Mainline Upgrading - Evaluation of a Range of Options for the Sydney - Brisbane Rail Link

Report

This study is one of a series concerned with the evaluation of upgrading options for inter-capital rail links in Australia. Analysis indicated that the Sydney-Brisbane line is already exhibiting signs of congestion and, given the expected traffic growth, will become seriously congested in the mid-1980s unless upgrading action is taken. The range of upgrading options considered include grade easement, centralised traffic control and crossing loop extensions.

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BUREAU OF TRANSPORT ECONOMICS

MAINLINE UPGRADING - EVALUATION OF A RANGE OF OPTIONS FOR THE SYDNEY-BRISBANE RAIL LINK

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FOREWORD

This study is one of a series carried out by the Bureau of Transport Economics to evaluate upgrading options for the inter-capital rail links in Australia. Various combinations of alternative investment plans and operating practices are evaluated in this report.

The results indicate that commitment of resources to increase the capacity of the line is justified on both commercial and resource cost grounds. For the potential benefits to be realised, however, it is essential that upgrading be undertaken simultaneously on both sides of the New South Wales-Queensland border and so close co-operation between the respective railway authorities and State Governments is vital.

The study was carried out by a team from the Operations Research Branch led by A.J. Storrey assisted by A. Edquist and K. Porra under the general direction of R.W.L. Wyers.

The study could not have been undertaken without the co-operation and assistance of officers of the Public Transport Commission of New South Wales and Queensland Railways. I would particularly like to thank I. de Mellow and T. Boardman for their work in maintaining effective liaison between the study team and the operational units of the Public Transport Commission.

(G. K. R. REID)
Acting Director

Bureau of Transport Economics,
Canberra,
August, 1977.

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SUMMARY

This study is one of a series concerned with the evaluation of upgrading options for inter-capital rail links in Australia. The series of upgrading studies themselves are part of a general assessment of railway freight operations being carried out at the request of the Australia Transport Advisory Council (ATAC).

Analysis indicated that the Sydney-Brisbane line is already exhibiting signs of congestion and, given the expected traffic growth, will become seriously congested in the mid-1980s unless upgrading action is taken. The range of upgrading options considered include grade easement, centralised traffic control and crossing loop extensions.

The identified upgrading options were evaluated from two viewpoints. Firstly options were assessed from the commercial viewpoint of the railway systems and secondly from the community viewpoint of optimal allocation of resources within the transport sector of the economy.

The study reveals that the most effective action is to introduce Centralised Traffic Control and extend all crossing loops to 900 metres immediately. The main benefits of such upgradings appear in the form of reduced costs to the railway systems although there is a small benefit in the form of reduced road usage. The social benefit-cost ratio of such an upgrading is in the range of 2.6 to 3.5 for discount rates between 7 and 12 per cent.

CHAPTER 1 - INTRODUCTION

Following a request by the Australian Transport Advisory Council (ATAC) in July 1973, the Bureau of Transport Economics has carried out a series of studies on railway freight operations. In 1975 two reports were published covering evaluations of a range of options for upgrading the Sydney-Melbourne and Melbourne-Serviceton links[(1)]. Studies have now been completed for the remaining links in the inter-capital rail network and this report contains details of the evaluation of upgrading options for the Sydney-Brisbane link.

Initial examination of the link indicated that it is the most congested of the inter-capital lines and that serious disruption to service because of delays is likely to occur from the mid-1980s onwards. This fact had been recognised by the railways and plans were in hand to upgrade the line by a number of methods including easement of grades, instalation of Centralised Traffic Control (CTC) and the extension of passing loops to 900 metres.

The report does not address the question of terminal development and upgrading which may be necessary as traffic grows. This is regarded as a separate item which interacts strongly with other parts of the transport system and which should be treated as a separate study. It must be recognised, however, that upgrading of the main line alone may not solve congestion problems for the link, but may simply move them to the terminals.

Another factor which is outside the terms of reference of the study, but which has an important bearing on the operation of the link, is the fact that two separate railway systems are involved (the NSW Public Transport Commission and Queensland Railways).

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(1) Bureau of Transport Economics, 'Mainline Upgrading - evaluation of a range of options for the Melbourne-Sydney rail link' (AGPS, Canberra, November 1975). Bureau of Transport Economics 'Mainline Upgrading - evaluation of a range of options for the Melbourne-Serviceton rail link' (AGPS, Canberra, November 1975).

These two organisations view the Sydney-Brisbane link in different ways because of its different relationship with the remainder of their individual systems. If the proposed upgrading is to be successful it must be implemented simultaneously on both sides of the state border. Hence co-operation between the two State Governments is essential to the success of the scheme. Since the benefits and costs related to upgrading the line are not equally divided between the two States it is apparent that negotiation and co-operation between them and the Commonwealth Government in respect of national interests, will be needed for an effective upgrading program to be developed.

Two bases for evaluation have been used in the study. Firstly, alternatives have been assessed in commercial terms, i.e. on the basis of their impact on railway finances. In this case the trade-off between the capital cost of the upgrading and the returns in terms of increased revenue and reduced operating costs has been calculated. Secondly an evaluation has been undertaken on the basis of optimal allocation of community resources in the transport sector. In this case the analysis is based on the total resource cost of carrying goods by rail, as against road or sea, as a function of the capacity of the railway. These two bases for evaluation would not necessarily be expected to produce the same relative ranking of alternative projects, but in this study the same upgrading options emerge as optimal under both sets of criteria.

It should be noted that this report is not intended as a development programme for the Sydney-Brisbane link, but simply indicates that upgrading options of the type proposed are justified economically. Many additional factors and constraints must be taken into account by the railway authorities in developing an effective works programme for upgrading.

The report is written in six chapters. The second chapter describes the existing facilities and current traffic on the link. The third contains the projections of future traffic on the line.

Chapter 4 discusses the upgrading options considered in the study and Chapter 5 describes the method of evaluation and the assumptions made. Chapter 6 presents details of the actual evaluations and the conclusions reached.

CHAPTER 2 - DESCRIPTION OF EXISTING FACILITIES

PHYSICAL LAYOUT

The Sydney-Brisbane line has been divided into three sections: Sydney-Telarah, Telarah-Greenbank, Greenbank-South Brisbane[(1)] The sections of line between Sydney and Telarah and between Greenbank and South Brisbane were not considered in detail in this study. The multiple track section from Sydney to Telarah carries a high volume of commuter and short distance coal and freight traffic. The single track section from Greenbank to South Brisbane carries a high volume of shunting trips and light engine movements and links the major Brisbane freight and passenger terminals. It is preferable to evaluate possible upgradings for these two sections in more localised studies.

