

The Case for a Public Road Authority

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revised July 1994

1. The background

Transport planning and transport investment are alike in crisis. The Conservative Government, with its hostility to planning and public expenditure, has yet to produce a satisfactory transport policy. It proposes to privatise parts of British Rail, and is entertaining possible private investment in the provision of roads and bridges. At present, public investment is under tight Treasury control, and macroeconomic circumstances have been main determinant of the infrastructural investment programme in both road and rail. Environmental lobbies are increasingly delaying major road and rail projects, but the Treasury is hostile to any hypothecation of road tax revenue for financing road investment. Congestion is reaching a critical level, with its true costs somewhat disguised by the recession, while railways continue to lose massive annual sums.

The government has recently begun to entertain the idea of road pricing in some form, possibly starting with charges for motorway access or use. While there is a steady flow of ideas and proposals emerging from the Department of Transport, such as the recent *Paying for Better Motorways* (HMSO, 1993), there does not yet seem to be a coherent strategy or set of guiding philosophical principals. This paper attempts to rectify that failing, as well as providing quantified estimates of the costs of paying for better motorways, and the inefficiencies that may arise from private toll roads.

2. Market solutions or planned allocation?

In competitive markets, the price rations access to the good and signals the need for investment. For market solutions to work in transport, users would need to be confronted with the correct price for each transport mode, and would also need some indication of future likely prices. On that basis, they could make short-run choices about whether and by which mode to use the transport system, and they would make longer term investment decisions about buying vehicles and choosing locations. For both road and rail the correct price has a number of separate elements. There is the direct wear and tear on the track, the scarcity or congestion price, and possible environmental costs due to pollution and

* Department of Applied Economics, University of Cambridge. Invited paper for the MPA 11th Annual Conference *An Integrated Transport Policy: How can it be achieved in a true market economy?* held in the Institution of Civil Engineers 28th October 1993. I am indebted to Michael Spackman, Bob Linnard, and John Pearman of the Department of Transport for help in chasing data, without wishing to implicate them in the use to which I have put them, and to Stephen Glaister and an anonymous referee for helpful comments. Support from the British Economic and Social Research Council under the project R000 23 3766 *The Impact of Electricity Privatisation on the British Energy Markets* is gratefully acknowledged.

noise. Track costs are in principal reasonably easy to determine for roads, and ought to be even easier to determine for rail given the considerable integration and control available to track operators. For roads, they are a small part of the total. The larger part of the costs for roads are the scarcity or congestion costs, and these vary by a factor of more than 100 to one on different classes of roads and at different times of the day. The situation for rail is probably less dramatic, and more concentrated at particular bottleneck points. Fig. 1 compares the costs of road (car), rail and underground for journeys at times when all three modes offer average speeds of 24kph or 15 mph.¹ The private costs of all three modes are close (including taxes and subsidies but excluding congestion costs) but if the congestion costs of roads (shown less the amount already paid in road taxes) are included, and rail subsidies are not paid, then cars become appreciably more expensive.²

The principals of road pricing are reasonably well understood, and the mechanisms for cost-effective solutions now technically available. A market-based solution to the transport problem would start with mechanisms for charging the correct prices to transport users, thereby creating a market for transport services and signalling to road users the true cost of their use.

The second part of the market solution would require the providers of transport infrastructure to respond to the revealed demand and willingness to pay for transport use, in determining the supply of that infrastructure. Both roads and railways have natural monopoly elements, in that over many routes it would not make sense to duplicate the facilities, in which case competition between alternative infrastructure suppliers will be either absent or inefficient. This raises the standard problem that private road provision would normally require regulation to ensure that market prices are set efficiently, even where the privately supplied road does not have a complete monopoly. If roads as a whole were privatised, then regulation would be essential to ensure that service provision is not restricted to raise prices and revenues above the efficient level. It is therefore worrying that the *New Roads and Street Works Act 1991* prohibits the regulation of tolls if the road is not a monopoly crossing of a river estuary (eg see HMSO, 1993, D2, p53).

This paper argues that if the technical problems of introducing electronic road pricing can be overcome at reasonable cost, then the advantages of the market-based solution are considerable.³ If these benefits are to be realised, the new proposal must be

¹ Newbery (1990, fig.4) shows that all modes have essentially the same average speed. The inner area off-peak average speed in London was 14.6 mph between 1986-90 and about 11 mph all day in the Central area. (Department of Transport, 1993, table 4.13)

² It is not clear whether the full scarcity cost of rail is included in the subsidy, or whether, as seems likely, capital costs which proxy for scarcity costs, are understated. Once track costs are separately identified when rail is privatised, such comparisons should become much simpler.

