Department of Transport

British Railways Board

Review of Main Line Electrification

Final Report

LONDON

HER MAJESTY'S STATIONERY OFFICE

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1. Submission By The Co-Chairmen

1. In May 1978 the Secretary of State for Transport and the Chairman of the British Railways Board appointed Mr David Bowick, a Vice-Chairman of the Railways Board, and Mr John Palmer, an Under Secretary in the Department of Transport, as co-chairmen of a group "to review the case for a programme of main line electrification, to analyse the various relevant considerations and formulate the issues for decision". The review has been carried out jointly by the Department of Transport and the British Railways Board. The steering group included representatives from the Treasury and the Department of Energy, and other Government Departments contributed. An interim report was made in September 1979. Mr Michael Posner, a member of the British Railways Board, succeeded Mr Bowick on the latter's retirement in January 1980. As co-chairmen, with the concurrence of the steering group, we now submit this final report.

2. We have taken the advice of a large number of outside organisations and individuals. We have also made enquiries of overseas administrations. Our main task has been a comprehensive financial analysis of different programmes of main line electrification, which would electrify the services to Newcastle, Leeds and Edinburgh, Cardiff and Plymouth and—in the largest option—to Hull, Aberdeen, Holyhead and Penzance. We have also considered the wider effects of a programme of main line electrification. The results are set out in the following chapters and appendices.

3. The financial analysis was carried out through computer models designed to predict the financial consequences of electrification and associated changes in traffic. Any such analysis must, at some cost, be capable of further refinement. We are satisfied that the work done, which was scrutinised in detail by both the Department of Transport and the Railways Board, gives results that are reliable; further refinement would not alter the conclusions to be drawn.

THE MAIN CONCLUSION

4. On the assumptions made, a substantial programme of main line electrification would be financially worthwhile. All the larger electrification options examined show an internal real rate of return of about 11%; the faster options give the higher net present values.

5. Looking at wider effects not taken into account in the financial evaluation, we have not identified any important disadvantage. There are two important advantages. The first is that electrification, while scarcely affecting total energy consumption, would reduce dependence on oil: the railways at present use about 3% of oil consumed by transport. The second is that a programme of electrification in the UK should assist the UK manufacturing industry to win more orders overseas, in an expanding market, and would be in keeping with

the Government's policy of using public purchasing more effectively to enhance the competitiveness of British industry.

6. We have considered the various ways in which the financial result described might be undermined. Given the present experience of the recession, we have thought it right to consider the effect of lower forecasts of passenger and freight traffic, forecasts significantly below any the Board considers likely. We have also examined the effect of costs turning out higher than expected. Our conclusion is that it would take an unlikely combination of adverse factors to undermine entirely the prospect that a programme of main line electrification would be financially worthwhile; ie earn a return of at least 7%—this is in part because of the greater scope now foreseen for divergence between oil and electricity prices. Similarly, the outcome could be better than 11% if favourable chances combine.

THE ISSUES FOR DECISION

7. Our terms of reference require us "to formulate the issues for decision". They seem to be as follows.

8. The first issue is whether the main assumptions underlying our work are valid. We draw attention to four key assumptions.

(i) The main commercial businesses of the railway—Inter-City, freight and parcels—would benefit most from electrification. We have assumed that these businesses will continue to win traffic and to flourish in a way that will justify substantial further investment—more than the Railways Board is investing in them at present—even if they continue with the present forms of traction. In effect, we have assumed increased investment in developing businesses, and have analysed whether the railway would do better with electric than diesel traction. It is therefore a major assumption underlying our work that these commercial businesses will in the future be able, by a combination of increased efficiency and adaptation to the market, to increase traffic at higher real fare levels and so improve financial results.

(ii) In particular, there are important assumptions on fares and labour costs with or without electrification. We have assumed that the competitive position of the railways will enable them to make real fares increases of an average of 1% a year, and that this will help to generate additional funds for investment. We have also assumed that while labour costs will move in line with GDP, corresponding gains in productivity with or without electrification will secure that this does not raise the unit cost of output.

(iii) We have assumed, in line with current experience, that electrification would bring increases in efficiency and lower operating costs. One of the large benefits to the railways from electrification arises from reductions in maintenance costs, which are largely staff costs. When the railway unions gave evidence to us, we raised with them the need for co-operation to secure these gains. The unions pointed to their record in advocating new investment and accepting the changes that flow from it.

(iv) We have assumed future changes in energy costs, and particularly a rise in oil prices greater than a rise in electricity prices, as described in the following chapters. The Department of Energy are currently preparing revised forecasts of energy prices. It is already clear that there is potential for oil prices to rise above the range we have considered and for the gap between oil and electricity prices to widen. To the extent that it does, the financial case for electrification will be improved.

A STRATEGIC DECISION

9. In the review we have examined what would be gained by practicable programmes of main-line electrification extending over 20 or 30 years. The questions now are about a strategy to change progressively to electric traction, how much to plan to spend, how much to commit, and when to start. These affect the level of investment in the railway and its requirements for external finance. We are very conscious that they raise wider issues of railway finances and of competing priorities for Government funds, outside our remit.

10. These wider considerations might suggest that only a *strategic decision in principle* need be taken now—whether the main Inter-City network should progressively be converted to electric traction. This would reject the alternative of a future main-line system worked by diesel traction, and British Rail would then plan on the assumption that most of their main-line traffic would in time be electrified. Such a strategic decision would give a base for the many individual decisions, for example, on the plans for designing new rolling stock, on renewing and modifying the track and signalling, on the disposition of depots, and on the traffic which the railways should aim to secure, all of which can be affected by the form of traction envisaged. It would allow flexibility in implementation but would still leave the Board, as hitherto, to put forward individual projects when they could justify them, and could accommodate them within their business plans.

COMMITMENT TO A PROGRAMME

11. With a strategic decision for electrification, there are arguments for going further towards *commitment to a specific programme*. They are:

(i) A programme of electrification would require commitments, from the supply industry and the workforce as well as railway management, which the *ad hoc* approval of individual projects could not command. This commitment should help to avoid abortive expenditure and to secure the cost reductions assumed in the study to result from continuity of production, which should also improve the industry's ability to compete overseas.

(ii) It would allow the Board a firm basis for financial plans, seeing that an electrification programme would make extra cash flow demands until the mid 1990s (in the case of the largest and fastest by £32m a year on average and by £60m or more in certain years—in 1980 survey prices*); it would also require investment in excess of that currently planned by the Board within the present investment ceiling set by the Government.

*The figures in this submission have been updated from those in subsequent chapters of this report, which are in 1978 prices.

(iii) Finally, the benefits of individual electrification proposals cannot be evaluated fully without including some judgements about the likely future extent of the electrified network; otherwise, investment decisions would be distorted.

HOW MUCH, HOW SOON

12. All the electrification programmes, except the smallest, give an internal rate of return of 11 %. The faster options give better net present values, but make the largest calls on cash flows over the first fifteen years. We have not identified any significant differences between the programmes, so far as wider effects are concerned.

13. It follows from this that if funds for railway financing were not constrained, the best course would be to choose now the largest and fastest programme. This would be completed in 20 years, extending electrification to Edinburgh and Aberdeen on the East Coast Main Line and from Edinburgh to Glasgow and Carstairs; to Sheffield on the Midland Main Line; across the Pennines from Liverpool to York; from York to Birmingham and Birmingham to Bristol and Reading on the North-East to South-West route; and on the Western Region as far as Swansea and Penzance. Over 80 % of passenger and some 70 % of freight traffic would then be electrically hauled. This very extensive electrification programme gives the highest net present value (£305m) and a rate of return of 11.1 %, but also makes the greatest cash flow demands. These would generally be between £24m to £42m a year for the first fifteen years, but in some years would exceed £60m.

14. At the other end of the scale, the smallest programme which we have considered would be completed within 15 years and would reach Newcastle on the East Coast Main Line, and Sheffield on the Midland Main Line. It would include Edinburgh to Glasgow and Carstairs (but nowhere else in Scotland) and York to Birmingham, but would not include electrification on Western Region, or extend south of Birmingham to Bristol. This option is in the first part of all the larger programmes but it has not only the smallest net present value (£84m) but also the lowest rate of return (9.9 %); 62 % of passenger traffic and 38 % of freight traffic would be hauled by electric traction. There would be a significant amount of diesel running (mainly freight) over the electrified network.

15. The results of our study indicate that it would be worthwhile to go on beyond the smallest programme of electrification. On the other hand it is not essential to take a decision now to go on to the final stages of the largest programme. This helps to focus the area of consideration for decisions on a medium-sized programme, which would extend electrification up the East Coast Main Line to Edinburgh; from Edinburgh to Glasgow and Carstairs; up the Midland Main Line to Sheffield; from Liverpool to York; along the whole of the North-East to South West route from York to Birmingham and thence to Bristol and Reading; and on the Western Region as far as Swansea and Plymouth. This would mean that 75 % of passenger and 54 % of freight traffic would be electrically hauled.

16. The issues for decision now are essentially how quickly to proceed and when to start. So far as the rate of progress is concerned, the choice is between having three or four teams engaged on construction work, ie between the slow and fast rates of progress. In either case there would be a planned and deliberate build-up period of three or four years to allow British Rail to complete design work and the private sector firms, who would do the bulk of the construction, to assemble the necessary resources.

(i) Three teams working simultaneously could complete a medium-sized programme of electrification (described in paragraph 15) within 25 years, and would take about 30 years to finish the largest programme examined (described in paragraph 13). Both programmes would make cash flow demands generally between £12m and £30m a year for the first fifteen years. The medium programme would give a net present value of £202m and the large programme's net present value would be £249m.

(ii) Four teams could finish a medium programme in about 15 years or a large programme in 20 years, by working on a greater number of routes at any one time. The cash flow demand in both cases would be higher—generally between £24m and £42m over the first fifteen years—but so would the net present values, at £239m for the medium programme and £305m for the large.

It might be possible to start at the slow rate and then accelerate in later years. We have not examined the effect of this, but would expect it to yield inferior returns than proceeding from the start at the fast rate.

17. Turning to the question of when to start, it would take about a year from the date of a decision to incur significant expenditure. Any programme would then take three or four years to build up a steady rate of work. Given our conclusion that electrification would earn over 10% in real terms, then any delay would cost money. A rough assessment that we have made suggests that a delay of four years for any of the larger programmes would reduce the net present values by £60m to £120m. We have not examined in detail the disadvantages of deferment. We cannot say that delaying the start of an electrification programme by up to one year would affect significantly the financial results. However, there is a need to provide some continuity of work to keep together the existing skilled construction team.

18. The amount of investment we have been considering for electrification assumes that the Board are in due course able to justify investment in their commercial businesses—especially freight—at higher than present levels. This depends both on Government decisions on total railway investment and on the Board's ability to generate more money. The requirements for electrification would be additional; the net total would be £775m undiscounted (at 1980 survey prices) over the 20 years' duration of the largest and fastest programme.

19. We should not close this final report without thanking all those outside organisations and individuals who gave us their help, and those within the

Government Departments and the British Railways Board who have done the detailed work.

JOHN PALMER
MICHAEL POSNER
8 December 1980

2: General Approach

20. For the interim report, it was decided that a central part of the study should be a financial comparison of different extents of electrification. This approach has been continued for this report, but considerably more detail has been added to provide for each of the options a full, year-by-year discounted cash flow appraisal which takes into account all railway costs and revenues which bear significantly on the case.

21. The reasons for adopting a financial appraisal, rather than a cost benefit analysis, were discussed in the interim report, paragraphs 17 to 20. The main reason was that most, though not all, of the benefits from main line electrification would arise in the Inter-City and freight businesses, which are required to meet a commercial remit as soon as possible and to meet the required rate of return on new investment, without Government support.

22. In addition to the financial analysis of the effects of electrification on the railway businesses, the study has examined some of the wider economic and social consequences of electrification which could not be expressed in financial terms.

23. The following paragraphs describe the different options which were studied and briefly outline the scope and nature of the financial analysis and of the evaluation of the wider effects of electrification.

THE OPTIONS EVALUATED

The Extent of Electrification

24. In the interim report, five different extents of electrification were considered. A base case (Option I) was established, in order to assess the future costs of continuing with a predominantly diesel-operated railway, much as exists today, with a few small, currently-planned electrification projects added. Four different electrification options were then drawn up for comparison—Option II provided for a modest extension of electrification, Options III and IV represented medium-sized electrified networks with emphasis respectively on passenger and freight flows; and Option V was a more extensive network of electrified routes.

25. The interim report showed that Option IV was too similar to Option III to justify separate evaluation and it has not been examined further. To help comparisons with the interim report, the options were not re-numbered for this report. Some very minor changes were made to the larger electrification options.

26. The options evaluated in this report are, therefore, as follows:

OPTION I — This is the base option and is unchanged from the interim report. It consists of the existing rail network plus the following electrification schemes which are already in hand or which were planned to have started by 1981:—

London Suburban	—	St Pancras to Bedford (almost completed)
East Anglia	—	Colchester to Norwich and Harwich; Bishops Stortford to Cambridge and Royston to Cambridge
West Coast Main Line	—	Edge Hill to Earlestown; Manchester to Euxton Junction and Preston to Blackpool
Strathclyde	—	Paisley to Ayr; Kilwinning Junction to Largs and Springburn to Cumbernauld

OPTION II — electrification from London northwards, including the East Coast Main Line to Leeds and Newcastle; the Midland Main Line via Sheffield; Birmingham to York; Edinburgh to Glasgow and Edinburgh to Carstairs. This too is unchanged from the interim report.

OPTION III — a medium network encompassing all the main Inter-City routes. These include, in addition to those in Option II, London to Bristol, South Wales and Plymouth; Birmingham to Taunton; Newcastle to Edinburgh and Manchester to Leeds. The main change to this option is the inclusion of the Birmingham/Coventry to Oxford route and several other important freight routes, which were part of Option IV in the interim report.

OPTION V — the largest option, including Plymouth to Penzance; Crewe to Holyhead; Edinburgh to Aberdeen and Doncaster to Hull. A few very minor changes have been made to this option, but the main routes included in it are unchanged.

27. The remit for the Review referred to a programme of "main line electrification". Consequently, the different networks do not include changes in the extent of electrification on the Southern Region commuter lines, or electrification of some other routes serving the major conurbations outside London. These are neither part of the main line network nor closely linked with it, but might well be considered for electrification in the future.

28. Table 1 shows the electrified route and track mileages encompassed by each of the options. The single track mileages given are slightly less than those currently contained in the route networks described, because the study assumed some future rationalisation of track layouts from the introduction of modern signalling.

29. The interim report concentrated on the "steady state", which assumed that all electrification work had been completed. It was, therefore, unnecessary to make any detailed assumptions about the rate of electrification or the

TABLE 1

ELECTRIFIED MILEAGE IN EACH OPTION (excluding sidings)

	Route miles	% of present network	Single track miles	% of present network	% of passenger and freight loaded train mileage electrically hauled	
					P	F
Option I: Base	2,580	23	6,390	29	52	23
II: Modest	3,460	31	8,770	40	62	38
III: Medium	4,620	42	11,450	52	75	54
V: Large	5,750	52	13,610	62	83	68
Total British Rail network at 1.7.80	11,006		21,892			

Maps of the main routes covered by each of the options are in Appendix 6.

ordering of schemes within the options (though a simplified staging analysis of Option V was conducted and is discussed in paragraphs 82–92 of the interim report). However, for this report it was necessary to consider both of these factors.

Rates of Electrification

30. Changes in the rate of construction would affect investment in fixed works and the deployment and cascading of rolling stock and would therefore alter the flow of costs and benefits and affect the returns from electrification. Two rates of progress were therefore evaluated for the larger electrification options (Options III and V). Option II was thought to be too small to warrant the extra work involved in evaluating two rates. Each separate combination of options and rates of construction required a complete re-working of the financial analysis. A total of six permutations was evaluated. These are:

Option I	(base)
Option II	
Option III	Slow (IIIS)
Option III	Fast (IIIF)
Option V	Slow (VS)
Option V	Fast (VF)

The Ordering of Electrification

31. The order in which electrification of the railway routes within each option might proceed was also considered. However, to postulate alternative orderings, as well as different extents and alternative rates of progress would have added substantially to the number of complete evaluations to be made. Therefore, only one detailed construction programme was devised for each option, using British Rail's commercial and operating judgement. The construction programmes sought, in particular, to give maximum benefit from electrification as early as possible, subject to a number of operational and engineering

constraints on the rate of progress. The latter included the output capacity of the construction teams, the need to minimise premature displacement of diesel traction and effects on existing services, and the need in some cases to re-signal a line before electrification could proceed. There were also constraints which dictated the minimum rate of progress. These included the need for a steady flow of work sufficient to achieve low unit costs and the need to introduce electric traction in time to avoid excessive renewal or life extension of the existing diesel fleet. Although the construction programmes may not be strictly optimal, they incorporate realistic judgements about the order of work and the rate of progress. However, in practice modifications might be made to any of the options, where these were shown to be financially advantageous.

32. The programmes established for each of the options assumed a common starting date for additional expenditure on electrification. 1981 was chosen as a convenient base year. For each option, a framework was drawn up, (see Table 2), which specified the annual volume of work, in single track miles, which was required in order to complete all the options by not later than 2010, ie within 30 years of the starting date. It was assumed, on the basis of previous experience, that about 125 single track miles a year could be electrified by each construction team. The frameworks allowed for build-up and run-down periods at the beginning and end of each option. The railway manufacturing and construction industry was consulted to ensure that the rates of work would not give rise to industrial output capacity problems (see Appendix 3 page 67).

TABLE 2

FRAMEWORK FOR PROGRAMMES OF ELECTRIFICATION WITH ASSUMED START IN 1981

	General rate (single track miles/year)	Additional electrification over present day		Complete work by
		Route miles	Track miles	
Option I (Base)		240	490	1988
Option II	250	1,120	2,870	1995
Option III Slow	250	2,280	5,550	2005
Option III Fast	500	2,280	5,550	1995
Option V Slow	300	3,410	7,710	2010
Option V Fast	500	3,410	7,710	2000

The work programmes drawn up within this framework for each option enabled the timing of expenditure and of conversion to electric traction to be established for each route. Table 3 indicates the years in which the main services would become electrically operated throughout assuming a 1981 start. It should be stressed that in practice electrification programmes might not correspond exactly to these proposals.

33. The study did not evaluate the effect of alternative starting dates. This does not imply that work must start in 1981. Indeed, it is now not possible for substantial amounts of work to be done in that year. However, a major proportion of the Board's traction and rolling stock fleet will in any case require

replacement over the next 10 to 15 years. Hence, if electrification were only begun at a much later date, it would be necessary to buy new diesel assets which might subsequently have to be converted or scrapped prematurely. Some of the financial benefits of electrification would then be lost.

TABLE 3

FIRST FULL YEAR OF ELECTRIC SERVICES ON PRINCIPAL MAIN LINES, ASSUMING A START IN 1981

	OPTION					
	I	II	IIIS	IIIF	VS	VF
West Coast Main Line						
Liverpool/Manchester-Glasgow	1985	1985	1985	1985	1985	1985
Euston – Blackpool	1984	1984	1984	1984	1984	1984
– Edinburgh		1986	1986	1986	1986	1986
– Holyhead					2007	1997
East Coast Main Line						
Kings Cross – Leeds/Bradford		1987	1987	1987	1987	1987
– Newcastle		1993	1992	1992	1992	1992
– Edinburgh			1995	1995	1995	1994
– Aberdeen					2010	2001
– Hull					1999	1997
Scottish Region						
Edinburgh – Glasgow		1988	1988	1987	1988	1987
Glasgow – Aberdeen					2008	2000
Trans-Pennine						
York – Liverpool			2004	1995	1997	1996
Midland Main Line						
St Pancras – Nottingham/ Derby/Sheffield		1990*	1990*	1989	1990*	1989
North East-S. Wales/ South West/S. Coast						
York – Birmingham		1994	1993	1993	1993	1993
– Bristol/Cardiff			2001	1993	2001	1993
– Plymouth			2002	1996	2001	1995
– Reading			2003	1994	2003	1995
Western Region						
Paddington – Bristol			1996	1990	1996	1990
– Swansea			1998	1991	1998	1991
– Plymouth			2002	1996	2001	1995
– Penzance					2003	1997

*St Pancras—Nottingham—Sheffield only in 1989.

THE FINANCIAL ANALYSIS

34. For electrification to be financially justified at a given discount rate, the increase in earnings and reduction in traction and rolling stock capital costs and train operating costs achieved by using electric traction in place of diesel must exceed the extra cost of constructing and maintaining the electrification

fixed works. Since the purpose of the review was to identify the various costs and benefits of electrification, not all railway costs and revenues were included, but only those which would change significantly with the degree of electrification. Costs taken into account included the provision and maintenance of the additional electrification fixed works; traction and passenger rolling stock provision and maintenance; energy and train crew. Costs excluded from the appraisal because they were assumed not to be significantly affected by electrification included general track costs; signalling and administration and the costs of freight and parcels wagons. The increase in passenger revenues from electrification was taken into account, but freight revenues were excluded from the analysis, since it was assumed for the purposes of this study that electrification would not significantly affect the volume of rail freight traffic. The returns from electrification have thus been calculated by comparing the costs and revenues attributed to the electrification options with those attributed to the base case (Option I). This calculation is the one appropriate to the question whether more electrification is justifiable, given the existing railway system. However, it does not show what return may be earned on the railway system as a whole, whether electrified or not.

35. In calculating the investment requirements of the options under evaluation, British Rail's present investment ceiling was not regarded as a constraint. The annual level of investment postulated in all the options—including the base—exceeds present levels of expenditure on corresponding categories of investment within this ceiling.

36. The main inputs to the financial analysis were provided by the Board's finance, operations and engineering departments and incorporated assumptions, endorsed by the Department of Transport, derived from the Board's studies of future passenger and freight business development. Wherever possible, the inputs were based on current experience, but in some cases they had to be derived from engineering and design studies. The scope for future technological developments in rail traction systems was considered, but on balance it did not seem likely that any significant bias would be introduced into the financial analysis by not including an allowance for this in the cost inputs.

37. For simplicity and ease of comparison 1978 price levels were used, as in the interim report. The majority of costs incorporated into the review were fixed at this price level. However, in the case of energy prices, staff costs and rail fares, allowance was made for increases in real terms throughout the period of the review. Following consultation with the Treasury, a 7% discount rate was used for converting all costs and revenues to 1978 values. This is the rate used for appraisal of other railway investment projects, and for road project appraisals by the Department of Transport. It is consistent with the requirements of the White Paper "The Nationalised Industries" (Cmnd 7131).

The Base Case

38. To evaluate the case for electrification, a year-by-year financial representation of the "base case" (Option I) had to be established, which made assumptions about the future size and shape of the railway businesses without substantial further electrification. These assumptions are described in more detail in Appendix 1 ("The Modelling Process"). The standard assumptions

made for the passenger business were that it would continue to provide the same network of services as at present, and that, without improvements in service quality, Inter-City traffic would grow by 1% a year, while other traffics would stay level. However, some service improvements were assumed to occur, including the introduction of the electric APT (Advanced Passenger Train) on the West Coast Main Line, some extension of diesel HST (High Speed Train) services and the replacement of existing DMUs (Diesel Multiple Units) at life expiry with new, faster DMUs. Fares generally were assumed to rise at 1% a year in real terms and some further real increases were assumed where there were significant service quality improvements.

39. The assumptions for the freight business gave greater difficulty because of the effects of the present recession. The standard assumption used in the study was that BR would carry a constant total volume of 175m tonnes a year, which is above the immediate present level of 150m tonnes but below British Rail's long term expectations.

40. Starting from 1979 data, the annual costs and revenues in the base case were projected forward over 30 years and the residual values calculated, to allow comparison with the slowest electrification programme evaluated.

