Economic Evaluation of Timber and Concrete Sleepers for Three Railway Lines

Report

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BUREAU
OF
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ECONOMICS

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Tarcoola - Alice Springs
Adelaide - Crystal Brook
Trans - Australian

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BUREAU OF TRANSPORT ECONOMICS

ECONOMIC EVALUATION OF TIMBER AND CONCRETE SLEEPERS FOR THREE RAILWAY LINES

TARCOOLA-ALICE SPRINGS
ADELAIDE-CRYSTAL BROOK
TRANS-AUSTRALIAN RAILWAY

OCTOBER 1972

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SUMMARY

The evaluations presented in this report have been made to determine the least cost sleeper alternative for each of three railway projects. They are the proposed new railway line from Tarcoola to Alice Springs, the standard gauge connection from Adelaide to Crystal Brook, and the re-sleepering of the Trans-Australian Railway.

The technique of evaluation has been to discount the costs associated with each type of sleeper over a 50-year period and to compare the totals thus obtained. The results are as follows :

Tarcoola-Alice Springs Railway: The primary alternatives are 9" x 6" x 8'3" and 10" x 5" x 8'6" jarrah sleepers (both treated and untreated) and concrete sleepers. The concrete sleeper is the least cost alternative. The next best choices, in order, are treated 10" x 5" sleepers, which would cost $1.649 million more, and treated 9" x 6" sleepers, which would cost $3.176 million more.

Adelaide-Crystal Brook Railway: The least cost alternatives, in order, are 10" x 5" red gum sleepers, followed by concrete sleepers at an additional cost of $0.294 million, and untreated 10" x 5" jarrah sleepers at an additional cost of $0.364 million.

Trans-Australian Railway: The primary alternatives were the same as for the Tarcoola-Alice Springs Railway. The least cost alternatives, in order, are concrete, followed by treated 10" x 5" jarrah sleepers at an additional cost of $0.237 million, and treated 9" x 6" jarrah sleepers at an additional cost of $2.807 million.

In addition to the costs identified in the evaluations, there are significant qualitative differences between various types of sleepers; for example, the greater weight of concrete

sleepers which adds to track stability. The current level of railway engineering knowledge does not enable the BTE to place a money value on such quality differences.

Subsidiary calculations were made of the savings that might result through the alleviation of unemployment in the areas of Western Australia and South Australia where sleepers are produced. These calculations did not change the order of preference but did indicate that, in social cost terms, the advantage of the least cost sleeper alternative would be reduced by a relatively small amount in each case.

INTRODUCTION

ORIGIN OF THE STUDY

In February 1972 the Minister for Shipping and Transport requested the B.T.E. to evaluate the relative merits of timber and concrete sleepers for the proposed standard gauge railway between Tarcoola and Alice Springs, the proposed standard gauge link between Adelaide and Crystal Brook, and the re-sleepering of the Trans-Australian Railway between Port Pirie and Kalgoorlie. Each of these routes would form a part of the interstate standard gauge railway system, as shown in Fig. 1.

PROJECT DESCRIPTIONS

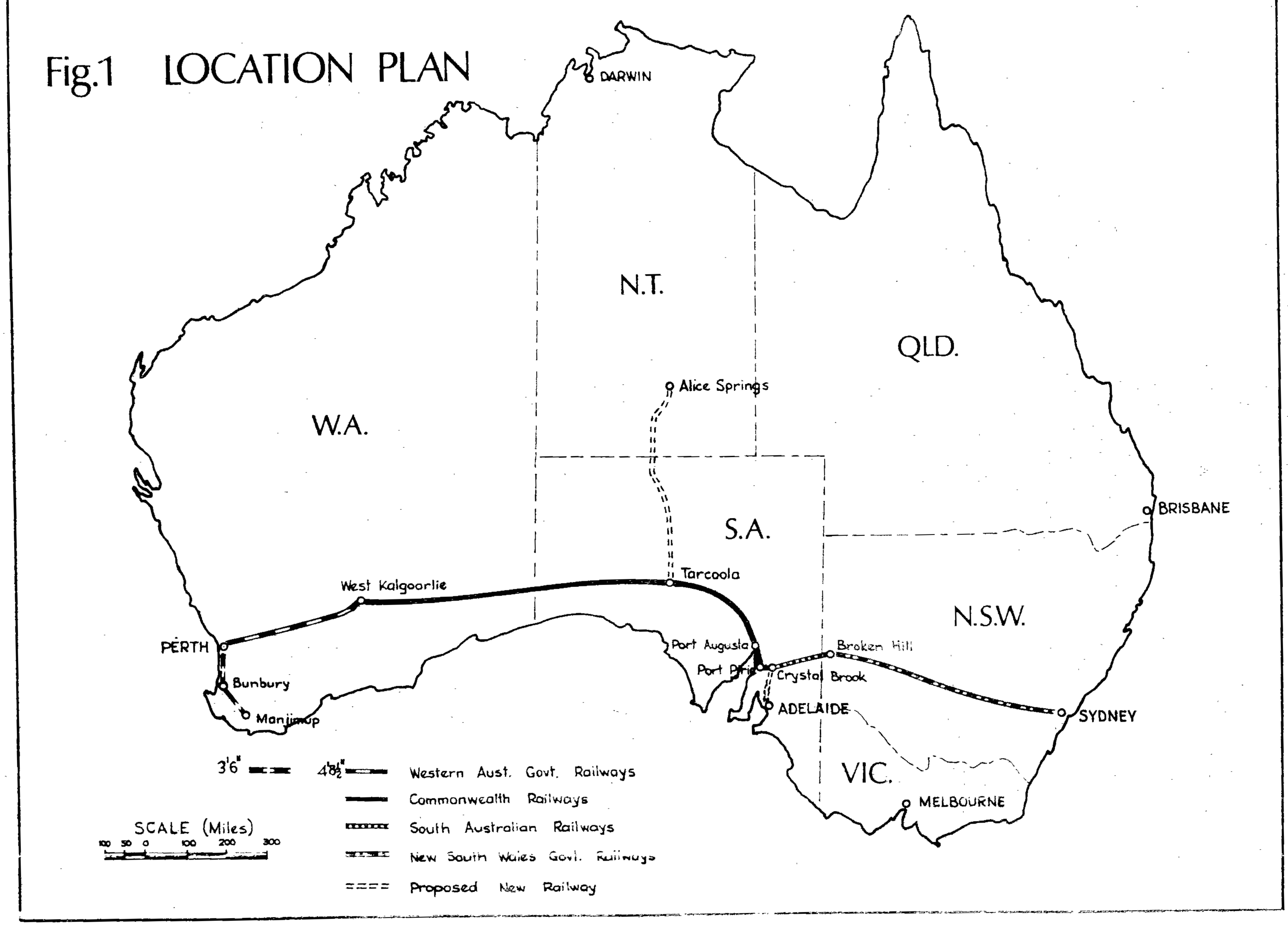
Tarcoola-Alice Springs Railway

The proposed railway is planned to replace the existing low standard, narrow gauge railway which extends from the standard gauge railhead at Marree to Alice Springs. Tarcoola is located on the Trans-Australian Railway 260 miles west of Port Augusta. Alice Springs is 520 miles north of Tarcoola. The new railway would be located on relatively high ground to the west of the Lake Eyre basin, largely to avoid problems associated with flooding.

Adelaide - Crystal Brook Railway

The proposed railway is designed to connect Adelaide with the standard gauge system. The route is roughly parallel to the existing groad gauge line and is 121 miles in length.

Fig.1 LOCATION PLAN



Trans-Australian Railway

In recent years the Trans-Australian Railway has been re-railed with 94 lb per yard continuously welded rail. Experience has shown that the existing 9" x 4½" x 8'0" timber sleepers do not provide adequate track stability for this type of rail.

The sleepers between Port Pirie and Port Augusta, the most heavily used section of the line, are at the end of their useful life and would be the first to be replaced. Following this, resleepering would proceed from Port Augusta west for two years, at a rate of approximately 85 miles per year. Thereafter sleepers would be installed in sections where renewals are most needed.

STUDY PROCEDURE

The major steps taken in the study were:

- assemble and critically review technical and cost data supplied by railway authorities and industry representatives,
- determine the net present value of all costs of supply, installation and maintenance which differ between specified types of timber and concrete sleepers,
- assess, for each project, the type of sleeper most appropriate on commercial grounds, and
- assess the significance of other factors relating to the most appropriate choice of sleeper.

The emphasis has been on project evaluation, not on the technical aspects of material qualities, sleeper dimensions and track assembly, nor on the effects of these factors on train operation. In these technical matters the B.T.E. was guided, as far as this was ascertainable, by the consensus of expert opinion obtained from Australian and overseas authorities.

SLEEPER CHARACTERISTICS

HISTORICAL

Because sleepers are an important element in the railway track, considerable attention has been given throughout the world to the use of alternative materials, designs and arrangements for sleepers. The materials that have been used extensively are softwood, hardwood, steel and concrete. The choice in any particular set of circumstances has generally been based on availability and on a judgement of quality against cost. Changing technology has been important in influencing the use of various types of sleeper. The current situation in most countries is that the use of both softwood and steel sleepers is declining rapidly, while concrete sleepers and hardwood timber sleepers treated with preservative are the main alternative materials [(1)].

In Australia, the ready availability of relatively durable hardwood has tended to inhibit technological development of other sleeper materials. However, in recent years treated timber sleepers and concrete sleepers have become more significant alternatives. As in other countries, it is becoming more clearly recognised that the most appropriate choice is a matter of economics, rather than one of clear technical superiority.

TIMBER SLEEPERS

Traditionally, timber sleepers have been used because of their availability, cost, lightness for handling, workability, resilience, good insulating properties and low

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(1) United Nations Economic and Social Council, Economic Commission for Europe, Timber Committee, "Wooden Railway Sleepers", Working Paper 177, August 1972. (Restricted distribution).

sensitivity to shocks. The main disadvantages are the need for continuous maintenance, largely because of progressive loosening of the rail fasteners, and susceptibility to weathering and biological attack. These maintenance difficulties are compounded because of the considerable variation in durability between individual sleepers. Timber sleepers can also be subject to significant wear from the rails.

These natural disadvantages limit the useful life of timber sleepers. However, life can be prolonged by providing steel base plates which reduce wear between rail and sleeper, designing fittings so that they can be re-fastened, providing end binding to reduce splitting and by impregnating with preservative. These measures reduce maintenance and replacement costs, but cause an added initial cost.

CONCRETE SLEEPERS

Reinforced concrete sleepers have been used to some extent in Europe for about 40 years. In some countries, such as East Germany, Czechoslovakia and Poland, a substantial proportion of the railway system is now laid with concrete sleepers. The primary advantages of concrete sleepers are long life, uniformity of quality and dimensions, and high resistance to wear and biological attack.

The main disadvantages in the past have been the initial cost, weight (about three times that of a hardwood sleeper) and sensitivity to shock. With the current change to continuous welded rail, the weight of concrete sleepers has become an advantage in resisting thermal forces, which are much greater than in tracks constructed in the traditional way. The common use of mechanical handling equipment has reduced the problem of weight. The disadvantage of poor resilience has become less important with welded rail, although a pad between rail and sleeper is still required. With automatic track signalling the electrical conductivity of concrete sleepers is a disadvantage.

TRACK ASSEMBLY

Typical track assemblies for timber and concrete sleepers are shown in Fig. 2 and Fig. 3. The components are those appropriate for welded rail, which would be used in each of the projects evaluated in this report.

In timber sleeper construction the rail rests on a double shouldered, steel baseplate which is fixed to the sleeper by two lockspikes. The rail is secured in each baseplate by two dogspikes. Rail anchors are steel fasteners which clip to the rail on either side of selected sleepers to resist longitudinal movement of the rail which could occur under thermal stress, during construction, or in the event of a rail breakage.

Concrete sleepers are constructed with four cast iron shoulders set in the concrete, one on each side of each rail position. When installed, the rail rests on a resilient pad (usually neoprene or rubber) placed between each pair of shoulders. The rail is fastened to each shoulder by a spring clip. For railways with automatic track signalling, an insulator is placed between the rail and each spring clip. In circumstances where it is expected that heavier rail will be laid at a later period, the sleeper is designed to accept the larger base of the heavier rail and steel spacers are used in the initial assembly.

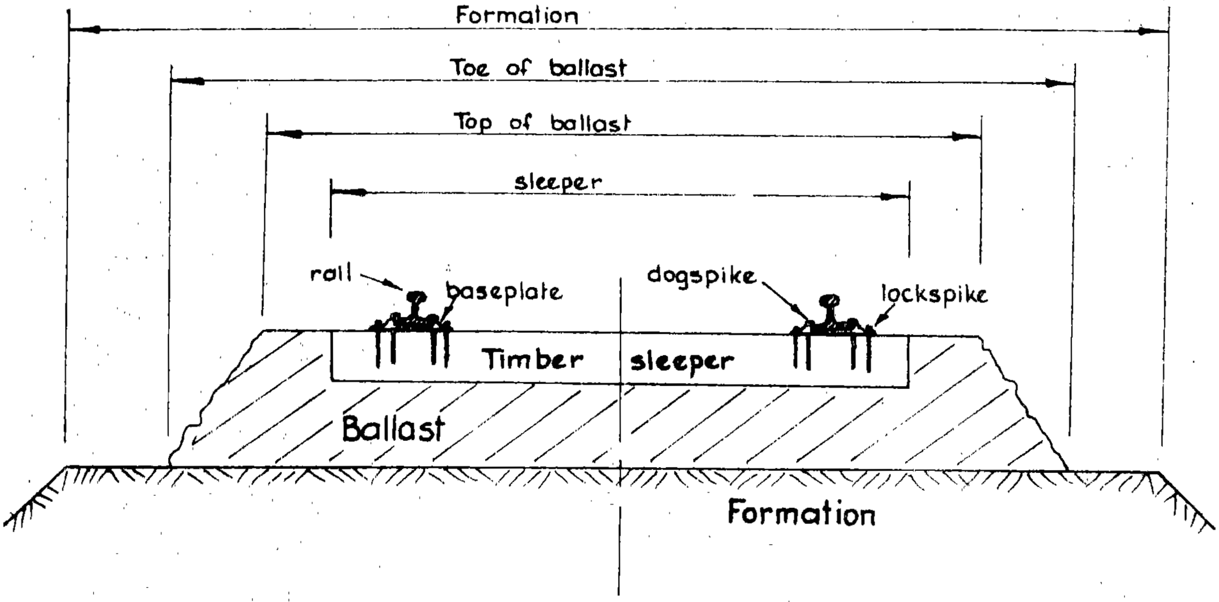

Fig.2 - Track assembly with timber sleepers

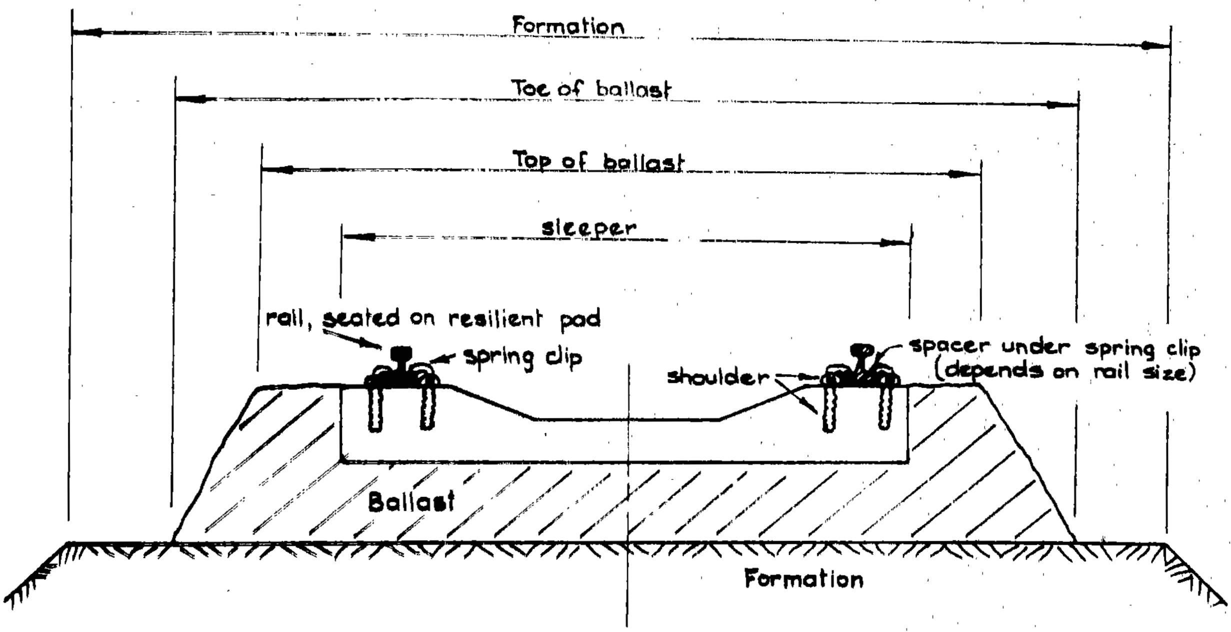

Fig.3 - Track assembly with concrete sleepers

SELECTION OF ALTERNATIVES

TIMBER SLEEPERS

The standard sleeper used in the past by Commonwealth Railways was 9" x 4½" x 8' 0" untreated jarrah supplied from Western Australia. South Australian Railways mainly use 10" x 5" x 8' 6" untreated river red gum sleepers, cut generally in Western Victoria.

