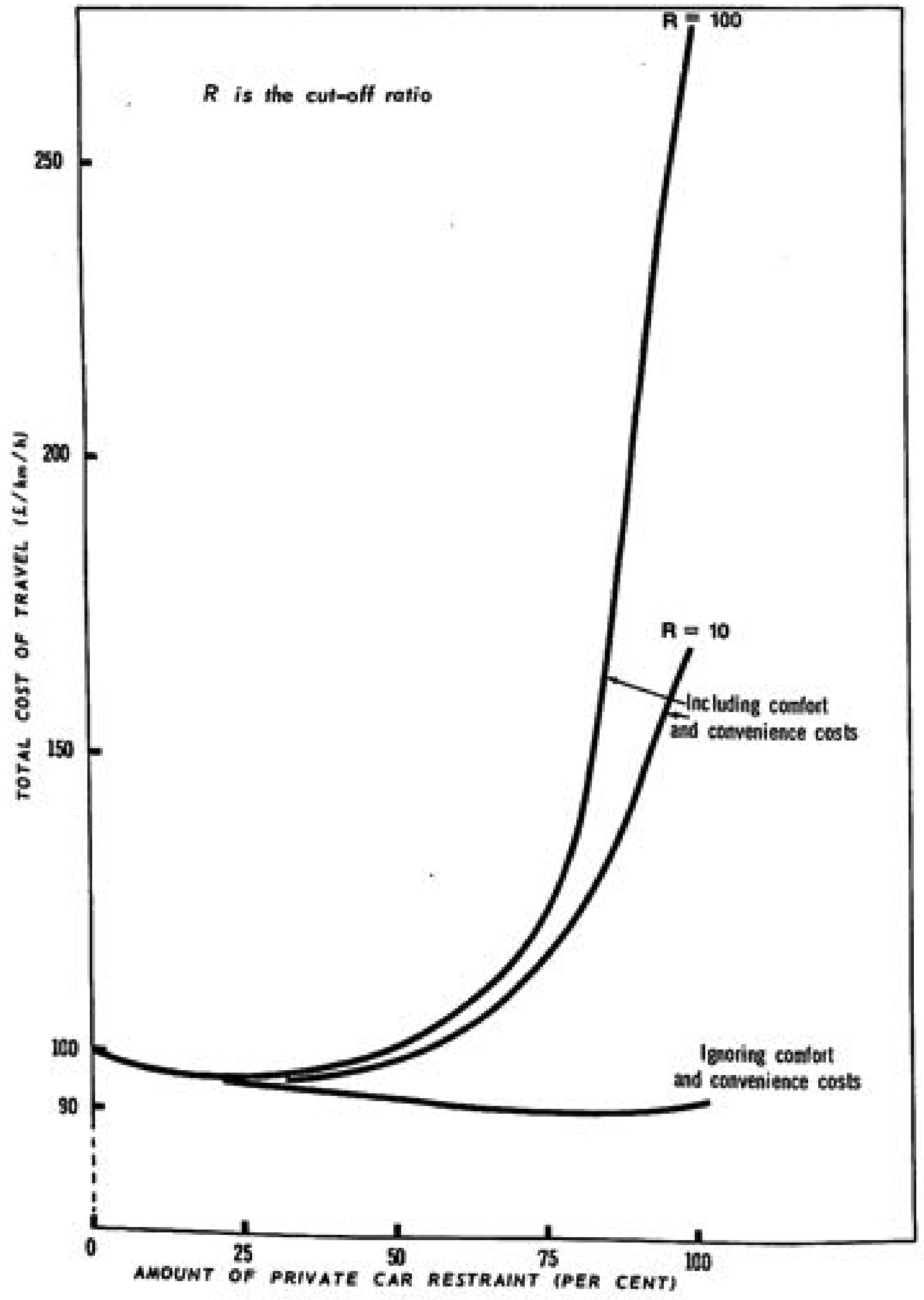

Figure 2

DIRECT JOURNEY SPEED (ORIGIN TO DESTINATION)
OF BUS TRAVELLERS AND CAR TRAVELLERS
AT OPTIMUM CAR RESTRAINT
DURING PEAK HOURS AND OFF-PEAK HOURS (SHEFFIELD AREA)

