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MANAGEMENT OBJECTIVES FOR LOCAL RAIL SERVICES

by

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ABSTRACT

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Using hierarchical logit modal split models, and trip data from West Yorkshire, the effects of pursuing a number of different operating strategies for local rail services were analysed. These were judged against two possible management objectives which railway operators might be set, to find which policies best served each objective.

The more pragmatic objective of maximising rail passenger-km. turned out to give similar policy implications to an objective of maximising social benefit. These were that both objectives could best be satisfied by a combination of lower fares and replacement of lightly loaded services by express bus. Conclusions on frequencies were less clearcut, but it appeared that very high elasticities would be required to justify peak frequencies above the minimum necessary to cope with the traffic. The major difference between the objectives came in the treatment of off-peak rail fares, where reductions could bring larger increases in passenger kilometres but similar or smaller social benefits per pound to peak reductions.

Much cruder estimates are given of the effects of varying fares on two inter city and one London suburban routes. It is shown that a fares increase on the London suburban service, if used to finance a reduction on the local provincial services, would bring in 3 times as many passenger kilometres; if used to finance a reduction on the inter city routes, the figure would be 2-4 times. Whether such a diversion would be justified depends on the external benefits of the London suburban services, measurement of which is very difficult and beyond the scope of this study.

CONTENTS

MANAGEMENT OBJECTIVES FOR LOCAL RAIL SERVICES

1. INTRODUCTION

As part of an SSRC-sponsored project on management objectives and methods of finance for rail transport, a detailed study has been made of the effects of following a range of different policy options for local rail services, taking West Yorkshire as a case study area. Most attention was paid to these services (rather than to Inter City and London and the South East) for two main reasons:-

1) The ready availability of data for all modes of transport in West Yorkshire, primarily from the WYTCONSULT surveys of 1975. This has permitted a more detailed measurement of the social costs and benefits of different policies for these services than for the other service groups.

2) The relative lack of knowledge of price and quality elasticities of demand for local provincial services. By contrast, a considerable amount of work has been undertaken recently on Inter City and London and South East services, which has provided parameters which can be incorporated into models of these sectors.

It should be noted that we were concerned to test the consequences of alternative simple objectives using conventional techniques applied to these services purely as a case study. The important political, social and instititutional factors which determine actual policy making are not considered in this paper, which is not intended to comment directly on the position in West Yorkshire. In any event, our data and conclusions relate to the position in 1975, prior to the signing of the Section 20 agreement under which the P.T.E. is now responsible for fares and service levels on these services.

2. THE MODELLING APPROACH

Given the importance of non-linearities and indivisibilies in the cost and demand functions faced by rail operators, it was not considered feasible to produce a single mathematical model which could be optimised with respect to the different objectives selected. Instead, the procedure has been to forecast demand under a variety of fares and service levels for the services under consideration, and to cost separately the specific changes in service levels and traffic implied by each policy.

For the local services, different techniques were employed for forecasting peak (predominantly journey to work) and off-peak trips. For the peak trips, a detailed analysis of the split of trips between modes was considered necessary, because it was assumed that most changes in rail traffic would be diverted to/from other modes. Also this was necessary to examine changes in social costs due to congestion. Data were available from the WYTCONSULT surveys on peak car, bus and rail trips at an aggregate zonal level, which were used to calibrate models of mode choice in the county. Details of the data and model structure selected are given in Hartley and Ortuzar, 1980, but basically the model followed a hierarchical logit structure. In this, trips were first split between bus and rail. A binary logit form of model was used in each of these two stages to calibrate models from the survey results. Trip characteristics were represented by generalised cost, which for car included network time, perceived operating cost divided by average occupancy and parking charges. For public transport the components were fares, in-vehicle time, and walking and waiting time (both weighted relative to in-vehicle time).

It was found that the difference in generalised costs gave the best model fit for short trips, and the ratio of generalised costs was best for long trips, (Hartley, 1979b). Trip making data was also disaggregated by household car ownership, into 0, 1 and 2+ cars per household with the division by distance, this gave six separate data sets, for each of which, models were calibrated using the WYTCONSULT data. The goodness of fit of the resulting set of models is illustrated in Table 1. It will be seen that trip totals by mode are closely reproduced, but that there is some tendency for the models to over-allocate longer trips to bus and shorter trips to rail and car. Nevertheless, it was felt to be sufficiently accurate for the sort of broad strategic issues with which we were concerned.

To investigate the effects of changing the rail operation (e.g. by altering fares or frequencies), it was assumed that total peak trips were fixed. Using the calibrated models with modified rail generalised costs to reflect the change, the total trips were divided between car and public transport, and then between bus and rail (all in the six categories described above). Finally, aggregating these six sets of results gave the total trips, passenger-km, link flows etc. for the three modes, which enabled an evaluation of the change to be made. To complete the evaluations, evening peak effects were assumed to be the reverse of those in the morning peak.

For the off-peak trips, data were available for rail movements, but not for bus and car travel. Consequently, simple constant elasticity estimates were made from time series ticket sales data of the effects of changes in off-peak (Hartley, 1979a). The costs of off-peak bus and rail operation were assumed to be independent of traffic levels, because of the high level of spare capacity off-peak. The disbenefits of car congestion in the off-peak should also be very much reduced compared with the peak, and were ignored in the evaluations. All results in the following sections are in comparison with the base 1975 figures.

Table 1.

