Mainline Upgrading - Evaluation of a Range of Options for the Kalgoorlie - Perth Rail Link

Report

This Report is the last of a series on railway mainline upgrading options and covers the evaluation of options for upgrading the standard gauge link between Kalgoorlie and Perth. The evaluation of upgrading options differs in this case from those previously reported, in that no capacity constraints are envisaged, but severe and continuing track deterioration has occurred between Koolyanobbing and Kwinana as a result of heavy axle loads in the iron ore and wheat trades. Thus the upgrading requirements in this case are concerned with the use of heavy rail and high standard track rather than the capacity to run more trains.

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BUREAU OF TRANSPORT ECONOMICS

MAINLINE UPGRADING - EVALUATION OF A RANGE OF OPTIONS FOR THE KALGOORLIE-PERTH RAIL LINK

AUSTRALIAN GOVERNMENT PUBLISHING SERVICE
CANBERRA 1978

Printed by Watson Ferguson and Co., Brisbane

FOREWORD

This report is the last of a series on railway mainline upgrading options and covers the evaluation of options for upgrading the standard gauge link between Kalgoorlie and Perth. It complements a previous report on the east-west link between Sydney, Adelaide, Port Pirie and Kalgoorlie.

The evaluation of upgrading options differs in this case from those previously reported, in that no capacity constraints are envisaged, but severe and continuing track deterioration has occurred between Koolyanobbing and Kwinana as a result of heavy axle loads in the iron ore and wheat trades. Thus the upgrading requirements in this case are concerned with the use of heavy rail and high standard track rather than the capacity to run more trains.

The report is primarily the work of Mr A. Edquist of the Operations Research Branch under the general guidance of Mr R.W.L. Wyers.

The study would not have been possible without the co-operation and assistance of officers of Westrail and, in particular, the work of Messrs W. Larke and A. Drew who maintained effective liaison between Westrail and BTE during the course of the study.

(G. K. R. REID)
Acting Director

Bureau of Transport Economics
Canberra
September 1978

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SUMMARY

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

The Kalgoorlie to Perth standard gauge mainline is the newest section of the east-west rail link, being opened for interstate traffic in November 1968. Heavy axle-loads associated with bulk traffic have lead to severe and continuing track deterioration between Koolyanobbing and Kwinana, and a major rehabilitation of the line will be required in the near future. This report summarises the evaluation performed by WESTRAIL of three alternative rehabilitation schemes, and in addition evaluates the timing of such rehabilitation.

In order to evaluate the optimum timing of rehabilitation, the report examines the consequences of continued deterioration of the line and estimates the total resource cost to the community of such deterioration. This study establishes that the total cost to the community of allowing deterioration to continue indefinitely far exceeds the capital cost of any of the rehabilitation schemes examined.

The three alternative rehabilitation schemes, involving re-railing with a rail weight of 50 kg/m, 60 kg/m, and 66 kg/m respectively, were compared on the basis of total cost reckoned on a common starting data for construction. The scheme involving rehabilitation to a rail weight of 66 kg/m would result in lowest total cost, but the difference in total cost between this scheme and the 60 kg/m scheme would be less than one-fifth of one per cent. The WESTRAIL evaluation noted that the 66 kg/m scheme would result in lowest total cost, but considered that the advantages accruing from the lower capital cost of the 60 kg/m scheme would outweigh the small difference in total cost, and concluded by recommending

the 60 kg/m rehabilitation scheme. If either the 60 kg/m scheme or the 66 kg/m scheme were implemented, then total transport cost to the community would be lowest if rehabilitation were to commence at once.

Total transport costs to the community are minimised by rehabilitation of the standard gauge mainline between Koolyanobbing and Kwinana to a rail weight of 66 kg/m, with construction commencing as soon as practicable.

CHAPTER 1 - INTRODUCTION

This study is one of a series of studies of railway freight operations being carried out by the Bureau of Transport Economics, following a request by the Australian Transport Advisory Council. Studies have now been completed for the intercapital rail network. This report is concerned with the Kalgoorlie to Perth standard gauge mainline.

This line is the newest of the Australian interstate rail links. It was constructed as part of the Gauge Standardisation Project and was opened to interstate traffic in November 1968. Major features of the traffic are iron ore transported in unit trains from Koolyanobbing to Kwinana, and grain transported in unit trains to Kwinana from the Wheat Belt. Interstate general goods traffic forms only a minor part of the total traffic.

Although traffic is relatively heavy no capacity problems are envisaged in the foreseeable future. The main problem is that of track deterioration resulting largely from the heavy axle-loads associated with the bulk traffics. A major rehabilitation of the line is required in the near future if onerous speed and axle-load restrictions, and eventual line closure, are to be avoided.

WESTRAIL has evaluated three alternative rehabilitation schemes, in which capital cost of rehabilitation, operating cost and track maintenance cost were estimated in order to determine the rehabilitation scheme which would result in the least total cost. The Bureau has reviewed the evaluation undertaken by WESTRAIL, and in addition has examined the consequences of gradual deterioration if no rehabilitation is undertaken. As part of this latter examination, estimates were derived for operating cost increases associated with deterioration, and for the costs associated with the diversion of traffics to other modes. These estimates of the costs of deterioration were used to determine the optimum timing of rehabilitation.

Chapter 2 of this report contains a description of the line and its present traffic, the current physical state of the track, and the expected further deterioration if rehabilitation is not undertaken. The third chapter presents details of the rehabilitation schemes examined by WESTRAIL, methods and assumptions of the evaluations, and the results. Chapter 4 details the methodology used by the Bureau in determining the optimum timing of rehabilitation and presents the results. The conclusions reached as a result of this study are presented in Chapter 5.

CHAPTER 2 - STATE OF THE LINE

DESCRIPTION OF THE EXISTING LINE

Layout

The standard gauge main line, opened for interstate traffic in 1968, connects Kwinana and Kalgoorlie, a total distance of 685km. At its eastern end the line joins the transcontinental standard gauge line at Kalgoorlie, thus completing Western Australia's rail link with the eastern States.

From Kalgoorlie, other standard gauge lines run north to Leonora and south to Esperance, providing a direct rail link for the major developments in this mineral-rich region. The standard gauge main line meets the narrow gauge network servicing the Wheat Belt at Merredin, Avon Yard and Northam, and at Toodyay West. The narrow gauge line from Albany meets the standard gauge main line at Northam. Other interconnections occur in the Perth region.

Terminals

Gantry cranes and facilities for containers and other non-bulk freight exist at West Kalgoorlie, West Merredin and at Avon Yard. There are large grain silos, marshalling yards for unit trains and other facilities for the bulk loading of grain at West Merredin and Avon Yard, as well as facilities for the transfer of freight between gauges. At the iron-ore mining centre of Koolyanobbing, there are marshalling yards for unit trains and facilities for the bulk-loading of iron-ore. All the rail freight terminal operations in the Perth region, except for unit trains for grain and iron-ore, take place at the new dual-gauge freight complex at Kewdale/Forrestfield. This complex was designed to provide for the new traffic conditions arising from the opening of the standard gauge main line, as well as upgrading existing narrow gauge freight terminal facilities. It is now

Western Australia's main non-bulk freight terminal. Unit trains for the grain and iron-ore export trades are marshalled and unloaded at Kwinana. Kwinana also has facilities for servicing overseas container traffic, and spur lines which run to the port areas of Robb Jetty and Fremantle.

Track and Signalling

The standard gauge main line is single track from West Kalgoorlie to Avon Yard. Automatic signalling is used from West Kalgoorlie to Koolyanobbing, and from Koolyanobbing to Avon Yard signalling is by Centralised Traffic Control. From Avon Yard to Forrestfield the line consists of double dual-gauged track, with Centralised Traffic Control signalling. From Forrestfield to Kwinana, the line is single track, and Centralised Traffic Control signalling is used. Figure 2.1 shows the main sections of the line, and the types of signalling employed on the various sections. Figures 2.2 and 2.3 show the lengths of the crossing and by-pass loops on the line, with their distances from Kwinana. With the exception of Midland, all crossing and by-pass loops are in excess of 1400 metres long.

Throughout much of its length the line traverses the geologically ancient inland plateau of Western Australia, and the line is characterised by gentle curves and gradients over this generally flat landscape. From Northam to Perth the line descends from the plateau to the coastal strip down the valley of the Avon River. Curves are more frequent and sharper in this section, and gradients are steeper.

Sections

Major components of the traffic enter and leave the line at a few specified points. Bulk grain traffic is transferred to standard gauge at Avon Yard and West Merredin. Iron-ore is loaded at Koolyanobbing. Kewdale serves as the major terminal for general

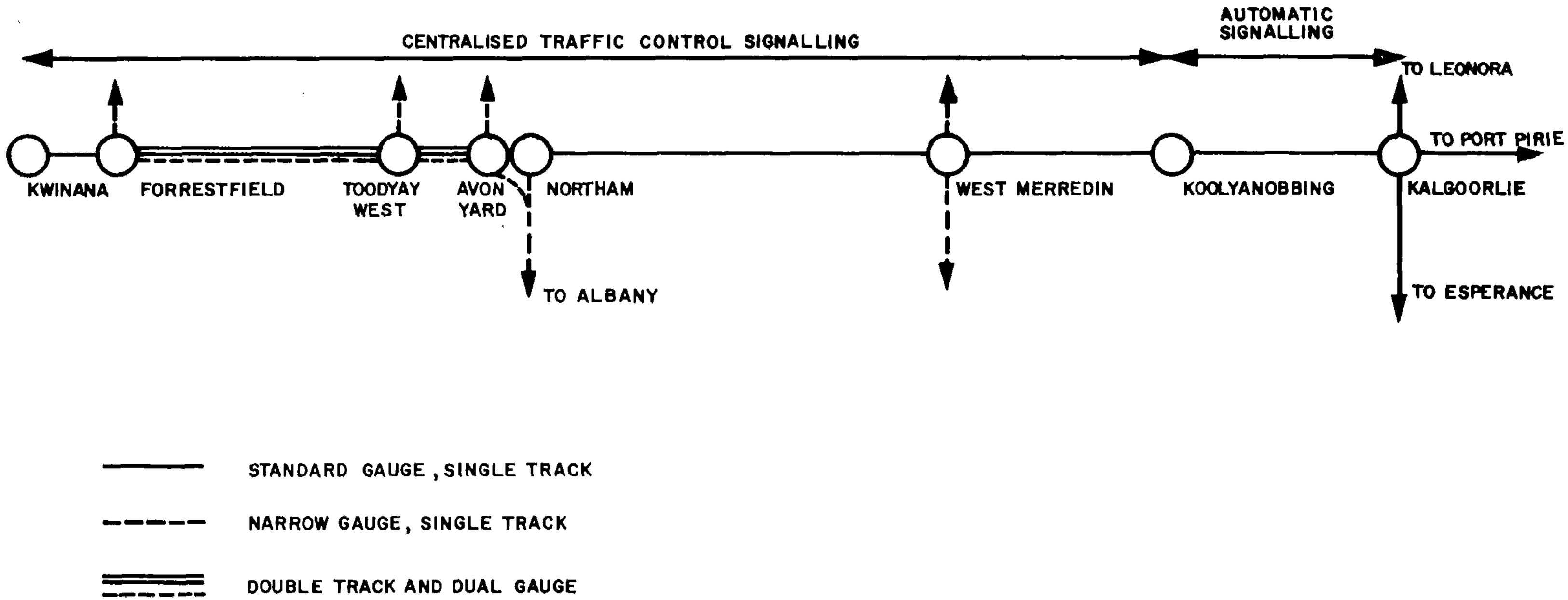

FIGURE 2·1

TRACK, SIGNALLING, AND INTER CONNECTIONS OF THE STANDARD GAUGE MAIN LINE

DISTANCE FROM KWINANA (KM)		LENGTH OF CROSSING OR BYPASS LOOP (METRES)
	KWINANA	Terminal
40	FORRESTFIELD	1550
47	MIDLAND	822
73	JUMPERKINE	1568
93	MOONDYNE	1510
121	TOODYAY WEST	1542
146	AVON YARD	2094
155	SEABROOK	1432
164	GRASS VALLEY	1446
185	MECKERING	1456
210	CUNDERDIN	1462
232	TAMMIN	1522
246	BUNGULLA	1760
260	KELLERBERRIN	1664
276	DOODLAKINE	1440
296	HINES HILL	1441
313	WEST MERREDIN	1526

