Review of Main Line Electrification

Joint Study by Department of Transport and the British Railways Board 1978-1981

1. Introduction

1.1 During the 1970's the British Railways Board (BRB) was concerned about the difficulties of developing and achieving agreement with the government about large investment projects. The particular problems were the length of time involved and the generally hesitant, critical and detailed investigatory attitudes of the Department of Transport (DTp).

1.2 Faced with a conviction of the need and value of large-scale electrification, and wishing to avoid this problem, the BRB and DTp agreed to pursue a joint study of the opportunities so that the relevant procedures, policies and technicalities could be examined jointly and currently, and agreed in principle.

1.3 The method was satisfactory and a comprehensive and positive review produced a strong case for a programme of electrification along the main railway routes. The review was not required to make a decision and was limited to "review the case for a programme of mainline electrification, to analyse the various relevant considerations and formulate issues for decision" (not quite the clear 'go ahead' the BRB had wanted but, probably, a step forward).

1.4 The report was a lengthy and, to permit easy understanding and quick appreciation, this is a summary. Some relevant and current observations are given in this introductory paper. It is a reminder of what was done and how it was done, and shows the facts, figures, arguments and projections and what they meant at the times.

1.5 Re - presenting the report brings the conclusions to the fore and encourages the projection of those earlier conclusions into current possibilities. Today's figures, values and projections can be inserted into the original calculations and the present-day situations revealed and used for feasibility studies and project proposals.

1.6 The study was accepted as worthwhile and relevant work and conclusions were accepted as an adequate case for extensive electrification. Regrettably, the political will was absent and the opportunity languished and was lost among subsequent developments.

1.7 It is clear that the opportunity has now re-appeared and the time is right for introducing the mainline electrification case again, The facts and results still apply and are strengthened by the following:-

(i) The work showed the results would be improved by increases in passenger and freight traffic, and both of these have grown considerably since 1981.

(ii) The effect of energy prices was very important, particularly if oil costs rose as predicted. In fact, they have probably increased to an even greater extent compared with electricity and this will improve the benefits of electrification. The mechanism of the study processes gives a means by which these changes can be measured.

(iii) The study paid little attention to environmental aspects as they were not very significant at the time but did indicate that electrification brought benefits. This is much more important now and adds much weight to the beneficial arguments.

(iv) The study showed the added benefits coming for the larger options; the natural 'add on' effects from the opportunities for using the technical assets over wider areas; and avoiding traction changes or diesel operation under the wires. Also of benefit would be the wider reach of electricity distribution and control system and overhead line maintenance facilities. There would also be a reduced need for duel-system trains planned now [Intercity Express Project, IEP] to replace the HST units.

1.8 There is growing interest for developing the case for mainline electrification in every aspect which might apply — operational efficiency, cost reduction, traffic development, environmental benefits and reduction in demand for oil. An effective way to do this would be take the proven case made in 1981 and the re-work the calculations using agreed up-to-date figures. In this was, the case can be made again quickly and at little cost, and the result would be incontrovertible. Network Rail seems to be the organisation that can and, perhaps, should do this.

2. CONCLUSION

2.1 The case for mainline electrification was made over 25 years ago. There is no need to start afresh — all that is needed is to bring it up to date with current figures.

David Cobbett,
16 August 2008

Review of Main Line Electrification Study 1978 - 1981

A Summary by David Cobbett

1 Submission by the Co-Chairmen of the Steering Group

1.1 The terms of reference for the study were to "review the case for a programme of mainline electrification to analyse the various relevant considerations and formulate the issues for decision." The review group also included representatives from the Treasury, the Department of Energy and other government departments and included the advice of many organisations and individuals.

1.2 There was a comprehensive financial analysis of various extents of electrification divided into size and speed of completion options and their wider implications.

1.3 Computer models were used to examine the financial consequences and effects upon traffic levels. The work was robust and although it could be refined, such refinements would not alter the conclusions.