	Base data	Model
Car		
Trips	87,723	87,930
Passenger km.	839,040	807,660
Mean trip length	9.56	9.19
Rail		
Trips	4,515	4,727
Passenger km.	93,174	84,584
Mean trip length	20.63	17.89
Bus		
Trips	44,307	43,888
Passenger km.	266,430	311,422
Mean trip length	6.01	7.10

3. RESOURCE REQUIREMENTS

As a preliminary to calculating the cost changes in each of the options examined, it was necessary to work out the changes in resources used to operate the revised services. All the local rail services were operated by diesel multiple-unit sets (2 or more cars together), and the number of cars in use during the peak determined the fleet size. This had to be inflated by 25% to allow for cars undergoing maintenance and repair.

For these peak services, the model output for the rail services was in the form of directional link flows over segments of route. The first requirement was to find how passengers over common stretches of route were distributed between Local and Inter city trains, and also between different local trains, for estimating train loadings and allocating revenue. The only sources of data to permit this allocation were the Passenger Train Surveys (P.T.S.) carried out by British Rail.

These listed train boardings, alightings and capacities at each station. The data set closest in time to the WYTCONSULT Rail Survey (June 1975) was that for November 1976, and for that reason, there may be some discrepancies in the allocations.

In the morning peak, the heaviest loads are found in the links nearest to Leeds and Bradford stations. The figures output by the model for these links were divided between the trains to compare loads and capacities, using factors derived from the P.T.S. counts. The capacity operated and the traffic shares observed by P.T.S. between services on each route in the morning peak are shown in the Appendix, Table A1. The corresponding split between local and Inter city trains is given in Table A2 which also shows the inter-peak proportions.

It was more involved to allocate passenger-km between local and Inter city trains. For each joint route, all the links had to be identified, the traffic proportions applied to the totals, and the results multiplied by the link length to give local and Inter city passenger-km. This procedure was used to separate trips and passenger-km for the modelled base position results, but for all the options analysed, the changes in traffic were assumed to take place on the local services, where all the supply changes were made. Therefore changes in local traffic were calculated by finding the differences in <u>total</u> figures for each run. It was then only necessary to split up the figures according to the factors in Table A1., in order to check on the capacity of local services. A maximum load factor of 80% was used for all local rail trains, with cars being added or removed according to the traffic levels, so as to maintain this load factor.

It was assumed in the inter-peak period that load factors would be low enough to allow any traffic increase to be catered for within the current capacity. Reductions in inter-peak traffic did not save stock, as the fleet size was determined by the peak.

Where service frequencies were altered, schedules were drawn up manually to estimate the number of sets of stock needed.*

In considering reduced frequencies, the possibility of singling track arises, but for the cases examined in the study, this was not feasible because of other traffic. Where rail passenger services were abandoned, it was assumed that track and signalling savings would only be possible on one route with negligible freight traffic, and that elsewhere the infrastructure would be required for freight traffic.

In practical terms, the position is more involved than this because of the way track costs are allocated to traffics. Where PTE passenger services and freight share track capacity, the majority of the track cost is attributed to the passenger services, with freight only being responsible for those costs which would cease to be incurred if it were withdrawn.

If the passenger service is removed from the route, then the full cost of the track falls on the freight operation. This could make the freight services unviable, with the result that all traffic on the route could cease and the full cost of track provision and maintenance would be saved, but with the loss of some freight revenue.

Even if withdrawing the P.T.E. services did not trigger off this chain of events, from the P.T.E. viewpoint there would be an immediate track cost saving when the allocation of costs changed from the P.T.E. to the freight services. Similar reallocations may be triggered off by a change in passenger frequencies, where a reduction may increase the

... ...

* This method was compared with B.R. allocations based on the time spent on each route, and with a T.R.R.L. model (Balcombe et al, 1973). The results from all three were very similar, and the manual method was adopted for simplicity.

proportion of track and signalling costs which would be avoided by the simultaneous removal of freight services and vice versa. So the cost figures in the tables should be interpreted as changes in costs experienced by the railways as a whole, rather than from the narrower interest of the P.T.E., or even an individual B.R. business sector. It is also the case that changes in contributory revenue are not passed on to the P.T.E., although this figure is small in the costs examined.

A further complication arises in one of the routes which goes outside the county boundary into a non-P.T.E. area. Here, the joint track costs for the section outside the metropolitan county fall again on the passenger services before freight, but this time as part of the Public Service Obligation from the Department of Transport. So, again, from the point of view of the passenger business, withdrawing such a service would save track costs, which would be re-allocated to freight.

4. COST, REVENUE AND BENEFIT ESTIMATION

The changes in costs of operating the rail services under each policy were calculated in detail when the changes in resource requirements had been found, as described in the last section, using 'typical' unit costs supplied by B.R. From the total cars figure were calculated full replacement cost depreciation, capital charges (at 10% interest for a 30 year life) and time-dependent maintenance and cleaning costs. Multiplying train lengths by route mileage and daily frequency gave daily car-miles, from which distance-related maintenance costs and fuel usage were found. Train crew needs were related to peak trains in service, assuming two crews would be needed for each peak train, and a pay train guard on every two cars where stations were unstaffed.

It should be stressed that these cost estimates are very much long-run upper bounds. In the short-run, cost changes from reductions in services are likely to be very much lower. Moreover, to the extent that like-for-like replacement with existing levels for fuel and maintenance cost is assumed, even in the long-run lower costs may be possible by use of cheap, lightweight vehicles. Also 7% would now be a more appropriate interest rate than the 10% upon which these figures are based. Together, these factors may reduce future costs by up to 30%, and thus make maintenance and/or increase of frequencies a much more attractive proposition.