The BTE discussed the question of timber material and dimensions at length with both of these railway authorities, and with a wide range of agencies concerned with timber utilization. The consensus was that although other timber species are available, jarrah is a primary alternative for each of the three railway projects and that for the Adelaide-Crystal Brook Railway only, red gum is also a primary alternative. In each case both treated and untreated timber were taken as alternatives for evaluation.

Agreement was also reached that 9" x 4½" sleepers are technically unsatisfactory for any of the railways because sleepers with these dimensions offer insufficient resistance against thermal stress. This is a critical technical consideration when using long lengths of welded rail, as large forces develop which tend to move the sleepers both horizontally and vertically. Horizontal movement of the track must be resisted largely by friction between the sleeper and ballast, which depends on sleeper weight and dimensions. Upward movement is principally resisted by the weight of the sleeper.

Current knowledge is not adequate to design a railway track in any precise way to resist the various forces which may act on it due to thermal effects and the dynamic loading of train operation. Under these circumstances, the BTE necessarily had to accept advice based on the experience of the railway authority directly responsible for each project. Accordingly, 10" x 5" x 8' 6" sleepers were accepted as the minimum size appropriate for the circumstances of the Adelaide-Crystal Brook Railway. Dimensions of 9" x 6" x 8' 3" were accepted as the minimum appropriate for the two Commonwealth Railways projects. However, for comparability of presentation, analyses of the 10" x 5" x 8' 6" sleepers are also detailed, in this report, for the Commonwealth Railways projects.

The spacing of sleepers is also a variable which relates to the safe transfer of loading from the rail, through the ballast to the foundation. As with sleeper dimensions, the most appropriate spacing can only be determined, at present, from engineering experience. On the advice of the Commonwealth and South Australian Railways, the timber sleeper spacings taken as appropriate for the evaluations were 2640 per mile for the two Commonwealth Railways projects and 2420 for the South Australian project.

CONCRETE SLEEPERS

Commonwealth Railways are currently using concrete sleepers in the construction of the Port Augusta-Whyalla Railway. The particular design of sleeper (C.R.1) was evolved following intensive investigations and has, consequently, been adopted for this evaluation.

The spacing of concrete sleepers adopted for the study was 2400 per mile for the Commonwealth Railways projects and 2420 per mile for the Adelaide-Crystal Brook project. These spacings were selected as providing equivalent bearing area to the timber sleepers selected for evaluation in each case.

METHOD OF EVALUATION

COMMERCIAL

The objective of the commercial evaluation was to determine, in the case of each project, the best alternative for the railway authority as a business enterprise. The criterion adopted was the least cost alternative of those considered by the railway authorities as technologically satisfactory. In determining the least cost alternative, all measurable cost items associated with the purchase, movement, installation, maintenance and renewal of sleepers were identified. Items common to each alternative were neglected, except in some cases where this would have complicated the estimating procedure.

In the absence of a committed work programme, the construction of each project was assumed to commence in 1972. Future costs were discounted at 7 per cent to this base year. All estimates were in constant 1972 dollar values; inflation and other temporal effects generally influence the various cost components in a relatively consistent manner. The one cost item that may not move in step with other costs is labour. Should labour costs rise at a greater rate than other costs, due to the difficulty of getting men to do maintenance work in remote areas, then timber sleepers will be a worse alternative than is shown in the results of the evaluation.

The period of evaluation was 50 years, being the expected life of concrete sleepers, the most durable of the alternative materials. Beyond this period some allowance was made for differences in the residual values of other alternatives. Other long term effects, such as the second cycle of concrete sleeper replacements, were neglected as insignificant to the choice of the best alternative.

The freight movements involved in the alternatives analysed for each project differed considerably, and in each case represented a substantial part of the measurable costs. It was important, therefore, to estimate the true marginal cost of freight movement to the railway authorities rather than to simply adopt the current railway freight rates. These estimates were made by assessing the additional cost of locomotive power, wagon utilization, rolling stock maintenance and track maintenance involved in each case.

SOCIAL-ECONOMIC

In the evaluation of public works it is necessary to consider the effects of each alternative on the community as a whole as well as the commercial implications to the operating authority. This involves estimating the resource values of the various cost items. For this particular evaluation the current prices of the cost items, with the exception of freight rates, were generally an acceptable estimate of the resource costs. However, it was considered that the effects on employment of the various alternatives could be significantly different from a community point of view.

The principle involved is that the cost of labour is the value of that labour in alternative employment. If selection of one alternative would lead to the employment of labour which would otherwise be unemployed, the cost of that labour would be very low.

It is obviously difficult to assess the amount of unemployment which may follow from selection of one or other of the sleeper alternatives, and the opportunity cost of utilizing this labour in sleeper production. This would involve forecasting the labour market by specific localities over a period of several years, assessing the mobility of labour and taking account of possibilities for alternative markets and other means of utilising labour. In view of these uncertainties, the evaluation considered the influence of employment on the selection of sleeper alternatives by making sensitivity tests to establish the maximum likely effect on the choice due to this factor.

COST ESTIMATES

GENERAL

The sleeper costs used in the evaluation were based on realistic estimates provided by Commonwealth Railways, South Australian Railways, major Western Australian sawmillers and the Victorian Sawmillers' Association. Other costs were based on detailed information supplied by the responsible railway authorities. The BTE carefully reviewed the cost information to ensure that the estimates were consistent, particularly in regard to the operations included in the analysis, the prices of basic materials, the costs of labour and the treatment of overhead costs. Freight costs associated with the construction and maintenance works were assessed by the BTE, using train operation information supplied by the railway authorities.

Generally, the cost estimates for sleeper installation and maintenance were built up from detailed estimates of all relevant items of material, plant and labour.

CONSTRUCTION PERIOD

The responsible railway authorities advised that the rates of construction most appropriate to the special circumstances of each project were 144 miles per annum for the Tarcoola-Alice Springs Railway, 45 miles per annum for the Adelaide-Crystal Brook Railway and 83.3 miles per annum (220,000 sleepers) for the Trans-Australian Railway. These estimates were accepted for the evaluation, so that the construction periods for the projects were 3.6 years, 2.7 years and 13.3 years, respectively.

INITIAL COSTS

Track Components

The unit costs for the material used in the various sleeper installations are shown in Table 1.

TABLE 1 - UNIT COSTS OF TRACK COMPONENTS

Item		Unit Cost
		$
Untreated sleepers	- 9" x 6" x 8'3" jarrah (ex-mill W.A.)	5.44
	- 10" x 5" x 8'6" jarrah (ex-mill W.A.)	4.72
	- 10" x 5" x 8'6" red gum (ex-mill Victoria)	3.85
Sleeper treatment (incl. boring)	- 9" x 6" x 8'3" jarrah	2.09
	- 10" x 5" x 8'6" jarrah	1.72
Baseplate	- 94 lb per yard rail	0.74
	- 107 lb per yard rail	0.97
Rail anchor		0.33
Dogspike	- Commonwealth Railways	0.11
	- South Australian Railways	0.094
Lockspike		0.105
Concrete sleeper		8.25
Spring clip		0.32
Resilient pad	- 80 lb per yard rail	0.315
	- 94 lb per yard rail	0.395
Spacer	- 80 lb per yard rail	0.086
	- 94 lb per yard rail	0.115
Insulator		0.12
Ballast		2.00 per yard

The estimated quantities of materials per mile for each of the three projects are shown in Table 2. These quantities exclude materials for switches and crossings, where timber sleepers would be used because of the need for varying lengths of sleeper. Sidings and crossing loops have also been excluded, in the absence of design details for each project. These omissions are not important in the comparisons of the primary alternatives. No allowance was made for baseplates and rail anchors on the Trans-Australian Railway because in recent years heavier rail has been installed using new fittings, which could be re-used. Insulators would not be required for the two Commonwealth railways projects because automatic track signalling would not be used.

TABLE 2 - MATERIALS FOR INITIAL INSTALLATION

Item	Tarcoola-Alice Springs	Adelaide-Crystal Brook	Trans-Australian
	(per mile)	(per mile)	(per mile)
Timber Sleepers			
Sleepers installed	2,640	2,420	2,640
Sleepers rejected	5	5	5
Baseplates	5,280	4,840	-
Rail anchors	3,520	3,620	-
Dogspikes	10,560	9,680	10,560
Lockspikes	10,560	9,680	10,560
Ballast (tons)			
- 9" x 6" sleeper	3,087	-	235*
- 10" x 5" sleeper	2,889	3,672	37*
Concrete Sleepers			
Sleepers installed	2,400	2,420	2,400
Sleepers rejected	10	10	10
Spring clips	9,600	9,680	9,600
Resilient pads	4,800	4,840	4,800
Spacers	9,600	-	9,600
Insulators	-	9,680	-
Ballast (tons)	3,367	4,198	515*

* The ballast quantities for the Trans-Australian Railway would raise the existing ballast level to the top of each sleeper.

The discounted costs of track components for the initial installation of sleepers of the three projects are shown in Table 3.

TABLE 3 - DISCOUNTED COSTS OF TRACK COMPONENTS FOR INITIAL INSTALLATION
($'000)

Type of Sleeper Installation	Tarcoola-Alice Springs	Adelaide-Crystal Brook	Trans-Australian
Jarrah			
9" x 6" x 8'3"			
treated	13,905	-	15,989
untreated	11,523	-	12,087
10" x 5" x 8'6"			
treated	12,541	3,282	13,675
untreated	10,649	2,838	10,465
Red Gum			
10" x 5" x 8'6"			
untreated	-	2,613	-
Concrete (C.R. 1)	13,476	3,651	18,574

Installation

The installation phase of initial construction is defined as the work of installing, or replacing, the sleepers and track assembly, after the components have been transported to the project area.

Table 4 shows the operations involved in the installation of timber sleepers for the Tarcoola-Alice Springs Railway and the estimated unit cost of these operations.

TABLE 4 - TIMBER SLEEPERS - UNIT COSTS OF TRACK ASSEMBLY: TARCOOLA-ALICE SPRINGS RAILWAY

Operation	Unit Cost
	($ per sleeper)
Transfer sleepers from rail wagon at railhead to road vehicle	0.06
Cart sleepers to site and stack	0.02
Space sleepers on formation	0.30
Transfer, distribute and space fittings	0.30
Spike baseplates to sleeper, lay rail, secure dogspike and rail anchors	
- treated sleepers (bored)	1.40
- untreated sleepers (includes boring in field)	1.85
Deliver and place ballast	($ per mile)
- 9" x 6" x 8'3" sleeper	449.00
- 10" x 5" x 8'6" sleeper	421.00

The subsequent operations of lifting the rail and sleepers, aligning the track and packing with ballast were excluded from the estimates as they would be comparable for all sleeper alternatives.

The cost of delivering and placing ballast was based on an average haul of 520 miles and a wagon maintenance cost of 1.4 cents per mile per 50-ton wagon.

The unit costs for track assembly with concrete sleepers are shown in Table 5.

TABLE 5 - CONCRETE SLEEPERS - UNIT COSTS OF TRACK ASSEMBLY: TARCOOLA-ALICE SPRINGS RAILWAY

	Unit Cost
	($ per sleeper)
Handle sleepers at railhead	0.15
Cart sleepers to site	0.05
Space sleepers on formation	0.60
Transfer, distribute and space fittings	0.25
Place resilient pads, lay rail, insert spacers or insulators, fix clips	0.45
	($ per mile)
Deliver and place ballast	490.24

The unit costs of installation for the Adelaide-Crystal Brook Railway are the same as for the Tarcoola-Alice Springs Railway, except for the cost of delivering ballast. The average haul for the Adelaide-Crystal Brook Railway is estimated as 30 miles, so the costs of delivering and placing are $31 per mile for timber sleepers and $35 per mile for concrete sleepers.

The installation costs for the Trans-Australian Railway differ in several respects from those for the other projects, both of which are new railways. For the Trans-Australian Railway, therefore, the installation costs were estimated independently by considering the plant and labour which would be involved in the operations of removing existing sleepers and replacing them with new sleepers. Tables 6 and 7 show details associated with the operation of one mobile gang for resleepering in timber. Two such gangs would be required to complete the project at the rate accepted for the evaluation.

TABLE 6 - TIMBER SLEEPERS - EQUIPMENT FOR ONE MOBILE RESLEEPERING GANG: TRANS-AUSTRALIAN RAILWAY

Equipment	Cost ($)	Life (years)
2 spike pullers	5,000	8
8 sleepers borers	3,200	8
4 spike drivers	28,000	8
3 scarifiers	45,000	8
6 sleeper renewers	36,000	8
1 tamping machine	85,000	8
1 ballast regulator	26,000	8
1 camp train	90,000	16

TABLE 7 - TIMBER SLEEPERS - LABOUR FOR ONE MOBILE RESLEEPERING GANG: TRANS-AUSTRALIAN RAILWAY

Labour	Unit Wage Rate
	($ per week)
2 Foremen	86.90
13 Machinemen	78.00
27 Fettlers	68.30
3 Cooks	91.80

Fuel and maintenance costs associated with the operation of timber resleepering equipment were estimated at 0.5 per cent of the equipment capital costs, excluding that for the camp train. The duration of effective operation was estimated as 40 weeks per year.

Labour costs were estimated on the basis of a 48 week working year, with a 43 per cent allowance for overheads (22 per cent leave, 8 per cent transport, 13 per cent tools and supplies).