³ The Green Paper HMSO (1993, B14-16) discusses the question of the cost of electronic charging without reaching conclusions. The more sophisticated electronic smart card systems such as the ADEPT system being tested in Cambridge might require an investment of £10,000 per beacon installation and possibly £100-£200 per vehicle to the receiver and associated equipment. The simpler Hong Kong

politically acceptable. Here, the critical question is whether the new system of prices would increase the cost of road use for most road users. If so, then it will be resisted and is likely to be politically infeasible. Calculations reported in Newbery (1990) and updated below suggest that if road pricing replaces existing taxes and charges on road users, (petrol and diesel taxes, the vehicle excise duty and road fund licence), then the level of charges appropriate to a proper system of road pricing would generate about the same amount of revenue as the present system of road charges and taxes. Of course, the pattern of payment would not be the same, and some road users would pay more while others would pay less. If on average the same amount is collected, then one would expect a majority of road users to pay less than at present, while a minority would pay rather more. The balance between rural and urban road users would change in favour of rural areas, but even those paying more under the system of road pricing would experience some benefits, in that they would by definition be using the more congested roads, which would experience a decrease in traffic as road users responded to the higher charges of using these roads. It is certainly possible that these road users, though paying more, would experience a sufficient improvement in service that on balance they would feel that the system were worth introducing.

The problem of financing railways would be greatly reduced, for much of the case for subsidising rail would vanish if road use were properly charged, particularly on high volume commuter lines competing with congested urban arterials. Rail charges would doubtless rise, and the system might contract in many areas, with consequent saving in costs as consumers demonstrate a lack of demand for the system. It might be argued that railways have increasing returns to increased density (though probably not to size), and that were they to charge marginal cost, they would run at a loss and continue to need subsidy. On this empirical question the vertical de-integration of British Rail should shortly shed light, and there are provisions to provide subsidies for socially desirable (on cost-benefit grounds, one hopes) but unprofitable lines. It seems clear that the overall level of socially justified subsidies will be reduced by efficient pricing of competing road and rail, and the practical question is whether the network as a whole generates sufficient revenue to cover total costs, or whether the prices needed to cover total costs would

electronic numberplate cost only £40 (Hau, 1992). To charge for motorways perhaps 1500-3000 beacons would be required and 20-25m tags, costing perhaps £15-30 million for the beacons and at £50/car, £1 billion for the car receivers. AVI (automatic vehicle identification) technology in use in Dallas, US is rented for \$24 per vehicle per year = £16 (Hau, 1992, p24), and the transaction costs on the operator appear to be 4-8 US cents/transaction depending on whether the system is retrofitted to existing tolls or introduced from scratch. Smart card technology, such as that tested in Randstad, The Netherlands, has a higher transaction cost of $DF10.24$ or 8p, but apparently produces a benefit-cost ratio of 4.5 (Hau, 1992, p37). If we assume that improvements might lower the cost to 5p/transaction, and the aim is for collection costs not to exceed 10 per cent of revenue, then given that current revenue is 4p/km for cars, tolls should not be collected more than every 13km using this smart card technology.

represent much of a distortion from the correct price levels.⁴

3. Putting Roads on a Commercial Footing

A market-based solution to road transport is not the same as privatising roads, nor is it consistent with the present methods of allowing private provision of roads under the *New Roads and Street Works Act 1991*. There are two main reasons for arguing that roads should remain in public ownership as public utilities, rather than be privatised. The first is one of practicality, that commercialisation is a necessary first step even if privatisation is thought a desirable end state. The second is more fundamental, and has to do with the difficulty of reversing privatisation, coupled with the need to represent public interests satisfactorily in the regulation that would be required for private ownership. The current system of regulating roads and road use rests on a complex web of law and administrative management, operating at several different levels, and responsive to various constituencies. It is difficult to imagine codifying this tangled web in a set of general principles that would cover the enormously diverse range of roads and land uses so that it could be delegated to private ownership subject to independent regulation, as with other public utilities. The test of commercialisation is whether there is some intermediate allocation of the powers of pricing and investment to a Road Authority and away from the Treasury, subject to regulation on this narrower range of powers, and which nevertheless provides good incentives for efficient management and investment.

The standard argument (Newbery, 1990) is that the correct scarcity price for the use of road space is the price that charges for the congestion costs road users impose on other road users. If there are constant returns to expanding road capacity (as seems empirically plausible for those roads carrying the larger fraction of total traffic), then these prices will equal the maintenance costs and the interest on the infrastructural capital involved in an optimally adjusted road network (Newbery, 1989). If the revenue exceeds interest and maintenance costs, roads should be expanded. If revenue falls short of the interest and maintenance costs, traffic should be allowed to increase until congestion costs and hence the price charged rises to cover the costs. The main problem would seem to lie with uncongested minor roads where congestion pricing would never cover costs. The logical solution would be to consider these as roads to be covered by access charges, as the roads enable access for particular users. As such, they could be charged to local rates, or against an annual licence fee, which grants the holder general access to road space. Balancing this, some roads will have higher marginal than average costs of expansion, given the local environmental and physical constraints, and would provide surpluses to offset some of the deficits elsewhere.

⁴ There may be problems in requiring that each separate route breaks even, as there are likely to be strong network externalities, in which the benefit of the network is more than the sum of its links. It may be possible to devise sophisticated charging systems in which one prices the option to access certain under-used routes, but it may be simpler to internalise these by maintaining large fractions of the network under single ownership. Subsidies to specific routes reflects the view that the major beneficiaries may be local inhabitants for whom the road or rail is a local public good best charged through local taxes.