Marginal terminal costs at staffed and unstaffed stations were assumed to be zero. Only in the options where stations were completely closed were costs assumed to be escapable. These covered station operating and maintenance, but not accounting charges for amortisation of buildings and depreciation of plant. Disposal values were not taken into account. Fixed annual costs for track were used, together with incremental wear and tear costs for service level charges. Signalling maintenance and operation costs were assumed only to be influenced by line closures, after allowance had been made for any freight trains remaining on the lines. Management and administration costs were assumed to consist of a fixed sum, and a variable portion equal to 10% of the costs of train services, terminals, track and signalling. All unit costs were reduced to per kilometre or per day figures (assuming 300 days operation per annum).

Bus operating costs were calculated more simply as a fixed cost per bus per day (for either peak-only operation or all day service), and a variable cost per bus mile, and were based on the Bradford Bus Study (R. Travers Morgan, 1976). The figures for bus trips and bus passenger-km were not disaggregated by route, but it was assumed that the number of peak buses in service would be closely related to the number of peak bus trips, so that a change of 50 peak trips would, on average, cause a change of 1 bus in the fleet requirement. This may be optimistic, for those cases where the change in traffic is in fact spread over several routes. In the inter-peak, it was assumed that traffic did not affect costs, except where new services were added.

Revenue for the rail services was calculated from the allocations of passengers and passenger-km discussed in the last section, and linear fare scales based on distance travelled, which gave good approximations to the Bullseye weekly season ticket and the standard fare. For each origin-destination pair, the lower of the two fares was found and all peak passengers were assumed to pay the lower fare; off-peak passengers were assumed to travel at standard rates. A similar procedure was applied to bus fares, except that there is a monthly Metrocard bus ticket which has a flat rate; this was averaged over 40 work trips per month. Again peak passengers were allocated to the lower cost fare system. This may have exaggerated the use of season tickets, as their use is only economic for regular travel, but no data were available on the split as between season and standard tickets for peak trips*. The total revenue of bus and rail was found by multiplying trip numbers and distances by the relevant fare scales, and adding the results. Peak passengers changing mode to or from bus in the policy evaluations were assumed to use metrocard.

One further aspect of rail receipts is the problem of contributory revenue, i.e. the effect on long distance rail trips from changes in the local network. In West Yorkshire (excluding Leeds) some 15% of originating rail passengers changed trains during their journey (usually at Leeds). To estimate the impact of the options tested, access data for Inter City rail journeys from Leeds to London was drawn from a study by Moss and Leake (1976). Taking those journeys which started on the local rail network, the effect of the change in the local service in relation to the total journey (local plus Inter city) was estimated. Inter city fares and journey time elasticities of 0.7 derived from other studies, were used to predict the change in Inter city journeys resulting from the local service alterations. Trips between Leeds and London account for approximately half of all Inter city trips made from West Yorkshire. Thus, this is very much a minimum estimate, but the magnitudes are so small that a doubling or trebling of the figure would not affect the conclusions.

The change in rail users' benefit was calculated by the conventional "rule of a half" measure for each origin/destination pair in the trip matrix as follows, and then summed to give the total effect:

$$\text{Benefit} = \tfrac{1}{2}\sum(Q_1 + Q_2)(C_1 - C_2)$$

where Q_1, Q_2 = number of trips before and after change.

C_1, C_2 = generalised cost before and after change.

... ...

* In theory this split should be dealt with as a third level in the hierarchical modal split model, but usage data would be needed to calibrate such an extension to the model.

When rail services were removed, a value of C_2 in the above equation had to be estimated. An examination of the modal split equations for bus and rail suggested that an additional generalised cost difference (rail cost-bus cost) of 40p would virtually eliminate rail trips. This figure was used in place of $(C_1 - C_2)$ in the benefit equation for rail trips which became impossible under a policy. This approach is inferior to obtaining a direct measure of benefit from integration of the demand equation but no simple analytical expression could be found for the case where generalised cost was in ratio form. Any bias should be in the direction of overestimating the benefits of the rail service, since the true relationship is likely to be convex rather than linear.

Changes in bus user benefits were only calculated for the cases in which bus fares were changed. There would be slight effects from the assumed peak service level adjustments in other cases, but in no case was the change in bus patronage more than 3%, so these would be small.

All of the policies which changed peak rail operations caused changes in the numbers of car trips. The effects of these on other car users, by way of an increase or a reduction in congestion, was estimated as follows. Link flows on the private vehicle network were output from the model. These were used to recalculate link speeds from the detailed speed/flow relationships for each link. From these new speeds, new costs were calculated for travelling on each link, and by summation over the routes, for each origin/destination pair. The change in car user benefit was then defined as the difference between this cost and the original cost multiplied by the number of car trips present both before and after the change.*

... ...

* This procedure does not allow any redistribution of trips because of the changed link costs, which would take place in practice. Nor does it consider further changes in modal split as a result of changed car costs. The modelling suites used were not able to reproduce such behaviour, and therefore the results for car user benefit changes will overestimate the true effects.

Finally, the change in petrol tax revenue due to changes in car passenger-kilometres was calculated. To the extent that this tax is matched by external costs (other than congestion, which was evaluated separately, as described above), this will also be an over-statement. One also has to take into account the fact that changes in public transport revenue are not net additions to the public purse. To the extent that revenue is diverted from taxed commodities, there is a loss of tax revenue elsewhere. This was estimated at 10% of the change in public transport revenue.

Neither the congestion effect nor the change in petrol tax was included in the inter-peak evaluation, since we did not have information with which to forecast the proportion of traffic switching modes. A similar problem arises with bus travel. Because of a lack of knowledge of the cross-elasticities of bus-rail substitution in the inter-peak period, two extreme values were worked out. The first with no bus-rail substitution, the second with full substitution, to give upper and lower bounds on the effect. Results in these cases are shown as ranges, rather than single values.

