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A COMPARATIVE COST/BENEFIT ASSESSMENT OF MINITRAM AND OTHER URBAN TRANSPORT SYSTEMS

by

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CONTENTS

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ABSTRACT

This report gives a summary account of a cost/benefit analysis of several hypothetical fixed track automatic passenger transport systems in an urban scenario based on the West Midlands. The assessment was carried out as part of the Minitram project study and is mainly concerned with a system using 20 place Minitrams, but other automatic systems studied for comparative purposes include a network cab system (Cabtrack) and Minitram systems using larger vehicles. Comparative work was also done on a rail rapid transit system, trams, and express buses running on ordinary roads.

The report includes a brief description of the methodology used, with particular reference to the problems of estimating modal split to a new mode when two or more existing modes are present.

The main conclusion reached from the study was that a suitable Minitram network is likely to produce enough cash revenue to cover its direct operating costs and to produce sufficient social benefit to give an internal rate of return of more than 10 per cent on its capital cost.

However the capital cost of the infrastructure is too great for capital charges to be paid out of net revenue, and a substantial capital grant would be required as an initial subsidy. The report stresses the importance of selecting appropriate economic criteria for optimisation before a valid economic comparison can be made with other systems.

1. INTRODUCTION

In the past decade various proposals have been made for new transport systems to improve mobility in urban areas. In the UK there has been considerable interest in the possibilities of systems using small automatically controlled vehicles operating on a network of segregated track. The automatic vehicles can either be operated in a tram-like mode between on-line stations on simple routes, carrying many passengers per vehicle, or in a taxi-like mode between off-line stations, making non-stop journeys on-demand for individual passengers over a complex network of intersecting tracks. Initially research was concentrated on the latter concept, in a system known as Cabtrack[1,2,3], but as the problems of implementing such a system became clearer, effort was transferred to a technically less ambitious tram-like system known as Minitram[4,5]. Vehicle capacities of twelve and twenty passengers have been proposed, though the use of larger vehicles would be possible.

Following the technical feasibility studies a project definition study of Minitram was carried out in 1973/4 (by external contractors) in order to produce detailed technical proposals for equipment, investigate methods of system operation, and estimate costs. As part of the study the planning and civil engineering problems of a proposed 'Public Demonstration System' in Sheffield[6] were investigated in detail. In parallel with these studies a cost/benefit assessment of Minitram in a typical urban scenario was undertaken in order to provide data for the decision on whether it would be worth making a major financial investment in research and development of the Minitram system.

A number of different Minitram systems were modelled and evaluated in a scenario based loosely on the West Midlands conurbation as it is predicted to be in 1981, using data provided by the West Midlands Transport Study[7]. Several alternative systems were also assessed for comparative purposes. The principal ones were the automatic taxi system, Cabtrack, and heavy rapid transit; the latter was based on the hypothetical system described in the Birmingham Rapid Transit Study[8]. There were also outline studies of the effect of running light rapid transit (tram) type vehicles on partially segregated tracks following the Minitram route alignments, of the effect of running express buses on one of the alignments, and of the effects of applying car restraint measures in combination with the introduction of Minitram.

All systems were evaluated against a base which is essentially the result of a 'do-nothing' policy, except that new roads already programmed were assumed to exist in the 1981 scenario. It must be emphasised that the Minitram and Cabtrack networks were designed purely for assessment purposes, and do not imply any intention to build a real system on these lines. The networks were laid out on alignments which looked plausible on the map, but no detailed engineering studies were made of the engineering and environmental feasibility of any of the routes. It should perhaps also be stressed that the purpose of the assessment was to determine the relative costs and benefits of different systems in a realistic scenario which happens to resemble the West Midlands; it was not to find a suitable transport policy for the West Midlands.

Most of the data used in the transport model was based on the value of the pound in 1969. In order to avoid very considerable complications in updating both these costs and the parameters used in the modal split and benefit models, the whole computation has been carried out in a cost base for 1969, and all results are quoted on the same basis. It is not strictly possible to give a simple conversion factor to relate the current value of the pound to the 1969 value, as different items have not changed their costs at the same rate. However, as a very rough working guide, money sums shown in this report should be multiplied by a factor of about 2.6 to convert to mid-1976 values.

This report provides a short summary of the work carried out in the Minitram assessment study. A set of working papers[9,10,11,12] describes various aspects of the study in more detail.

2. SYSTEMS STUDIED

2.1 Minitram

Two Minitram networks and one line-haul system were studied. Figure 1 shows the relationship of the areas served by these systems to the whole area (975 sq km) covered by the West Midland Transport Study.

The 'small' Minitram network (Figure 2) served an area of 32 sq km, and consisted of six radial links with terminal loops feeding on to a central ring. There was a total of 39.4 kilometres of routes, of which 16 kilometres was double track. There were 62 stations, giving an average station spacing of 0.6 kilometre.

An average overall running speed of 8.5 m/s (30 km/h) was assumed. Access to stations was assumed to be purely by walking. With the benefit of experience gained during the study a more efficient network could be designed. The junctions between the radial links and the central ring give rise to severe scheduling problems, so that for the purposes of the assessment it had to be assumed that the central ring was operated independently, with passenger inter-change at the junctions to the radials. The whole network was too small to generate enough traffic to be viable without the use of car or bus feeders, but it was not possible during the study to assess the improvement possible by adding feeder services. Since the assessment showed poor cost/benefit and financial results, these are not reproduced here. Full details are given in reference 12.

The 'large' Minitram network (Figure 3) consisted of five separate double track routes, with interchanges, serving an area of 137 sq km. There were a total of 132 stations and 108 route kilometres of track, giving an average station spacing of about 0.8 kilometre. An average overall running speed of 10 m/s (36 km/h) was assumed, with a maximum speed of 15 m/s (54 km/h). It was again assumed that access to stations was purely by walking, and trips using car or bus feeders were not considered in the assessment.

Minitram on the rapid transit alignment (Figure 4) followed exactly the same route as the rapid transit system described in Section 2.3 below, used a similar system of bus feeders, and was assumed to operate at the same average overall speed of 13.9 m/s (50 km/h). The area served, including the bus feeder services, was 248 sq km.

2.2 Cabtrack

Two Cabtrack networks were studied, within the same 'small' and 'large' study areas as for Minitram, but using different track layouts. The 'small' network had 59 kilometres of one-way track (45 route kilometres), 66 stations and 55 junctions. The 'large' network had 246 kilometres of one-way track (214 route kilometres), 171 stations and 192 junctions. Both networks therefore gave a better coverage of their areas than the corresponding Minitram networks. Normal running speeds were assumed to be 10 m/s (36 km/h) for the small network and 15 m/s (54 km/h) for the large network, though in the latter case sensitivity studies included the effect of reducing speed to 10 m/s (36 km/h).

As with Minitram, access to stations was assumed to be only by walking. The 'small' Cabtrack network appears to have been too small to be viable without feeder buses or cars, and like the 'small' Minitram network showed poor cost/benefit and financial results. These are not reproduced here, but are presented in detail in Reference 12.

2.3 Rapid transit

The rapid transit line (Figure 4) was laid out on the alignment used for the Birmingham Rapid Transit study[8], but was shortened slightly to 29 km, 18 stations, in order to lie wholly within the area for which adequate travel data was available. Two cases were considered, in one of which access to stations was entirely by walking, serving an area of 45 sq km, and in the other of which a frequent service of feeder buses was provided, serving a total area of 248 sq km.

2.4 Light rapid transit

Light rapid transit was represented by the operation of large (75 to 100 place) vehicles with drivers on the routes of the 'large' Minitram network. The provision of drivers allows a reduction in the degree of segregation of track; this will in turn decrease the capital cost of track but also reduce the average operating speed. It was not possible to investigate these effects in detail; for assessment purposes it was assumed that the average speed was reduced by 25 per cent, and alternate assumptions of reductions in capital cost of 20 per cent and 50 per cent were made.

The possible use of manned light rapid transit vehicles on the rapid transit alignment was also investigated. In this case it was assumed that full segregation of track would be maintained, in view of the high traffic flows, and so there would be no reduction in average speed or capital cost arising from the provision of drivers.

For comparative purposes the use of large automatic vehicles (up to 100 places) was also assessed on the 'large' Minitram network and rapid transit alignments. In this case full track segregation had to be maintained throughout.

2.5 Express bus

The express bus service was assumed to be operated by conventional 50 seat buses running on ordinary roads, but providing a faster service than existing buses, achieved by high service frequency and a limited number of stops. For assessment purposes it was assumed that a road existed on the alignment of the rapid transit route, having speed and flow characteristics similar to the nearby A34 road. Bus stops for the express service were placed on the same sites as the rapid transit stations. Feeder services were provided over the same routes as for the rapid transit system; in some cases through buses were provided from feeder routes on to the main line, in other cases interchange was required between main line and feeder services.

The construction of totally segregated busways was not considered, as the possibility had already been examined and rejected by the Birmingham Rapid Transit Study[8], on the grounds that rail rapid transit would provide a cheaper alternative. This was mainly due to the high cost of central area tunnelling for segregated busways.

2.6 Car restraint

A situation was considered in which car restraint was enforced by a pricing policy. This was assessed both in isolation (ie added to the base system) and operating in conjunction with the large Minitram and Rapid Transit networks.

2.7 Fare policies

All systems were assessed over a range of fare systems. The basic fare level was 0.942 p/km (air-line distance), which is the equivalent of the average bus fare in the area in 1969. Distance-variable fares of up to three times this basic level were used. The effect of zero fares was investigated for the 'large' Minitram network, and a range of flat fares (5p, 10p etc) was also used.