FIGURE 2.2

LENGTHS OF CROSSING AND BYPASS LOOPS

KWINANA TO WEST MERREDIN

DISTANCE FROM KWINANA (KM)		LENGTH OF LOOP (METRES)
	WEST MERREDIN	1526
328	BOORAN	1452
344	BURRACOPPIN	1446
363	CARRABIN	1458
386	BODALLIN	1437
409	MOORINE ROCK	1452
436	SOUTHERN CROSS	1455
460	LAKE JULIA	1455
488	KOOLYANOBBING	1497
524	DARRINE	1536
562	JAURDI	1538
595	WALLAROO	1549
621	STEWART	1526
655	BONNEVALE	1523
685	WEST KALGOORLIE	1995

FIGURE 2.3

LENGTHS OF CROSSING AND BYPASS LOOPS

WEST MERREDIN TO WEST KALGOORLIE

freight, and the sole terminal for interstate freight. As a result, the line can be divided into five sections, which are distinct in terms of traffic use. These sections are:

- Kwinana to Forrestfield
- Forrestfield to Avon Yard
- Avon Yard to West Merredin
- West Merredin to Koolyanobbing
- Koolyanobbing to Kalgoorlie

PRESENT TRAFFIC

The present traffic falls into a number of classes in terms of train type, origin and destination. These classes can be summarised as:

- Passenger traffic
- Iron ore and Nickel
- Wheat and other grain
- Oil and fertiliser
- General intrastate traffic
- Interstate traffic

The only passenger trains on the standard gauge main line are the trans-continental passenger trains, the 'Indian Pacific' and the 'Trans Australian', and the Perth to Kalgoorlie train, the 'Prospector'. These trains provide daily services.

Estimates of net tonnages carried in 1976 for the various classes of freight traffic are detailed in Table 2.1.

The mineral traffic is transported in unit trains for refining and export at Kwinana. Iron-ore originates at Koolyanobbing, and nickel comes from developments in the Kalgoorlie region. Wheat and other grain traffic is almost wholly for export and is transported in unit trains to Kwinana, mainly from the grain bulk-loading facilities at Avon Yard and at West Merredin, but

TABLE 2.1 - ESTIMATED TRAFFIC IN 1976

('000 tonnes)

Commodity	Kwinana-Forrestfield	Forrestfield-Avon Yard	Avon Yard-West Merredin	West Merredin-Koolyanobbing
Iron ore and nickel	2930	2930	2930	2930
Grain	2380	2380	952	218
Oil and Fertiliser	616	616	252	134
General freight	-	862	264	218
Interstate freight	-	1055	1055	1055

with a minor component of the traffic coming from the Esperance region. Table 2.2 gives some characteristics of the train types. Except for passenger trains, it is rare for the non-unit trains to achieve their maximum number of wagons, or their maximum axle-loading, although some long trains are used for interstate container traffic.

TABLE 2.2 - CHARACTERISTICS OF EACH TRAIN TYPE

Train Type	Maximum number of wagons per train	Number and type of locomotive	Maximum Axle-load per wagon (tonnes)
Passenger	12 or 24	1 or 2 GM	-
Iron and nickel	69	2 L class	22.5
Grain	40	1 L class	21
Oil and fertiliser	69	1 or 2 L class (1)	19
General freight	69	1 or 2 L class (1)	19
Interstate freight	69	1 or 2 L class (1)	19

(1) The number of locomotives depends on trailing load.

Oil and fertiliser originates from the petrochemical industry at Kwinana. Most fertiliser is off-loaded at Avon Yard and at West Merredin, for transport throughout the Wheat Belt, with the remainder continuing to Kalgoorlie, with an ultimate destination in the Esperance region. Oil products are in universal demand with quantities off-loaded at Avon Yard, West Merredin, Koolyanobbing, and Kalgoorlie. Westbound general intrastate freight consists mainly of minor mineral freight and primary produce. The major origins are Kalgoorlie and Avon Yard, and the freight is transported to Kewdale, and hence to the industrial areas of Perth. Eastbound general freight is onloaded at Kewdale, and the major off-loading points are Avon Yard and Kalgoorlie. Interstate freight is a through traffic, from Kewdale to equivalent freight terminals in the other capital cities.

A typical day's traffic in May 1976 is shown in Table 2.3. In addition to the trains shown in this table, there are a number of movements of an auxillary nature.

TABLE 2.3 - NUMBER OF TRAINS OF EACH TRAIN TYPE IN A TYPICAL DAY'S TRAFFIC

Train Type	Kwinana-Forrestfield	Forrestfield-Avon Yard	Avon Yard-West Merredin	West Merredin-Koolyanobbing	Koolyanobbing-Kalgoorlie
Passenger	0	4	4	4	4
Iron and nickel	6	6	6	6	0
Wheat and grain	2	2	2	2	0
Oil, fertiliser and General freight	0	7	7	5	4
Interstate freight	0	2	2	2	2

Crossing and by-pass loops on the standard gauge main line are of sufficient length to make productive use of the unit train concept for the bulk grain and mineral traffics. The majority of other traffic is between the regional transhipment centres at Avon Yard, West Merredin and Kalgoorlie, and the main freight terminal at Kewdale, with resultant advantages in operating efficiency arising from such grouped traffic. No significant congestion problems have arisen since the opening of the line, and no significant congestion or delay problems are expected to arise in the forseeable future, under current traffic forecasts. Bureau and WESTRAIL forecasts are detailed in Annex A, and some suggested upgradings to improve traffic flow are discussed in Annex B.

HISTORY OF THE LINE

The standard gauge main line was constructed as part of the Gauge Standardisation Project, work on which commenced in Western Australia in 1962. The line was designed from the outset to carry bulk traffic for the planned industrial complex at Kwinana, and the Kewdale/Forrestfield freight handling complex was designed and constructed as a complementary project. The initial conception of the line was to convey iron-ore from Koolyanobbing to Kwinana at an annual rate of 1 million tonnes. Subsequently the project was broadened to include connection with the trans-continental link at Kalgoorlie, and to provide for haulage of up to 2 million tonnes per annum of iron ore.

The relevant Commonwealth/State agreement set out the standards to which the line was to be constructed, including definition of the rail weight, 47 kg/m.

Haulage of iron-ore commenced over the Koolyanobbing to Kwinana section in May 1967, and interstate freight haulage started in November 1968. When track standards were agreed on, the intended maximum axle-loading for bulk traffic was 20 tonnes. However, when the railway was opened, the permissible axle-loading promulgated was 23.5 tonnes, with heavy haul locomotives having axle-loads of 22.5 tonnes. Although these high axle-loads were in advance of general world practice at that time, no particular difficulties were anticipated and it was thought that operating cost savings would more than offset any increased maintenance costs.[1]

Restrictions

The first difficulties in maintaining the track under the prevailing speed restrictions were reported in 1970, and shortly thereafter the first reductions in permissible speed were introduced. In March 1973, the first of a series of derailments attributable to track failure occurred, and as a result, reductions in permissible axle-loadings, and further reductions in speed were introduced. It was considered that the rapid deterioration in track stability, which could not be contained with resources available for general maintenance, had been due to track flexing induced by heavy loads and high speeds. It was reported that fastenings had also worked loose, and that faults in rails and welds were developing at a rate causing concern.[2]

Despite further speed restrictions and strengthening of fastenings by lock-spiking in 1974, the opinion of WESTRAIL engineers is that working stresses on the rail are still in excess of normal rail practice, and that rail damage is still continuing.[3]

EXPECTED FUTURE DETERIORATION

Without a large-scale rehabilitation program, normal maintenance procedures will be unable to prevent further deterioration of the line. Railway policy on main line track maintenance is that the line should be maintained to a standard which will allow trains to run safely at their operationally optimum speed. This optimum

(1) WESTRAIL, Interim Report: Standard Gauge main line Kwinana-Koolyanobbing Section (Oct 1976), p. 8.
(2) Ibid, p. 7.
(3) Ibid, p. 7, pp 23-30.

speed is determined by balancing operating cost reduction due to increased rolling stock utilisation at higher speeds against the increased track maintenance expenditure required to ensure safe running at these higher speeds. Deterioration of the standard gauge mainline has now reached such a point that increases in track maintenance expenditure are no longer justified by the avoidance of operating cost increases gained thereby. In such circumstances, deterioration will continue, and speed and axle-load restrictions must become more severe.

As deterioration continues, a time is reached when the track cannot be economically maintained at a level which would permit trains to run at what railway management consider to be minimum commercially acceptable operating constraints on speed and axle-loads. At this point, railway management must consider closing the line on commercial grounds. WESTRAIL considers that this point will be reached on the four affected sections of the standard gauge main line at various times between 1981 and 1987. The exact time will depend on the regime of speed and axle-load restrictions adopted beforehand.

Figure 2.4 depicts the expected expiry dates of the commercial life of both sleepers and rail for the four affected sections under the present regime of axle-load and speed restrictions. Table 2.4 details the currently envisaged scheme of speed and axle-load restrictions that will be introduced before commercial expiry.