The Electrification Options

41. The base case costs and revenues, expressed as present values, were compared with those of the five electrification options listed in paragraph 30. The annual forecast passenger revenues differ between the base case and the alternative electrification programmes mainly because the shorter journey times made possible by the introduction of electric traction would increase the volume of, and earnings from, passenger traffic above its level in the base case. Real fares rises were assumed following electrification. On the other hand, small losses of revenue would result from longer journey times on partially electrified routes, caused by traction changes, and from service modifications and delays while routes were being electrified. These were taken into account, as was passenger resistance to higher fares. Freight and parcels revenues were assumed to be unaffected by electrification.

42. Differences in costs between the base case and the alternative electrification programmes stem from a number of factors. On the one hand, there are the costs of constructing and maintaining the fixed electrification works. On the other hand, the capital costs of electric traction vehicles are generally lower than those of equivalent diesel vehicles. Moreover, because electric vehicles run faster, require less frequent and simpler maintenance and return to the depot less often, they can do more work. Fewer are therefore needed to carry a given amount of traffic and crew costs are somewhat lower. Maintenance and fuel costs are also lower for electric traction. These factors were taken into account, as were the costs of premature retirement or life extension of existing diesel traction equipment necessary to allow for the phasing in of electrified services.

43. The results of the financial analysis are presented in the following chapter of this report. Chapter 4 presents the tests which were conducted to establish the effect on these results of changes in the main input assumptions used.

Appendix 1—"The Modelling Process"—describes the input assumptions and methodology in greater detail.

WIDER EFFECTS

44. In addition to the year-by-year financial appraisal described above, it was an objective of the study to assess wider economic and social effects of electrification which could not be quantified financially but could nevertheless be important. Amongst the effects considered were the potential of electrification for saving energy, especially oil; the effect of an electrification programme on private industry; and various environmental effects. The overall conclusions reached on the wider effects are presented in chapter 5 of the report. A fuller assessment of these wider effects is given in Appendix 3.

3: The Financial Results

45. The financial results described in this chapter were produced by the modelling process described in Appendix I. They relate to the standard passenger and freight traffic forecasts and the standard assumptions about costs. Other results, including the number of loaded train miles eventually transferred to electric haulage in each option, are also presented. The results are as reliable as possible in assessments looking more than 30 years ahead, and the approximations made were examined in the tests discussed in Chapter 4.

46. Table 4 presents the financial benefits of each electrification option expressed in net present value (NPV) terms, using a 7% discount rate. For ease of comparison, the benefits are shown in terms of surplus over Option I, the base case. The Table also shows the internal rates of return (IRRs). The net present value is normally taken as the key indicator of financial return and for ranking options. Both measures show that the benefits are positive for all the electrification options. A fast rate of electrification is ranked higher than a slow rate, and more extensive electrification is ranked higher than less extensive. Thus Option V Fast emerges with the highest NPV, but there is little to choose between Option V Slow and Option III Fast. Option III Slow falls behind Option III Fast, while Option II has the lowest NPV. It can be seen that in moving from smaller to larger extents of electrification, and from slower to faster rates, the returns on the incremental investments do not diminish. The IRRs of the incremental investments have been separately calculated, and remain at around 11%.

TABLE 4

FINANCIAL COMPARISON OF ELECTRIFICATION OPTIONS WITH OPTION I (BASE)

	NPV surplus (£m, 1978 money values, discounted at 7%)	Internal rates of return (%)
Option II	70	9.9
Option III Slow	169	11.0
Option III Fast	200	11.0
Option V Slow	208	11.1
Option V Fast	255	11.1

47. Table 5 presents the sources of the benefits and costs in each option. The analysis is by revenue and major cost category. The first column shows the present values of the revenues and the costs assessed for the base case; subsequent columns record the relative advantages of the other options compared with the base case. (A negative sign indicates that a cost is higher than in the base option.) The sources of benefits and costs are also presented in diagram 1.

TABLE 5

NPVs OF ELECTRIFICATION OPTIONS COMPARED WITH OPTION I, SUMMARISED BY REVENUE AND COST CATEGORY

(£m, 1978 money values, discounted at 7%)

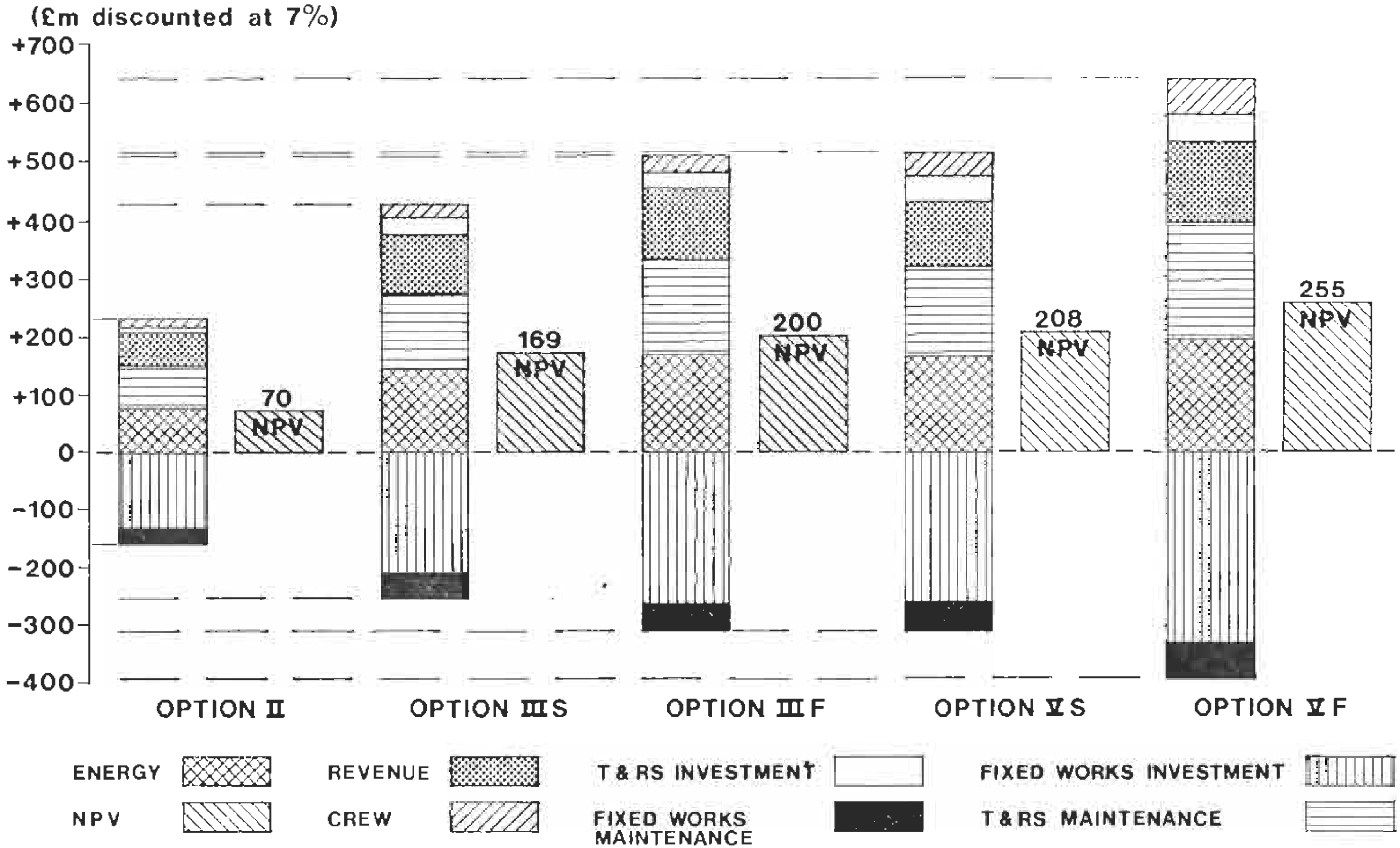
	NPV of Option I	Better/worse (−) than Option I				
		Option II	Option IIIS	Option IIIF	Option VS	Option VF
Passenger Revenue	10,353	57	102	123	114	141
Working Expenses						
Oil	1,356	187	340	411	395	486
Electricity	695	−111	−198	−245	−231	−294
Crew	2,049	13	21	28	39	50
Traction & rolling stock maintenance	3,093	72	130	166	158	201
Fixed works maintenance	7	−26	−40	−47	−48	−58
Total	7,200	134	254	313	312	386
Investment						
Traction & rolling stock	1,286	13	27	25	40	54
Fixed Works	32	−134	−213	−261	−258	−326
Total	1,317	−121	−186	−236	−218	−271
NPV Grand Total	1,835	70	169	200	208	255

NOTE:—Totals are affected by rounding.

48. Table 5 shows that in all electrification options the present value of cost savings is greater than the additional fixed works costs. The savings on fuel and on traction and rolling stock maintenance are of similar magnitude in each electrification option and, taken together, account for the majority of the cost savings. There are smaller, but still significant savings on crew costs and traction and rolling stock investment; the latter arise mostly within the freight business. Even allowing for reductions in traction and rolling stock investment, all the electrification options require considerably more capital expenditure than the base case. There are also additional fixed works maintenance costs. All the electrification options produce passenger revenue benefits, after taking account of the revenue lost through the disruption of traffic by electrification work.

49. The benefit of electrification to the various rail businesses varies with the extent and, to a lesser degree, with the rate. Table 6 and diagram 2 show that around two thirds of the benefits of the electrification options arise in the passenger business; rather more in the smaller options and less in Option V. Approximately one quarter of all the benefits of electrification are measured in increased passenger revenues. Table 7 and diagram 3 show where the incremental

DIAGRAM 1: NPVS OF ELECTRIFICATION OPTIONS COMPARED WITH OPTION I, SUMMARISED BY REVENUE AND COST CATEGORY



benefits arise in moving from smaller to larger extents of electrification. In moving from Option IIIF to Option VF, gross benefits to Inter-City rise from £295m to £339m; gross benefits to other passenger services rise from £52m to £72m; and gross benefits to freight rise from £133m to £193m. Thus nearly half the extra benefits arise in the freight business. Option III was primarily designed to cover the main network of Inter-City, trunk freight and parcels services, and the results are consistent with this. The increment between Options III and V was intended to measure the further impact of electrification on a wider freight network and regional passenger services outside Inter-City and London and South East. The smaller options could be justified on passenger benefits alone, while the justification for moving from Option III to Option V rests on the inclusion of benefits to the freight business.

50. Table 8 shows electric and diesel train mileage in each option in 1981 and 2011, when all electrification programmes would be complete. Since the figures for the fast and slow variants of Options III and V are the same, only one result is given for each Option. The table reveals that three quarters of the passenger train mileage transferred to electric traction in Option III is Inter-City, and there is only limited additional transfer of Inter-City mileage beyond Option III. The table confirms that benefits to freight and secondary passenger services continue in moving from Option III to Option V. It also shows that the greater part of the transfer of parcels mileage is accomplished by Option III.

TABLE 6

NPVs OF ELECTRIFICATION OPTIONS COMPARED WITH OPTION I, SUMMARISED BY BUSINESSES

(£m, 1978 money values, discounted at 7%)

	NPV of Option I	Better/Worse (−) than Option I				
		Option II	Option IIIS	Option IIIF	Option VS	Option VF
Inter-City Revenues	5,617	53	95	113	104	127
Direct Costs	2,723	90	170	182	190	212
Net Total	2,894	143	265	295	294	339
Other Passenger Revenues	4,736	3	6	10	10	15
Direct Costs	3,074	14	23	42	37	58
Net Total	1,662	17	29	52	47	72
Passenger Net Total	4,556	160	295	347	341	411
Freight Direct Costs	1,992	64	111	133	151	193
Parcels and Departmental Direct Costs	690	5	17	28	23	35
Fixed Works Costs	39	−160	−253	−308	−307	−384
Grand Total	1,835	70	169	200	208	255

NOTE: Totals are affected by rounding.

DIAGRAM 2: NPVS OF ELECTRIFICATION OPTIONS COMPARED WITH OPTION I, SUMMARISED BY BUSINESSES

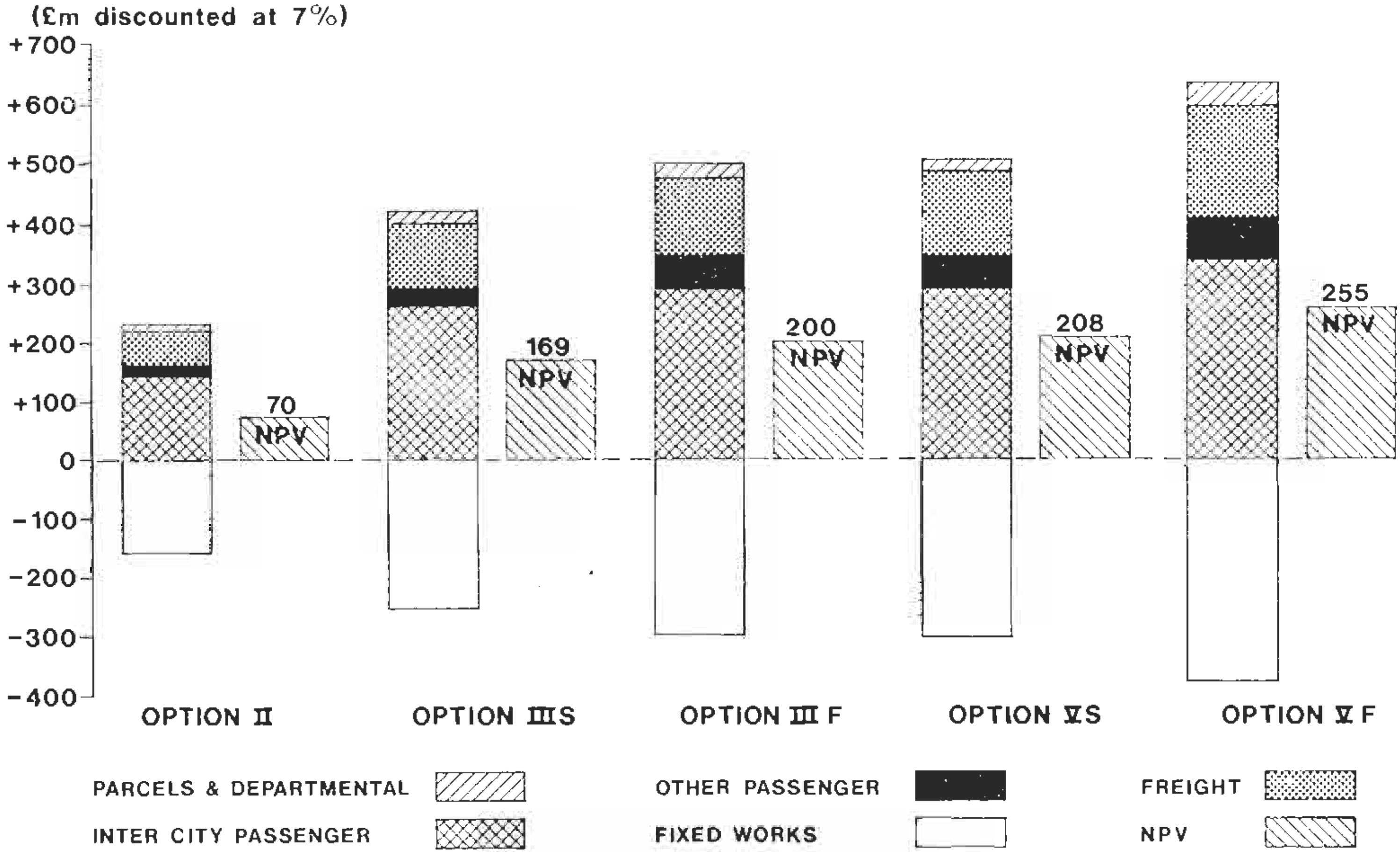


TABLE 7

INCREMENTAL COMPARISON OF NPVs, BY BUSINESSES

(£m, 1978 money values, discounted at 7%)

	Option II-I	Option IIIF-II	Option IIIF-I	Option VF-IIIF	Option VF-II	Option VF-I
Inter-City	143	152	295	44	196	339
Other Passenger	17	35	52	20	55	72
Freight	64	69	133	60	129	193
Parcels & Departmental	5	23	28	7	30	35
Infrastructure	−160	−148	−308	−76	−224	−384
NET TOTAL	70	130	200	55	185	255

TABLE 8

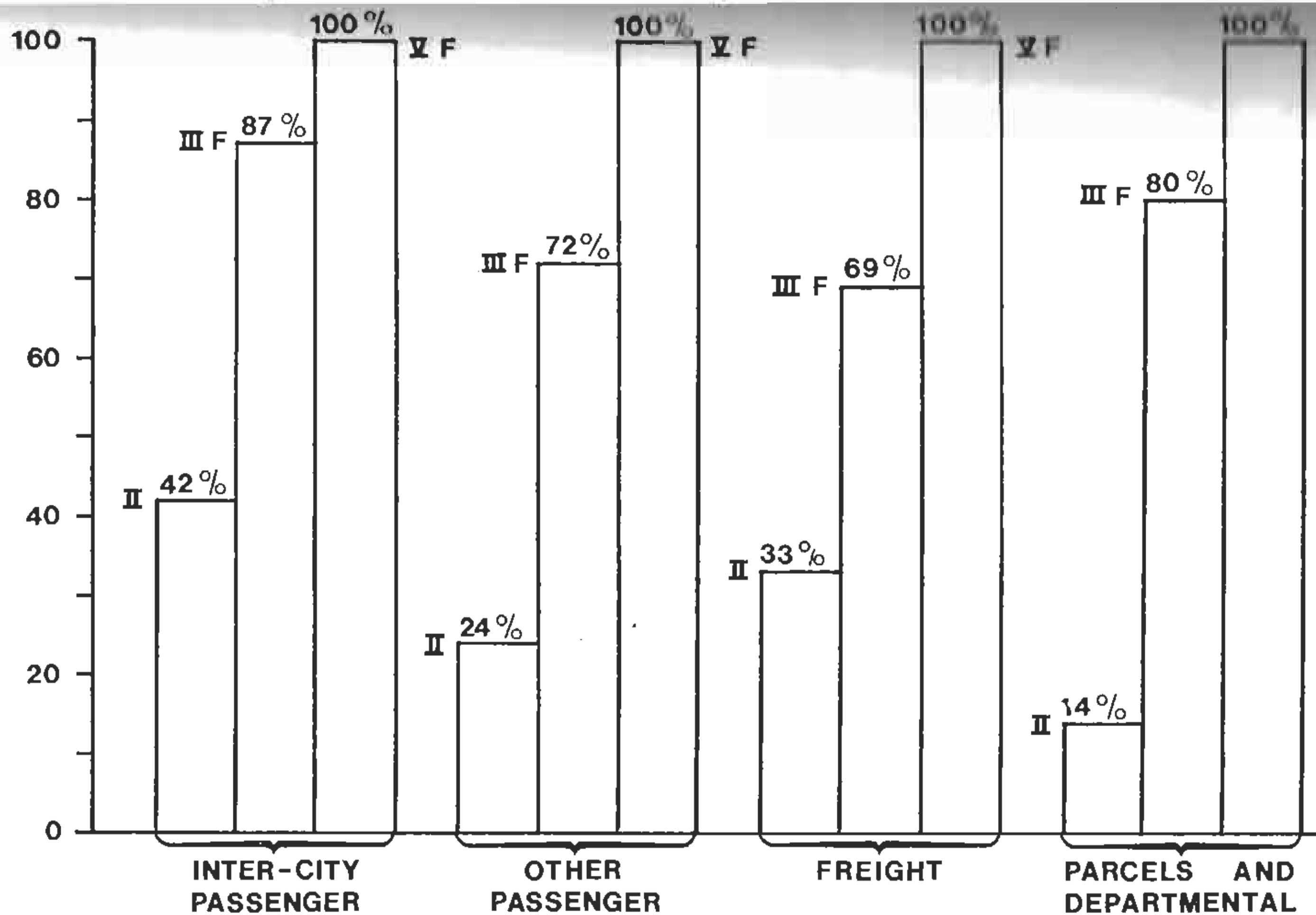
LOADED TRAIN MILES IN 1981 AND 2011, BY BUSINESS SECTOR

millions of loaded train miles

	1981	2011			
	All Options	Option I	Option II	Option III	Option V
Inter-City:					
Diesel	47	46	31	11	5
Electric	20	24	39	58	64
% Electric	30	34	56	84	92
London and South East:					
Diesel	13	12	11	8	7
Electric	65	67	67	70	71
% Electric	83	85	86	90	91
Other Passenger:					
Diesel	44	41	37	32	21
Electric	13	16	19	25	35
% Electric	22	28	34	44	62
All Passenger:					
Diesel	104	98	78	51	34
Electric	98	106	126	153	170
% Electric	48	52	62	75	83
Freight:					
Diesel	29	24	19	14	10
Electric	4	7	12	17	20
% Electric	13	23	38	54	68
Parcels:					
Diesel	8	4	3	2	1
Electric	3	2	3	5	6
% Electric	26	34	49	72	84
Departmental:					
Diesel	9	8	8	7	7
Electric	0	0	1	1	2
% Electric	0	0	7	12	21

DIAGRAM 3: INCREMENTAL COMPARISON OF NPVS, BY BUSINESSES

% of benefits of option VF obtained in Options II and IIIF



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51. The traction and rolling stock fleets available in 1981 and the eventual fleets required in 2011 in all Options are shown in Table 9. Table 10 presents total and average annual expenditure on building and refurbishment over the period of the review. Table 11 shows the average annual investment in fixed works. The tables illustrate the high level of investment which has to be supported by the rail businesses assuming a continuance of present traction policies, as in the base case. They also show the reduction in traction and rolling stock investment made possible by further electrification, which would require fewer vehicles to discharge a comparable work load. (In Option VF, the total traction and rolling stock investment is less than in the base case.) This offsets to some extent the additional fixed works costs.

TABLE 9

TRACTION AND ROLLING STOCK FLEETS

(numbers)

	1981	2011			
	All Options	Option I	Option II	Option III	Option V
APT sets	3	75	137	232	231
HST sets	81	179	106	0	0
Electric Locomotives:					
Passenger	98	66	97	141	170
Freight	124	136	240	348	462
Parcels	41	32	58	76	76
Departmental	3	2	6	28	38
Diesel Locomotives:					
Passenger	417	278	243	158	99
Freight	1,503	1,008	888	801	585
Parcels	111	65	52	30	18
Departmental	168	101	97	70	54
Locomotive-hauled Coaches	5,491	3,639	3,629	3,592	3,582
Electric Multiple Unit vehicles	7,182	5,329	5,405	5,600	5,849
Diesel Multiple Unit vehicles	3,042	1,525	1,438	1,218	900

Note.—The figures for Options III and V are for the fast rates of progress. The figures for the slow rates of progress differ very slightly.

52. In determining a practical policy for traction on BR and the financing arrangements, the negative cash flows consequent upon electrification programmes will need to be considered. Table 12 shows, for each electrification option, five-yearly average annual cash flows. The full year-by-year cash flows are also shown in Graph A. All the electrification options generate negative net cash flows until the mid-1990s. The size of this is more dependent on the rate of electrification than on the extent.