3. METHODOLOGY

3.1 Trip distribution and modal split

The assessment was greatly simplified by an assumption that the total number of trips between any zone pair was the same before and after the introduction of the new mode, so that the total number of trips could be obtained directly from the West Midland Study 1981 projection. This meant in effect that it was assumed that no new trips were generated, and that the distribution of existing trips between zone pairs was not changed. This is likely to give an underestimate of the benefits attributable to the introduction of a new system. Data was only available for peak hour trips, so 24-hour trip data was estimated by grossing up from peak trips.

The modal split model used was an extension of the two-mode exponential cost difference model. In this the proportion of trips made by each mode between any specific pair of zones is assumed to be affected only by the generalised cost of travel between these zones by each mode (ie money costs plus time costs). The model gives the proportion of trips on mode X as

$$n_X = \frac{\exp(-\alpha C_X)}{\exp(-\alpha C_X) + \exp(-\alpha C_B)} \qquad \cdots\cdots \quad (1)$$

Where C_X is the generalised cost of travel on mode X

C_B is the generalised cost of travel on mode B

α is the model split constant (assumed to be constant for all pairs of zones in the study area).

Previously two methods have been commonly used to extend the use of this type of model to more than two modes. Consider a situation in which there are two public transport modes X and B, and a private mode C. In one model, it is assumed that public transport can be represented by a single mode, which is either mode X or mode B for any specific pair of zones, depending on which mode has the lower generalised cost of travel between those two zones. The modal split between private and public transport is then calculated from equation 1 above. The end result is that the proportion of trips on mode X can be represented by:–

$$n_X = 0 \qquad \text{if } C_X > C_B$$

$$n_X = \frac{\exp(-\alpha C_X)}{\exp(-\alpha C_X) + \exp(-\alpha C_C)} \qquad \text{if } C_X < C_B \qquad \cdots\cdots \quad (2)$$

using a similar notation to equation 1. C_C represents the generalised cost of travel on mode C.

In the 'three-mode' model, all modes are treated as being equally independent of each other and the proportion of trips on mode X is given by the expression

$$n_X = \frac{\exp(-\alpha C_X)}{\exp(-\alpha C_X) + \exp(-\alpha C_B) + \exp(-\alpha C_C)} \qquad \cdots\cdots \quad (3)$$

Recent work has shown that the 'two-mode' model (equation 2) effectively represents a situation in which the two public transport modes are very similar in all their characteristics, including route structure and location of access points, as in the well known 'red bus/blue bus anomaly' (described in Reference 9). The 'three-mode' model represents a situation in which the two modes are as 'unlike' each other as either is to the private transport mode. In practice the situation probably lies between these two extremes, and a new modal split model has been derived which introduces a new parameter R (the 'red-bus' factor) which describes the likeness or unlikeness of the public transport modes. A value of R = 0 corresponds to a situation in which the two modes are completely alike, and the modal split model becomes identical to equation 2. A value of R = 1 corresponds to a situation in which the modes are totally unalike, and the modal split model becomes identical to equation 3. It was not possible to calculate a suitable value of R for the Minitram assessment as no calibration data was available. As Minitram was thought to differ significantly from the bus mode, but not to be as different from it as the car mode, it was decided to use the mean value of R = 0.5 for most of the studies.

In practical application of the model there are further complications due to the effects of limited access to the car mode, the introduction of a walk mode, and the necessity of producing a model which gives an exact fit to the base data (the West Midland 1981 projections for each mode) in the absence of the new mode.

Full details of the theoretical aspects of the modal split model are given in Reference 9 and details of its application in the West Midland Minitram study are given in Reference 10.

3.2 Estimation of benefits

Benefits were assessed under the broad headings of user benefits and non-user benefits.

User benefits were estimated by evaluating the 'consumer surplus' separately for each zone pair. The consumer surplus was calculated by direct integration of the demand curve (showing demand as a function of generalised cost.) For example, if the cost of travel by mode X is changed:

$$B = \int_{C_{X2}}^{C_{X1}} T_X \, dC_X \qquad \cdots\cdots (4)$$

where B is the consumer surplus arising from the change in cost

T_X is the number of trips on mode X when the generalised cost of travel by mode X is C_X

C_{X1} is the generalised cost of travel by mode X before the change

C_{X2} is the generalised cost of travel by mode X after the change

The introduction of a new mode can be represented by an initial situation in which the generalised cost of travel is too high for any travellers to use that mode, so the upper limit of integration is set to infinity. With a modal split model of the type shown in equation 3, it can be shown that the integration of equation 4 leads to a value for the consumer surplus of:—

$$B = \frac{T}{\alpha} \log_e \left[\frac{\sum \exp(-\alpha C_K) \text{ final situation}}{\sum \exp(-\alpha C_K) \text{ initial situation}} \right] \qquad \cdots\cdots (5)$$

where T is the total number of trips by all modes

C_K is the average generalised cost of travel by any mode K, and the summation is applied to all relevant modes.

It can be shown that, assuming that each traveller chooses the mode which is cheapest for him (in terms of his perception of generalised cost), then the estimate of consumer surplus gives the sum of all the (perceived) cost savings for every individual transferring to the new mode. This is not the same as the figure reached by multiplying the difference between the costs on the modes by the number of travellers transferring, as in general the travellers transferring will perceive generalised travel costs on each mode which are not equal to the average generalised costs for those modes.

The net benefit estimated by the consumer surplus method has to be corrected subsequently to convert it from the 'user's' perception of benefit into society's valuation of benefit and costs. For example, an individual's perception of the money value of his time saved may differ considerably from the 'value of time' that the community ordains shall be used in cost/benefit assessments. On the cost side, an individual bus traveller would estimate his money cost for a trip in terms of the price of the ticket, while the community looks at the resource cost necessary to move him. Full details of these corrections are given in References 9 and 10.

Non-user benefits were assumed to result from road decongestion and were estimated under the following headings:—

Passenger time saved	– for remaining travellers by car and bus
Driver time saved	– for drivers of bus and goods vehicles
Decreased operating costs	– due to speed increase of car*, bus and goods vehicles
Reduction in accidents	

*the reduced operating cost of cars was estimated in terms of marginal costs only; any effect on standing costs was excluded from the calculation.

The values of these benefits were estimated from average figures of traffic movement in the area, and average speed/flow relationships. The results are insensitive to errors in the total traffic movement, but would be sensitive to errors in the speed/flow relationships. The total error is unlikely to be serious, as except for cases involving car restraint the non-user benefits were only a small proportion (about 15 per cent to 20 per cent) of the total benefits.

3.3 Costs

Costs of Cabtrack were assumed to be the same as those quoted in Reference 13, except for vehicle maintenance and energy costs, which were re-estimated and increased in the light of experience of cost estimation for Minitram. It is probable that the capital cost of vehicles has also been significantly underestimated, but the original capital cost estimates have been retained in the present assessment.

The cost of the Rapid Transit system was taken directly from the Birmingham Rapid Transit Study[8]. However, the vehicle capacity assumed was reduced somewhat, as the estimates used in Reference 8 were thought to represent an unacceptable level of overcrowding in the peak period.

Capital costs of Minitram are based on the results of the Minitram project definition studies and the civil engineering studies for the proposed Sheffield Public Demonstration system[6]. These were derived in terms of prices in the period 1973–74, but have been suitably factored to give equivalent costs in 1969. Data on maintenance and staff costs have been estimated with the aid of London Transport figures[14]. Full details of Minitram cost estimations are given in Reference 11.

3.4 Presentation of results

The cost/benefit assessment results are presented in terms of a simplified discounted cash flow calculation of costs and social benefits. Results are also included of the financial profitability of the systems in terms of costs and revenue from fares, both in terms of the surplus of revenue over direct operating costs, and in terms of a discounted cash flow calculation taking capital costs into account.

The main simplification in the discounted cash flow calculations is an assumption that after the opening date the system operates at a constant level of benefits and operating costs. The assessment point is assumed to be the opening year. Building costs are assumed to have been incurred over the preceeding three years, with the civil engineering capital costs equally spread over that three year period, but all vehicles are assumed to have been purchased in the final year. The Net Present Value (NPV) calculated for the system is based on a life of 20 years, and an interest rate of 10 per cent. The infrastructure of a system such as Minitram would of course be expected to have a life of more than 20 years, but it was considered prudent to restrict the NPV calculation to a period no longer than the minimum likely time after which major changes could occur in land use and transport planning. Vehicle lives of 20 years were assumed for Minitram and rapid transit systems, but of only 10 years for Cabtrack and bus systems.

Cost/benefit results of the following quantities are tabulated:—

(i) Total Capital Cost: this is the total cost incurred up to the commencement of operation, discounted at 10 per cent during the period of construction.

(ii) Net Present Value of Social Benefits. This is the sum of all costs and benefits related to the system over an operating period of 20 years, discounted at 10 per cent.

(iii) Internal Rate of Return (Social Benefits). This is defined as the discount rate which will give a zero value of NPV.

The financial results are tabulated in terms of the following quantities:—

(iv) Net Annual Revenue, defined as the difference between gross receipts and the direct operating cost, excluding all capital costs.