Figure 2.1 shows a schematic layout of the section of line from Telarah to Greenbank giving the position and length of crossing loops. There is an alternative route between Maitland and Brisbane via Tenterfield and Warwick. However, this route was not considered a viable alternative because of its length, its grades and the need to trans-ship freight between the narrow and standard gauge vehicles at Wallangarra. The length of the majority of the crossing loops on the main line is inadequate to take full advantage of the hauling power of the Class 44 mainline diesel locomotive which is used on this line. The loops were adequate for steam locomotives which were less powerful than the diesel and which were not frequently coupled together into double or triple headers as are the diesel locomotives.

The crossing loops are much more widely spaced north of Casino where there are longer average section running times.

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(1) Telarah is 195 kilometres north of Sydney and Greenbank 31 kilometres south of Brisbane.

KEREWONG

DISTANCE FROM SYDNEY (KM)		LOOP LENGTH (METRES)
433	KENDALL	405
418	JOHNS RIVER	415
403	COOPERNOOK	453
392	MELINGA	417
379	TAREE	470
367	WINGHAM	452
360	KILLAWARRA	445
353	KIMBRIKI	402
342	MOUNT GEORGE	393
334	BUNDOOK	422
324	BULLIAC	402
316	YUMBUMGA	429
309	GLOUCESTER	595
302	BERRICO	401
291	CRAVEN	453
278	WEISMANTLES	402
267	STROUND ROAD	422
254	MONKERAI	400
245	DUNGOG	394 & 407
232	WALLAROBBA	404
223	KILBRIDE	489
213	PATERSON	534
203	MINDARIBBA	404
195	TELARAH	605

FIGURE 2.1

POSITION AND LENGTH OF EXISTING LOOPS

DISTANCE FROM SYDNEY (KM)			LOOP LENGTH (METRES)
		RAPPVILLE	
	756	CAMIRA CREEK	392
	743	BANYABBA	433
	728	GURRANANG	381
	714	KYARRAN	393
	699	GRAFTON	777
	696	GRAFTON CITY	415
	683	BRAUNSTONE	438
	664	KUNGALA	437
	652	GLENREAGH	462
DORRIGO			
	640	NANA GLEN	454
	628	CORAMBA	393
	620	LONDRIGANS	424
	608	COFFS HARBOUR	407
	596	BONVILLE	425
	586	RALEIGH	388
	565	NAMBUCCA HEADS	410
	552	MACKSVILLE	412
	534	EUNGAI	395
	521	TAMBAN	402
	503	KEMPSEY	410
	487	KUNDABUNG	406
	472	TELEGRAPH POINT	417
	455	WAUCHOPE	479
	446	KEREWONG	432
		KENDALL	

FIGURE 2.1

POSITION AND LENGTH OF EXISTING LOOPS

(CONTINUED)

DISTANCE FROM SYDNEY (KM)		LOOP LENGTH (METRES)
956	GREENBANK	412
938	KAGARU	427
909	TAMROOKUM	399
888	GLENAPP	421
875	BORDER LOOP	419
853	THE RISK	403
834	KYOGLE	385
816	FAIRY HILL	385
		MURWILLUMBAH
805	CASINO	450
794	LEEVILLE	383
776	RAPPVILLE	390

CAMIRA CREEK

FIGURE 2.1
POSITION AND LENGTH OF EXISTING LOOPS
(CONTINUED)

The ruling grade loads, in trailing tonnes, for the Class 44 locomotives (1340 kW) on the various sections are:

SECTION	UP (tonnes)	DOWN (tonnes)
Sydney to Telarah	620	620
Telarah to Grafton	1020	1020
Grafton to Casino	715	715
Casino to Brisbane	820	820

The track is laid with 53 kg rails in the main line and 40 or 45 kg rails in crossing loops.

The line was constructed in sections between 1905 and 1930 primarily for the carriage of intrastate rural produce and it was not until assistance was received from the Commonwealth that the standard gauge line was extended to South Brisbane and inter-system traffic diverted from the Wallangarra line.

Because of the terrain and numerous waterways and for economy reasons the alignment is a series of curves with very few straight sections. The sharpness of the curves imposes permanent speed restrictions. Thus, although the track structure is to Class 1 standard for 115 km/h speeds, there are few sections where this speed can be permitted or attained.

Bridges are numerous and consist of 4.3 m or 7.3 m timber spans, transom top, on timber trestles.

Major crossings have steel girder and truss spans but almost invariably have timber approach spans.

The timber spans have received regular maintenance, but because of age and the increased loadings are now considered by Public Transport Commission engineers to have reached the end of their economic life. In a number of instances these bridges are subject to speed restrictions because of deterioration due to age.

SIGNALLING

The section of line between Sydney and Telarah is double track with automatic signalling except between Fassifern and Cockle Creek where Block Telegraph working is used.

All sections of the line between Telarah and South Brisbane rely on the Electric Staff token system of safeworking. The 63 intermediate crossing stations are manned by signalmen for almost all periods of each day and night. However, provision exists for train crews to perform the safeworking functions at some locations when a signalman is not on duty. This causes a delay of 7 to 10 minutes per train.

Equipment is provided for the staffs to exchange automatically and without the train reducing speed at all signal boxes (crossing loops) except Taree North and South, Grafton City, Casino, Glenapp, Tamrookum, Kagaru, Greenbank, Beaudesert Road, Clapham, Yeerongpilly and South Brisbane. At each of these signal boxes the staff is exchanged by hand which necessitates the train slowing to 25 km/h during daylight and 15 km/h during darkness.

Under the Electric Staff system of safeworking a train which is being crossed at a station must arrive 5 minutes before the arrival of the train from the opposite direction if the latter is not to be delayed. It is usually able to depart 5 minutes after that train has passed.

TERMINALS

This report does not consider the implications of traffic growth on the capacity of terminals as the whole question of terminal performance and freight wagon utilisation is under separate study by the Bureau. It is obvious, however, that the upgrading of terminals and the mainlines must be co-ordinated and balanced if the full benefits of upgrading are to be realised.

The Brisbane terminals, in particular, will have capacity problems within a few years if the traffic volume grows as expected. There were severe problems in these yards during the economic boom in the early 1970s. In a study[1] of the Acacia Ridge terminal in 1974, the Bureau showed that there was substantial economic benefit to be gained from developing that terminal quickly. Queensland Railways intends to move all handling of steel, motor cars and containers, except that destined for private sidings, to Acacia Ridge. This will relieve some of the pressure on the Clapham yard.

PRESENT TRAFFIC

The trains on the line can be divided into five different classes related to the importance of the traffic they carry. The priority allocated to each class for the purposes of computer simulation is shown below. These priorities coincide approximately with those used when the timetables are prepared. The priority given to any train on any particular day by a train controller is, of course, based on many additional factors.

PRIORITY	TRAIN TYPE
1	Express passenger services
2	North Coast Mail and highest priority express freight trains which must run to schedule i.e. perishables, flexivans
3	Express freight trains
4	Steel and general goods trains
5	Empties returning from Brisbane

The distribution of the traffic within these train classes for a typical busy day in 1976 is given in Table 2.1.

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(1) Bureau of Transport Economics, 'Development of a Rail Freight Terminal at Acacia Ridge' (February 1974).