It is not very helpful to argue this in the abstract without some sense of the costs and charges that might be involved. Consider two examples, the first for the average costs of new construction, the second for the higher costs associated with the M25. Recent figures in the Department of Transport 1993 Report (p54) give the average unit costs of motorway schemes in 1991-1992 as £0.68 million per lane kilometre for motorway schemes and the same sum for all-purpose trunk roads. These figures have been moderately stable for the past five years. If we take average motorway traffic in 1992, of 9,406 vehicles per lane per day, then a charge of 1.6p/km kilometre would generate an 8% return on the capital cost of providing the additional motorway lanes (8% being the current Treasury required rate of return on investments). To this would need to be added the maintenance costs which would vary substantially between passenger cars and heavy goods vehicles, and a small additional amount for other costs involved in operating the system. These extra costs are estimated in Table 1 below to be about 0.6p/km for passenger cars, giving a total cost of 2.2p/km.⁵

The second example is taken from proposals to increase the capacity of the M25 where bridges and interchanges need reconstruction. The costs cited in DoT's *M25 Improvements between Junctions 12 and 15* are £144 million for 12 km of 6 lanes, or £2 million per lane km. A similar consultation document *M25 Junctions 15-16 Link Roads* envisages spending £52 million for 30 lane km, or £1.73 million per lane km. Both of these are expensive per lane km, involving complex junctions and landscaping, but are justified by the high traffic loads carried and the current serious congestions experienced. The annual average daily traffic (AADT) on Dual-4 sections of the M25 is currently about 20,000/lane and on Dual-3 sections about 19,000/lane, both of which may be above the efficient level. At 20,000 vehicles/lane/day and £2 million per lane km, the capital cost at 8% real is 2.2p/km, while at 15,000 vehicles/lane/day the capital charge would be 2.9p/km. Clearly, the costs will depend on the nature of the expansion, and will be lower through virgin countryside, and rather higher in built-up areas (though so will traffic flows).

Once the cost of expanding highway capacity is determined, then the pricing and investment decisions of the Road Authority are fairly simple. Suppose for that passenger cars the total cost of a proposed expansion scheme were 2.2p/km, then the Authority would look at traffic forecasts, and decide when congestion costs reached 2.2p/km, at which point expansion would be justified. That price would be charged for the additional traffic, and would cover the costs of providing the capacity for the additional traffic without decreasing the quality of service to existing traffic. The existing traffic in turn would only make journeys that were worth more than 2.2p/k, while the new users would be willing to pay for the additional infrastructure. In more expensive areas such as the

⁵ maintenance costs, policing and wardens, *less* costs attributable to road damage and gross vehicle mass, per PCU km = 0.55p/km from Table 1. HMSO (1993, p40) reports that the 1993 estimated allocation of maintenance cost to cars would be 0.5p/km, and 6p/km for heavy vehicles, but their methodology is not entirely satisfactory, as explained in Newbery (1988).

M25 corridor, the charge needed would be somewhat higher, perhaps 3p/km. It is worth stressing that this investment and charging rule will only work provided other competing routes are also correctly charged, otherwise the motorway charge will encourage some vehicles to travel on adjacent roads where congestion costs may be even higher. These network externalities are of fundamental importance in deciding on charging strategies and private sector participation, and are discussed further below.

It is worth asking at this point whether there is any point in tolling motorways, as suggested in the Green Paper. It would seem that the costs of providing extra motorway capacity even in expensive and difficult locations such as the M25 fall short of the 4p/km average tax paid by cars.⁶ Moreover, the costs per km of providing extra capacity do not seem to vary that much (perhaps between 2p and 4p/km), so there is little advantage in introducing a system which could charge at different rates for different motorways. On the other hand, the main case for charging directly for road use is to reflect large differences in the scarcity value (or congestion costs) in urban areas in busy periods. Unless the traffic flows vary significantly over the course of the day on motorways, and the proposal is to charge only during congested periods (perhaps charging one third the total traffic flow at three times the average cost of road provision, perhaps 5-9p/km, with zero charges at other periods) there would seem to be little reason to introduce motorways tolls rather than continue with the current set of road taxes/charges. It certainly seems somewhat unreasonable to charge tolls in addition to the already rather high road taxes paid. The real problem seems to be to introduce some logic into financing road building, while reserving road pricing for congested urban areas, where road expansion may be difficult, and rationing scarce road space of higher priority. It is the financial problem that is directly addressed by the proposal to commercialise the road system. Road pricing may then be easier to introduce once the new structure and its finance are in place.

One mechanism for commercialising the road system, and distinguishing sharply between road user charges and ordinary taxation, would be to vest the Authority with the capital value of the existing road infrastructure. Rough calculations presented in Newbery (1990) suggested a total value for this infrastructure of £80 billion at the end of 1990. Since then capital expenditure has averaged £2,870 m (at 1992/93 prices), the price index for new roads has fallen, reflecting the slump in the construction industry, but that for maintenance has risen. The average of the two indices shows no change since 1989/90, so a very rough estimate of the 1992/93 stock of roads at 1992/93 prices might be £88 billion, or, rounding up to reflect currently depressed construction costs, perhaps £90 - 100 billion. Appendix B discusses the problem of valuing roads further.