The installation costs for resleepering the Trans-Australian Railway with concrete sleepers were calculated on the same basis as that adopted for timber sleepers. However, the items of equipment differ as shown in Table 8 (compare Table 6): with this equipment, the gang required to install concrete sleepers would comprise 2 foremen, 12 machinemen, 18 fettlers and 3 cooks.

TABLE 8 - CONCRETE SLEEPERS - EQUIPMENT FOR ONE MOBILE RESLEEPERING GANG: TRANS-AUSTRALIAN RAILWAY

Equipment	Cost ($)	Life (years)
1 rail lifter	5,000	8
3 spike pullers	7,500	8
4 sleeper removers	24,000	8
4 scarifier/inserters	60,000	8
2 4-WD slewing crane/forklift	80,000	8
1 tamping machine	85,000	8
1 ballast regulator	26,000	8
1 camp train	80,000	16

The total discounted costs of track installation for each of the three projects are summarised in Table 9.

TABLE 9 - DISCOUNTED COSTS OF INITIAL INSTALLATION OF SLEEPERS

($'000)

Type of Sleeper Installation	Tarcoola-Alice Springs	Adelaide-Crystal Brook	Trans-Australia
Jarrah			
9" x 6" x 8'3"			
treated	2,471	-	5,448
untreated	2,965	-	5,448
10" x 5" x 8'6"			
treated	2,459	541	5,448
untreated	2,938	656	5,448
Red Gum			
10" x 5" x 8'6"			
untreated	-	656	-
Concrete (C.R.1)	1,701	391	5,128

RESURFACING

Resurfacing is the work associated with maintaining the rail lines true to alignment and level. Principally, it is accomplished by tamping the ballast beneath the sleeper. Resurfacing is carried out by a special gang, with appropriate equipment. The frequency of this maintenance operation is related to the deformation of the ballast and depends largely on the loading applied and the stiffness of the track. If other factors are relatively constant (e.g. axle loads, speeds), resurfacing frequency is a function of the annual gross tonnage carried by the track and sleeper stiffness.

The Tarcoola-Alice Springs Railway is expected to carry 0.5 million tons in the initial year of operation, increasing to 3.0 million tons in the 50th year (1). The loading during

(1) Based on the application of a factor of 2.5 to estimates of net tonnage in "The Economic Evaluation of Alternative Improvement Options for Rail/Road Facilities between Port Augusta and Alice Springs", Inter-Departmental Working Committee, January 1970.

the construction period is estimated as equivalent to the loading in the first year of operation. On the basis of current railway practice in Australia, it is estimated that tamping intervals, throughout the evaluation period, would be 4 years for timber sleepers and 5 years for concrete sleepers. Five years is taken to be the longest period that Commonwealth Railways would allow between resurfacings, even with low traffic density.

Although the traffic expected on the Trans-Australian Railway is rather higher than for the Tarcoola-Alice Springs Railway, the same tamping frequencies are considered appropriate. On the Adelaide-Crystal Brook Railway, however, anticipated loading is substantially greater, so a tamping cycle of 2 years for timber sleepers and 3.5 years for concrete sleepers was adopted for the maintenance costing.

The labour and equipment appropriate to each project varied according to the established practice of the two responsible authorities. There were also differences in estimated unit costs, partly due to the relative isolation of the Commonwealth Railway projects and the type of equipment used. Details for timber sleepers are shown in Tables 10 and 11.

TABLE 10 - TIMBER SLEEPERS - LABOUR FOR RESURFACING MAINTENANCE GANG

Commonwealth Railways*		South Australian Railways	
Labour	Unit Wage Rate	Labour	Unit Wage Rate
	($ per week)		($ per week)
1 Foreman	86.90	1 Foreman	82.55
2 Machinemen	78.00	2 Tamper Operators	64.65
2 Fettlers	64.30	1 Regulator operator	66.95
1 Cook	91.80	1 Cook	60. 75

* Commonwealth Railways wage rates include special allowances related to remoteness and living conditions.

TABLE 11 - TIMBER SLEEPERS - RESURFACING MAINTENANCE EQUIPMENT

Commonwealth Railways		
Equipment	Initial Cost	Life
	($)	(years)
1 Tamping machine	85,000	8
1 Ballast regulator	26,000	8
1 Camp train	36,000	16

South Australian Railways		
1 Tamping machine	120,000	8
1 Ballast regulator	35,000	8
1 Motor vehicle	4,000	8
1 Camp train	52,400	20

In estimating annual costs on Commonwealth Railways projects, wages, overheads, fuel and maintenance were calculated as in the estimates of initial installation costs for the Trans-Australian Railway. Labour overheads on the South Australian project have been calculated in a slightly different way and amount to 50 per cent of the wages (compare 43 per cent on C.R. where wage rates are higher). Also, specific estimates of fuel and maintenance were used for South Australian Railways (see first three items of Table 17 in subsequent section on Reconditioning).

With timber sleepers, two gangs would be required full time for resurfacing maintenance of the Trans-Australian Railway. For the Tarcoola-Alice Springs Railway, one gang would be required full time and one gang for each third year. One gang operating for a 6 month period every 2 years would be appropriate for the resurfacing of the Adelaide-Crystal Brook Railway.

If concrete sleepers were installed initially on the Trans-Australian line, the labour and equipment for resurfacing would be the same as with timber sleepers, except that one less fettler would be required because of the lower rate of sleeper replacement. With concrete sleepers on the Tarcoola-Alice Springs Railway only one gang would be required, working 4 of every 5 years. In the case of the Adelaide-Crystal Brook Railway, the resurfacing gang for concrete sleepers would only operate for 6 months in each 3.5 years.

Whenever a resurfacing gang would be surplus to any one of the projects it was assumed, in the evaluation, that the gang would operate elsewhere in the system.

The total discounted costs of resurfacing for the three projects are summarised in Table 12.

TABLE 12 - DISCOUNTED COSTS OF RESURFACING
($'000)

Type of Sleeper Installation	Tarcoola-Alice Springs	Adelaide-Crystal Brook	Trans-Australia
Jarrah			
9" x 6" x 8'3"			
treated	761	-	1,505
untreated	761	-	1,505
10" x 5" x 8'6"			
treated	761	214	1,505
untreated	761	214	1,505
Red Gum			
10" x 5" x 8'6"			
untreated	-	214	-
Concrete (C.R.1)	624	125	1,419

REPLACEMENT OF INSULATORS

The insulators which would be required for concrete sleeper construction of the Adelaide-Crystal Brook Railway are expected to gradually deteriorate. Although adjustments could be made in the power supply to compensate for electrical losses, at some future time it would be economic to replace the insulators.

Although no specific evidence is available on the effective life of insulators, it is judged that this would be about 10 years.

Consideration of the operations involved indicated that a gang of one foreman and three fettlers could replace insulators at a rate of 1,500 feet of track per day. Using labour and material rates previously tabulated, the cost was estimated at 15 cents per insulator. Accordingly, the total discounted cost of a ten year cycle of insulator replacement was estimated at $169,528.

REPLACEMENT OF RESILIENT PADS

The resilient pads used in concrete sleeper construction gradually deteriorate due to the effects of sunlight and other ageing processes. Enquiries made by the BTE, particularly relating to experience on South African Railways where climatic conditions are similar to those for the three projects, indicated that resilient pads should be replaced after about 15 years. This conclusion was consistent with tests carried out in Australia by Commonwealth Railways.

Consideration of the steps involved in replacing resilient pads indicated that a crew of one foreman and three fettlers could replace pads at a rate of 1,000 feet per day. Using labour and material rates previously tabulated, costs were estimated at 45 cents per pad on the Tarcoola-Alice Springs Railway and 41 cents per pad for the other two projects.

The total discounted cost of a 15 year cycle of resilient pad replacement was estimated at $415,434 for the Tarcoola-Alice Springs Railway, $121,498 for the Adelaide-Crystal Brook Railway and $727,784 for the Trans-Australian Railway.

SLEEPER RECONDITIONING

Reconditioning Programme

Reconditioning is the operation of restoring the railway track to some desired condition. It involves sleeper replacement, reballasting, regauging, adjusting fastenings and tamping. The reconditioning cycle is a function of sleeper life which is, consequently, of central importance in the evaluation. Results of surveys and tests of sleeper life are reviewed in Annex A. On the basis of this evidence the average life taken for the evaluation is 20 years for untreated jarrah and red gum sleepers, 30 years for treated jarrah sleepers and 50 years for concrete sleepers.

Replacement of a set of untreated timber sleepers can be represented as a distribution of individual sleeper replacements commencing about the tenth year after initial installation, with a peak at the twentieth year after installation and diminishing to zero about the thirtieth. The interaction between the service lives of the original sleepers and the replacement sleepers leads to a theoretical damped harmonic replacement pattern. This was used as a basis for estimating the size and number of reconditioning gangs required over a fifty year evaluation period, commencing at the end of the initial installation of sleepers. (See diagrams in Annex B).

The replacement distribution for treated timber sleepers is of the same character as for untreated sleepers, but it leads to a simpler maintenance pattern due to the longer average service life.

Available evidence indicates that undamaged concrete sleepers will last at least fifty years (see Annex A).

However, allowance was made in the installation cost estimates for an initial rejection of 10 sleepers per mile. As a basis for the reconditioning programme, it was assumed that 2.5 per cent of all concrete sleepers would fail prematurely and would be replaced between the 30th and 50th year of operation of the Commonwealth Railways projects and in projects years 30 and 40 of the Adelaide-Crystal Brook project.

Composition of Mobile Reconditioning Gangs

Table 13 indicates the typical equipment which would be used, on each project, by a mobile gang for reconditioning timber sleepered track. Table 14 shows the corresponding gang composition. The differences between projects reflect locational characteristics and the current practice of the two railway authorities.

TABLE 13 - TIMBER SLEEPFRS - EQUIPMENT FOR ONE RECONDITIONING GANG

Equipment Item	Life	Tarcoola-Alice Springs		Adelaide-Crystal Brook		Trans-Australian	
		No.	Cost	No.	Cost	No.	Cost
	(years)		$		$		$
Rail Lifter	8			1	5,000		
Spike puller	8	1	2,500	1	2,500	2	5,000
Sleeper exchanger	8	3	18,000	1	8,000	6	36,000
Scarifier	8	1	15,000	1	8,000	3	45,000
Sleeper crane	8			1	14,000		
Sleeper inserter	8			1	4,500		
Sleeper borer	8	4	2,400	1	8,000	8	3,200
Spike driver	8	2	14,000	2	12,000	4	28,000
Trailer	8			1	500		
Motor vehicle	8			4	16,000		
Tamper	8	1	30,000	1	120,000	1	85,000
Ballast regulator	8	1	26,000	1	35,000	1	26,000
Camp train	20			2	104,800		
Camp train	16	1	75,000			1	90,000

TABLE 14 - TIMBER SLEEPERS - LABOUR FOR ONE RECONDITIONING GANG

Labour	Tarcoola-Alice Springs		Adelaide-Crystal Brook		Trans-Australian	
	No.	Wage Rate	No.	Wage Rate	No.	Wage Rate
		($ per week)		($ per week)		($ per week)
Foreman	2	86.90	2	82.55	2	86.90
Asst. Foreman			1	78.85		
Machineman	8	78.00	14	64.65	13	78.00
Fettlers	13	68.30	7	59.75	22	68.30
Caretaker			1	56.45		
Cook	2	91.80	2	60.75	3	91.80

Corresponding details of equipment and labour which would be used on each project by a mobile gang for reconditioning concrete sleepers are shown in Tables 15 and 16.

TABLE 15 - CONCRETE SLEEPERS - EQUIPMENT FOR ONE RECONDITIONING GANG

Equipment Item	Life	Each Project	
		No.	Cost
	(years)		($)
Scarifier	8	1	15,000
Sleeper renewer (with crane)	8	1	20,000
Tamper	8	1	30,000
Ballast regulator	8	1	26,000
Camp train	16	1	75,000

TABLE 16 - CONCRETE SLEEPERS - LABOUR FOR ONE RECONDITIONING GANG

Labour	Commonwealth Railway Projects		Adelaide-Crystal Brook	
	No.	Wage Rate	No.	Wage Rate
		($ per week)		($ per week)
Foreman	1	89.60	1	82.55
Machineman	5	78.00	5	64.65
Fettlers	3	68.30	3	59.75
Cook	1	91.80	1	60.75

Annual costs for fuel, maintenance, wages and labour overheads were calculated as for the initial installation and resurfacing. The complete schedule of fuel and maintenance costs for South Australian Railways equipment is shown in Table 17.

TABLE 17 - FUEL AND MAINTENANCE COSTS FOR MAINTENANCE EQUIPMENT, ADELAIDE-CRYSTAL BROOK RAILWAY

Equipment	Unit Rate
	($ per day)
Duomatic tamper	60
Ballast regulator	20
Motor vehicle	5
Rail lifter	3
Dog puller	2
Sleeper exchanger	4
Scarifier	3
Sleeper crane	4
Sleeper inserter	3
Multiborer	3
Dog driver	3
Trailer	1

Reconditioning Rate

The gangs for reconditioning timber sleepers, which were detailed in Table 14 (with the equipment shown in Table 13), would achieve the reconditioning rates shown in Table 18. On the Commonwealth Railways projects, replacement would proceed continuously, with gangs being engaged or discharged throughout the evaluation period, as indicated by the profile of demand (see Annex B). On the Adelaide-Crystal Brook project, a different policy would be followed, as shown by the renewal patterns in Figs. B.2 and B.5 of Annex B. The different policy influences the reconditioning rate and has been taken into account in Table 18. In view of the high turnover of labour on such projects, no particular difficulty is expected in accommodating the fluctuating replacement programmes.

TABLE 18 - TIMBER SLEEPERS - RECONDITIONING RATES WITH SPECIFIED GANGS

Tarcoola-Alice Springs		Adelaide-Crystal Brook		Trans-Australian	
Wkly Rate	Ann.Rate	Wkly Rate	Ann.Rate	Wkly Rate	Ann.Rate
1,000	42,000	2,400	100,000	2,000	84,000

In all projects, concrete sleeper replacement would only require a typical gang to work for a short period in each year, as shown in Table 19. It was assumed that all equipment, except the sleeper renewer, would be utilised elsewhere in the railway system for the balance of the year. The crane on the sleeper renewer was also assumed to be suitable for use elsewhere. The capital costs of equipment attributable to each project and the associated operating costs were estimated on this basis.

TABLE 19 - CONCRETE SLEEPERS - RECONDITIONING RATES

Tarcoola-Alice Springs			Adelaide-Crystal Brook			Trans-Australian		
Wkly Rate	Annual Replacements *	Weeks Worked	Wkly Rate	Annual Replacements **	Weeks Worked	Wkly Rate	Annual Replacements *	Weeks Worked
300	1,560	5.2	300	3,350	12	300	3,000	10

* For the Commonwealth Railways projects, reconditioning is assumed to be spread over the period from the 30th to the 50th year of operation

** For the Adelaide-Crystal Brook project, reconditioning is assumed to be carried out in project years 30 and 40 only.

Materials

The unit costs for the materials used in reconditioning are the same as for the initial installation in each case. Based on railway experience, allowance was made for the renewal of 20 per cent of all dogspikes and lockspikes on the timber sleepers renewed, and all resilient pads and 5 per cent of all spring clips on the concrete sleepers renewed. No allowance was made in the evaluation for the disposal of old sleepers as the cost of disposal, or the possible resale value, is largely a matter of unpredictable local circumstances.