1.4 The main conclusions were:

1.4.1 On the assumptions made, a substantial programme of main line electrification would be financially worthwhile. The greater the extent produces an internal real rate of return of about 11%. Higher values come from faster implementation.

1.4.2 There are no important wider disadvantages.

1.4.3 Electrification would scarcely affect total energy consumption and would reduce dependency on oil.

1.4.4 A programme should assist UK manufacturing to secure more overseas orders.

1.4.5 Only an unlikely combination of adverse factors could undermine entirely a financially worthwhile programme. This is partly because of the foreseen difference between oil and electricity prices.

1.4.6 The outcome of 11% could be better if favourable changes combine.

1.5 The "issues for decision" in the remit were deemed to be:

1.5.1. The first issue was whether the key assumptions were valid. They were:-

(i) There will be increased investment in the main continuing railway businesses i.e. intercity, freight and parcels, which will be able by increased efficiency and adaptation to the market to increase traffic at higher levels of fares and charges and so improve financial results.

(ii) The railways will be able to make real fares increases of 1% p.a.

(iii) That labour cost will move in line with GDP and that gains in productivity will prevent rises in the unit costs of output.

(iv) Electrification will bring increases in efficiency and lower operating costs, reductions in maintenance costs (largely staff costs) and that the trade unions will accept this (which they confirmed).

(v) Oil prices will rise more than electricity. The Department of Energy research suggests that there was potential for oil prices to rise above the range assumed in the study, which would improve the case for electrification.

1.5.2 The strategic decisions concerned the possible gain from practical programmes of main line electrification extending over 20 - 30 years; changing progressively to electrification; how much to spend; commitment and when to start and the effects upon general investment in the railway; need for external finances and implications upon competing priorities for government funds.

1.5.3 The possibility of making a strategic decision "in principle" was suggested, meaning that most of the main line traffic would be under electrification. This would be a base for many separate decisions such as design of rolling stock, track and signalling renewals, location of depots, traffic acquisition, allowing flexible implementations of individual projects at appropriate times. This was rejected because the benefits of making a commitment to a specific programme were preferred. They were:-

(i) Long term commitment — technical, productivity and workforce interest could be achieved which would not be available from an ad hoc approach to projects. Abortive expenditure could be avoided; cost reductions from continuity of production would be available, which would, also, help overseas competitiveness.

(ii) There would be a firm base for longer term financial plans and management of the increased cash flows, which would be greater than the investment levels currently planned by British Rail within government ceilings.

(iii) The benefits of individual schemes are related to the likely future extent of electrification i.e. interactions and 'add on' benefits and distortion of decisions could be avoided.

1.5.4 Major questions of "how much? and how soon?" were answered. Observations on these were:-

(i) As all the larger programmes gave an IRR [internal rate of return] of 11% and the faster the work was carried out the better the N.P.Vs [net present values] it followed that, given unrestricted availability of funds, the largest and fastest option should be taken. This could take 20 years, extending electrification to Aberdeen, Edinburgh to Glasgow and Carstairs, Sheffield, between Liverpool and York, cross-country to Birmingham, Bristol and Reading and London to Swansea and Penzance. This spread would enable over 80% of the passenger and some 70% of freight traffic to be electrically hauled. At 1981 prices this programme would produce a N.P.V. of £305m and a return of 11.1%. Correspondingly, the cash flow demands would be high — up to £60m in some years.

(ii) The smallest programme (which would of course be part of each programme) would take 15 years. It would terminate at Newcastle and would only cover Edinburgh to Glasgow/Carstairs but nowhere else in Scotland. It would exclude Birmingham to Bristol and the whole of the Western Region. It presents the smallest N.P.V. (£84m) and the rate of return was 9.9%. 62% of passenger and 38% of freight traffic would have electric traction.