Although railway management would wish to close the line once the commercial expiry point has been reached, in practice it is hard to say at what point the line would be closed. Annex C examines the effects on traffic of the deterioration expected before commercial expiry, and also examines the effect on the community of closure of the line. Closure on commercial grounds is not economically justified if the resource costs to the community of the cheapest alternative modes are greater than the total resource

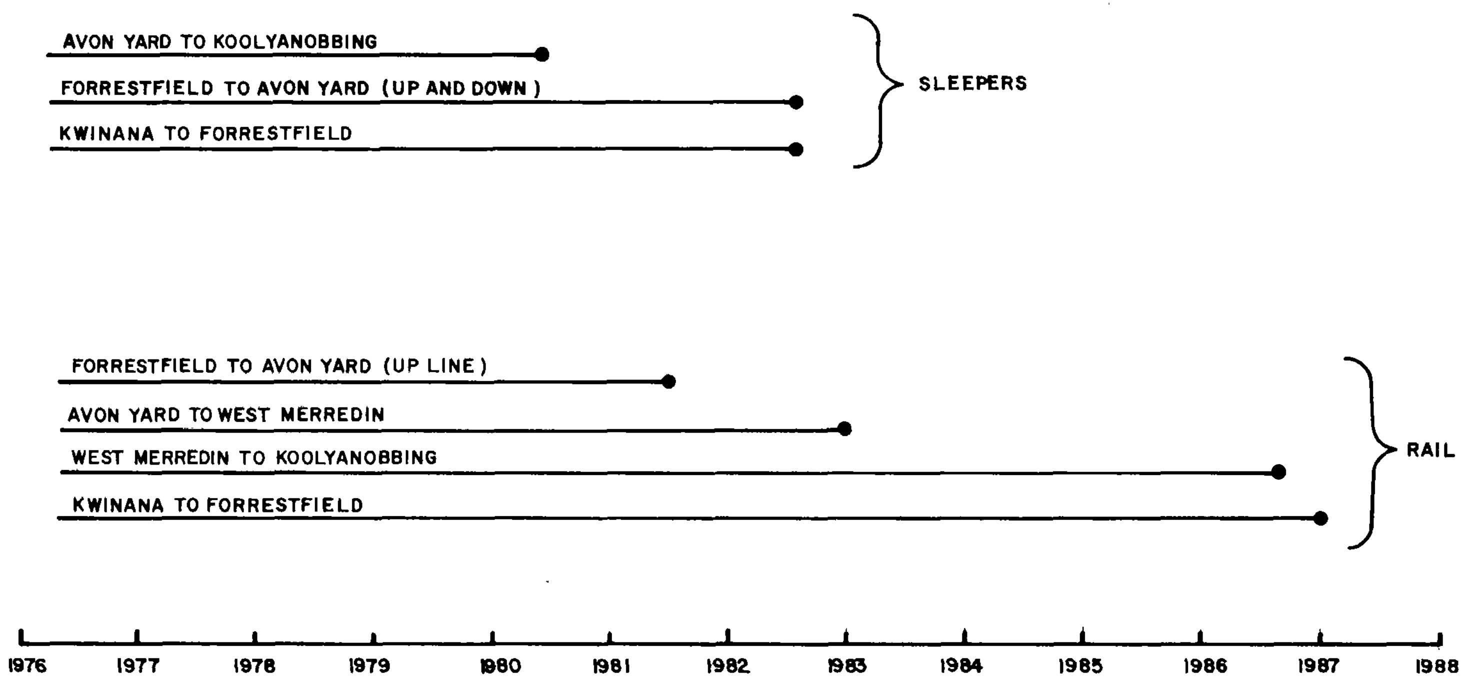

FIGURE 2·4

EXPECTED LIFE–EXPIRY OF RAILS AND SLEEPERS UNDER PRESENT AXLE LOAD RESTRICTIONS

TABLE 2.4 - CURRENT AND PROJECTED AXLE-LOAD AND SPEED RESTRICTIONS (WITHOUT REHABILITATION)

Year	Kwinana-Forrestfield		Forrestfield-Avon Yard		Avon Yard-West Merredin		West Merredin-Koolyanobbing	
	Axle-load (tonnes)	Speed (km/h)	Axle-load (tonnes)	Speed (km/h)	Axle-load (tonnes)	Speed (km/h)	Axle-load (tonnes)	Speed (km/h)
1976	22	70	22	70	22	70	22	70
1977	22	70	22	70	22	70	22	70
1978	22	70	21	50	21	50	22	70
1979	21	60	21	50	21	50	21	50
1980	21	60	16	50	21	50	21	50
1981	21	60	16	50	16	50	16	50
1982	16	50	16	40	16	40	16	40
1983	16	50	16	40	16	40	16	40
1984	16	40	16	40	16	40	16	40
1985	16	40	CLOSE RAIL					
1986	16	40						
1987	CLOSE RAIL							

costs of keeping the rail link open. Financially, however, if rail was kept open past the commercial expiry point, deterioration would lead to very rapid increases in track maintenance expenditure and operating costs, and consequently either a rapidly increasing deficit, or very sharp increases in freight charges. Any decision to close the line would almost certainly be made on political grounds rather than strict economic grounds. As long as the total costs of keeping the rail open are less than the costs to the community of line closure, the balance of community pressure would probably ensure that the line would remain open.

The cost to the community of line closure is large. Thus it is quite possible that, without rehabilitation, the line would be kept open until deterioration had reduced it to a condition resembling the Central Australian Railway, or the Meekatharra line. On such lines massive continuous track maintenance expenditure is required to ensure slow and unreliable service.

Annex C considers the consequences of line closure and the costs to the community of such closure in general terms. In Chapter 4, however, a minimum figure is obtained for the cost to the community of line closure. This figure is much greater than the total cost of any planned rehabilitation scheme. As continued deterioration of the line will ensure that total rail costs will eventually increase to equal the costs of closure, the only real questions involved are as to which rehabilitation scheme to adopt, and the time of commencement of rehabilitory track works.

CHAPTER 3 - THE WESTRAIL PROPOSALS FOR UPGRADING

HISTORY OF INVESTIGATION

By the beginning of 1976 it had become clear to WESTRAIL that the deterioration of the standard gauge main line had reached such a point that increases in track maintenance expenditure would not be justified by avoidance of operating cost increases gained thereby, and that speed and axle-load restrictions must become more severe.

Accordingly, it was decided to determine the residual commercial life of the existing rail, sleepers and fastenings, and to determine the most acceptable replacements. In April 1976, the interim reports: "Sleepers and Fastenings", and "Existing Rail, Residual Life" were released. In October 1976, the latter was superseded by the interim report: "Standard Gauge Main Line, Kwinana - Koolyanobbing Section", prepared under the auspices of the Chief Engineer, WESTRAIL. The objectives of this report were[(1)]

- To report on the condition of the existing rail and the expected residual life.
- To report on the alternative combinations of replacement rail size, axle-loading and speed which could be efficiently adopted.
- Establish under which of these combinations was total cost at a minimum.
- To recommend a replacement rail size together with maximum axle-loads and speeds to operate over that rail.

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(1) Ibid, p. 9.

THE RELATION BETWEEN RAIL SIZE, RAIL LIFE AND AXLE-LOAD

Rail engineers in several countries have studied the relationship between rail-life and rail weight.[1] Many factors affect rail-life, but the principle one is gross tonnes hauled. If other factors are held equal, then rail-life can be effectively measured by the total gross tonnage which that rail can carry. A heavier rail is distinctly more resistant to wear induced by traffic, and effective rail-life increases very rapidly with increased rail weight.

A heavier rail not only has a longer effective life, but also allows improved operating practices. Trains can run at higher speeds with heavier axle-loads than would be permissible on lighter rails, and the track can be maintained to standards which permit this with a reduced maintenance effort. In order to determine a suitable rail size, decreases in operating cost and reductions in track maintenance expenditure can be offset against the higher capital cost of a heavier rail. The aim is to select that rail size which minimises total cost.

THE THREE PROPOSALS

Available Rail Sizes

Rail currently in use by State and national railways in Australia is manufactured in accordance with a Standards Association of Australia specification established in 1964. The rail sizes covered in this specification are 31 kg/m, 41 kg/m, 47 kg/m and 53 kg/m.[2] The private railways in the north west of Australia are constructed of heavier rail. BHP has the capability to manufacture rail in the sizes 59 kg/m, 66 kg/m and 68 kg/m, in accordance with American Railway Engineers Association specifications. Increased traffic on the main lines has increased the

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(1) Ibid, pp 18-21.
(2) Standards Association of Australia specification E22-1964.

importance of rail quality and robustness, and Australian railways are co-operating in drafting new Standards Association of Australia specifications, which will include standards for rail sizes of 50 kg/m and 60 kg/m, as well as the rail sizes covered in the old specifications. The new specifications will include tighter control of the manufacturing process to reduce the incidence of rail defects.

Rail sizes currently available in Australia, in the medium to upper weight range, are 47 kg/m, 50 kg/m, 53 kg/m, 60 kg/m and 66 kg/m. Technical aspects of the 47 kg/m and the 53 kg/m rail sizes led WESTRAIL engineers to consider them as unsuitable for heavy bulk traffic. Consequently only the three rail sizes 50 kg/m, 60 kg/m and 66 kg/m were considered for evaluation(1).

Rail-life, Axle-loads and Speeds

The maximum axle-loads and speeds which WESTRAIL engineers consider suitable for these three rail sizes are set out in Table 3.1.(2)

TABLE 3.1 - RECOMMENDED MAXIMUM AXLE-LOADS AND MAXIMUM SPEEDS FOR UNIT TRAINS UNDER THE THREE PROPOSALS

	Rail Size (kg/m)	Maximum Axle-load (tonnes)	Maximum Speed (km/h)
Proposal 1	50	21	60
Proposal 2	60	25	70
Proposal 3	66	25	80

(1) Ibid, pp 35-37.
(2) Ibid, p. 41.

The speed restrictions shown apply to the bulk freight unit trains only. General freight, which is usually carried at axle-loads considerably below the maximum permitted, has a higher maximum speed limit.

The effective rail life of the three rail sizes, as measured in total gross tonnage, has been estimated by WESTRAIL engineers as follows:[1]

50 kg/m	-	205 million gross tonnes
60 kg/m	-	425 million gross tonnes
66 kg/m	-	620 million gross tonnes

The three combinations of rail size, maximum axle-load and maximum speed, will be referred to as the three proposals in following pages of this report.

The Construction Program

As current operating restrictions are already imposing a considerable operating cost penalty on the line, WESTRAIL decided that the rehabilitation program should commence as soon as was practicable. The question of timing of the commencement of the rehabilitation program is considered in detail in Chapter 4 of this report. The nature of railway construction is such that the same construction programme can be followed, regardless of the weight of the rail being laid, and so the same construction programme was considered for all three proposals. Timber sleepers will be replaced by concrete sleepers as part of any rehabilitation scheme. The re-sleepering and re-railing programme is depicted in Figure 3.1.

In addition to the rehabilitation schemes outlined, an independent programme is planned to re-sleeper the line in both directions in the Forrestfield to Avon Yard section in 1980. This programme

(1) *Ibid*, p. 42.