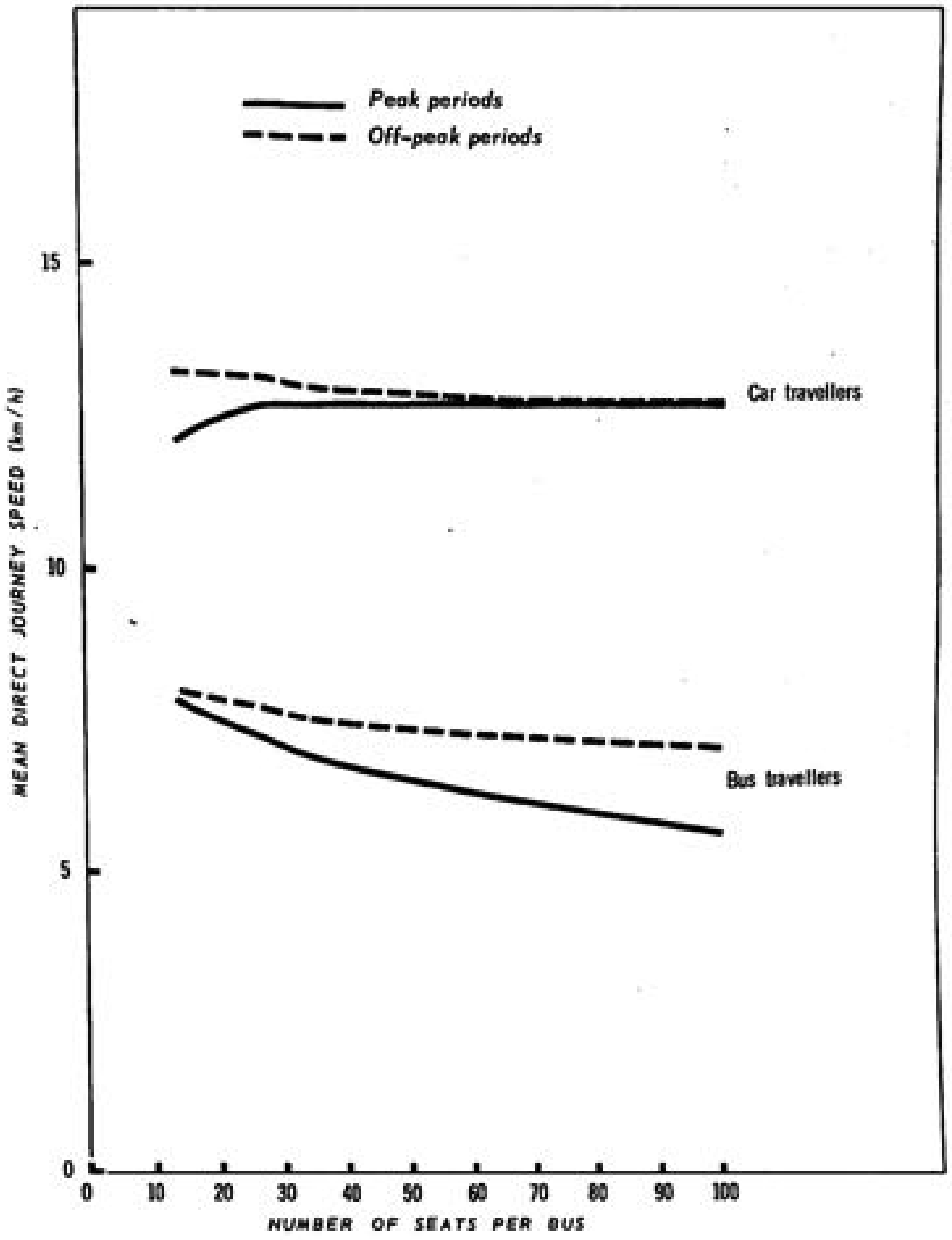

Figure 3

A PATTERN OF ROAD PRICING TOLLS GENERATED FOR A PEAK HOUR

(The charges for each link are shown in units of 1/2 d i.e. 0.21 p)