The Road Authority would be required to pay a specified real rate of return on this capital, much as the former public utilities such as electricity were required to pay a rate of return on their asset value at written down replacement cost. At 8%, the 1993

⁶ HMSO (1993, p39) estimates road taxes on cars as 4p/km, somewhat higher than the 1993 estimated car tax divided by car km travelled, presumably because of higher petrol consumption (accounting for 3p out of the 3.5p/km total tax) at motorway speeds.

estimated cost per PCU kilometre was nearly 2.5p/km, as shown in Table 1, updated from Newbery (1990).⁷ The total road taxes for 1992/93 were £14.7 billion, (Department of Transport, 1992, p36) compared to my estimated total road costs of about £10.4 billion, (between £7.7bn and £14.1bn, taking the full range of capital values and interest rates set out in Appendix B), though congestion pricing might have justified levels of charges yielding £16 billion.⁸ As already noted, the marginal cost of providing addition capacity where congestion is high, such as on the M25, are higher than the average costs of the schemes undertaken recently by the Department of Transport, and probably closer to 3-4p/km, implying higher prices for these roads, offsetting lower prices for less heavily trafficked roads.

⁷ Costs for vehicle km travelled have been combined with PCU, but only amount to 0.1p/km. A compromise figure of £90 billion for the value of the stock of road infrastructure has been taken, reflecting part of the recession, which also affects the PCU km travelled. Higher values for the capital stock and a lower discount rate would give similar figures to the 8% TDR, as argued in Appendix B, but a combination of a high discount rate and a high estimate for the capital stock could increase the cost per PCUkm to 3.7p/PCUkm.

⁸ Uprating Newbery (1990) by the earnings index (of 1.15) to reflect the increased money value of time, and noting that PCU have not increased, so there should be no increase in congestion, gives congestion charges as £14.9b, to which should be added £1.1b for other items in Table 1. This figures excludes other externalities such as pollution, noise, and accidents, discussed in Pearce (1994). Excluding particulates from diesel of £2b and a carbon tax for CO₂, pollution would amount to less than £0.4b, noise was given as £0.6b, and accidents might be 0 - £7.5b, the figure of zero reflecting the fact that accidents have fallen as traffic has grown, consistent with the psychological theory of risk compensation that road users adjust risk levels to a pleasing level, and (costlessly) take more care as traffic volumes grow and driving becomes more dangerous. Non-congestion externalities such as CO₂ should be subject to an additional and separate tax (such as a carbon tax) whose revenue accrues to the Treasury, not the road authority (see Newbery, 1992 on carbon taxes on transport).

Table 1
Road costs at 1992/93 prices

£ million

<i>Cost category</i>	<i>Annual average</i>	
	<i>5% TDR</i>	<i>8% TDR</i>
Interest on capital (Capital expenditure)	4500	7200 (2867)
Maintenance <i>less</i> costs attrib to pedestrians Policing and traffic wardens		2742 420
Total road costs	7662	10362
<i>of which attributable to</i>		
road damage costs		424
Gross vehicle mass		661
<i>Balance</i> attributable to PCU	6577	9277
PCU km (billion)		380 billion km
<i>Cost per PCUkm pence/km</i>	<i>(1.73p/km)</i>	<i>(2.44p/km)</i>

Source: Department of Transport (1992a).

Notes: Figures are annual averages for the years 1990/91 to 1992/93

TDR: Test Discount Rate; PCU: passenger car unit.

These three figures for 1993, of the costs of providing transport services (£10+ billion), of the charges needed to ration road use efficiently (£16 billion), and the level of road taxation (£15 billion), are sufficiently close that we are well placed to make the move to commercial pricing principals. The most contentious part of the calculation would be the required rate of return to be earned on the capital stock, and the related question of the valuation of the capital stock. Practical politics and fiscal necessity require that the current flow of revenue from road users remain roughly unchanged, so that a lower required rate of return on capital would require a higher initial valuation of the stock to generate the same flow of interest and dividends to the Exchequer, or separate pure taxes on road users to preserve fiscal neutrality.

This raises one of the most difficult questions for the operation of the Road Authority - how to price roads when the system is not in long run equilibrium, as at present, when congestion pricing might lead to higher revenues than the cost of supplying roads. If the Authority is allowed to raise prices as demand grows relative to supply, there is a danger that they will attempt to restrict supply (or connive with environmental lobbies to achieve the same effect) in order to generate higher profits, though of course as a natural monopoly the Authority would have to be subject to regulation. If, following the example of the regulation of other public utilities, they are limited to a price cap per PCU km, and they are required to maintain standards of ease of flow by adjusting road capacity, they may be unable to achieve this because of planning delays, in which case

they will be underpricing scarce road space as well as failing to meet congestion standards. On balance a price or revenue cap seems desirable, leaving the Road Authority to adjust the balance of prices between different roads to correspond to relative congestion. This would have the additional advantage that road users would have more confidence in the stability of prices, while removing the constraint on financing expansions.

Once these prices had been fixed at the appropriate level and the implied revenue determined, the final stage in the calculation would be to determine the level of other taxes on road users, to deal with non-congestion externalities (eg carbon taxes), and to raise the balance of revenue demanded by the Treasury.