TABLE 10

TRACTION AND ROLLING STOCK INVESTMENT

(£m, 1978 money values, undiscounted)

Average per year, including refurbishment costs

Period	Option I	Option II	Option IIIS	Option IIIF	Option VS	Option VF
1981–1985	85	80	79	79	80	79
1986–1990	128	124	118	114	117	116
1991–1995	90	100	105	118	104	117
1996–2000	138	138	149	132	147	117
2001–2005	96	94	83	81	89	80
2006–2010	84	83	81	87	67	82
Total 1981–2010	3,103	3,091	3,074	3,058	3,021	2,956

TABLE 11

FIXED WORKS INVESTMENT

(£m, 1978 money values, undiscounted)

Average per year, including immunisation renewal costs

Period	Option I	Option II	Option IIIS	Option IIIF	Option VS	Option VF
1981–1985	7	24	23	31	24	32
1986–1990	3	22	29	45	31	48
1991–1995	—	11	27	34	30	46
1996–2000	—	1	21	2	28	26
2001–2005	—	1	10	2	26	2
2006–2010	—	—	1	1	13	1
Total 1981–2010	48	295	554	570	756	771

TABLE 12

AVERAGE ANNUAL NET CASH FLOWS FROM ELECTRIFICATION COMPARED WITH OPTION I

(£m, 1978 money values, undiscounted)

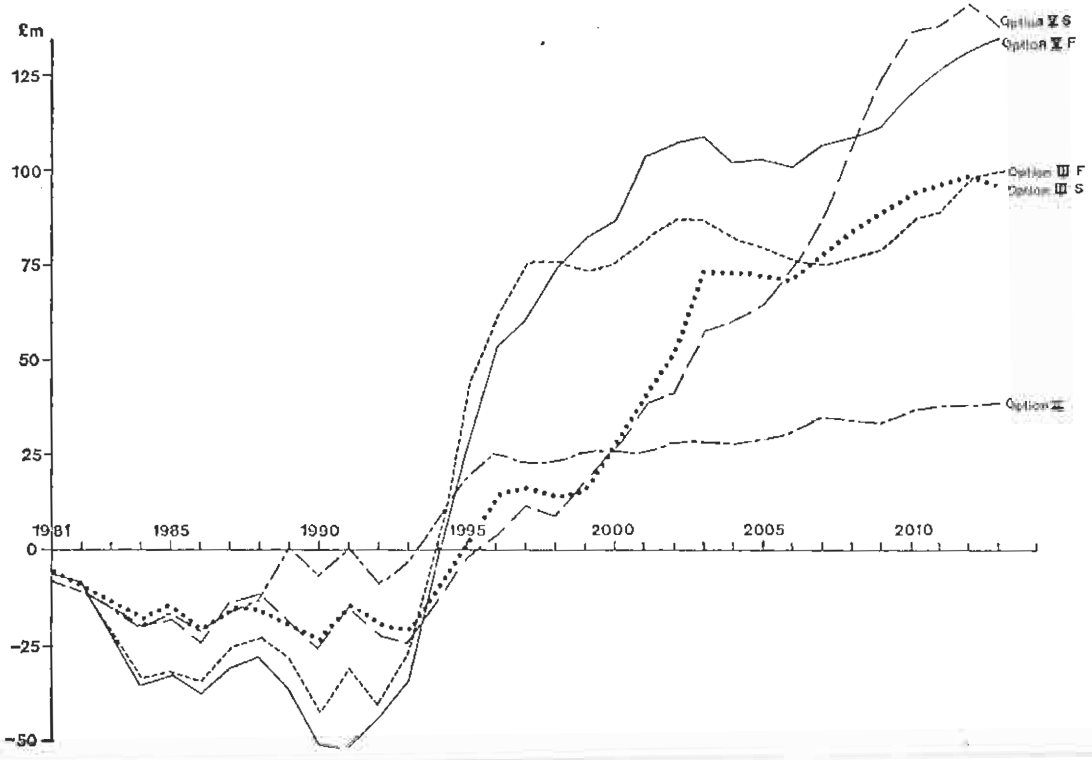
	Option II	Option IIIS	Option IIIF	Option VS	Option VF	
1981–1985	−11.9	−10.5	−19.0	−12.7	−19.9	Cash Flows mainly negative
1986–1990	− 9.4	−13.7	−22.4	−12.9	−27.9	
1991–1995	− 1.5	−23.6	−24.8	−26.1	−34.1	
1996–2000	+25.3	+10.3	+74.0	+ 8.6	+73.1	Cash Flows mainly positive
2001–2005	+29.5	+72.6	+86.6	+58.6	+108.3	
2006–2010	+34.3	+84.9	+77.4	+108.1	+108.2	

GRAPH A

FINANCIAL COMPARISONS OF ELECTRIFICATION OPTIONS WITH OPTION I (BASE)

YEAR BY YEAR NET CASH FLOW (UNDISCOUNTED)

(WITH TRACTION & ROLLING STOCK INVESTMENT COSTS SMOOTHED)



53. Graphs B to F in Appendix 2 show components of the undiscounted cash flows shown in Graph A. The positive impact of fuel costs and maintenance on the case for electrification is evident, as is the larger net investment requirement of the faster options.

54. Table 13 shows the years by which payback is achieved (assessed in NPV terms). While this indicator is not in general considered a very reliable method of assessing the quality of an investment, it has some merit in assessing risk. Graph G compares the cumulative discounted cash flows of the electrification options. In all electrification options the payback years occur after 2000, but within the appraisal period. While these payback years lie far into the future, the comparisons in the review are rather unusual, since investment is spread over a number of years and not concentrated in the first few.

TABLE 13

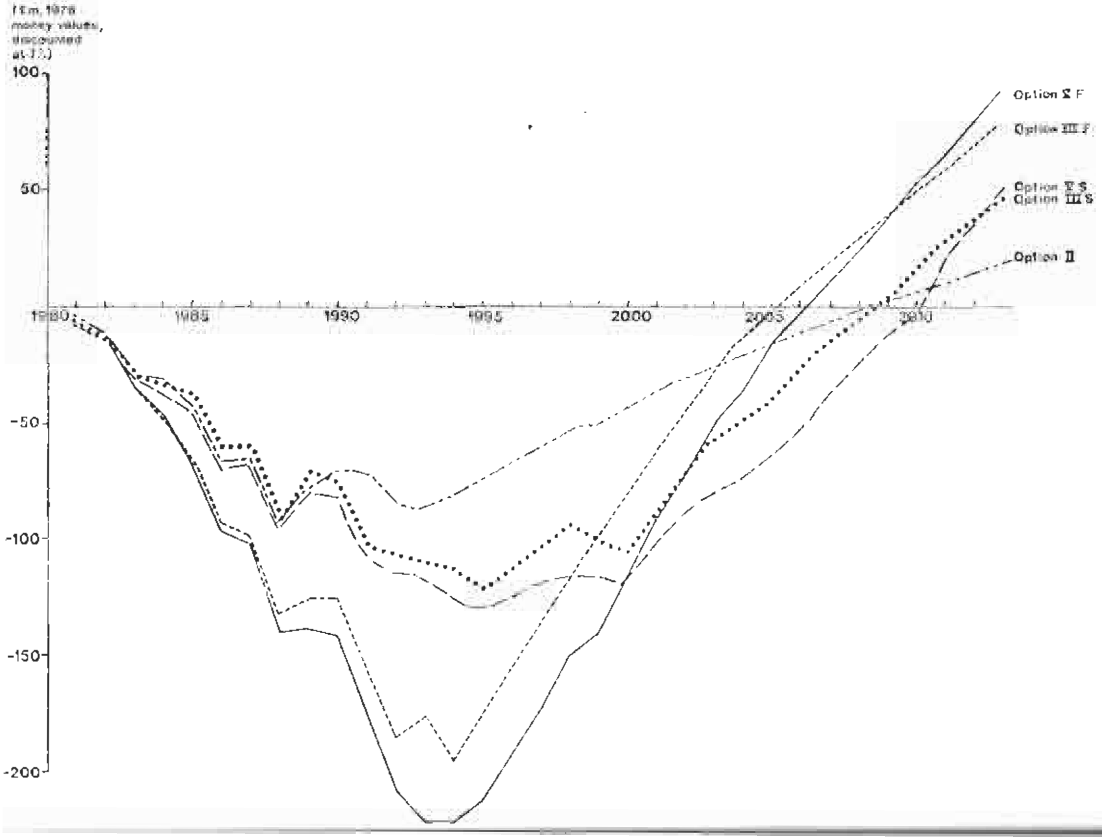
PAYBACK YEARS

Option II	Option IIIS	Option IIIF	Option VS	Option VF
2009	2009	2006	2010	2007

55. The results discussed in this chapter show that on the standard traffic forecasts all the electrification options yield a positive NPV. The faster options produce better NPVs than the slower, and the larger are better than the smaller. The rate of return is broadly 11 % in real terms in all options except Option II. Cash flows are negative until the mid-1990s, but all options break even before 2011.

GRAPH G

FINANCIAL COMPARISONS OF ELECTRIFICATION OPTIONS WITH OPTION I (BASE) CUMULATIVE NPV BY YEAR (DISCOUNTED)



4: Tests of the Financial Results

56. Tests have been made to see how far the financial results described in the previous section of the Report would be changed by plausible changes in the assumptions that underlie the calculations. (In technical terms, these are "sensitivity tests"). The purpose of the tests is to establish which assumptions have most effect on the results; to see how far the financial results would be undermined by changes in individual assumptions, or plausible combinations of assumptions; and to see whether changes of this kind would alter the relative ranking of the different options. The tests also show the extent to which the financial results would be improved if the standard assumptions turned out to be conservative.

57. The following paragraphs describe the results of varying each of the individual assumptions on its own. Then the effects of changes in combinations of assumptions are described. In the Tables, the first line of figures shows the net present values of the electrification options compared with the base case, using the standard assumptions. (These are the results discussed in the previous chapter of the Report.) The following lines show the changes in the net present values resulting from changes in the assumptions being considered.

ENERGY COSTS

58. At 1980 prices for oil and electricity, the net present value advantage of Option VF, on all the other standard assumptions, would be £165m. The assumptions made about future movements in energy prices have an important effect on the financial results, the extent of divergence between oil and electricity prices being more significant than changes in the absolute level of prices (though the latter will be more significant for the finances of the railway). The range of fuel price forecasts used in the Review was prepared by the Department of Energy in the latter part of 1979, and is set out (in index form) in the following Table:

TABLE 14

FUEL PRICE FORECASTS

Year		1978	1980	1990	2000	2010
Diesel oil:	Low	100	145	170	190	215
	Standard	100	145	190	230	275
	High	100	145	210	270	335
Electricity:	Low	100	100	110	120	105
	Standard	100	100	125	165	150
	High	100	100	140	210	195

The standard forecasts for both oil and electricity were used in the standard calculations. It is extremely unlikely that a high trend in electricity prices would occur with a low trend in oil prices, and the reverse combination is also improbable. The following Table shows the changes in the net present values of the electrification options resulting from other combinations of oil and electricity price forecasts:

TABLE 15

EFFECTS OF DIFFERENT TRENDS IN ENERGY PRICES

NPVs of Electrification Options Compared With Base (£m)					
	Option II	Option IIIS	Option IIIF	Option VS	Option VF
Results using standard *assumptions*	70	169	200	208	255
Effect of more favourable assumptions:					
1. High oil, standard electricity	+32	+63	+73	+74	+87
2. Standard oil, low electricity	+27	+52	+61	+61	+75
3. High oil, high electricity	+5	+11	+11	+13	+12
Effect of less favourable assumptions:					
1. Low oil, low electricity	−5	−11	−11	−13	−12
2. Standard oil, high electricity	−27	−52	−61	−61	−75
3. Low oil, standard electricity	−32	−63	−73	−74	−87

It should be noted that the assumptions least favourable to electrification *represent futures in which electricity prices rise faster, from 1980, than oil prices.*

59. The Department of Energy are now preparing new long-term energy price forecasts. Their assessment suggests that crude oil prices could double in real terms compared with their 1980 level by the year 2000. This would give oil prices above the range examined in this review. The Department of Energy's re-examination of electricity price assumptions is not yet completed, but the potential for divergence between oil and electricity prices is growing. A trend of this nature is illustrated by the "high oil, standard electricity" price combination shown in Table 15.

TRAFFIC LEVELS

60. The standard assumptions about traffic levels for the passenger business include a background rate of growth of 1% per annum for Inter-City traffic and zero for other passenger sectors, and estimates of passenger response to changes in journey times and fares levels, the net effect of which was to increase revenues, but not total passenger mileage, by the year 2013. Alternative assumptions were tested, involving in the lower case, a fall in passenger traffic

of about 40% by the year 2013, and in the upper case, an increase of 25%. These assumptions are shown in Appendix 1, Tables 30 and 31, and discussed in paragraphs 3 to 12. For the freight business, the standard assumption was a constant traffic level of 175 million tonnes per annum. An upper case was tested, in which freight traffic rose to 210 million tonnes by the year 2010. These forecasts are discussed in Appendix 1, paragraph 19, and shown in Table 32.

61. Table 16 below shows the effect of the alternative assumptions about passenger and freight traffic forecasts on the net present value of the electrification options:

TABLE 16

EFFECTS OF DIFFERENT FORECASTS OF PASSENGER AND FREIGHT TRAFFIC

NPVs of Electrification Options Compared with Base (£m)					
	Option II	Option IIIS	Option IIIF	Option VS	Option VF
Results using standard assumptions	70	169	200	208	255
Effect of different assumptions:					
1. Lower passenger, standard freight	−46	−75	−94	−85	−105
2. Standard passenger, upper freight	*	*	+29	+45	+53
3. Upper passenger, upper freight	*	*	+106	*	+135

*not evaluated.

It will be seen that varying the passenger forecast downwards from the standard to the lower forecast, without altering the freight forecast, reduces the net present value of Option VF by £105m, to £150m. This assumes that there would be no reduction in the frequency of off-peak services in response to the falling demand, but in practice, if traffic declined as in the lower forecast, the Board would probably reduce off-peak service frequencies, and it is judged that this might reduce the NPV of Option VF by a further £15m to £20m. Increasing the freight forecast from the standard to the upper level, without changing the passenger forecast, improves the net present value of that Option by £53m. Without the help of further calculations, this suggests that if freight carryings turned out to be even lower than the standard forecast, to the extent that freight traffic did not rise above its currently depressed level, the reduction in the NPV of Option VF should not be more than £50m, since in these circumstances the Board would not electrify so much route mileage. It can thus be seen that the most pessimistic traffic forecasts considered would still leave an internal rate of return above 7%. The ranking of the options is unchanged by changes in the traffic forecasts.

62. Tables 17 to 22 in Appendix 2 give more detailed information about the results of the non-standard traffic cases shown in Table 16 above.

FREQUENCY OF SERVICE

63. The standard traffic forecasts assumed that the frequency of passenger train services in peak periods would be adjusted proportionately to passenger volume, and that off-peak frequencies would in general be held constant at 1979 levels. A test examined the effect on the results if it were judged that to reduce off-peak service frequency by the equivalent of 30% would give net financial benefits to the railway. As Table 23 shows, this reduces the net present value of all the electrification options. This is because the major benefits of electrification arise from savings in operating costs (traction and rolling stock fleets being dictated by peak requirements), and these savings are proportionately reduced with the lower level of train mileage.

TABLE 23

EFFECTS OF REDUCING OFF-PEAK SERVICE FREQUENCY

NPVs of Electrification Options Compared with Base (£m)					
	Option II	Option IIIS	Option IIIF	Option VS	Option VF
Results using standard assumptions	70	169	200	208	255
Effect of lower off-peak frequency	−23	−42	−52	−48	−58

OPERATING COSTS: TRACTION AND ROLLING STOCK MAINTENANCE

64. If diesel equipment costs more to maintain than has been assumed, the comparative advantage of electrification is increased. Conversely, if electric equipment costs more to maintain than has been assumed, the advantage of electrification would be reduced. The following Table shows the effect of a 10% variation up or down in the net present value of traction and rolling stock (T&RS) maintenance costs, considering diesel and electric separately. By framing the test in terms of a variation of the NPV, the need to make a specific assumption about the cause of the variation was avoided. Thus the variation could either represent the effect of unit maintenance costs being higher or lower than estimated or an unforeseen increase in maintenance costs over time, or any path of costs consistent with an overall ±10% variation in NPV.

65. In addition, because there must be more uncertainty about the maintenance costs of the Advanced Passenger Train (APT), since this advanced equipment is not yet in regular service, Table 24 shows the effect of a 25% variation either way in the forecast maintenance costs of the APT.

TABLE 24

EFFECTS OF DIFFERENT TRACTION AND ROLLING STOCK MAINTENANCE COSTS

	NPVs of Electrification Options Compared with Base (£m)				
	Option II	Option IIIS	Option IIIF	Option VS	Option VF
Results using standard assumptions	70	169	200	208	255
Effect of more favourable assumptions:					
1. Diesel T & RS+10%	+17	+31	+40	+38	+50
2. Electric T & RS−10%	+10	+18	+24	+22	+30
3. APT alone−25%	+17	+26	+33	+26	+33
4. APT−25%; other electric T & RS−10%	+20	+34	+43	+38	+49
Effect of less favourable assumptions:					
1. Diesel T & RS−10%	−17	−31	−40	−38	−50
2. Electric T & RS+10%	−10	−18	−24	−22	−30
3. APT alone+25%	−17	−26	−33	−26	−33
4. APT+25%; other electric T & RS+10%	−20	−34	−43	−38	−49

It seems unlikely that there would at the same time be significant rises in the costs of maintaining diesel equipment and significant falls in the costs of maintaining electric equipment, or *vice versa*. However, if this did occur, Table 24 shows that the effect on the NPV of Option VF would be a variation of £80m either side of the standard value of £255m. If a 10% variation in electric equipment maintenance costs generally is combined with a 25% variation in APT maintenance costs, the range of change is £50m either side of the standard value. These relatively large ranges reflect the fact that the forecast savings in traction and rolling stock maintenance provide one of the largest benefits from electrification.

OPERATING COSTS: FIXED EQUIPMENT MAINTENANCE

66. The estimates of the costs of maintaining the fixed electrification equipment allow for reductions of up to 20% in unit costs below present levels for the latest equipment in the larger and denser electrified networks. Since these costs are small, variations make only small changes to the financial results. The following Table shows the effect of a 10% variation up or down in the present value of these costs.

TABLE 25

EFFECTS OF DIFFERENT FIXED EQUIPMENT MAINTENANCE COSTS

NPVs of Electrification Options Compared with Base (£m)

	Option II	Option IIIS	Option IIIF	Option VS	Option VF
Results using standard assumptions	70	169	200	208	255
Effect of:					
1. 10% rise in costs	− 3	− 4	− 5	− 5	− 6
2. 10% fall in costs	+ 3	+ 4	+ 5	+ 5	+ 6

STAFF COSTS

67. The standard assumption was that staff costs would rise in line with the rate of growth assumed for the economy as a whole and that this additional cost would be offset by improvements in productivity. The following Table shows the effects on the net present values of changing the assumption about the future growth in unit staff costs within the range 1% to 2% per annum in real terms (see Appendix 1 paragraphs 47 and 48 and Table 41), without altering the productivity assumption:

TABLE 26

EFFECTS OF DIFFERENT STAFF COST FORECASTS

NPVs of Electrification Options Compared with Base (£m)

	Option II	Option IIIS	Option IIIF	Option VS	Option VF
Results using standard assumptions	70	169	200	208	255
Effect of:					
1. Lower staff cost forecast	− 3	− 8	− 9	−11	−14
2. Higher staff cost forecast	+ 5	+12	+14	+16	+20

The reason why a higher unit staff cost forecast improves the net present value secured by investment in electrification—though of course it would worsen the finances of the railway—is that an electrified railway requires fewer staff than a diesel railway, and higher staff costs increase the value of this saving.

TRAIN CREW COSTS

68. Statistical analysis indicated that electrification would permit a reduction of roughly 10% in passenger train crew costs and 20% in freight train crew costs. Changes in these inputs have a relatively small effect on the financial results. The following Table shows the effect of varying the net present value of the assumed reduction in passenger train crew costs by 25% and the saving in freight train crew costs by 50%, the difference in the tests reflecting the greater difficulty encountered in the statistical estimation of freight train crew costs.

TABLE 27

EFFECT OF DIFFERENT CREW COST REDUCTIONS

NPVs of Electrification Options Compared With Base (£m)

	Option II	Option IIIS	Option IIIF	Option VS	Option VF
Results using standard assumptions	70	169	200	208	255
Effect of varying saving in crew costs	±6	±10	±11	±16	±19

CAPITAL COSTS: TRACTION AND ROLLING STOCK AND FIXED WORKS

69. The following Table shows the effects of varying up or down by 10% the assumed capital costs of diesel traction and rolling stock, electric traction and rolling stock, and fixed electrification works. (The standard assumptions are described in Appendix 1, paragraphs 34 to 37.) Such evidence as is available suggests that the impact of higher future energy prices on the unit costs of these capital assets should be small, and certainly within the range of variation covered in the Table.

TABLE 28

EFFECTS OF A 10% VARIATION IN CAPITAL COSTS

NPVs of Electrification Options Compared With Base (£m)

	Option II	Option IIIS	Option IIIF	Option VS	Option VF
Results using standard assumptions	70	169	200	208	255
Effect of variation in T&RS capital costs:					
1. Diesel +10%	+14	+25	+30	+30	+37
2. Diesel −10%	−14	−25	−30	−30	−37
3. Electric +10%	−13	−22	−27	−25	−32
4. Electric −10%	+13	+22	+27	+25	+32
Effect of variation in fixed equipment capital costs: +10%	−13	−21	−26	−26	−33
−10%	+13	+21	+26	+26	+33

70. None of the individual tests considered comes at all close to eliminating the net present values of the electrification options. That is to say, each of the downward changes taken individually would still leave an internal rate of return well above 7%. None of the changes considered upsets the ranking of the options.

COMBINATIONS OF TESTS

71. It is more important to consider how far any of these changes might occur in combination with others. The results of the individual tests cannot

strictly be added together because there are different degrees of uncertainty about the assumptions tested and because some of the changes would be interdependent. Nevertheless, the following Table, which summarises the individual tests, allows a broad judgement of the effects of combinations of changes on the financial case for electrification. It must of course be remembered that the various changes considered could have quite different effects on the financial results of the railway.

TABLE 29

SUMMARY OF SELECTED INDIVIDUAL TESTS

NPVs of Electrification Options Compared With Base (£m)

	Option II	Option IIIS	Option IIIF	Option VS	Option VF
Results using standard assumptions	70	169	200	208	255
Effect of:					
1. High oil, standard electricity prices	+32	+63	+73	+74	+87
2. Standard passenger, upper freight traffic forecast	*	*	+29	+45	+53
3. Lower passenger, standard freight traffic forecast	−46	−75	−94	−85	−105[1]
[4. Lower freight traffic levels	*	*	*	*	−25 to −50][2]
5. Lower off-peak service frequency	−23	−42	−52	−48	−58
6. ±10% on diesel T&RS maintenance	±17	±31	±40	±38	±50
7. ±10% on electric T&RS maintenance	±10	±18	±24	±22	±30
8. ±25% on APT maintenance	±17	±26	±33	±26	±33
9. Lower staff cost forecast	− 3	− 8	− 9	−11	−14
10. Higher staff cost forecast	+ 5	+12	+14	+16	+20
11. Variation in crew cost saving	± 6	±10	±11	±16	±19
12. ±10% on diesel T&RS capital costs	±14	±25	±30	±30	±37
13. ±10% on electric T&RS capital costs	±13	±22	±27	±25	±32
14. ±10% on fixed works capital costs	±13	±21	±26	±26	±33

NOTES:

1. The NPV falls by a further £15m to £20m if reductions in service levels are assumed.
2. This is a rough estimate of the effect of assuming a lower trend in freight carryings.

72. The latest work on energy price forecasts suggests that the "high oil, standard electricity" price combination should be taken as a reasonable measure of the extent to which prices might diverge. The following paragraphs consider the other possible changes in this light.

73. The traffic assumptions have a major impact on the results. However, even if passenger traffic fell to the lower forecast, and freight traffic did not increase above its present very depressed level, and off-peak service frequency was reduced in the way examined, the net present value of all the larger options would still be positive; taking account of the higher energy price forecast, the internal rate of return would still be about 9%.