Annual Costs

The estimated annual costs of sleeper reconditioning are shown for each project in Tables 20 to 27.

TABLE 20 - UNTREATED TIMBER SLEEPERS - RECONDITIONING COSTS, TARCOOLA-ALICE SPRINGS RAILWAY

Year	Sleepers Per year ('000)	Gang Changes	Annual Cost ($)				
			Equip't	Oper'n & Maint'ce	Labour	9"x6"x8'3" Sleepers & Fittings	10"x5"x8'6" Sleepers & Fittings
17	42	A starts	182,900			235,620	205,380
18	42			22,659	129,153	"	"
19	84	B starts	182,900	"	"	471,240	410,760
20	84			45,318	258,306	"	"
21	168	C,Dstart	365,800	"	"	942,480	821,520
22-24	168			90,636	516,612	"	"
25	126			"	"	706,860	616,140
26	126	A ends	-37,500	67,977	387,459	"	"
27	84			"	"	471,240	410,760
28	84	B ends	-37,500	45,318	258,306	"	"
29	42		107,900	"	"	235,620	205,380
30	42	C,D end	-37,500	22,659	129,153	"	"
31	42	E starts		"	"	"	"
32-36	42			"	"	"	"
37	42	E ends	182,900	"	"	"	"
38	42	F starts		"	"	"	"
39-40	42			"	"	"	"
41	84		182,900	"	"	471,240	410,760
42	84	G starts		45,318	258,306	"	"
43-44	84			"	"	"	"
45	84	E ends	107,900	"	"	"	"
46	84	H starts		"	"	"	"
47-48	84			"	"	"	"
49	42			"	"	235,620	205,380
50	42	G ends	-37,500	22,659	129,153	"	"
51-52	42			"	"	"	"
53	42		182,900	"	"	"	"
54		H ends	-164,725	"	"		

NOTE: Negative costs represent the salvage value of camp trains.

TABLE 21 - UNTREATED TIMBER SLEEPERS - RECONDITIONING COSTS, TRANS-AUSTRALIAN RAILWAY

Year	Sleepers per year ('000)	Gang Changes	Annual Cost ($)				
			Equip't	Oper'n & Maint'ce	Labour	9"x6"x8'3" Sleepers & Fittings	10"x5"x8'6" Sleepers & Fittings
17	84	A starts	318,200			471,240	410,760
18	84			45,640	203,572	"	"
19	168	B starts	318,200	"	"	942,480	821,520
20	168			91,280	407,145	"	"
21	336	C,Dstart	636,400	"	"	1,884,960	1,643,040
22-24	336			182,560	814,290	"	"
25	252			"	"	1,413,720	1,232,280
26	252	A ends	-45,000	136,920	610,717	"	"
27	168			"	"	942,480	821,520
28	168	B ends	-45,000	91,280	407,145	"	"
29	84	E starts	228,200	"	"	471,240	410,760
30	84	C ends	-45,000	45,640	203,572	"	"
31-36	84			"	"	"	"
37	84	F starts	318,200	"	"	"	"
38-40	84			"	"	"	"
41	168	G starts	318,200	"	"	942,480	821,520
42-44	168			91,280	407,145	"	"
45	168	H starts	228,200	"	"	"	"
46-48	168			"	"	"	"
49				"	"		
50		F,G,H end	-181,600				

NOTE: Negative costs represent the salvage value of camp trains.

TABLE 22 - UNTREATED TIMBER SLEEPERS - RECONDITIONING COSTS, ADELAIDE-CRYSTAL BROOK, 10" x 5" x 8'6" JARRAH OR RED GUM

Years	Sleepers per year	Annual Cost ($)			
		Equip't	Oper'n & Maint.	Labour	Sleepers & Fittings
17,23,29 37,43,49	100,000	34,428	35,100	125,658	489,000 (Jarrah) 402,000 (Red Gum)

TABLE 23 - TREATED TIMBER SLEEPERS - RECONDITIONING COSTS, ADELAIDE-CRYSTAL BROOK, 10" x 5" x 8'6" JARRAH

Years	Sleepers per year	Annual Cost ($)			
		Equip't	Oper'n & Maint.	Labour	Sleepers & Fittings
25,32,39	100,000	34,428	35,100	125,658	661,000

TABLE 24 - TREATED TIMBER SLEEPERS - RECONDITIONING COSTS, TARCOOLA - ALICE SPRINGS

Year	Sleepers per year	Annual Cost ($)				
		Equip't	Oper'n & Maint'ce	Labour	9"x6"x8'3" Sleepers & Fittings	10"x5"x8'6" Sleepers & Fittings
20	42,000	182,900			323,400	277,620
21-27	"		22,659	129,153	"	"
28	"	107,900	"	"	"	"
29-35	"		"	"	"	"
36	"	182,900	"	"	"	"
37-43	"		"	"	"	"
44	"	107,900	"	"	"	"
45	"		"	"	"	"
46	42,000		"	"	"	"
47			"	"	"	"
48		-90,876				

TABLE 25 - TREATED TIMBER SLEEPERS - RECONDITIONING COSTS, TRANS-AUSTRALIAN RAILWAY

Year	Sleepers per year	Annual Cost ($)				
		Equip't	Oper'n & Maint'ce	Labour	9"x6"x8'3" Sleepers & Fittings	10"x5"x8'6" Sleepers & Fittings
20	84,000	318,200			646,800	555,240
21-27	"		45,640	203,572	"	"
28	"	228,200	"	"	"	"
29-35	"		"	"	"	"
36	"	318,200	"	"	"	"
37-43	"		"	"	"	"
44	"	228,200	"	"	"	"
45	"		"	"	"	"
46	84,000		"	"	"	"
47			"	"		
48		-170,750				

TABLE 26 - CONCRETE SLEEPERS - RECONDITIONING COSTS, TARCOOLA - ALICE SPRINGS

Year	Sleepers per year	Annual Cost ($)			
		Equip't	Oper'n & Maint'ce	Labour	Sleepers & Fittings
33		33,695			
34-39	1,560		2,366	5,773	13,978
40	1,560	24,140	"	"	"
41-47	1,560		"	"	"
48	1,560	33,695	"	"	"
49-53	1,560		"	"	"
54		-15,538			

TABLE 27 - CONCRETE SLEEPERS - RECONDITIONING COSTS, ADELAIDE-CRYSTAL BROOK

Year	Sleepers per year	Annual Cost ($)			
		Equip't	Oper'n & Maint'ce	Labour	Sleepers & Fittings
30	3,350	19,033	5,460	11,624	30,753
40	3,350	19,033	5,460	11,624	30,753

TABLE 28 - CONCRETE SLEEPERS - RECONDITIONING COSTS, TRANS-AUSTRALIAN RAILWAY

Year	Sleepers per year	Annual Cost ($)			
		Equip't	Oper'n & Maint'ce	Labour	Sleepers & Fittings
29	3,000	50,952			26,820
30-36	3,000		4,550	11,101	"
37	"	33,095	"	"	"
38-44	"		"	"	"
45	"	50,952	"	"	"
46-49	3,000		"	"	"
50			"	"	"
51		-24,688			

Discounted Costs

The total discounted costs of sleeper reconditioning for each of the three projects are shown in Table 29.

TABLE 29 - TOTAL DISCOUNTED COSTS OF SLEEPER RECONDITIONING ($'000)

Type of Sleeper Installation	Tarcoola-Alice Springs	Adelaide-Crystal Brook	Trans-Australian
Timber			
9" x 6" x 8'3"			
treated	1,623	-	3,065
untreated	3,634	-	6,649
10" x 5" x 8'6"			
treated	1,472	317	2,762
untreated	3,361	575	6,113
Concrete (CR1)	31	13	79

ROUTINE MAINTENANCE

Definition

Routine maintenance ('housekeeping') is defined as all of the activities carried out by a permanent gang assigned to a section of railway. Many of these activities relate to the maintenance of the whole permanent way and do not vary according to the type of sleeper installation. The labour requirements for such duties were not included in the evaluation. Also, no allowance was made for local packing to rectify minor variations of level and alignment, because costs would be similar for all sleeper types. However, the following maintenance activities of a permanent gang can be related to sleeper type, and are not included in the specific maintenance operations previously estimated:

(i) The permanent gang would provide general assistance to the special resurfacing gangs. The participation would be related to resurfacing rate and frequency. For timber sleepers, in all projects, assistance was estimated at the equivalent of 0.5 man day per mile of track per year. Assistance for concrete sleepers was estimated at 0.4 man days per mile per year for the Commonwealth Railway projects and 0.3 man days per mile per year for the Adelaide-Crystal Brook railway which has a different resurfacing frequency.

(ii) Assistance would also be provided to reconditioning gangs. For untreated timber sleepers this was estimated as the equivalent of 0.75 man days per mile of track per year for all projects. The corresponding estimate for treated timber sleepers was 0.5 man days per mile per year. No allowance was necessary for concrete sleepers.

(iii) The permanent gang would renew sleepers which were found defective between reconditioning cycles. It was estimated that a total of 32 timber sleepers would require replacement per mile between cycles, and that they would be replaced at a rate of 4 per man day. No allowance was necessary for concrete sleepers.

(iv) It is estimated that the permanent gang would commence to cross bore and regauge untreated timber sleepers 10 years after installation and treated timber sleepers 14 years after installation. Therefore, 4 per cent of all sleepers would be cross bored annually, at a rate of 0.75 man hour per sleeper. The labour required for the operation would be 11 man days per mile per year for the Commonwealth Railways projects and 9.2 man days per mile per year for the Adelaide-Crystal Brook railway.

Staff Estimates

Staff estimates for the specified routine maintenance activities are shown in Table 30.

TABLE 30 - STAFF FOR DIFFERENTIAL ROUTINE MAINTENANCE

Year	Tarcoola-Alice Springs			Adelaide-Crystal Brook			Trans-Australian		
	Timber		Concrete	Timber		Concrete	Timber		Concrete
	T	Un		T	Un		T	Un	
2							64	64	60
3							64	64	55
4							64	64	51
5				6	7	1	64	64	46
6	2	2	1	6	7	1	64	64	41
7	2	2	1	6	7	1	64	64	37
8	2	2	1	6	7	1	64	64	32
9	2	2	1	6	7	1	64	64	27
10	2	2	1	6	7	1	64	64	23
11	2	26	1	6	7	1	63	64	18
12	2	26	1	6	7	1	63	64	14
13	2	26	1	6	7	1	63	64	9
14	2	26	1	6	7	1	63	64	4
15	26	26	1	6	7	1	63	64	-
16	26	26	1	6	7	1	63	64	-
17	26	26	1	6	7	1	63	64	-
18	26	31	1	6	7	1	63	64	-
19	26	31	1	6	7	1	63	64	-
20	26	31	1	6	7	1	63	64	-
21 & later years	30	31	1	6	7	1	63	64	-

T = Treated Un = Untreated

The estimate for concrete sleepers on the Trans-Australian Railway involves a reduction of staff after the initial re-sleepering with concrete. A time lag of one year was assumed so that staff reduction could be co-ordinated with normal turn-over of staff.

Annual Costs of Differential Routine Maintenances

The average wage rate for routine maintenance staff, for each project, was estimated at $3,250 per annum.

The annual cost of maintaining existing accommodation on the Trans-Australian Railway was estimated at $630 per employee. It was considered that existing South Australian Railways accommodation could be used by the routine maintenance staff for the Adelaide-Crystal Brook Railway. In this case, the annual cost of maintaining accommodation was estimated at $285 per employee.

For the Tarcoola-Alice Springs railway, new accommodation would need to be provided. This was estimated to cost $25,000 per house (one for each employee). The subsequent cost of maintenance for each house was estimated at $300 per annum for the first 20 years, and $630 per annum thereafter.

The estimated annual costs associated with the Adelaide-Crystal Brook project are $21,210 for treated timber, $24,745 for untreated timber, and $3,535 for concrete. The corresponding costs for the Commonwealth Railways projects are shown in Table 31.

TABLE 31 - ANNUAL COST FOR DIFFERENTIAL ROUTINE MAINTENANCE, COMMONWEALTH RAILWAYS PROJECTS

($)

Year	Tarcoola-Alice Springs			Trans-Australian		
	Timber		Concrete	Timber		Concrete
	Treated	Untreated		Treated	Untreated	
2				248,320	248,320	232,800
3				248,320	248,320	213,400
4				248,320	248,320	197,880
5	50,000	50,000	25,000	248,320	248,320	178,480
6	6,500	6,500	3,250	248,320	248,320	159,080
7	6,500	6,500	3,250	248,320	248,320	143,560
8	6,500	6,500	3,250	248,320	248,320	124,160
9	7,100	7,100	3,550	248,320	248,320	104,760
10	7,100	607,100	3,550	248,320	248,320	89,240
11	7,100	85,100	3,550	244,440	248,320	69,840
12	7,100	85,100	3,550	244,440	248,320	54,320
13	7,100	85,100	3,550	244,440	248,320	34,920
14	607,100	92,300	3,550	244,440	248,320	15,520
15-16	85,100	92,300	3,550	244,440	248,320	-
17	85,100	217,300	3,550	244,440	248,320	-
18-19	92,300	108,550	3,550	244,440	248,320	-
20	192,300	108,550	3,550	244,440	248,320	-
21-23	105,300	110,050	3,550	244,440	248,320	-
24-25	106,500	110,050	3,550	244,440	248,320	-
26-30	107,160	110,710	3,880	244,440	248,320	-
31-34	107,160	118,630	3,880	244,440	248,320	-
35-37	115,080	118,630	3,880	244,440	248,320	-
38-40	115,080	121,540	3,880	244,440	248,320	-
41-49	116,400	121,540	3,880	244,440	248,320	-
50	116,400	121,540	3,880	244,440	248,320	-
51-54	116,400	121,540	3,880	244,440	248,320	-

Discounted Costs

The total discounted costs of differential routine maintenance for each project are shown in Table 32.

TABLE 32 - TOTAL DISCOUNTED COSTS OF DIFFERENTIAL ROUTINE MAINTENANCE

($)

Sleeper Type	Tarcoola-Alice Springs	Adelaide-Crystal Brook	Trans-Australian
Untreated Timber	1,114,466	240,826	3,194,927
Treated Timber	853,415	206,422	3,168,631
Concrete	52,853	34,404	1,103,572

FREIGHT ON SLEEPERS AND FITTINGS

Freight is a major item in the comparative evaluation of the costs of installing different types of sleeper in all three projects. The movement involved is the carriage, by rail, of sleepers and fittings for the initial installation and track reconditioning.

The basis of the jarrah sleeper price is free-on-rail at Manjimup in Western Australia. From this source, the sleepers would be hauled by WAGR narrow gauge line from Manjimup to Forrestfield, by WAGR standard gauge line to Kalgoorlie, and by Commonwealth Railways standard gauge line to the construction area, in the case of the Commonwealth Railways projects, or to Port Pirie for the Adelaide-Crystal Brook project. In this latter case, the final section would be South Australian Railway broad gauge line.

Red gum sleepers for the Adelaide-Crystal Brook Railway were assumed to be cut in western Victoria. Two-thirds of the sleepers were assumed to be loaded on Victorian Railways and hauled to Serviceton, whence they would be hauled to the work site by South Australian Railways. The remaining sleepers would be loaded directly on the South Australian Railway system near Naracoorte.

Concrete sleepers were assumed to originate at Port Augusta for the Tarcoola-Alice Springs Railway, at Adelaide for the Adelaide-Crystal Brook Railway and at both Port Augusta and Kalgoorlie for the Trans-Australian Railway.