TABLE 2.1 - NUMBER OF TRAINS PER PRIORITY CLASS

Section	Priority Class 1	2	3	4	5	Total
Telarah-Greenbank	2	6	4	4	4	20
Telarah-Grafton	2	2	2	4	-	10
Telarah-Casino	2	1	1	-	-	4
	6	9	7	8	4	34

The trains simulated do not include slow goods or wayside pickup trains. These trains are assumed to run at times which cause no delay to the more important simulated trains.

The simulated trains average approximately 800 gross trailing tonnes. The major constraint in trying to raise the average train load by multiple locomotive working is the length of the crossing loops. At present, only steel trains are worked with two locomotives hauling 1500 tonnes. The high density of steel enables these trains to fit into all crossing loops.

CHAPTER 3 - RAIL FREIGHT PROJECTIONS 1975-1995

The standard gauge rail link between Sydney and Brisbane provides four services:

- interstate freight;
- NSW intrastate freight;
- interstate passenger; and
- NSW intrastate passenger.

This chapter of the report is concerned with forecasting the demands for each of these services over the period 1975-76 to 1994-95.

Prediction of any economic activity over a 20 year time span is a difficult task and this comment certainly applies to long distance rail transportation. Examination of historical data for use in long term predictions is complicated by the dominance of cyclical and transient movements which tend to obscure long run trends.

Generally the approach has been to use expected growth in production as a basis for growth in transportation. The important interstate component involves the examination of both total freight growth and the road/rail/sea traffic split. In particular, the substantial competition and subsequent scope for substitution between road and rail must be considered in order to ensure consistent forecasts for individual modes and total flows.

PASSENGER MOVEMENTS

Over the past few years the number of passengers using the interstate passenger trains has remained stable. The patronage of the intrastate passenger trains has declined, but the Commission (P.T.C.) expects to halt this decline by 1977. Under these circumstances it was assumed that the number of passenger services offered will remain constant at the present level.

INTRASTATE FREIGHT

Intrastate rail freight levels remained static over the;period from 1956 to 1970, but there is evidence of a downward trend since then. For this study it was assumed that intrastate rail services will continue at current levels throughout the study period.

INTERSTATE FREIGHT

Data are available on the total interstate freight movements between Sydney and Brisbane for the years 1971-72 to 1974-75. The modal split between rail, road and sea transport is given in Table 3.1.

TABLE 3.1 - ESTIMATED FREIGHT TRAFFIC: SYDNEY - BRISBANE, BY MODE ('000 tonnes)

Year	Rail	Road	Sea	Total
1971-72	1201 (16%)	2947 (39%)	3339 (45%)	7487 (100%)
1972-73	1449 (20%)	2865 (39%)	3111 (42%)	7425 (100%)
1973-74	1550 (19%)	2929 (36%)	3669 (45%)	8148 (100%)
1974-75	1534 (18%)	3026 (36%)	3820 (46%)	8380 (100%)
Average	1434 (18%)	2942 (38%)	3485 (44%)	7860 (100%)

Sources: (1) Rail - Derived from P.T.C. and Bureau 'Development of a rail freight terminal at Acacia Ridge' (February 1974).
(2) Road - Interstate truck movements monitored at Gailes and Carmera, extracted from 'Truck and Bus Transportation'. Assumed average payload of 20 tonnes.
(3) Sea - Derived from Bureau reports 'Port Authority Cargo Movements', 1971-72, 1972-73, 1973-74, 1974-75.

Estimates of the major commodities for the total freight task over the 3 years 1972-73 to 1974-75 are detailed in Table 3.2. The four major commodity groups account for more than 85 per cent of the total freight task in each year.

TABLE 3.2 - ESTIMATED FREIGHT TRAFFIC: SYDNEY - BRISBANE, BY COMMODITY

('000 tonnes)

Commodity Group	1972-73	1973-74	1974-75
Petroleum, fertilisers & chemicals	3206 (43%)	3768 (46%)	3970 (48%)
Containers and bulk loading	1435 (19%)	1441 (18%)	1505 (18%)
Steel and metal products	934 (13%)	1018 (12%)	984 (12%)
Fruit, vegetables & other foodstuffs	815 (11%)	718 (9%)	772 (9%)
General goods	518 (7%)	464 (6%)	650 (8%)
Building materials	246 (3%)	476 (6%)	288 (3%)
Other farm products	229 (3%)	236 (3%)	171 (2%)
Livestock	30 (0%)	26 (0%)	10 (0%)
Total	7413(100%)	8147(100%)	8350 (100%)

TABLE 3.3 - COMMODITY ANALYSIS BY MODE 1974-75

('000 tonnes)

Commodity Group	Rail		Road		Sea		Total	
Petroleum, fértilisers & chemicals	58	(1%)	278	(7%)	3634	(92%)	3970	(100%)
Containers & bulk loading	709	(47%)	796	(53%)	-		1505	(100%)
Steel & metal products	520	(53%)	426	(43%)	38	(4%)	984	(100%)
Fruit, vegetables & other foodstuffs	94	(12%)	678	(88%)	-		772	(100%)
General goods	105	(16%)	400	(62%)	145	(22%)	650	(100%)
Building materials	15	(5%)	270	(94%)	3	(1%)	288	(100%)
Other farm products	32	(19%)	139	(81%)	-		171	(100%)
Livestock	1	(10%)	9	(90%)	-		10	(100%)
Total	1534	(18%)	2996	(36%)	3820	(46%)	8350	(100%)

An indication of commodity tonnages is avalable for rail and sea traffic, but not for road. However, based on the Bureau 1972-73 sample of traffic through Berowra and the knowledge that the total volume of road freight is about four times greater than that moving through Berowra, road tonnages have been assigned to the major commodity groups in the same proportion as traffic moving through Berowra. The commodity analysis by mode thus obtained is typified by the analysis for 1974-75 is shown in Table 3.3.

Commodity group 1 which dominates the movement by sea in the Sydney-Brisbane corridor consists mainly of petroleum (3.5 million tonnes),originates in Victoria and is almost exclusively carried by ship. It is certain that this situation will continue. The balance of the commodities moved by sea comprises less than 4 per cent of the total transport task. In this situation, it is assumed that those products carried by sea are most unlikely to shift to either rail or road. Hence sea transport is excluded from the modal split analysis which is restricted to rail and road. Table 3.4 presents the results of the modal split analysis for the years 1971-72 to 1974-75.

TABLE 3.4 - RAIL/ROAD INTERMODAL SPLIT, SYDNEY - BRISBANE

Year	Rail	Road	Total
1971-72	1201 (29%)	2947 (71%)	4148 (100%)
1972-73	1449 (34%)	2865 (66%)	4314 (100%)
1973-74	1550 (35%)	2929 (65%)	4479 (100%)
1974-75	1534 (34%)	3026 (66%)	4560 (100%)
Average	1434 (33%)	2942 (67%)	4376 (100%)

The implicit assumption is made that no major changes will occur in competing modes and, on this basis, that the modal split between rail and road for the land transport task will remain constant over the study period.