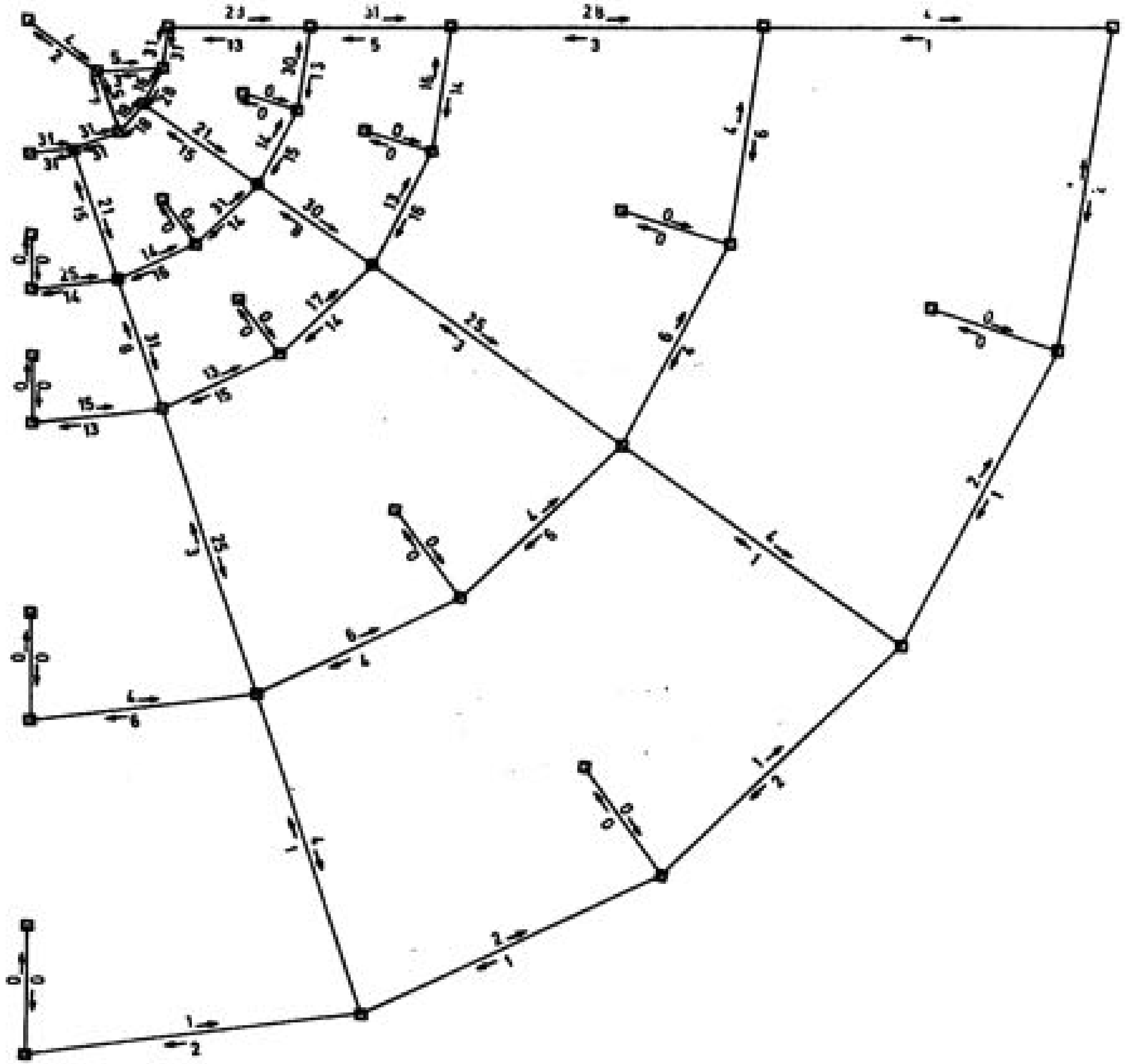

Figure 4

NET BENEFIT OF OPTIMUM TOLL SCHEME

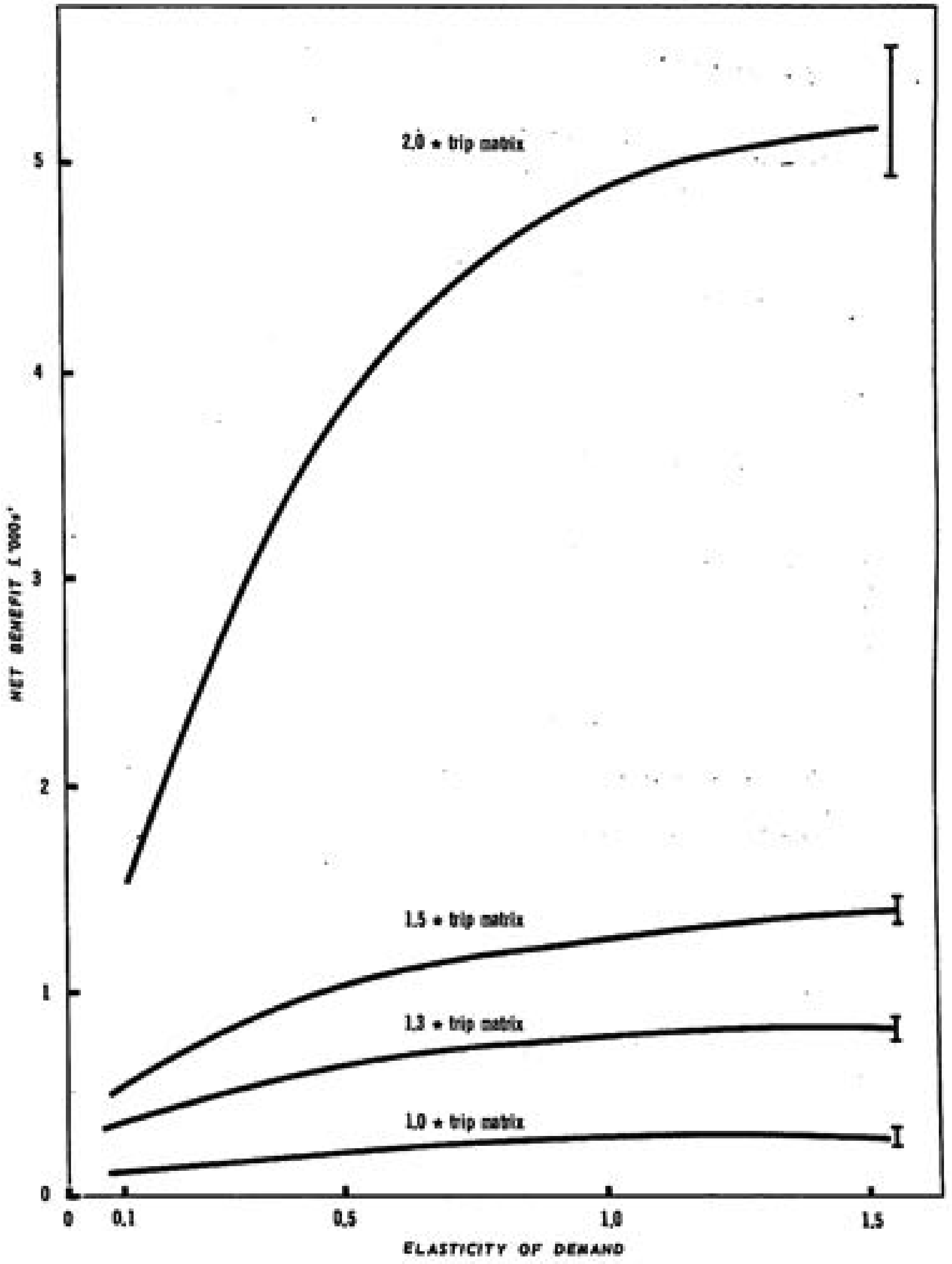

