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**URBAN TRANSPORT MARKET THEORETICAL
ANALYSIS**

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URBAN TRANSPORT MARKET: THEORETICAL ANALYSIS

Executive Summary

1. The Institute for Transport Studies (ITS) was commissioned by the Department of Transport (DoT), the Association of Metropolitan Authorities (AMA) and the Passenger Transport Executive Group (PTEG) to undertake this project in November 1992.

2. The objectives of this study were:

- (a) to establish a simple economic model of urban transport operations, based on present policies;
- (b) to estimate, using the model, the theoretically optimal form of intervention in urban rail under the present policy constraints, and differences between this optimum and current procedures;
- (c) to investigate how improved procedures might be implemented in practice in the light of the kind of data which are currently available or become available in the course of a Section 56 appraisal and to make suggestions for additional data collection.

3. The first objective was achieved by developing a stylised model of urban transport operations within a given corridor. This model was based loosely on work carried out by ITS in assessing new rail services between Mansfield and Nottingham. The model has been given the acronym MUPPIT (Model of Urban Pricing Policy in Transport) and contains a number of features which represent an advance over previous models of this type.

4. MUPPIT produces three main evaluation measures:

- a Financial Net Present Value (NPV), which takes into account rail operator costs and revenues. This is also referred to as financial appraisal;
- a Social NPV, which takes into account bus and rail operators' costs and revenues, and changes in bus, rail and car user times and costs, including accidents. This is also referred to as full social cost-benefit analysis;
- A Restricted Cost-Benefit Analysis (RCBA) NPV, which takes into account rail operator costs and revenues, and changes in car user times and costs, including the external element of accident costs. RCBA is required in a Section 56 appraisal. The Department of Transport's 1989 circular on Section 56 Grant for Public Transport indicated that the financial losses of an investment project should be minimised (ie maximise financial NPV) and that these losses should be exceeded by non-user benefits. In addition, additional grant, beyond the minimum required, may be provided if it can be shown that this is offset by an increase in non-user benefits (ie maximise RCBA NPV).

5. MUPPIT contains a mode choice model which estimates the extent to which a new rail service attracts traffic from car and bus, and a numerical optimisation routine which adjusts rail service frequencies and fares so as to maximise any of the three evaluation measures. An important feature of MUPPIT is that it incorporates the interaction between rail and the road-based modes by examining the second round effects of:

- recongestion on the road network, and

- bus operators reducing services or increasing fares in order to maintain profitability.

6. We interpreted the second objective as follows. In a situation where the policy maker cannot control prices in either the car market (where, without intervention, price will be below marginal social cost) or the bus market (where, without intervention, price will be above marginal social cost), then there are no simple rules concerning the optimal rail price. Second-best theory tells us that in such situations the optimal rail price may be either above or below marginal social cost. It is an empirical matter as to which should hold. One argument for the current 'Section 56' appraisal procedures for new rail schemes is that the restricted cost-benefit analysis acts as a proxy for the optimal second-best prices for rail because they take into account the cross-elasticity between car and rail, and the extent of the divergence between marginal social cost and average social cost on the congested road system. It is this argument which we wished to test.

7. This was done by a series of runs of the MUPPIT model. It was found that:

- maximising Social NPV led to lower rail fares, higher rail frequencies and higher rail demand (typically 50% higher) than maximising RCBA NPV. Gross costs were typically 15% higher, gross benefits were 20% higher and net social benefit was typically over 60% higher when maximising Social NPV than when maximising RCBA NPV.
- rail user time and cost changes, which are included in a Social NPV measure but not in a RCBA or Financial NPV measure, typically account for 28-50% of gross scheme benefits.
- maximising RCBA NPV typically led to lower rail fares, higher rail frequencies and higher rail demand than maximising Financial NPV, but the differences were not great.
- for the theoretical scheme being considered, in all model runs tested the RCBA NPV was negative, while in 90% of the model runs undertaken the Social NPV was positive.

8. These results were obtained consistently across a range of different scenarios, including:

- allowing for the indivisibility of rail supply by restricting rail frequency to integer numbers of trains per hour;
- taking into account lost tax revenue to Government;
- changing the income elasticities, price elasticities and speed-flow relationships used in the model.

9. We therefore conclude that the current procedures concerning the appraisal of new rail schemes can be distorting. In the theoretical case being examined, the current procedures would result in the scheme not being pursued, whereas the theoretically optimal form of intervention suggested by the Social NPV results would be to support the rail scheme through a capital grant. More generally, the results suggest that current procedures do not lead to the maximisation of the social benefits of any particular scheme.

10. We obtain these results for two reasons. Firstly, the non-user benefits to car users are relatively modest when the re-congestion effects of travellers transferring to road because of improved road speeds are taken into account. This result may be sensitive to the level of and variation in motorists' values of time (the values used in this study are lower than those used in some other Section 56 studies), the volume of road traffic abstracted by rail and the degree to which the road network and key junctions are congested in the base year. Secondly, user benefits are substantial and cannot be captured through pricing-up (despite higher fares in

the peak). This result is dependent on our assumption that the rail operator can only price discriminate in terms of distance travelled and time of travel, although we believe these are the two dimensions of discrimination most commonly used in practice for urban rail services.

11. Our third objective was achieved by analysing the model results. We conclude that the proper application of current procedures needs to take into account the interaction between rail, car and bus. Many practical applications of current procedures have neglected these interactions, thus potentially overstating the benefits of congestion relief, and have ignored the disbenefits to bus users. In other words, in practice the Financial, Social and RCBA NPVs may all be biased upwards thus strengthening the case for new rail schemes. This means that the actual divergence between current practice and the theoretical optimum may be smaller than our work has suggested. Moreover, taking into account re-congestion effects when appraising rail schemes but not taking into account re-congestion when appraising road schemes (which, by and large, is current practice) would distort comparisons by local authorities and central government of road and rail schemes.

12. We have identified a number of areas where additional data collection could improve current practice:

- detailed data on base travel patterns;
- data on cross-elasticities of demand between modes;
- data on user and operator cost characteristics by mode;
- data on the relationship between congestion, traffic patterns and new rail schemes;
- data on actual responses by bus operators to new rail schemes.

A number of areas for further research are also suggested.

13. Overall, we conclude that the current procedures for determining intervention in the rail market, given current policy constraints on intervention in the bus market, and the optimal form of intervention exhibit important differences. Hence, if Section 56 appraisals are undertaken, they should be accompanied by full social cost-benefit analysis so that any distortions which do arise are clear. Our understanding is that this has recently become a Department of Transport requirement for Section 56 grant appraisal.

1. INTRODUCTION

1.1 This note constitutes the final report on the above study, undertaken by the Institute for Transport Studies (ITS) on behalf of the Department of Transport (DoT), the Association of Metropolitan Authorities (AMA) and the Passenger Transport Executive Group (PTEG).

1.2 The objectives of this study were as follows:

- (a) to establish a simple economic model of urban transport operations, based on present policies,
- (b) to estimate, using the model, the theoretically optimal form of intervention in urban rail under the present policy constraints and differences between this optimum and current procedures,
- (c) to investigate how improved procedures might be implemented in practice in the light of the kind of data which are currently available or become available in the course of a Section 56 appraisal and to make suggestions for additional data collection.