The resource cost of additional freight movement on an existing rail system is the incremental cost of providing and operating rolling stock to carry the freight and the additional track maintenance incurred. These costs depend on the particular circumstances of each freight task. However, for each of the three projects, the unit costs in Table 33 were adopted, unless otherwise noted.

TABLE 33 - UNIT COSTS FOR FREIGHT ESTIMATES

Item	Unit Cost
Wagon	$12,000
Wagon depreciation	$400 per annum
Wagon maintenance	1.4c per mile
Locomotive opportunity cost	$25,000 per annum
Locomotive maintenance	60c per mile
Crew cost (including overtime)	$6,000 per annum
Locomotive fuel (total)	15.0c per mile
Locomotive fuel (attributed to sleepers hauled on normal trains)	1.5c per mile
Shunting	10.0c per ton
Bogie exchange (Port Pirie)	$0.50 per wagon
Sleeper transfer from narrow gauge to standard gauge at Forrestfield	$1.00 per ton

Tarcoola-Alice Springs Railway

(i) Concrete Sleepers

The distance from Port Augusta to the mid point of the proposed line is 520 miles. At 2410 sleepers per mile and 3.73 sleepers per ton, the loading for the initial construction of the project is 335,979 tons of sleepers. This could be carried by 104 wagons operating on a turnaround time of 7 days. The average daily travel by each wagon would be 130 miles.

Sleepers could be transported using two locomotives operating between Port Augusta and Tarcoola, and one locomotive operating between Tarcoola and the construction site. Each locomotive would travel an average of 260 miles per day, and each day two shunting operations would be required at Tarcoola, and two at the manufacturing works.

Aggregation of the individual cost estimates for various aspects of the movement of concrete sleepers between Port Augusta and the project led to a calculated marginal freight cost of 1.05 cents per ton-mile for this type of operation.

(ii) Jarrah Sleepers

Due to the imbalance of freight between Perth and the Eastern States, a substantial number of rail wagons travel empty in an easterly direction on the Trans-Australian Railway. This capacity would be used to transport jarrah sleepers from Kalgoorlie to Tarcoola. Sufficient tractive power is available for the sleepers to be hauled on existing trains. From Tarcoola the wagons of sleepers would be hauled north to the construction area by a locomotive assigned to the project.

The freight distances for this part of the haulage are 800 miles from Kalgoorlie to Tarcoola and 260 miles from Tarcoola to the midpoint of the project railway.

Using wagons for sleeper haulage and diverting them to the construction area would result in their being withdrawn from normal service for the equivalent of seven days on each trip. In total, the sum of the seven-day diversions of wagons from normal service is equivalent to the use of 40 wagons continuously.

The unit costs of wagon and locomotive operation were taken to be the same as for concrete sleepers. In this case, however, the only locomotive required specifically for sleeper haulage would be the one operating north of Tarcoola. For the Kalgoorlie-Tarcoola section of the route, only the marginal cost of operation would be involved. This would include shunting at Kalgoorlie and at Tarcoola (for both full and empty wagons).

The cost estimates for the various haulage components between Kalgoorlie and the mid point of the Tarcoola-Alice Springs line gave an average marginal freight cost of 0.74 cent per ton-mile. On the assumption that haulage on the 406 miles of standard gauge railway between Forrestfield and Kalgoorlie has comparable characteristics to haulage between Kalgoorlie and the project area, the cost of 0.74 cent per ton-mile was applied to this section of the route also.

Between Manjimup and Forrestfield, it was assumed that special trains would be required to ensure a continuous supply of sleepers. Thus, the task would be similar to the movement of concrete sleepers from Port Augusta to the project, and the same marginal freight cost of 1.05 cents per ton-mile was adopted.

(iii) Fittings

It was assumed that all fittings would be freighted from Port Augusta. The average haulage distance is 520 miles. The estimated annual tonnage of fittings was 1,659 for concrete sleepers and 6,722 for timber sleepers. The freight rate was taken to be the same as for concrete sleepers, 1.05 cents per ton-mile.

(iv) Track Reconditioning

The unit costs of freight movement developed for the initial installation were applied directly in estimating the freight costs associated with the various maintenance and reconditioning operations to be carried out during the evaluation period.

(v) Annual Costs

The annual costs of freight for the project are summarised in Table 34.

TABLE 34 - ANNUAL FREIGHT COST FOR SLEEPERS AND FITTINGS, TARCOOLA-ALICE SPRINGS RAILWAY

($'000)

Year	Untreated Jarrah		Treated Jarrah		Concrete
	9"x6"x8'3"	10"x5"x8'6"	9"x6"x8'3"	10"x5"x8'6"	C.R.1
2	447.7	446.9	446.7	446.2	519.3
3	447.7	446.9	446.7	446.2	519.3
4	447.7	446.9	446.7	446.2	519.3
5	273.6	273.1	273.0	272.7	317.3
17-18	58.0	54.0	-	-	-
19	116.1	108.0	-	-	-
20	116.1	108.0	52.8	50.0	-
21-24	232.2	216.0	52.8	50.0	-
25-26	174.1	162.0	52.8	50.0	-
27-28	116.1	108.0	52.8	50.0	-
29-33	58.0	54.0	52.8	50.0	-
34	58.0	54.0	52.8	50.0	2.3
35-40	58.0	54.0	52.8	50.0	2.3
41-45	116.1	108.0	52.8	50.0	2.3
46	116.1	108.0	52.8	50.0	2.3
47-48	116.1	108.0	-	-	2.3
49-53	58.0	54.0	-	-	2.3

Adelaide-Crystal Brook Railway

(i) Concrete Sleepers

A total of 78,500 tons of concrete sleepers would be required for the initial installation. The average haul would be 60 miles and the task could be carried out by adding 25 wagons per week to the existing train services.

The unit costs of wagons, locomotives and shunting were assumed to be the same as for the Tarcoola-Alice Springs project. For the Adelaide-Crystal Brook railway, shunting would only be required at Adelaide and at the delivery station. On this basis, the average freight cost was calculated to be 0.39 cent per ton-mile.

(ii) Jarrah Sleepers

The freight costs for the movement of jarrah sleepers between Forrestfield and Port Pirie were estimated on the same basis as that adopted for the Tarcoola-Alice Springs project. Twenty wagons would be required for the task at a round trip time of 5 days. The mileage attributable to each trip would be 1,107 miles.

For the Manjimup-Forrestfield section, only the marginal cost of locomotive operation was included in the estimate because the scale of the project would not involve the operation of special sleeper trains. The same assumption was applied in estimating the cost of freight on the broad gauge track south of Port Pirie.

The estimate of jarrah sleeper freight costs included shunting at Manjimup and Forrestfield, a sleeper transfer at Forrestfield, and a bogie exchange at Port Pirie.

On this basis, the freight cost for jarrah sleepers was equivalent to a rate of 0.17 cents per ton mile.

(iii) Red Gum Sleepers

Red gum sleepers would be carried from the cutting areas in western Victoria and South Australia on existing trains. The two-thirds of the sleepers hauled from western Victoria would fully engage 21 Victorian Railways wagons; the average haul would be 340 miles. For the remainder, ten South Australian Railways wagons would be required; the average haul would be 305 miles. Shunting would be necessary at the Victorian centres, at Serviceton, at Adelaide and at the project site. Generally, each wagon would be shunted approximately three times per trip.

Based on these data and the unit costs adopted for the estimates, the equivalent overall freight cost for red gun sleepers was 0.2 cents per ton-mile.

(iv) Fittings

It was estimated that all fittings would be transported from Adelaide to the midpoint of the project at 0.39 cent per ton-mile, the rate calculated from the estimates of freight costs for concrete sleepers. The annual tonnage of fittings involved would be 523 for concrete sleepers and 2,130 for timber.

(v) Track Reconditioning

The tonnages involved in reconditioning sleepers, for each of the years in which this operation would take place, would be 9,881 for untreated red gum, 9,225 for untreated jarrah, 8,562 for treated jarrah and 898 for concrete. Annual costs for the freight involved in each case were calculated using the appropriate average marginal freight rate.

(vi) Annual Costs

The annual freight costs for the project are summarised in Table 35.

TABLE 35 - ANNUAL FREIGHT COST FOR SLEEPERS AND FITTINGS, ADELAIDE-CRYSTAL BROOK RAILWAY

($'000)

Year	Jarrah 10" x 5" x 8'6"		Red Gum 10" x 5" x 8'6"	Concrete
	Untreated	Treated	Untreated	C.R.1.
1	30.5	30.5	7.8	6.9
2	30.5	30.5	7.8	6.9
3	21.0	21.0	5.3	4.8
17	28.0	26.0	6.6	-
23	28.0	26.0	6.6	-
29	28.0	26.0	6.6	-
30	-	-	-	0.2
37	28.0	26.0	6.6	-
40	-	-	-	0.2
43	28.0	26.0	6.6	-
49	28.0	26.0	6.6	-

Trans-Australian Railway

(i) Concrete Sleepers

Initially, 107,300 tons of concrete sleepers would be manufactured in Port Augusta over a two year period and these would be installed west from Port Pirie. It was assumed that the haulage would be carried out on a cyclic basis by a special train involving a locomotive and 22 wagons. Shunting would be required at the manufacturer's depot each day. The annual costs were calculated from the appropriate unit costs as tabulated for the Tarcoola-Alice Springs project, and the resulting average freight cost was 1.24 cents per ton-mile.

After the initial two years, sleepers would be delivered at the rate of 53,600 tons per year for 12 years and installed in sections where renewals would be most needed. To take advantage of the imbalance of freight between west and east, these sleepers would be manufactured in Kalgoorlie. The average haulage on the existing train service to the midpoint of the track remaining to be resleepered would be 470 miles from Kalgoorlie. Twenty-two additional wagons would be required to carry these sleepers; shunting would be required at the manufacturer's depot and at the station nearest to the resleepering. Haulage from the nearest station to the work site would be by special train.

(ii) Jarrah Sleepers

The freight costs for the movement of jarrah sleepers between Manjimup and the mid-point of the Trans-Australian Railway were estimated on the same basis as that detailed for the Adelaide-Crystal Brook railway. The haulage would involve 20 wagons, an average journey of 1,157 miles, with a shunt at Manjimup and a transfer at Forrestfield.

On this basis, the freight cost for jarrah sleepers was equivalent to a cost of 0.63 cent per ton-mile.

(iii) Fittings

Fittings would be transported from Port Augusta for an average of 526 miles (the midpoint of the project) at 1.24 cents per ton-mile. The annual tonnage of fittings involved would be 960 for concrete sleepers and 943 for timber sleepers.

(iv) Track reconditioning

The tonnages involved in reconditioning sleepers vary in accordance with the annual requirements, as shown in tables 22, 24 and 27. Annual freight costs were calculated using the appropriate average marginal freight rate.

(v) Annual Costs

The annual freight costs for the project are summarised in Table 36.

TABLE 36 - ANNUAL FREIGHT COST FOR SLEEPERS AND FITTINGS, TRANS-AUSTRALIAN RAILWAY

($'000)

Year	Jarrah				Concrete
	9"x6"x8'3"		10"x5"x8'6"		C.R.1.
	Treated	Untreated	Treated	Untreated	
1	196.6	197.0	196.5	196.6	74.4
2	196.6	197.0	196.5	196.6	80.7
3-13	196.6	197.0	196.5	196.6	100.7
14	55.8	55.9	55.8	55.8	28.6
17-18	-	80.0	-	74.6	-
19	-	160.0	-	149.2	-
20	72.9	160.0	69.3	149.2	-
21-24	72.9	320.0	69.3	296.5	-
25-26	72.9	240.0	69.3	223.7	-
27-28	72.9	160.0	69.3	149.2	-
29-40	72.9	80.0	69.3	74.6	5.2
41-45	72.9	160.0	69.3	149.2	5.2
46	72.9	160.0	69.3	149.2	5.2
47-48	-	160.0	-	149.2	5.2
49	-	-	-	-	5.2

Discounted Freight Costs

The total discounted costs for freight for each project are shown in Table 37.

TABLE 37 - TOTAL DISCOUNTED FREIGHT COSTS FOR SLEEPERS AND FITTINGS ($'000)

Railway	Jarrah				Red Gum	Concrete
	9"x6"x8'3"		10"x5"x8'6"		10"x5"x8'6"	C.R.1.
	Treated	Untreated	Treated	Untreated	Untreated	
Tarcoola-Alice Springs	1,465	1,817	1,455	1,777	-	1,503
Adelaide-Crystal Brook	-	-	82	96	24	16
Trans-Australian	1,906	2,373	1,893	2,326	-	820

RESIDUAL VALUES

The residual values of the sleepers installed in the track at the end of the project duration have only a slight effect on the overall results because discounting at 7 per cent reduces the value of a dollar in year 50 to 3.4 cents in the base year. The residual value of maintenance equipment has been included under the appropriate maintenance function.

A linear rate of depreciation for the 30-year life of treated timber sleepers and the 20-year life of untreated timber sleepers has been used in the calculation of residual values. No credit has been given for any extension of the effective life of concrete sleepers beyond 50 years.

Discounted Residual Values

The total discounted residual values for each project are shown in Table 38.

TABLE 38 - TOTAL DISCOUNTED RESIDUAL VALUES
($)

Railway	Jarrah				Red Gum
	9"x6"x8'3"		10"x5"x8'6"		10"x5"x8'6"
	Treated	Untreated	Treated	Untreated	Untreated
Tarcoola-Alice Springs	99,776	114,947	87,705	102,987	-
Adelaide-Crystal Brook	-	-	25,926	28,503	23,249
Trans-Australian	423,336	458,755	362,056	398,037	-

EVALUATION RESULTS

The total of all costs considered in each project, discounted to 1972 at 7 per cent, are shown in Table 39. Generally, costs which are independent of sleeper type were excluded from the evaluation. The discounted costs are also shown in Annex C, where they are broken down into separate categories such as initial cost of track components, installation cost, and the various elements of maintenance.

Red gum sleepers were not evaluated for the Commonwealth Railways projects because the BTE was advised that this type of sleeper was unacceptable to the authority.

TABLE 39 - EVALUATION RESULTS: TOTAL DISCOUNTED COSTS ($'000)

Sleeper	Tarcoola-Alice Springs	Adelaide-Crystal Brook	Trans-Australian
Jarrah			
9" x 6" x 8'3"			
treated	20,979	-	30,659
untreated	21,698	-	30,801
10" x 5" x 8'6"			
treated	19,452	4,616	28,089
untreated	20,497	4,591	28,653
Red Gum			
10" x 5" x 8'6"			
untreated	-	4,227	-
Concrete	17,803	4,521	27,852

SENSITIVITY TESTS

The evaluation results represent a central estimate based on the best current judgement of many items of cost, as well as the life, service characteristics, sizes and spacing of sleepers. Also, the results are confined to the anticipated commercial implications of the sleeper alternatives considered. It was not practicable to investigate the possible effects of variations in each of these parameters, but some selected sensitivity tests were considered useful in indicating the significance of some of the engineering judgements, the discount rate and the social effect of sleeper choice.

SLEEPER SIZE

Railway authorities have fairly firm views on the minimum dimensions appropriate for sleepers in particular circumstances. These views are based on experience, rather than on formal engineering calculations, and to an extent are an implied economic judgement. Essentially, this judgement is that any tangible cost saving which could be made by adopting a lower standard would be exceeded by losses of a kind not included in the evaluations. For example, Table 40 shows that some direct cost saving could be made by using the 9" x 5" or 9" x 4½" sleeper; their rejection implies that, in the judgement of the railway authorities, the cost saving would be outweighed by the loss of track stability resulting from the use of these smaller sleepers.

