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This paper describes the approach to some aspects of strategic transport planning that the authors put forward in their work in connection with the Greater London Development Plan. The principles involved are of a general nature; the paper describes work on London, but the methodology is applicable to any large conurbation. The role of transport planning in the conurbations today is especially significant, not only because of the economic effects of the enormous investment programmes that are thought necessary, but because of the lasting impact on city structure and environment.

We are all aware of the fundamental differences between the public and private transport pricing mechanisms. This paper is concerned with the possible adjustment of the current pricing system to bring about a desired balance in the usage of private and public modes.

There are two fundamental methods of achieving this:

(i) Subsidies may be used to make the travel costs for public transport more comparable with those for the private car, by taking into account consumer surplus, the fare payment then being unrelated to the full journey cost.

(ii) The relationship between the individual's perceived cost and society's cost may be brought home more to car users.

The latter would be preferable, since it would allow the market to respond to an equitable comparison of costs, and the resulting modal split of demand would provide the opportunity to assess the "worth while" level of road provision. This approach is in marked contrast to the customary investment appraisal methods.

Any of the following techniques could be used to alter the price mechanism:

(i) Parking charges
(ii) Licensing by area or time period
(iii) Indirect taxation or fuel taxation
(iv) Road pricing.

The advantages and disadvantages of these alternatives have been examined in considerable depth by others (e.g. [1] and [2]), and no reason has been found to disagree with their general findings that road pricing offers the greatest potential benefits. The main reasons for this preference lie in the relative sophistication of road pricing in dealing with those areas and time periods where congestion would be

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most likely to occur. The other techniques either affect all vehicles, including those whose journeys do not contribute to the congestion (as in the case of higher fuel taxation), or have no influence at all on certain elements of the traffic (e.g. through trips in an area of parking control).

The potential benefits of road pricing are therefore a reflection of its characteristic of controlling vehicle-mileage in particular areas, rather than controlling all vehicle-mileage or controlling vehicle trips.

**ASSESSMENT OF RESTRAINT BY ROAD PRICING**

The method of assessing the levels of restraint which could be achieved with any given level of road pricing has had to be developed within the constraints of time and cost which were compatible with the GLDP Public Inquiry. The development of a computer-based model had to be rejected and less sophisticated techniques employed, which still produced realistic and interpretable results. It will be seen that the methods used have tended to be “pivot-point” techniques, modelling changes in demand rather than absolute levels, and hence achieving equilibrium solutions with the minimum number of iterations.

The procedure developed is based on deriving the level of restraint needed to make the flows predicted in the conventional land-use transportation model “do-nothing” situation (in the case of London—GLC Test 15) compatible with the existing network capacity.

In view of the magnitude of the task of looking at every road, it was decided to tackle the problem on a zonal basis. A comparison of vehicle-miles assigned [3] with vehicle-miles of capacity within a zone can lead to a misleading conclusion on the ability of drivers to find alternatives to a congested route. It was considered that the overall conclusions to be drawn from the work were not invalidated by this approximation, but care must be exercised in considering the situation at the local level.

A system of 71 zones was employed, covering the GLC area and consisting of amalgamated London Transportation Study districts. The zoning was designed so that the smallest zones were located in and around the three boroughs of Greenwich, Croydon and Hounslow, for which more detailed information was required.

**Capacity Assumptions**

The supply of road space for 1991 within each zone has been based on highway capacity data available from the GLC data bank. These capacities have been used to derive zonal aggregates of highway capacity, since they cover the whole of the GLC area and are based on a consistent method of calculation. The capacities are experimental, and they do not reflect junction capacities. However, this exercise has been less concerned with the capacity of individual links than with the aggregate capacity over a screenline. Screenline analyses have shown that the capacities used are approximately equal to the present-day maximum hourly flows. The implication is that the capacities are realistic for present-day levels of service, provided that the capacity of the links can be matched by the junction capacities.

The interpretation of existing traffic flows, however, is that levels of service over a considerable proportion of the day fall well below acceptable standards; we have
therefore based our analyses on 70 per cent of these capacities, which represents a considerable improvement in the levels of service.

This figure of 70 per cent broadly conforms with the Department of the Environment figures of practical capacities. An alternative analysis has been carried out, using the data bank capacities, to examine the implications of pricing to existing peak-hour levels of service.

The fact that this data is limited to the GLC area has resulted in an analysis terminating at the GLC boundary. It should be appreciated that this boundary for the road pricing analysis is merely a result of the available data, and not of a specific intention to delineate the boundary of a managed demand strategy. It would seem more likely that the pricing area boundary would be a price-free Ringway 3, on the assumption that such a facility could be justified economically.

The vehicle-mileage assigned in Test 15 was factored by 0.083 to give an estimate of peak-hour demand. This figure was derived from an analysis of the 1991 hourly variation in car-driver trips. The analysis showed that the morning and evening peak traffic flows were not substantially above the daytime off-peak flows, and it is expected that it would be necessary for pricing to operate for a 12-hour period between 8 a.m. and 8 p.m.