1.3 The main analytical tool used to achieve these objectives was a micro economic partial equilibrium model of stylised urban transport operations within a given corridor. This model has been based loosely on work we have done at ITS on the Nottingham-Mansfield corridor, is computer based and has been given the acronym MUPPIT (Model of Urban Pricing Policy in Transport). The approach adopted has some similarities with work undertaken by others (Beesley, Gist and Glaister, 1983; Glaister, 1987).

1.4 Approaches based on adapting strategic integrated transport models such as START (MVA, 1992) were rejected for the following reasons:

- although these models are simplifications of the traditional land-use and transport study (LUTS) model the level of geographic detail is not appropriate for this study
- the feedback between demand and supply in these models is not usually explicit.

The use of area-wide simulation models such as GUTS (Game of Urban Transport Simulation; Ortuzar and Willumsen, 1978) and its successor PLUTO (Planning Land-Use and Transport Options; Bonsall, 1992) were rejected for similar reasons.

1.5 The bulk of this report consists of the results of the base MUPPIT model runs (section 2), sensitivity analyses (section 3) and the conclusions (section 4).

1.6 Three technical notes have been produced: on the underlying theory of second best pricing (Preston and Nash, 1993), on empirical evidence of urban transport elasticities (Toner, 1993) and on the details of the MUPPIT computer model of urban transport operations (Cooper and Preston, 1993).

1.7 MUPPIT is corridor based and consists of three generation zones and one attraction zone. In the initial situation there are two modes (bus and car). A new mode (rail) is then introduced and its market share estimated using binary logit models.

1.8 The binary logit models were not thought to be appropriate for sensitivity analysis. Instead negative exponential demand models were developed based on empirical evidence on price elasticities, values of time and abstraction rates. Linear additive public transport cost models have been developed, with car cost based on a parabolic speed-flow curve.

1.9 It is believed that MUPPIT is an advance on previous models for the following reasons:

- it focuses on a single corridor rather than a whole conurbation
- it can incorporate local fare and service level changes as well as global changes

- it can distinguish between peak and off-peak times of day
- it incorporates up-to-date empirical evidence on service elasticities
- all elasticities are transparent and capable of being changed by the model user
- speed-flow relationships can be adjusted to represent a variety of congested and uncongested conditions
- secondary effects of re-congestion on the road network are taken into account
- bus operations are constrained to earn normal profits (defined as a 10% mark-up on costs)
- the shadow price of public funds can be incorporated
- accident costs have been included as per the DoT note on "The Treatment of Accidents in Section 56 Appraisals" (February 1992)
- demand changes over time have been taken into account through the assumption of a 30 year project life and real income growth of 2% per annum and the use of income elasticities.

1.10MUPPIT produces three main evaluation measures

- a Financial Net Present Value (NPV) that takes into account the changes in rail operator cost and revenue. This is also referred to as financial appraisal.
- a Social Net Present Value that takes into account changes in bus and rail operators' costs and revenues and changes in bus, rail and car user times and costs (including accidents and, if required, adjusted for taxation). This is also referred to as social cost-benefit analysis. Without adjusting for taxation, it is assumed that any loss of tax revenue to Government is compensated by equivalent savings in resource costs. With the tax adjustment, it is assumed that the loss of tax revenue to Government is a disbenefit. This is equivalent to assuming that taxation is a non resource cost and is the procedure used in road scheme appraisal.
- a Restricted Cost-Benefit Analysis (RCBA) Net Present Value that takes into account rail operator costs and revenue and changes in car user times and costs (including external elements of accident costs).

1.11MUPPIT has a numerical optimisation routine that adjusts rail fares and frequencies so as to maximise any of the three evaluation measures for any individual year or for all 30 years.

1.12MUPPIT has been written in FORTRAN, and can thus run on any hardware on which is mounted a suitable FORTRAN compiler. PC-based and SUN-based versions are currently available. For the PC-based version, 486 machines offer a considerably enhanced performance over 386 machines.

1.13The demand elasticities used in the model are based on the best available evidence for typical own-price elasticities (Toner, 1993, HFA et al., 1993). Evidence on cross-elasticities is less secure, and so these have been derived by recourse to theoretical reasoning. A similar approach has been used to obtain the various time elasticities required. It should though be noted that this approach, although internally consistent, led to relatively low headway elasticities. However, evidence from the town of Preston (Mackie and Preston, 1988) suggests that where there are high service levels the headway elasticity may be around -0.1, whilst evidence from Nottingham suggests that urban rail may have a headway elasticity of around -0.2. All these values can be changed during a specific application to make use of the available location-specific evidence. The base price elasticities, in-vehicle time elasticities, headway elasticities, peak/off-peak price elasticities and income elasticities used

were as follows:

Base demand elasticities						
Own elasticities	Peak			Off-peak		
	Bus	Car	Rail	Bus	Car	Rail
Price elasticity	-0.3	-0.1	-0.7	-0.5	-0.3	-0.9
In-vehicle time elasticity	-0.132	-0.070	-0.267	-0.171	-0.129	-0.326
Headway elasticity	-0.084	0	-0.195	-0.110	0	-0.220
Peak/off-peak elasticity	0.150	0.050	0.350			
Income elasticity	-0.3	1.2	0.6			

1.14 The theory behind MUPPIT is that of second-best pricing (see Preston and Nash, 1993). Optimal second-best pricing, where the price of both bus and rail can be adjusted to offset distortions in the car market, requires that the price of rail be set below its marginal cost given that car is priced below marginal cost and that car and rail are substitutes. Where the bus price cannot be controlled and is found to be above bus marginal cost, the restricted second-best price for rail can be either above or below marginal cost depending on the differences between price and marginal cost in the bus and car markets, the cross-elasticities between the modes and the extent of economies of scale in bus and rail operations.

1.15 The optimal restricted second-best price for rail is determined in MUPPIT by maximising the Social NPV. The resultant prices and resource allocations can be compared with those obtained when maximising the Financial or RCBA NPVs. This enables us to test the assertion that the RCBA measure required in a Section 56 appraisal represents a good proxy for optimal restricted second-best pricing. It should be noted that the key criteria for the award of Section 56 grant set out in the Department of Transport's 1989 Grant Circular were that financial losses should be minimised (ie Financial NPV maximised) and that non-user benefits should exceed these losses. Annexe A to the Grant Circular (Department of Transport, 1989) indicated that the DoT might be willing to provide additional grant, beyond the minimum required, if it could be shown that this grant is offset by non-user benefits (ie maximise RCBA NPV). It is this latter criterion that forms the basis for the restricted social cost-benefit analysis undertaken in this report. Maximising the Financial NPV may be expected to lead to rail price above marginal cost, and acts as a benchmark against which the other two policies of maximising Social NPV and maximising RCBA NPV may be assessed.

2. BASE MODEL RUNS

2.1 For the base demand and cost models, the following MUPPIT runs were undertaken:

- maximise welfare
- maximise producer surplus
- maximise RCBA net benefits.

In each case MUPPIT was run with a tax adjustment (assumes tax revenue lost by Government is a net disbenefit) and without a tax adjustment (ignores tax revenue lost by Government) and with and without integer service levels (to reflect indivisibility of supply). This involved 12 model runs in the base situation.

2.2 Key outputs include rail fare for the three zones (outer, middle, inner) and two time periods (peak and off-peak) and Net Present Values, based on an 8% discount rate and a 30 year project life, for each of the three evaluation scenarios. The results are given by Tables One to Eight.