(v) Annual net revenue less depreciation allowance. This is equal to item (iv), plus the annual cost of vehicle depreciation, calculated on a linear basis over the life of the vehicle and excluding any interest charges on the initial capital cost of vehicles.*

(vi) Net Present Value (Cash). Net present value of all costs and cash receipts, summed over an operating period of 20 years and discounted at 10 per cent.

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*The calculation of 'realistic' depreciation allowances can cause considerable difficulty in a period of rapidly increasing cost of replacement (due to inflation) and high interest rates, as the use of different assumptions can give widely differing results. Linear depreciation based on historic cost is widely used in practice and was felt to be the least controversial method to use here. (The point is discussed further in References 10 and 12).

In the study an attempt was also made to calculate the NPV in terms of overall resource costs to the community, by subtracting time savings from the benefit estimation, excluding those which could be directly quantified as resource cost savings (eg time savings for drivers of buses and goods vehicles were considered to represent genuine resource cost savings, but time savings for car drivers or car and bus passengers were not). These resource cost savings are not listed here, but are shown in full in Reference 12.

4. ASSESSMENT RESULTS

4.1 Minitram

Table 1 shows the number of passenger trips and the cost/benefit results of two Minitram networks, for a range of fares in each case. (Distance dependent fares are quoted in terms of 'air-line' distances throughout this report. Actual trip distances are, on average, about 1.27 times the 'air-line' distance.)

TABLE 1

Cost/benefit results for Minitram networks

Fare	Passenger trips per day	Total capital cost	Net Present Value of Social Benefits	Internal rate of return (Social Benefits)
		£M	£M	
'Large' Minitram network				
Free travel	560 000	135	39	13.6%
0.942 p/km = bus fare	430 000	123	21	12.2%
1.884 p/km = 2 x bus fare	240 000	104	–3	9.6%
15 p flat fare	115 000	97	–22	6.9%
Minitram on rapid transit alignment with feeder buses				
0.707 p/km = 0.75 x bus fare	275 000	46	49	22.3%
0.942 p/km = bus fare	230 000	42	40	21.0%
1.413 p/km = 1.5 x bus fare	180 000	38	31	19.7%
15 p flat fare	86 000	33	10	13.7%
Minitram on rapid transit alignment without feeder buses				
0.942 p/km = bus fare	80 000	29	2.0	10.9%

Both the 'large' and 'rapid transit alignment' networks give internal rates of return (in terms of social benefit) of over 10 per cent, provided that excessively high fares are not charged. However, it is noteworthy that the 'rapid transit alignment (with feeder buses) has the higher NPV (net present value), although the capital cost is only just over one third that of the 'large' network. The high IRR (internal rate of return) is at least partly due to the fact that a substantial proportion of the passenger kilometres are carried on the feeder buses, which have a low capital cost. The intensive feeder bus network, in fact, has to be run at an operating loss, but this is more than counterbalanced by the operating surplus on the Minitram part of the network.

The major part of the benefit arises from user benefits (perceived cost savings by individuals transferring to Minitram, and resource cost savings by a reduction in car and bus travel); only about 15 per cent to 20 per cent of the estimated benefit results from decongestion. The overall effect on traffic in the area is not large. It was estimated that the two Minitram networks would each reduce car trip kilometres (including through trips) by about 10 per cent to 15 per cent in the areas they served, depending on the fares charged. Further details of the breakdown of benefits and of decongestion effects are given in Reference 12.

Table 2 shows the predicted financial results of Minitram operation.

TABLE 2

Financial results for Minitram

Fare	Total Capital Cost	Annual net revenue	Annual net revenue less depreciation allowance	Net present value (cash)
	£M	£M	£M	£M
	'Large' Minitram			
Free travel	135	−5.0	−7.2	−177
0.942 p/km = bus fare	123	2.2	0.5	−104
1.884 p/km = 2 x bus fare	104	3.8	3.0	−72
15 p flat	97	3.5	3.0	−67
Minitram on rapid transit alignment with feeder buses				
0.707 p/km = 0.75 x bus fare	46	−0.5	−1.6	−50
0.942 p/km = bus fare	42	0.3	−0.7	−40
1.413 p/km = 1.5 x bus fare	38	1.2	0.4	−28
15 p flat	33	0.9	0.3	−27
Minitram on rapid transit alignment without feeder buses				
0.942 p/km = bus fare	29	0.47	0.14	−25

According to these estimates Minitram should produce enough revenue to cover the direct operating costs and an allowance for vehicle depreciation, provided that fare levels are not too low. On this basis the 'large' network would be 'profitable' at a fare equal to the existing bus fare, but the 'rapid transit alignment' system would need somewhat higher fares. With the 'rapid transit alignment' system the Minitram route itself is highly profitable, the only reasons for the small annual operating loss (including allowance for vehicle depreciation) is the loss on the feeder buses. However, a reduction in the level of feeder services to reduce this loss would cause a significant reduction in overall benefits.

Unfortunately the small annual operating surpluses are only possible, with a fixed track system like Minitram, after the expenditure of a considerable capital sum to build the system. The Net Present Value, taking capital costs into account, is a large negative quantity for both systems and all fare levels assessed. (The same applies to the NPV of resource cost savings, which are not tabulated here, see Reference 12 for details.) Over the range of fare levels investigated the NPV is improved (negative value decreased) by increasing fare levels, though further increases beyond these levels would be expected to worsen the position again. Increasing the fare level both tends to increase net revenue, and also decreases the capital cost of vehicles required, owing to the decreased passenger demand. This improvement in financial results by raising fares is of course in direct contrast to the decrease in NPV of social benefits, suggesting the importance, when determining a fare policy, of deciding whether the objective is to optimise social benefits or financial returns. As an example of this problem, net annual benefits and revenues and Net Present Values of these for the 'large' network are shown as a function of fare in Figure 5. On the evidence of this assessment there is not a great deal to choose between distance dependent and flat fares, for the types of network investigated, though the revenue and benefit results were slightly 'worse' with flat fares. A clear distinction must be drawn here between the problems of determining a fare policy for a supplementary transport system such as Minitram, and a single public transport system such as the existing bus services. If a high flat fare is used on the Minitram system, as shown in the examples in Tables 1 and 2, it is assumed that short distance travellers still have a public bus service available; if a high flat fare is used on a bus only system, short distance travellers can suffer severe disbenefits. In this assessment the use of high flat fares raised the average trip distance on Minitram from 5½ km to 7½ km on the 'large' network, and from 8 km to 10½ km on the 'rapid transit alignment'.

Table 3 shows the sensitivity of the results from the large network to changes in average operating speed and access times; speeds are relative to the 'standard' average speed of 10 m/s (36 km/h) used elsewhere in the assessment.

TABLE 3

Sensitivity to average operating speed of revenue and benefits from the large network

(Fare = 0.942 p/km, equal to bus fare)

Condition	Passenger trips per day	Total capital cost	NPV benefits	IRR benefits	NPV revenue
		£M	£M		£M
1.33 x standard speed	470 000	116	45	14.8%	−102
standard speed	430 000	123	21	12.2%	−104
0.75 x standard speed	370 000	128	−14	8.5%	−112
Increase access and egress times by 2 minutes each	350 000	118	2	10.2%	−103

This table suggests that it is desirable to run a system as fast as practicable. However, the assessment assumed that the only additional cost of high speed was from greater energy requirements. In practice a higher operating speed may also increase maintenance costs, and may require more expensive vehicles and track. These additional costs would partially counterbalance the saving in capital costs due to better utilisation of vehicles, and the additional benefits accruing from the larger number of passenger trips and greater time savings. This problem has not been investigated in detail, but it is thought that in practice there might be problems in increasing average speeds much above those selected for the assessment (30 km/h for the 'small' network, 36 km/h for the 'large' network, and 50 km/h for the rapid transit alignment).

It will be seen that small changes in access times to stations also have a very significant effect on the net benefit accruing to a system. This emphasises the problem in planning station locations for a real network of compromising between easy access (requiring small station spacings) and high average speed (requiring large station spacings).

4.2 Cabtrack

Table 4 shows the number of passenger trips and the cost/benefit results of the large Cabtrack network, for a range of fares in each case.

TABLE 4

Cost/benefit results for the 'large' Cabtrack network

Fare	Passenger trips per day	Total capital cost	Net Present Value of social benefits	IRR (social benefits)
		£M	£M	£M
0.942 p/km = bus fare	540 000	141	–50	4.8%
1.884 p/km = 2 x bus fare	420 000	128	–51	4.0%
10 p flat fare	295 000	118	–34	5.8%
15 p flat fare	180 000	105	–45	3.6%

It is clear that this system is unlikely to meet the viability criterion of a 10 per cent social benefit rate of return, for any fare structure. The estimated rate of return shown here is much lower than in earlier Cabtrack studies, due to the increase in estimated energy and maintenance costs resulting from the Minitram studies. In practice it is likely that the rate of return would be even lower, as it is now thought that the capital cost of vehicles may have been underestimated, so that the total capital cost should be higher than the figure shown in the Table. It is not possible to re-estimate the vehicle costs without considerable additional work.

It is interesting to note that the use of flat fares apparently increases the social rate of return on the large network. This is thought to be because the terminal costs of operation are high compared with running costs, for a system like Cabtrack. The use of a flat fare discourages passengers from making short trips which are expensive to provide, but from which they derive only small benefits.

Table 5 shows the predicted financial results of Cabtrack operation.