TABLE 40 - SENSITIVITY TEST OF JARRAH SLEEPER DIMENSIONS, TARCOOLA-ALICE SPRINGS RAILWAY

Dimensions and Treatment		Total Discounted Cost
		($'000)
9" x 4½" x 8'0"	treated	17,714
	untreated	18,337
9" x 5" x 8'0"	treated	18,660
	untreated	19,367
9" x 6" x 8'3"	treated	20,979
	untreated	21,698
10" x 5" x 8'6"	treated	19,452
	untreated	20,497

DISCOUNT RATE

The choice of discount rate for a project evaluation represents a combined judgement on a number of inter-related factors. In the view of the BTE, 7 per cent is the most appropriate rate for the sleeper evaluation. However rates in the range of 7 to 10 per cent are commonly used for transport project evaluation in Australia, so it is of interest to consider the degree to which the order of choice of alternatives would be altered by adoption of the higher discount rate.

Table 41 shows the effect of discount rate on the evaluation results for the three projects. For the Tarcoola-Alice Springs and Adelaide-Crystal Brook projects, the least cost alternative remains the same at both discount rates.

The results of the evaluation for the Trans-Australian Railway are more sensitive to discount rate than for the other projects. The sensitivity test shows that at a discount rate of 10 per cent, longer sleeper life is much less valuable than at 7 per cent, due to the interaction of the cost components. Accordingly, at 10 per cent discount rate, 10" x 5" x 8'6" jarrah sleepers would displace concrete as the least cost alternative.

TABLE 41 - SENSITIVITY TEST OF DISCOUNT RATE
(Total discounted cost in $'000)

Sleeper	Tarcoola-Alice Springs		Adelaide-Crystal Brook		Trans-Australian	
	7%	10%	7%	10%	7%	10%
Jarrah						
9" x 6" x 8'3"						
treated	20,979	17,922	-	-	30,659	24,286
untreated	21,698	17,627	-	-	30,801	23,138
10" x 5" x 8'6"						
treated	19,452	16,595	4,616	4,118	28,089	22,195
untreated	20,497	16,652	4,591	3,986	28,653	21,485
Red Gum						
10" x 5" x 8'6"						
untreated	-	-	4,227	3,676	-	-
Concrete	17,803	15,913	4,521	4,149	27,852	23,141

CONCRETE MANUFACTURING LOCATION

Due to the significance of freight costs and the length of the Trans-Australian Railway there are considerable differences in the total costs of resleepering depending upon the source of sleepers.

In the case of concrete sleepers, the optimum was assessed as manufacture at Port Augusta for resleepering to a point 120 miles west, and manufacture of the remaining sleepers at Kalgoorlie. This would cost $27.852 million. Manufacturing all sleepers at Port Augusta would cost $29.376 million.

SOCIAL-ECONOMIC EVALUATION

The major social effect of a decision to use either concrete or timber sleepers is on the level of employment in the producing regions. In a fully employed economy, the men would be drawn from other jobs, and the wages paid to them would be a fair measure of the opportunity cost to the community of diverting them into sleeper production. On the other hand, if the men used in sleeper production would have been unemployed but for this job then their labour would have no cost to the community, and the price of the sleepers would overstate their social opportunity cost.

In any particular project the true social cost of labour could range between zero and the current wage rate. However it is normally reasonable to adopt the latter for an evaluation because of the difficulty of judging the likely alternative employment of displaced labour and the general presumption that the inability of an industry to compete, in the Australian economy, indicates that an economically rational adjustment process is in progress.

There are, however, some features of the sleeper industry, such as current unemployment, remoteness of location and the type of worker engaged, which suggest that the evaluation results should be tested for the assumption that presently unemployed labour is costless. The Tarcoola-Alice Springs project was chosen for this sensitivity test.

The production of sleepers for the Tarcoola-Alice Springs Railway was estimated to involve 230 men for timber sleepers, or 115 men for concrete sleepers. Unemployment in the Western Australian timber districts of Bunbury and Manjimup varied from 172 in April 1971 to 543 in January 1972 and 245 in April 1972. Of the men unemployed in April 1972, 169 in the unskilled and semi-skilled categories could be utilised in timber production. As there is currently a declining trend in timber industry employment, it is possible that the use of timber sleepers in the project could reduce unemployment by the whole 230 required for sleeper production.

Correspondingly, the production of concrete sleepers could reduce unemployment by the full 115 men required for the task, because unemployment in the Port Augusta-Whyalla area has ranged from 403 in April 1971, to 394 in January 1972, and 205 in April 1972.

In either area, if the sleeper contract is not obtained, unemployment will eventually attain an equilibrium level by workers moving to other areas, or by the creation of new jobs locally. Hence the judgement was made that the sleeper order is only likely to reduce unemployment on the average, by the equivalent of one year for each of the men employed.

This means that the project cost of 9" x 6" and 10" x 5" timber sleepers, from the community point of view, could be reduced by a total amount of $724,000 and $619,000 respectively. Similarly, the project cost of concrete sleepers could be reduced by $360,000. After discounting over the 4 year production period, these labour cost reductions become $632,000 and $541,000 for 9" x 6" and 10" x 5" timber sleepers, and $314,000 for concrete sleepers.

A comparison between the commercial and social economic-evaluation is shown in Table 42. The test indicates that the employment effect incorporated in the social-economic evaluation is not large enough to make the least cost alternative from a community point of view differ from the commercially least cost alternative, in the case of the Tarcoola-Alice Springs project.

TABLE 42 - COMPARISON OF COMMERCIAL AND SOCIAL-ECONOMIC EVALUATION, TARCOOLA-ALICE SPRINGS RAILWAY : TOTAL DISCOUNTED COSTS ($'000)

	Commercial Evaluation	Social-Economic Evaluation
Jarrah		
9" x 6" x 8'3" treated	20,979	20,347
10" x 5" x 8'6" treated	19,452	18,911
Concrete	17,803	17,489

In the case of the Trans-Australian Railway, a specific calculation of social cost savings associated with employment effects was not made. Annual sleeper production for the project would be about half that estimated for the Tarcoola-Alice Springs project. Nevertheless, the employment effect would reduce the small advantage of concrete sleepers over 10" x 5" timber sleepers or the advantage over 9" x 6" timber sleepers.

For the Adelaide-Crystal Brook Railway the main comparison is between concrete and red gum. Production of red gum sleepers is largely in the hands of small private contractors. They are relatively adaptable people whose labour is, consequently, unlikely to have zero social opportunity cost.

It is more likely that the social opportunity cost of the concrete sleepers would be reduced by employment effects in South Australia. On similar assumptions to those made for Tarcoola-Alice Springs, the social cost saving would be about one-third of the $294,000 commercial cost advantage of red gum.

CONCLUSIONS

TARCOOLA-ALICE SPRINGS RAILWAY

Concrete sleepers are the best choice for this project. This conclusion would remain true for any reasonable alternatives of timber sleeper size, range of discount rate, or interpretation of employment effects. The saving in using concrete sleepers instead of 9" x 6" jarrah sleepers would be in the order of $3 million.

ADELAIDE-CRYSTAL BROOK RAILWAY

The best choice of sleeper material for this project, on both commercial and social economic grounds, is red gum. The cost advantage relative to concrete sleepers, the next best alternative, ranges from $294,000 to $196,000.

TRANS-AUSTRALIAN RAILWAY

The central evaluation showed that on commercial grounds concrete sleepers, manufactured in specified quantities at Port Augusta and Kalgoorlie, would be the best choice for the project. The cost advantage relative to 9" x 6" jarrah sleepers would be $2.8 million.

The results of the evaluation, however, are sensitive to timber sleeper dimensions, place of manufacture of concrete sleepers, interpretation of employment effects and choice of discount rate. The evaluation indicates that there is little difference, either in commercial or in social terms, between concrete sleepers and 10" x 5" jarrah sleepers. The choice must rest primarily on technical considerations of relative performance characteristics, such as greater safety margin in resisting temperature effects.

ANNEX A

RAILWAY SLEEPER LIFE : SURVEYS AND TESTS

Untreated Sleepers

Untreated jarrah sleepers are used extensively by Commonwealth Railways and Western Australian Government Railways and, to a lesser extent, by South Australian Railways. Their experience is considered together with the results of tests carried out by the Division of Building Research, CSIRO.

In February 1972 the WAGR concluded a comprehensive research programme into the causes of failure and the length of life of untreated 9" x 4½" x 7'0" jarrah sleepers on the WAGR system. On the very lightly trafficked lines in the south-west of the State, where climatic conditions are also favourable to sleepers, the average life was 26.1 years[(1)]. However, jarrah sleeper life in the drier areas varied between 16 and 19 years. Sleeper life was 18.1 years on the relatively heavily trafficked Geraldton-Mullewa line. The results of this study are shown in in Table A.1.

In December 1968 a survey was made by the Division of Forest Products, CSIRO (now Division of Building Research) to determine the causes of failure of rail sleepers removed from the main line of the South Australian Railways between Murray Bridge (S.A.) and the Victorian border[(2)]. The objectives of this survey were to establish the pattern of failure and assess the average life. The results, shown in Table A.2, indicate an average life of the failed untreated 10" x 5" x 8'6" jarrah sleepers to be approximately 19 years and red gum sleepers to be approximately 21 years. The percentage of sleepers that had not failed was so small that the average life of all sleepers would be no more than half a year greater than these figures.

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(1) A.B. Holm (Chief Civil Engineer), 'The Life of the Timber Sleeper', WAGR unpublished paper, 1972.

(2) E.A. Bowers and F.A. Dale, A Survey of the Causes of Failure of Rail Sleepers in Australia (1968 Survey in South Australia), CSIRO Division of Forest Products, May 1969.

The only Australian railways with experience of the 9" x 6" jarrah sleeper are the mineral railways in the north-west of Western Australia and it is difficult to relate the sleeper life achieved under the high axle loads, high gross tonnages, and considerably shorter maintenance cycles to the projects under consideration.

Commonwealth Railways have indicated that the average life of the large number of 9" x 4½" x 8'0" jarrah sleepers removed from the Trans-Australian Railway over the past 22 years is approximately 17 years.

The evidence obtained from the three railway systems indicates that under very dry climatic conditions the expected life of untreated jarrah sleepers without baseplates is between 17 and 18 years. It has been assumed that the use of baseplates would extend the average life to 20 years.

TABLE A.1.- WESTERN AUSTRALIAN GOVERNMENT RAILWAYS SLEEPER LIFE AND CAUSE OF FAILURE SURVEY 1971 - SUMMARY OF FINDINGS

Section of Line	No. of Sleepers in Survey	Average Assessed Life		Av.Ass. Life All Sleepers (11% Wandoo*)	Annual Gross Tonnage ('000 tons)
		Jarrah	Wandoo		
Geraldton-Mullewa	2,950	18.1	20.9	18	2,070
SWR Main	1,750	17.5	22.8	18	1,620
Brunswick Jct.-Collie	800	18.0	23.1	19	1,100
Narrogin-Wagin Contract 1141 based on sleepers removed	13,719	15.9	30.4	21	950
Acton-Northcliffe	3,550	15.9	18.5	16	720
Watheroo-Walkaway	3,800	17.9	21.6	18	580
Collie-Narrogin	3,100	19.0	23.8	20	490
Buntine-Mullewa	5,550	17.7	20.8	18	450
Mullewa-Meekatharra	6,300	18.7	21.1	19	270
Picton-Dardanup & Boyanup-Busselton	1,100	19.9	28.7	21	230
Donnybrook-Katanning	4,850	20.8	24.6	21	160
Bowelling-Wagin	2,250	22.8	27.3	23	60
Wonnerup-Nannup	1,000	26.1	27.5	26	40

* Wandoo sleepers are now being supplied at the rate of 11% of all sleepers. Failure resulted from Perishing 43%, Spikekilling 38%, other causes 19%.

Source : Holm, A.B. (Chief Civil Engineer WAGR) 'The Life of the Timber Sleeper', unpublished paper, 1972.

TABLE A.2 - CAUSES OF FAILURE IN TIMBER SLEEPERS - SOUTH AUSTRALIAN RAILWAYS SURVEY (1968) MURRAY BRIDGE-VICTORIAN BORDER

	Jarrah	Red Gum
Number of sleepers	370	114
Percentage failed	97.2	97.5
Number of sleepers from which average life calculated *	269	76
Calculated average life**	19	21

* The sleepers from which the average was determined were those with date nails still intact at the time of the inspection

** Even if the sleepers which have not failed are assumed to last for 30 years, the average life is raised only slightly.

Source : E.A. Bowers and F.A. Dale, A Survey of the Causes of Service Failure of Rail Sleepers in Australia (1968 Survey in South Australia), Laboratory Report No.2, CSIRO Division of Forest Products, May 1969.

Treated Sleepers

Until recent years, treatment of timber sleepers was confined mainly to non-durable timbers, the object being to extend their life to that of naturally durable hardwoods. The major area of experimentation in the treatment of naturally durable hardwoods has been in south-west Western Australia where the WAGR, in conjunction with the CSIRO, has conducted tests on treated and untreated jarrah since 1954. The sleepers under test have a wide range of preservative retention. Performance to date has been assessed by officers of the CSIRO and the WAGR, and an average life of 30 years has been predicted. Results of the tests are shown in Table A.3.

The amount of preservative absorbed by the sleepers during treatment is averaged over the number of sleepers in a batch. It has been ascertained that the absorption of preservative per sleeper may vary from unacceptably low to abnormally high. CSIRO have recommended that a minimum retention should be part of any specification for treated timber sleepers, but state that:

> " The difficulty of measuring individual retentions in boultonized (treated) sleepers is admitted but it is essential that some form of individual quality control be established as soon as possible for every type of rail sleeper treatment. " (1)

This evaluation has accepted the assessment of the officers of the CSIRO and WAGR, subject to resolving the quality control of the treatment process as recommended by the CSIRO.

(1) Communication to BTE from CSIRO dated March 1972.

TABLE A.3 - RESULTS OF TESTS ON OIL-TREATED JARRAH SLEEPERS - WESTERN AUSTRALIAN GOVERNMENT RAILWAYS AND COMMONWEALTH RAILWAYS

System	WAGR[a]	WAGR[a]	WAGR[a]	CR[b]
Number laid in 1954	48	144	12	24
Number remaining in 1970	48	144	12	15
Preservative and treatment details[c]	50/50	48-50/50 48-F.O. 48-3%PCP	Untreated	Bitumen sprayed
Percentage incised[d]	50	50	-	-
Average retention of preservative (lbs/cu.ft.)	6.2	7.8	-	-
Retention range (lbs/cu.ft.)	0.9-23.1	1.6-22.4	-	-
Biological condition	98	100	78	100
Mechanical condition (100 = perfect)	96	98	86	82
Estimated minimum average life (years)	20+	20+	19	19
Possible average life (years)	25	30	20+	20

a. The WAGR sleeper tests are located at Bowelling in south-west Western Australia.

b. The C.R. sleeper tests are located at Haig on the Trans-Australian railway.

c. 50/50 is a mixture of 50% Heavy Furnace Oil and 50% K.55 Creosote

F.O. is 100% Heavy Furnace Oil

3% PCP is a mixture of 97% Heavy Furnace Oil and 3% Pentachlorphenol.

d. The purpose of incising sleepers before treatment with preservative is to increase the depth and unformity of preservative penetration.