(iii) A possibility was suggested for a medium programme, i.e. to Edinburgh, Glasgow, Carstairs, and Midland mainline to Sheffield, Liverpool to York, the whole of the North-East/South-West route between York, Birmingham, Bristol and Reading to Swansea and Plymouth. Thus 75% of passenger and 54% of freight would be electrically hauled.

(iv) The essential decisions related to how quickly to proceed and when to start. Various numbers of work trains and rates of progress were illustrated, starting from a planned and deliberate build up period of 3 - 4 years to allow planning, design and assembly of teams and resources. These teams could complete the medium option within 25 years but would need 30 years for the largest. At these rates the N.P.V of the medium option would be £202m and that or the largest 249m.

(v) Four simultaneous teams would complete the medium option in 15 years and the largest in 20. The annual cash flow demands would be higher but the N.P.Vs would also be better, i.e. £239m for the medium and £305m for the large.

(vi) When to start? A delay in starting would cost money and reduce the N.P.V. of the larger programmes. Probably an early start would be advantageous because a year would elapse before any significant expenditure (and progress) would be incurred and three or four years would be needed to build up a steady rate of work. An early start would also provide continuity of work to keep together the existing skilled construction team.

2. The general approach to the study

2.1 It was decided to make a full, year by year, discounted cash flow appraisal of each optional extent of electrification considering all the relevant costs and revenues.

2.2 A cost benefit appraisal was not pursued because the main benefits of electrification were considered to fall to the commercial businesses of the railway.

2.3 Some of the wider economical social consequences, not financially quantifiable, were examined.

3. The options evaluated.

3.1 (i) A base case (option 1) - The existing diesel operated railway plus a few currently planned electrification projects.

(ii) Option 2- A modest extension of electrification.

(iii) Option 3 & 4 - Medium extensions with emphasis on passenger and freight flows. They were so similar and were considered one (3) in future work.

(iv) Option 5 - A more extensive network.

3.2 In more detail, the options were:

Option 2. East Coast main line to Newcastle, Leeds; Midland main line to Sheffield; Birmingham to York; Edinburgh to Glasgow and Carstairs.

Option 3. All main intercity routes. Also Birmingham/Coventry to Oxford and several important freight routes.

Option 5. As for 3 and including Plymouth to Penzance, Holyhead, Edinburgh to Aberdeen, Doncaster to Hull.

Note. Southern region and major commuter routes were excluded from the study.

3.3 The extent of each option is shown in the table below.

Table 1

Electrified mileage in each option (excludes sidings)

Option	Route Miles	Single Track Miles	% of Passenger & freight loaded train miles electrically hauled.	
			P	F
1	2580	6390	52	23
2	3460	8770	62	38
3	4620	11450	75	54
5	5750	13610	83	68

4. Rates of electrification

4.1 Rates of electrification would effect investment, cascading of traction and rolling stock, flow of costs and benefits and returns. Two rates were considered for the larger options (3 and 5). Six permutations were examined i.e.

Option 1 (base)
Option 2 (small)
Option 3 slow
Option 3 fast
Option 5 slow
Option 5 fast

5. Order of Electrification

5.1 There could be very many choices of the order of work, but only one detailed construction programme was used for each option using operational judgement. This sought to give maximum early benefits, including construction capacity, premature traction & rolling stock displacement considerations, signalling schemes, abortive replacement, flows of work.

5.2 Assessments were made for each option and rate showing annual volumes of work, to complete not later than 2010, including reasonable rates of progress and construction and supply abilities.

5.3 These programmes enabled the timing of expenditure and conversion to electric traction to be measured and the effects upon the necessary replacement programmes for existing traction and rolling stock, in an attempt to avoid replacement of diesel units, which might have to be scrapped prematurely.

6. The financial analysis

6.1 Justification for electrification requires that increases in earnings and reductions in relevant costs (i.e., excluding those not directly affected by electrification) must exceed the costs of constructing and maintaining the electrification fixed works.

6.2 In the study, increases in passenger revenue were taken into account — but not freight, which was considered to be charging at market rates not likely to be affected by the form of traction.