TABLE 5

Financial results for the 'large' Cabtrack network

Fare	Total capital cost	Annual net revenue	Annual net revenue less depreciation allowance	Net present value (Cash)
	£M	£M	£M	£M
0.942 p/km = bus fare	141	−9.8	−12.4	−235
1.884 p/km = 2 x bus fare	128	−2.5	− 4.5	−157
10 p flat fare	118	−3.1	− 4.8	−351
15 p flat fare	105	−0.6	− 1.7	−115

Cabtrack appears unable to cover its direct operating costs at 'normal' fares, though at high fares the gap between direct operating cost and revenue becomes quite small. However, at these high fares the number of passengers is low (see Table 4), and the rate of return of social benefits is low. When allowance for the high capital cost is made, the net present value of cash costs and receipts is a very large negative quantity, and the overall financial return is clearly much worse than for Minitram.

4.3 Light and heavy rapid transit

Table 6 shows the effect of changing vehicle size and of providing drivers on the 'large' network. The table is divided into three sections. The first shows the effect of varying vehicle size, while retaining the 'Minitram' concept of automatic operation on fully segregated track. The second shows the effect of replacing the automatic operation by a service of manned vehicles operating on partially segregated track, assuming that track capital costs can be reduced by 20 per cent. The third is similar to the second, but assumes a reduction of 50 per cent in the capital cost of track. The latter two cases correspond to light rapid transit systems. It is assumed that the average speed of manned vehicles operating on partially segregated track is only 75 per cent of the average speed for the automatic systems operating on fully segregated track; this causes a slight reduction in passenger demand (see Table 3). In all cases a fare level of 0.942 p/km (equal to bus fare) is assumed.

TABLE 6

Effect of variation of vehicle type on the 'large' Minitram network

(Fare = 0.942 p/km)

Vehicle size	Total capital cost	NPV (social benefits)	IRR (social benefits)	Annual net revenue less vehicle depreciation	NPV (Cash)
Places	£M	£M		£M	£M
		Automatic vehicles			
12	127	12.6	11.3%	–0.4	–113
20	123	21.4	12.2%	0.5	–104
30	124	24.1	12.5%	1.0	–102
50	130	20.0	12.0%	1.5	–106
100	151	0.9	10.1%	1.7	–125
	Manned vehicles, assuming 20% reduction in track capital cost				
50	112	– 2.1	9.8%	0	–100
100	130	–12.3	8.7%	0.9	–110
	Manned vehicles, assuming 50% reduction in track capital cost				
50	85	24.9	13.7%	0	– 73
100	96	21.6	12.8%	0.9	– 77

Considering first the automatic vehicles, it will be seen that the highest NPV of both social benefits and cash is obtained with a vehicle size of about 30 places. Above this point the capital and operating costs of vehicles continue to decrease with increasing vehicle size, but the effect of this is more than outweighed by the increase in the cost of the track necessary to support the heavier vehicles. The actual values of NPV vary quite slowly with vehicle size and the optimum size could change if different assumptions were used for the dependence of track cost on vehicle weight. The net revenue, neglecting capital charges other than vehicle depreciation, increases steadily with increasing vehicle size, due to the reduction in maintenance and energy costs.

The use of manned vehicles increases operating costs, and in this case reduces benefits and revenues slightly due to the slower operating speed (caused by some running on unsegregated track). If the track capital cost is reduced by 20 per cent, compared with the automatic system, the NPV of social benefits and the internal rate of return are significantly lower than with the automatic system. However, if the use of some unsegregated track can reduce track capital costs by 50 per cent, then the NPVs and the IRR are significantly higher than for the automatic system. The optimum vehicle size is larger than for an automatic system, and in fact the operation corresponds very closely to modern light rapid transit. (The apparent optimum vehicle size is smaller than is usual for modern LRT. This is mainly due to an assumption that vehicles could run coupled together, with a single driver, in peak periods. The assumed relation between track cost and vehicle size may also be partly responsible.) It will be noted that in spite of the higher NPVs, due to low capital costs, the annual net revenue (neglecting capital charges) is lower than for an automatic system, though it is just positive.

Table 7 shows a comparison between automatic vehicles of various sizes and heavy rapid transit, operating on the 'rapid transit' alignment. It is assumed throughout that feeder buses are used.

TABLE 7

Effect of variation of vehicle type on the 'rapid transit' alignment

(Fare = 0.942 p/km)

Vehicle size	Total capital cost	NPV (social benefits)	IRR (social benefits	Annual net revenue, less vehicle depreciation	NPV (Cash)
Places	£M	£M	£M	£M	£M
		Automatic vehicles			
20	42	40	21.0	–0.5	–40
30	42	43	21.8	–0.2	–38
50	42	43	21.7	0.05	–37
100	47	40	19.9	0.25	–40
		Heavy Rapid Transit			
120 (6 car trains in peak)	53	36	17.8	0.85	–44

The figures for the system with automatic vehicles follow a similar trend to those for the 'large' Minitram network, showing an optimum vehicle size in the range of 30 to 50 places. The capital costs of the heavy rapid transit system are higher than for the automatic system, partly due to the more expensive track necessary with the heavier vehicles, but more importantly, due to the bigger and more elaborate stations necessary to cater for the relatively infrequent service of long, high capacity trains. These higher infrastructure costs more than outweigh the lower capital cost of the heavy rapid transit vehicles. However, the operating costs of heavy rapid transit are lower due to the low maintenance costs of the simple and well proven technology involved. It should perhaps be stressed that even though it is assumed in this case that vehicles and stations are manned, it is equally assumed that every effort has been made to cut staff to the minimum practicable level. The rather large average spacing between stations (1.7 km) helps to reduce the cost of staffing stations.

4.4 Express bus

Table 8 shows the estimated effect of operating an express bus service over ordinary roads parallel to the 'rapid transit' alignment. The table is divided into three sections. In the first, it is assumed that the feeder routes are served by buses running through from the 'main line', so that passengers can make through trips without interchanges. In the second, it is assumed that the feeder routes are served by buses running independently from the main services, so that through passengers are required to make an interchange (which is shown as an additional time penalty in the trip cost). In the final section feeder routes are omitted, and buses only serve the main line spine route.

TABLE 8

Cost benefit results for express buses operating on the Rapid Transit alignment

Fare	Passenger trips per day	Total capital cost	NPV (social benefits)	Annual net revenue, less vehicle depreciation	NPV (Cash)
		£M	£M	£M	£M
Through buses without interchange penalties					
0.942 p/km = bus fare	166 000	4.4	32	−2.3	−22
1.178 p/km = 1.25 x bus fare	155 000	4.1	32	−1.6	−16
1.413 p/km = 1.5 x bus fare	132 000	3.7	30	−1.2	−12
Separate feeder buses with interchange penalties					
0.942 p/km = bus fare	121 000	3.7	19	−2.3	−22
1.178 p/km = 1.25 x bus fare	111 000	3.4	19	−1.8	−18
1.413 p/km = 1.5 x bus fare	95 000	3.2	17	−1.5	−15
No feeder routes					
0.942 p/km = bus fare	43 000	0.60	13	0.01	−0.3
1.178 p/km = 1.25 x bus fare	40 000	0.53	13	0.16	1.1

The way in which the feeder routes are operated is seen to have a significant effect on patronage and benefits, though rather less on net revenue. In practice it would not be possible to serve all feeder routes with through services, though it is clearly desirable to provide as many through buses as possible. The poor revenue performance of the services including feeder buses is due to the high service frequency provided on the feeder routes, with correspondingly poor load factors. However, if the frequency of feeder services is reduced the overall service becomes less attractive, and the number of passengers carried and the benefits attributable to the system both drop. An attempt was made to estimate the change in revenue and benefits with changes in the level of feeder bus services, using an approximate method which did not involve re-running the complete assessment programme. The method is described in detail in Appendix 3 of Reference 12. The results in terms of NPV of revenue and benefits are shown in Figure 6. It will be seen that the NPV of benefits has a long flat maximum, at a service frequency substantially below that assumed in the basic analysis (4 minute headway), but drops again quite sharply when feeder services are totally eliminated.

(The kink in the curve is probably an artifact of the method used.) The NPV of revenue, on the other hand, continues to rise as feeder services are reduced, and the most profitable service is one which concentrates entirely on the 'main line' route, with its high demand. In practice it would probably pay to retain a few of the most heavily used feeders; the assessment method assumed that services were reduced uniformly on all feeder routes, which is unrealistic.

When the results from the bus systems are compared with those for Minitram on the 'rapid transit' route (Tables 1 and 2) it will be seen that Minitram shows a somewhat higher NPV of benefits, shows a significantly smaller annual operating loss, but also shows a worse cash NPV due to the very much higher initial capital cost. (In practice the choice of a bus system instead of fixed track system like Minitram could involve additional future capital expenditure on road and car park construction. This would effectively increase the capital cost attributable to the bus system, though it is a cost to be incurred at some future date rather than an immediate cost like Minitram infrastructure. It was not possible to quantify such costs during the present work, and they have been omitted from the assessment.)

The express bus without feeders, operating at a fare slightly higher than existing bus fares, is notable as the only system examined which actually showed a positive cash NPV. It also showed the lowest NPV of social benefits, demonstrating that the profitable operation was only obtained at the expense of a (quantifiable) loss of service to the community.

4.5 Car restraint

The effects of car restraint were studied by placing a fixed charge on every car trip which had both trip ends in the study area. (Car trips without both origin and destination within the study area were considered to be unable to divert to Minitram.) Studies were made on both the 'large' and 'rapid transit alignment' areas, and included both the effects of car restraint operating in conjunction with a Minitram system, and of car restraint applied to the 'do nothing' scenario.