Net social benefit is calculated as the sum of changes in rail and bus operators revenue, plus the net change in tax receipts, plus the sum of changes in rail, bus and car user benefit less the sum of changes in rail and bus operators' costs.

5. POLICIES TESTED AND THEIR EVALUATION

(a) Changes in Rail Fares

The first set of policies examined involved raising or lowering peak or off-peak rail fares by 20%, other things held constant (Table 2). It is noteworthy that changes in peak fares have substantial effects on rail traffic; indeed, the fact that either raising or lowering them reduces revenue shows them to be in 1975 at approximately the revenue maximising level. This high elasticity of peak rail trips has been confirmed by a time series analysis of Bullseye (the local equivalent of weekly season) ticket sales (Hartley, 1979a).

Table 2. Changes in Rail Fares
(All effects are measured per normal working day)

	Raise peak 20%	Lower peak 20%	Raise off-peak 20%	Lower off-peak 20%
(i) Traffic				
Rail Trips	- 2224	+ 2784	- 939	+ 939
Rail Passenger km.	-38228	+47588	-21530	+21530
Bus Trips	+ 1494	- 1788	0 to +939	0 to -939
Bus Passenger km.	+26592	-31150	0 to +21530	0 to -21530
Car Trips	+ 730	- 994	0	0
Car Passenger km.	+10536	-14616	0	0
(ii) Financial Effects (£)				
Rail Costs	- 822	+ 826	0	0
Rail Revenue	- 162	- 48	+ 14	- 123
Contributory Revenue	- 42	+ 42	0	0
Rail Subsidy	- 618	+ 832	- 14	+ 123
Bus Costs	+ 1041	- 1180	0	0
Bus Revenue	+ 224	- 268	0 to +252	0 to -252
Bus Subsidy	+ 817	- 912	0 to -252	0 to +252
Petrol Tax	+ 64	- 88	0	0
Tax Adjustment (at 10%)	- 2	+ 27	-1 to - 27	+12 to +38
(iii) User Benefits (£)				
Rail User Benefits	- 370	+ 490	- 316	+ 370
Bus User Benefits	0	0	0	0
Car User Benefits	- 602	+ 908	0	0
(iv) Overall Results				
Net Social Benefits (£)	- 1109	+ 1417	-313 to -77	+259 to +33
Net Social Benefits per £ rail Subsidy	1.79	1.70	22.29 to 5.50	2.11 to 0.27
Net Social Benefits per £ public transport subsidy	*	*	22.29 to 0.29	2.11 to 0.27
Rail Passenger km per £ rail Subsidy	61.9	5.72	1538	175
Public Transport passenger km. per £ public transport Subsidy	*	*	0 to 1538	0 to 175

* Indicates that the two elements move in opposite directions.

Changes in peak rail fares have a considerable impact on cost when train lengths are adjusted, although this is more than offset by changes in bus operating costs. Around two-thirds of the traffic diverts to or from bus, which has a higher marginal peak operating cost per passenger kilometre. The remaining traffic diverts to/from car, involving considerable changes in car user benefit through the effect on congestion. (The WYTCONSULT Home Interview survey found that 42% of journeys to work by rail were made by persons with a car available for that journey).

Overall, lower peak rail fares involve net social benefits of around £1.70 per £ subsidy (and vice versa); changes in peak rail fares gain or lose around 50-60 passenger kilometres per £ subsidy, so that net social benefit per passenger kilometre is around 3p.

Turning to off-peak fares, raising these involves losses of passenger kilometres and net social benefit per £ subsidy saved. Lowering off-peak fares would produce net social benefits, although these would be insignificant if the extreme case held that all the traffic attracted was diverted from bus, but no reductions in bus service levels followed. If most traffic were new to public transport, the net benefit per £ subsidy would be similar for lowering off-peak or peak rail fares.

The question must arise as to whether the benefits of cutting peak rail fares are predominantly the result of bus fares for commuters being too low, due to the existence of the 'Metrocard' which substantially undercuts rail fares for longer journeys. The next set of options examines this issue.

(b) Changes involving Metrocard

Three options are considered here. The first is to abolish metrocard in the peak altogether; the second to permit its use on rail at no extra charge and the third to retain it, and raise both bus and rail fares by 20% in the peak. It should be noted that the possible repercussions for off-peak traffic and revenue of these changes have not been evaluated.

Table 3. Changes involving Metrocard

	Abolish Metro-card	Allow Metro-card on rail	Raise peak rail and bus fares 20%
(i) Traffic			
Rail Trips	+ 3382	+ 3632	- 2498
Rail Passenger km.	+ 71434	+91522	-41588
Bus Trips	- 5054	- 2558	- 452
Bus Passenger km.	-103576	-57254	+ 2702
Car Trips	+ 2086	- 1074	+ 2950
Car Passenger km.	+ 25066	-22198	+32790
(ii) Financial Effects (£)			
Rail Costs	+ 930	+ 1174	- 1055
Rail Revenue	+ 822	- 146	- 216
Contributory Revenue	0	0	- 42
Rail Subsidy	+ 108	+ 1320	- 797
Bus Costs	- 3488	- 1753	- 187
Bus Revenue	- 584	- 384	+ 1782
Bus Subsidy	- 2904	- 1369	- 1969
Petrol Tax	+ 150	- 134	+ 197
Tax Adjustment	- 24	+ 53	- 152
(iii) User Benefits (£)			
Rail User Benefits	0	+ 1048	- 365
Bus User Benefits	- 1580	0	- 1726
Car User Benefits	- 934	+ 1032	- 1752
(iv) Overall Results			
Net Social Benefits (£)	+ 408	+ 2048	- 1032
Net Social Benefits per £ rail Subsidy	3.78	1.55	1.29
Net Social Benefits per £ public transport subsidy	*	*	0.37
Rail Passenger km per £ rail Subsidy	661.4	69.3	52.2
Public Transport passenger km. per £ public transport Subsidy	11.5	*	14.1

* Indicates that the two elements move in opposite directions.