For the purposes of this analysis we adopted a system of pricing in terms of mileage, as opposed to systems of area screenline pricing. The preferred system involves the derivation of a system of restraints by zone, based on the imbalance of available 1991 capacity and the 1991 demands, both expressed in terms of vehicle-mileage per hour. However, this 1991 analysis does not prejudge the possibility of introducing a screenline-based system initially, pending conversion to a more complex system of pricing at a later stage. Any analysis which aims at examining the implementation and effects of road pricing in any particular area must, of necessity, investigate the prices prevailing outside that area, since the restraint achieved will be a function of the total journey costs.

Interdependence of zones in the application of zonal pricing

In order to determine the inter-relationship in a system of charges, it was necessary to devise a series of mathematical relationships based on the trip length distribution curve used in LTS Phase III [4] to express the quantity of vehicle-mileage in any zone, which is dependent on vehicles which cross the zonal boundary. The theoretical approach to this problem of interdependence is based on consideration of a single straight road running through a series of zones; we assumed that origins and destinations are uniformly spaced along the road, and that the trip length distribution is the same at all points.

The procedure involved the calculation for any zone of vehicle-mileage associated with trips through adjacent priced zones. By performing this calculation for each trip length category, and summing in proportion to the number of trips of each trip length category, we obtained the total vehicle-mileage. The effect of pricing in one zone on the adjacent zones is dependent not only on the price itself but also on its effect on the total cost of travel. It has therefore been assumed that the impact of the charge will be in proportion to the length of the trip over which the charge is paid. By performing this calculation for each trip length category it was possible to derive the reduction in vehicle-mileage in adjacent zones, for any degree of zonal restraint.
Iterative Procedure

Listing the demand/capacity ratios in descending order gave an initial appraisal of the relative extent of the restraint necessary in each zone, and the relative severity of the congestion likely to occur in the absence of restraint. Considering first the most congested zone, it is possible to derive the degree of restraint necessary to reduce the peak demand down to the available capacity. But this reduction in zonal mileage will obviously have repercussions for several neighbouring zones, thereby engendering a reduced peak demand and consequently a reduced demand/capacity ratio. The size of that reduction will be dependent upon the matrix of inter-related vehicle-mileages. The new demand/capacity ratios were calculated and the ranked order was amended accordingly.

For the next highest demand/capacity ratio it was possible to perform a similar computation, finding the restraint necessary in the zone and the changes in demand/capacity ratios which would result in all neighbouring zones. This technique was continued until the demand in each zone had been restrained down to its capacity, or a reduction down to its capacity had resulted from restraint applied elsewhere. As the analysis continued, it was found that many zones which had been restrained down to capacity at an early stage in the analysis, and had subsequently suffered further demand reductions as a result of restraint in adjoining areas, were now operating below capacity. This implied that there could be a relaxation of the restraint in these areas, as a second stage in the process, thereby bringing the demand back up to the zonal capacity. But that relaxation resulted in an overloading of adjacent zones, and a third step was necessary to reimpose some of the restraint. The results of the third stage are shown in Figure 1.

Elasticity of Demand

The interpretation of the degrees of restraint in terms of user charges depends on the pricing policy adopted. In order to assess the order of prices appropriate to the results shown in Figure 1, elasticities of demand for each zone were determined. The elasticity of the amount of travel with respect to travel cost is defined as

\[ e = \frac{\text{proportional change in amount of travel}}{\text{proportional change in perceived user cost}}. \]

The elasticities of demand were used in terms of a range of values for different journey purposes. Combining these ranges in proportion to the peak-hour purpose split, it was possible to derive a work and non-work range, which was then related to the range of zonal public transport accessibilities from Volume II of LTS to reflect the variation in elasticity commensurate with variation in the quality of the public transport available. There was not enough reliable evidence to enable us to define accurately the elasticities for each journey purpose; the accessibility variations have therefore been calculated from somewhat tentative estimates of the base elasticities. The range of alternative estimates of base elasticities used was from −0.15 to −1.0.

Results

Although in global terms the “data bank” network capacity balances the Test 15 assigned demand, this represents a low level of service. To achieve practical capacity
standards of operation, a reduction in Test 15 vehicle-mileage of about 25 per cent would suffice on average over the GLC area. Such a reduction would be achieved by a user charge of the order of 3–5p. per vehicle-mile if we assume a low elasticity; it would depend on the true average perceived cost. This gives an indication of the level of price that would be required in a pricing scheme. It will be noted that there are areas where the price would need to be higher to eliminate congestion, and other areas where no charge would be necessary. The actual prices would obviously depend on the pricing policy adopted.

CALCULATION OF INVESTMENT WHEN ROAD PRICING OPERATES

All that has been shown so far is how a road pricing system could operate in order to minimise congestion where a minimum of roads are constructed. We have yet to answer the important question of the optimal level of investment in highway facilities. To do so we must make certain assumptions which may legitimately be queried, but which it is felt are basically sound and lead to results which provide a useful guide to decision making.