In forecasting the total transport task growth rates for each commodity class were obtained using indicators derived from 10 year trends in various sectors of the Queensland economy. The economic indicators used were:

- the building industry (value of new building work completed);
- the manufacturing industry (value added);
- overseas imports, particularly imports through NSW ports;
- fruit and vegetable production; and
- grain production.

For commodity groups to which the indicators do not apply, qualitative information from Queensland Railways and the P.T.C. of NSW was used to determine the growth rates shown in Table 3.5.

TABLE 3.5 - TRAFFIC GROWTH RATES, BY COMMODITY

Commodity Group	Assumed Growth Rate
Petroleum, fertilisers and chemicals	4.7%
Containers & bulk loading	2.6%
Steel and metal products	4.7%
Fruit, vegetables and other foodstuffs	4.0%
General goods	0.0%
Building materials	5.0%
Other farm products	1.8%
Livestock	0.0%

These forecasts of traffic to be shared between road and rail imply an average growth rate of 3.5 per cent compound over the study period.

CHAPTER 4 - UPGRADING ALTERNATIVES

For the purposes of this study, the standard gauge link between Sydney and Brisbane has been considered in three sections: Sydney-Telarah, Telarah-Greenbank, Greenbank-South Brisbane. A detailed description of the existing sections is given in Chapter 1 of this report. The main limitations of each section seem to be:

- Sydney-Telarah: a succession of steep grades, excessive headway on some parts of the multiple track line, and insufficient loops available for overtaking purposes;

- Telarah-Greenbank: congestion due to slow mechanical signalling procedures based on Electric Staff working, insufficient long crossing loops; and relatively long section running times north of Kyogle;

- Greenbank-South Brisbane: this section overlaps the Brisbane suburban system and has similar problems to the Telarah-Greenbank section.

SYDNEY-TELARAH

Grade easement

The length of track involved is such that if a plan to ease grades to 1:75, or even 1:80, were considered it is highly unlikely to be economically justified with the current traffic level. The costs would be high relative to the benefits of easement. These would be mainly motive power savings which could accrue only if the entire section of the line is regraded. This upgrading option is not considered further in this study.

TELARAH-GREENBANK

CTC schemes

In addition to replacement of existing mechanical signalling by power signalling, and remote control of the power signals from one central point, CTC schemes may also incorporate the construction of new crossing loops or extension and rationalisation of existing crossing loops. Selective extension of crossing loops may produce marked decreases in delays if long trains are timetabled to cross at them although this may not be easy to achieve in practice. Further delay reductions are expected from the introduction of power signalling, especially on densely trafficked lines, because it reduces each crossing delay from about five minutes for the manual exchange of staff, to about one minute. The reduction of crossing delays can lead to significant increases in line capacity. In addition, CTC eliminates potential delays from human factors such as dropped or missed tokens, illness of signalmen or simple failure to clear signals after a train has passed.

Remote control of the power signals has no direct effect on line capacity, but allows considerable manpower savings as stations do not have to be manned for signalling purposes. Centralised control may, however, lead to more effective scheduling by considerably facilitating the train controller's task, and thus improving line capacity indirectly, but this possible benefit is not quantified in this study.

CTC on existing loops

The P.T.C. plans to call tenders in early 1977 for the installation of CTC equipment on existing crossing loops. The plans cover only the section from Telarah to Casino where the P.T.C. expects CTC to be implemented by June 1980. In this study, we have examined the installation of CTC on the whole section from Telarah to Greenbank, which would take 6 months longer to implement, and which would require the co-operation of the Queensland and, possibly, the Commonwealth Governments.

The capital costs of this scheme are:

	$(1976)
. install local signalling on 60 existing crossing loops @ $150 000 per loop	9 000 000
. CTC equipment @ $25 000 per loop	1 500 000
. linewires carrying CTC supervisory circuits and signalling interlocking circuits @ $280 per km	2 136 400
. microwave radio link	1 150 000
	13 786 000
add 10 per cent contingencies	1 378 640
	15 165 040

TOTAL: $15.7 million

The installation of a CTC system would require an increase in electrical and line maintenance staff, but would result in a reduction in mechanical maintenance staff.

It is estimated that the additional annual cost to maintain the CTC system would be $80 000.

Savings accrue from the introduction of CTC because all stations may then operate without signalling staff. The saving in manpower is estimated by the Bureau(1) to be $5.0 million per annum.

CTC on existing loops simultaneously extended to 900 metres

The capital costs of extending all the existing crossing loops and installing CTC simultaneously are:

	$(1976)
. install local signalling on 900 metre loops,@ $160 000 per loop	9 600 000

(1) Based on a P.T.C. estimate of $4.4 million savings produced by CTC installation as far as Casino.

		$(1976)
.	CTC equipment @ $25 000 per loop	1 500 000
.	linewires @ $2 800 per km	2 136 400
.	microwave radio link	1 500 000
.	extension of loops to 900 metres @ $80 000 per loop	4 800 000 (1)
		19 186 000
	add 10 per cent contingencies	1 918 640
		21 105 040

TOTAL: $21.11 million

The estimated additional cost of maintaining the CTC system is $80 000 per annum and the estimated manpower savings are $5.0 million per annum.

No direct cost savings accrue from the extension of crossing loops, but, as indicated previously, extension allows the use of longer trains which gives indirect savings.

CTC installed on existing loops subsequently extended to 900 metres

The capital costs are:

		$(1976)
.	extension of loops to 900 metres @ $80 000 per loop	4 800 000
.	altering the local signalling @ $18 000 per loop	1 080 000
		5 880 000
	add 10 per cent contingencies	588 000
		6 468 000

TOTAL: $6.47 million

(1) Because of the uncertainty associated with the cost of loop extensions, the analysis was repeated with an assumed cost of $160 000 per loop. The results of this variation are presented in the appropriate sections of this report.

Regrade Lawrence Road section

The Lawrence Road section between Grafton and Casino could be regraded at an estimated cost of $11.0 million. The regrading would allow one locomotive to haul 1020 tonnes from Broadmeadow to Casino, where a branch line locomotive could be attached to assist the train over the steep grades near Border loop.

The costing of this proposal arrived too late for it to be included in this study. A preliminary examination indicates that the proposal is unlikely to match the economic benefits which flow from the proposal to extend loops, but it should be considered when a decision is being made on a final upgrading programme.

Replacement/renewal of wooden bridge structures

The age of the wooden bridge structures on this line necessitates the imposition of temporary speed restrictions to slow traffic over the bridges. This delay is conservatively estimated by the P.T.C. to be in excess of 30 minutes for the main passenger train, the Brisbane Limited. With these speed restrictions and regular maintenance the bridges do not present any safety problem.