Both the first options involve a rise in the rail subsidy; the first, because the cost of catering for additional peak traffic exceeds the increase in revenue; the second, a very much greater increase since there is a loss of revenue. This is more than offset by user benefits and a reduction in bus operating costs, however, to leave very much greater net social benefit for the policy of allowing metrocard on rail than for its abolition. By contrast, retaining metrocard and raising both bus and rail fares involves a loss of net benefits, although a substantial reduction in public transport subsidy. The rise in bus passenger km. under this policy arises because some longer trips transfer from rail as the absolute difference in fares increases. On the other hand there is a transfer of shorter trips from bus to car reducing the total number of bus trips.

(c) Changes in Rail Service Frequencies

We were hampered in this part of our work by the lack of evidence on rail frequency elasticity. The only major change in West Yorkshire in the period under consideration was a 33% increase in service on one high frequency route. Unfortunately, this came in at a time of traffic recession, but may have led to the stabilisation of traffic on this route, whilst elsewhere traffic fell by some 10%. More recently a low frequency route has experienced a more than doubling of frequency, raising traffic levels by some 80%.

Within the peak model, frequencies are represented solely as changes in waiting time, which have a substantial impact on mode split. But for relatively low frequency services, to assume waiting times to be half the headway may overstate their significance.

The changes we considered took two of the higher-frequency routes; on one we doubled frequency from 4 to 8 per hour either for the peak or all-day; on the second, we reduced frequencies by one third from 3 to 2 for the peak or all day. In the former case, the increase in frequency would have strained line capacity to its limits and might therefore have imposed certain additional track and signalling costs not evaluated here. The implied frequency elasticities were 0.25 for the frequency increase but nearly 3 for the decrease. The latter result seemed grossly exaggerated, and we therefore adjusted the waiting time algorithm to produce an elasticity of 0.4. These results are shown in Table 4; the original results in Table 4a.

Table 4. Changes in Rail Service Frequency

(Low Elasticity)

	Reduce Peak Frequency (Route A)	Reduce All Day Frequency (Route A)	Double Peak Frequency (Route B)	Double All Day Frequency (Route B)
(i) Traffic				
Rail Trips	- 256	- 533	+ 472	+ 538
Rail Passenger km.	-4036	-8633	+4920	+5737
Bus Trips	+ 198	+198 to +475	- 282	-282 to -368
Bus Passenger km.	+3410	+3410 to +8007	-3242	-3242 to -4059
Car Trips	+ 60	+ 60	- 188	- 188
Car Passenger km.	+ 746	+ 746	-1846	-1846
(ii) Financial Effects				
Rail Costs	- 807	- 838	+ 376	+ 451
Rail Revenue	- 52	- 84	+ 72	+ 86
Contributory Revenue	- 20	- 20	+ 16	+ 16
Rail Subsidy	- 735	- 734	+ 288	+ 349
Bus Costs	+ 138	+ 138	- 138	- 138
Bus Revenue	+ 30	+30 to +58	- 42	-42 to -54
Bus Subsidy	+ 108	+108 to +80	- 96	-96 to -84
Petrol Tax	+ 4	+ 4	- 12	- 12
Tax Adjustment	+ 4	+ 7 to + 5	- 5	- 6 to - 5
(iii) User Benefits				
Rail User Benefits	- 32	- 50	+ 60	+ 99
Bus User Benefits	0	0	0	0
Car User Benefits	- 4	- 4	+ 166	+ 166
(iv) Overall Results				
Net Social Benefits	+ 599	+583 to +609	+ 17	-17 to - 6
Net Social Benefits per £ rail Subsidy	*	*	0.06	*
Net Social Benefits per £ public transport subsidy	*	*	0.09	*
Rail Passenger km per £ rail Subsidy	5.49	11.76	17.08	16.44
Public Transport passenger km. per £ public transport Subsidy	2.00	1.96 to 9.34	8.74	6.33 to 9.86

* Indicates that the two elements move in opposite directions.

Table 4a. Changes in Rail Service Elasticity (High Elasticity)

	Reduce Peak Frequency (Route A)	Reduce All Day Frequency (Route A)
(i) Traffic		
Rail Trips	- 932	- 1763
Rail Passenger km.	-19066	-32857
Bus Trips	+ 828	+828 to +1659
Bus Passenger km.	+16916	+16916 to 30,707
Car Trips	+ 102	+ 102
Car Passenger km.	+ 1208	+ 1208
(ii) Financial Effects		
Rail Costs	- 807	- 838
Rail Revenue	- 222	- 318
Contributory Revenue	- 20	- 20
Rail Subsidy	- 565	- 500
Bus Costs	+ 625	+ 625
Bus Revenue	+ 124	+124 to +208
Bus Subsidy	+ 501	+501 to +417
Petrol Tax	+ 7	+ 7
Tax Adjustment	+ 10	+ 20 to + 11
(iii) User Benefits		
Rail User Benefits	- 247	- 301
Bus User Benefits	0	0
Car User Benefits	- 42	- 42
(iv) Overall Results		
Net Social Benefits	- 208	-317 to -242
Net Social Benefits per £ rail Subsidy	0.37	0.63 to 0.48
Net Social Benefits per £ Public Transport Subsidy	3.25	* to 2.92
Rail Passenger km per £ Rail Subsidy	33.7	65.7
Public Transport Passenger km per £ Public Transport Subsidy	33.6	* to 25.9

* Indicates that the two elements move in opposite directions.