74. The possible variations in those costs which are more within the control of the railway must also be considered. It is very unlikely that the maintenance costs of diesel equipment and of electric equipment would move in different directions. If changes were in the same direction, this would lead to adjustments up or down of £20m in the NPV of Option VF. There is more uncertainty about APT maintenance costs, and it is possible that these could vary independently of the maintenance costs of other traction and rolling stock types, giving a total range of variation for maintenance costs of £66m. Changes in the same direction in traction and rolling stock capital costs would give a range of variation of £6m up or down in the net present value. It will broadly be seen that if both these movements were adverse in the lower passenger, lower freight traffic case, then adding the adverse tests for crew costs (a £19m worsenment for Option VF) and the capital cost of fixed works (a £33m worsenment) would between them reduce the internal rate of return to only slightly above 7%. It should be emphasised that this combination puts a very stringent test on the results. It seems unlikely that in the circumstances being considered the unit costs of labour would rise above those assumed in the standard case.

SUMMARY

75. It is thus reasonable to conclude that, on the standard traffic forecasts and the latest energy forecasts, a programme of main line electrification can confidently be expected to earn a rate of return well above 7%. How much above would depend on the extent to which the assumed reductions in costs were secured.

76. If traffic were to fall to the lowest level considered, then a programme of main line electrification should still earn more than 7%, but it would be vital for the cost reductions to be secured. If the railways can win the traffic assumed in the higher forecasts, then the case for a substantial programme of main line electrification will be enhanced.

5: Wider Effects

77. Amongst the wider effects considered during the review were energy savings, benefits to the UK railway manufacturing industry, effects on railway safety, on noise and pollution levels, visual intrusion, landscape and old buildings, land use and settlement patterns and the transfer of traffic from other modes.

78. A fuller report on each of the wider effects is given in Appendix 3. Broadly speaking, electrification would save 120 million gallons of oil a year, assuming 80% of passenger and 70% of freight traffic were electrically hauled. This is equivalent to ½% of current national oil consumption, amounting to a small but useful contribution to reducing the nation's dependence on oil. Changing to electric traction would improve the security of the railway's fuel supply. Although increased electrification would add to the nation's electricity consumption, it would give greater flexibility in the use of basic fuels and would reduce pollution by the railways because the reduction in localised emissions would outweigh the increase in power station emissions, which are more widely and thinly dispersed.

79. As well as making the railways cleaner, electrification would probably reduce the noise nuisance which they cause and make them safer, particularly to the railway work force. On the other hand, the presence of overhead wiring would make the railways more dangerous to trespassers. The wiring would also intrude slightly on the landscape in some areas and could mar the appearance of some listed buildings and other structures such as viaducts, but careful design could reduce this to some extent.

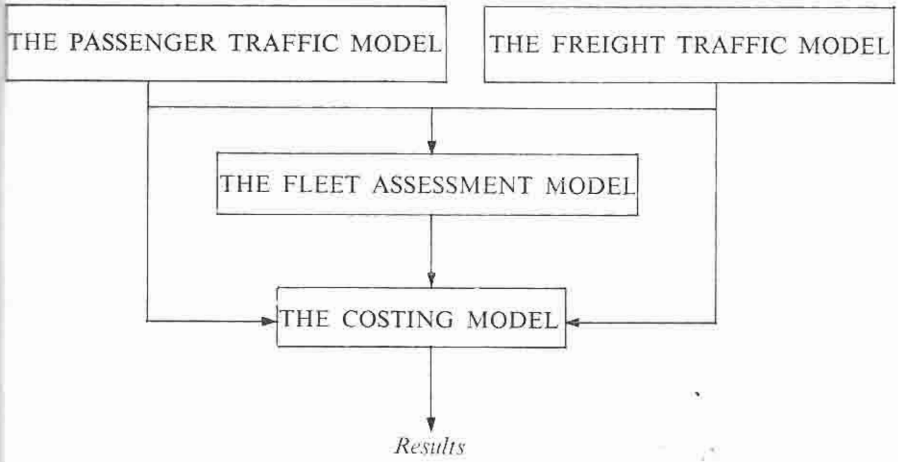
80. An important consideration is the effect of an electrification programme on the UK railway manufacturing industry. Electrification would of course bring substantial orders and more job opportunities for the industry. A high and reasonably stable level of domestic demand should produce lower unit costs of production and develop technology, and so assist the industry to compete for overseas electrification work more effectively.

81. Some other possible wider effects of electrification proved difficult to assess. It seems unlikely that electrification would have a significant effect on industrial location, particularly in the heavy industries (coal, steel-making, aggregates and chemicals) which account for a large part of the railway freight business. There may be some effect on settlement patterns, but this is impossible to assess, given the wide variety of factors which affect where people want to live. Some travellers would transfer from road to rail, but on the assumptions used in the study there is unlikely to be more than a very small reduction in road traffic as a result.

APPENDIX 1: THE MODELLING PROCESS

INTRODUCTION

1. The key relationships in the evaluation of the case for electrification were described in four mathematical models, so that the bulk of the calculations could be made by computer. This permitted proper expression of the complex interactions in the costs and revenues and allowed repeated performance of similar calculations. The relationship of these computer models is shown in the following diagram:



2. The two TRAFFIC MODELS determined the level of passenger and freight train mileage, and hence the traction and rolling stock fleet requirement, in each successive year during the implementation of the base case and each electrification option, starting from the forecast level of train mileage in 1979. From this, the FLEET ASSESSMENT MODEL worked out the necessary traction and rolling stock building programme for each year, starting from the existing fleet and its age profile. It assigned both the existing and new vehicles in the fleet to particular business sectors. Finally, the COSTING MODEL calculated the annual costs and revenues of each option. Each model was worked through separately for the base case and for each of the electrification options. To assess the sensitivity of the results to alternative traffic input assumptions, the model runs were repeated from the beginning with new inputs. Additional runs, mainly of the COSTING MODEL, allowed the testing of different assumptions about costs and revenues. The main principles of the models, and the assumptions incorporated in them, are described in the following sections.

THE PASSENGER TRAFFIC MODEL

3. The Passenger Traffic Model forecast the levels of passenger traffic and revenues in each option (including the base). From the traffic levels the model predicted the train mileage and the traction and rolling stock fleet which would have to be operated. The starting point for these projections was 1979 data, taken from the Railways Board's Profit Planning and Cost Centre Analysis (PP&CCA) system, which breaks down the budgeted expenditures and revenues of rail activities into "profit centres". There are over 300 passenger profit centres, each representing an identified service. For the review, which concentrated on those services where a change from diesel to electric traction would occur, it was possible to aggregate the profit centres to 133 "Working Units", at which level all traffic levels, revenues, operations and traction and rolling stock requirements were determined. Supplementary current operating data for the Working Units were also provided. The calculations made in the Passenger Traffic Model were repeated for all 133 Working Units and finally aggregated into five sub-sectors of the passenger business.

4. The Passenger Traffic Model projected the 1979 base data forward year by year over the evaluation period, making the adjustments described in the following paragraphs to take into account the assumptions made about the background growth in passenger traffic, the effects of electrification and other service improvements and the effects of assumed changes in fares levels. As a second stage, the model estimated annual train mileage and traction and rolling stock fleet requirements, having regard to forecast traffic levels and to the effects of electrification on traction and rolling stock utilisation. Three factors were used in deriving annual forecasts of passenger mileage:

(i) *the exogenous traffic trend*, representing the growth or decline in rail travel that would occur if fares and quality of service remained unchanged;

(ii) *journey time elasticities*—The introduction of faster services would lead to an increase in traffic and this was calculated by means of journey time elasticities which measured the response of passenger traffic to changes in journey time. For example, an elasticity of −0.85 would reflect an assumption that a 1% decrease in journey time would lead to a 0.85% increase in traffic;

(iii) *fares elasticities*—Passenger response to assumed fares changes was calculated by means of fares elasticities analogous to the journey time elasticities mentioned above. Thus an assumption that a 1% increase in fares would lead to a 0.65% decrease in traffic was represented in the model as an elasticity of −0.65.

5. The values adopted for each of these three factors were taken from the Board's Passenger Business Strategy Study (PBSS). The main purpose of the PBSS was to provide a physical and financial appraisal of passenger business strategy in the medium and long term and to establish a framework for business planning and investment decisions. Although this study was carried out by British Rail, various aspects of the inputs to it were reviewed jointly with the Department of Transport. It was agreed that the ranges of exogenous traffic

growth, journey time elasticities and fares elasticities established for PBSS should be adapted for use in this study. The factors were specified separately for the Inter-City and non Inter-City market sectors, as ranges around central values, so that the sensitivity of the results to changes in the factors could be tested. Table 30 shows the values chosen.

TABLE 30

PASSENGER TRAFFIC AND REVENUE INPUT ASSUMPTIONS

	Lower	Standard	Upper
(i) Exogenous traffic trend, per annum:			
Inter-City	−0·5%	+1·0%	+1·5%
Other	−1·0%	0	+0·5%
(ii) Journey time elasticity:			
Inter-City	−0·7	−0·85	−1·0
Other	−0·4	−0·6	−0·8
(iii) Fares elasticity	−0·8	−0·65	−0·5

6. In order to assess the changes in journey times which would occur in each Working Unit, it was necessary to specify the different types of trains which would be used and their relative performances. The Board currently operates a large number of different types of traction and rolling stock, but to make the modelling process more manageable, these and all future fleet types were represented in the model by a limited range of types. For the passenger railway these were:—

1. 125 mph electric Advanced Passenger Train (APT)
2. 125 mph diesel High Speed Train (HST)
3. Class 87 100 mph electric locomotive with Mark III coaches
4. Class 50 100 mph diesel locomotive with Mark III coaches
5. Electric Multiple Unit
6. Diesel Multiple Unit.

7. The future traction types for each service, whether diesel or electric, were specified according to the traction strategy determined by the Passenger Business Strategy Study. The following six main service groups would operate with high speed (125 mph) traction, using diesel HST or electric APT according to the option being considered:

West Coast Main Line	London to Manchester/Glasgow
East Coast Main Line	London to Newcastle/Edinburgh
Western Main Line	London to Bristol/S. Wales
West of England Route	London to Exeter/Plymouth
Midland Main Line	London to Nottingham/Sheffield
North-East to South-West Route	Newcastle to South Wales/South West

All others would be operated with locomotives or multiple units as at present. It was also assumed that service patterns would remain unaltered, thus imposing some locomotive changing in electrification options which might otherwise be avoidable given the freedom to revise the pattern of through train services.

Where APT services crossed electrification boundaries, it was assumed that the trains would be hauled by diesel locomotives over the non-electrified parts of their journeys.

8. For each of the passenger train types included in the model a performance specification was drawn up which included relative operating speeds. While both HST and APT are 125 mph trains, APT's superior acceleration and tilting through curves would give it a speed advantage. (When hauled by a diesel locomotive, APT service speed would be limited to 100 mph maximum.) The existing electric Class 87 and the diesel Class 50 are both 100 mph locomotives, but the electric locomotive can achieve overall average speeds some 10% higher than those for the diesel locomotives on most routes, because of superior acceleration and general performance. Similarly, the EMU vehicle would be about 10% faster than the DMU in equivalent operation. The model recognised that the performance of passenger trains and the relative advantage from electrification would vary depending on the services in question. For example, the relative advantage of APT over HST on the Midland Main Line would be greater than on the Paddington to Bristol/South Wales route. In the case of overnight services there would be no speed advantage either from electrification or from improved diesel traction.

9. The speed benefits were specified in the model and, via the journey time elasticities, used to derive the traffic levels which would result from introducing electric traction. The same journey time elasticities were also used to calculate the revenue effects of delay to services attributable to the construction of the fixed electrification works. Such delays are small compared with those attributable to route improvements and resignalling, and were assessed at an average of 3 minutes for each Inter-City train and 1½ minutes for other trains. The amount of delay was based on an engineering evaluation of the extent of electrification works necessary and the time of day and week when they would occur.

10. For changes from electric to diesel traction (or *vice versa*) at the limits of the electrified network, 8 minutes were allowed in the case of locomotive-hauled trains, but only 3 minutes where it was necessary to diesel haul APT, because the power car would not be detached. Such traction changes would apply only to some services on long routes, either temporarily in a staged programme, or permanently. These delays were applied to that proportion of passengers who would be affected.

11. It was considered that some real increases in fares levels would be needed, both in relation to railway business targets and in relation to service improvements. For this study, three forms of future real fares increases were assumed. The first was a general increase of 1% per annum, which was applied throughout all the options, as a contribution towards achieving the financial objectives for the passenger business. Secondly, where electric traction was introduced, an additional, once-for-all fares increase of up to 6% was assumed, spread over the three years following the introduction of electric traction. Thirdly, another increase of up to 6% spread over three years was assumed following the replacement of locomotive haulage with high speed traction (HST or APT). The total amount of the fares increases for service improvement

was limited to ensure that, after allowing for the effects of the fares elasticity, the level of passenger traffic did not decline.

12. The final passenger mileage forecasts produced by the Passenger Traffic Model were calculated by combining the effects of the assumed rate of exogenous growth, the journey time improvements and fares increases for each Working Unit. To examine each possible combination of Upper, Standard and Lower input assumptions (see Table 30) for each of the options would have required 162 separate runs of the model, which would have produced an unmanageable volume of results. In order to cover the full range of outcomes from the assumptions made, it was decided to evaluate the standard combination of assumptions and two other cases combining respectively the most favourable and the least favourable assumptions. The net effects of these combinations of assumptions on forecast passenger mileage by the year 2013 are shown in Table 31 below:

TABLE 31

PASSENGER TRAFFIC LEVELS IN OPTION I

(Figures for other options are not significantly different)

TRAFFIC CASE	Sector	Passenger miles (thousand million) per annum			
		Total in 1979	Change 1979–2013: Effect of exogenous growth	Change 1979–2013: Net effect of speed and fares changes	Total in 2013
LOWER (lower exogenous growth, lower journey time elasticity, upper fares elasticity)	Inter-City	9.5	−1.5	−1.8	6.2
	Other	10.1	−2.9	−1.6	5.6
	Total	19.7	−4.4	−3.4	11.9
STANDARD (standard exogenous growth, standard journey time elasticity, standard fares elasticity)	Inter-City	9.5	+3.8	−2.3	11.0
	Other	10.1	0	−1.7	8.4
	Total	19.7	+3.8	−4.1	19.4
UPPER (upper exogenous growth, upper journey time elasticity, lower fares elasticity)	Inter-City	9.5	+6.3	−1.9	13.9
	Other	10.1	+1.9	−1.4	10.6
	Total	19.7	+8.2	−3.4	24.5

NOTE: Totals are affected by rounding.

Each combination of assumptions was designed to give passenger mileage totals which are similar for all options, including the base, in any particular year. The earnings resulting from these traffic levels were substantially higher in the electrification options because of the additional fares increases following electrification. The fact that the ultimate levels of traffic are substantially similar in the base and in the electrification options indicates that most of the real value of the improved service quality has been converted into revenue for the railway businesses rather than allowed to stimulate an increase in demand. However, some "consumer surplus" remains as a benefit to railway passengers, as explained in Appendix 3, page 77. It does not follow that the Board's future fares policy would necessarily match the assumptions made in this study, although a general intention to price up as electrification proceeds is part of the Board's strategy.

13. The resulting passenger mileage forecasts were then converted into forecast train mileages for each year. It was assumed (in line with PBSS) that the rate of growth in passenger mileage would be the same in peak and off-peak periods, but the number of train miles required would only be changed in the peak travelling periods. Off-peak train mileage, and hence frequency, was assumed to remain at its current level, although in the low traffic case some estimate was made of the financial effect of reducing off-peak frequencies. (The peak period in this context was defined as that in which the number of train miles to be run determined the total traction and rolling stock requirement.) It was not practicable to estimate for each individual service the proportion of train mileage falling within the peak. 40% of Inter-City train mileage and 15% of non-Inter-City train mileage was initially assumed to occur within this period.

14. Since high speed and locomotive-hauled services were assumed to be operated by trains of fixed formation (within a Working Unit), the peak loaded train mileage for 1979 was multiplied by the forecast change in passenger miles to estimate the new peak (and hence total) train mileage appropriate for each year. The model also adjusted loaded train mileage in line with any changes in train capacity stemming from the changes in the train types used. Thus the passenger miles/seating capacity relationship remained constant within each Working Unit.

15. A similar principle applied to multiple unit services, except that it was assumed that changes in passenger mileage would first be accommodated by changes in train length, and hence in vehicle mileage, while keeping loaded train miles constant. Only when maximum or minimum train size was reached was the level of train mileage adjusted. In the non-Inter-City sector, a further adjustment was made to the vehicle mileage over the period 1981 to 1986 to increase peak load factors, reflecting the Board's policy.

16. The traction and rolling stock resources required were related to train miles during the peak. The Passenger Traffic Model adjusted the 1979 traction and rolling stock complement of each Working Unit by the calculated trend in peak loaded train miles (vehicle miles in the case of multiple units), in order to give the appropriate vehicle requirement for each year. Other adjustments were made to reflect the better utilisation achieved through higher operating speeds, the additional locomotives required to provide for traction changes, and the extra vehicles needed to operate services at slower speeds during the construction period. In calculating the traction and rolling stock requirement and the operating mileages, the amount of 'light running' required was also taken into account. This is the additional mileage run when travelling to maintenance depots, re-positioning trains or, in the case of diesel traction, when running to fuelling points. For a given loaded train mileage, diesel locomotives would travel roughly 5% further than electric locomotives, reflecting the former's more frequent trips to maintenance depots, as well as the fuelling requirement.

17. The Freight Traffic Model estimated annual train mileages and locomotive requirements for each Option. In some respects it was simpler than the Passenger Traffic Model, because of the assumption, for the purposes of the study, that the tonnage of freight carried and also the revenue obtained would not increase with the extra speed and greater reliability of electric traction. Consequently revenue did not have to be modelled since it was the same in all options. It also followed that there would be broadly similar wagon requirements in each option, so they too could be left out of account. In another respect the Freight Traffic Model was more complex than the Passenger Traffic Model because a route specific approach had to be used in which traffic flows between pairs of terminals were identified. The Freight Traffic Model went through three stages: first, it was necessary to forecast the trains to be run and the lines over which they would operate; second, to determine whether the trains would be hauled by electric or diesel locomotives, and to calculate the resulting totals of electric and diesel hauled loaded train miles; and third, to use this operating data in estimating requirements for electric and diesel locomotives. The data and procedures used in these stages are described below with particular reference to freight commodities. The model went through a similar process for Parcels trains, and a compatible, though simpler, treatment was given to the railway's domestic traffic (which is referred to as "Departmental" in this report).

18. Two types of freight locomotive were postulated for the purposes of the study:

1. Electric Class 88
2. Diesel Class 58

Both types are new, the Class 58 being a development from the existing Class 56 locomotive and the Class 88 being an electric locomotive of the same size and axle arrangement, using several major components in common with the Class 58. The electric locomotive would be more expensive to build but cheaper to maintain. The performance characteristics would also be very different. The ability to start trains from rest would be much the same, because the locomotives would weigh the same. But once on the move, the electric Class 88 would have a much faster rate of acceleration and a higher sustainable steady speed, because it could draw on extra power from the supply system, whereas the diesel would be limited by the maximum output of its on-board engine. For example, hauling trains of 1200 tonnes up a 1 in 200 gradient, Class 88 and 58 locomotives could sustain speeds of 60 mph and 40 mph, respectively. Alternatively, to allow the same speed of 50 mph on a 1 in 200 gradient, the relative loads would be 1900 tonnes and 800 tonnes. These characteristics mean that electric locomotives would achieve higher utilisations than diesel and also would be able to haul larger payloads. This was taken into account in the model, but allowance was made for limitations on the extent to which these factors could be used to advantage in practice.

19. The freight tonnage forecasts to be used in the study were agreed between the Department and the Board. Originally it was intended to use three alternative sets of forecasts, giving "high", "central" and "low" cases analogous to the three exogenous growth forecasts used in the Passenger Traffic Model.

However, during the course of the work it was decided not to evaluate the high freight forecast, owing to a downward revision of short to medium term rail freight projections. (It may be noted that the expected BR out-turn for 1980 is around 150m tonnes.) Thus only the central and low forecasts were evaluated, with the "low" forecast being adopted as the standard forecast, to which sensitivity tests were applied, and the "central" forecast being taken as the "upper". These forecasts are summarised in Table 32:

TABLE 32

FREIGHT TRAFFIC FORECASTS (COMMON TO ALL OPTIONS)

Units: millions of tonnes per annum

Commodity Group	[1979 Actual]	1989 Forecast	1995 Forecast	2000 Forecast	2005 Forecast	2010 Forecast
Coal:						
upper	[93]	100	100	100	105	105
standard		95	95	95	95	95
Other:						
upper	[77]	88	95	100	100	105
standard		80	80	80	80	80
Total:						
upper	[170]	188	195	200	205	210
standard		175	175	175	175	175

The forecasts were specified for the "key" years shown in the Table; intermediate values were derived by interpolation. The broad financial results of a still lower freight volume forecast were investigated, but no lower forecasts were made for processing through the model.

20. The volume forecasts for the Parcels business were expressed as total loaded and empty train miles, rather than in tonnes, because the former were more convenient measures:

TABLE 33

PARCELS TRAINS VOLUME FORECASTS (COMMON TO ALL OPTIONS)

Units: million train miles per annum

1979 actual	1989 forecast	1995–2013 forecast
12.6	8.7	7.5

The forecasts assume some rationalisation of the Parcels business over the period in question. The faster rationalisation of the business announced since this review was conducted would not significantly affect the financial results. Departmental traffic did not vary between the options.

Stage 1 of the Freight Modelling Process

21. The freight tonnage forecasts were made for 27 individual commodities. For each commodity the largest existing freight flows were identified and projected forward with modifications to take account of likely future business developments. In all there were some 800 flows, representing about 85% of mid

1980 tonnage. Tests were carried out to confirm that the samples would represent adequately for all traffic the journey lengths and proportions electrically hauled. The model converted these flows into train movements, using average train payloads for each commodity. The average train payloads for some commodities were increased over time to reflect the growing proportion of more powerful locomotives. For commodity groups other than coal and wagon load, allowances were also made for higher payloads when trains were electrically hauled throughout, or for the major part of their journey. These allowances took account of the marketing and practical operating constraints of heavier and longer trains, and for each option increased over time as the electrified network extended. The allowances ranged from a 3% to a 9% increase on the corresponding average diesel hauled payload. About 280,000 annual train movements were modelled. For each key year these movements were mapped onto a computer representation of the railway network required for freight, which was divided up into 1200 route sections.

Stage 2

22. Where any of these route sections was included in the electrification programmes for any options, the date of electrification was specified in the model. The computer employed decision rules to determine for each key year which flows or parts of flows would be hauled by electric traction. The rules required that to justify a traction change between diesel and electric, a train must run continuously over at least 50 miles of electrified route. This rule was derived from operating and costing experience. By applying the rules, the model produced totals of electric and diesel loaded train mileages for each key year, together with the number of traction changes required. Values for intermediate years were found by interpolation. These figures were summarised into six commodity groups for use in the next stage to estimate the locomotive requirement.

Stage 3

23. As a preliminary to these calculations, it was necessary to estimate the year-by-year amount of empty train mileage and additional locomotive running, in order to convert loaded train miles into locomotive traction miles. The initial estimates of the operating requirement for locomotives were obtained by dividing annual traction miles by the expected annual mileages per locomotive. These annual utilisations took account of service speeds, commodities hauled, the routes taken and the need for light running to maintenance and diesel refuelling points. Allowances were also made for the varying ease of electric and diesel locomotive diagramming as the electric network expanded. The locomotive requirement both for diesels and electrics was increased by the amount needed to allow time for traction changes. Further adjustments were made to reflect sharing of locomotives with the passenger business (see the next paragraph) in order to produce the final total annual requirement for locomotives in the form of annual statements of electric and diesel locomotives for each of the six commodity groups.