The effects of applying car restraint were to divert car passengers to both bus and Minitram modes (where Minitram existed). Some diverted car travellers actually benefited from the diversion, as their perceived loss (due to increase of time costs) was more than compensated by the (unperceived) saving in the actual resource costs of operating their cars. Other diverted car users suffered a reduction in benefits, but bus travellers and remaining car users benefited from the decrease in congestion. On balance, the introduction of a moderate car charge of up to about 10p (1969 prices) gave increasing overall benefits with increasing charges. With further increases above this level the increase in overall benefit flattened off, and eventually the benefit started to fall again.

When the effects were compared of applying car restraint with and without the introduction of Minitram, it was found that the benefits were not additive. The marginal increase in benefit by adding Minitram to an existing car restraint scheme was not as high as the benefit from installing Minitram alone (and similarly from adding car restraint to an existing Minitram scheme). Further details of benefit and revenue charges resulting from car restraint are given in Reference 12.

4.6 Staffing requirements

A summary of the staffing requirements for the three Minitram networks is given in Table 9. (This assumes operation at a fare equal to bus fare.) As well as the staff required to operate the Minitram system, Table 9 also shows the estimated saving on existing bus operations that would no longer be required, and the number of staff that would be required to operate a bus system to carry the same number of passengers as the Minitram system. (This is larger than the number of passengers diverted from existing bus services, as it is assumed that the better service provided by Minitram will attract some existing car users.)

TABLE 9

Staffing requirements for Minitram systems

System	Number of staff to operate Minitram system	Number of staff saved from existing bus services	Number of staff to operate bus system carrying all Minitram passengers
'Small' Minitram (12 place vehicles)	244	128	208
'Large' Minitram (20 places vehicles)	923	1600	2140
Rapid Transit Alignment with feeder buses	982*	1100	1648
Rapid Transit Alignment without feeder buses	217†	370	452

*includes 648 to operate feeder bus services
†note reduction in staff numbers due to lower demand for Minitram when feeder bus services are removed

There are significant savings in staff resulting from the introduction of Minitram, except in the case of the 'small' Minitram network. This is labour intensive due to the small scale of the operation. In effect an automatic system needs a certain number of staff to operate at all, but the number of staff does not have to be increased much if the capacity of the system is considerably increased. It is therefore possible for a low capacity automatic transport system to require more staff to operate it than a manually operated system of similar capacity, and it appears that the 'small' network is below the threshold where it is worth applying complete automation. This problem is discussed in more detail in Reference 11.

The staff requirements for both the other two systems could be slightly reduced by the use of larger vehicles than the 20 place ones assumed. It should in practice also be possible to reduce the staff required to operate feeder buses for the rapid transit alignment, by reducing service frequencies on the less used feeder routes.

4.7 Effect of changing economic conditions

The economic assessment results described above are dependent on the two assumptions that costs are stable throughout the assessment period, and that interest rates remain at the historically high level of 10 per cent. In fact there has been a rapid increase in costs since the 1969 base period, and actual interest rates have fluctuated considerably, but always at very high levels. The interest rate used by public undertakings for assessment purposes has in fact remained at 10 per cent throughout the period since 1969, and it could even be argued that in the fictitious environment of constant prices the 'assessment' interest rate should be lower. However, this is not the place in which to discuss inflation accounting methods, and a study of the effects of changing economic circumstances on Minitram assessment will be confined to a sensitivity study of two possibilities.

It is known that the operating cost of labour intensive operations, such as bus services, has been increasing more rapidly than the cost of other items. Between 1969 and 1973 the operating cost of buses rose by a factor of about 1.71, but in the same period the estimated operating cost of Minitram (including capital charges) rose by a factor of 1.43. The operating cost of buses therefore rose by nearly 20 per cent relative to the operating cost of Minitram, and the effect of this on the economic analysis of Minitram and bus operation will be investigated. It is also considered possible that future interest rates might be lower than the current 10 per cent, and the effect of a drastic cut to 4 per cent was studied.

Table 10 shows the effects of these economic changes, in isolation and in combination, on the Net present values of social benefit and cash revenue for the Minitram and express bus systems operating on the rapid transit alignment.

TABLE 10

Effect of economic changes on the NPV estimates for
Minitram and express bus systems on the rapid transit alignment

(Fare = 0.942 p/km throughout)

Economic changes	Net present value of benefits		Net present value of cash revenue	
	Minitram*	Express Bus†	Minitram*	Express Bus†
	£M	£M	£M	£M
Standard conditions	40	32	–40	–22
20% increase in bus operating cost	36	23	–44	–30
Interest rate 4%	90	53	–38	–33
20% increase in bus operating cost Interest rate 4%	84	39	–44	–46

*With bus feeders
†Through buses on feeder routes without interchange penalties

There are very significant changes in the results as the economic scenario is altered. In standard conditions the NPV of benefits is somewhat higher for Minitram than for the bus, but the loss shown by the cash NPV is nearly twice as great. However, in the extreme case of 20 per cent increase in bus operating costs (which also applies to the Minitram bus feeders) and a reduction of interest rate to 4 per cent, the NPV of benefits is over twice as much for Minitram as for bus and the cash loss is actually less for Minitram than for the bus.

In general it seems likely that future changes in the economic scenario will increase the attractiveness of high capital cost labour saving systems like Minitram relative to the low-cost labour intensive bus system.

4.8 The effect of varying the 'red-bus' factor in the modal split model

It has been shown above (Section 3.1) that in order to produce a satisfactory modal split model for the multi-mode situation, it is necessary to introduce an additional parameter R, the 'red-bus' factor. As the assessment was dealing with the hypothetical introduction of a new and untried transport mode, it was not possible to estimate an appropriate value of R by direct calibration, and an arbitrary assumption had to be made. Since the estimated values of modal split and benefits will vary as R is changed, it is desirable to study the sensitivity of these results to variations in R.

Table 11 shows the effect of varying the value of R in the economic assessment of the 'large' Minitram system.

TABLE 11

Effect of varying the red-bus factor R on the
economic assessment of the 'large' Minitram network

(Fare = 0.942 p/km)

R	Passenger trips per day	Proportion of trips diverted from:*		Estimated NPV (social benefits)	Estimated IRR	Estimated NPV (Cash)
		Car	Bus			
				£M		£M
0	490 000	14.5%	84%	–44	5.0%	–106
0.25	460 000	21.5%	76%	– 9	9.0%	–105
0.5	430 000	28%	68%	21	12.2%	–104
0.75	410 000	35%	60%	49	14.9%	–104
1.0	395 000	41%	53%	74	17.3%	–103

*Proportion of trips directed from walk mode not shown

In the example shown, changing the value of R has a moderate effect on the number of trips made on Minitram, though the relative proportion diverted from the existing car and bus modes varies considerably. There is a very small effect on the NPV of cash revenue, but a very large effect on the estimation of NPV of social benefits and Internal Rate of Return. Similar results are found in other examples, not shown here (see Reference 12 for more details).

In a real situation the model parameters have to be calibrated from a knowledge of trip numbers on various modes; the relatively slow variation of trip numbers with R suggests that there could be problems in calibrating R in practice, unless the relative proportion of trips diverted from existing modes can be estimated accurately. This is unfortunate, as it will be necessary to know R very precisely if a reasonably accurate estimation of benefits is to be obtained. It is possible that this is a demonstration of a fundamental difficulty in obtaining good estimates of benefit changes when more than two travel modes are involved. The use of disaggregated information for model calibration might help to solve the problem.

5. GENERAL DISCUSSION

The original purpose of this assessment was to estimate costs and benefits likely to arise from the introduction of Minitram into a typical urban area, in order to decide whether it was worth making a major investment in research and development of such a system. However during the course of the study a number of problems of evaluation methodology were exposed, and various questions were asked about the relative desirability of alternative transport investments, so the scope of the work was enlarged considerably beyond the initial intentions.

The problems in methodology were concerned with modal split models for more than two modes, and with internal consistency of the modal split and benefit evaluation processes. None of the existing modal split models seems very satisfactory for the type of evaluation required for Minitram, and comparison between different models showed alarmingly large variations in the estimates of user benefits. A new model was eventually developed, which gave a useful insight into the problems of multi-mode modelling, and overcame the anomalies of the existing models. Effectively the new model takes account of possible correlations between costs on different modes, and allows the correlation to have any (predetermined) value, whereas the existing models were confined to situations in which there was either no correlation or complete correlation. The new model was used throughout the assessment, but it should be noted that its estimates of trip numbers and benefits always lie between the extreme values predicted by different existing models.

In determining the desirability of developing any particular type of transport system, it is important to decide what particular economic parameters it is desired to optimise. In comparing the fixed-track and bus systems, the problem is largely one of 'pay now' or 'pay later'. The bus solution is cheaper in first cost, but involves continuing revenue losses throughout its subsequent operation, and generates significantly lower benefits than the fixed-track systems. The operating losses are likely to increase in the future if inflation continues, whereas the interest payments on the capital intensive systems are likely to decrease in real terms in the future. This is partially a reflection of the very high interest rates charged in an inflationary period, though it could also be construed as payment now to provide a subsidy for the next generation. A decision to concentrate solely on a bus system might also involve future capital expenditure on roads and car parks, which would not be required if a fixed-track system were built. It was not possible to estimate the size of these additional capital costs in the present study.