6.3 The returns from electrification were calculated by comparing them with those of the base case (option 1).

6.4 The main inputs were provided by British Rail with assumptions endorsed by the Department of Transport, derived from the BR Board's studies of future developments.

6.5 1978 price levels were used generally, but energy and staff costs and rail fares were increased in real terms throughout the period of the review. The Treasury agreed to a 7% discount rate to bring all costs and revenues to 1978 levels.

7. The base case

7.1 The base case (Option 1) was established year by year on a financial basis with assumptions about the future size and shape of the railway businesses without substantial further electrification. The passenger service network would be the same with inter-city traffic growing by 1% per year with service improvements arising from improved forms of equipment e.g. A.P.T [Advanced Passenger Trains] and H.S.Ts. Fares were, generally assumed to rise at a rate of 1% a year. It was assumed that there would be a total volume of 175m tonnes of freight traffic per year.

7.2 Annual costs and revenues of the base case were projected forward over 30 years and the residual values calculated to allow comparisons with the slowest electrification programme evaluated.

8. The Electrification options

8.1 The five electrification options figures were compared with the base case, reflecting expected increases in traffic and reductions in costs from electrification and real income increases. Losses due to operating interruptions, whilst work was carried out, were incorporated.

8.2 Capital cost variations, maintenance economies, fuel cost reductions and the cost of premature retirement or life extensions of diesel equipment to allow for phasing in of electrified services were taken to account.

8.3 Wider effects

The effects upon many wider aspects were considered where it was not possible to apply a financial dimension, i.e., energy saving reductions in the use of oil, manufacturing industry, the environment.

9. The Financial Results

9.1 The financial results of the electrification options compared with the base (option 1) are shown in table 2 below.

Table 2

	NPV surplus (£m 1978 money values, discounted at 7%)	I.R.R %
Option 2	70	9.9
Option 3 Slow	169	11
Option 3 Fast	200	11
Option 5 Slow	208	11.1
Option 5 Fast	255	11.1

9.2 The sources of benefits and costs in each option are shown in Table 3 below. The first column shows the present values of the base case and subsequent columns show the relevant advantages of the other options by comparison.

TABLE 3 - NPV's OF ELECTRIFICATION OPTIONS COMPARED WITH BASE CASE (£m1978 VALUES DISCOUNTED AT 7%) BY REVENUE AND COST CATEGORY

		NPV Better/Worse than Option 1				
	NPV of Option 1	Option 2	Option 3 slow	Option 3 fast	Option 5 slow	Option 5 fast
Passenger Revenue	10353	57	102	123	114	141
Working expenses						
Oil	1356	187	340	411	395	486
Electricity	695	-111	-198	-245	-231	-294
Crew	2049	13	21	28	39	50
Traction & rolling stock maintenance	3093	72	130	166	158	201
Fixed works maintenance	7	-26	-40	-47	-48	-58
Total	7200	134	254	313	312	386
Investment						
Traction & rolling stock	1286	13	27	25	40	54
Fixed works	32	-134	-213	-261	-258	-326
Total	1317	-121	-186	-236	-218	-271
NPV Grand Total	1835	70	169	200	208	255

Note - Figures in all tables are affected by rounding.

9.3 All the options show that the present value of the cost savings exceed the additional costs of fixed works. Savings on fuel and T &RS maintenance are similar magnitudes in each option and together produce most of the cost savings; crew costs are less, so is T &RS investment mostly in the freight business. However, each option requires more capital expenditure than the base and fixed works maintenance increase. Each option produces more passenger revenue benefits.

9.4 The businesses benefit from electrification depending upon its extent. Rather more than two thirds of the benefits go to the passenger business, a higher proportion in the smaller options than in option 5. About one quarter of all the benefits is increased passenger revenue. Moving to the larger options (3Fast to 5Fast) increases freight gross benefits from £133m to £193m, i.e., nearly half the extra benefit. This is because option 5 was designed to cover a wider freight network and extra regional passenger services outside inter-city and London and South East. In summary, the smaller options can be justified on passenger benefits alone but freight benefits would justify the larger programmes. See Tables 4 and 5 for details.