2.3 Tables One, Two and Three refer to the situation where non integer rail service is permitted and there are no tax adjustments.

2.4 Table One, part (a), shows that in all situations peak fares are substantially greater than off-peak fares and fares increase with distance from the central area. Welfare maximisation involves substantially lower fares and higher service levels than either profit maximisation (loss minimisation) or RCBA NPV maximisation. Rail fares tend to fall (with exceptions in the outer zones) and service levels increase between years one and thirty, reflecting the increased competitiveness of rail given road congestion. Rail fares and service levels are broadly the same between the profit maximising and RCBA maximising scenarios in year one but in year 30 the RCBA maximising scenario gives lower fares particularly in the peak. Again this is related to increased road congestion in year thirty. MUPPIT, as it currently stands, does not produce marginal cost calculations as part of the model output. However, marginal costs can be estimated from the outputs that are produced. For example, by comparing the producer surplus maximising and welfare maximising outputs in Table One, it was estimated that rail's marginal operating cost was £0.40 per passenger. It can be seen that all rail fares in Table One, part (a) are substantially above this level.

2.5 Table One, part (b), illustrates the effect of the different policies on demand levels. In year one, under welfare maximisation, rail has a 10% share of trips to the centre, compared with the bus share of 52% and the car share of 38%. By year 30, rail's share has increased to 15%, car's share has increased to 47% and bus's share has decreased to 38%. Similar trends are found under the other two policy options. Rail demand in year one under welfare maximisation is 54% greater than rail demand in year one under producer surplus maximisation and 52% greater than under RCBA maximisation. By year 30, the corresponding figures are 64% and 56%.

2.6 Table Two, part (a), shows that in the welfare maximising scenario, a Social NPV of £9.0 million is achieved compared to a Financial NPV of -£12.4 million and a RCBA NPV of -£8.4 million for the same fare/service level combination. Table Two, part (b), shows that the incorporation of a shadow price of public funds of 1.2 adjusts these results to become £6.5 million, -£14.9 million and -£10.9 million respectively. Table Two, part (c), shows that if

the shadow price of public funds is set at 2.0, these results become -£3.3 million, -£24.8 million and -£20.8 million respectively. The middle row of this table also shows that, with a high shadow price of 2.0, there is little to choose between the various maximisation criteria in terms of the calculated social welfare effects, although the three NPV measures presented for each maximisation criteria remain strongly divergent. The evaluation results are clearly sensitive to assumptions concerning the shadow price of public funds. However, it should be noted that, unless stated otherwise, in what follows the results do not incorporate a shadow price of public funds.

2.7 By contrast, profit maximisation reduces the Social NPV to £5.0 million but increases the RCBA NPV to -£5.7 million and the Financial NPV to -£9.2 million (i.e. a saving of £3.2 million in public funds). Similarly, RCBA maximisation reduces the Social NPV to £5.5 million and increases the RCBA NPV to (roundly) -£5.7 million and the Financial NPV (roundly) to -£9.2 million. In evaluation terms, maximising Financial NPV and RCBA NPV is broadly the same. Compared with earlier results (Preston, 1992), we no longer are able to achieve a positive RCBA NPV as, due to re-congestion, non-user benefits are only valued at a maximum of £4 million over 30 years.

2.8 Table Three, part (a), gives a breakdown of daily gross costs and benefits for the welfare maximisation option in years one and thirty. In year one, rail capital costs (annualised assuming a 30 year project life and an 8% interest rate) make up 53% of gross costs, compared to the 35% contributed by rail operating costs, the 8% contributed by cost changes to bus operators (due to declining absolute profits) and bus users (due to increased journey times as a result of service withdrawals) and the 4% contributed by rail accidents costs. In year thirty, rail capital costs, although constant in absolute terms, reduce in relative importance to 47% of gross costs, whilst rail operating costs increase to 37% and costs to the bus system increase to 10%. In terms of gross benefits in year one 40% are attributed to rail revenue, 50% to rail user benefits and only 10% to road user benefits. Only around 44% of rail users' willingness to pay is captured through the fare box and user benefits are five times larger than non-user benefits. However, by year thirty, non-user benefits increase to form 18% of gross benefits and user benefits are less than three times larger than non-user benefits.

2.9 Table Three, part (b), breaks down daily costs and benefits for the objective of maximising rail producer surplus. The main features are that capital costs become relatively more important (contributing to 60% of gross costs in year one), the amount of rail users' willingness to pay captured by the fare-box has increased (to 56% in year one and to 65% in year thirty) and the ratio of user to non-user benefits has decreased (to 4:1 in year one and 1.3:1 in year thirty).

2.10 Table Three, part (c), breaks down daily costs and benefits for the objective of maximising RCBA NPV. The results are broadly similar to those of maximising rail producer surplus, except that rail revenue is less important as a source of gross benefits and rail user benefit is more important, especially in year thirty.

2.11 To be consistent with the emerging Common Investment Appraisal Framework (MVA et al., 1993) it would be desirable for the results in Table Three to be re-expressed as thirty year

present values. MUPPIT is not currently set up to provide such output but it is hoped that the program can be modified to do so in the future.

2.12 Nevertheless, comparisons between Tables Three (a) and (c) give some indication of the causes of the differences in Social NPV under the various maximisation criteria noted in paragraphs 2.6 and 2.7 above. It can be seen that total benefits are some 22% higher in year one (20% in year thirty) under Social Welfare maximisation than under RCBA NPV maximisation and that the main difference is in rail user benefits (50% higher). Total costs, on the other hand, are only 18% higher in year one (16% in year thirty), with the main change being in rail operating costs (up 30%). Given that gross benefits and costs are quite similar in magnitude, these relatively slight differences in the percentage variations in gross costs and benefits translate into large differences in net benefits. Net benefits are 78% higher in year one (28% higher in year thirty) under Social Welfare maximisation than under RCBA NPV maximisation.

2.13 Tables Four and Five refer to the situation where only an integer level of rail service is permitted and there is no tax adjustment. The main effect is that Financial NPV reduces with a corresponding effect on Social NPV and RCBA NPV. In some instances in Table Four (for example Outer, Peak - Year One), the fare when maximising RCBA NPV is higher than the fare which maximises rail producer surplus, despite the same frequencies. This result may be attributed to imprecision in the iteration process, and may be thought of as a form of rounding error (see also paragraph 3.2).

2.14 Tables Six and Seven refer to the situation where non integer rail service is permitted and an adjustment is made to take into account transfers from highly taxed car to zero taxed rail. In Table Six fares tend to increase and service levels tend to decrease compared to Table One for the welfare maximisation and RCBA NPV maximisation scenarios (the producer surplus maximisation scenario is unaffected). As expected the social benefits of rail are reduced, with the maximum Social NPV being £5.5 million, the Financial NPV being -£11.7 million and the RCBA NPV being -£11.2 million. Assuming that the shadow price of public funds is 1.2, these figures become £2.2 million, -£14.0 million and -£13.5 million respectively. The reduction in the social benefits of rail means that the patronage under welfare maximisation and RCBA NPV maximisation is less than in the case where no tax adjustments are made.