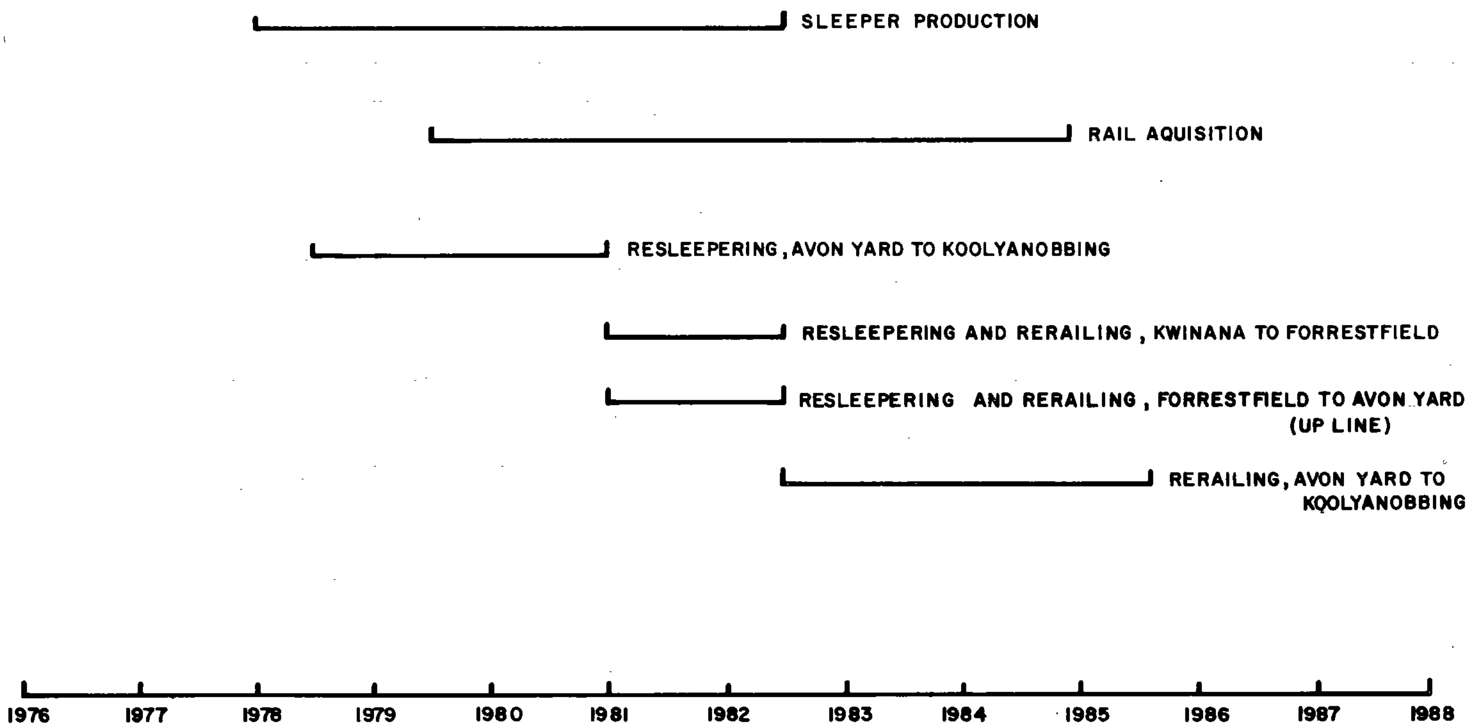

FIGURE 3·1

PROPOSED CONSTRUCTION PROGRAMME

is independent of any decision on replacement of rail, but if one of the major rehabilitation schemes is adopted, then the two programmes will be integrated. In the double track and dual gauge section of the line from Forrestfield to Avon Yard, only the standard gauge Up line (towards Perth) is suffering damage from bulk traffic. However, replacement of the standard gauge Up rails will necessitate the replacement of the narrow gauge Up rail by the same weight of rail to maintain a level surface across all three rails.

Although the initial phase of the construction programme is the same for all three proposals, if the 50 kg/m proposal is adopted then a further rehabilitation and replacement programme will have to be carried out towards the end of the twenty year study period, as the life of the 50 kg/m rails will have expired on the heavy wear Up standard gauge line between Forrestfield and Avon Yard. The exact time at which this becomes necessary depends on the quantity of future traffic carried. Under WESTRAIL's maximum traffic forecast this will not become necessary before 1990, and under the minimum traffic forecast it will not become necessary before 1993.

The Kwinana to Forrestfield, and West Merredin to Koolyanobbing sections are to be re-railed before the state of deterioration on these sections makes this strictly necessary, in order to maintain a continuous programme of rehabilitation.

Cash Flows

Table 3.2 details the capital cost streams of construction associated with the three proposals.[1] No provision has been made for the sale of recovered materials during the initial phase of the construction programme, but the proceeds from such sales

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(1) *Ibid*, Appendices 17/1, 17/2, 17/3.

would be the same for the three proposals. The timing of the cost stream shown for the further rehabilitation work entailed with the 50 kg/m proposal is that for the maximum traffic forecast, and for this further construction work, provision has been made for the sale of recovered material as this materially affects the comparison of capital costs between the proposals. The residual values of the three proposals are those which would be reached under the maximum traffic forecast. All costs are in 1976 dollars, and the independent re-sleepering programme for the line between Forrestfield and Avon Yard, scheduled for 1980, has an estimated cost of $7.5 million in 1976 prices.

TABLE 3.2 - RE-RAILING AND RE-SLEEPERING COST STREAMS FOR THE THREE PROPOSALS (UNDER MAXIMUM TRAFFIC FORECAST)

($'000)

Year	Proposal 1 (50 kg/m)	Proposal 2 (60 kg/m)	Proposal 3 (66 kg/m)
1977-78	934	934	934
1978-79	7044	7044	7044
1979-80	7695	7695	7695
1980-81	13491	14443	15016
1981-82	8512	9207	9626
1982-83	3997	4594	4954
1983-84	4674	5395	5828
1984-85	2705	3045	3249
1985-86			
1986-87			
1987-88			
1988-89			
1989-90			
1990-91	3614		
1991-92	1491		
1992-93	-		
1993-94	1908		
1994-95	3920		
Residual Value	(32660)	(39711)	(45508)

METHODOLOGY OF THE WESTRAIL EVALUATION

WESTRAIL evaluated the three proposals by using the present value of total costs during the study period as the criterion of selection. Cost components used in the calculation of total costs were:

- Capital costs of construction
- Total track maintenance costs
- The variable part of operating costs
- The residual value of the line at the end of the study period.

A twenty year study period was chosen, from 1975-76 to 1994-95, and a discount rate of 10% was used in calculating present value.

To establish the sensitivity of the evaluation to traffic forecast, costs were developed independently for both the maximum and the minimum WESTRAIL traffic forecasts. Traffic forecasts affect the components in total cost in various ways. For the capital cost of construction, the timing of the further rehabilitation required for the 50 kg/m proposal is affected by the traffic forecast used. The residual value of the line under each proposal is also affected by traffic forecast. Total track maintenance costs were calculated from WESTRAIL developed formulae which give the relationship between annual track maintenance cost per kilometre, annual gross tonnage carried, average axle-loading, and rail weight.(1) Variable operating costs in the functional areas of terminal costs, line-haul costs, administration, and capital costs of rolling stock, were developed from unit variable costs in these areas established by WESTRAIL in an internal cost report.

A range of sensitivity tests were carried out, to establish the robustness of the evaluation to uncertainties in the calculation of rail life, track maintenance costs, operating costs and capital costs.

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(1) Ibid, pp 49-50.

RESULTS OF THE WESTRAIL EVALUATION

The results for the evaluation, for the maximum traffic forecast and the minimum traffic forecast respectively, are summarised in Table 3.3.A and Table 3.3.B. The results for both forecasts reveal that the 66 kg/m proposal is superior to the 60 kg/m proposal, and that both the heavier proposals are superior to the 50 kg/m proposal.

TABLE 3.3.A - PRESENT VALUE OF CAPITAL, OPERATING AND TRACK MAINTENANCE COSTS FOR THE THREE PROPOSALS (10% DISCOUNT RATE, MAXIMUM TRAFFIC FORECAST)

($'000)

	Proposal 1 (50 kg/m)	Proposal 2 (60 kg/m)	Proposal 3 (66 kg/m)
Capital Cost	29140	28773	29742
Residual Value	(4855)	(5903)	(6765)
Capital Cost less Residual Value	24285	22870	22977
Operating and track Maintenance costs	234989	232744	232277
TOTAL	259274	255614	255254

TABLE 3.3.B - PRESENT VALUE OF CAPITAL, OPERATING AND TRACK MAINTENANCE COSTS FOR THE THREE PROPOSALS (10% DISCOUNT RATE, MINIMUM TRAFFIC FORECAST)

($'000)

	Proposal 1 (50 kg/m)	Proposal 2 (60 kg/m)	Proposal 3 (66 kg/m)
Capital Cost	27976	28773	29742
Residual Value	(5403)	(6512)	(7162)
Capital Cost less Residual Value	22573	22261	22580
Operating and track Maintenance costs	185536	183266	182662
TOTAL	208109	205527	205242

Sensitivity testing on uncertainty in rail-life considered a lengthening of rail life by about 25% and a shortening of rail life by about 25%, with respect to the current estimates of rail life.[1] As was expected, due to the effect of rail life estimate on the estimated residual value, a lengthening of rail life relatively favoured the 50 kg/m proposal, whilst a shortened rail life relatively favoured the heavier 60 kg/m and 66 kg/m proposals. However, the changes in total cost due to an extension of rail life were not enough to alter the overall ranking. It was considered most unlikely that actual rail life would lie outside the range tested.

Track Maintenance contributed about 5% to the total cost of each proposal. The evaluation assumed that a heavier rail would entail a reduction in track maintenance costs, and a sensitivity test was performed assuming no reduction in track maintenance costs for heavier track. The test narrowed the difference in total cost between the proposals but did not alter the relative ranking.[2]

Much of the capital cost of construction is common to all three proposals, the major differences being the cost of the rail themselves, and the costs of fastenings and welds. A sensitivity test was performed assuming a 20% increase in capital costs, under the minimum traffic forecast (which relatively favours the light 50 kg/m proposal), for the West Merredin to Koolyanobbing section, where rail costs are highest. No change occurred in the relative ranking of the proposals. For the Forrestfield to Avon Yard section, where a second rerailing must take place within the study period under the 50 kg/m proposal, an increase in rail costs would produce a result relatively less favourable to the 50 kg/m rail.[3]

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(1) Ibid, pp 54-55.
(2) Ibid, p. 56.
(3) Ibid, pp 56-57.

The line haul cost component of operating cost represents a large proportion of total cost (over 30%).[1] Line haul is labour intensive, and a sensitivity test was performed assuming a 100% increase in line haul costs. Again no change was observed in the relative ranking of the proposals, and the results of the test indicated that line haul costs would have to increase five-fold to effect a change in the ranking of the proposals.

Other components of operating cost were of less overall significance than line haul costs, and thus the results of this sensitivity test which produced no change in relative ranking, on line haul cost can be taken as applying to these components as well.[2]

WESTRAIL Conclusions

Sensitivity tests on capital cost, rail life, track maintenance and operating costs revealed that the difference in total costs between the 60 kg/m proposal and the 66 kg/m proposal were marginal, but that a real difference existed between the two heavier proposals and the 50 kg/m proposal. WESTRAIL concluded by recommending the 60 kg/m proposal, on the ground of lower capital cost with respect to the 66 kg/m proposal, and lower total cost with respect to the 50 kg/m proposal.

THE BUREAU RANKING OF THE PROPOSALS

Although the difference in total cost between the 60 kg/m proposal and the 66 kg/m proposal is small, it is nevertheless significant, and the difference persisted throughout the sensitivity tests. As the capital cost of the 66 kg/m proposal remained greater than the capital cost of the 60 kg/m proposal throughout the sensitivity evaluations, persistence of the difference in total cost implies that the decrease in the sum of operating and track maintenance costs between the two proposals was greater than the increase in capital costs, in each of the range of possibilities

(1) Ibid, p 57.
(2) Ibid, pp 57-58.

tested in the evaluations. This implies in turn that the incremental benefit to cost ratio involved in selecting the 66 kg/m proposal over the 60 kg/m proposal is consistently greater than 1, in each case.