TABLE 4 - NPVs OF ELECTRIFICATION OPTIONS COMPARED WITH BASE CASE (£m 1978 VALUES DISCOUNTED AT 7%) - BY BUSINESSES

		Better/worse(-) than base case				
	NPV of Base Case	Option 2	Option 3 Slow	Option 3 Fast	Option 5 Slow	Option 5 Fast
Intercity revenues	5617	53	95	113	104	127
Direct Costs	2723	90	170	182	190	212
NET TOTAL	2894	143	265	295	294	339
Other Passenger Revenues	4736	3	6	10	10	15
Direct Costs	3074	14	23	42	37	58
NET TOTAL	1662	17	29	52	47	72
Passenger NET TOTAL	4556	160	295	347	341	411
Freight Direct Costs	1992	64	111	133	151	193
Parcels Departmental Direct costs	690	5	17	28	23	35
Fixed works costs	39	-160	-253	-308	-307	-384
GRAND TOTAL	1835	70	169	200	208	255

TABLE 5 - INCREMENTAL COMPARISONS OF NPVs BY BUSINESSES (£m 1978 VALUES 7% DISCOUNT)

	Option 2-1	Option 3 Fast -2	Option 3 Fast -1	Option 5 Fast- 3 Fast	Option 5 Fast .2	Option 5 Fast -1
Intercity	143	152	295	44	196	339
Other Passenger	17	35	52	20	55	72
Freight	64	69	133	60	129	193
Parcels and departmental	5	23	28	7	30	35
Infrastructure	-160	-148	-308	-76	-224	-384
NET TOTAL	70	130	200	55	185	255

9.5 The report gives totals of T&RS fleets available in 1981 and those needed in 2011 in all options, with present expenditure and average annual expenditure on building and refurbishing over the period. Also tabled is the average annual investment in fixed works. Those tables reveal the high level of investment needed to continue the existing traction policies and the reductions made possible by further electrification, e.g., in Option 5 Fast the total T &RS investment is less than for the base case, but this is offset to same extent by the additional fixed works costs.

9.6 During the construction period electrification programmes produce negative cash flows. All the options produce negative cash flows until the mid 1990's, the size being more dependent upon the rate of work rather than the extent. Table 6 shows details of the situation.

Table 6 - AVERAGE ANNUAL NET CASH FLOW FROM ELECTRIFICATION COMPARED WITH OPTION 1 (fm 1978 MONEY VALUES 7% DISCOUNT).

	Option 2	Option 3 Slow	Option 3 Fast	Option 5 Slow	Option 5 Fast	
1981-85	-11.9	-10.5	-19	-12.7	-19.9	
1986.90	-9.4	-13.7	-22.4	-12.9	-27.9	Cash flows are negative
1991-95	-1.5	-23.6	-24.8	26.1	-34.1	
1996-2000	25.3	10.3	74	8.6	73.1	
2001-2005	29.5	72.6	86.6	58.6	108.3	Cash flows are positive
2006-2010	34.3	84.9	77.4	108.1	108.2	

9.7 It can be seen from this table that the cash flow position improves over progress with the options.

9.8 Other details in the report show the positive impact of fuel costs and maintenance on the case for electrification but, also, the larger net investment requirement of the faster options.

9.9 The years of pay-back are shown in the report, which detail is helpful in assessing risk. In all options the pay-back occurs several years after the start of work, but within the appraisal period. This later time could be acceptable as the investment is spread over a number of years and not concentrated in the first few. Table 7 shows the payback years.