SOURCE: Communications from CSIRO to BTE dated May 1972.

Concrete Sleepers

The concrete sleeper included in each project evaluation is the Commonwealth Railways C.R.1 as used on the Port Augusta-Whyalla Railway. This monoblock sleeper is based upon the current British Railways F.27 sleeper, the only variation being that the C.R.1 has fewer, but larger prestressing wires to provide equivalent strength.

On the basis of 20 years experience using monolithic prestressed concrete sleepers British Railways have estimated sleeper life at 50 years, and have stated that it is now becoming increasingly apparent that the life of such sleepers may even extend to 100 years[1].

In the USSR, a concrete sleeper similar in design to the British Railways type has been in operation for 17 years. Based on recent tests carried out on these sleepers, researchers are said to be confident that they will achieve a service life of from 40 to 50 years[2].

Concrete sleepers are used in many other countries, but the designs vary. Consequently, it is not valid to compare the estimates of average life.

Based on the experience and estimates of the British and Russian authorities, a 50 year average life for the C.R.1 concrete sleeper has been assumed.

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(1) D.H. Coombs, UK Railway Advisory Service - British Permanent Way, Ian Allan (Printing) Ltd.

(2) J. Levett, 'Trackmen in Russia faced many big challenges' Track and Structures, February 1972.

ANNEX B

RECONDITIONING PROGRAMME

Untreated Sleepers

The theoretical damped harmonic curve of sleeper failures, shown in Figures B.1, B.2, B.3 is based upon actual sleeper renewals carried out by the Commonwealth Railways on the Trans-Australian Railway over the past 20 years. A similar pattern of sleeper failure, based upon experience in the United States, summarised by the U.S. Forest Service in Technical Note No. 130, has been superimposed on each figure.

These figures were used to estimate the size and number of reconditioning gangs required for each project over the 50 years of operation.

Reconditioning on both of the Commonwealth Railways projects was programmed to follow the sleeper failure profile as closely as possible. Gangs would be engaged as required, and the discharge of each gang be arranged to coincide with the end of the useful life of its equipment.

The total number of sleeper replacements on the Adelaide-Crystal Brook line would be relatively small and the pattern of replacement has been arranged so that approximately one third of the sleepers would be renewed in specific years.

Treated Sleepers

The replacement programme for treated timber sleepers is simpler than that for untreated sleepers due to the longer service life. Figures B.4, B.5, B.6 are based on the Probable Failure Curve derived by the U.S. Forest Service in Technical Note No. 130, and each shows the assumed pattern of reconditioning.

For the Commonwealth Railways projects it is necessary to maintain a reconditioning gang on the line from year 21 to year 47. The requirements of the 1107 mile Trans-Australian Railway, would be approximately double those of the 520 mile Tarcoola-Alice Springs line and gang structures have been adjusted to accommodate the required replacement rate.

Concrete Sleepers

The average life of concrete sleepers used in the evaluation is 50 years. However, it has been assumed that approximately 2½ per cent of sleepers will be damaged during installation and fail prematurely. This is in addition to the allowance of 10 sleepers per mile to be discarded due to damage before placement in the track.

Replacement of the 2½ per cent of sleepers is programmed to occur at a rate of 3000 sleepers per year between the 30th and 50th year of operation on the Commonwealth Railways projects and in project years 30 and 40 of the Adelaide-Crystal Brook project.

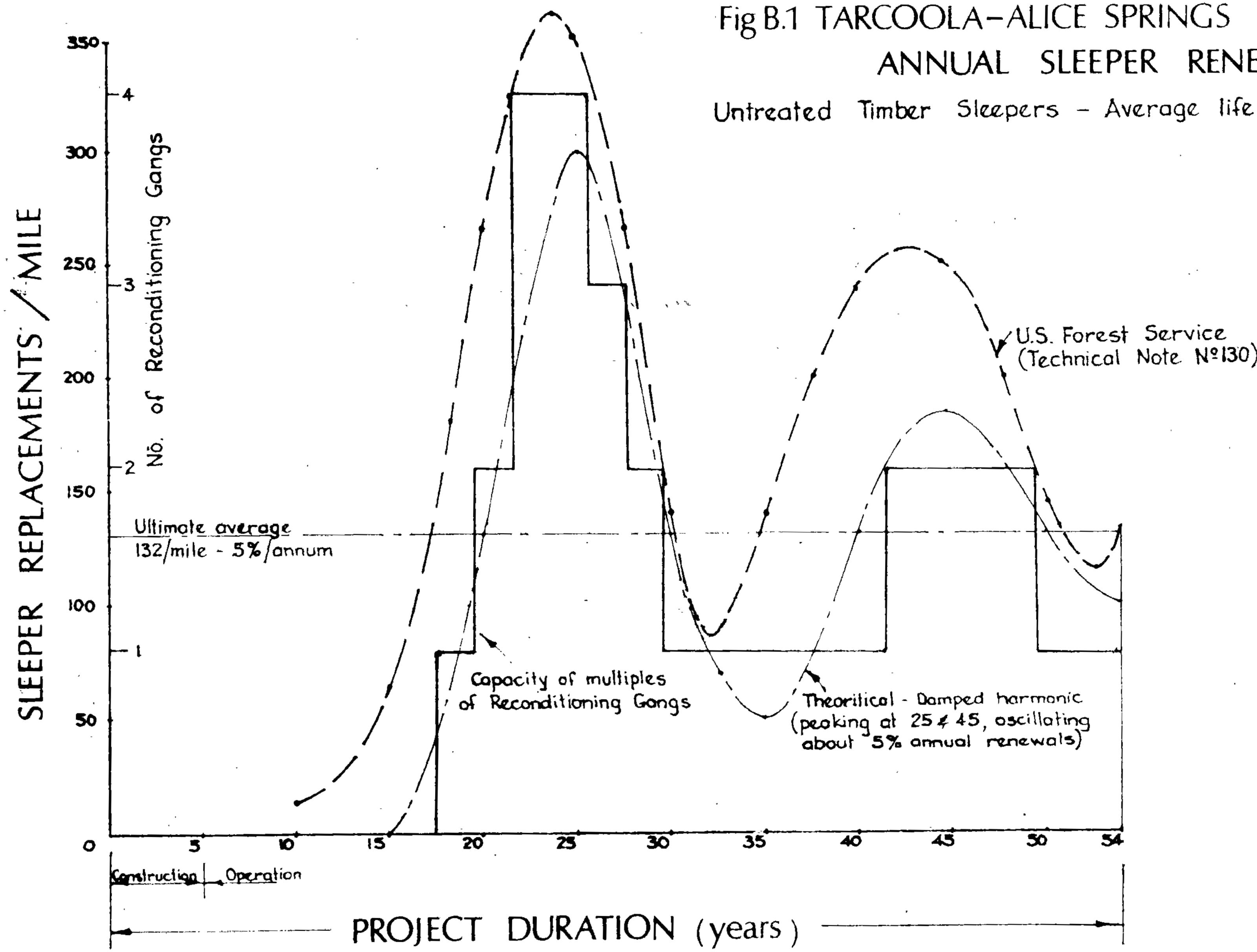


Fig B.1 TARCOOLA–ALICE SPRINGS
ANNUAL SLEEPER RENEWALS
Untreated Timber Sleepers – Average life 20 years

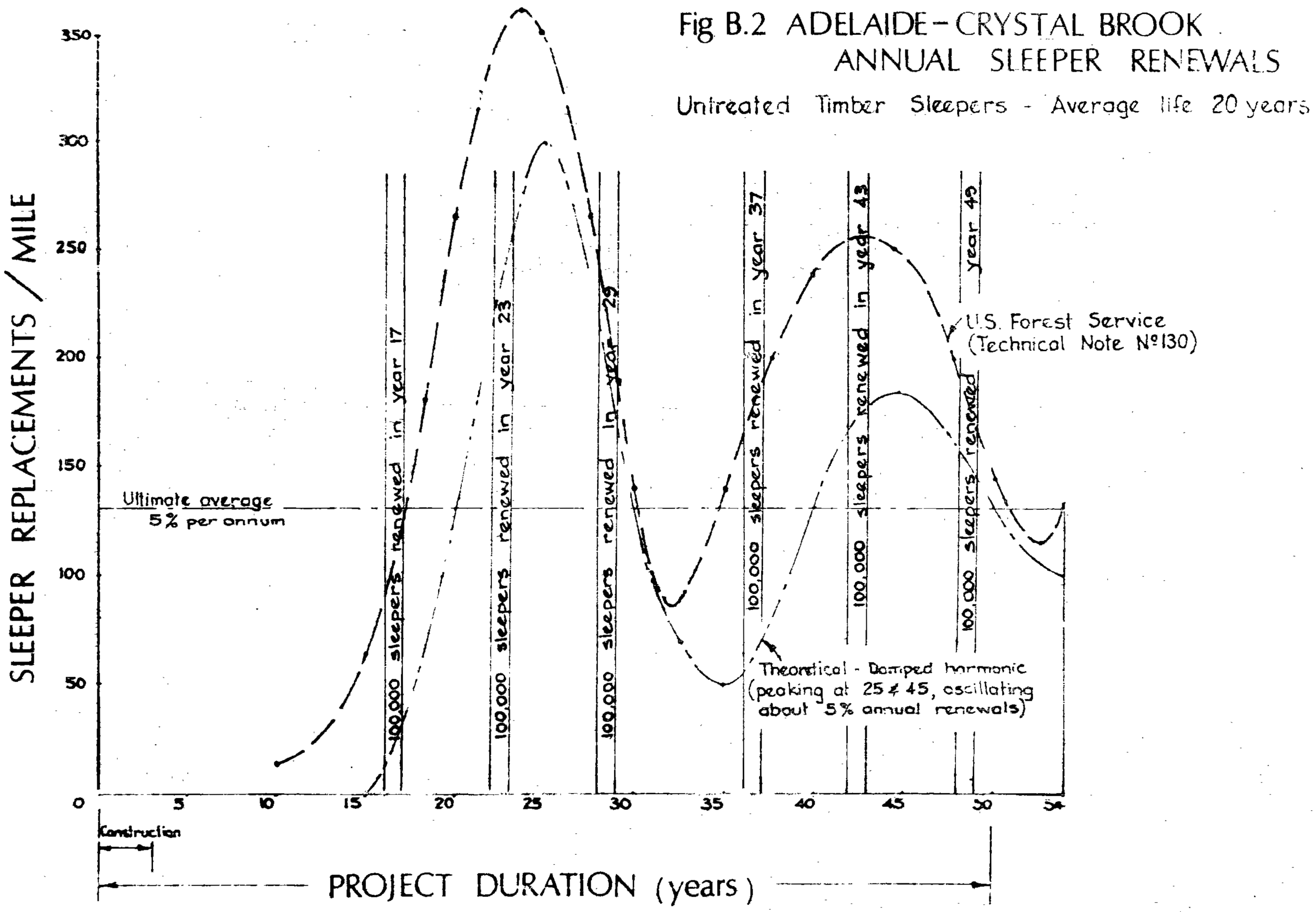


Fig B.2 ADELAIDE-CRYSTAL BROOK
ANNUAL SLEEPER RENEWALS
Untreated Timber Sleepers - Average life 20 years
SLEEPER REPLACEMENTS / MILE
350
300
250
200
150
100
50
0
5
10
15
20
25
30
35
40
45
50
54
Ultimate average
5% per annum
100,000 sleepers renewed in year 17
100,000 sleepers renewed in year 23
100,000 sleepers renewed in year 29
100,000 sleepers renewed in year 37
100,000 sleepers renewed in year 43
100,000 sleepers renewed in year 49
U.S. Forest Service
(Technical Note Nº130)
Theoretical - Damped harmonic
(peaking at 25 & 45, oscillating
about 5% annual renewals)
Construction
PROJECT DURATION (years)