In this context the recent discussion paper *Paying for Motorways* is rather evasive in noting that 'The Government would take into account the relationship between any new charges and the existing motoring taxes in setting their respective levels.' (HMSO, 1993, 3.16). The main opposition to road charging comes from those who believe, probably correctly, that the Government wishes to continue with the present set of road taxes, and impose additional charges. The solution proposed here would be to replace part of the present road taxes by appropriate road charges, perhaps following the model of Table 1, then to decide what additional externality charges for noise and pollution should be added (and how they should be levied), and finally, to decide on a basis for pure taxes on transport. (Notice that the road charges and inputs such as vehicles and fuel would continue to attract VAT, so that transport would be treated like other services.) Thus if cars were to be subject to a road charge averaging 2.5p/km, as suggested by Table 1, then the Treasury might reasonably insist on an additional fuel excise tax of 1p/km equivalent to recover the same total revenue.

The Road Authority would be equipped with the assets of the present road system, and sufficient indexed government debt whose servicing would require the appropriate transfer of income. Road expansions would then be financed out of retentions and/or borrowing, but there is a potentially embarrassing discrepancy between the current requirement to earn 8% real on new investment, and the cost of borrowing through index-linked government securities, currently less than 3.5% real. This problem is not peculiar to roads and has raised the vexed question of the appropriate return on investment in water companies and gas transmission. In the past nationalised industries have been required to pay required rates of return via external financial limits, and it may be that the Road Authority should be equipped both with indexed debt and equity (held by the Treasury), with the equity paying a higher real rate of return. Provided this is combined with a suitable capital sum for the road network, it should be possible to ensure that the combination of debt and equity pays the required annual sum.

4. A Public Road Authority or Privatised Roads Plc?

If the market can set and charge prices that insure efficient use of existing roads and provide signals for and finance to expand roads, why not transfer road ownership to a private authority? The attractions of private management are that in the presence of

competition, private owners will seek to minimise costs and search out profitable investments. The problem is that many roads are natural monopolies, and would require regulation that may reduce most of the benefits of private ownership. There is the additional complication that the road network is a network, and investment or charges on one sector will effect the traffic flows and profitability of other sectors. The difficulties of pricing component parts of an integrated network are such that most networks have been retained intact, as with the National Grid, the gas transmission system, British Telecom, and, nearer to the present case, British RailTrack. The least satisfactory part of the privatisation of those three utilities is the regulation of charges for access to the network, and in none of these three cases has a completely satisfactory solution yet emerged. The natural solution is to retain ownership in public hands, with a clearly defined objective of providing transport services efficiently, rather than just profitably.

Some measure of the difficulties of handling intermodal spillovers is suggested by fig. 2. This summarises the results of various cost-benefit studies on two proposed rail links in London, that between Chelsea and Hackney (C-H) and the East-West Cross Rail (E-W X). The larger part of the total present value (at 7 per cent real discount rate) of the costs are the capital costs, with additional running costs very small, and adequately covered by fare revenue (shown in black). These revenues fall far short of the total costs. If rail users could be charged for the improvement in service (time saved) the projects would only just break even, but if the benefits in reduced congestion and faster travel for road users are counted, the projects both look very attractive. If road users were properly charged, it might be possible to raise fares to include much of the improved quality of service without encouraging rail users to switch to road, but if road congestion is reduced, then congestion charges should fall. It is very difficult to see how private owners of road and rail would coordinate such investments where major benefits accrue to the users of the other mode, and where the impact will be a fall in revenue and a rise in consumer surplus, though perhaps a closely regulated private transport authority covering all modes would go some way to internalising these spillovers.

The weakest parts of the present system lie in identifying and efficiently constructing cost effective expansions, and in managing the road network at least total social cost. In some countries the public administration is so inefficient that transferring these responsibilities to the private sector under various franchising or contracting arrangements may offer significant improvements. It is hard to judge how far this might be true in the UK, but it might be worth some small scale experiments in this direction.

The logical way to structure the public Road Authority would be on a regional basis, somewhat like the old electricity area boards and gas councils or water boards, so that comparisons could be made between different regions to assess their efficiency and provide incentives for their improvement. In such a framework, it might be possible to consider experiments in sub-contracting or franchising in one or other regions on a trial basis. London presents particular difficulties because of the need to coordinate transport investments across a variety of modes.

Compare this system with that proposed for the Birmingham Northern Relief Road

where the idea is that the road builder should be allowed to charge unregulated tolls for 54 years in order to finance the construction (Midlands Expressway Limited, 1992).⁹ The effect of this will be that tolls will be higher than the efficient level, with adverse effects on alternative routes, and a lost opportunity to optimise traffic flow in this area. I have made some rough calculations to estimate just how adverse these impacts may be, using a simple model set out in Appendix A. As a reasonable approximation, the length of the BNRR and the alternative route on the M6 are both 50km, so a vehicle planning to make the entire journey will weigh up the tolls charged on the BNRR (currently proposed to be £1.50 for a passenger car) with the extra delays and unpleasantness of travelling along the more congested M6. Those with a high value of time will choose the BNRR, those with lower valuations will choose the M6, and the concessionaires will doubtless choose a toll that maximises their revenue. The level of toll is quite sensitive to the total corridor traffic flow, for if the M6 is uncongested there would be no advantage to the alternative route. Depending on the speed-flow relationship on the M6 and the value of time saved, profit-maximising tolls rise from about 2p/km at a corridor AADT of 230,000 to about 8p/km at 360,000, assuming that there is a uniform distribution of time valuation from £2 to £10/vehicle hr, as shown on the right hand y-axis in fig. 3.¹⁰