Locomotive Sharing

24. It is the practice for some locomotives to be shared between the railway businesses, since passenger locomotive demand is higher by day, and parcels and freight demand is higher at night. To simulate this sharing, the Passenger

Traffic Model produced estimates of surplus night time locomotives, electric and diesel, and the Freight Traffic Model used these surplus locomotives partly to satisfy night time demand for parcels and freight trains. Over the evaluation period, some daytime locomotive-hauled passenger trains were replaced by high speed unit trains, and this reduced the number of locomotives available for sharing.

THE FLEET ASSESSMENT MODEL

25. The third component of the modelling process, the Fleet Assessment Model, matched the demand for traction and rolling stock, derived from the Traffic Models, with the existing traction and rolling stock fleet available in each year, and determined the new building and refurbishing requirement. It also calculated the average age of the fleet in each year, for use in the maintenance cost calculations.

26. The model was interactive, requiring an operator to match existing and new fleets to cover the development of the operating requirements year by year taking account of a number of practical factors. As explained previously, the input of operating requirements for traction and rolling stock already allowed for time spent in moving to and from refuelling points and maintenance depots, in other light or empty running, and in change-overs of locomotives. The Fleet Assessment Model added allowances for vehicles undergoing maintenance and regular overhaul. The ratio of the operational fleet to the total fleet is expressed as "availability", and the figures estimated for future builds were:

TABLE 34

AVAILABILITY OF TRACTION AND ROLLING STOCK

Vehicle types	Availability (%)
APT Power and Trailer cars	85
HST Power car	82
Class 87 electric locomotive	85 (87 if in freight use)
Class 50 diesel locomotive	75 (77 if in freight use)
HST or locomotive-hauled coach	86
Electric multiple unit	87
Diesel multiple unit	80
Class 88 electric freight locomotive	87
Class 58 diesel freight locomotive	77

Other figures were used to represent existing types. Broadly, the availability of electric vehicles is better than diesel because the former require less frequent and less time-consuming maintenance work.

27. Other input data to the Fleet Assessment Model were the numbers and age profiles of existing fleets, authorised or planned building programmes in the early years, and some special factors relating the lower performance capabilities of some existing locomotives to the more powerful future types in which the input requirements were enumerated. Standard working lives were specified for each vehicle type, as follows:

TABLE 35

LIVES OF TRACTION AND ROLLING STOCK

	Standard working life (years)
Existing Vehicles:	
HST Power car	25
Electric locomotive	35
Diesel locomotive	25–30 (according to type)
HST or hauled coach	30–40 (according to type)
Electric multiple unit	40
Diesel multiple unit	25
Future Vehicles:	
APT Power car	25
APT coach	35
Electric locomotive	35
Diesel locomotive	30
Hauled coach	40
Electric multiple unit	27
Diesel multiple unit	25

The standard working lives of selected groups of vehicles could be extended or shortened to adjust the general size of the fleet to match requirements and to reflect existing policies for life extension. In this way the sizes of the existing fleets in any future year could be manipulated to some extent to avoid the construction of new (primarily diesel) vehicles, which would only be required for a short period. For example, it was assumed that some 600 existing diesel locomotives would have their lives extended to 35 years and that the lives of many of the existing diesel multiple units would be extended beyond 25 years.

28. Where parts of diesel fleets would become surplus well before the end of their normal lives, it was assumed that they would be converted as far as possible for further use on other duties. Two sorts of conversions were represented in the model, although in practice other types might turn out to be preferred. Firstly, as the progress of electrification would result in surpluses of HST trains, the power cars were assumed to require conversion to either of two types; less expensively, to push-pull formations; and more expensively, to 100 mph diesel locomotives of more general application (although their light weight would make them unsuitable for most freight work). It emerged that there would be insufficient other work for all such potential conversions in Options III and V and the remainder of surplus HST power cars were treated as being scrapped prematurely at up to 10 years less than their standard life. HST coaches are similar to ordinary locomotive hauled coaches and could be redeployed with small additional costs, which were taken into account.

29. The other form of conversion was to change future builds of DMUs into EMUs by the construction of new power cars to accompany existing trailer vehicles. Conversions would be necessary even in the base option (though in lesser numbers than needed with electrification), because of a generally declining demand for DMU vehicles which followed from the input traffic assumptions.

30. The figures describing the characteristics of multiple unit vehicles were representations of mixed fleets of conventional and future lightweight types. Thus, for example, the life of 27 years for EMUs in Table 35 combined vehicles having lives of 40 and 20 years.

31. The input demands for traction and rolling stock were expressed annually in 14 types, subdivided between the 5 passenger sectors, freight, parcels and departmental. 27 types of existing, new or converted vehicles were available to meet these demands.

32. The processes performed in each run of the model were to allocate the existing fleets to the demands as far as possible (including cascading older types from primary to secondary services), to construct building programmes for new vehicles and allocate them, to devise necessary programmes of conversions in order to use surplus vehicles to best advantage and, finally, to adjust the scrapping programmes through changes to working lives until a close match was obtained between the input demands and the assessed fleets. The outputs of the model were in the form of:—

a. building programmes and the allocation of investment to businesses
b. age profiles for all fleet types
c. the allocation of the total fleets to the business sectors year by year.

THE COSTING MODEL

33. The final part of the modelling process, the Costing Model, converted into discounted annual costs and revenues the physical data on numbers of vehicles, annual building programmes, traction miles operated and passenger traffic, which were derived from the first three models. Essential ingredients of the costing process were the unit costs, eg prices of new locomotives, or maintenance costs per locomotive mile. In estimating the amount of these unit costs, particular attention was given to obtaining proper comparability between electric and diesel traction. With the exception of energy and those railway staff costs which were taken into account in the study, it was assumed for the standard evaluation that all costs would remain constant at 1978 price levels.

34. The estimated capital costs of the new traction and rolling stock types specified in the Review were:

TABLE 36

TRACTION AND ROLLING STOCK CAPITAL COSTS

	£m (1978 price levels)
APT set (568 seats)	2.173
HST set (488 seats)	1.818
Diesel Class 58 locomotive (freight)	0.600
Electric Class 88 locomotive (freight)	0.636
Diesel Class 50 locomotive (passenger)	0.708
Electric Class 87 locomotive (passenger)	0.543
Diesel multiple unit (per vehicle)	0.143
Electric multiple unit (per vehicle)	0.155

An additional £40,000 was assumed for those APT sets equipped for haulage by diesel locomotive. The DMU and EMU types postulated for the Review were notional. The DMU cost reflected a weighted average of the new Class 210 DMU (cost £0.168m to £0.186m per vehicle) and a future light-weight DMU (cost £0.110m per vehicle), while the EMU cost was a weighted average of the cost of a new Class 317 EMU (£0.155m to £0.179m per vehicle) and a future light-weight EMU (£0.143m per vehicle). Thus the multiple unit costs calculated in the Review were representative of a mix of vehicle types, although they were presented in terms of only one EMU and one DMU type.

35. Where possible, the capital costs assumed for the traction and rolling stock types were based on equipment being purchased or designed today. For assets not yet in production, the cost estimates used took account of current building techniques, design specifications and the costs of known components. As a standard assumption, the capital costs of traction and rolling stock were taken as constant in real terms. Alternative assumptions were tested. The costs were assumed to be incurred in the year before the assets were introduced into service. Most vehicles were assumed to be refurbished at half their standard lives (see paragraph 27). This cost was calculated as a proportion of each vehicle's initial capital cost and was added in the appropriate year. Diesel traction refurbishment costs were higher than those for electric traction, reflecting the greater mechanical complexity of diesel traction.

36. The costs of modifications to vehicles—for example, the conversion of DMUs to EMUs, or normal two power-car HST sets to single power car 100mph formations—were entered into the calculations in the year before the modified vehicles were to be introduced into service.

TABLE 37

VEHICLE MODIFICATION COSTS

	£m (1978 price levels)
HST power car to 100 mph power car (including extra cost of driving trailer)	0.031
HST power car to locomotive	0.120
DMU vehicle to EMU vehicle (average)	0.055

37. Fixed works capital investment was calculated in three components. The first was overhead line and power supply equipment, costed at £55,000 per single track mile electrified. The second was civil engineering work, costed at £28,000 per single track mile electrified. The third component, signalling immunisation, was costed at between £7,000 and £32,000 per single track mile, depending on the nature of the existing signalling and telecommunications equipment to be immunised. These are average values, and would in practice vary considerably with location. Overhead line capital costs were based on experience with the Bedford-St. Pancras project. An allowance was made for

some future cost reduction, recognising the potential economies of scale in a large electrification programme. The fixed works investment in each year was based on the electrification programmes for each option and the model spread the expenditure over several years before electric trains would run, to represent normal lead times. In estimating the track mileages to be electrified, a 7% addition was made to the total running line single track mileage in order to represent the railway sidings mileage which would need to be electrified. An 8% reduction was assumed on those lines with mechanical signalling, to reflect the scope for track rationalisation. In the electrification options there would be opportunity for other track savings because electric trains use track capacity more efficiently, but no account was taken of this in the calculations.

38. The possibility that the programme of electrification might require some premature expenditure on signalling modernisation schemes was considered. This could arise because of differences in the relative timings of electrification and signalling projects. However, on the basis of the limited information available about the future programming of resignalling schemes, it appeared that little conflict was likely. The maximum estimated discounted capital cost of re-signalling advancement or premature immunisation was £7 million. Owing to the uncertainties over the advancement of re-signalling and immunisation, the small costs involved, and difficulties in estimating the corresponding advancement of cost and revenue benefits, it was decided not to include this expenditure in the costing model.

39. As well as calculating the annual capital investment costs, the Costing Model estimated for each year of the evaluation the four categories of operating costs which would be affected significantly by electrification. These are fuel, train crew, traction and rolling stock maintenance and electrification fixed works maintenance costs.

TABLE 38

RATES OF ENERGY CONSUMPTION

	Electricity (KWh)		Diesel (gallons)	
	Highest	Lowest	Highest	Lowest
PASSENGER				
APT (per mile)	28.6	21.1	—	—
HST (per mile)	—	—	1.80	1.60
Loco-hauled (per mile)	34.0	22.0	1.70	1.26
Multiple unit (per vehicle mile)	4.16	2.02	0.228	0.108
FREIGHT				
Loco-hauled (per mile)	26.6	12.4	1.78	0.84
PARCELS				
Loco-hauled (per mile)	15.3		1.02	
DEPARTMENTAL				
Loco-hauled (per mile)	16.1		0.96	

Fuel Costs

40. To calculate fuel costs it was necessary first to specify the fuel consumption characteristics of each traction type in the analysis. The estimates used reflected past experience of the relative energy consumption rates of diesel and electric traction and allowed for the differences in operating speeds and loads which were assumed in the Passenger and Freight Traffic Models. For passenger trains, consumption rates varied with traction type and service group; for freight trains the rates varied with traction type and commodity group. Examples are shown in Table 38.

41. These fuel consumption rates were applied to the diesel and electric traction miles figures derived from the Traffic Models in order to calculate the total oil and electricity consumption in each year.

42. Other inputs to the fuel cost calculations were forecasts of diesel oil and electricity price changes over the evaluation period. These were provided by the Department of Energy. The forecasts, which were made in 1979, are shown in index form below:

TABLE 39

ENERGY PRICE FORECASTS

Year	1978	1980	1990	2000	2010
Diesel Oil					
Low	100	145	170	190	215
Standard	100	145	190	230	275
High	100	145	210	270	335
Electricity					
Low	100	100	110	120	105
Standard	100	100	125	165	150
High	100	100	140	210	195

The diesel fuel price forecasts were based on projections of crude oil prices, taking account of additional processing and transport costs. The tax element was assumed to remain constant in real terms. The electricity price forecasts were based on assessment of the long run marginal costs for typical loading patterns imposed by BR traction on the national electricity supply system. The standard values for both oil and electricity were used for the standard financial calculations, though these do not necessarily represent the most likely outcome; some alternative outcomes were tested. In the cost calculations, these index numbers were applied to the railways' 1978 costs per gallon of gas oil, or per KWh of electricity. (The likelihood that the differential between oil and electricity prices will increase is discussed in Chapter 4, paragraph 59.)

Traction and Rolling Stock Maintenance Costs

43. Traction and rolling stock maintenance cost rates were estimated for each traction type as a percentage of initial capital costs, as shown in the following table for the standard types:

TABLE 40

TRACTION AND ROLLING STOCK MAINTENANCE COSTS

Vehicle type	Annual maintenance costs	
	% of capital cost	£000s (1978 prices)
APT power car	6.5	44
APT Coach	10.0	16
HST power car	14.0	70
HST Coach	10.0	10
Class 87 electric locomotive	6.5 Passenger use	35
	5.0 Freight use	27
Class 50 diesel locomotive	11.0 Passenger use	78
	9.0 Freight use	64
Electric multiple unit vehicle	5.0	8
Diesel multiple unit vehicle	7.6	11
Mk III passenger coach	10.0	10
Class 88 electric freight locomotive	5.0	32
Class 58 diesel freight locomotive	9.0	54

These costs, which were based on design mileages, were applicable at the middle year of the asset's life. In order to reflect the effects of ageing on maintenance costs it was assumed that they would rise by 3% per annum compound over the life of each vehicle. There was no well defined statistical information to support this estimate, but the use of an alternative 1% assumption was shown not to affect significantly the overall results. The traction maintenance costs for diesels are generally higher than those for electrics, reflecting the greater complexity of diesel traction. All annual maintenance cost estimates were split into time and mileage-related components in proportions considered representative of long-term expectations. The time component gave a simple annual cost per locomotive or vehicle; the mileage component was divided by the annual design mileage to provide a cost per locomotive or vehicle traction mile. The calculation of maintenance costs in each year required the ages of assets within each traction type, the number of vehicles, and the number of traction miles run. The railway staff cost proportion of maintenance costs was identified, so that the effects of productivity and real cost escalation could be estimated.

Fixed Electrification Works Maintenance Costs

44. Electrification fixed works maintenance costs were based on experience at the Carstairs maintenance depot, which services only the latest overhead line equipment of the type assumed for the review. Here an annual average cost per single track mile of £1,200 has been experienced (1978 prices). Since distance from the depot is the major constraint on the length of line which can be maintained from each depot, it follows that in the larger options the greater density of electrified route would lead to considerable economies of scale, and consequently maintenance costs were assumed to fall by up to 20% as the electrified network expanded. For the maintenance of signalling and telecommunications immunisation, an average annual cost of £130 per single track mile was included. The other element of fixed equipment capital cost, civil engineering work, related largely to electrification clearances, and would not

require additional maintenance. The Costing Model calculated the total annual costs by applying the appropriate costs per single track mile to the cumulative mileage electrified in each year. The proportion of railway staff costs was identified for use in subsequent calculations.

Train Crew Costs

45. The calculation of passenger train crew costs was based on a statistical analysis of current costs at Working Unit level, reflecting current working practices and agreements. The statistical analysis indicated that crew costs could best be explained in terms of the number and type of traction vehicles allocated to each Working Unit and the average utilisation achieved by those vehicles. In general, it was found that passenger crew costs per mile for electric traction were about 10% below those for diesel traction. In the case of APT, where no experience of electric running existed, an appropriate differential in relation to HST crew costs was worked out, using experience of other traction types and expected differences in utilisation.

46. Freight train crew costs were also based on a statistical analysis of current costs for main commodity groups, taking account of the number of locomotives required, their average utilisation and the inherent advantages of electric traction. Analysis indicated that freight crew costs per loaded train mile for electric traction were about 20% lower than those for diesel.

Staff Costs

47. When calculating the future costs of train crews, and the railway staff cost element of traction and rolling stock maintenance and fixed works maintenance, it was assumed that railway staff costs would rise in real terms, in line with whatever rate of growth in output was achieved by the economy as a whole. This is broadly consistent with historical experience and reflects the need for BR to remain competitive in the labour market if it is to attract and retain suitable personnel. The standard forecast for growth used in the evaluation for the period 1980–85 reflected the GDP growth rate forecast used in the 1980/81 Public Expenditure White Paper, and all the forecasts are consistent with those currently used by the Department of Transport for road project evaluations. The growth forecasts are:

TABLE 41

GDP GROWTH/STAFF COSTS FORECASTS

Period	Lower case	Standard case	Upper case
1980–1985	0.5% pa	0.75% pa	1.5% pa
1986–2010	1.0% pa	1.5% pa	2.0% pa

The costing model used the standard forecasts in all standard runs.

48. It was assumed for the purposes of the Review that improvements in productivity would be sufficient, in the standard traffic case, to keep staff costs per unit of railway output constant, even without the benefits of additional

electrification. The inclusion of a reasonable productivity assumption ensured that the NPVs of the electrification options would not be over-stated. There is no guarantee that such a level of productivity will in practice be achieved. However, if improvements in railwaymen's earnings are to be obtained while maintaining the present level of service, there must be continued improvement in the productivity of the railway's resources, especially manpower. The consequences of alternative assumptions about future economic growth rates, and hence staff costs, were tested.

Passenger Revenues

49. The Costing Model calculated annual passenger revenues from the passenger miles data derived from the Passenger Traffic Model, taking account of all fares increases assumed in the analysis (see paragraph 11). As previously explained, freight and parcels revenues were assumed to be unaffected by electrification, and so were not calculated.

THE FINAL CALCULATIONS

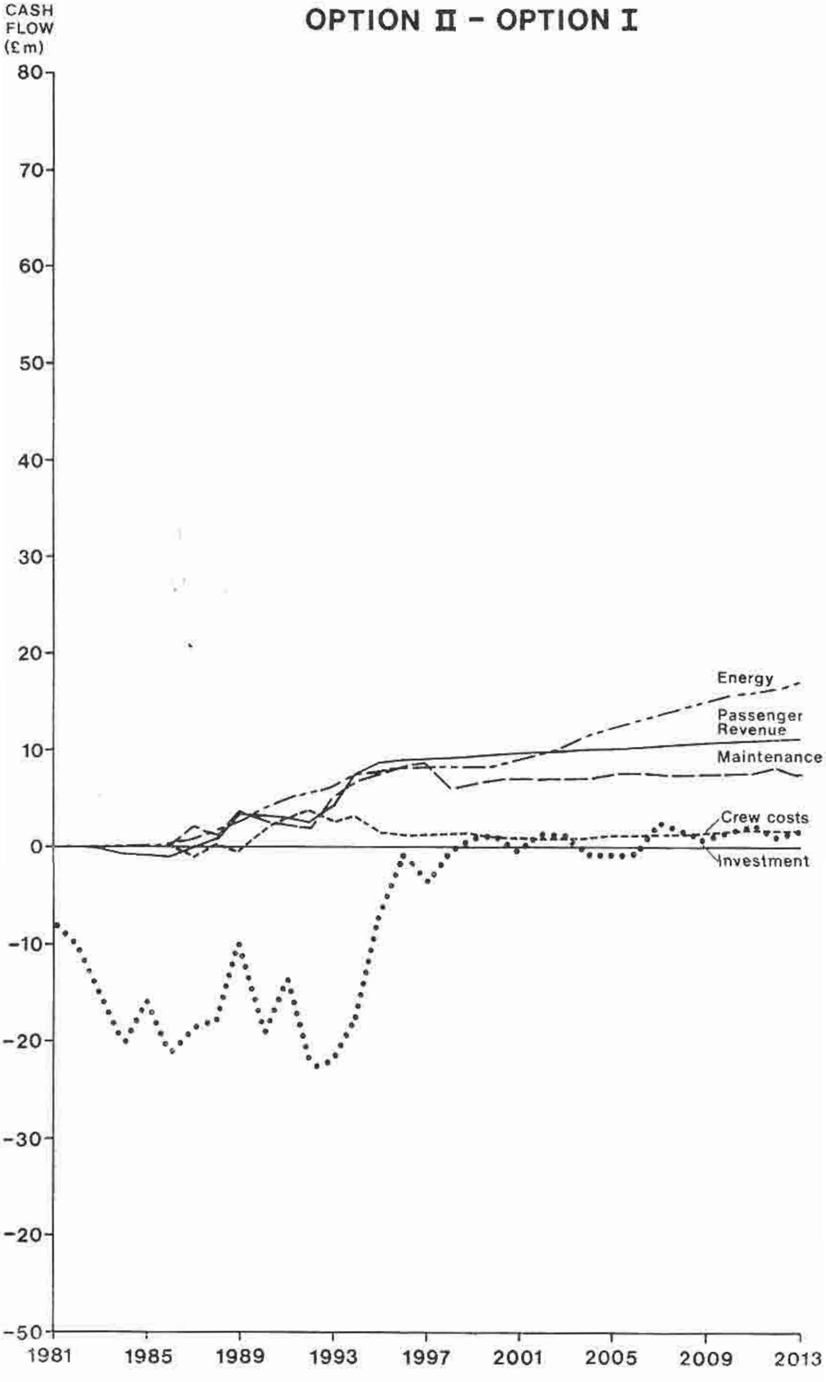
50. The Costing Model brought together for each option the revenue, the investment and the annual costs described above as cash flows for the years 1981 to 2013 (ie the evaluation period). These cash flows were then discounted to 1978 at a rate of 7% per annum. The model then added for each option the discounted residual values. The residual value is the stream of net benefits after the end of the appraisal period (ie after 2013) made possible by the investment undertaken earlier. Traffic levels, revenues and operating costs were assumed to remain at their 2013 level. The cost of replacing assets at life expiry was allowed for by calculating the appropriate annual capital charge for each type of asset over its replacement cycle. Net annual benefits for each year (revenues minus operating costs and annual capital charges) were calculated and summed in perpetuity to give the total residual value for each option in 2013. This was then discounted back to 1978 using the 7% discount rate.

51. The discounted residual values plus the discounted net annual benefits during the evaluation period gave the final results, as net present values, for each option. These are discussed in Chapter 3 of the report.