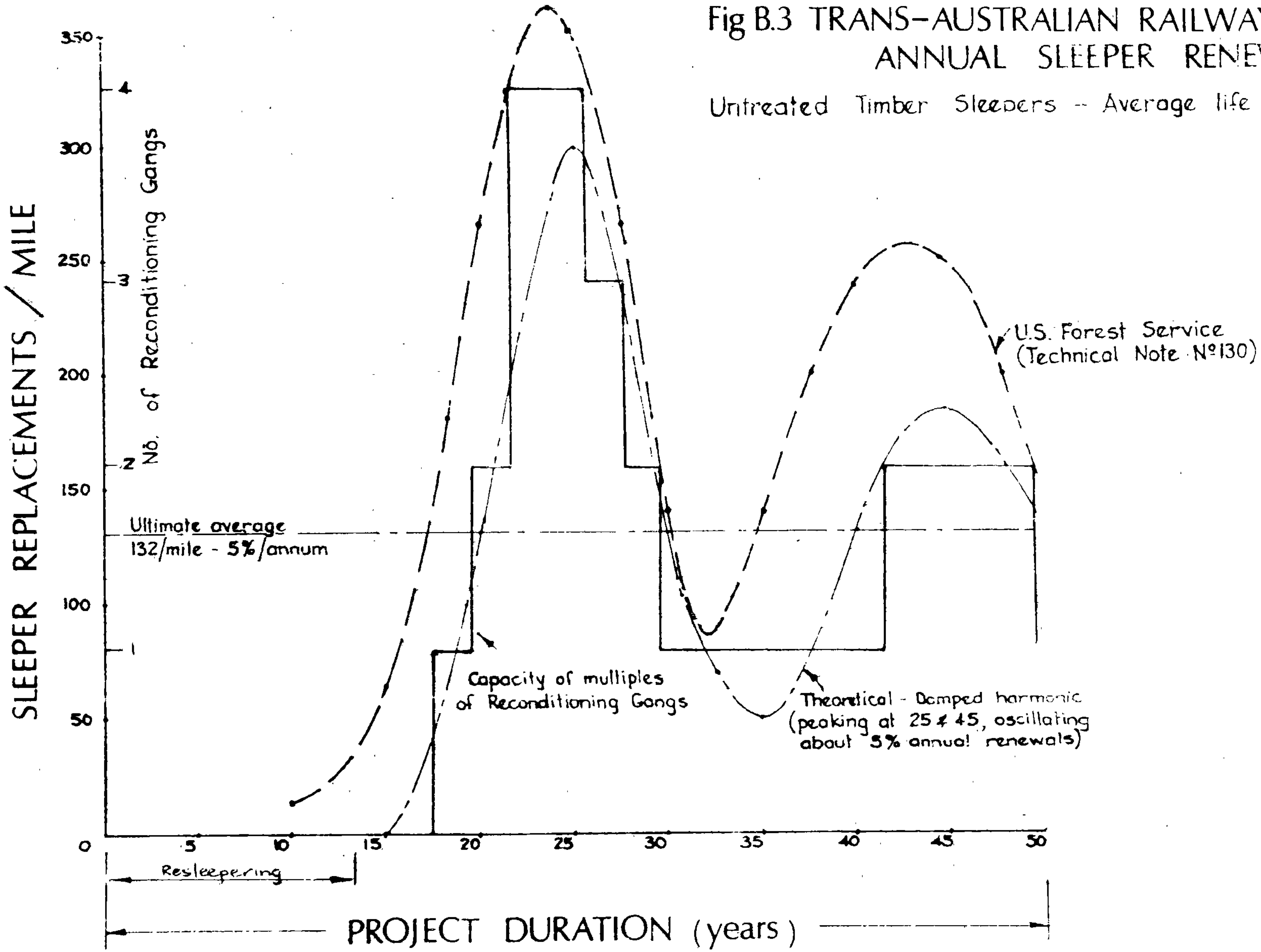


Fig B.3 TRANS–AUSTRALIAN RAILWAY ANNUAL SLEEPER RENEWALS

Untreated Timber Sleepers – Average life 20 years

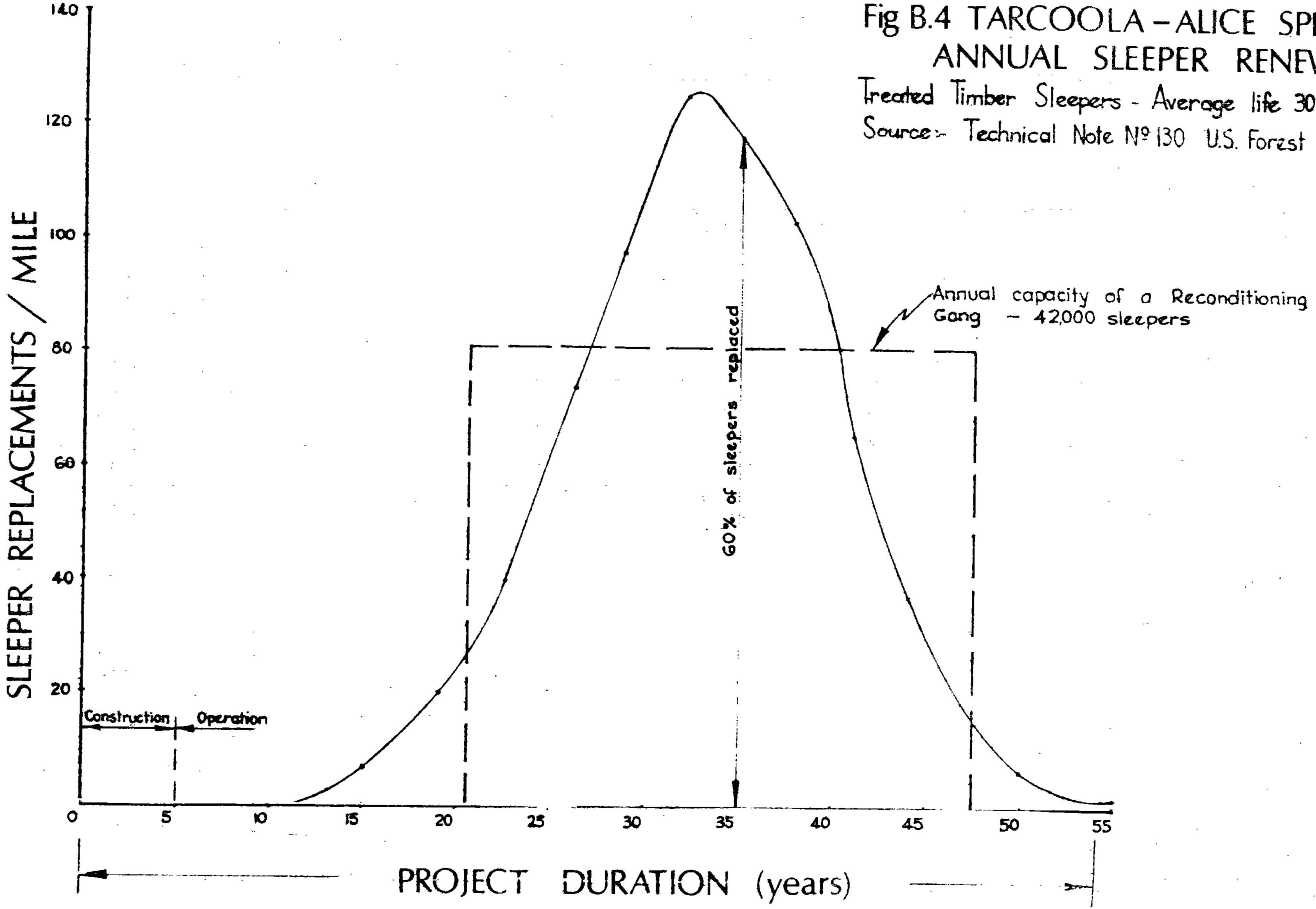


Fig B.4 TARCOOLA – ALICE SPRINGS ANNUAL SLEEPER RENEWALS

Treated Timber Sleepers - Average life 30 years

Source:- Technical Note Nº 130 U.S. Forest Service

Fig B.5 ADELAIDE – CRYSTAL BROOK ANNUAL SLEEPER RENEWALS

Treated Timber Sleepers - Average life 30 years

Source:- Technical Note Nº 130 U.S. Forest Service

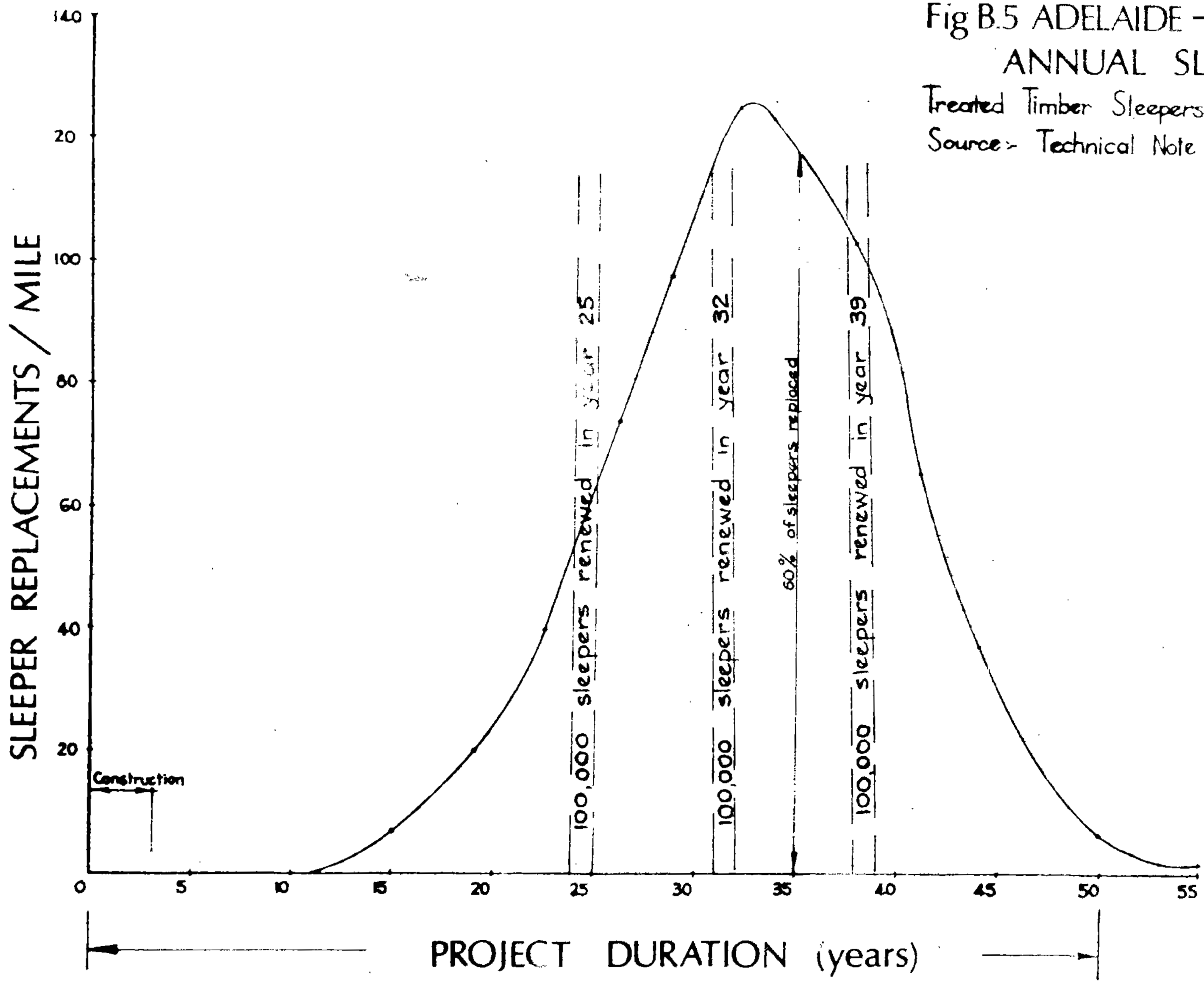
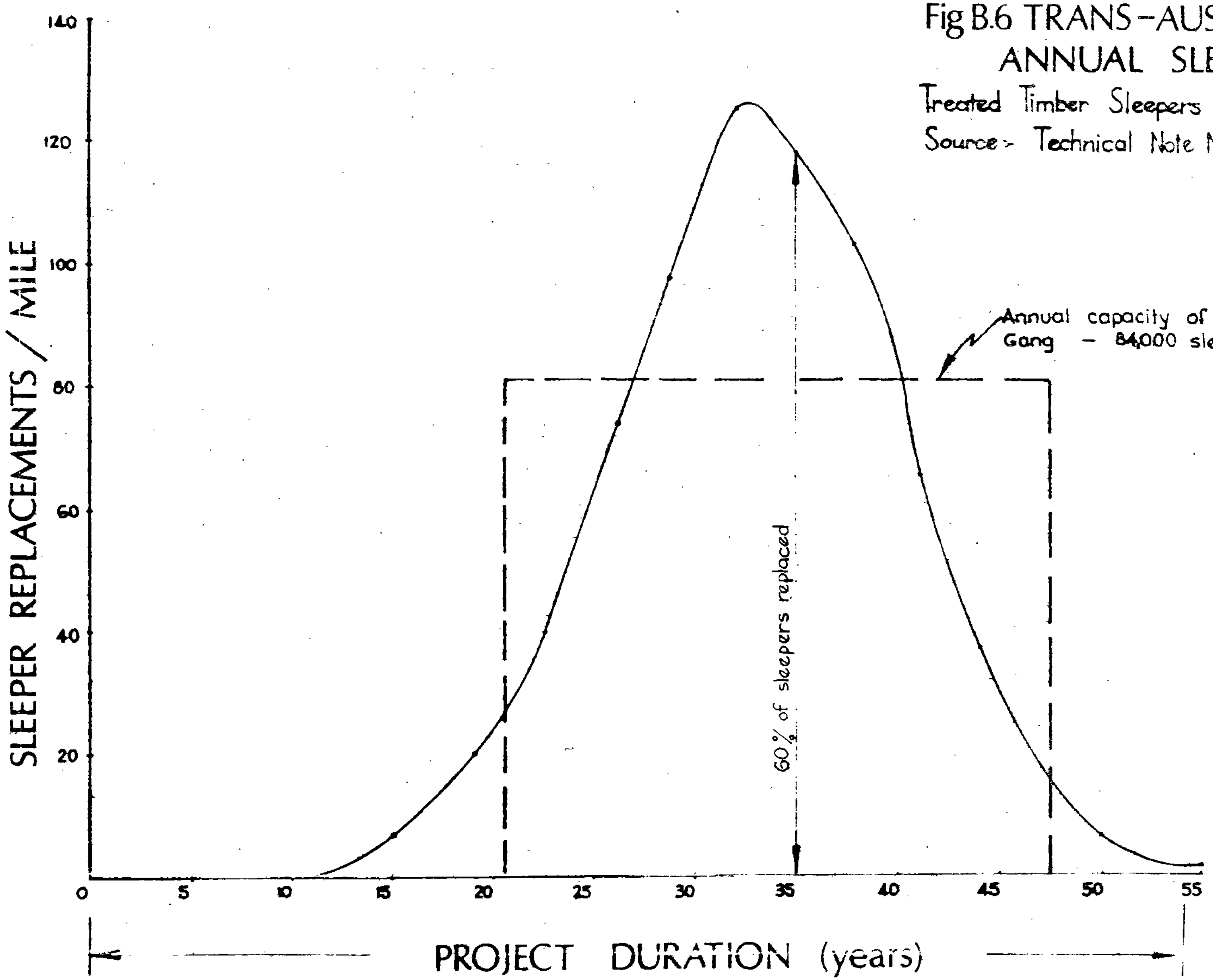


Fig B.6 TRANS-AUSTRALIAN RAILWAY ANNUAL SLEEPER RENEWALS

Treated Timber Sleepers - Average life 30 years

Source :- Technical Note Nº 130 U.S. Forest Service



ANNEX C

TABLE C.1 - SUMMARY OF COSTS DISCOUNTED TO BASE YEAR, TARCOOLA-ALICE SPRINGS RAILWAY : 7% DISCOUNT RATE
($'000)

	Timber				Concrete
	9" x 6" x 8'3"		10" x 5" x 8'6"		2400/Mile
	Treated	Untreated	Treated	Untreated	
Track components	13,889	11,511	12,527	10,639	13,442
Installation	2,471	2,965	2,459	2,938	1,701
Spare sleepers for installation	16	11	13	10	34
Maintenance					
- Resurfacing	761	761	761	761	624
- Routine mtce	853	1,114	853	1,114	53
- Reconditioning	552	1,507	552	1,507	15
- Materials for reconditioning	1,072	2,127	920	1,854	16
- Resilient pads	Nil	Nil	Nil	Nil	415
Freight	1,465	1,817	1,455	1,777	1,503
Residual value	-100	-115	-88	-103	Nil
TOTAL	20,979	21,698	19,452	20,497	17,803

TABLE C.2 - SUMMARY OF COSTS DISCOUNTED TO BASE YEAR, ADELAIDE-CRYSTAL BROOK RAILWAY : 7% DISCOUNT RATE ($'000)

	Timber			Concrete
	Treated Jarrah	Untreated Jarrah	Untreated Red Gum	
	$	$	$	$
Track components	3,279	2,835	2,611	3,642
Installation	541	656	656	391
Spare sleepers for installation	3	3	2	9
Maintenance				
- Resurfacing	214	214	214	125
- Routine Mtce	206	241	241	34
- Reconditioning	72	164	164	7
- Materials for reconditioning	245	411	338	6
- Resilient pads	Nil	Nil	Nil	121
- Insulation pads	Nil	Nil	Nil	170
Freight	82	96	24	16
Residual value	-26	-29	-23	Nil
TOTAL	4,616	4,591	4,227	4,521

TABLE C.3 - SUMMARY OF COSTS DISCOUNTED TO BASE YEAR, TRANS-AUSTRALIAN RAILWAY : 7% DISCOUNT RATE ($'000)

	Timber				Concrete
	9" x 6" x 8'3"		10" x 5" x 8'6"		Minimum Freight Case
	Treated	Untreated	Treated	Untreated	
	$	$	$	$	$
Track components	15,962	12,068	13,652	10,448	18,516
Initial re-sleepering	5,448	5,448	5,448	5,448	5,128
Spare sleepers for installation	27	19	23	17	58
Maintenance					
- Resurfacing	1,505	1,505	1,505	1,505	1,419
- Routine mtce	3,169	3,195	3,169	3,195	1,104
- Reconditioning	921	2,470	921	2,470	35
- Materials for reconditioning	2,144	4,179	1,840	3,642	44
- Resilient pads	Nil	Nil	Nil	Nil	728
Freight (marginal cost)	1,906	2,376	1,893	2,326	820
Residual value	-423	-459	-362	-398	Nil
TOTAL	30,659	30,801	28,089	28,653	27,852