The results show that, on this type of service, peak frequencies in excess of those needed to handle the traffic involve additional costs greatly in excess of the revenue generated. The effect on net social benefit depends on the frequency elasticity, but this would have to be very large to justify maintenance of frequencies on route A; the increase on route B appears easier to justify. The off-peak frequency adjustments have relatively small affects; and the decision is marginal. However, even where there are benefits from holding up or increasing peak frequencies, it appears likely that the additional net benefits or passenger km. per £ of subsidy is well below that for fares adjustments. Thus the social benefit or passenger km. maximising operator will reduce peak frequencies to the minimum necessary to cater for the traffic, and use the savings to reduce fares.

(d) Replacing Lightly Loaded Services with Express Bus Services

The most lightly loaded routes were selected for replacement by express bus services, which were tested on the basis of either standard bus fares (i.e. with metrocard) or the much higher rail fares. The routes in question carry a total of 1,696 peak and 740 off-peak rail trips. At bus fares, a little over a quarter of the peak trips divert to car, the remainder using the express bus service. If rail fares applied, the proportion diverting to car is over a third. For the off-peak, a range of values corresponding to 0 to 100% diversion to bus was evaluated. The losses of benefits, both to rail users and car users, are substantial. But the cost savings greatly outweigh these benefit losses, and the passenger kilometres lost per £ subsidy saved are fairly low. Even if the peak diversion to car were double that predicted, or if substantial numbers of peak trips ceased to be made at all, these closures would show net social benefits, and the loss of passenger kilometres per £ subsidy saved would be less than for price increases.

As a final option, we tested the combined effects of lowering rail fares by 20% all day, reducing frequencies on one route as described above and replacing three routes by express buses operating at rail fares. The results are not quite additive, due to interactive effects, but there are no surprises. As expected, these measures succeed in achieving major reductions in the cost of the public transport system with no net loss of benefit or traffic. The benefits could either be taken as reduced support requirements, or used to reduce public transport fares further.

Table 5. Replacing Lightly Loaded Rail Services
(With Express Buses)

	(bus fares)	(rail fares)	Combination of 3 policies (see text)
(i) Traffic			
Rail Trips	- 2436	- 2436	+ 206
Rail Passenger km.	-48790	-48790	+1145
Bus Trips	+1212 to +1952	+1052 to +1792	-44 to -243
Bus Passenger km.	+24460 to +4146	+24666 to +41612	+3326 to -1258
Car Trips	+ 484	+ 644	- 240
Car Passenger km.	+ 7084	+ 9784	-3424
(ii) Financial Effects			
Rail Costs	- 3108	- 3108	-3331
Rail Revenue	- 596	- 596	- 765
Contributory Revenue	- 6	- 6	+ 16
Rail Subsidy	- 2506	- 2506	-2582
Bus Costs	+ 1437	+ 1165	+ 26
Bus Revenue	+182 to +381	+252 to +443	0 to -25
Bus Subsidy	+1255 to +1056	+913 to +722	+25 to +51
Petrol Tax	+ 42	+ 59	- 21
Tax adjustment	+ 42 to + 22	+ 35 to + 16	+ 75 to + 77
(iii) User Benefits			
Rail User Benefits	- 584	- 648	+ 226
Bus User Benefits	0	0	0
Car User Benefits	- 304	- 392	+ 346
(iv) Overall Results			
Net Social Benefits	+ 646 to + 427	+646 to +819	+3157 to +3185
Net Social Benefits per £ rail Subsidy	*	*	*
Net Social Benefits per £ public transport subsidy	*	*	*
Rail Passenger km per £ rail Subsidy	19.47	19.47	*
Public Transport passenger km. per £ public transport Subsidy	19.45 to 30.79	4.02 to 16.14	*

* Indicates that the two elements move in opposite directions.

6. GENERAL IMPLICATIONS OF RESULTS

The first important point to make is the close interdependence between peak rail and bus operations in this area. Action which increases the rail subsidy has a large compensating effect on the bus subsidy and vice versa. This potential for trip diversion may be a particular characteristic of the services we have examined, in that the rail routes are paralleled by bus routes which, although slower, are for peak commuters very much cheaper. This anomaly arises particularly because of the existence of a bus only travelcard that is very much cheaper than the equivalent rail ticket.

Secondly, it is interesting that whether the objective is one of maximising passenger kilometres carried, or the wider one of maximising net social benefit, the same general policies would be followed. Wherever additional traffic may be accommodated by raising load factors and/or lengthening trains, it is much more cost-effective to attract additional traffic and benefits by lowering fares than by raising service frequencies, at any rate in the peak. Moreover, some of the more lightly loaded services would be better handed over to express buses.

Table 6 shows the social benefit and cost per passenger kilometre gained or lost under each of the rail options. There is a fair degree of consistency in the social benefit per passenger kilometre for the different policies at about 5p. The most radically different results come not surprisingly when one considers changing off-peak fares in isolation. Off-peak passenger kilometres have much lower social benefits than peak, especially if they are largely diverted from bus. It would clearly be necessary to give these a much lower weight than peak passenger kilometres, probably of the order of one third (less if they are diverted from bus services).