The possibility of renewing these structures was not included in this study as it is considered that the proposal is not a line upgrading so much as a normal maintenance/replacement task and hence outside the terms of reference for this study.

GREENBANK-SOUTH BRISBANE

Upgrading of this section was not considered in this study. It was considered more appropriate for this section to be included in a study of rail developments in the Brisbane area.

CHAPTER 5 - METHOD AND ASSUMPTIONS

The question of how and when to upgrade a railway line is not a simple one. Given a traffic forecast, the problem is essentially one of trading off the reductions in transport cost resulting from the upgrading against the cost of introduction. Like any other production facility, railway lines exhibit an increasing cost characteristic as output is increased beyond a certain point. The main source of additional cost is congestion, reflected as increased train crew costs and motive power and rolling stock investment. Ultimately the point is reached beyond which the railway cannot carry any further increase in traffic, and further growth in freight movements is diverted to alternative transport modes. This suggests two points of view for economic evaluation of railway line upgrading; firstly, the commercial viewpoint which in essence is a profit maximising exercise, and secondly, the resource viewpoint which takes into account the additional cost of diversion of traffic to another mode.

The analysis of the upgradings from the commercial viewpoint requires not only an estimate of the direct and indirect costs of carrying the growth in interstate freight traffic, but also an estimate of the revenue generated by that traffic. Rail revenue can be considered as a variable during the study period because it would be rational for the railways to increase rates as congestion costs rise, leading to a new supply/demand equilibrium as the demand curve shifts in response to growth. In practice, however, competition for railway services is far from perfect with interstate freight dominated by contract arrangements between the railways and a small number of customers. The range of pricing strategies available to the railways therefore tends to be attenuated by the averaging process inherent in lumpy contracts. For similar reasons, freight rates are not expected to fall in the latter part of the study period. Thus, in this study, commercial evaluations of upgrading are based on constant revenue per unit from the growing traffic over the study period. The average revenue rate for traffic on the Sydney-Brisbane link is 1.57 cents per tonne km.

In estimating the resource costs of diverting general freight to another mode when rail cannot accept further traffic, attention has been concentrated on the road alternative. General freight traffic favours the higher frequency and shorter transit time of the land modes when compared to sea transport. The two land modes are also readily interchangeable.

The evaluation procedure used in this study was as follows. Starting from the freight forecast for each year, the average number of trains in each direction was calculated for an 'average busy day'; each year's traffic was then exercised on a single track simulation of the sections of line subject to congestion delays for both the present line and the proposed upgraded configurations. The estimated delay characteristics were then translated into delay costs and incorporated into an annual net revenue variation as traffic grows. This led to the estimation of line capacity from both commercial and resource viewpoints, which then became the basis for the selection and timing of upgradings.

TRAINS REQUIRED TO MEET PROJECTED DEMAND

Since interstate freight is assumed to be the only growth area in traffic on the line, all other traffics were assumed to operate indefinitely on the present timetable. In practice the timetable would be adjusted periodically to take account of operational and demand changes, but it was assumed that in relation to the growing congestion delays, the effect of these adjustments may be ignored.

The present interstate freight trains have an average gross weight of about 800 tonnes. Steel trains, at 1500 gross tonnes, are much heavier than average, but the marked directional imbalance in traffic on the line means that currently there are also four empty trains per day returning from Brisbane. From data supplied by the

P.T.C. the average ratio of gross tonneage to load carried was calculated to be 2:1. This ratio was assumed to remain constant during the study period.

The use of heavier interstate freight trains can be beneficial provided that the increase in train length can be accommodated in the existing goods yards and crossing loops, that the heavier train fits into the general traffic pattern with respect to speed and that the corresponding reduction in train frequency does not adversely affect market demand. Heavier, but fewer, trains can increase the tonneage capacity of the line, reduce train crew costs and may lead to a reduction in the size of the locomotive fleet.

In the particular case of Telarah-Greenbank, the introduction of heavier trains would not be possible until crossing loops are extended. In this study, it has been assumed that the extension of crossing loops will allow the amalgamation of the present nine interstate trains per day in each direction into seven trains per day in each direction and that future trains will only be timetabled when existing trains average 1400 gross tonnes.

In calculating the number of trains per day, given a freight forecast and train weight, it is unrealistic to assume that the traffic would be uniformly distributed across 365 days per year. From an examination of the timetable it was estimated that the 'average busy day' traffic may be calculated on the basis of 312 days per year.

It was necessary to postulate a timetable for these new trains before the likely congestion delays could be quantified. Timetables for the projected interstate trains were prepared according to the following guidelines:

(a) Initially the trains were timetabled to depart during normal working hours or to arrive at their destination before 9 am so that they would be able to be turned around in the minimum possible time.

(b) As the line became congested further trains were added in such a way as to achieve an even spread of trains over the whole day. This involves extensive use of the current 'off-peak' periods.

CONGESTION DELAYS AND CAPACITY

Congestion delays

The congestion delays were estimated by simulating the various line configurations of interest using the Single Track Railway Simulation (STS) model jointly developed by the Bureau and IBM Systems Development Institute. The model allows for the input of departure times, sectional transit running times for the various train classes, track configuration data and train priority weighting factors for resolving crossing conflicts. The model generates synthesised timetables and delay statistics by train class.

Delays produced by STS were similar to those computed from actual train diagrams (see Table 5.1). This result, together with experience gained with STS in other mainline studies, supports the contention that STS gives realistic estimates of the delays caused by traffic levels in the region of track capacity.

Physical capacity of any line configuration is defined as that traffic level at which the next additional train cannot complete its journey within 24 hours. In practice, it would be impossible to sustain the highest traffic levels synthesised by STS because of non-traffic delays such as late departures and speed restrictions imposed by track maintenance and other operational factors.

In this study, the upgradings are all scheduled before physical capacity is reached, and the capacity definition only affects the magnitude of the benefit-cost ratios in the case of resource cost calculations. The calculated ratios are actually a lower limit on the actual ratios.

TABLE 5.1 - COMPARISON OF ACTUAL AND SIMILATED DELAY TIMES: EXISTING LINE, MAITLAND-SOUTH BRISBANE 1975-76

Train Class	Actual Delay (minutes/train)	STS Delay (minutes/train)	Number of Trains/ day in train class
1	15	59	6
2	118	141	9
3	259	188	6
4	261	265	6
5	294	382	4
Weighted Average	176	189	31

Commercial and Resource Capacity

Whenever an additional train is scheduled it produces an increment of revenue and, at the same time, an increment of cost. At low traffic density relative to the line capacity the additional revenue is greater than the additional cost. However, as traffic increases the revenue from each additional train remains substantially constant while the costs increase because of the congestion effects on existing traffic. Thus the net revenue increment for each additional train decreases with increased total traffic and the point is eventually reached where an additional train adds nothing to total net revenue. This is defined as the commercial capacity of the line and defines that point at which the railway, as a commercial operator, would decline further traffic. Subsequent growth in the total freight would be diverted to the next preferred mode.