As an example, the results summarised in Table 3.3.A, for the maximum traffic forecast, reveal the following incremental information.

- Increase in capital cost less residual value between the 60 kg/m proposal and the 66 kg/m proposal: $107,000

- Decrease in sum of operating and maintenance costs between the 60 kg/m proposal and the 66 kg/m proposal: $467,000.

Hence the incremental benefit to cost ratio involved in selecting the 66 kg/m proposal over the 60 kg/m proposal is 4.36. If full capital costs had been used in the above argument, and if the increase in residual value between the two proposals had been treated as a benefit instead of as a reduction to capital cost, then the incremental benefit to cost ratio would still have been greater than 1 (see Annex C).

In the light of these facts the Bureau is of the opinion that it would be desirable to select the 66 kg/m proposal in spite of its higher capital cost.

CHAPTER 4 - TIMING OF THE UPGRADING PROPOSAL

THE NEED TO INVESTIGATE TIMING

The WESTRAIL evaluation of the three upgrading proposals was performed in order to determine that combination of rail size, axle-load limitation, and speed restriction, which would result in the least total cost over a twenty year period. The evaluation compared the three upgrading proposals on the basis of a common construction program, and ignored the question of finding a suitable starting date for the schedule of construction. An investigation of the starting date of construction is necessary, however, if an optimal allocation of resources is to be achieved. Within a decision to rehabilitate the track the question of what particular scheme of rehabilitation to adopt can be answered on the grounds of least cost to the railway. However, the decision to rehabilitate, and the timing of such rehabilitation, must take into account the role played by the railway in the total transport system.

An upgrading of a particular mode within a transport corridor will generally affect the allocation of traffic between modes. Transport costs will alter on modes other than that being upgraded. Evaluation of the upgrading with respect to allocation of resources throughout the community must therefore take into account the effects of the upgrading on all modes. In a situation where transport costs are time dependent (as they must be, for example, in a case of increasing annual traffic), evaluation of the timing of an upgrading becomes necessary.

In the WESTRAIL evaluation, a delayed schedule of rehabilitation would have the effect of increasing rail operating costs and track maintenance costs. The sensitivity tests on operating and track maintenance costs undertaken as part of the evaluation indicate that this increase would not affect the relative ranking of the three proposals. Evaluation of rehabilitation with respect to resource allocation need only evaluate the least total cost rehabilitation, namely the 66 kg/m proposal, as the three rehabilitation alternatives have similar effects on modes other than rail.

The DYNATREE model, developed by the Bureau[(1)] specifically for evaluation of the timing of railway upgrading proposals, was used to determine the optimum timing of the 66 kg/m proposal.

THE DYNATREE MODEL

The DYNATREE model schedules and evaluates transport investment proposals for a transport corridor. The corridor is considered to consist of a number of modes, each of which carries a number of traffic classes. Each class on each mode has its own performance characteristics, which are specified as input to the model. The volume of traffic in each class is also specified as input to the model, so the effects of change in modal allocation can be easily evaluated. For each possible timing of the proposed upgrading, the model calculates the present value of total transport cost on each mode over the study period, including the capital cost of the proposed upgrading. From this, the timing which results in the least total transport cost can be selected. Details of data used for the model, and sources for the data, are set out in Annex E.

Estimates of the effect which deterioration of the line would have on modal allocation, and estimates of the re-routing of traffic to other modes which would follow upon closure of the line are presented in Annex C. As one of the objectives of the Bureau evaluation was to determine whether rehabilitation was justified at all, a "worst case" attitude was adopted towards non-rail costs, i.e. minimum possible values were used in each case. If rehabilitation is justified using this cost model, then it can be justified under any cost model.

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(1) Bureau of Transport Economics, "Mainline Upgrading: Evaluation of a range of options for the Melbourne-Sydney link" (Nov 1975) Annex B.

Standard gauge main line costs were represented by the variable parts of operating costs and track maintenance costs. Ship operating costs were used as a measure of the costs of transporting iron ore from Port Hedland to Kwinana. Detailed information is lacking on operating costs for the privately owned railways, and the rail operating cost figure assumed for the cost of transporting iron ore to Port Hedland from the mining areas can only be regarded as approximate. Road transport costs were represented by truck operating costs, and no attempt was made to represent road maintenance or congestion costs. A small amount of traffic would be diverted to the narrow-gauge network by deterioration of the main line. As this amount of traffic is too small to effect the overall results of the evaluation, and as narrow gauge costs are difficult to obtain, road costs were used as proxy for narrow gauge rail costs. This is tantamount to assuming that all traffic, except iron ore, would be diverted to road.

To maintain comparability with other Mainline Upgrading studies undertaken by the Bureau, the model used three traffic forecasts, maximum, medium and minimum, which were produced by the Bureau in accordance with the methods and assumptions used in other Mainline Upgrading study traffic forecasts. The major difference between the Bureau and WESTRAIL traffic forecasts is in the growth rates assumed for interstate freight and general freight, but this difference is smaller than the difference between the Bureau maximum and minimum forecasts. Bureau and WESTRAIL traffic forecasts are set out in Annex A.

The DYNATREE model calculates costs on a year by year basis. Although the capital cost of an upgrading proposal can be spread over several years in the model, the model assumes that all changes brought about by an upgrading occur in the space of a single year. Whilst in itself this is an unrealistic depiction of a lengthy construction schedule, cost differences between timings indicated by the model will be valid indications of cost differences expected between construction schedules with different starting dates. Thus the results indicated by the model must be interpreted in this light.

The model uses a twenty year study period, with base year 1975-76. All cost data were in January 1976 dollars. Three evaluations, using discount rates of 7%, 10% and 12% were performed for each of the three traffic forecasts.

RESULTS OF THE DYNATREE EVALUATIONS

The results of the DYNATREE evaluations are set out in Table 4.1. This table lists the present value of total transport costs for several of the possible timings of introduction of the 66 kg/m rehabilitation, as well as the total transport costs of the options of closing the rail altogether, and of closing the rail for a period before re-opening after rehabilitation. Each timing option has total transport costs calculated using three discount rates for each of the three traffic forecasts.

INTERPRETATION OF THE RESULTS

Timing

As indicated above, the DYNATREE model assumed that, in effect, rehabilitation takes place in a single year, and the results of the DYNATREE evaluation, set out in Table 4.1, indicate that such a rehabilitation should take place in 1980-81. Although this timing consistently results in the lowest total transport cost for a range of discount rates and traffic forecasts, the results indicate that rehabilitation in 1979-80 or in 1981-82 would result in total transport costs which differ from the optimum cost by less than two per cent. As a rapid rehabilitation is quite unrealistic, the results are better interpreted as indicating that the mid-point of a lengthy construction program should occur about 1980 or 1981. The construction program proposed by WESTRAIL is depicted in Figure 3.1, and inspection of the program indicates that the mid-point of construction occurs between June 1980 and

TABLE 4.1 - DYNATREE RESULTS: PRESENT VALUES OF TOTAL TRANSPORT COSTS FOR TIMING ALTERNATIVES, UNDER A RANGE OF TRAFFIC FORECASTS AND INTEREST RATES

($ million)

Timing Alternative	TRAFFIC FORECAST	MAXIMUM			MEDIUM			MINIMUM		
	DISCOUNT RATE	7%	10%	12%	7%	10%	12%	7%	10%	12%
Shutdown in 1985		407.4	310.7	265.6	381.0	291.5	249.7	292.6	227.3	196.8
Re-open in 1986-87 after shutdown in 1985		222.2	195.2	180.8	207.8	183.2	170.0	164.6	147.3	137.9
Rehabilitation in 1983-84		185.8	169.1	159.8	174.0	159.1	150.8	141.0	130.8	125.0
Rehabilitation in 1981-82		176.8	162.4	154.4	166.3	153.4	146.3	137.2	128.5	123.6
Rehabilitation in 1980-81		173.2	159.7	152.3	163.0	151.1	144.5	135.3	127.5	123.0
Rehabilitation in 1979-80		173.8	161.0	153.9	163.8	152.6	146.3	136.5	129.2	125.1
Rehabilitation in 1978-79		175.1	163.0	156.3	165.2	154.7	148.8	138.1	131.6	128.0

June 1982. Thus the timing indicated by the DYNATREE model is in broad agreement with the schedule of construction proposed by WESTRAIL.

The DYNATREE evaluation was performed for the 66 kg/m rehabilitation proposal. This proposal produces the largest savings in operating and track maintenance costs. As the DYNATREE model calculates the present value of total costs over the study period, this means that the timing indicated by the model for the 66 kg/m proposal is later than those timings which would be obtained for the 60 kg/m proposal and the 50 kg/m proposal. An independent DYNATREE evaluation of the 60 kg/m proposal, performed by WESTRAIL, indicated a preferred timing for this proposal of 1979-80, one year earlier than the Bureau preferred timing for the 66 kg/m proposal. Although the WESTRAIL evaluation used WESTRAIL traffic forecasts, the robustness of both the Bureau and the WESTRAIL evaluations with respect to variations in traffic forecast indicates that the differences between the Bureau and the WESTRAIL traffic forecasts would not have affected the timings indicated. The same basic cost data were used in both the WESTRAIL and the Bureau evaluations.

Robustness of Results

The results of the Bureau evaluation are consistent through a range of discount rates and traffic forecasts. Variations in traffic forecasts are reflected directly in the model as variations in total cost, and so the robustness of the optimum timing under variations in traffic forecast is an indication that the results would be similarly robust under variations of the same magnitude in the various cost components.

Closure of the Line

As road truck operating costs only were used as a measure for road transport costs, and as many other costs associated with closure of the standard gauge main line were ignored, the present value of total transport cost following closure of the line, shown in Table 4.1, must be taken as a minimum estimate of cost to the community. The present value of the saving in transport cost produced by rehabilitation is shown in Table 4.1 to lie between $73.8 million and $234.2 million, depending on the traffic forecast and discount rate chosen. If we compare these figures with the present value of the capital cost of the 66 kg/m rehabilitation proposal, we see that the benefit-to-cost ratio of rehabilitation, compared to the option of allowing the rail to close, lies between 2 and 5, depending on traffic forecast and discount rate.

CHAPTER 5 - CONCLUSIONS

No significant congestion or delay problems are expected on the standard gauge main line during the next twenty years. The Kewdale freight terminal was designed as a complementary project to the standard gauge, and has adequate capacity to manage the extra traffic expected during the next twenty years.

The physical condition of the line between Koolyanobbing and Kwinana is deteriorating rapidly. Unless a large-scale rehabilitation of the line is undertaken, severe operating restrictions will have to be introduced. Rehabilitation of the line with a rail of heavier weight would solve the problem of physical deterioration, and would lead to savings in operating costs and track maintenance expenditure.

WESTRAIL evaluated three alternative rehabilitation programmes with regard to capital cost of the proposals, operating costs, and track maintenance expenditure. The programme involving rehabilitation with rails of 66 kg/m weight was found to result in the least total cost.

The Bureau investigation of the timing of introduction of the 66 kg/m rehabilitation programme found that the construction schedule proposed by WESTRAIL resulted in less resource cost to the community than construction schedules which commenced at later dates.