The different systems analysed were compared on a basis of the Net Present Value, calculated by adding all receipts and expenditure of the system, appropriately discounted at the proper interest rate (10 per cent in this case), over the economic life of the system (assumed to be 20 years). The NPV was calculated both in terms of social benefit and in terms of cash receipts. The conclusions reached were somewhat complex, but are summarised briefly below:–

(a) Minitram gave a better return than Cabtrack in terms of both social benefit and cash receipts for all cases in which a comparison was made. Although Cabtrack attracted more trips than Minitram and so produced higher benefits and revenues, this was more than offset by the higher operating costs. With the cost estimates used, there seems to be a small advantage in using a rather larger vehicle than the 20 place Minitram vehicle assumed in the analysis reported here. Other vehicle sizes were considered in the Minitram studies.

(b) Minitram was able to show a surplus of revenue over direct operating cost, and a positive Net Present Value of social benefits (corresponding to an Internal Rate of Return of over 10 per cent) for most of the situations assessed. In these terms it appears to be viable for average (one-way) peak flows of about 1000 passengers per hour, corresponding to about 4000 passengers per hour on the busiest links. The best internal rates of return (social benefits) were about 13½ per cent on the 'large' network, and over 20 per cent on the 'Rapid Transit' Alignment, on which part of the service was provided by (low capital cost) feeder buses.

However for all situations investigated the Net Present Value of cash revenue was well below zero, showing that in purely financial terms the systems would not be viable. The financial deficit for the complex 'large' network, with its relatively low flows, was much higher than for the simple 'rapid transit' alignment system, with its high flows, even though the Net Present Value of benefits for the latter was higher.

The 'small' network (see Reference 12 for detailed results) was viable neither in terms of social benefit nor of cash revenue. The network was too complex and expensive to operate, and the passenger flows attracted were too small. It might have attracted more passengers if feeder buses had been used, and redesign and simplification of the network, in the light of experience, could probably have cut operating costs.

It should be noted that the best results in social benefit terms were obtained at low fares, below existing bus (1969) fare levels. The best results in financial terms (highest net revenue and lowest loss in overall Net Present Value) were obtained at high fares, well above existing (1969) bus fares.

(c) A comparison between automatic and manned vehicles showed that if the capital cost of the infrastructure were the same for both cases, then the automatic system had lower operating costs and a higher Net Present Value in both social benefit and revenue terms. (The heavy rapid transit system appeared to have slightly lower operating costs than Minitram, due to the low maintenance costs attributed to its well proven design. This advantage was more than counterbalanced by the higher infrastructure cost of its track and stations).

However, if the provision of a driver made it possible to achieve significant savings in infrastructure costs (eg due to non-segregated track, simpler stations) without changing any other factors, which is unlikely, then although the net annual revenue would be slightly lower, the Net Present Value of social benefit and cash revenue would be increased. In practice the cheap infrastructure would lead to a reduction in average speeds, but the analysis suggested that the system might still be able to provide better returns than the automatic system in terms of Net Present Value.

(d) A comparison between Minitram and a hypothetical express bus system serving the same area showed that the Minitram system would attract significantly more passengers, generate higher benefits, and be cheaper to operate. However the capital costs for Minitram are much higher, so that though the Net Present Value of social benefits is higher for Minitram, the Cash Net Present Value is higher (less in deficit) for the bus.

The different scale effects for bus and Minitram are very evident in this part of the study. With a system like Minitram it appears to be worth providing a high quality feeder bus service which is in itself loss making, but which attracts sufficient traffic to Minitram to increase the overall 'profitability' of the system by improving the utilisation of the expensive infrastructure. With the express bus service it was found better to reduce the level of feeder bus services, in order to improve utilisation of the individual buses.

Future changes in the economic scenario, such as increases in direct labour costs or a decrease in interest rates would make Minitram more attractive in comparison with the express bus, as would full accounting of possible future savings in construction costs of car parks and improved roads. Such changes would affect the long term accounting for the systems; in the short term in a period of financial stringency a disadvantage of a fixed track system must always be the high capital cost of construction before operation can start.

(e) The replacement of some bus services by a suitable Minitram system could give significant staff savings, probably up to about 40 per cent of the original bus staff. These savings would occur in spite of the increase in travel by public transport caused by the greater attractiveness of Minitram. A Minitram system would need a minimum of about 10 per cent of its staff establishment on duty in order to be able to run any service at all; it is not known how this compares with the number of bus staff on duty in 'awkward hours' in a typical bus operation.

6. CONCLUSIONS

1. Assessment of Minitram in comparison with other forms of public transport showed up problems in modal choice prediction and in benefit evaluation. Progress and improvements have been made in the methodology in both areas.

2. The criteria for selecting a new transport system have to be carefully defined before precise comments can be made on the relative suitabilities of different modes. At the risk of over simplification, some of the main results from this assessment study are:–

    (a) Minitram is better than Cabtrack both in social benefit and purely financial terms.

    (b) Minitram gave a surplus of revenue over direct operating cost and a positive NPV of social benefit (with a discount rate of 10%) in most situations, but the capital cost is so high that in financial terms the system would not be viable.

    (c) Minitram, when compared with an express bus service, showed higher patronage, higher benefits, and cheaper operating costs. But again the high capital cost gave a larger deficit for Minitram than for the express bus.

    (d) Any future increase in operating costs relative to capital costs – for example, lower interest rates in real terms and higher labour rates – would favour Minitram more than a bus solution.

    (e) A Minitram system could show savings of staff of up to about 40% of the number required to run a bus service.

3. A comparison between automatic (driverless) and manned vehicles indicated that, with the same infrastructure cost, the automatic system had lower operating costs and a higher NPV in social and revenue terms. However if the use of the driver enabled savings in track and station costs – for example, by allowing some non segregated track – NPV of social benefits and revenue could be higher for the manned system. Probably the crucial factor here is whether the conflict with road traffic and environmental problems with non segregated track are acceptable to the public.

7. ACKNOWLEDGEMENT

The work described in this report was carried out in the Advanced Systems Division of Transport Systems Department of TRRL.

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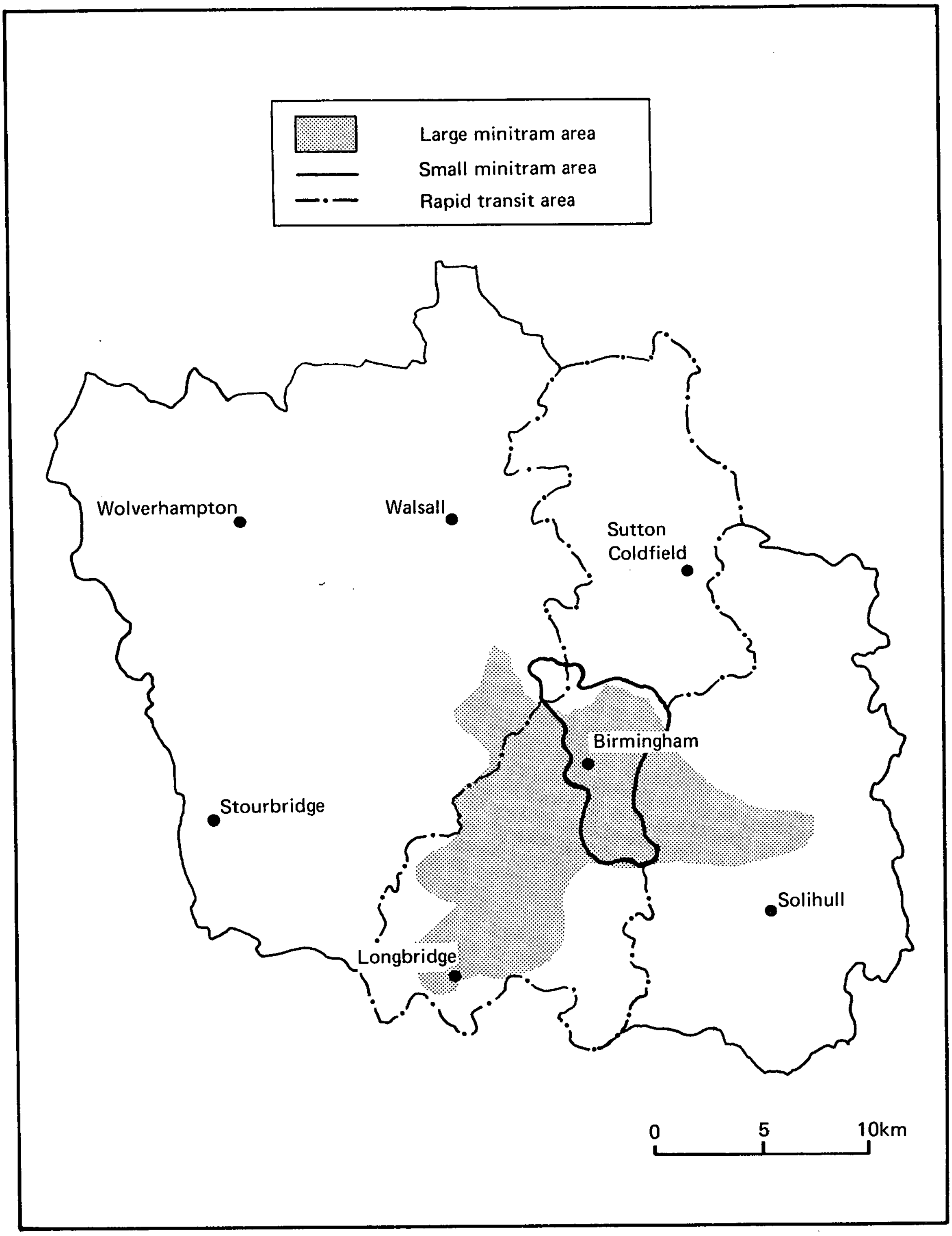

Fig. 1 THE WEST MIDLANDS STUDY AREA AND THE AREAS SERVED BY THE MINITRAM SYSTEMS STUDIED.