From a resource point of view, the railways should continue to accept this additional traffic until the marginal resource cost by rail equals the marginal resource cost by the alternative mode. This point is defined as the resource capacity of the line. It would be expected to lie somewhere between the commercial and physical capacity.

SELECTION AND TIMING OF UPGRADING

The upgradings were compared on the basis of net present value over a range of discount rates, 7, 10 and 12 per cent using an investment analysis computer program especially developed for this task.

The program selects the optimal year (or years) in the study period in which to introduce an upgrading (or sequence of upgradings) in such a way as to maximise the net present value of the project over the study period.

In this study, the upgradings are all economically justified before commercial capacity is reached. In this case, it can be shown[(1)] that the optimal timing is independent of the selection criterion (commercial or resource) and the revenue rate.

RESOURCE COST OF TRANSPORTING THE INTERSTATE FREIGHT TRAFFIC

The total resource cost of transporting the railway share of the Sydney-Brisbane freight can be calculated as the sum of the following:

- total rail line haul cost, including that due to congestion, and rail-road transfer at the railheads;
- cost of rail upgrading, expressed as an annuity during the appropriate part of the study period, less savings directly attributable to the upgrading;
- average truck operating cost for diverted traffic, when applicable;
- additional cost to diverted traffic and other road users, when applicable; and

(1) Melbourne-Sydney and Melbourne-Serviceton Mainline Upgrading reports.

cost of carrying diverted steel traffic by sea, when applicable.

The year by year total resource cost may then be discounted to a single present value at a specified discount rate. The difference between the present values for the situations with and without rail upgradings is then the net present value of the resource benefit attributable to the upgrading.

CHAPTER 6 - EVALUATION OF OPTIONS

The freight projections used in the evaluation were calculated from the base year 1975-76. The interstate freight train projections are set out in Table 6.1. The study period is 1975-76 to 1994-95 with all costs expressed in 1976 Australian dollars and all discounted present values being based on 1975-76. For convenience, the years of the study period are designated 1 to 20.

TABLE 6.1 - EXPECTED NUMBER OF INTERSTATE FREIGHT TRAINS/BUSY DAY

Year	Sydney to Brisbane		Brisbane to Sydney[a]	
	800 gross tonne trains	1400 gross[b] tonne trains	800 gross tonne trains	1400 gross[b][c] tonne trains
1975-76	9.0	7.0	9.0	7.0
1976-77	9.3	7.0	9.3	7.0
1977-78	9.7	7.0	9.7	7.0
1978-79	10.0	7.0	10.0	7.0
1979-80	10.3	7.0	10.3	7.0
1980-81	10.7	7.0	10.7	7.0
1981-82	11.1	7.0	11.1	7.0
1982-83	11.5	7.0	11.5	7.0
1983-84	11.9	7.0	11.9	7.0
1984-85	12.3	7.0	12.3	7.0
1985-86	12.7	7.3	12.7	7.0
1986-87	13.2	7.5	13.2	7.0
1987-88	13.6	7.8	13.6	7.0
1988-89	14.1	8.1	14.1	7.0
1989-90	14.6	8.4	14.6	7.0
1990-91	15.1	8.6	15.1	7.0
1991-92	15.6	8.9	15.6	7.0
1982-93	16.2	9.3	16.2	7.0
1993-94	16.8	9.6	16.8	7.0
1994-95	17.3	9.9	17.3	7.0

(a) Includes empty trains due to imbalance in up and down traffic.
(b) Minimum number of trains allowed is 7 each way.
(c) Return empty trains assumed to have 50% more wagons than loaded trains.

Figure 6.1 shows the delay curves for the existing and upgraded line configurations when the freight traffic grows at the expected rate. The delays are plotted in the form of a congestion factor