2.15 Tables Eight and Nine refer to the situation where only an integer level of rail service is permitted and tax adjustments have been made. Compared to Table Two, rail services are the same but rail fares tend to be higher for the maximise Social NPV and maximise RCBA NPV scenarios. The social benefits of rail are again reduced compared with the appropriate Table (Table Five), with the Social NPV reducing to £4.5m, the Financial NPV to -£12.8 million and the RCBA NPV reducing to -£12.0 million. Assuming that the shadow price of public funds is 1.2, these results become £1.9 million, -£15.4 million and -£14.6 million.

3. SENSITIVITY ANALYSIS

3.1 Sensitivity analysis was undertaken with respect to assumptions concerning income elasticities, fares elasticities and speed-flow relationships. The results are given by Tables Ten to

Nineteen.

- 3.2 Tables Ten and Eleven, which depict the case where income elasticities for all modes are set to zero, show that the assumption of traffic growth over time contributes substantially to the various NPV measures. Under no growth, the optimal fares and frequencies remain unchanged over time (subject to rounding errors). The result is that Producer Surplus maximisation and RCBA maximisation cannot show positive Social NPVs, given the particular values input into the model in this case study. This is because the lack of road traffic growth means there is no increase in congestion. It is also worth noting that the loss in social welfare from following Producer Surplus maximisation is reduced from £4.0 million (Table Two) to £2.9 million (Table Eleven) if there is zero traffic growth.
- 3.3 Tables Twelve and Thirteen present the results under a conservative assumption of low road traffic growth, achieved by setting the road traffic income elasticity equal to 0.2. The welfare maximisation and RCBA NPV maximisation results for year 30 have slightly higher fares and lower service levels than the base (Tables One and Two) and the NPVs are lower, with a Social NPV of £5.8 million under welfare maximisation (£9.0 million with higher growth), and a RCBA NPV of -£7.9 million (low growth) compared with -£5.7 million. Lower road traffic growth reduces the size of the decline in the bus market, due to slower growth in congestion making bus services more attractive. The increase in rail traffic over the life of the project is smaller, the smaller increase in road congestion meaning that fewer drivers switch to rail.
- 3.4 Tables Fourteen and Fifteen show the effects of increasing the assumed own-price elasticities for public transport. The values tested were -0.8 for rail in the peak and -1.1 in the off-peak and -0.4 for bus in the peak and -0.7 in the off-peak. The most significant differences are the reduced fares under Producer Surplus maximisation, the increased off-peak service frequencies, and the reduced off-peak fares under welfare maximisation and RCBA NPV maximisation. This may lead to important changes in differentials. For example, in Table One the outer zone peak fare is 30% lower under welfare maximisation than under producer surplus maximisation. In Table Fourteen the difference is reduced to 26%. Whatever the optimand, each NPV measure (financial, social and RCBA) is reduced. For example, the Social NPV under welfare maximisation is £7.7 million compared with £9.0 million, and the Financial NPV under RCBA NPV maximisation is -£9.7 million compared with -£9.2 million.
- 3.5 Tables Sixteen to Nineteen show the effects of an exogenous shift in the speed-flow curves and has been incorporated as a proportionate reduction in speed at a given capacity. Reductions of 10 per cent (Tables Sixteen and Seventeen) and 20 per cent (Tables Eighteen and Nineteen) were used. By and large these changes cause off-peak fares to fall and peak fares to rise compared with the base. This result occurs because of the cross effects between peak and off-peak rail and car travel and the differences in rail and car peak and off-peak marginal costs. As the absolute difference between peak and off-peak road journey times increases, so does the attractiveness in both financial and social terms of carrying rail passengers in the off-peak rather than the peak. Peak service levels are broadly unchanged, but off-peak train service frequency increases. The result of this is to hasten the decline in patronage of the bus industry (due to the slower speeds, bus is less attractive), lessen the increase in car traffic and increase the use of rail. All this combines to give higher NPVs

whichever measure is used. A 20% reduction in speeds causes the best RCBA NPV figure to increase from -£5.7 million to -£2.8 million, of which £2.1 million is due to the improved financial performance. So in more congested conditions, a scheme is more justifiable whatever the assessment criterion used.

4.CONCLUSIONS

4.1 Results for all evaluation measures suggest in most cases that rail fares and frequency should be higher in the peak than the off-peak. Zonal fares should increase with distance but not in a strict proportional manner.

4.2 Three different objectives have been assessed:

- minimise losses (i.e. maximise Financial NPV)
- maximise net external benefits, defined in our model as benefits to road users (i.e. maximise RCBA NPV)
- maximise net social benefits (i.e. maximise Social NPV), either unconstrained or constrained so that rail revenue covers operating costs. (In this example, it turned out that maximising Net Social Benefits always resulted in rail revenue covering operating costs.)

4.3 The model results show that the main trade-off is between subsidy and unpriced user benefits. For example, taking Table Two, part (a), and comparing the results of welfare maximisation with those of producer surplus maximisation, our work suggests that spending an additional £3.22 million on subsidy yields an additional £0.50 million in non-user benefits and £6.74 million in user benefits. User benefits are substantial and can not be fully captured through pricing-up. This result is dependent on our assumption that the rail operator can only price discriminate in terms of distance travelled and time of travel. However, we believe this assumption is realistic for urban transport but may be less so for inter-urban transport where more sophisticated price discrimination may be practised.

4.4 Throughout the model runs, it was not possible to obtain a positive RCBA NPV measure, notwithstanding that a number of actual studies of new rail schemes have done so (Preston, 1992; Tyson, unpublished). A possible reason for this is that, while conventional studies have calculated only the first round decongestion benefits to remaining road traffic on the introduction of rail, MUPPIT then allows a transfer back from rail to road as a result of increased traffic speeds, and keeps on iterating until the road system has reached a stable equilibrium position. The true benefits of RCBA maximisation, given by the Social NPV, are always considerably less than the optimal form of intervention as given by the Social NPV under welfare maximisation. Indeed, because RCBA maximisation does not coincide with welfare maximisation, a choice of projects based on the RCBA criterion may lead to the wrong decision being made, since the RCBA NPV result under welfare maximisation is necessarily inferior to the best RCBA NPV. While the precise results obtained depend on the input parameters, the pattern is clear. The base case obtains net social benefits of £5.468 million if RCBA benefits are maximised compared with a theoretical maximum of £9.040 million. This sort of difference of £3 million or so (or one third of the net benefits) occurs across all the scenarios evaluated.

4.5 These findings support the views of Bates and Lowe (1989) that the Section 56 rules (as defined in the 1989 Grant Circular) are unlikely to be met except in the case where revenue exceeds

costs, so obviating the need for grant, unless above average values of time for some or all transferring car users allow higher public transport revenue while maintaining non-user benefits. It should be noted that the model used assumes relatively low values of time (around one to two pence per minute at 1988 prices) and hence low in-vehicle time elasticities. In addition, it should be noted that in the case study modelled only a modest volume of traffic is abstracted from road (around 2,800 person trips per day or 2,300 vehicle trips per day in year one of the base run) and that the road system is relatively uncongested.