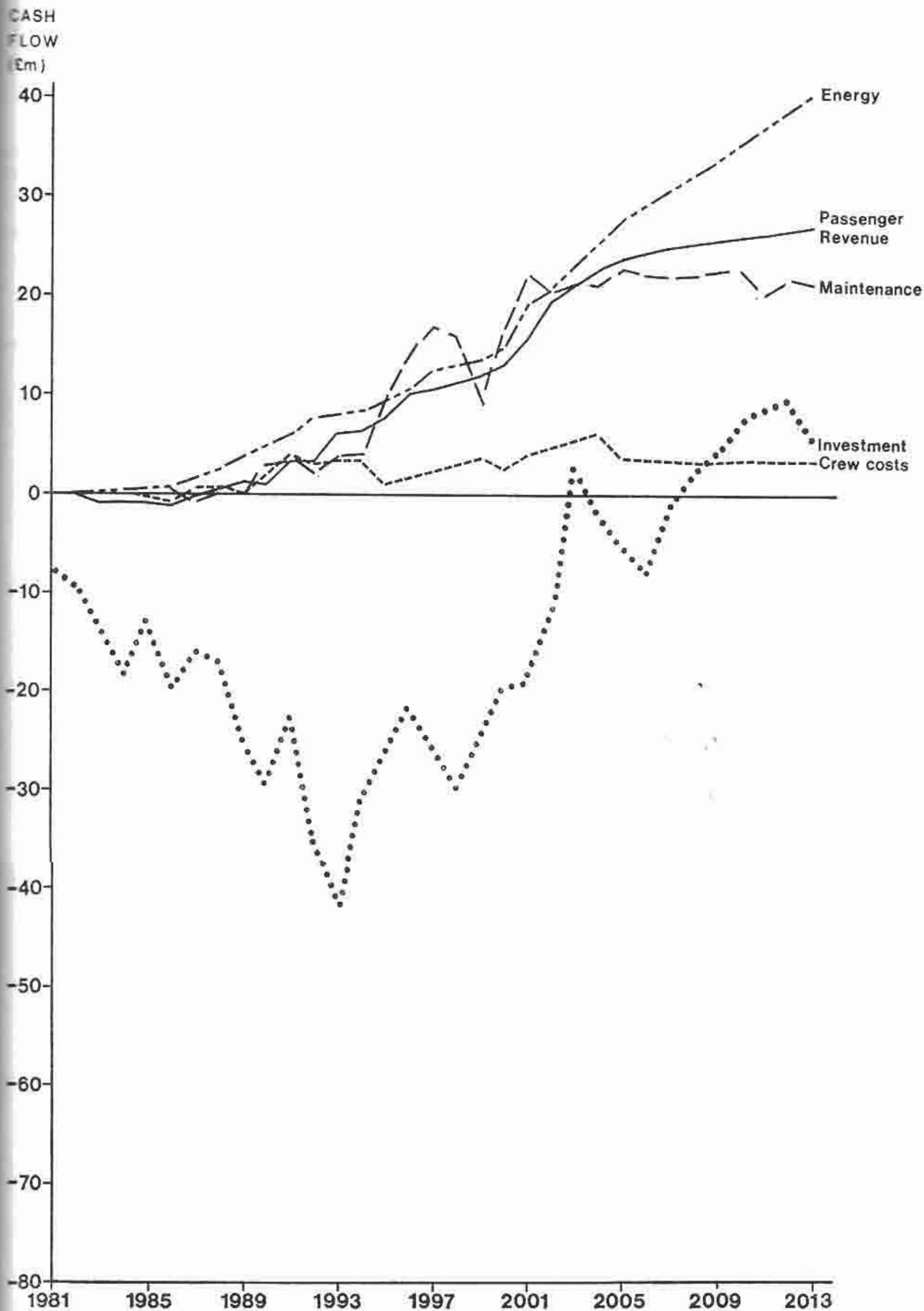
APPENDIX 2: SUPPLEMENTARY FINANCIAL DETAILS

GRAPH B

UNDISCOUNTED CASH FLOWS BY COST HEADING OPTION II - OPTION I

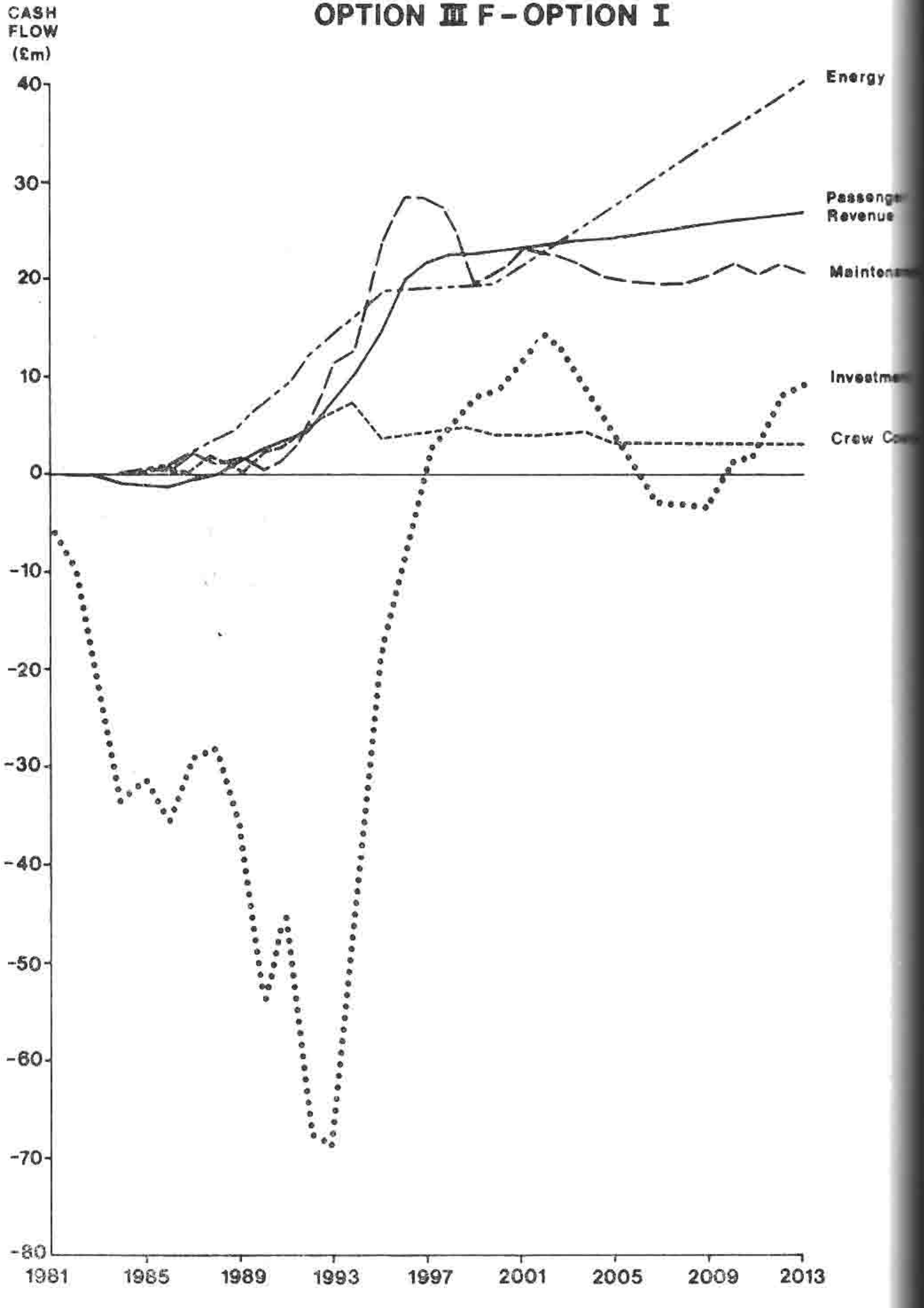


UNDISCOUNTED CASH FLOWS BY COST HEADING
OPTION III S - OPTION I

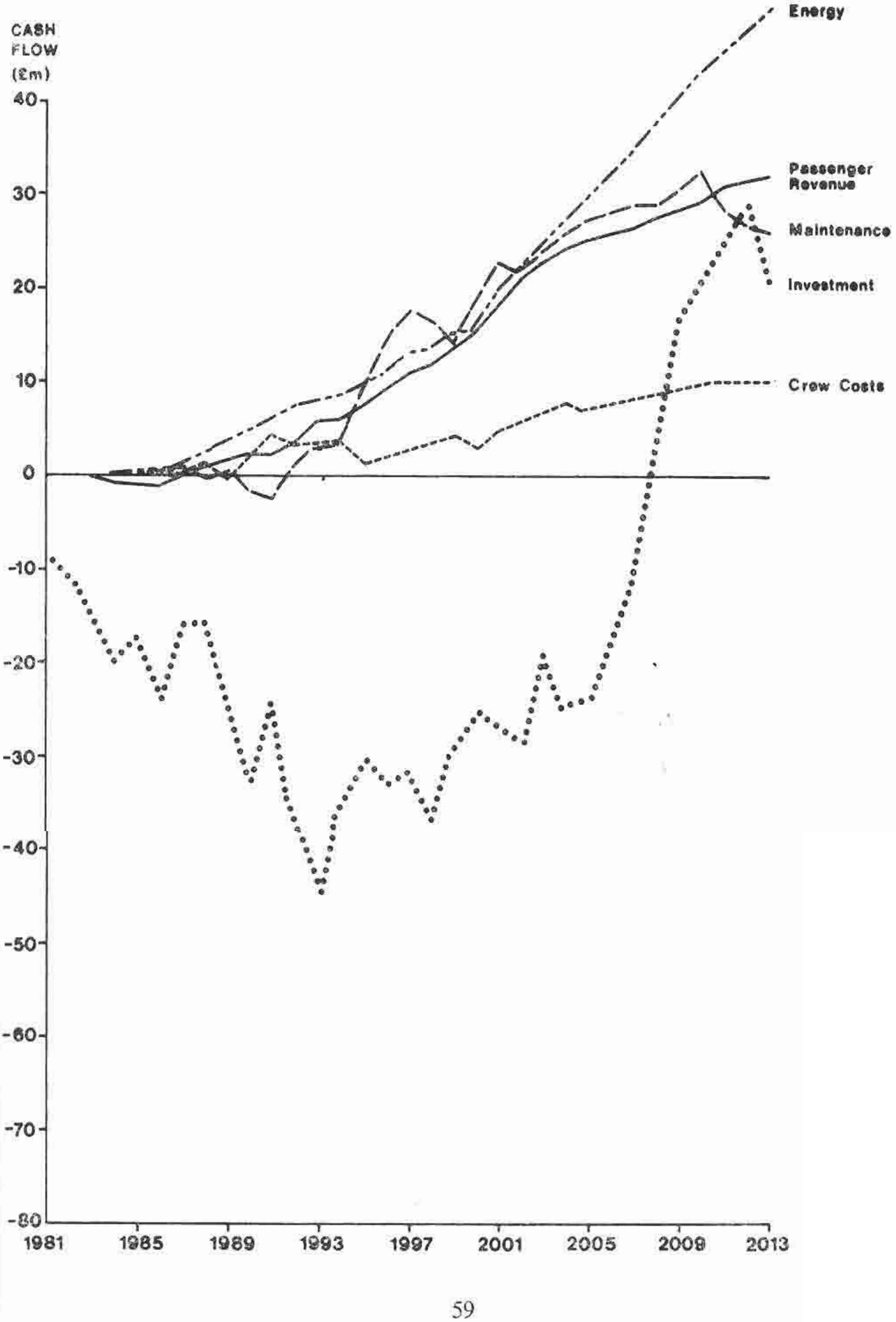


GRAPH

UNDISCOUNTED CASH FLOWS BY COST HEADING
OPTION III F – OPTION I



UNDISCOUNTED CASH FLOWS BY COST HEADING OPTION V S - OPTION I



GRAPH F

UNDISCOUNTED CASH FLOWS BY COST HEADING
OPTION ⅤF-OPTION Ⅰ

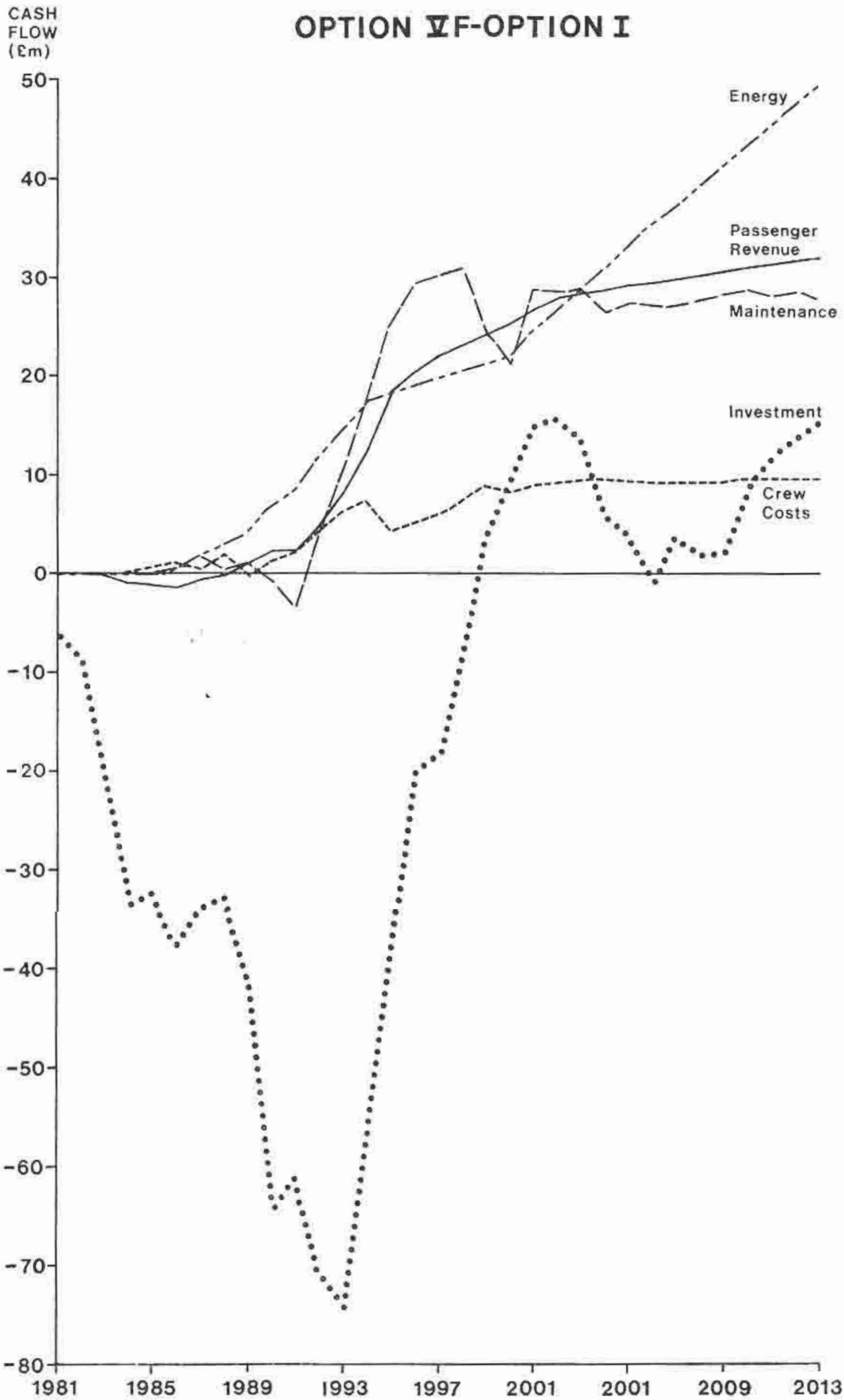


TABLE 17

NPVs OF ELECTRIFICATION OPTIONS COMPARED WITH OPTION I, SUMMARISED BY REVENUE AND COST CATEGORY

(£m, 1978 money values, discounted at 7%)

	NPV of Option I	Better/Worse (—) than Option I				
		Option II	Option IIIS	Option IIIF	Option VS	Option VF
Passenger revenue	8,307	27	47	58	53	67
Working expenses:						
Oil	1,286	169	306	372	357	441
Electricity	622	−101	−178	−222	−209	−268
Crew	1,950	12	22	30	42	55
T & RS maintenance	2,871	60	120	150	145	183
Fixed works maintenance	7	−26	−40	−47	−48	−58
Total	6,735	115	230	282	286	353
Investment:						
T & RS	997	16	30	26	43	56
Fixed works	32	−134	−213	−261	−258	−326
Total	1,029	−118	−183	−234	−215	−270
NPV Grand Total	543	24	94	106	123	150

Totals are affected by rounding.

LOWER PASSENGER, STANDARD FREIGHT TRAFFIC LEVELS

TABLE 18

NPVs OF ELECTRIFICATION OPTIONS COMPARED WITH OPTION I, SUMMARISED BY BUSINESSES

(£m, 1978 money values, discounted at 7%)

	NPV of Option I	Better/Worse (–) than Option I				
		Option II	Option IIIS	Option IIIF	Option VS	Option VF
Passenger						
Revenues	8,307	27	47	58	53	67
Direct costs	5,011	86	169	192	196	230
Total	3,296	113	216	250	249	297
Freight						
Direct costs	2,021	66	114	137	159	201
Parcels and Departmental						
Direct costs	693	5	17	27	22	36
Fixed works costs	39	–160	–253	–308	–307	–384
Grand Total	543	24	94	106	123	150

Totals are affected by rounding

STANDARD PASSENGER, UPPER FREIGHT TRAFFIC LEVELS

TABLE 19

NPVs OF ELECTRIFICATION OPTIONS COMPARED WITH OPTION I, SUMMARISED BY REVENUE AND COST CATEGORY

(£m, 1978 money values, discounted at 7%)

	NPV of Option I	Better/Worse(—) than Option I				
		Option II	Option IIIS	Option IIIF	Option VS	Option VF
Passenger revenue	10,353	*	*	123	114	141
Working expenses:						
Oil	1,439			445	430	528
Electricity	703			−263	−249	−317
Crew	2,119	*	*	28	45	58
T&RS maintenance	3,170			180	172	219
Fixed works maintenance	7			−47	−48	−58
Total	7,439			343	350	431
Investment:						
T&RS	1,367	*	*	25	48	62
Fixed works	32			−261	−258	−326
Total	1,399			−236	−211	−263
NPV Grand Total	1,514	*	*	229	253	308

Totals are affected by rounding

*—Not evaluated

TABLE 20

NPVs OF ELECTRIFICATION OPTIONS COMPARED WITH OPTION I, SUMMARISED BY BUSINESSES

(£m, 1978 money values, discounted at 7%)

	NPV of Option I	Better/Worse (–) than Option I				
		Option II	Option IIIS	Option IIIF	Option VS	Option VF
Passenger:						
Revenues	10,353			123	114	141
Direct costs	5,797	*	*	223	227	270
Total	4,556			346	341	411
Freight:						
Direct costs	2,318	*	*	163	197	245
Parcels and Departmental:						
Direct costs	685	*	*	28	22	36
Fixed works costs	39	*	*	–308	–307	–384
Grand Total	1,514	*	*	229	253	308

Totals are affected by rounding

* – Not evaluated

UPPER PASSENGER, UPPER FREIGHT TRAFFIC LEVELS

TABLE 21

NPVs OF ELECTRIFICATION OPTIONS COMPARED WITH OPTION I, SUMMARISED BY REVENUE AND COST CATEGORY

(£m, 1978 money values, discounted at 7%)

	NPV of Option I	Better/Worse (−) than Option I				
		Option II	Option IIIS	Option IIIF	Option VS	Option VF
Passenger revenue	11,589	*	*	189	*	216
Working expenses:						
Oil	1,478			468		554
Electricity	741			−278		−333
Crew	2,187	*	*	25	*	54
T&RS maintenance	3,284			186		215
Fixed works maintenance	7			−47		−58
Total	7,697			354		430
Investment:						
T&RS	1,557	*	*	23	*	69
Fixed works	32			−261		−326
Total	1,588			−237		−257
NPV Grand Total	2,304	*	*	306	*	390

Totals are affected by rounding

*—Not evaluated

UPPER PASSENGER, UPPER FREIGHT TRAFFIC LEVELS

TABLE 22

NPVs OF ELECTRIFICATION OPTIONS COMPARED WITH OPTION I, SUMMARISED BY BUSINESSES

(£m, 1978 money values, discounted at 7%)

	NPV of Option I	Better/Worse (−) than Option I				
		Option II	Option IIIS	Option IIIF	Option VS	Option VF
Passenger						
Revenues	11,589			189		216
Direct costs	6,267	*	*	238	*	282
Total	5,322			427		498
Freight						
Direct costs	2,297	*	*	157	*	240
Parcels and Departmental						
Direct costs	683	*	*	29	*	35
Fixed works costs	39	*	*	−308	*	−384
Grand Total	2,304	*	*	306	*	390

Totals are affected by rounding

*—Not evaluated

APPENDIX 3: WIDER EFFECTS

ENERGY

1. The likelihood that energy will become increasingly scarce and more expensive and that oil could become a less competitive fuel for rail transport is reflected in the financial analysis using the range of price forecasts provided by the Department of Energy (see Appendix 1, paragraph 42).

2. The most important non-financial aspect of further railway electrification from an energy standpoint is the contribution that it can make to reducing our dependence on oil. This will become an increasingly significant factor in the longer term when UK oil production is in decline and the UK once again has to rely on less secure sources of imported oil. Substitution of electricity for oil also has the advantage that electricity can be generated from the most appropriate or readily available fuels with the bulk of the contribution likely to fall to coal and, for the future, nuclear generation. The detailed analysis undertaken in the second stage of the review confirmed the finding of the interim report—that on completion of Option V, nearly 120 million gallons of diesel oil consumption could be saved each year. This corresponds to around $\frac{1}{2}$% of the nation's current demand for oil products, or 3% of current demand for oil for transport purposes. The potential savings under Options II and III are smaller but still significant, at around 40 million gallons and 90 million gallons a year, respectively.

3. While electrification will reduce diesel oil consumption, there would be a corresponding increase in electricity consumption. Electric traction offers an advantage in terms of reduced primary energy consumption (an equivalent diesel service could incur a primary energy penalty of 30% compared with electric traction) but in practice, to assure the best commercial use of resources, the greater part of this theoretical advantage is translated into an improved, faster service. In the case of Option V it is estimated that electricity consumption could increase over time by nearly 1.8 TWH, equivalent to an increase in current UK electricity demand of about $\frac{3}{4}$%.

CAPACITY OF THE UK RAILWAY MANUFACTURING INDUSTRY

4. An electrification programme would mean an increased level of investment in the railway. The Department of Industry was therefore asked to consider whether the UK railway manufacturing industry would be able to cope with this increased workload.

5. The requirement of teams to install overhead lines was discussed with the industry who are confident that a sufficient number of teams could be built up to cope with any of the electrification options. The existence of a rolling programme would encourage the industry to assemble teams and enable these teams to remain in being for several years, with consequent benefits in experience and cost.

6. In all options the average annual requirement for traction units over the period is considerably higher than the average number of units supplied during the 1970s. However, the peak requirement will not arise under any of the options for several years (see Chapter 3, Table 10) and a decision to institute a rolling programme should provide the necessary confidence for the railway manufacturing industry to invest in the greater capacity necessary to meet this peak demand. There should be no problems in the shorter term since the industry has at present a certain amount of spare capacity and could bring additional capacity on stream fairly easily, in some cases diverting capacity which has been released in other sectors of the engineering industry.

BENEFITS FOR UK EXPORT PERFORMANCE

7. Table 1 below shows the value of the world market for railway equipment in recent years, and the UK share of that market.

TABLE 1

Railway Equipment Exports

£m

	1973	1974	1975	1976	1977	1978
World market by value (current prices)	384.0	625.2	1053.7	1120.7	1297.2	N/A
% increase on previous year	– 3.8	62.8	68.4	6.3	15.8	N/A
U.K. exports by value (current prices)	18.9	35.5	63.6	67.8	68.3	104.3
U.K. share of world market (%)	4.92	5.68	6.03	6.05	5.26	N/A

Source: Overseas Trade Statistics of EEC countries (less Eire and Denmark), USA, Japan and Switzerland.

NOTES:

1. These figures exclude electrical equipment for motive power units, civil and engineering contracting and consultancy fees. Their inclusion would slightly increase the U.K.'s share of the market but the overall picture would be little changed.

2. The figures include sales of one-off items, spares etc which are not part of a project and do not take account of sales of other items—eg telecommunications equipment—which are part of a project but cannot be separately identified for railways.

3. The UK's market share in 1978 was possibly 7–8%. In contrast to the sharp improvement in the UK's performance, France and Japan (which between them had 54% of the market in 1977) both suffered falls in exports by value. French sales fell by some 6%, Japanese sales by about 13%.

8. The Railway Industry Association has argued that an important benefit to the nation of a rolling programme of electrification would be its impact on improving export performance. The Departments of Industry and Trade have examined this argument.

9. The ability of any industry to compete internationally depends on low unit costs and high quality products. Low costs can be more readily achieved with a high and stable level of production which in turn is most easily secured where there is a buoyant home market. The large USA market for diesel traction has helped General Motors, for example, to secure a leading position in the world market for diesel locomotives.

10. As noted in the section on the capacity of the UK railway manufacturing industry, the steady and assured level of home demand provided by a rolling programme of electrification would encourage the UK railway manufacturing industry to build up and retain teams of skilled and experienced people. This would be particularly helpful in the catenary sector. It should also encourage industry to invest in more efficient plant and in research and development. All these factors should help to reduce unit costs (an allowance for the benefit of this to BR was included in the model), and so make UK industry more competitive overseas.