Figure 5

PEAK HOUR BUS BENEFIT

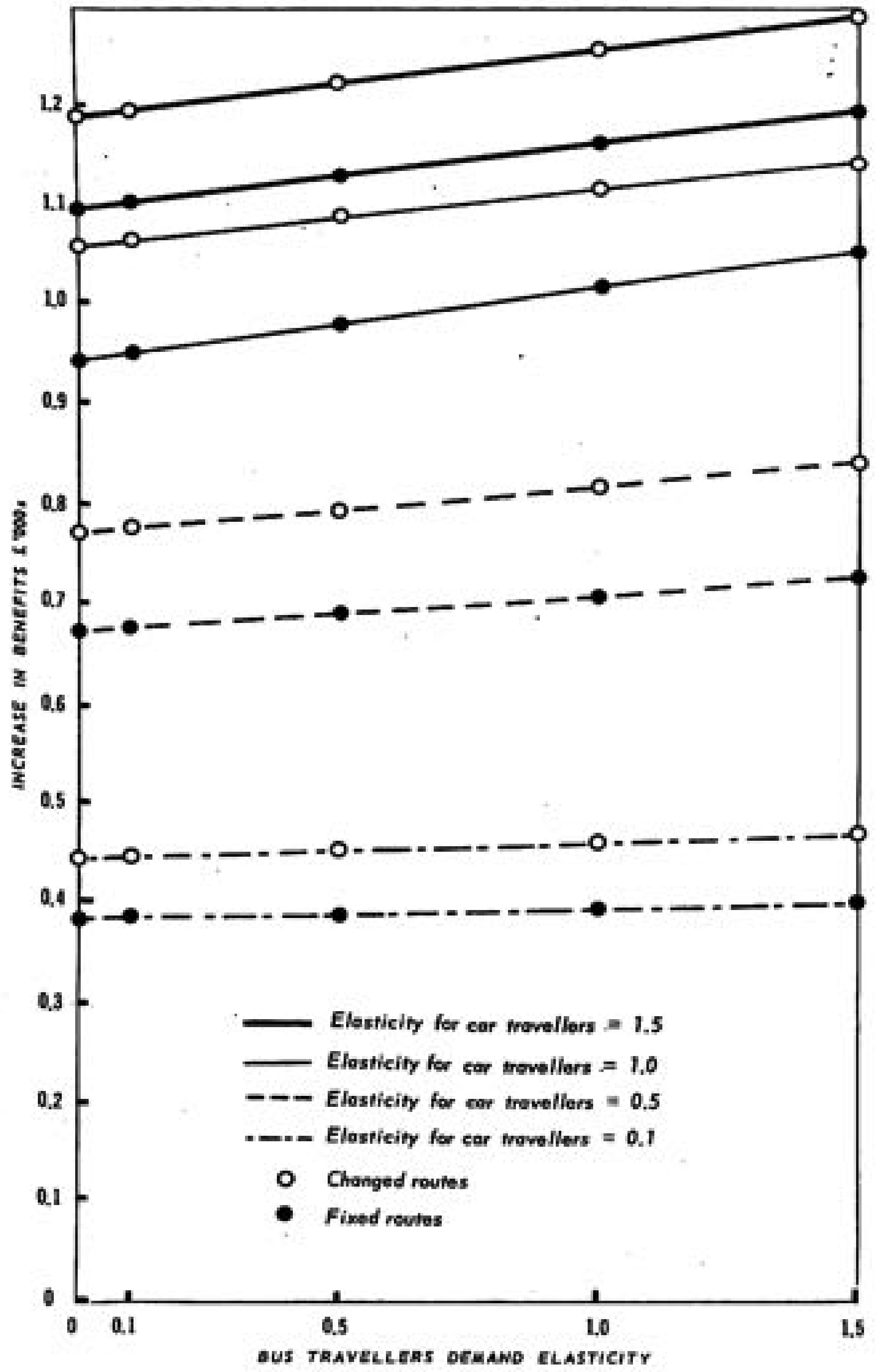

Figure 6

FINAL BENEFITS OF OPTIMUM TOLL SCHEME AT PEAK HOUR, ASSUMING THE SAME OVERALL ELASTICITY OF DEMAND FOR CAR AND BUS TRAVELLERS