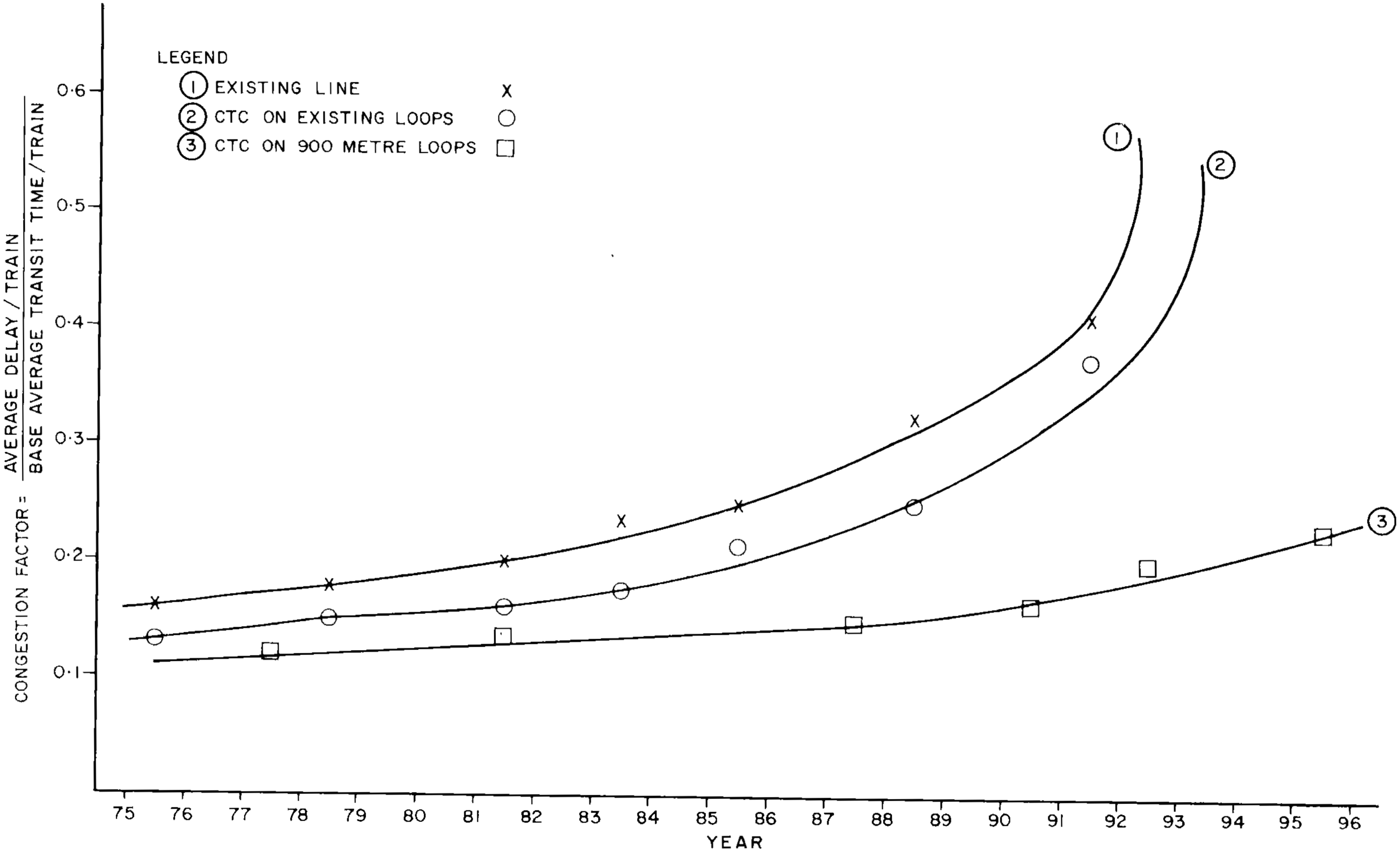

FIGURE 6·2
SYDNEY-BRISBANE DELAY CURVES-EXPECTED TRAFFIC GROWTH

which is defined as the average delay per train divided by the base average transit time per train. This normalised delay allows direct comparison of the lines under study at the Bureau on a comparable basis. It has been found from experience that unless the congestion factor for a particular line configuration exceeds 0.25 during the 20 year study period it is unlikely that any upgrading can be economically justified. This approach permits a preliminary ordering of the sections of line which should be given priority for upgrading from a national point of view. The graphs, however, do not give any indication of the optimal timing of those upgradings.

EVALUATION OF UPGRADINGS - COMMERCIAL CRITERIA

In this section, the three proposed upgradings for the Telarah-Greenbank line are evaluated from the railways point of view as commercial operations.

The existing situation

Figure 6.1 shows that if no upgrading of the line occurs the line will reach physical capacity by 1992-93 with the level of congestion from the mid 1980s being very high. This level of congestion would prove to be commercially unacceptable and freight traffic which would otherwise go by rail would transfer to other modes.

CTC installed on existing loops

This upgrading has very little effect on the line capacity. Figure 6.1 shows that physical capacity of the upgraded line would be reached by 1993-94. The capital cost of this upgrading is estimated to be $15.17 million and the direct net cost savings of the upgrading $4.92 million per annum. Indirect cost savings accrue from the reduced trip times of all trains on the upgraded line. The benefits associated with lower crew and fuel costs, locomotive and wagon maintenance costs, and the improved locomotive and wagon utilisation have been calculated. Also, account was taken of the increased revenue flowing to rail during the latter years of the study period from the slightly increased capacity of the line. The results of this upgrading are given in Table 6.2.

TABLE 6.2 - COMMERCIAL RESULTS, INSTALLATION OF CTC ON EXISTING LOOPS

	Discount Rate		
	7%	10%	12%
Best year to introduce upgrading	1	1	1
Present value of net revenue associated with upgrading ($ million)	83.76	52.86	37.81
Present value of net revenue associated with no upgrading ($ million)	70.85	45.52	33.22
NPV of upgrading ($ million)	12.91	7.34	4.59

CTC installed on existing loops with loops extended simultaneously to 900 metres

Figure 6.1 shows that this upgrading has a great effect on line capacity. With all loops extended to 900 metres and the average weight of trains allowed to rise from 800 gross tonnes to 1400 gross tonnes the congestion factor plotted in Figure 6.1 is expected to rise to just over 0.2 during the study period.

The capital cost of this upgrading was estimated as $21.11 million and has direct net cost savings of $4.92 million per annum. In addition to the indirect benefits detailed for the previous upgrading, the lengthened loops allow longer and heavier, but fewer, trains to carry the expected freight. At current freight levels it allows amalgamations of some trains. Substantial crew cost reductions accrue from this operational change. The results for this upgrading are shown in Table 6.3.

TABLE 6.3 - COMMERCIAL RESULTS, CTC ON 900 METRE CROSSING LOOPS

	Discount Rate		
	7%	10%	12%
Best year to introduce upgrading	1	1	1
Present value of net revenue associated with upgrading ($ million)	125.10	84.68	64.86
Present value of net revenue associated with no upgrading ($ million)	70.85	45.52	33.22
NPV of upgrading ($ million)	54.25 (49.50)	39.16 (34.36)	31.64 (26.84)

(a) The figures in brackets indicate the results if the cost of loop extensions is doubled.

CTC installed on existing loops, subsequent extension of all loops to 900 metres

The total capital cost for this upgrading is $21.64 million with the installation of CTC causing a direct net cost reduction of $4.92 million per annum.

The results for this sequence of upgradings are given in Table 6.4.

TABLE 6.4 - COMMERCIAL RESULTS, CTC FOLLOWED BY EXTENSION OF ALL LOOPS TO 900 METRES

	Discount Rate		
	7%	10%	12%
Best years to introduce upgradings	1,2	1,2	1,2
Present value of net revenue associated with upgrading ($ million)	121.70	81.54	61.86
Present value of net revenue associated with no upgrading ($ million)	70.85	45.52	33.22
NPV of upgrading ($ million)	50.85 (46.25)	36.02 (31.73)	28.64 (24.42)

(a) The figures in brackets indicate the results if the cost of loop extensions is doubled.

EVALUATION OF UPGRADINGS - RESOURCE CRITERIA

From a resource point of view, the evaluation is concerned with minimisation of the total cost to the community of transporting goods in the Sydney-Brisbane corridor.

It has been shown previously that the best option tested for upgrading the Sydney-Brisbane line using commercial criteria, is to increase gross freight train weight to 1400 tonnes, introduce CTC and extend all crossing loops. All these upgradings would be introduced before commercial capacity is reached and are primarily cost reducing measures. Thus, it would be expected that the application of resource criteria would show similar results to those produced for commercial criteria. It will therefore be sufficient to present resource benefit-cost ratios of the short list of options considered for the commercial evaluation.

Rail revenue is not included in resource calculations and the 'base case' consists of the existing rail link which carries all traffic in 800 tonne trains up to physical capacity, beyond which future growth would be diverted to road.

Table 6.5 shows the total resource cost of transporting the railway share of interstate freight traffic, including the resource cost of traffic diverted when physical capacity is reached. The results are shown for a range of discount rates.

The resource benefit-cost ratios are shown in Table 6.6. The cost term is simply the present value of the capital cost of the upgrading implemented over 3 years; the benefits are calculated as the reduction in operating costs over a 20 year period.

A breakdown of the resource costs and savings produced by upgrading is given in Table 6.7. It may be seen that the major savings accrue to the railway systems themselves with only a small proportion of the benefits going to road users. The major benefits are in the form of reduced manpower for train control purposes and better utilisation of rolling stock and train crews.