- 4.6 We are aware that recent studies in South Hampshire and Leeds have resulted in evaluations in which the RCBA NPV has been positive but the Financial NPV has been negative, even though use was made of a modelling technique (SATCHMO) that allows for the second round effects of re-congestion (Willumsen et al., 1993). The South Hampshire and Leeds studies assume higher values of motorists' time (6.8 pence per minute and 5.4 pence per minute respectively) and may have forecast higher volumes of traffic abstracted from road or assumed higher base levels of congestion (or both) than in our study.
- 4.7 It is also clear that it is necessary for the input parameters, that is the elasticities, the valuations of time and the speed-flow relationships, to be determined accurately in each application of the model. Importing incorrect parameters from elsewhere may cause unacceptably large divergences between forecast and actual financial and social performances of schemes. However, in the case studied the sensitivity tests showed that, over plausible ranges, the same result occurred, namely that the new rail scheme could be justified on the basis of a full social cost-benefit appraisal but could not be justified on the basis of a restricted cost-benefit (Section 56) appraisal.
- 4.8 Results suggest that the rail fares and frequencies resulting from the objective of maximising net social benefits are different from the other objectives. The results from financial appraisal and restricted social cost-benefit analysis appear broadly similar. The results of the model runs largely conform to a priori expectations. Welfare maximisation generally leads to noticeably higher frequencies and lower fares than producer surplus maximisation or RCBA NPV maximisation. RCBA NPV maximisation more often than not produces higher frequencies and lower fares than producer surplus maximisation, but the difference is often not pronounced.
- 4.9 Sensitivity analysis has been undertaken with respect to income, price and service elasticities, and with respect to speed-flow conditions. This has shown that the benefits of potential schemes depend crucially on forecasts of overall traffic growth, in particular on increasing traffic creating congestion which a scheme can then alleviate.
- 4.10 When considering the model results with respect to the theoretical optimum form of intervention in urban rail, under the present policy constraints, and differences between this optimum and current procedures, we conclude that the current procedures can lead to distortions. In our base case (Table Two, part (a)), RCBA NPV maximisation leads to a 40% reduction in net social benefit compared with welfare maximisation. Moreover, in none of our twenty seven model runs are we able to produce a positive RCBA NPV, while a positive Social NPV is obtained in all but two of our model runs. Thus in the vast majority of cases studied, full social cost-benefit analysis and restricted cost benefit analysis are giving different policy signals.

4.11 Detailed recommendations on the way that Section 56 appraisal may be implemented in the light of the way data are currently available or become available in the course of an appraisal have been made by HFA (1991). Our work has highlighted the following areas where existing practice requires particular improvement:

- the determination of base year matrices, times and costs for bus and car;
- the need for a modelling process which deals explicitly with suppressed and generated trips. Our approach was based on negative exponential functions, although other functional forms could be used;
- demand and cost models are required to determine the appropriate fares for rail under a given set of objectives. These fares should vary by time of day and distance;
- the need to take into account the effect of re-congestion of the road network. Our work was based on truncated parabolic area speed-flow curves. A particular problem emerged in conditions of saturation, where it was necessary to cap demand on the road network. Nevertheless, at the new equilibrium, typically only two-thirds of the traffic initially abstracted from road remains with rail, a figure consistent with the 50-75% range suggested by HFA. It should, though, be noted that taking into account re-congestion when appraising rail schemes but not taking re-congestion into account when appraising road schemes (by and large the current practice) would distort comparisons by local authorities and central government of road and rail scheme returns;
- the need to take into account the effects on the bus network. In order to maintain normal profits, bus operators are assumed to reduce service frequencies. This leads to losses in consumer surplus for existing bus users. This effect has been neglected by many studies;
- the effects on accidents are non-trivial and should be included as a separate item rather than lumped together with time savings and operating cost reductions;
- important changes in demand and supply will occur over the life of a project, and these should be explicitly considered.

4.12 The main points to emerge from our study are, firstly, that it is not sensible to examine a rail scheme in isolation, since there are important interactions between modes. In particular, the interaction with the bus market has been neglected in past studies. Secondly, we have highlighted that one of the main areas for improvement is the use of demand and cost models to determine the optimal level and structure of fares for any given objective and the use of these models to assess how these fares and service levels might change over the appraisal period.

4.13 In terms of additional data collection, we suggest the following:

- Our theoretical work has shown that the key determinants of optimal rail price in the restricted second-best case considered are:
 - the cross-elasticities of rail, bus and car demand. Additional empirical evidence is required, possibly based on diversion factors (that is, the proportion of new demand on mode A abstracted from mode B);
 - the social cost characteristics (ie operator costs, user costs and non-user costs) of car, rail and bus travel. Work in this area initiated by Meyer, Kain and Wohl (1965) might be updated and extended to include new modes such as light rapid transit;

- work should be undertaken on assessing the impact of new urban rail services on area speed-flow relationships for the competing road system;
- work should be undertaken on assessing the response of competing bus operators to new urban rail services.

We understand that monitoring work has been commissioned by the DoT and others on the Manchester Metrolink and Sheffield Supertram schemes, and we recommend that the issues mentioned here be addressed in these studies.

4.14 In terms of further work, we suggest the following:

- continued development and testing of MUPPIT. For example, as part of his dissertation, an MA student is using the program to assess the effect which road pricing might have on new rail schemes;
- the development of network based approaches. We have assumed a single link between each origin and destination pair and have therefore avoided the problems of definition of base year and future networks and assignments. However, this has also meant that we have only been able to measure congestion on the basis of area speed-flow relationships. A network-based approach would allow more detailed congestion monitoring based on junction delay. Use of the nascent elastic assignment and multi-modal assignment packages (such as SATCHMO) might be considered;
- an extension to include the effects of environmental and developmental benefits;
- comparison of the results from this study with the results of similar studies based on strategic integrated transport models and area-wide simulation models;
- the implications of our work with respect to the common investment appraisal framework project is that the framework should be capable of comparing the performance of different price/service level options for any given rail scheme. Further, such comparisons should be able to bring out the probable trade-off between user benefits and financial appraisal and the impacts on bus service levels and patronage of the introduction of competing rail-based transport. We understand that the proposed framework put forward by MVA (1993) seems to meet these requirements.

4.15 Overall, we conclude that current procedures for determining intervention in the urban rail market and the optimal form of intervention exhibit important differences. Hence, if Section 56 appraisals are undertaken, the restricted cost-benefit analysis should be accompanied by full social cost-benefit analysis so that any distortions which do arise are clear. The Department of Transport has acknowledged, in a House of Commons Written Answer in July 1992 that full cost-benefit analysis may have a wider role to play in urban transport schemes. The recent Transport Policies and Programme Circular (2/93) specifically asked local authorities to supplement Section 56 grant appraisal with the results of a full social cost-benefit analysis.