Provided that there would be some congestion on both roads in the absence of a toll, it may be desirable to set a toll on the BNRR even if there is none on the M6, in order to selectively attract those vehicles for whom the value of time is higher, and to give them a less congested route. It is possible to compute the socially optimal toll, though in the figure it remains zero over the range considered. If the lower bound of the value of time falls to £1/hr, the optimal toll becomes positive (but small) at about 250,000 AADT. The figure also shows the annual profits on BNRR charging the profit maximising toll, the speed of traffic on the M6, and the deadweight loss of the toll. This last concept measures the extra total cost of transport on the two routes (excluding the transfers of toll revenue from motorists to BNRR) when the profit maximising toll is charged, *less* the total cost from charging the socially optimal toll (that minimises the total transport cost). The figure shows the result for one particular set of parameters, and tolls would vary directly with the value of time.¹¹

⁹ The BNRR is to be authorized under the provisions of the *New Roads and Street Works Act 1991* which prohibit the regulation of tolls if the road is not a monopoly crossing of a river estuary.

¹⁰ Toll is proportional to the average value of time. The model is calibrated in vehicles/lane/hr, with zero congestion at 750/lane/hr, and a slope parameter β in the speed-flow relation ship $v = \alpha - \beta q$ of 0.035, as in Newbery (1990). AADT/lane is then taken as 10 times hourly traffic flows/lane.

¹¹ Calculating the average value of time is not easy, let alone the distribution of the value of time, as required in this calculation. MVA *et al* (1987) give base values as a function of income levels ranging from 3.6p/min to 5p/min at 1985 prices, or £3.9 to £5.40/hr at 1992 wage rates. A considerable fraction of traffic will be commercial, with higher wages costs per hour, or multi-occupancy, while some retired drivers have a lower value. The assumption of a uniform range from £2 to £10/hr is intended to reflect this variation.

The more interesting calculation is that the ratio of the deadweight loss to the profit earned by the concessionaires is between 3 and 8, (higher at lower traffic) depending on the traffic flow. (This ratio is shown as DW loss/profit on the right hand scale of fig. 3.) If the lower bound on the value of time is lower, so that the socially optimal toll is positive, the ratio falls, but for a range of parameters remains above 3. What this demonstrates is that isolated privately financed toll roads are potentially very costly methods of raising the finance to relieve congestion. Furthermore, the idea that such a franchise would attract the necessary capital to finance the investment is suspect. The first problem is that under the proposed public Road Authority, road charges would be the only charge for road use, whereas at present vehicles already pay road user charges through various taxes on fuel and ownership. It is possible that the Treasury would transfer some part of the average road user charge already collected from vehicles (about 4p/km for cars in 1993, according to HMSO, 1993, p39) using the new private toll road.

Alternatively, the Government may decide that if private roads are to be allowed to charge tolls, then so also should motorways, in order not to distort competition between public and private roads. The effect on the choice facing motorists between the BNRR and the M6 are effectively the same whether the M6 charges a toll of, say 2p/km, or the Government transfers 2p/km per vehicle to reduce the toll levied on the BNRR, for in both cases the difference between the costs of the two roads has been reduced by 2p/km, if traffic flows do not adjust.¹² Of course, flows will adjust, and the new equilibrium is shown in fig. 4. The effect of relatively raising the price of the M6 by 2p is to raise the profit maximising toll charged by BNRR by about 1p/km (or about one half the toll on the M6). BNRR profits rise, and deadweight losses fall substantially, so that the ratio of deadweight loss to profit falls dramatically, as shown in fig. 4.

The other information given in the figures is the marginal cost of congestion (MCC, at a time cost of £6/veh. hr) on the M6, and it will be seen that this is lower when the M6 is tolled (or the BNRR receives transfers). If the M6 is widened to cope with additional traffic as the MCC reaches some pre-determined value, then the system will reach an equilibrium largely determined by the expansion criterion. For example, if the MCC is allowed to reach 6p/km before widening is undertaken, as well as being tolled, then the profit maximising toll on the BNRR is about 4p/km, the ratio of deadweight loss to BNRR profit is about unity, and the profits of BNRR will be stabilised at about £60 million per year. If the M6 is not tolled, but is expanded at a MCC of 6p/km as before, the profit maximising toll on the BNRR is below 3p/km (the proposed initial toll for cars), profits are lower, and deadweight losses are higher.

Any shareholder in such a road would be nervous that later governments would reconsider the franchise and terminate what would obviously seem an unsatisfactory arrangement. Even if the franchise were not altered, the ability of the government to

¹² There is a difference between the relative attractions of motorways and alternative roads as between tolling motorways and transferring road charges to private toll roads, unless all alternatives to the private toll road were tolled.

expand the M6 or otherwise alter the terms of competition between the BNRR and the M6 would make the BNRR a risky or unpredictable undertaking. The scheme would therefore run into the danger that private investors would doubt the security of their investment, and would need to charge such a high price for road use that it would have very adverse effects on traffic, and would precipitate the feared renegotiation of the contract or other responses such as widening the M6.