Finally, it might be argued that examining objectives in terms of rail operations alone is inappropriate, in any case, given the clear case for co-ordinating public transport fares and services through the existence of the P.T.E. Tables 2-5 also show net benefit per £ of public transport subsidy in total, and change in public transport passenger kilometres per £ of public transport subsidy. Generally, the ranking of options is unchanged by this switch, although the spread of values between the best options and the worst is increased.

Table 6. Costs and benefits of rail passenger km gained or lost (£ per passenger km)

	Social Benefit *	Operating Cost
Raise peak fares 20%	0.0505	0.0215
Lower peak fares 20%	0.0470	0.0174
Raise off-peak fares 20%	0.0023 to 0.0133	0
Lower off-peak fares 20%	0.0015 to 0.0120	0
Allow Metrocard on rail	0.0450	0.0128
Reduce frequency - peak	0.0419 to 0.0525	0.2000
- all day	0.0219 to 0.0295	0.0971
Increase frequency - peak	0.0596	0.0764
- all day	0.0776 to 0.0798	0.0786
Express buses on certain routes (bus fares)	0.0508 to 0.0549	0.0637
Express buses on certain routes (rail fares)	0.0475 to 0.0519	0.0637

* Revenue + user benefit + net external benefit.

7. COMPARISONS WITH RESULTS FOR OTHER SERVICES

No such detailed analysis was possible for inter-city or London suburban services because of data limitations. However, the effects on revenue and user benefits of raising or lowering fares was calculated for three types of service - a prime East Coast Main Line service, a secondary inter-city service and a London suburban service. Results are shown in Table 7. Fares elasticities were taken to be 0.7 for the inter-city services and 0.3 for the London suburban service. Revenue and cost data for the services was supplied by BR; passenger kilometres were estimated on the basis of the mean fare paid per passenger kilometre in 1977 for that service.

For the two inter-city services, it was assumed that the loss of traffic due to a 20% fares increase would lead to no reductions in services, and therefore no cost savings. Where fares were reduced, however, this could put pressure on peak load factors, and allowance has been made for one additional service in each direction per day. No increase in traffic has been assumed as a result of this enhanced service. This was costed on the basis of a notional cost per train kilometre for the type of stock involved; no changes in terminals or track and signalling costs have been assumed. On the London suburban service, which is a high frequency service geared towards peak volumes, it was assumed that frequencies, and therefore train service costs, would be adjusted in proportion to changes in volume.

In comparing results with those given earlier, it is necessary to take account of the fact that these results are in 1977 prices; thus, they have been deflated by 35.2% to allow for the price increase since 1975.

The results again are unsurprising. Whilst day-long changes in fares afford losses or gains of 70 - 100 passenger km./£ subsidy on the local network, the figure for London and the South East is only 16 - 20. That for inter-city is much higher than both as long as service levels are held constant; however, if increases or decreases in service levels result from the change in traffic, the figure falls to 68 in the case of the prime inter-city route and a much lower figure of 48 for the secondary service where costs are higher relative to revenue. In other words, a rise in the general level of Inner Suburban fares in London could generate four times as many passenger kilometres as those lost if devoted to lowering fares on local provincial services and three times as many on inter-city services.

Table 7. Fares changes on other services (Annual totals)

	East Coast Main Line		Secondary Inter City Service		London Inner Suburban Service	
	+20%	-20%	+20%	-20%	+20%	-20%
Passenger km. (m)	-53	+53	-14	+14	-6	+6
Revenue *	+325	-893	+51	-149	+270	-324
Costs *	0	+315	0	+315	-200	+200
Contribution*	+325	-1208	+51	-464	+470	-524
User Benefit*	-1888	+2172	-312	+359	-409	+434
Tax adjustment*	-32	+89	-5	+15	-27	+32
Net Social Benefits*	-1594	+1053	-266	-90	?	?
Passenger km per £ contribution	163	44	275	31	13.7	12.3
Net Social Benefit per £ contribution	4.90	0.87	5.21	-	?	?
Social Benefit per passenger km	0.0309	0.0271	0.0184	-	?	?
Results deflated to 1975 prices						
Passenger km per £ contribution	252	68	424	48	18.5	16.6
Social Benefit per passenger km	0.0200	0.0176	0.0119	-	?	?

* (£000)

If we assume that there are no external benefits from inter-city passenger km. we find the value of social benefit per passenger km. to be very much lower than that for peak local provincial services, but similar to - or higher than - that for off-peak. It has not been possible to estimate the external benefits of London Inner Suburban services in this study, but they would need to total some 4p per passenger km. to justify failing to raise fares on these services relative to those on the primary inter-city route and perhaps 12p to justify not raising these fares relative to peak local provincial.

We have not examined changes in frequency in any detail for these sectors, since the issue of trading off frequency against train length is less relevant. However, for primary inter-city services, it is clear that even a low elasticity could justify frequency improvements. For instance, one additional service each way per day adds about 8% to frequency and costs about £315,000 p.a. With an elasticity of 0.3, this would add 9,089,000 passenger km. on the primary route and 2,437,000 on the secondary route. In the former case, there would be a gain of 126 passenger km. per £ reduction in contribution; in the latter, 8.9. Obviously, a frequency elasticity of 0 would give a result of zero in each case. Thus, for the former route, even a low elasticity would justify higher frequencies; for the latter, the elasticity would need to be very high. For the former service, such an elasticity would greatly enhance the case for fare cuts.