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Table One (a)
 Rail Fares and Service Levels (Non Integer Service Levels and No Tax Adjustment)

	Welfare Maximisation		Producer Surplus Maximisation		RCBA Maximisation	
	Year 1	Year 30	Year 1	Year 30	Year 1	Year 30
Outer - Peak Fare	£1.40	£1.43	£1.99	£2.01	£1.99	£1.85
- Off-Peak Fare	£0.85	£0.71	£1.44	£1.44	£1.39	£1.39
Middle - Peak Fare	£0.96	£0.88	£1.48	£1.48	£1.47	£1.29
- Off-Peak Fare	£0.72	£0.63	£1.06	£1.06	£1.09	£1.01
Inner - Peak Fare	£0.51	£0.49	£0.79	£0.79	£0.76	£0.73
- Off-Peak Fare	£0.39	£0.32	£0.54	£0.54	£0.56	£0.54
Service - Peak	2.35	2.81	1.71	1.87	1.82	1.87
- Off-Peak	1.63	2.04	1.10	1.35	1.11	1.36

Table One (b)
 Daily Demand Levels (Non Integer Service Levels and No Tax Adjustment)

	Welfare Maximisation		Producer Surplus Maximisation		RCBA Maximisation	
	Year 1	Year 30	Year 1	Year 30	Year 1	Year 30
Bus	23978	19453	24642	20475	24620	20401
Car	17551	24615	18245	25960	18220	25887
Rail	4952	8033	3218	4885	3275	5156

Table Two (a)
 Net Present Values (Non Integer Service Levels and No Tax Adjustment) (£m)

	Welfare Maximisation	Producer Surplus Maximisation	RCBA Maximisation
Financial	-12.383	-9.163	-9.181
Social	9.040	5.017	5.468
RCBA	-8.400	-5.686	-5.657

Table Two (b)
 Net Present Values (Non Integer Service Levels and No Tax Adjustment. Shadow Price of Public Funds 1.2) (£m)

	Welfare Maximisation	Producer Surplus Maximisation	RCBA Maximisation
Financial	-14.860	-10.997	-11.017
Social	6.563	3.184	3.631
RCBA	-10.877	-7.519	-7.493

Table Two (c)
 Net Present Values (Non Integer Service Levels and No Tax Adjustment. Shadow Price of Public Funds 2.0) (£m)

	Welfare Maximisation	Producer Surplus Maximisation	RCBA Maximisation
Financial	-24.766	-18.326	-18.362
Social	-3.343	-4.146	-3.713
RCBA	-20.783	-14.849	-14.838

Table Three (a) Breakdown of Daily Costs and Benefits. Welfare Maximisation. (Non Integer Service Levels and No Tax Adjustments) (£)

Year One

Costs		%	Benefits		%
Rail Capital	4427.1	53	Rail Revenue	3712.7	40
Rail Operating	2962.0	35	Rail User	4649.3	50
Bus Operator	449.4	5	Car Users	344.0	4
Bus User	277.5	3	Car Accidents	559.5	6
Rail Accidents	301.9	4	Bus Accidents	42.3	-
TOTAL	8417.9	100		9307.8	100

Year Thirty

Costs		%	Benefits		%
Rail Capital	4427.1	47	Rail Revenue	5091.8	33
Rail Operating	3443.8	37	Rail User	7430.6	49
Bus Operator	670.4	7	Car Users	1925.2	13
Bus User	299.5	3	Car Accidents	733.8	5
Rail Accidents	489.7	5	Bus Accidents	26.8	-
TOTAL	9330.5	100		15208.2	100

Table Three (b) Breakdown of Daily Costs and Benefits. Producer Surplus Maximisation. (Non Integer Service Levels and No Tax Adjustments) (£)

Year One

Costs		%	Benefits		%
Rail Capital	4213.6	60	Rail Revenue	3730.5	50
Rail Operating	2267.9	32	Rail User	3007.8	40
Bus Operator	57.9	-	Car Users	315.6	4
Bus User	331.7	5	Car Accidents	413.1	6
Rail Accidents	196.1	3	Bus Accidents	42.3	-
TOTAL	7067.2	100		7509.3	100

Table Three (b) Continued

Year Thirty

Costs		%	Benefits		%
Rail Capital	4427.1	56	Rail Revenue	5506.3	52
Rail Operating	2542.8	32	Rail User	2963.6	28
Bus Operator	587.5	7	Car Users	1695.4	16
Bus User	107.5	1	Car Accidents	491.6	5
Rail Accidents	297.8	4	Bus Accidents	16.6	-
TOTAL	7962.7	100		10673.5	100

Table Three (c) Breakdown of Daily Costs and Benefits. RCBA NPV Maximisation. (Non Integer Service Levels and No Tax Adjustments) (£)

Year One

Costs		%	Benefits		%
Rail Capital	4213.6	59	Rail Revenue	3751.2	49
Rail Operating	2291.7	32	Rail User	3078.6	41
Bus Operator	73.5	1	Car Users	317.3	4
Bus User	329.3	5	Car Accidents	419.4	6
Rail Accidents	199.6	3	Bus Accidents	42.3	-
TOTAL	7107.7	100		7608.8	100

Year Thirty

Costs		%	Benefits		%
Rail Capital	4427.1	55	Rail Revenue	5524.3	44
Rail Operating	2568.5	32	Rail User	4858.2	38
Bus Operator	593.9	7	Car Users	1731.3	14
Bus User	125.9	2	Car Accidents	506.2	4
Rail Accidents	314.4	4	Bus Accidents	17.4	-
TOTAL	8029.8	100		12637.4	100

Table Four (a)
Rail Fares and Service Levels (Integer Service Levels and No Tax Adjustment)

	Welfare Maximisation		Producer Surplus Maximisation		RCBA Maximisation	
	Year 1	Year 30	Year 1	Year 30	Year 1	Year 30
Outer - Peak Fare	£1.48	£1.38	£1.98	£1.98	£2.00	£1.82
- Off-Peak Fare	£0.81	£0.72	£1.46	£1.46	£1.40	£1.40
Middle - Peak Fare	£1.03	£0.86	£1.46	£1.46	£1.40	£1.28
- Off-Peak Fare	£0.65	£0.65	£1.09	£1.09	£1.08	£1.06
Inner - Peak Fare	£0.53	£0.61	£0.78	£0.80	£0.75	£0.74
- Off-Peak Fare	£0.34	£0.25	£0.56	£0.54	£0.57	£0.55
Service - Peak	2.00	3.00	2.00	2.00	2.00	2.00
- Off-Peak	2.00	2.00	1.00	1.00	1.00	1.00

Table Four (b)
Daily Demand Levels (Integer Service Levels and No Tax Adjustment)

	Welfare Maximisation		Producer Surplus Maximisation		RCBA Maximisation	
	Year 1	Year 30	Year 1	Year 30	Year 1	Year 30
Bus	23894	17380	24626	18287	24610	18138
Car	17485	24548	18249	26083	18232	25967
Rail	5179	8640	3136	4746	3189	4978

Table Five
Net Present Values (Integer Service Levels and No Tax Adjustment) (£m)

	Welfare Maximisation	Producer Surplus Maximisation	RCBA Maximisation
Financial	-13.289	-9.541	-9.560
Social	8.254	4.262	4.669
RCBA	-8.836	-5.973	-5.964

Table Six (a)
Rail Fares and Service Levels (Non Integer Service Levels and Tax Adjustments)

	Welfare Maximisation		Producer Surplus Maximisation		RCBA Maximisation	
	Year 1	Year 30	Year 1	Year 30	Year 1	Year 30
Outer - Peak Fare	£1.42	£1.44	£1.99	£2.01	£2.05	£1.95
- Off-Peak Fare	£0.95	£0.81	£1.44	£1.44	£1.54	£1.48
Middle - Peak Fare	£1.03	£0.93	£1.48	£1.48	£1.50	£1.43
- Off-Peak Fare	£0.74	£0.69	£1.06	£1.06	£1.12	£1.12
Inner - Peak Fare	£0.51	£0.50	£0.79	£0.79	£0.79	£0.77
- Off-Peak Fare	£0.41	£0.34	£0.54	£0.54	£0.56	£0.57
Service - Peak	2.29	2.81	1.71	1.87	1.69	1.88
- Off-Peak	1.60	2.05	1.11	1.35	1.07	1.31