11. Confidence generated by the rolling programme would also encourage expenditure on developing and improving the new technology which railway operators will require. The industry will need to work closely with British Rail on this and British Rail will wish to ensure as far as possible that its specifications match those of potential customers overseas. The industry's ability to export will be further improved if it can cite a British Rail decision to purchase its products and if it can demonstrate new technology on the UK railway system.

12. A switch of emphasis by British Rail from diesel to electric traction would probably have adverse consequences for the UK's ability to export diesel equipment. But the Department of Industry's judgement, and that of the industry, is that the balance of advantage lies in concentrating on electric traction, particularly because of the USA's relatively strong position in diesel traction. Moreover, the electric market is expanding as countries throughout the world electrify: it is forecast that 40% of world rail systems will be electrified in the year 2000, compared to only 18% in 1978. The railway equipment industry has managed to export around a quarter of its output in recent years. The development of a larger home market should not divert the UK industry's attention away from overseas opportunities. Even with the higher level of sterling and the prospect of increasing industrialisation in the developing world, the UK should be able to improve its place in world markets, based on its reputation for quality and advanced technology.

Conclusion

13. A rolling programme should enhance the industry's ability to compete overseas by reducing unit costs, encouraging technological development and providing a shop window for the industry's products and capability.

EFFECTS ON POLLUTION

14. The Department of Industry's Warren Spring Laboratory was invited to consider the possible effect of changing from diesel to electric traction on air

pollution both from the railways directly and from the power generating plant which would be required for electrification.

15. In estimating the emissions of the more common pollutants (sulphur dioxide; particulates; oxides of nitrogen; hydrocarbons and carbon monoxide), the following assumptions were used:

(i) the primary energy input for diesel traction would be 10% higher than for a comparable quantity of electric traction, taking into account the higher speeds assumed for electric traction;

(ii) nuclear power would account for either 25% or 50% of electricity generation for the railway by the year 2010 (it accounts for 12% at present);

(iii) there would be a reduction of 440,000 tonnes per annum in the oil used for diesel traction at the completion of Option V, the equivalent amount of electric traction being substituted.

16. The likely effect of large-scale electrification (the completion of Option V) on air pollution is set out in the following table:

TABLE 2

TOTAL RAILWAY POLLUTANT EMISSIONS (Includes emissions from traction equipment and from coal-fired power stations generating electricity for traction).

Average area ground level concentrations:

Pollutant	Total UK emissions from all sources (000 tonnes per annum)	Total railway traction emissions in Option I		Total railway traction emissions after completion of Option V			
				A*		B**	
		000 tonnes per annum	% of total UK emissions	000 tonnes per annum	% of total UK emissions	000 tonnes per annum	% of total UK emissions
Sulphur dioxide	5280	46.5	0.9	48.9	0.9	35.2	0.7
Particulates	550	9.4	1.7	5.1	0.9	5.0	0.9
Oxides of nitrogen	1725	58.7	3.4	38.6	2.2	34.0	2.0
Carbon monoxide	8000	18.2	0.2	9.9	0.1	9.6	0.1
Total hydro-carbons	1150	12.3	1.1	6.5	0.6	6.5	0.6

A*—25% of electricity nuclear-generated B**—50% of electricity nuclear-generated

It will be seen that electrification to the extent of Option V should reduce average area ground level concentrations of railway traction pollutants by up to 50%, though the percentage reductions would be less for oxides of nitrogen and sulphur dioxide. The railway traction contribution to the total emission of these pollutants is very small to start with, in any case. However, the measure of average area ground level concentration does not reflect the fact that railway pollutant emissions from traction equipment alone (not including power station emissions) will be concentrated in the immediate vicinity of rail lines. A switch to electrification would therefore be expected to have a more significant effect in these areas. The concentration of pollution emitted by fossil fuel power stations generating electricity for the railway would be lower than the concentration produced by diesel traction because of the much greater extent of dilution and dispersal achieved by the high chimneys of power stations.

17. The Department of the Environment was asked to consider whether generating the electricity required for a largely electrified railway by nuclear power would mean an increase in radioactive effluent emissions. They concluded that if 100% of the electricity required by large-scale electrification were generated by nuclear means, this would raise the annual radiation dose to the entire UK population from nuclear power generation, fuel reprocessing and waste disposal, by less than 0.5% on current levels and still only about 0.5% on levels expected in the year 2000. This increase represents only about 0.001% of the annual dose from natural background radiation.

Conclusion

18. The effect of electrification on air pollution levels generally would not be significant. However, there could be a noticeable improvement in pollution levels in the immediate vicinity of rail lines, in stations and in rail workshops.

RAILWAY NOISE

19. Public response to railway noise was studied by the Institute of Sound and Vibration Research at Southampton University. They surveyed noise levels alongside railway routes in Britain, and coupled this with a social survey of residents at different sites and noise levels. In all, some 1,400 people were interviewed at 400 different sites, the principal aim being to discover an objective measure of noise which correlated well with annoyance and might be used nationally for prediction purposes. The equivalent continous sound level (leq) measured in dB(A) was found to satisfy these requirements. However, because of the size and comprehensive nature of the survey, it was possible to analyse, on the same scales of annoyance, people's reactions to different forms of railway traction—overhead electric, third rail electric, and diesel. Previous studies have shown that above about 45 mph, equivalent diesel and electric hauled trains produce substantially the same noise level in dBA. The ISVR survey showed that there was no difference in reaction at low values of leq, but at higher levels overhead electric traction was substantially less annoying than diesel traction for a given noise level and third rail electrified routes were only slightly less annoying than diesel routes. The difference in response to the two forms of electric traction is difficult to explain. The clear difference between the responses to overhead electrification and diesel traction was subjected to rigorous statistical tests and shown to be highly significant. Possible explanations such as the proportion of freight traffic, the extent of welded rail, ambient noise levels, settlement density, atmospheric pollution, number and speed of trains, region of the country, distance from the track, main line/suburban distinction and effects

of errors in noise measurements have been examined and found to have no influence on the difference in reaction to the two traction types. Since this detailed examination failed to identify any non-acoustic explanation, it seems that much of the difference is genuinely due to acoustic factors.

20. One obvious acoustic difference is the greater content of low frequencies in the noise spectrum from the diesel locomotive. The dB(A) measure which is almost universally used for work related to human response, and which was used in this study, gives a low weighting to low frequency noise. To assess the possible importance of this factor, the survey data was reassessed using a unit in which all frequencies are weighted equally, db(Lin). This greatly reduced the difference in reactions to the two traction types, but it was still significant. This suggested that low frequency noise could play a greater part in people's perception than would be predicted from the dB(A) level. Since the noise data in the survey was obtained outside the dwellings and the reactions of the occupants could have been dominated by their response inside, the greater transmissibility of low frequency sound through building structures (a known phenomenon) might be a contributory factor.

Conclusion

21. Although no completely satisfactory explanation of the differences in responses has been identified, all the survey analyses indicate that noise from electric trains drawing power from overhead wires causes less annoyance than equivalent noise from diesel hauled trains.

EFFECTS ON RAILWAY SAFETY

22. The implications of a programme of main line electrification for railway safety have been examined by the Department of Transport's Railways Inspectorate, who made a survey of accidents and failures reported to the Department by British Rail between 1973 and 1977 under the Regulation of Railways Act 1871. Accidents with current modes of diesel traction, including the High Speed Train, were compared to accidents with electric traction operating on the 25KV ac overhead wire system.

23. The accidents considered are those which relate directly to the type of traction system in use. They fall into three categories: accidents to locomotives and multiple units while in service (including fires, mechanical and electrical failures); accidents during the maintenance of traction equipment; and accidents relating to the overhead line equipment.

24. The incidence, as a proportion of vehicles in service, of serious fires (defined as those which cannot be extinguished by train crew) is not very different in diesel and electric locomotives. But when the more intensive utilisation of the electric locomotives is taken into account—electric locomotives at present comprise only 19% of the locomotive fleet, but they are used for 40% of total loaded train miles—electric locomotives have a somewhat better record. Fires are $2\frac{1}{2}$ times more likely to occur in diesel multiple units than in electric multiple units. It is here that the greatest risk of injury to passengers lies,

because diesel traction involves the carriage of fuel oil which makes it vulnerable to fire.

25. Diesel locomotives appear to have slightly fewer serious mechanical or electrical failures than electric ones, though again this does not take into account the greater utilisation of the electric fleet. Serious failures are defined as those which actually caused an accident to a train or injury to persons, or which had the potential to do so. Once again, the risk of failures in diesel multiple units is significantly higher than in electric multiple units. Considering all failures of locomotives when in traffic, electric locomotives have a clear advantage, as demonstrated by the following figures*:

Class 47 diesel locomotives	: 12–14,000 miles/failure
High Speed Trains	: 15,000 miles/failure
Class 86 and 87 electric locomotives	: 35–40,000 miles/failure

26. The maintenance of diesel locomotives and multiple units appears to involve a greater risk to the health and safety of railway workers than the maintenance of electric traction units, largely from oil spillage and fumes in diesel maintenance depots. Each year there is a small number of cases of skin disease caused by oil contamination and on average about a dozen persons a year are injured, usually by slipping and falling on oily surfaces. Accidents in electric traction depots are less frequent, although there is always the risk of accidental contact with live equipment.

27. Wholly to the debit of overhead electric traction is the presence of high voltage electric equipment over and alongside railway lines. Some accidents occur during the erection of overhead line equipment and on average about 5 accidents have occurred each year to maintenance crew falling from ladders or gantries. Once construction work is completed, overhead line equipment is a continuing source of danger, particularly to trespassers. Between 1973 and 1977 an average of just under four persons were killed each year by electrocution (over half of whom were trespassers) and about 20 persons a year were injured (75% of them children).

Conclusion

28. Electric traction is more reliable than diesel and so safer for passengers and train crew. It is also cleaner, and safer to maintain. The toll of injuries and deaths caused by overhead line equipment (mainly to trespassers) might over a long period swing the balance marginally against electrification, but the difference in safety between diesel and electric traction does not seem very material.

VISUAL INTRUSION CAUSED BY ELECTRIFICATION

29. Most of the environmental bodies consulted by the Steering Group felt that on the whole, railway electrification would make a positive contribution

*These figures include all fires (including those extinguished by train crews) as well as a wide range of mechanical and electrical failures in addition to the more serious ones mentioned above.

to the quality of the environment. But the point was made that overhead electrification equipment can be somewhat unsightly and might have an adverse effect on the scenery in rural areas.

30. Early electrification schemes, such as Crewe to Liverpool, used elaborate overhead fixed works which caused considerable visual intrusion, particularly at major rail junctions. Since then, however, there has been substantial progress in the design of overhead line equipment. Recent electrification schemes have used wire headspans in place of the earlier heavy metal portals. On rural lines, the height of masts supporting cantilevered overhead line equipment has been reduced, and masts are now generally constructed of single "I" section galvanised steel beams, in place of the former, more elaborate double channel masts. Moreover, galvanised steel tubes blending with the masts have replaced copper-coloured steel tubes which had a tendency to turn blue or green through atmospheric pollution.

31. Visual intrusion is inevitably a subjective consideration; objective measurement is impossible. However, an attempt was made to assess the extent of visual intrusion which might be caused by electrification in National Parks or Areas of Outstanding Natural Beauty (England and Wales), and National Scenic Areas (Scotland). The following table shows the estimated route mileage passing through those areas which would be electrified in each option, discounting the lengths of route which pass through tunnels or cuttings, and those which form the border of the areas concerned, rather than pass through them.

TABLE 3

VISUAL INTRUSION IN NATIONAL PARKS AND AREAS OF OUTSTANDING NATURAL BEAUTY

Location	Approximate Route Mileage not in Tunnels or Cuttings	Option(s) Affected
National Parks		
1. Lake District—Lancaster to Barrow-in-Furness line	2	III, V
2. Peak District—Manchester to Sheffield (Hope Valley) line	9	V
3. Dartmoor—Totnes to Plymouth line	2½	III, V
Areas of Outstanding Natural Beauty		
1. Anglesey—Bangor to Holyhead line	4½	V
2. Dedham Vale—London (Liverpool Street) to Ipswich line*	3½	I, II, III, V
3. Cotswolds—Cheltenham to Swindon line	3½	III, V
4. Cotswolds—Swindon to Bristol (Parkway) line	1½	III, V
5. North Wessex Downs—Reading to Westbury line	23	III, V
6. North Wessex Downs—London (Paddington) to Oxford line	9	III, V
7. Arnside and Silverdale—Lancaster to Barrow-in-Furness line	7½	III, V

*Part of the 'Anglia' electrification scheme, included in the base option but not yet electrified

Total route mileage in OPTION I: 3½ OPTION V: 66
OPTION II: 3½ OPTION III: 52½

32. The table shows that the additional route mileage electrified on the overhead system in Option V compared to the base option would be 13 miles in National Parks and 49 miles in Areas of Outstanding Natural Beauty. Even in the largest option, no lines passing through National Scenic Areas in Scotland would be electrified.

Conclusion

33. Electrification would bring overhead wiring to some stretches of railway line in National Parks and Areas of Outstanding Natural Beauty. This must in some degree mar the scenery. What weight should be attached to that is entirely a matter of judgement.

EFFECT OF ELECTRIFICATION ON HISTORIC BUILDINGS

34. One of the amenity societies consulted suggested that the erection of overhead electrification equipment might spoil some railway buildings and structures of historic interest. In relation to the planning controls affecting listed buildings, British Rail are in the same position as any private individual. There would be an opportunity for consideration under the general standing procedures of any electrification proposals which would require alteration of listed buildings.

35. The views of the Department of the Environment's Urban Conservation and Historic Buildings Division were sought. They did not consider that electrification could have such a deleterious effect on historic buildings as to cast doubt upon the desirability of an electrification project, particularly bearing in mind the advances made in recent years in the design of electrification equipment. However, they felt that there might be cases where a proliferation of wires and supporting structures could mar the setting of a historic building or a conservation area and non-standard engineering solutions aimed at reducing the visual impact of electrification might therefore merit consideration. In such cases, it would be helpful for British Rail to consult the local authority concerned.

Conclusion

36. Electrification should not pose a threat to the preservation of historic railway buildings and structures. However, it could have an adverse visual impact on some buildings, and due care should be taken in the design of overhead equipment to minimise this impact.

EFFECTS ON LAND USE, SETTLEMENT AND INDUSTRIAL LOCATION

37. Transport 2000 suggested that a main-line electrification programme would influence the locational decisions of railway customers, both individuals and businessess, and so lead to greater use of the railway. Industries might be encouraged to re-locate close to rail services, leading to some transfer of long distance freight from road to rail. Individuals might choose to move closer to the improved rail passenger services, with consequential effects on property

and rateable values. Changes of this kind, it was suggested, would be valuable to the community.

38. So far as such changes will yield financial benefits to the railway passenger business they are already taken into account. Increased demand because of shorter journey times is quantified using journey time elasticities which have been determined empirically from past experience of speed improvements (see Appendix I, paragraph 5). This would include any increased demand from population movement.

39. It has been assumed for this study that no additional traffic will be generated in the freight business as a result of electrification. Although electrification will reduce freight operating costs, there will be only limited scope for attracting more traffic through pricing action because the Board already operate a market pricing policy. However, rail freight is most competitive in the heavy train-load market (eg coal, iron and steel, chemicals, aggregates), serving industries whose location is constrained by other factors. It seems to follow that electrification is unlikely to have a significant effect on locational decisions by industry.

40. It is on the passenger business side that electrification might be expected to influence locational decisions by individuals or firms, to whom electrification can offer a significantly improved product. A number of organisations were consulted to learn whether any research work had been done into the impact of transport provision on land use which might be relevant to the consideration of this effect. The organisations included the Department of Environment, the Transport and Road Research Laboratory (TRRL), and the University of Leeds. It emerged that the volume of research in this area is very limited, and the work which has been undertaken generally considers only the localised and fairly immediate effects of individual transport projects, often in urban or suburban areas. It is therefore of questionable relevance to this study, which is concerned with marginal improvements to the existing main line rail network, over a period of many years. The net effect of such changes on land use and population is difficult to predict, and this difficulty is compounded by the existence of external factors, such as general economic changes and natural demographic trends, which would in practice operate simultaneously.

41. It was argued by one of the outside organisations consulted earlier in the review that the improvement of rail transport communications between conurbations would attract industry to inner city areas and that this would in turn encourage the repopulation of such areas. It was not possible to assess this. As has been explained, electrification seems unlikely to have a dramatic effect on industrial location decisions.

42. Another suggestion made was that electrification might increase property and rateable values in areas benefitting from the improved rail services. There is evidence that this has occurred with previous electrification schemes, but it has not been possible to assess the magnitude of the effect which might arise from a large electrification programme. Any real increase in property values near rail stations would presumably be at the expense of property values elsewhere, unless there was a substantial overall net increase in property demand at the same time.

Conclusion

43. It has not proved possible, within the scope of this study, to reach a view on how a national programme of main line railway electrification might affect land use and settlement patterns. No relevant research material has been discovered. The diffuse and long-term nature of the transport improvements under consideration, and the large number of extraneous factors at work, make it very doubtful whether the effects could be identified and monitored. There is insufficient evidence of the relationship between a programme of main-line electrification and future land use or settlement patterns to enable a view to be taken.

INTER-MODAL TRANSFER

44. An examination was attempted of whether a programme of electrification would lead to a reduction in congestion on the roads by attracting traffic from road to rail. In particular, a special survey was made of the evidence throughout the world of the extent to which improved rail passenger services could attract passengers who would otherwise make the journey by road. The evidence is sparse, but tends to support a conclusion that there will be some diversion of traffic. However, there is a great deal of uncertainty about the total level of diversion, which would in any case be small compared with the total growth in road traffic which is forecast. As a result, no attempt was made to identify the proportion of the increased rail passenger traffic assumed in this study which might be attributable to inter-modal transfer. Revenue benefits to the rail passenger business arising from inter-modal transfer following electrification would be caught within the total revenue effects assumed in the financial analysis.

CONSUMER SURPLUS

45. The difference between what people would be prepared to pay for a certain commodity and what they are actually charged for it is defined as the "consumer surplus". By reducing journey times for existing passengers, electrification will make rail traffic more attractive to them and thereby increase their consumer surplus. On the assumptions used in the electrification review most of this consumer surplus is converted into revenue for the railway businesses by 6% real pricing, spread over three years following electrification (see Appendix 1, page 40, paragraph 11). The growth in passenger volume stemming from electrification is reduced by this pricing action, but it is not eliminated (See Appendix 1, paragraph 12, and Table 31). This means that there is a residual consumer surplus from electrification which is not converted into railway revenue (and therefore not included in the financial appraisal), which will remain as a benefit to rail travellers.

SECURITY

46. The Defence Planning and Emergencies Division of the Departments of Environment and Transport was consulted about the possible implications of electrification for the security of rail transport. Their view was that taken overall, electrification would not significantly affect the security of the railways, provided that the number of diesel locomotives remaining in service did not

fall below the level where a useful emergency back-up service could be provided using diesel traction. This is unlikely to happen, because even in the largest electrification option, a substantial proportion of railway traffic would remain diesel-hauled.

APPENDIX 4: FOREIGN EXPERIENCE OF RAILWAY ELECTRIFICATION

1. The development of railway businesses in other countries has been influenced by historical, geographical and economic factors which are often very different from those prevailing in Great Britain. Nevetheless, it was considered that it would be of value to investigate foreign experience of railway electrification, to see if lessons could be learned and in particular to discover whether other countries had used different techniques for appraising the case for electrification, or had considered factors which had been overlooked in Britain.

2. Advice was therefore sought from a number of foreign Governments and Railway Administrations, covering a wide range of business conditions. The Steering Group wishes to thank those consulted for their kind assistance. Thanks are also due to the Editor of Railway Gazette International, for permission to publish a summary of the article "Investing in Electrification" (RGI, January 1979), which constituted the SNCF response to the consultations.

3. Attention was also drawn to a report* commissioned by the Australian Commonwealth Department of Transport, and published in May 1980, which considered the case for the electrification of the line between Sydney and Melbourne in Australia.

Summary And Conclusions

4. With the exception of the United States, where the role and organisation of the railways is very different from in Europe, all the countries consulted had considered electrification of the most heavily used sections of their rail networks worthwhile. Electrification works have been undertaken in other countries for reasons largely related to economic conditions and geographical factors. In Italy and France for example, electrification began very early this century, major considerations being the availability of cheap and abundant hydro-electric power and the need to cope with steep gradients; while in other countries the key consideration was the need to phase out steam traction in order to reduce consumption of imported fossil fuels at a time when diesel traction was not sufficiently developed to be a realistic replacement. Of the countries consulted, Denmark appears to present the closest parallel to British experience, though the Danish railway network is of course much smaller than the British. Danish railways, like British Rail, are faced with the need to replace much of the diesel locomotive fleet that operates the main lines over the next few years. On the basis of a detailed study, the Danish Government has recently authorised electrification of the 50% of the rail network that carries 90% of train miles.

5. With the exception of Germany, Italy and Holland where a substantial proportion of trains are already electrically hauled, all the countries consulted

*"Sydney-Melbourne Railway Electrification Study", Joint Consultants, ElRail, Sofrerail, R Travers Morgan.

have in recent years undertaken studies of the case for the extension of electrification. The approach adopted for these studies has been similar in concept to that used in this review, evaluations being based primarily on financial criteria reinforced by some consideration of social and environmental factors. The costs and benefits also appear to be similar in kind to those identified in this review, though their absolute values and relative importance vary according to national circumstances. All the factors mentioned by the countries consulted have been examined in this study.

6. Two of the countries consulted referred to expected technological developments in the design of electric traction equipment. The SNCF referred to the reduced capital and maintenance costs of locomotives incorporating solid state thyristor control, while the DB contribution described recent research into three-phase asynchronous traction motors.

7. The responses received from each of the countries consulted are summarised below.

DENMARK (DSB)

8. In the early 1950s it was decided that the DSB should convert from steam to diesel, rather than to electric traction, on the grounds that the diesel option had a lower investment requirement and the change could be implemented more rapidly. Therefore, apart from suburban lines around Copenhagen, DSB have no electrified lines at present.

9. In 1973, DSB decided that the case for electrification should be re-examined, for the following reasons:

(i) the volume of rail traffic had doubled since the early 1950s;

(ii) the traffic pattern had changed;

(iii) passenger and freight service speeds had increased;

(iv) there had been significant developments in electric traction and power plant technology;

(v) it was considered that the effects of electrification on railway costs should be re-examined;

(vi) the era of low, stable oil prices had ended;

(vii) there was thought to be considerable potential for future increases in traffic; and

(viii) some 60% of the diesel locomotive fleet was due for renewal by 1980 and some additional locomotives were needed to cope with the extra traffic, so substantial investment was required even to continue operating a diesel railway.

10. Against this background, DSB mounted a study of the case for electrifying about 50% of the national network, on which 90% of DSB traffic is run.

The study, which was primarily financial in nature, indicated significant savings from electrification in energy and maintenance costs, combined with operational advantages from greater train speeds, more reliable services, better utilisation of infrastructure and rolling stock and a cleaner, less noisy traffic environment. Greater flexibility in fuel sources was thought to be another benefit of electrification.

11. The outcome of the study was a recommendation for electrification, and this was accepted by the Danish Government. Last year the Danish Parliament approved a Bill under which funds for electrification will be made available from 1982, with the aim of completing the programme by the mid 1990s.