A more rational strategy might be to grant the concessionaires of any new road the deemed road charge per km per vehicle instead of tolls (eg 4p/km for cars, if all the current road taxes are deemed road user charges, but probably less if some part is kept back as pure taxation). No toll collection would be required, only an audit of traffic flows, and none of the largely inefficient diversion of traffic to other roads would then take place (though there might be a case for an optimal toll to reserve less congested roads for more urgent traffic, as argued in Appendix A).

A better solution is hinted at in the Green Paper (HMSO, 1993, 8.16) where it remarks that 'The level of charge which bidders proposed to levy would be an important consideration in awarding franchises', though how this would be contracted over 50 years given the specific exclusion of regulation for new roads in the 1991 Act is not set out. The impression one has is that the regulatory and pricing framework for roads has still not been thought through adequately to permit a satisfactory relationship between both public and private provision of roads, and that until it is, roads should remain in public ownership to avoid the kind of distortions illustrated by the above example.

5. Conclusions

The main argument for private initiatives is to escape the constraints of financing that presently restrict road investment. The solution is commercialisation, not privatisation, with clear safeguards on the ability of the Road Authority to finance profitable or efficient road expansions, if necessary by borrowing from abroad. It would also be necessary to regulate the setting of road user charges to prevent monopoly abuse, with the additional advantage that the costs and benefits of road investment would be more open to public debate than at present.¹³

Consider some of the other advantages of this system. At one stroke, the national debt (as measured under the Maastricht definition) would be reduced as possibly £100 billion of debt were transferred to the Road Authority, backed by the assets of the road system. This would lower the national debt by over 40 per cent. It would lower taxes by £10 billion per year or 1.7% of GDP, nearly 5% of tax revenue, as those road taxes that are properly road user charges are made explicitly into charges. No-one in the past pretended that charges for electricity were taxes for the Treasury and nor they should for road use. Sterile Treasury debates about hypothecation would end, while the more

¹³ The consultative document on *M25 Improvements between Junctions 12 and 15* confines its remarks on the benefits to the phrase 'represents excellent value for money'. Other consultation documents are typically more evasive, though they do at least give the estimated costs.

important issues of ensuring proper regulation and public accountability of roads and road charges would need to be addressed, allowing a serious discussion of road pricing to take place, as the technology to introduce it becomes available. Given the time taken to make such large institutional changes, the sooner the issue is placed on the political agenda, the better.

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Appendix A Modelling the costs and profits of the BNRR

The Birmingham Northern Relief Road (BNRR) will be a 30 mile or 50 km dual 3-lane toll motorway from near junction 4 of the M6 to rejoin the M6 near junction 11. To a first approximation both routes can be considered of equal length. The cost of engineering will be some £270 million, including substantial sums for mitigating the environmental impact. Midland Expressway Limited (MEL) signed a memorandum of Agreement with the Government to finance the road on 12 August 1991. The cost per lane km is thus £0.9 million, somewhat higher than recent motorway projects, but about half the cost of widening the M25. The proposed initial toll is £1.50 for cars, equivalent to 3p/km for those using the entire length. If maintenance is taken as 0.5p/km, MEL could generate 10% real return (including amortization over 50 years) at an AADT from cars alone of 60,000. As heavy vehicles are charged more (but incur higher road damage costs), provided they contribute the same surplus over running costs, this figure should be conservative. For comparison, dual 3-lane sections of the M25 carry over 100,000 AADT, so the BNRR will break even at a low load factor.

Suppose that the traffic volume in the relevant corridor free to choose between the BNRR and the M6 is Q (per lane/hr on the M6, i.e. $6Q$ is the hourly traffic flow in the corridor, where $60Q$ is the AADT in the corridor),¹⁴ and that q choose to take the M6, or a fraction $x = q/Q$. For simplicity assume that Q is independent of travel costs (though this could readily be included, with minor additional complication). Traffic speed will depend on traffic flow, and is assumed to obey the relationship

$$v = \text{Min}[\bar{v}, \alpha - \beta q] = \text{Min}[\bar{v}, \alpha - \beta Qx], \quad (1)$$

where v is average speed in kph, \bar{v} is the mean free speed (or speed limit), taken as 110 kph, $\alpha = 145$ or 135 kph, $\beta = 0.035$, and both q and v are to be considered as averages over the entire length (see Newbery, 1990 for a defence of this formulation).

¹⁴ Thus Q measures flows at a relatively congested period. The problem is here being simplified by assuming uniform flows over the day and year. This is appropriate if the BNRR charges tolls which vary with time of day, day of week and seasonally, allowing them effectively to be made traffic dependent, but in that case computing profits and costs would require the equivalent of a load-duration curve.