The Bureau concludes that the standard gauge main line between Koolyanobbing and Kwinana should be rehabilitated to a rail weight of 66 kg/m, and that the schedule of construction should commence as soon as is practicable.

ANNEX A
TRAFFIC FORECASTS

BUREAU TRAFFIC FORECASTS

As in the traffic forecasts produced for other Mainline Upgrading studies, traffic forecasts for the standard gauge mainline has been undertaken in two stages. First, the factors influencing the rate of growth of overall traffic for the various traffic classes were considered, and estimated rates of growth were established. Secondly, the factors influencing the proportion of overall traffic carried by rail were assessed for each of the traffic classes. These assessments were combined to produce the forecasts for rail traffic. Three forecasts were produced, a maximum forecast, a medium forecast, and a minimum forecast. It is considered most unlikely that rail traffic would be less than the minimum forecast, or would exceed the maximum forecast, whilst the overall balance of probabilities is represented by the medium forecast.

Passenger Traffic

It was considered unlikely that passenger traffic would fall off during the study period, and consequently the medium and minimum forecasts assume that passenger traffic will remain stable during the study period. For the maximum forecast, it was assumed that an additional Indian Pacific train would be introduced about 1980, to cater for increased tourist demand.

Freight Traffic

Estimates of the likely growth in the various classes of freight traffic were made in the formulation of WESTRAIL's traffic forecasts[(1)], and these estimates form the basis of the Bureau's estimates. The modal allocation of traffic is, of course,

(1) WESTRAIL: "Mainline Upgrading Study, Traffic Forecasts, EGR 1976-1995", J. Stewart, Senior Planning Officer, May 1976.

critically dependent on the state of the standard gauge mainline, and the effect on traffic of deterioration of the line is discussed in Annex C of this report. If, however, rehabilitation of the line does take place, the major factors which could affect modal allocation are:

- the sealing of the Eyre Highway
- the eventual fate of coastal shipping, and
- possible deregulation of road transport within Western Australia.

Bulk Mineral Traffic

Discussions with organisations(1) involved with iron ore movement on the standard gauge mainline indicated that no consistent growth was likely in iron-ore requirements. Analysis of the iron-ore traffic over the last eight years indicates a demand fluctuating between about 2.3 million tonnes and 3.2 million tonnes. Discussions with Western Mining Corporation indicated that no consistent growth was likely in nickel concentrates traffic, but that matte traffic would possible continue to grow until 1980.

Wheat and Other Grain

Forecasting of agricultural production is made difficult by the vagaries of weather and international trade, and general trends are subject to large fluctuations. Discussions with state organisations involved in wheat agriculture indicated that increases in wheat production would arise from new acreage and increasing yield per acre and that the likely rate of increase would be about 2% per annum. Consequently, a growth rate of 2% per annum was assumed for the maximum and medium forecasts, and the minimum forecast assumed that wheat traffic would remain stable at 1976 levels.

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(1) BHP and Australian Iron and Steel are the main shippers. Agnew Clough-Wundowie has a requirement of about 100,000 tonnes annually.

Fertiliser

Growth rates were assumed to follow the growth rates for wheat. It was considered that deregulation of road transport would have a marked effect on the proportion of this traffic carried by rail, and consequently the minimum forecast assumes that fertiliser traffic by rail will fall to one-fifth of the 1976 level after 1980.

Oil and General Freight

Growth rates for oil were assumed to be 3% per annum for the maximum forecast and 2% per annum for the medium forecast. An allowance was made for the continuation of decentralisation policies in the case of general freight, and the growth rates assumed for the maximum and medium forecasts were 3.5% and 2.5% respectively. Deregulation of road transport would have the effect of re-directing the growth in these two traffics to road, and consequently the minimum forecast for these two traffics assumed that the traffics would remain constant at 1976 levels.

Interstate Freight

Interstate freight was assumed to grow at the same rate as the national economy. Before November 1975, a proportion of interstate traffic was carried by the Associated Steamship Company Pty Ltd (ASP), and this traffic was treated separately in the Bureau forecasts. The minimum forecast assumes the resumption of coastal shipping. It was considered possible that the sealing of the Eyre highway could redirect about one-fifth of the rail traffic to road after 1981, and this possibility is allowed for in the minimum forecast. The maximum forecast assumed a growth rate of 5% per annum for interstate traffic, and the medium forecast assumed a growth rate of 4.5% per annum for ten years and 3.5% per annum thereafter, in line with the expected reduction in population growth rate.

Estimated traffic on the Standard Gauge mainline in 1976 is shown in Table A.1, and a summary of estimated growth rates for the three forecasts is shown in Table A.2.

WESTRAIL TRAFFIC FORECASTS

The WESTRAIL traffic forecasts were formulated before complete information on 1976 traffic levels was available. Consequently three estimates for 1976 traffic levels were produced. These estimates are detailed in Table A.3. A summary of WESTRAIL estimates of growth rates for the maximum, medium and minimum forecasts is detailed in Table A.4.

TABLE A.1 - BUREAU TRAFFIC FORECASTS, ESTIMATED TRAFFIC IN 1976

('000 tonnes)

Traffic Class	Kwinana to Forrestfield	Forrestfield to Avon Yard	Avon Yard to West Merredin	West Merredin to Koolyanobbing
Iron Ore	2700	2700	2700	2700
Nickel	230	230	230	230
Grain	2380	2380	952	218
Fertiliser	339	339	82	19
Oil	290	290	171	119
General Freight	-	1121	525	477
ASP Interstate	-	86	86	86
Other Interstate	-	796	796	796
TOTAL	5939	7942	5542	4645

TABLE A.2 - BUREAU TRAFFIC FORECASTS, GROWTH RATES PER ANNUM OVER THE STUDY PERIOD

Traffic Class	Maximum Forecast	Medium Forecast	Minimum Forecast
Iron Ore	Constant at 3.13 million tonnes	Constant at 2.7 million tonnes	Constant at 2.28 million tonnes
Nickel	Constant at 240,000 tonnes	(a)	Constant at 210,000 tonnes
Grain	2%	2%	Constant
Fertiliser	2%	2%	(b)
Oil	3%	2%	Constant
General Freight	3.5%	2.5%	Constant
ASP Interstate	5%	(c)	(d)
Other Interstate	5%	(c)	(e)

(a) 230,000 tonnes in 1976. Increases by 2500 tonnes per year till 1980, constant at 240,000 tonnes thereafter.

(b) Assumes road traffic is de-regulated. Fertilizer traffic falls to about a fifth of its 1976 tonnage by 1980, constant thereafter.

(c) 4% p.a. growth rate till 1985, 3.5% p.a. growth rate thereafter.

(d) Assumes coastal shipping resumes. 2% p.a. growth rate till 1981, then reduced to zero.

(e) Assumes an effect from sealing of the Eyre Highway. 2% p.a. growth rate till 1981, on a basis of the 1976 tonnage. 2% p.a. growth rate after 1981, on a basis of 20% less than the 1981 tonnage.

TABLE A.3 - WESTRAIL TRAFFIC FORECASTS, ESTIMATED TRAFFIC IN 1976

('000 tonnes)

Traffic Class	Kwinana to Forrestfield	Forrestfield to Avon Yard	Avon Yard to West Merredin	West Merredin to Koolyanobbing
Iron Ore				
Maximum forecast	2200	2200	2300	2300
Medium forecast	2200	2200	2300	2300
Minimum forecast	2200	2200	2280	2280
Nickel				
Maximum forecast	190	190	190	190
Medium forecast	190	190	190	190
Minimum forecast	185	185	185	185
Grain				
Maximum forecast	2669	2669	1049	236
Medium forecast	2380	2380	952	218
Minimum forecast	2356	2356	944	216
Oil & Fertiliser				
Maximum forecast	679	647	253	138
Medium forecast	616	616	252	134
Minimum forecast	614	614	250	135
General Freight				
Maximum forecast	-	871	267	215
Medium forecast	-	862	264	218
Minimum forecast	-	854	262	211
Interstate Freight				
Maximum forecast	-	1284	1284	1284
Medium forecast	-	1055	1055	1055
Minimum forecast	-	854	854	854

TABLE A.4 - WESTRAIL TRAFFIC FORECASTS, GROWTH RATES PER ANNUM OVER THE STUDY PERIOD

Traffic Class	Maximum Forecast	Medium Forecast	Minimum Forecast
Iron Ore -			
Koolyanobbing - Avon Yard	Constant at 3,130,000 tonnes	Constant at 2,700,000 tonnes	Constant at 2,280,000 tonnes
Avon Yard - Kwinana	Constant at 3,000,000 tonnnes	Constant at 2,600,000 tonnes	Constant at 2,200,000 tonnes
Nickel	(a)	(b)	(c)
Grain	2%	2%	1%
Oil & Fertiliser	3%	2%	1%
General Freight	2%	1%	Constant
Interstate Freight	(d)	(d)	(d)

(a) 1976 base 190,000 tonnes. Increasing to 270,000 tonnes in 1985, constant thereafter.
(b) 1976 base 190,000 tonnes. Increasing to 260,000 tonnes in 1985, constant thereafter.
(c) 1976 base 185,000 tonnes. Increasing to 230,000 tonnes in 1985, constant thereafter.
(d) Constant increase of 92,000 tonnes per year.

ANNEX B

OTHER UPGRADING PROPOSALS

No significant congestion problems have arisen on the standard gauge main line since its opening to interstate traffic in 1968. A manual simulation of line operations, with traffic levels equal to traffic forecasts twenty years hence, indicated that no serious congestion problems would arise during the study period. The Kewdale freight terminal was designed specifically to cater for the new traffic conditions brought about by the opening of the standard gauge, and no capacity problems have arisen so far, and no capacity problems are anticipated within the next twenty years.

Although no serious congestion problems have arisen, delays do occur, however, and it is worthwhile examining the costs and benefits associated with upgrading proposals aimed at reducing existing delays. The section most seriously affected is the Avon Yard to West Merredin section, where timetable problems have arisen with high-priority traffic at peak periods. Two upgrading proposals have been suggested for this section. These are:

- Addition of an extra crossing loop, of length 1750m, between Mekering and Cunderdin. The estimated cost of this project is $450,000, and it is expected to reduce delays to high priority traffic by 20 minutes per train.

- Duplication of the line between Avon Yard and Meckering, and between Doodlakine and West Merredin. The estimated cost of this proposal is $11.4 million, and it is expected to reduce delays for all trains by about 100 minutes per train.

Typical delays at current traffic levels range from 50 to 100 minutes for high-priority freight, to 300 to 400 minutes delay for low priority traffic, on the journey from West Kalgoorlie to Forrestfield.

To estimate the benefits associated with these reductions, a method is needed for calculating the costs of delay. Such costs are composed of operating cost imposts due to less efficient use of rolling stock and labour, and the loss imposed on consignor and consignee by the unavailability of goods in transit. A method for calculating the costs of delay has been developed by the Bureau(1), and is outlined below.