Table Six (b)
Daily Demand Levels (Non Integer Service Levels and Tax Adjustments)

	Welfare Maximisation		Producer Surplus Maximisation		RCBA Maximisation	
	Year 1	Year 30	Year 1	Year 30	Year 1	Year 30
Bus	24070	19611	24642	20475	24699	20502
Car	17649	24789	18245	25960	18301	25998
Rail	4786	7751	3218	4885	3041	4760

Table Seven
Net Present Values (Non Integer Service Levels and Tax Adjustments) (£m)

	Welfare Maximisation	Producer Surplus Maximisation	RCBA Maximisation
Financial	-11.693	-9.163	-9.188
Social	5.477	2.399	2.006
RCBA	-11.159	-8.306	-8.297

Table Eight (a)
Rail Fares and Service Levels (Integer Service Levels and Tax Adjustments)

	Welfare Maximisation		Producer Surplus Maximisation		RCBA Maximisation	
	Year 1	Year 30	Year 1	Year 30	Year 1	Year 30
Outer - Peak Fare	£1.52	£1.41	£1.98	£1.98	£2.08	£1.91
- Off-Peak Fare	£0.92	£0.81	£1.46	£1.46	£1.49	£1.51
Middle - Peak Fare	£1.07	£0.92	£1.46	£1.46	£1.44	£1.39
- Off-Peak Fare	£0.73	£0.71	£1.09	£1.09	£1.15	£1.14
Inner - Peak Fare	£0.54	£0.59	£0.78	£0.78	£0.77	£0.77
- Off-Peak Fare	£0.37	£0.28	£0.56	£0.54	£0.58	£0.57
Service - Peak	2.00	3.00	2.00	2.00	2.00	2.00
- Off-Peak	2.00	2.00	1.00	1.00	1.00	1.00

Table Eight (b)
Daily Demand Levels (Integer Service Levels and Tax Adjustments)

	Welfare Maximisation		Producer Surplus Maximisation		RCBA Maximisation	
	Year 1	Year 30	Year 1	Year 30	Year 1	Year 30
Bus	24001	17491	24626	18287	24655	18254
Car	17600	24645	18249	26083	18279	26047
Rail	4991	8323	3136	4746	3054	4685

Table Nine
Net Present Values (Integer Service Levels and Tax Adjustments)

	Welfare Maximisation	Producer Surplus Maximisation	RCBA Maximisation
Financial	-12.830	-9.541	-9.563
Social	4.473	1.631	1.394
RCBA	-12.035	-8.604	-8.616

Table Ten (a)
 Rail Fares and Service Levels (Non Integer Service Levels and No Tax Adjustment)
 with no traffic growth

	Welfare Maximisation		Producer Surplus Maximisation		RCBA Maximisation	
	Year 1	Year 30	Year 1	Year 30	Year 1	Year 30
Outer - Peak Fare	£1.40	£1.41	£1.99	£1.99	£1.99	£1.93
- Off-Peak Fare	£0.85	£0.85	£1.44	£1.44	£1.39	£1.43
Middle - Peak Fare	£0.96	£0.96	£1.48	£1.48	£1.47	£1.39
- Off-Peak Fare	£0.72	£0.72	£1.06	£1.06	£1.04	£1.04
Inner - Peak Fare	£0.51	£0.51	£0.79	£0.77	£0.76	£0.76
- Off-Peak Fare	£0.39	£0.39	£0.54	£0.56	£0.56	£0.56
Service - Peak	2.35	2.35	1.71	1.74	1.82	1.84
- Off-Peak	1.63	1.63	1.11	1.10	1.11	1.09

Table Ten (b)
 Daily Demand Levels (Non Integer Service Levels and No Tax Adjustment)
 with no traffic growth

	Welfare Maximisation		Producer Surplus Maximisation		RCBA Maximisation	
	Year 1	Year 30	Year 1	Year 30	Year 1	Year 30
Bus	23978	23961	24642	24789	24620	24763
Car	17551	17556	18245	18235	18220	18214
Rail	4952	4955	3218	3184	3275	3238

Table Eleven
 Net Present Values (Non Integer Service Levels and No Tax Adjustment) (£m)
 with no traffic growth

	Welfare Maximisation	Producer Surplus Maximisation	RCBA Maximisation
Financial	-13.272	-10.948	-10.953
Social	2.348	-0.530	-0.324
RCBA	-11.736	-9.719	-9.560

Table Twelve (a)
 Rail Fares and Service Levels (Non Integer Service Levels and No Tax Adjustment)
 with low car traffic growth

	Welfare Maximisation		Producer Surplus Maximisation		RCBA Maximisation	
	Year 1	Year 30	Year 1	Year 30	Year 1	Year 30
Outer - Peak Fare	£1.40	£1.46	£1.99	£2.00	£1.99	£1.93
- Off-Peak Fare	£0.85	£0.75	£1.44	£1.43	£1.39	£1.42
Middle - Peak Fare	£0.96	£1.00	£1.48	£1.48	£1.47	£1.41
- Off-Peak Fare	£0.72	£0.64	£1.06	£1.06	£1.04	£1.07
Inner - Peak Fare	£0.51	£0.53	£0.79	£0.79	£0.76	£0.78
- Off-Peak Fare	£0.39	£0.34	£0.54	£0.54	£0.56	£0.55
Service - Peak	2.35	2.70	1.71	1.88	1.82	1.87
- Off-Peak	1.63	2.00	1.11	1.32	1.11	1.31

Table Twelve (b)
 Daily Demand Levels (Non Integer Service Levels and No Tax Adjustment)
 with low car traffic growth

	Welfare Maximisation		Producer Surplus Maximisation		RCBA Maximisation	
	Year 1	Year 30	Year 1	Year 30	Year 1	Year 30
Bus	23978	20056	24642	20959	24620	20997
Car	17551	18973	18245	19889	18220	19880
Rail	4952	7367	3218	4591	3275	4608

Table Thirteen
 Net Present Values (Non Integer Service Levels and No Tax Adjustment) (£m)
 with low car traffic growth

	Welfare Maximisation	Producer Surplus Maximisation	RCBA Maximisation
Financial	-12.281	-9.501	-9.523
Social	5.769	2.251	2.520
RCBA	-10.438	-7.849	-7.859

Table Fourteen (a)
 Rail Fares and Service Levels (Non Integer Service Levels and No Tax Adjustment)
 with higher price elasticities

	Welfare Maximisation		Producer Surplus Maximisation		RCBA Maximisation	
	Year 1	Year 30	Year 1	Year 30	Year 1	Year 30
Outer - Peak Fare	£1.37	£1.49	£1.84	£1.85	£1.78	£1.72
- Off-Peak Fare	£0.73	£0.58	£1.19	£1.18	£1.19	£1.15
Middle - Peak Fare	£0.81	£0.92	£1.35	£1.35	£1.33	£1.17
- Off-Peak Fare	£0.64	£0.51	£0.88	£0.90	£0.86	£0.85
Inner - Peak Fare	£0.40	£0.58	£0.71	£0.75	£0.69	£0.70
- Off-Peak Fare	£0.35	£0.23	£0.45	£0.44	£0.46	£0.45
Service - Peak	2.36	2.81	1.72	1.87	1.81	1.87
- Off-Peak	1.82	2.49	1.24	1.57	1.23	1.55