8. CONCLUSIONS

The results suggest that, for the local services examine, a policy of keeping peak frequencies to the minimum necessary to cope with the traffic, and of replacing lightly used services with express buses, in order to hold down fares within a given budget constraint, would be adopted by either a passenger-miles or a net social benefit (as conventionally defined) maximiser. In most cases, passenger miles maximisation appears to give a good approximation to social benefit maximisation. In the relative treatment of peak and off-peak rail fares, however, the two objectives differ. Passenger miles maximisation, as might be expected, places far too much emphasis on attracting additional off-peak traffic which yields low external benefits. This might be counteracted by giving such passenger miles a weight of, say, one-third that of peak passenger kilometres.

In terms of comparing fares on the local services with those on the inter-city and London suburban services considered, it is more difficult to draw conclusions because of lack of data on cross-elasticities and external benefits. It is unlikely that inter-city passenger traffic yields significant external benefits, in which case this traffic yields net benefits per passenger kilometre of only around a third that of peak local traffic (although similar to, or greater than, off-peak local traffic). On the other hand, whilst holding down fares on the London suburban services produces far fewer passenger km. per £ than on the inter-city or local provincial service, this could be justified if major external benefits, in terms of reduced congestion and environmental degradation exist.

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APPENDIX

The Allocation of Trips Between
Inter-city and Local Services

Table A1. Trip Allocation Between Local Services in A.M. Peak

Model Link	Route	Trains	Cars	Capacity	Traffic Share*
		TO/FROM LEEDS			
LEEDS					
2300-2313	Goole	1/0	2/0	117/0	0.35/0.00
	Castleford	1/1	2/2	137/137	0.08/0.23
	Sheffield (Barnsley)	1/1	2/3	137/188	0.28/0.77
	Wakefield K	1/0	2/0	117/0	0.29/0.00
2300-2304	Knareborough	3/2	9/6	547/359	0.74/1.00
	Harrogate	1/0	3/0	188/0	0.26/0.00
2300-2318	Garforth	2/0	6/0	376/0	0.33/0.00
	Hull	1/0	4/0	242/0	0.29/0.00
	York	2/1	7/2	430/117	0.27/1.00
2300-2322	Ilkley	3/1	9/3	539/188	1.00/1.00
2300-2327/8	Skipton	2/1	5/6	305/359	0.91/0.86
2300-2330	Bradford	3/5	7/13	422/798	0.47/0.59
	Manchester (Halifax)	2/1	8/5	493/305	0.49/0.41
2300-2331	Huddersfield	3/1	8/3	493/188	1.00/1.00
2300-2332	Huddersfield (Direct or Dewsbury only)	2/2	8/10	462/548	0.00/0.00
2300-2336	Doncaster	1/1	3/2	188/137	0.41/0.09
	Wakefield W	1/0	2/0	117/0	0.19/0.00
2300-2319	Hull (Direct from Selby	1/1	5/5	274/274	0.00/0.00
BRADFORD F.S.					
2309-2308	Keighley	2/2	4/4	234/234	0.33/0.42
	Ilkley	3/2	6/4	351/234	0.67/0.58

* Note: Where the proportions do not add to 1.0, it is because Inter-city trains carry the remaining traffic.

Table A2. Trip Allocation Between Local and Intercity Services Peak and Inter Peak

		TO/FROM LEEDS		TO/FROM LEEDS	
		PEAK LOCAL	PEAK INTERCITY	INTER PEAK LOCAL	INTER PEAK INTER CITY
Model Link	Route	Traffic Share	Traffic Share	Traffic Share	Traffic Share
LEEDS					
2300-2313	Goole	1.00/1.00	0/0	1.00/1.00	0/0
	Castleford	1.00/1.00	0/0	1.00/1.00	0/0
	Sheffield (Barnsley)	1.00/1.00	0/0	1.00/1.00	0/0
	Wakefield K	1.00/1.00	0/0	1.00/1.00	0/0
2300-2304	Knareborough	1.00/1.00	0/0	1.00/1.00	0/0
	Harrogate	1.00/1.00	0/0	0.95/0.94	0.05/0.06
	All	1.00/1.00	0/0	0.97/0.97	0.03/0.03
2300-231	Hull	1.00/1.00	0/0	0.68/0.71	0.32/0.29
	York	0.70/1.00	0.30/0.00	0.65/0.71	0.35/0.29
	All	0.89/1.00	0.11/0.00	0.66/0.71	0.34/0.29
2300-2322	Ilkley	1.00/1.00	0/0	1.00/1.00	0/0
2300-2327	Skipton	0.91/0.86	0.09/0.14	0.38/0.39	0.62/0.61
2300-2328	"	0.91/0.86	0.09/0.14	0.38/0.39	0.62/0.61
2300-2330	Bradford	0.92/1.00	0.08/0.00	0.89/0.96	0.11/0.04
	Manchester (Halifax)	1.00/1.00	0.00/0.00	1.00/1.00	0.00/0.00
	All	0.96/1.00	0.04/0.00	0.94/0.98	0.06/0.02
2300-2331	Huddersfield	1.00/1.00	0.00/0.00	1.00/1.00	0.00/0.00
2300-2332	Huddersfield	0.00/0.00	1.00/1.00	0.00/0.00	1.00/1.00
2300-2336	Doncaster	0.51/0.16	0.49/0.84	0.57/0.17	0.43/0.83
2300-2319	Hull (Direct)	0.00/0.00	1.00/1.00	0.00/0.00	1.00/1.00
BRADFORD F.S.					
2309-2308	Keighley/ Ilkley	1.00/1.00	0/0	1.00/1.00	0/0