Table 7 - Pay-back years

Option 2	Option 3 Slow	Option 3 Fast	Option 5 Slow	Option 5 Fast
2009	2009	2006	2010	2007
Note start year is 1981				

9.10 Summarised, these results show that on the standard traffic forecasts all the electrification options yield a positive N.P.V., the faster options produce better N.P.V.s than the slower, and the larger are better than the smaller. The rate of return is broadly 11% in real terms in all the options, except 2. Cash flows are negative until mid-programmes but all break even before the end.

10. Test of financial results

10.1 Sensitivity tests covering up and downside variations of the key assumptions were made to see how far the financial results would be undermined or improved by changes in individual or combinations of items. They were in the following areas:-

(i) Energy costs- These would have a very important effect, with the extents of divergence between electricity and oil costs being significant. The estimates used were prepared by the Department of Energy. In all cases, except where the price of oil was regarded as standard or low, the improvements in electric traction N.P.V. were significant.

At the time of the study, the Department of Energy thought that crude oil prices could double by 2000 and felt that the potential for the divergence of prices was growing. In such a situation the N.P.V. for the largest fastest option 5 Fast increased from 255 to 342.

(ii) Traffic levels- Results are sensitive to passenger traffic levels and showed that if the levels dropped the N.P.V. was affected quite seriously, but if it remained the same or grew the results improved. An increase in freight traffic ‘under these wires’ was assumed and this produced considerably better results. Overall the most pessimistic traffic forecasts would still leave IRRs above 7%.

(iii) Frequency of services- Lower services and frequencies produced lower N.P.V.s because major benefits of electrification came from the savings in operating costs and traction and rolling stock fleets at high levels of service and utilisation.

(iv) Operating costs and traction and rolling stock maintenances- A 10% variation — up or down — of diesel and electric traction and rolling stock fleet levels could have significant effects upon results. If the variation was favourable, i.e. diesel +10% and electricity -10%, there would be an N.P.V. improvement in option 5 Fast of about 17%. In the opposite situation, the effect was reversed. These quite large changes reflect the fact that changes in the costs of T &RS maintenance provide one of the largest benefits from electrification.

(v) Operating costs- Overall, fixed equipment maintenance costs are small and variations make only small changes to the financial results.

(vi) Staff costs - An electrified railway requires fewer staff than a diesel railway and higher staff costs increase the value of the saving. The statistical tests showed that electrification produced savings of about 10% in passenger crew costs and 20% in freight and changes would have a relatively small effect upon the results.

(vii) Capital costs, T&RS and fixed works - A 10% variation in capital costs provided a range of +37 to -32 differences in N.P.V. of option 5 Fast — positive if diesel increased and negative if electric increased. A 10% variation in fixed works casual costs would result in a + or - change of 33.

10.2 Summary of sensitivity tests.

(i) None of the individual tests comes at all close to eliminating the N.P.V. of the electrification options. Each taken individually would still leave the IRR well above 7% and none upset the ranking of the options.

(ii) Various combinations of tests were made based upon judgements of likely combinations and occurrences; none showed sufficient significantly adverse effects to overturn the positive N.P.V.s, the effects being greater in the smaller options than the larger.

(iii) The review concluded that, in standard traffic forecast situations and likely energy costs forecasts, an electrification programme could be expected, confidently, to earn a rate of return well above 7%. If higher traffic levels occurred the increase would be enhanced.

11. Wider effects

The effects of electrification upon such matters as energy savings, benefits to the UK manufacturing industry, railway safety, noise and pollution, visual intrusion, landscape and old buildings, land use and settlement patterns and the transfer of traffic from other transport modes was considered. In all cases there would be no serious adverse effects. In particular, there would be a worthwhile reduction in oil consumption. The increase in electricity consumption would be offset by greater flexibility in the use of basic fuels and there would be a reduction in pollution.

NOTE:

This summary of the report presents the main conclusions and the important supporting figures behind the results. It does not describe the detailed methodology, the computer processes and calculations and the supporting arithmetic — all of which were accepted as relevant and appropriate when the report was published. These details can be studied, if required, within the pages of the final and interim reports themselves.