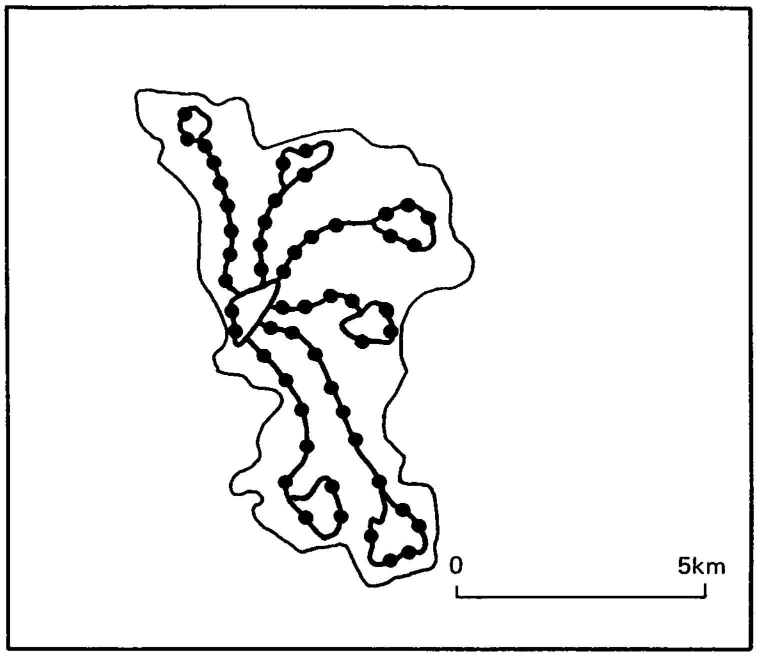

Fig. 2 SMALL MINITRAM SYSTEM

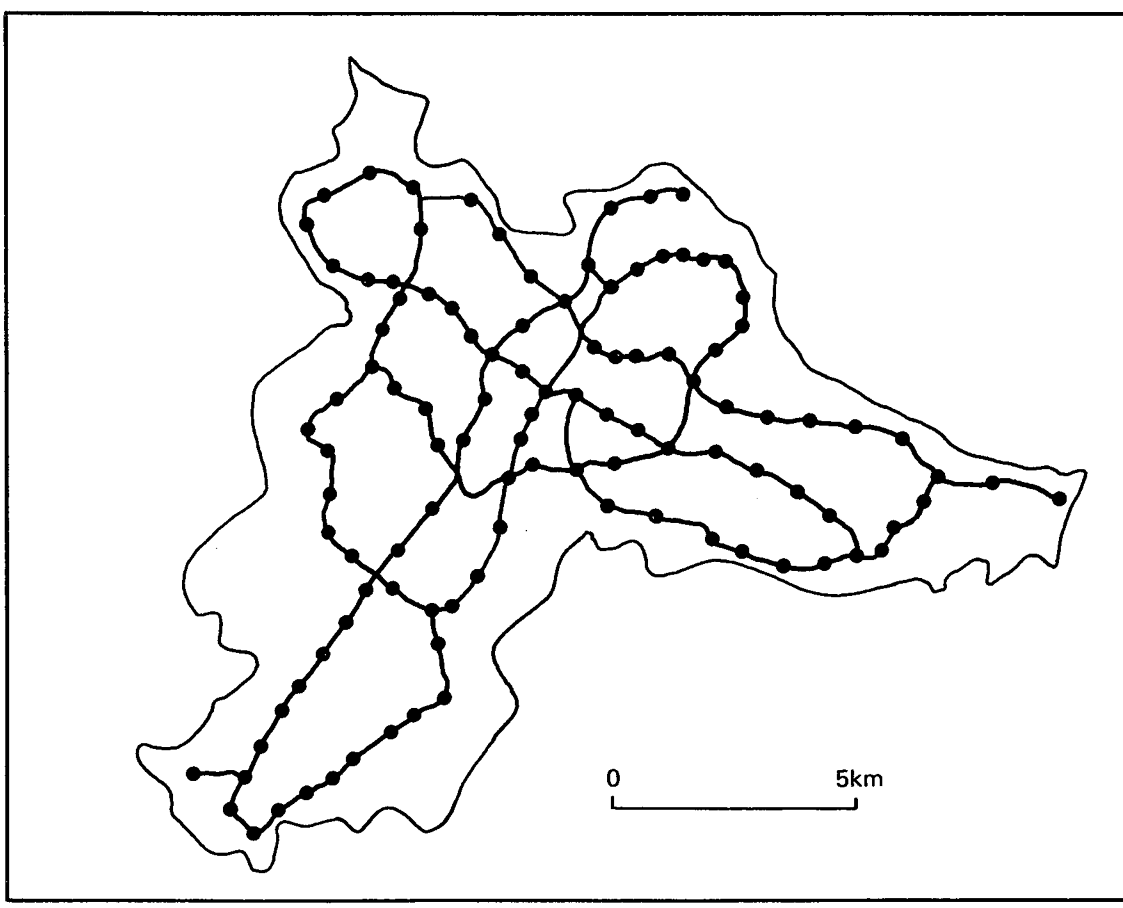

Fig. 3 LARGE MINITRAM SYSTEM

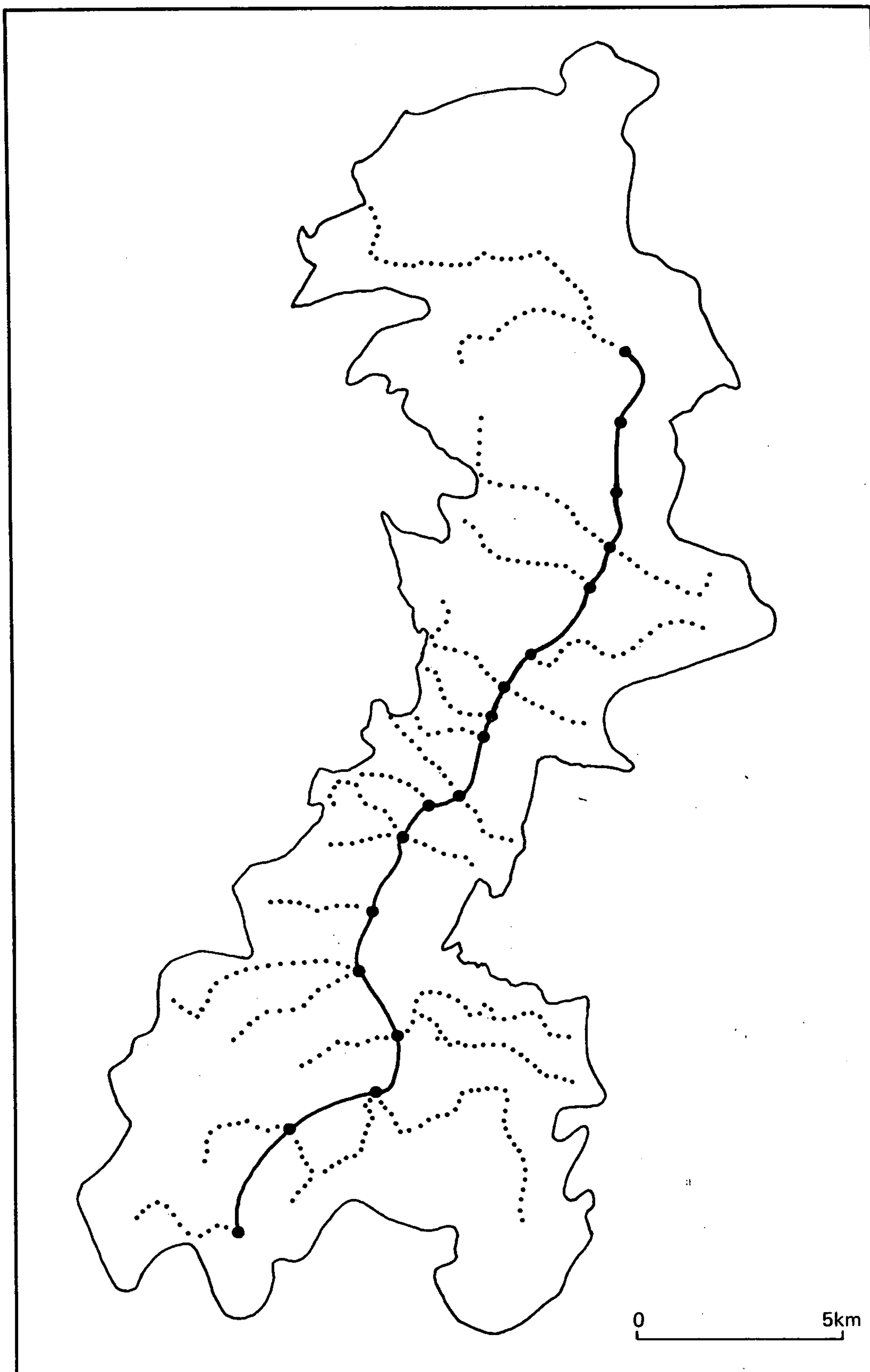

Fig. 4 RAPID TRANSIT ALIGNMENT WITH FEEDER BUS ROUTES

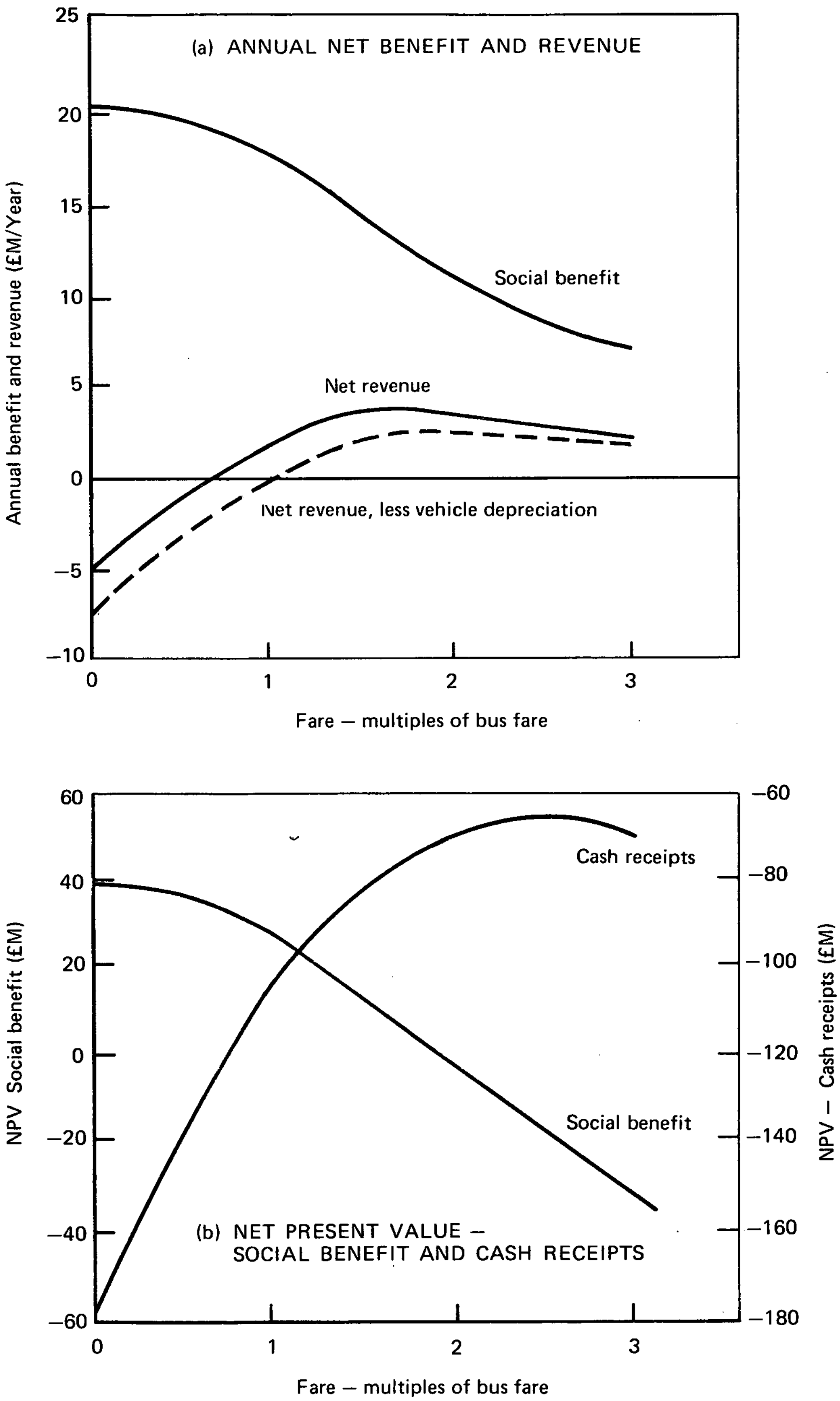

Fig. 5 VARIATION OF SOCIAL BENEFITS AND CASH RECEIPTS WITH FARE LEVEL. LARGE MINITRAM NETWORK.

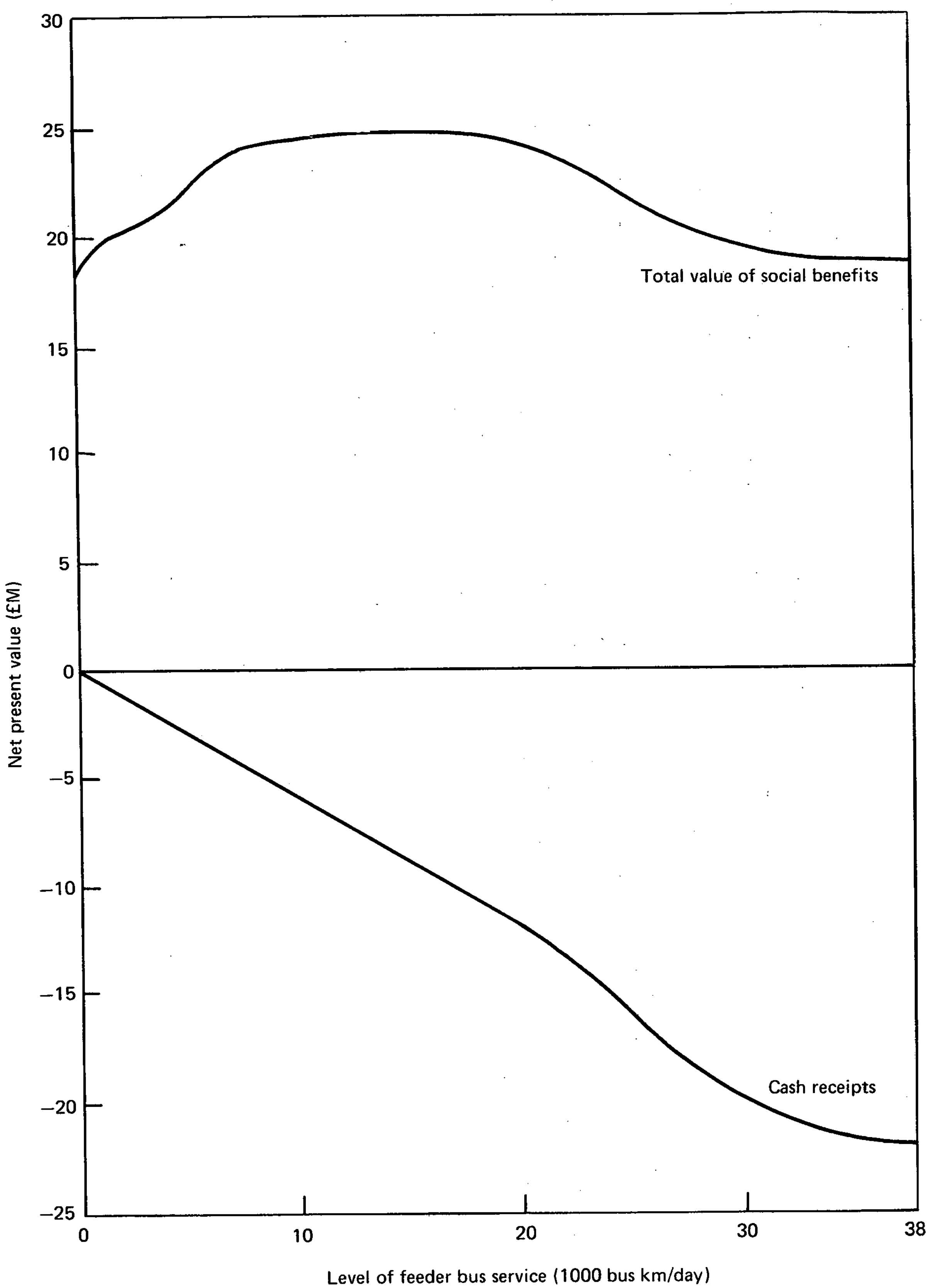

Fig. 6 EXPRESS BUS SYSTEM (RAPID TRANSIT ALIGNMENT) – VARIATION OF NET PRESENT VALUE WITH LEVEL OF FEEDER BUS SERVICES (ASSUMING INTERCHANGE PENALTIES)

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ABSTRACT

A comparative cost/benefit assessment of Minitram and other urban transport systems: M G LANGDON: Department of the Environment, Department of Transport, TRRL Laboratory Report 747: Crowthorne, 1977 (Transport and Road Research Laboratory). This report gives a summary account of a cost/benefit analysis of several hypothetical fixed track automatic passenger transport systems in an urban scenario based on the West Midlands. The assessment was carried out as part of the Minitram project study and is mainly concerned with a system using 20 place Minitrams, but other automatic systems studied for comparative purposes include a network cab system (Cabtrack) and Minitram systems using larger vehicles. Comparative work was also done on a rail rapid transit system, trams, and express buses running on ordinary roads.

The report includes a brief description of the methodology used, with particular reference to the problems of estimating modal split to a new mode when two or more existing modes are present.

The main conclusion reached from the study was that a suitable Minitram network is likely to produce enough cash revenue to cover its direct operating costs and to produce sufficient social benefit to give an internal rate of return of more than 10 per cent on its capital cost.

However the capital cost of the infrastructure is too great for capital charges to be paid out of net revenue, and a substantial capital grant would be required as an initial subsidy. The report stresses the importance of selecting appropriate economic criteria for optimisation before a valid economic comparison can be made with other systems.

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