FRANCE (SNCF)

12. Electrification of the French railway network started early in the century using overhead or third rail dc systems, primarily around Paris and in mountainous areas, where the availability of hydro-electric power and the need for high performance traction equipment were important considerations. The spread of the 1.5KV dc overhead system continued up to 1940, when 3,360 route kilometres had been energised, and resumed in 1946. But electrification of the Aix-les-Bains to Annecy line on the 25KV ac overhead system, commissioned in 1950, heralded a world-wide change to that standard. By 1970 27% of the SNCF network was electrified (9,360 route-km), of which nearly half (4,230 route km) was on the 25KV ac overhead system. The electrified network carried 74% of inter-city passenger services and 77% of freight services.

13. After 1970, the extension of electrification ceased, but the oil crisis of 1973/74, which altered the relative costs of oil and electricity in France, led to a re-appraisal. Other factors which influenced the re-appraisal were improvements in electric traction design and technology which reduced maintenance requirements, increased power and made it easier to design dual standard traction equipment which would operate both on 25KV ac and on 1.5 KV dc, thus enhancing the network benefits of electrification. As a result of this re-appraisal a further electrification programme was started in 1977 and the SNCF hope to electrify a further 4,000 route-km by the year 2000, bringing 82% of passenger Inter-City traffic, 100% of Paris commuter traffic and 88% of freight traffic into electric haulage.

14. SNCF electrification projects are evaluated individually, using a financial form of appraisal, with future net costs and benefits being discounted over 20 years, though the residual value of equipment at the end of this period is also taken into account.

WEST GERMANY (DB)

15. Electrification of railway lines in Germany, which began in 1905, spread rapidly from 1950 onwards, so that by the end of 1978 about 10,600 route-km had been electrified, corresponding to about 37% of the total route length

of the DB system. 82% of services (in gross tonne-km) are now hauled by electric traction. Almost all Inter-City lines are electrified.

16. Electrification projects have been assessed primarily on financial criteria. Important benefits of past projects include increased efficiency of train operation, rationalisation of personnel, maintenance facilities, plant and rolling stock and improved service profitability. Factors of secondary importance were the environmental benefits of electrification and a reduction in primary energy consumption. It is expected that the latter factor will acquire greater importance in future, but it is not thought likely to become decisive. Projects will continue to be assessed primarily against financial criteria.

17. In future, DB plans to electrify the new Stuttgart to Mannheim and Hannover to Wurzburg lines (a total of about 300km) and a number of feeder and connecting lines and extensions to urban rail systems (about 470km). In the longer term, DB hopes that the introduction into service of locomotives with three-phase, asynchronous traction motors (if service trials prove satisfactory) will enable both high-speed passenger and heavy freight trains to be hauled by the same locomotive type, achieving considerable operating cost savings.

ITALY (FS)

18. Shortage of fossil fuels, combined (at the time) with a relative abundance of hydro-electric power and the need for locomotives able to cope with difficult mountainous conditions led to an early start on electrification in Italy. By 1940, 55% of the network was electrified. Today all heavily used lines are electrified (8,500km out of the total network), with about 72% of passenger and freight traffic being electrically hauled.

19. Now that diesel traction offers a more competitive level of performace and the major source of electricity is thermal power stations, FS considers that further electrification would only be justified on isolated lines in predominantly electrified areas, on lines with severe gradients and on lines used for diverted main-line traffic or to cope with excess peak main-line traffic. In 1974 the Italian Government authorised the electrification of a further 750km of track and determined that FS should continue with diesel traction for all remaining lines and for most shunting operations, thus ensuring adequate utilisation of the diesel fleet and associated facilities and availability of diesel locomotives as back-up in the event of electricity supply failures.

THE NETHERLANDS (NS)

20. Netherlands Railways had to reconstruct the Dutch rail network virtually from scratch after the Second World War. It was then decided to electrify a substantial part of the network, partly because of the need to save coal (diesel traction was not then competitive with electric in performance terms). Since the immediate post-war period small extensions to the main electrified network have been made and it was also decided to electrify some new lines which have

been built or are currently under construction. At the moment 61 % of the network is electrified.

21. Individual projects have been assessed primarily on financial criteria, though in some recent cases, when costs and benefits were roughly in balance, environmental benefits were taken into account.

THE UNITED STATES OF AMERICA

22. With the large distances between major cities, air travel is especially competitive for passenger Inter-City traffic and the American railways are largely freight orientated. Some 50 major independent companies operate over a network of about 195,000 route miles, in some cases competing with one another in the same corridor. Although electrification studies in the past have indicated a reasonably good rate of return on investment, projects generally have not gone forward because the private railway firms have not been able to raise the money for this optional investment in addition to the funds needed for renewal of essential assets (traction, rolling stock and track etc). Very little of the American network has therefore been electrified. However, the American Government is studying ways of making investment in electrification more attractive, for example by offering loan guarantees for projects with a good financial return and by supporting technical research.

BELGIUM (SNCB)

23. Since 1947, 33 % (1,300 km) of the Belgian railway network has been electrified. In 1970, SNCB drew up a ten year investment plan which envisaged electrification of a further 700 km of lines by 1984, bringing 50 % of the network under the wires. The decision to start electrification in 1947 was made primarily on financial criteria, but the 1970 plan includes lines for which the financial case is more marginal. These are included for operational reasons (eg isolated stretches of non-electrified line in predominantly electrified areas) or for social or political reasons (all areas of the country wish to benefit from the improvements in the quality of service which electrification brings).

AUSTRALIA

24. The case for electrification of the line from Sydney to Melbourne was reviewed in 1980 against a background of improved efficiency of electric traction, escalating oil prices and increasing freight traffic. Very little traffic on this 963 kilometre line is passenger (25 % of train miles and 10 % of revenue earnings) owing to competition from air travel over the long distances involved.

25. The methodology adopted for the Australian study was very similar to that used in this study, though some of the inputs could be specified in greater detail because the Australian study considered a single route, rather than a network. A base case, which included some investment in track improvements, as well as in diesel locomotives, was established. This was compared to elec-

trification on the 25KV ac overhead system, which was confirmed as the most cost-effective for the route. Alternative traffic growths were considered. The project was discounted over a range which encompassed the Review's DCF rate of 7%, and until the year 2016, at which point residual values were calculated. The principal benefits of electrification were shown to be savings on energy costs, locomotive maintenance costs and crew costs. The residual values of the assets were also important in determining the case for electrification.

26. The possible wider effects of electrification were considered, including noise, visual intrusion/historic structures, pollution emissions and public risk (safety). The employment implications of electrification during the construction period were also considered. The project is currently under discussion between the Commonwealth Government and the State Governments of New South Wales and Victoria, and if approved, is expected to be completed by 1991.

APPENDIX 5: TERMS OF REFERENCE

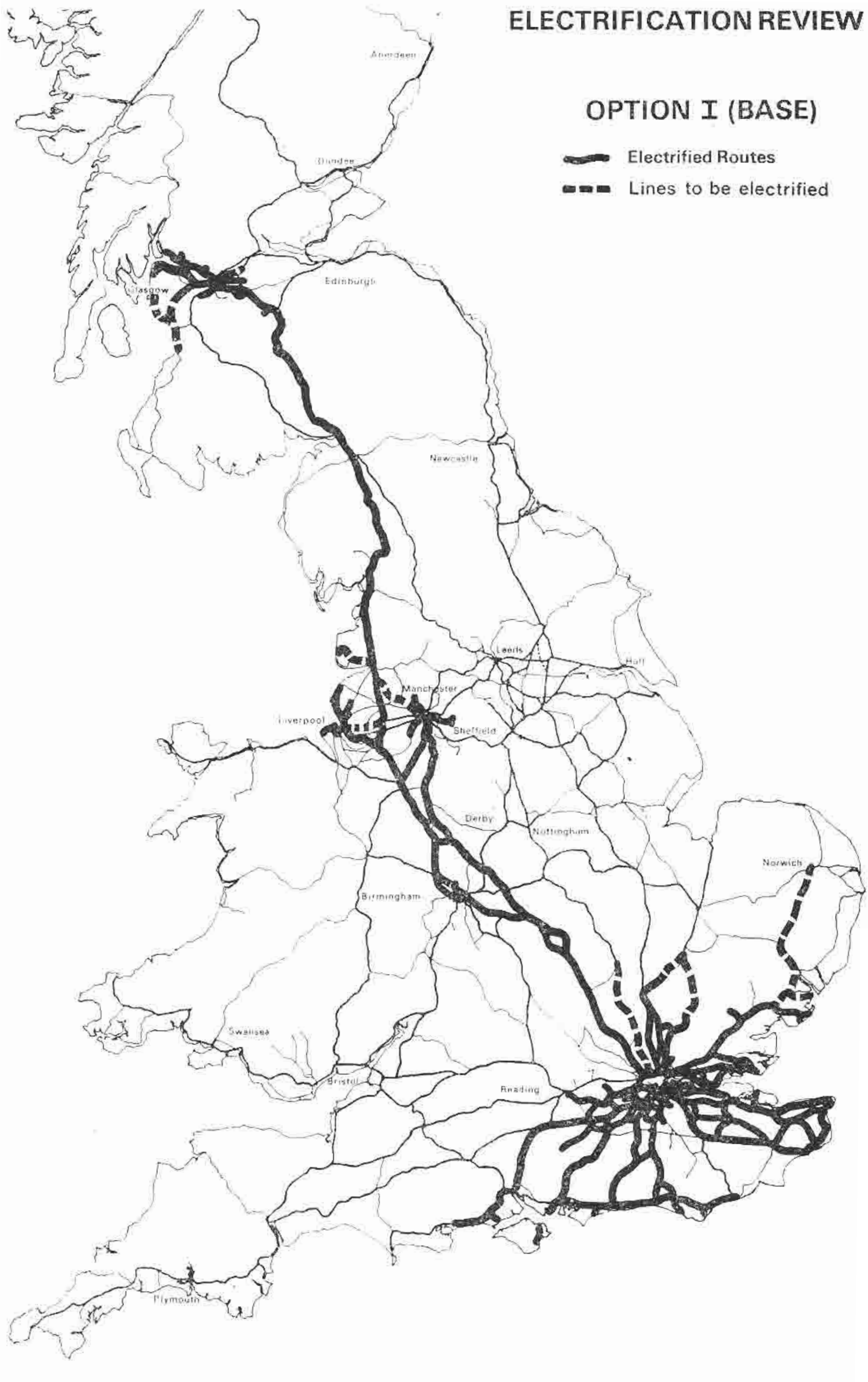
1. The terms of reference given to the joint Department of Transport/British *Railways Board Steering Group in May 1978 by the then Secretary of State for* Transport were:

"To review the case for a programme of main line electrification, to analyse the various relevant considerations and formulate the issues for decision."

APPENDIX 6: NETWORK MAPS

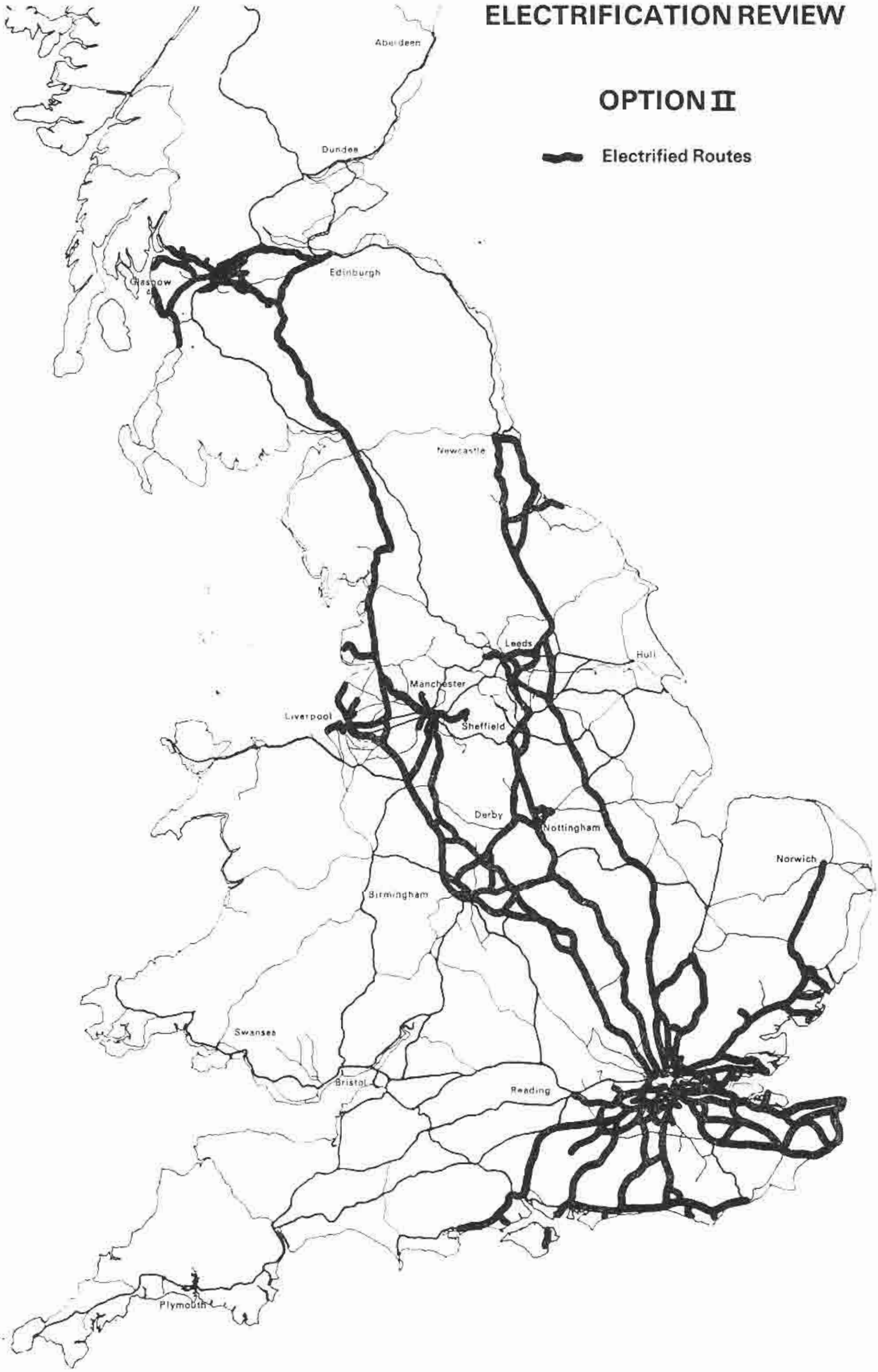
ELECTRIFICATION REVIEW

OPTION I (BASE)



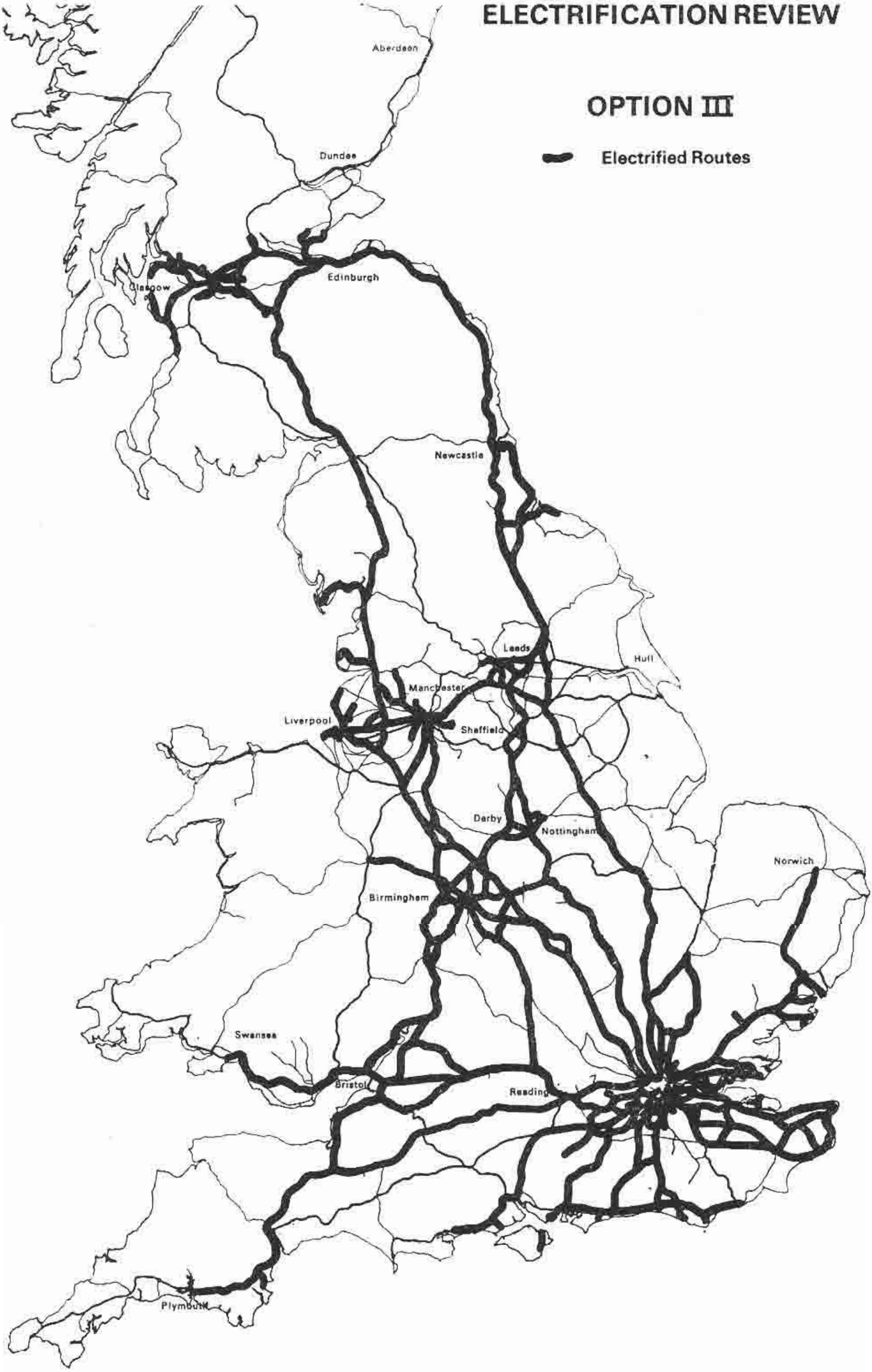
ELECTRIFICATION REVIEW

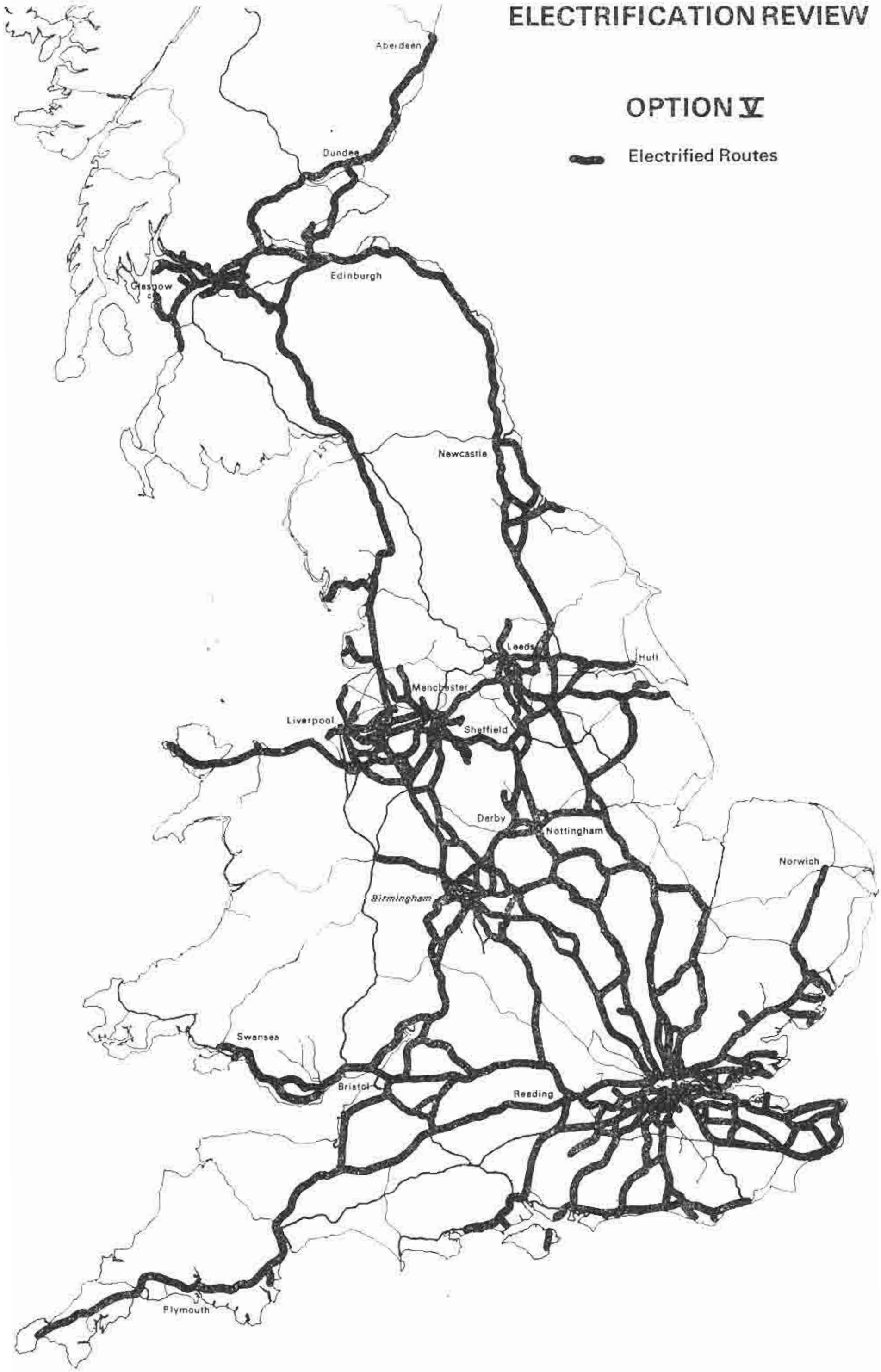
OPTION II



ELECTRIFICATION REVIEW

OPTION III




ELECTRIFICATION REVIEW
OPTION V
Electrified Routes
Aberdeen
Dundee
Edinburgh
Newcastle
Leeds
Hull
Manchester
Liverpool
Sheffield
Derby
Nottingham
Norwich
Birmingham
Swansea
Bristol
Reading
Plymouth

APPENDIX 7
REPRESENTATIONS FROM OUTSIDE ORGANISATIONS AND INDIVIDUALS

1. The following organisations were invited to submit written and/or oral evidence to the Steering Group conducting the electrification review—

Association of County Councils
Association of District Councils
Association of Metropolitan Authorities
*Associated Society of Locomotive Engineers & Firemen
*British Electrical & Allied Manufacturers' Association Ltd
*British Road Federation
British Tourist Authority
*British Transport Officers' Guild
Central Transport Consultative Committee
Chartered Institute of Transport
Civic Trust
Confederation of British Industry
Confederation of British Road Passenger Transport
*Conservation Society
Convention of Scottish Local Authorities
*Committee for Environmental Conservation
Council for the Protection of Rural England
Countryside Commission
Fellowship of Engineering
Freight Transport Association
Friends of the Earth
Greater London Council
Institute of Fuel
Institution of Civil Engineers
Institution of Electrical Engineers
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London Boroughs Association
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National Council on Inland Transport
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Noise Advisory Council
*Railway Industry Association
Road Haulage Association
Royal Society for the Prevention of Accidents
Scottish Association for Public Transport
Town & Country Planning Association
Trades Union Congress
*Transport 2000
*Transport & the Environment Group
*Transport Salaried Staffs Association

*Organisations who submitted oral evidence to the Steering Group

2. In addition, many helpful responses, including one from the Transport and General Workers Union, were received to the Secretary of State's open invitation to contribute.

3. The Steering Group wish to express their gratitude to all those who contributed.

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