The travel cost per km of a vehicle experiencing a value of time of y per hour is

$$c(y) = a(y) + y/v + t, \quad (2)$$

where a may vary with ownership characteristics, and t is the toll per km where appropriate. Different road users have different values for the value of time, which is assumed to be distributed rectangularly on $[m, m+k]$; that is, a fraction x of the road users will have a value of time equal or higher than $m+xk$. In the simulations m is taken as £2/hr and $m+k$ as £10/hr, but all the tolls, costs and profits are proportional to m and k and so can be readily recomputed.

Road users will choose between the two routes on the basis of the total transit time, comparing the slower speeds of the M6 against the toll of the BNRR, with richer drivers choosing the BNRR. The value of time of the marginal road user, indifferent between the two routes, satisfies

$$y/v_m = y/v_b + t, \quad (3)$$

where v_m is the average speed on the M6 (which will depend on q and hence x), and v_b is the average speed on the BNRR. If the BNRR is uncongested, so that $v_b = \bar{v}$, the value of x will satisfy

$$\beta Q k x^2 + [k(\bar{v} - \alpha) + \beta Q(\bar{v}t + m)]x + m(\bar{v} - \alpha) - \bar{v}\alpha t = 0. \quad (4)$$

This may be solved for $x(t)$. If Q is so large that both roads are congested, then the solution to (3) is

$$\beta Q(\beta Q t + 2k)x^2 - \beta Q(\beta Q t + k + 2m)x + \alpha t(\beta Q - \alpha) - m\beta Q = 0.$$

In both cases $x = x(t)$ and the revenue from the toll road (per lane km/hr) is $R(t) = (1-x)Qt$. The profit or revenue maximising toll t^* can be found from the first order condition for maximising this (if necessary, after deducting vehicle-specific operating costs).

Social costs are taken to be the total cost of time involved in transport, ignoring transfer payments from motorists to MEL. The total social costs per km will be $C(t)$. The socially optimal toll \bar{t} is that which minimises $C(t)$. The deadweight loss associated with the profit maximising toll t^* is then $L = C(t^*) - C(\bar{t})$.

$$\begin{aligned}
C &= \frac{1}{v_m} \int_0^q y dq + \frac{1}{v_b} \int_q^Q y dq \\
&= \frac{kQ}{2v_b v_m} [v_m + x^2(v_b - v_m)] + Qm \left[\frac{x}{v_m} + \frac{(1-x)}{v_b} \right]
\end{aligned} \tag{6}$$

The solutions were computed numerically in Quattro Pro 4 using the optimize routine for the AADT $60Q$, multiplied by 50 to give the total costs and profits for the 50km length, and the results graphed.

Appendix B Valuing the road network

Until 1982 the CSO published an estimate of the gross capital stock at depreciated replacement cost in the *National Income and Expenditure Blue Book*, and Newbery (1988, p168) uprates these values to give a 1986 value of £50 bn, or, including land, perhaps £56 bn.¹⁵ Since then the CSO publishes figures for the gross capital stock in ‘Civil engineering works’, and roads form the largest single item for local authorities and central government. The 1986 estimate at current prices was £75.4 bn, but in 1975 the total was £23.6bn, compared to the estimated value of roads alone on £14.5 bn, so about 60 percent of civil engineering works were then roads. If the same relationship held in 1986, the figure would be £46 bn, close to the estimate of £50 bn. Newbery (1988) also estimated the value from the length of the road network and the construction cost (in 1986 prices, excluding land, of £0.47m, £0.30m and £0.07m per km of motorways, peri-urban divided roads, and rural secondary roads). The result including land came to £60 bn in 1986, reasonably close to the capital stock estimates. Uprating these be cumulative investment and price changes to 1990 gave a figure of about £80 bn (Newbery, 1990), and further uprating to 1992/93 but recognising that the construction cost index is temporarily very low and hence not a good long run predictor of the replacement cost) gives a figure of perhaps £90-100 bn.

If we attempt to value the construction cost of new roads using the published data on the cost of completing motorways and trunk roads (Department of transport, 1993, Table 3.19) we find that the most recent figures for the cost of completed motorways and principle roads gives a figure of £0.67 per *lane* km. The 1992/93 index of construction costs has not changed since 1985 (though it rose by 23 per cent to 1989) so price changes do not explain why these figures are six times as high as the earlier figures for 1986, themselves derived from TTRL (1970). If we further assume that all motorways have 6 lanes, all dual carriageways have 4 lanes, trunk roads have an average of 3 lanes, principle

¹⁵ Valuing land used for roads, which in turn affects the value of land rendered accessible, is complex, and properly done can give counterintuitive results, as Arnott (1978) demonstrates. As there is no simple rule that says market prices will over or understate shadow values, the land value here is taken at market prices. A more extensive research project would doubtless improve on this estimate, though it seems unlikely that it would change the results very much.

roads 2 lanes, that B and C roads cost £0.15 per km, and unclassified roads cost £0.1 per km, then the total replacement cost of the UK road network would be £128 bn, or, including land at 14 per cent, £146 bn.

There is thus a great deal of uncertainty about the capital value to impute to the stock of roads, perhaps ranging between £80bn and £150bn. If we take a figure of 5 per cent to earn on the larger sum, the interest charge would be £7.5 bn, not far from that shown using the lower capital sum of £95 bn at 8 per cent, as in Table 1. But the figure might be as high as £12 bn at the higher capital value and interest rate.