TABLE 6.5 - RESOURCE RESULTS; NPVs, EXPECTED FREIGHT PROJECTION

	Discount Rate		
	7%	10%	12%
Existing line			
Present value of total resource cost ($ million)	184.8	154.6	139.6
CTC on existing loops			
Present value of total resource cost ($ million)	174.1	148.6	135.9
Best year of introduction	1	1	1
NPV of upgrading ($ million)	10.7	6.0	3.7
CTC on 900 metre loops			
Present value of total resource cost ($ million)	133.6	117.2	109.1
Best year of introduction	1	1	1
NPV of upgrading ($ million)	51.2	37.4	30.5
CTC on existing loops followed by loop extensions			
Present value of total resource cost ($ million)	136.9	120.4	112.1
Best years of introduction	1,2	1,2	1,2
NPV of upgrading ($ million)	47.9	34.2	27.5

TABLE 6.6 - RESOURCE RESULTS: MINIMUM BENEFIT-COST RATIOS EXPECTED FREIGHT PROJECTION

Upgrading	Discount Rate		
	7%	10%	12%
CTC on existing loops	1.8	1.4	1.3
CTC on 900 metre loops	3.5	2.9	2.6
CTC followed by 900 metre loops	3.3	2.7	2.4

TABLE 6.7 - RESOURCE COSTS AND SAVING ELEMENTS: EXPECTED FREIGHT PROJECTION, 10% DISCOUNT RATE

($ million)

Cost Elements	NPVs of Savings		Net Savings from Upgrading
	CTC and long loops in 1975-76	existing line	
Rail costs			
Cost of upgrading	-24.6	-	-24.6
Manpower savings (CTC)	34.0	-	34.0
Train capital	-36.7	-47.5	10.8
Train crew	-15.8	-26.6	10.8
Track maintenance	-5.1	-5.1	-
Rolling stock maintenance and fuel	-67.3	-69.1	1.8
Gantry capital	-1.8	-2.1	0.3
Gantry operating	-3.0	-3.5	0.5
Road costs			
All road costs	-	-0.6	0.6
TOTAL	-120.3	-154.5	+34.2

CONCLUSIONS

The following conclusions may be drawn from the above evaluation of upgradings:

(a) The best upgrading is to introduce CTC and extend all crossing loops to 900 metres at an estimated capital cost of $21.11 million.

(b) The timing of the upgradings is insensitive to the discount rates used.

(c) The optimal year in which the upgrading should be introduced is 1975-76.

(d) Upgrading is fully justified on both commercial and resource allocation grounds.

(e) The best upgrading could be implemented over a 3 year period with expenditure equally spread over the 3 years. The annual expenditure would be approximately $7 million. The resource benefit-cost ratio is 3.4 using a 10 per cent discount rate.

ANNEX A

DATA USED IN STUDY

TRACK DISTANCES AND GRADE RESTRICTIONS

Section	Distance (km)	Grade Restriction (tonnes/loco)
Maitland-Grafton City	503	1020
Grafton City-Casino	109	715
Casino-Greenbank	151	820
TOTAL	763	

VEHICLE CAPITAL COSTS

Vehicle	Cost ($)	Lifetime (years)	Annual Distance Travelled (km)
Locomotive	640 000	25	144 000
Wagons	35 000	25	34 000

NUMBER OF WAGONS ON TRAINS (EXCLUDING THE BRAKEVAN)

Train	Wagons (steel)	Wagons (other)
800 gross tonnes	13	18
1400 gross tonnes	22	31
Short empties		18
Long empties		46

CREW COSTS

Train	Cost ($/hour)
Freight	26
North Coast Daylight	70
Brisbane Ltd	117
Gold Coast Motorail	113
North Coast Mail	34

These costs include Saturday, Sunday and night penalties, and service expenses.

MAINTENANCE COSTS

Type	Cost (cents/km)	Annual Marginal Cost (cents/gross tonne km)
Locomotive	74.51	
Wagons	3.76	
Single track line		0.02
Double track line		0.04

FUEL COSTS[1]

Train	Cost (cents/km)
800 gross tonnes	17.2
1400 gross tonnes	30.1
Short empties	7.7
Long empties	19.8

CTC STAFF SAVINGS

Stage	Staff Saving	Salary Saving (including all overheads)
		($million/annum)
Telarah-Taree	81	1.51
Taree-Kempsey	57	1.07
Kempsey-Grafton City	64	1.23
Grafton City-Casino	35	0.66
	237	4.47

(1) These figures are based on a cost of 3.08 cents/litre. Current estimate 5.62 cents/litre. The effect of this increase would be to increase the benefits of upgrading the line.

Savings for the Casino-Greenbank section have not been collated by the P.T.C. The Bureau estimates the saving for this section to be of the order of the saving on the Grafton City-Casino section. The total CTC manpower saving is estimated by Bureau as $5.0 million per annum.

CTC CAPITAL COSTS

Item	Cost
. Install local signalling on existing length crossing loop	$150 000/loop
. Install local signalling on 900 metre long crossing loop	$160 000/loop
. Alter local signalling later if an existing short loop is extended to 900 metres	$ 18 000/loop
. Line wires	$ 2 800/km
. Microwave radio link	$1 150 000
. CTC equipment	$ 25 000/loop
. Expected lifetime	20 years

CAPITAL COSTS OF LOOP EXTENSIONS

The average cost of extending a crossing loop on this line to 900 metres is estimated as approximately $80 000 per loop. This cost covers such items as earthworks, drainage, rails, sleepers, sleeper plates, ballast and relocation of points. This figure can only be used as a guide since, by the very nature of earthworks estimates, they cannot be accurately estimated without very extensive tests being carried out on site.

The lifetime of the extended loops is assumed to be 20 years.

FREIGHT REVENUE

Traffic	Total ('000 tonnes)	Rate (cents/tonne km)
NSW to Queensland	882	1.64
Queensland to NSW	341	1.24
Intersystem to Queensland	187	1.76
Intersystem to Queensland via Broken Hill	56	1.66
Intersystem ex Queensland	39	1.24
Intersystem ex Queensland via Broken Hill	23	1.54

Average freight revenue 1.57 cents per tonne km.

AVERAGE WAGON CHARACTERISTICS

Length	15.8	metres
Tare weight	20	tonnes
Gross weight	62	tonnes (steel)
	45	tonnes (other)

GANTRY COSTS

These costs are based on costs at the Tamworth freight centre and are used to estimate the road-rail interchange costs when calculating resource costs, under the assumption that all increased interstate freight traffic is containerised.

Capital cost $326 000

Power and maintenance $700/gantry/year

Average cost per shift $24 200 (based on the operation of 4 gantries, 3 shifts per day).

GANTRY CHARACTERISTICS

Load/unload time	3 minutes
Placing train and checking brakes	1 hour
Capacity (800 gross tonnes)	8.6 trains/day
Capacity (1400 gross tonnes)	5.9 trains/day
Capacity (short empties)	8.6 trains/day
Capacity (long empties)	4.3 trains/day

COST OF OVERFLOW TO ROAD

The truck costs were obtained from firms running a semi-trailer shuttle service between Sydney and Melbourne using the Hume Highway. They are based on 20 tonne five-axle trucks achieving an average speed of 56 km/h and travelling 159 000 km per year. The costs relevant to this study are:

Truck capital (excluding sales tax)	$64 000
Truck life	5 years
Operating costs/vehicle km	22.58