Table Fourteen (b)
 Daily Demand Levels (Non Integer Service Levels and No Tax Adjustment)
 with higher price elasticities

	Welfare Maximisation		Producer Surplus Maximisation		RCBA Maximisation	
	Year 1	Year 30	Year 1	Year 30	Year 1	Year 30
Bus	23187	17844	24004	19124	23982	19038
Car	17260	23509	18152	25395	18131	25327
Rail	5699	10258	3755	5993	3785	6190

Table Fifteen
 Net Present Values (Non Integer Service Levels and No Tax Adjustment) (£m)
 with higher price elasticities

	Welfare Maximisation	Producer Surplus Maximisation	RCBA Maximisation
Financial	-12.829	-9.687	-9.723
Social	7.650	4.164	4.688
RCBA	-8.257	-5.497	-5.477

Table Sixteen (a)
 Rail Fares and Service Levels (Non Integer Service Levels and No Tax Adjustment)
 with speeds reduced by 10%

	Welfare Maximisation		Producer Surplus Maximisation		RCBA Maximisation	
	Year 1	Year 30	Year 1	Year 30	Year 1	Year 30
Outer - Peak Fare	£1.29	£1.52	£2.03	£2.03	£1.91	£1.84
- Off-Peak Fare	£0.78	£0.64	£1.41	£1.41	£1.41	£1.36
Middle - Peak Fare	£0.80	£0.94	£1.49	£1.49	£1.41	£1.30
- Off-Peak Fare	£0.69	£0.58	£1.07	£1.07	£1.05	£1.03
Inner - Peak Fare	£0.48	£0.60	£0.82	£0.82	£0.81	£0.75
- Off-Peak Fare	£0.35	£0.26	£0.52	£0.52	£0.52	£0.53
Service - Peak	2.46	2.81	1.72	1.87	1.86	1.87
- Off-Peak	1.76	2.24	1.18	1.45	1.17	1.45

Table Sixteen (b)
 Daily Demand Levels (Non Integer Service Levels and No Tax Adjustment)
 with speeds reduced by 10%

	Welfare Maximisation		Producer Surplus Maximisation		RCBA Maximisation	
	Year 1	Year 30	Year 1	Year 30	Year 1	Year 30
Bus	22897	18208	23677	19284	23645	19225
Car	17271	24211	18097	25689	18065	25624
Rail	5798	9325	3638	5507	3727	5750

Table Seventeen
 Net Present Values (Non Integer Service Levels and No Tax Adjustment) (£m)
 with speeds reduced by 10%

	Welfare Maximisation	Producer Surplus Maximisation	RCBA Maximisation
Financial	-12.139	-8.061	-8.093
Social	10.334	5.704	6.248
RCBA	-7.650	-4.251	-4.213

Table Eighteen (a)
 Rail Fares and Service Levels (Non Integer Service Levels and No Tax Adjustment)
 with speeds reduced by 20%

	Welfare Maximisation		Producer Surplus Maximisation		RCBA Maximisation	
	Year 1	Year 30	Year 1	Year 30	Year 1	Year 30
Outer - Peak Fare	£1.56	£1.56	£2.05	£2.05	£1.98	£1.84
- Off-Peak Fare	£0.72	£0.59	£1.40	£1.40	£1.35	£1.34
Middle - Peak Fare	£0.94	£0.94	£1.51	£1.51	£1.44	£1.31
- Off-Peak Fare	£0.65	£0.56	£1.05	£1.05	£1.05	£1.03
Inner - Peak Fare	£0.40	£0.65	£0.82	£0.84	£0.82	£0.79
- Off-Peak Fare	£0.34	£0.24	£0.53	£0.52	£0.53	£0.53
Service - Peak	2.43	2.81	1.77	1.87	1.86	1.87
- Off-Peak	1.85	2.35	1.26	1.53	1.24	1.55

Table Eighteen (b)
 Daily Demand Levels (Non Integer Service Levels and No Tax Adjustment)
 with speeds reduced by 20%

	Welfare Maximisation		Producer Surplus Maximisation		RCBA Maximisation	
	Year 1	Year 30	Year 1	Year 30	Year 1	Year 30
Bus	22177	17214	22979	18313	22954	18248
Car	16984	23783	17840	25424	17817	25368
Rail	6463	10577	4030	6115	4088	6347

Table Nineteen
 Net Present Values (Non Integer Service Levels and No Tax Adjustment) (£m)
 with speeds reduced by 20%

	Welfare Maximisation	Producer Surplus Maximisation	RCBA Maximisation
Financial	-11.692	-7.001	-7.039
Social	11.492	6.960	7.569
RCBA	-6.880	-2.806	-2.755

REFERENCES

- Bates, J and Lowe, S (1989) "Criteria for Public Sector Support in Urban Public Transport", PTRC
- Beesley, M, Gist, P and Glaister, S (1983) "Cost Benefit Analysis and London's Transport Policies", *Progress in Planning*, pp169-269
- Bonsall, P (1992) "PLUTO Computer Assisted Training for Transport Planners", *UTSG Conference*, Newcastle
- Cooper, A and Preston, J (1993) "MUPPIT Model Development", *Technical Note 2*, Urban Transport Market Theoretical Analysis Project
- Department of Transport (1989) "Section 56 Grant for Public Transport", *Circular 3/89*
- Glaister, S (1987) "Allocation of Urban Public Transport Subsidy", in Glaister, S (ed) *Transport Subsidy*, Policy Journals, Newbury
- Halcrow Fox and Associates (HFA) (1991) *Research into the Application of Section 56 Grant Criteria: Phase Two. Summary and Appraisal Guide* Report for the Passenger Transport Executive Group with the Department of Transport
- Halcrow Fox and Associates et al. (1993) "Road Pricing in London: Review and Specification of Model Elasticities". *Final Report*. Prepared for the Department of Transport.
- Meyer, J, Kain, J and Wohl, M (1965) *The Urban Transportation Problem*, Harvard University Press, Cambridge, Mass.
- MVA (1992) "Strategic Transport Policy Model Development and Testing Exercise", *Interim Report*
- MVA et al. (1993) "Common Appraisal Framework for Urban Transport Projects", *Interim Report*
- Mackie, P and Preston, J (1988) "Competition in the Urban Bus Market: A Case Study", *PTRC Summer Annual Meeting*, Bath.
- Preston, J (1989) "Nottingham - Mansfield - Worksop New Rail Service Project", *Final Report* Prepared for Nottinghamshire County Council.
- Ortuzar, J and Willumsen, L (1978) "Learning to Manage Transport Systems", *Traffic Engineering and Control*, 19,5,236
- Preston, J (1992) "Financing New Local Rail Services", *World Conference on Transport Research*, Lyon, France
- Preston, J and Nash, C (1993) "An Application of Second Best Pricing Theory", *Technical Note 1*, Urban Transport Market Theoretical Analysis Project

Toner, J (1993) "Review of Urban Demand Elasticities", *Technical Note 2*, Urban Transport Market Theoretical Analysis Project

Willumsen, L, Bolland, J, Hall, M and Arezki, Y (1993) "Multi-modal Modelling in Congested Networks: SATURN and SATCHMO". *Traffic Engineering and Control*, 34, 6, 294-301.

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