The (measurable) benefit received by the marginal user of a facility is equivalent to the cost of making the journey, i.e. excluding consumer surplus. The variation in the demand for travel with perceived cost is shown by the demand curve DD in Figure 2. The slope of the demand curve at a particular point is given by the elasticity of demand at that volume and cost. For the purposes of the calculation, it has been

![Diagram](image-url)

**Figure 2**
Variation of costs and benefits with quantity of travel.
assumed that elasticities remain constant over the range of volumes considered. This
curve gives the benefit received by the marginal user at each volume, and it may be
described as the marginal benefit curve.

At each volume of traffic there is, in theory, a facility which results in the minimum
average total cost to users, made up of variable user costs and facility costs. These
minimum costs form a curve which gives the lowest total travel cost per user, at
each volume of traffic. This is known as the long-run marginal cost curve (LRMC
in Figure 2). Although the LRMC curve is indicated as a straight line, in practice
it varies with the volume of travel, since road capacity can be provided only in
discrete units. The difference between the marginal benefit at the restrained volume,
as given by the demand curve, and the long-run marginal cost curve indicates the
desirability of further investment. If the benefit received from constructing one unit
of additional capacity exceeds the cost of providing that capacity plus the variable
costs, then expansion will increase the net benefit to society. Consequently, the
optimum network size is given by the intersection of the demand curve with the
long-run marginal cost curve. This is the criterion for investment that has been
adopted. In Figure 2 this is represented by the point X [5], [6].

The procedure employed to estimate the amount of investment that would be
worth while assumed that operating conditions were the same regardless of the size
of the network, and that the average vehicle speed on the primary roads would be
30 m.p.h. It has also been assumed that the capital costs of expansion must be
covered by the benefits to the additional users. Most of the costs were based on
motorway costs per mile, since our principal concern was to determine the level
of expenditure on primary roads. As the cost per vehicle-mile of a lower class of
facility might prove less in particular circumstances, the exercise should be repeated
to determine the level of capacity provision at that cost. In order to calculate the
user benefits necessary to cover the facility costs, it was assumed that annual benefits
could be discounted at 10 per cent per annum.

The calculation of the optimum network size for a zone depends on the shape of
the demand curve, and on how the tax element of the present perceived user cost
is treated.

The effect of high and low elasticities of demand, derived as described above, was
also tested; all the user tax was taken as contributing to facility costs, and none of
the tax was taken into account. The most conservative set of assumptions, which
produce the maximum network size, are a combination of low elasticity and low
perceived user cost. The Test 15 network capacity assumed was that used in the
first exercise described above.

In the absence of a demand curve, we have assumed that the Test 15 results
represent a point on the demand curve corresponding to current perceived costs.
The vehicle-miles assigned to each zone in Test 15 were then factored to give the
amount of traffic at a user cost equal to the facility cost plus the marginal user cost.
This leads directly to the justified increase in capacity in the zone, and hence to the
appropriate level of investment. Providing this capacity reduces the demand/supply
ratio; this is shown, with the justifiable investment, in Figure 3.

The interpretation of the results in terms of actual network improvements raises
difficulties in the divisibility of capacity provision, the effect of the network on
demand patterns, and the feasibility of improvements. The figures depend to a
degree on the zonal pattern adopted. The zonal boundaries therefore do not define where the capacity should be provided. One further point that should be noted is that the analysis deals with a static situation, while in practice the conditions are dynamic. In particular, a more sophisticated procedure should take into account shifts in the demand curve and changes in the resource costs of car usage. Also, the issue of environmental costs and benefits has not been dealt with explicitly, although these would be incorporated in the calculation by appropriate changes in facility cost.

CONCLUSIONS

Planning objectives must be clearly stated and their relative priority made explicit. A clear distinction must be made between the primary objectives and other subsidiary objectives which derive from them, and the logic which connects them should be set out. It should be possible to formulate several alternative plans, each consistent in itself but each reflecting a different order of priorities. The choice between these alternatives will be a political matter, and by presenting a number of possibilities the planners may stimulate an informed debate which will allow the fullest possible participation by the public at an early stage.

What cannot be controlled cannot be planned, but any variable which can be controlled or influenced is a potential instrument which a planner may use. To ignore any instrument is to deny oneself what may be a means of achieving what is best for society. One very powerful instrument which needs to be taken much more into consideration in transport planning is the price mechanism. If consistently applied throughout the transport system, it could bring about a great improvement in the efficiency of utilisation of that system, though care must be taken to ensure that the impact of a pricing system is not inequitable or socially regressive.

In particular, the relation of prices (or user costs) to demand must never be ignored. When predicting demand, it is not enough merely to extrapolate past trends in exogenous variables. Demand predictions must be related to the perceived costs of travel. Relative user costs in different modes are especially critical, as they may significantly influence the inter-model split, and hence determine the apportionment of investment resources between public transport and roads. Those who ignore the importance of user costs, and the fact that they may be adjusted by the planners, may be led to a passive acceptance of this continuation of past trends; for example, of the decline of public transport. Yet by use of the price mechanism these trends may be modified or reversed.

REFERENCES