Capital Cost of Delay

The total available annual time (8766 hours) for rolling stock is made up of running time, terminal time, and repair and maintenance time. There is some evidence that repair and maintenance takes place on a regular basis, irrespective of use, so that time taken for repair and maintenance is an annual constant. If running time and terminal time taken together are referred to as utilisation time, then the capital cost of one hour's delay will be the capital cost of one hour's utilisation time as delays do not affect time spent on repair and maintenance.

Annual utilisation time for locomotives has been estimated as 5420 hours for locomotives on the Trans Australia link.(2) This value will be used below for locomotives on the standard gauge main line. The capital cost of a locomotive is $660,000 (in 1976 prices), and this figure can be converted to an annual capital cost by using the annuity formula(3). At a discount rate of 10%, and using an effective life of 25 years, the annual capital cost of a locomotive is $72,711. Then the capital cost of one hour of utilisation time, and hence of delay is $13.42.

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(1) Bureau of Transport Economics, "Mainline Upgrading: Evaluation of a Range of Options for the Trans-Australia Link", June 1978, Annex C, pp 140-143.
(2) Ibid, p. 141.
(3) The annuity formula is:

$$c = \frac{P.i}{1 - (1 + i)^{-L}}$$

where, c is the annual cost
P is the capital cost
L is the effective life in years
i is the interest rate.

Wagons spend less time than locomotives in repair and maintenance, but the time spent on repair and maintenance is probably greater than about 10% of total time. Thus 5420 hours and 8000 hours are reasonable lower and upper bounds for wagon utilisation time. Wagon capital costs, annual capital costs at a discount rate of 10% for an effective life of 25 years, and resultant capital cost per hour, for utilisation times of 5420 hours and 8000 hours, are shown in Table B.1.

TABLE B.1 - WAGON CAPITAL COSTS, ANNUAL CAPITAL COSTS, AND COSTS OF AN HOUR'S DELAY

(Discount rate 10%)

	Bulk Mineral	Bulk Grain	Other Freight
Capital Cost of a Wagon	\$25,530	\$33,450	\$24,650
Annual Capital Cost (discount rate 10%)	\$2,812.6	\$3,685.1	\$2,715.6
Capital Cost per Hour (utilisation = 5420 hours)	51.9¢	68.0¢	50.1¢
Capital Cost per Hour (utilisation = 8000 hours)	35.2¢	46.1¢	33.9¢

Inventory Costs of Delay

The destinations of bulk freight traffic are large storage facilities, from which material is taken as needed. In such cases, delays in transit from one storage facility to another will result only in operating cost increases. The situation is different for high priority goods such as interstate freight. For such goods, interest rates and depreciation impose a definite penalty on the time spent in transit.

If the annual tonnage is T and the trip time is t hours, then on average, the amount of goods in transit at any one time is Tt/8766 tonnes. If the average value of the goods per tonne is p, and the interest rate is r, and the depreciation rate is d, then the transit time of t hours imposes a total penalty over the year of $pTt(r+d)/8766$.

This reduces to $p(r+d)/8766$, for the inventory cost per tonne-hour.

The average wagon load for interstate freight is 17 tonnes, and the average value per tonne has been estimated at between $1500 and $2000 per tonne.[1] If the rate of interest is 10%, and the average depreciation is 5%, the inventory cost per wagon per hour of transit time is 43.7¢ for an average value of $1500 per tonne, and 58.2¢ for an average value of $2000 per tonne.

Inventory costs for other non-bulk freight are difficult to estimate, due to the heterogeneous nature of the goods carried, and the varying priorities assigned to different classes of freight. In what follows, an inventory cost per wagon per hour for non-bulk freight has been assumed, equal to half the inventory cost per wagon per hour for interstate freight.

Crew costs per freight train are $26.1 per hour.

Table B.2 shows the capital, inventory, and crew costs of an hour's delay for the various classes of freight trains. The costs shown assume that each class of train has its maximum number of wagons, and the maximum delay costs per wagon are used, so that the costs detailed are maximum delay costs per train.

Assuming an average interstate freight wagon load of 17 tonnes, and 60 wagons per train, current interstate traffic levels imply about 1000 trains a year. A saving of 20 minutes delay time for interstate freight trains would thus result in a cost saving of $42,550 a year. The present value of this annual cost saving amounts to $425,500 at a discount rate of 10%. The proposed new crossing loop between Meckering and Cunderdin, which would bring

(1) *Ibid*, p. 142.

about this saving in delay time, has a capital cost of $450,000 and thus the project cannot be justified at this discount rate for the current traffic levels.

TABLE B.2 - CAPITAL, INVENTORY, AND CREW COSTS OF AN HOUR'S DELAY PER TRAIN
(DISCOUNT RATE 10%, DEPRECIATION 5%)
(Maximum estimates)

	Bulk Mineral	Bulk Grain	Interstate Freight	Other Freight
Capital Cost of locomotives	$26.83	$13.42	$26.83	$26.83
Capital cost of wagons	$35.81	$27.20	$34.57	$34.57
Inventory cost of goods	-	-	$40.16	$20.08
Crew cost	$26.10	$26.10	$26.10	$26.10
TOTAL	$88.74	$66.72	$127.66	$107.58

A lower discount rate would increase the present value of a given annual saving, but as capital and inventory costs would be decreased in proportion with the discount rate, the annual savings due to a reduction in delay would also decrease. Thus if a project cannot be justified at a discount rate of 10%, say, it is probable that discount rates at which it could be justified would be unrealistically low.(1)

Even though the project is not justified at current traffic levels, the forecast increase in traffic indicates that this project will become justifiable in a few years time, on the figures presented for the costs of delay. A more detailed study of this particular project is thus well worthwhile.

(1) If any constant annual saving is present, a discount rate of zero implies an infinite benefit, and so any project with a finite cost, no matter how expensive, can be justified at a zero discount rate.

Duplication of the line between Avon Yard and Meckering, and between Doodlakine and West Merredin, is expected to result in a reduction in delay of 100 minutes for all trains. Assuming that bulk freight unit trains run at full capacity (4761 tonnes for iron ore, and 2520 tonnes for grain), and assuming that freight (other than interstate freight) trains run at an average of two thirds of their maximum capacity of 1500 tonnes, then the current traffic levels imply an annual traffic of 522 iron-ore trains, 378 grain trains, and 516 other freight trains. The specialised bulk freight unit trains have no backloading traffic, so for the purposes of calculation, the numbers of trains needed for the two bulk traffics were doubled, to 1044 iron-ore trains per year, and 756 grain trains per year. Assuming an annual traffic of 1000 interstate freight trains, the annual cost saving produced by a reduction in delay of 100 minutes amounts to $543,761. The capital cost of duplication is estimated at $11.4 million, and so the project cannot be justified at current traffic levels. Traffic would need to double in order for the project to become marginally attractive.

ANNEX C

CONSEQUENCES OF DETERIORATION

If rehabilitation does not take place, then further deterioration of the standard gauge main line is unavoidable with normal maintenance procedures. If rehabilitation does take place, then an evaluation of the timing of such rehabilitation must take into account the rate and extent of deterioration, the effects of deterioration on track maintenance and rail operating costs, and the effects deterioration of the line will have on the allocation of traffic between rail and other modes.

Effects of Deterioration

Track maintenance policy is to maintain the line to a standard which ensures safety at the level of speed and axle-load restraints currently in force. Although safety is assured, extra delays incurred because of increased maintenance work would affect the reliability of service. Speed and axle-load restrictions are determined by balancing the reductions in operating cost obtained by higher speeds and increased axle-loads against the increase in track maintenance required to ensure safe operation at these higher speeds and greater axle-loads. As deterioration progresses and it becomes more expensive to maintain the track to a given standard, progressively more severe speed and axle-load restrictions will be introduced. Thus track maintenance expenditure will tend to rise more slowly than operating costs.

The main commercial effects of deterioration would be the increased costs brought about by more severe operating constraints, and the decreased reliability of service. The effect of reduced axle-load limits would be confined mainly to the unit trains for bulk freight, as non-bulk freight is carried at average axle-loads which are well below the maximum permitted. Increased transit time caused by reduced speed would result in direct increases in operating costs. For non-bulk freight, an increased transit time would also lead to an increase in the inventory costs of the goods in transit. Estimates of the increase in capital, inventory and crew costs which would result from an hour's increase in transit time are given in Annex B. The commercial effects of decreased reliability of service are difficult to estimate, but it is known that for certain classes of goods reliability of service is an important factor in shippers' choice of mode. These goods include perishable goods and small, high-value items. In general, those goods with a high inventory cost of transit would also be dependent on a highly reliable service.

The combined effect which rail deterioration would have on the allocation of traffic between modes is difficult to determine. In what follows, subjective judgement based on the commercial experience of WESTRAIL officers was used to estimate the effect on modal allocation.

Interstate passenger traffic would be insensitive to a further 5 to 6 hours delay, and delays of this order would not necessitate the purchase of extra cars. However, the Kalgoorlie passenger service can be expected to cease as a result of more than 5 hours delay, and passenger traffic for this service would be diverted to road coach. Iron-ore, nickel and other minerals would be insensitive to delays, as would the existing grain traffic. However, the increase in operating costs associated with deterioration can be expected to divert any growth in the grain traffic to road. It was considered unlikely that deterioration would have an effect sufficient to divert intrastate traffic to either road or the narrow gauge network, but it is known that interstate traffic is sensitive to delay. It was considered likely that, as a result, the growth component in interstate traffic would be carried by road after the introduction of a 40 km/hour speed restriction.

Consequences of Closure

The closure of the standard gauge main line would impose a severe strain on the entire transport system of Western Australia.

Transport of iron-ore by road would be extremely expensive in both truck operating costs and in associated road maintenance and congestion costs. An estimate is made in Annex E of truck operating costs per net tonne-kilometre, and these alone amount to almost twenty times the corresponding operating costs per net tonne-kilometre for unit iron-ore trains. A cheaper and more likely solution for the Kwinana smelting development would be to transport iron-ore from the Pilbara to Kwinana. Mines are already in operation which transport large quantities of iron ore by private rail to Port Hedland and Dampier, and shipping services dedicated to iron-ore transport around the coast exist. Thus the extra iron-ore traffic would not impose developmental or other overhead costs, although the shipping of iron-ore from the Pilbara to Kwinana will either require new investment in ships, or impose opportunity costs on the existing fleet. About two thirds of the current output of the mining development at Koolyanobbing is transported by ship from Kwinana to Port Kembla and Newcastle. As this iron-ore is supplementary to iron-ore from the Pilbara and the Middle-back ranges in South Australia, and can easily be replaced by ore from these sources, it is likely that the mining development at Koolyanobbing would be closed down following closure of the standard gauge line.[1] Closure of the Kwinana smelting development is considered unlikely as both BHP and the State Government have extensive commitments to this development, but such an option cannot be entirely ruled out in present economic circumstances.

Upon closure of the standard gauge, grain would be forced to travel either by road or by narrow gauge rail. However, the levels of track maintenance, the size of the operating fleet, and the standards of operation of the narrow gauge rail, have all been set on the basis of the continued operation of the standard

(1) It would not be commercially justifiable for BHP to take over the standard gauge line, and associated rehabilitation commitments, solely for the purpose of transporting supplementary ore-from Koolyanobbing. If the rail also carried general goods, then the nature of ownership is irrelevant to the question of efficient use of community resources.

gauge line. It is considered that prohibitive difficulties would arise if an attempt was made to absorb the bulk grain traffic onto the narrow gauge network. Road truck operating costs are much greater than rail operating costs for bulk traffic, and the increase in costs would either be passed onto the shipper, or if the State Government decided to offset the increase in costs by a subsidy, would remain as an impost on the public purse. In addition to truck operating costs, there would be a substantial increase in road maintenance costs, in road congestion costs (especially in the Perth metropolitan region), and in road accident costs. The absolute size of bulk grain traffic would require a large investment in new trucks. To the extent that such investment did not take place, opportunity costs would be imposed on the existing fleet. This would be likely to result in higher charges for all road freight traffic.

Part of the intrastate general goods traffic could be absorbed on the narrow-gauge network. However such an increase in traffic would result in increased maintenance and congestion costs. Conversion of bogie wagons would require a capital outlay on narrow gauge bogies, offset by the sale of standard gauge bogies. Conversion of locomotives and fixed wheel wagons is a more expensive task. Investment in new narrow gauge rolling stock would be offset by the sale of existing standard gauge stock, but to the extent that new investment and conversion of rolling stock did not take place, opportunity costs would be imposed on the existing fleet. If demand was not rationed by passing such opportunity costs onto shippers, then the speed and reliability of service would suffer from the resulting shortage of rolling stock.

That part of intrastate traffic which would be diverted to road upon closure of the standard gauge would have effects similar to that of bulk grain, but to a smaller extent. All interstate traffic which passed through Kalgoorlie would travel by road from Kalgoorlie to Perth if the standard gauge was closed. What percentage of interstate traffic which would pass through Kalgoorlie, and what percentage would travel by sea to and from the eastern capitals, depends upon the eventual fate of coastal shipping.

Other important social consequences would also follow from the closure of the standard gauge main line. The line is a large-scale employer of labour. Upon closure the employees could be retrenched, but it is likely that social pressure would force WESTRAIL to redeploy most of the work-force on the narrow gauge network. While some redeployment would be justified by the increased traffic, many of the jobs would have to be found by decreasing the efficiency of labour. Employment opportunities elsewhere would be provided by increased traffic on other modes, but increased freight charges following increased operating costs would have a deleterious effect on the economy as a whole. If Government, either State or Federal, decided to subsidise the increase in operating costs, then either taxes must increase, or expenditure on other social objectives must be reduced.

ANNEX D

A NOTE ON INCREMENTAL COSTS AND BENEFITS

In Chapter 3, an example was given of the incremental benefit to cost ratio involved in selecting the 66 kg/m proposal over the 60 kg/m proposal. In the example, benefits were considered to be savings in operating and track maintenance costs, and costs were considered to be the increase in capital cost less residual value. As the residual value of the 66 kg/m proposal is greater than the residual value of the 60 kg/m proposal, the increase in residual value could as equally well be considered a contribution to benefit as a decrement to cost. This alternate treatment will clearly change the numerical value of the incremental benefit to cost ratio. The question arises as to whether it is possible for one method of treatment of residual value to result in an incremental benefit to cost ratio greater than 1, whilst the alternate method results in an incremental benefit to cost ratio less than 1. In other words, do the two alternative methods of treatment of residual value produce a consistent ranking of the proposals?

Consider two proposals, with present values of capital costs (over some study period) C_1 and C_2 respectively, with present values of operating costs O_1 and O_2 respectively, and with present values of residual value R_1 and R_2 respectively. Suppose that the two proposals are ranked by total cost (capital cost plus operating cost less residual value), and suppose that the first proposal has a higher total cost than the second proposal. Then we have the inequality:

$$C_1 + O_1 - R_1 > C_2 + O_2 - R_2$$

If the first proposal also has a greater capital cost, the second proposal may be selected unequivocally. A case of interest arises only if the second proposal has a greater capital cost and a lesser total cost.

If capital costs are grouped on one side of the inequality, and operating costs and residual values are grouped on the other side, the following inequality results.

$$(O_1 - O_2) + (R_2 - R_1) > C_2 - C_1$$

In other words, the sum of savings in operating cost plus the increase in residual value is greater than the increase in capital cost.

If residual values are now regrouped with capital costs, the following inequality is obtained.

$$O_1 - O_2 > (C_2 - R_2) - (C_1 - R_1)$$

In other words, the savings in operating costs alone is greater than the increase in capital cost less residual value.

Thus the two methods of treating residual value in incremental benefit to cost studies result in consistent ranking of the proposals.

As an example, consider Table 3.3.B, where the results of the WESTRAIL evaluation, for the minimum traffic forecast, are given. The selection of the 66 kg/m proposal over the 60 kg/m proposal involves the following incremental changes:

. Increase in capital cost	\$969,000
. Increase in residual value	\$650,000
. Decrease in operating and track maintenance cost	\$604,000

If the increase in residual value is treated as a benefit, the incremental benefit to cost ratio is 1.29.

If residual value is considered as a decrement to capital cost, then the increase in capital cost less residual value is $319,000, and the incremental benefit to cost ratio is 1.89.

The results of the WESTRAIL evaluation, for the maximum traffic forecast, are detailed in Table 3.3.A. If the increase in residual value is treated as a benefit, the incremental benefit to cost ratio involved in selecting the 66 kg/m proposal over the 60 kg/m proposal is 1.37. If residual value is treated as a decrement to capital cost, the incremental benefit to cost ratio is 4.36.

ANNEX E

COST DATA USED IN THE DYNATREE MODEL

All costs have been expressed in 1976 prices.

STANDARD GAUGE MAIN LINE COSTS

WESTRAIL has supplied the following information on capital, operating and track maintenance costs:

Locomotives

Capital Cost (L class locomotive)	$660,000
Fuel and maintenance costs	$0.58 per kilometre
Annual distance travelled	136,000 kilometres

Wagons

Maintenance cost for mineral wagons	$0.0087 per kilometre
Maintenance cost for other freight wagons	$0.0201 per kilometre

TABLE E.1 - CAPITAL COST, NET CAPACITY AND ANNUAL DISTANCE TRAVELLED FOR EACH CLASS OF FREIGHT WAGON

Class	Capital Cost ($'000)	Net Capacity (tonnes)	Annual Distance Travelled ('000 kilometres)
Iron	25.5	69	187
Nickel	25.5	61.5	187
Grain	33.5	63	70
General Freight	24.7	25	33
Interstate Freight	24.7	25	65

An effective life of 25 years was assumed for rolling stock.

Crew Costs

Freight Trains	$26.1 per hour
Passenger Trains	$121.0 per hour

Track Maintenance

WESTRAIL has developed the following formula(1) relating annual track maintenance costs per kilometre to rail weight, annual traffic, and maximum axle-load restriction.

$$M = k\, T^{0.3} A/W^{1.6} \qquad \text{(Equation E.1)}$$

where,

M is the annual track maintenance cost per kilometre
T is the annual gross tonnage carried, in millions of tonnes
A is the maximum axle-load in tonnes
W is the rail weight in kg/m
k is a constant

Maintenance cost per kilometre is estimated to be about 10% greater for timber sleepers than for concrete sleepers, other things being equal.

For the case of 47 kg/m rails, with a maximum axle-load of 22.5 tonnes, and wooden sleepers, the formula becomes

$$M = \$1372\, T^{0.3} \qquad \text{(Equation E.2)}$$

where,

T is the annual gross tonnage, in millions of tonnes
M is the annual track maintenance cost per kilometre

For the case of 66 kg/m rails, with a maximum axle-load of 25 tonnes, and concrete sleepers, the formula becomes

$$M = \$803\, T^{0.3} \qquad \text{(Equation E.3)}$$

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(1) WESTRAIL, "Interim Report: Standard Gauge Main Line, Kwinana-Koolyanobbing Section" (Oct 1976), pp 49-50.

With the aid of these formulae, estimated total track maintenance expenditure was calculated for each year of the study period.[1] Traffic forecasts indicate that traffic carried will increase steadily throughout the study period, and the marginal track maintenance expenditure due to the increase in traffic carried was calculated, and used in the DYNATREE model. For the medium traffic forecast, marginal annual track maintenance expenditure was as follows:

47 kg/m rail, timber sleepers	0.017¢ per net tonne-kilometre
66 kg/m rail, concrete sleepers	0.009¢ per net tonne-kilometre

PRIVATE RAIL COSTS

Detailed information about costs on the private railways in the Pilbara is difficult to obtain. On the basis of the information that is available, an aggregate cost of $0.30 per tonne-kilometre was assumed.

SHIPPING COSTS

The following information was supplied by the Coastal and Overseas Bulk branch of the Department of Transport, and applies to a 60,000 dwt ore carrier, foreign built and Australian operated.

Capital cost	$18 million
Loading at Port Hedland	$0.30 per tonne
Discharge at Kwinana	$0.13 per tonne
Days at sea (north and south bound)	5.4 days

(1) Gross to net tonnage ratios are as follows:

Forrestfield to Avon Yard	1.62
Avon Yard to West Merredin	1.93
West Merredin to Koolyanobbing	1.95

Loading (@ 6,000 tonnes per hour)	0.5 days
Discharge (@ 450 tonnes per hour)	5.5 days
Average delays	1.5 days
Hence, average voyage length	12.9 days
Voyage operating costs	$7,500 per day
Other costs	$100,560 per voyage

The effective life of an ore carrier was assumed to be 16 years.

ROAD TRUCK OPERATING COSTS

The following information is taken from F.D. Gallagher "Road Train Operation - Cost Savings on Line Haul to the Pilbara Region", Director General of Transport, Western Australia, Jan 1976.

Capital cost of truck	$49,000
Effective life	5 years
Annual distance travelled	200,000 kilometres
Operating costs	$0.33 per kilometre
Capacity	22.5 tonnes

COMPARISON OF ROAD AND RAIL LINE-HAUL COSTS FOR BULK FREIGHT

Capital costs for both road and rail vehicles were converted into annual costs by the annuity formula, and the annual capital costs were divided by the annual distances travelled to obtain capital costs per kilometre. These costs were added to fuel, maintenance and other operating costs to obtain total line-haul costs per kilometre. These were divided by net capacities to obtain total line-haul costs per net tonne-kilometre. The results are shown below, for iron-ore, and a discount rate at 10%,

Road Truck

Capital Cost	\$49,000
Effective life	5 years
Annual distance travelled	200,000 kilometres
Annuitized capital cost (at 10%)	\$0.245 per kilometre
Operating Costs	\$0.33 per kilometre
Capacity	22.5 tonnes
Total line-haul costs	1.75¢ per net tonne-kilometre

Unit Train

Effective life of rolling stock	25 years
Annual distance travelled	
Locomotives Wagons	136,000 kilometres 187,000 kilometres
Capital cost per unit train	
2 locomotives	@ \$660,900 per locomotive
69 wagons	@ \$25,500 per wagon
Annuitized capital cost (at 10%)	\$2.09 per kilometre
Locomotive fuel and maintenance Wagon maintenance	\$1.61 per kilometre \$0.60 per kilometre
Crew Cost @ 70 kilometres per hour	\$26.1 per hour \$0.37 per kilometre
Capacity of train	4,761 tonnes
Total line-haul cost	0.089¢ per net tonne-kilometre