Study of Port Pirie Bogie Exchange

Report

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BUREAU OF TRANSPORT ECONOMICS

A STUDY OF PORT PIRIE BOGIE EXCHANGE

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FOREWORD

Because of separate development by the individual States the Australian railway network contains links of a number of different gauges. For this reason bogie exchange facilities have been established at several locations including two in South Australia, at Port Pirie and Peterborough, where the State broad gauge system meets the interstate standard gauge system. The intention of these exchanges is to allow ready transfer of loaded and unloaded freight wagons from one system to the other. Traffic through the exchange at Port Pirie has increased to the extent that difficulties are being experienced in handling it.

This report presents the results of a study of the Port Pirie bogie exchange. The study was instigated to define the costs and operational difficulties currently experienced at the Port Pirie bogie exchange and to examine the operational and economic worth of a range of upgrading proposals.

The study was undertaken by a team consisting of L. Krbavac, L. Freeman and G. Stinton under the leadership of P. Ferrari. General oversight and assistance were provided by R. Heacock and N. Gentle.

The Bureau of Transport Economics acknowledges the assistance received from the South Australian Railways and the Australian National Railways for the provision of data and the South Australian Railways for detailed discussions.

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Acting Director

Bureau of Transport Economics
Canberra
February, 1977.

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SUMMARY

This report is the result of a study of the Port Pirie bogie exchange.

The objectives of the study were to examine the existing exchange operation, to define the costs incurred and the operational difficulties being experienced, to suggest and define a range of alternative upgrading options aimed at reducing both costs and delays and to perform a basic evaluation of the economic worth of these options. A further objective was to provide details of upgrading options to be evaluated within the context of a study of the East-West Rail Link.

Overall, the average time spent in the Port Pirie yard for wagons requiring transfer was found to be 27.4 hours. Specific planned connections between arrival and departure trains are very rarely achieved. Both these problems appear to result from a combination of factors including congestion due to inadequate storage space in the Port Pirie yard, restrictive location of the bogie exchange shed within the yard and problems created by directional traffic imbalances.

The current costs incurred by each wagon passing through the exchange was found to be $24.23. If delay costs are included the average cost was estimated as between $35.23 and $39.23 per wagon.

Considerable scope exists for reducing both delays and costs. This report proposes four upgrading options ranging in cost from $200 000 to $7.2m, three of which appear to have considerable economic merit and warrant further detailed investigation.

An important conclusion of the study has been that an expenditure of approximately $7.2 million could provide facilities to handle all expected bogie exchange traffic in the Port Pirie area for at least the next twenty years with substantially lower delays than are currently occurring.

CHAPTER 1 - BACKGROUND

The Bureau of Transport Economics initially became involved in consideration of bogie exchange problems when approached by SAR in relation to establishing a bogie exchange facility in Adelaide as part of the Adelaide to Crystal Brook standardisation. At much the same time the BTE had been requested by ATAC to examine rail freight operations in Australia[1]. The importance of bogie exchanging was immediately obvious, but at that stage there was no available information on the real costs incurred by bogie exchanges in terms of operations and delays. It was therefore decided to conduct a detailed appraisal of current bogie exchanging practice. This report describes the work completed to date.

Bogie exchange is the most important of the current methods of load transfer at break of gauge locations on Australia's railway network. In principle, the method involves raising each wagon and its load off bogies of one gauge, and then lowering the wagon onto bogies of the second gauge.

The bogie exchange at Port Pirie is basically intended to form a link between standard and broad gauge for freight wagons travelling from Melbourne and Adelaide destined for Western Australia and vice versa.

The Port Pirie Bogie Exchange facility is currently handling approximately 46,000 vehicles annually. This through-put is significantly higher than any of the other three bogie exchange centres in Australia being almost twice the through-put of Dynon and Peterborough exchanges. It is not surprising then that the Port Pirie exchange has been the first facility to develop problems in handling the traffic imposed on it.

It has become evident in recent times that wagons passing through the Port Pirie Bogie Exchange[2] often incur long delays. A

(1) ATAC meeting, July 1973.
(2) Referred to as P.P.B.E. through this report.

survey conducted October to December 1974 indicated that 40% of wagons travelling from the eastern states to Western Australia were delayed for one day or more at Port Pirie[1]. Subsequent growth in traffic implies that delays in Port Pirie have increased above this level although detailed information about the extent and cause of delays has not previously been available.

Officers of the South Australian Railways have expressed the opinion that the Port Pirie facility is nearing its practical capacity. This would appear to result from a combination of factors including the size and arrangement of the Port Pirie yard and train scheduling. The PPBE will be required to operate at least until a standard gauge connection to Adelaide is completed, and even allowing for minimal traffic growth, it is felt that in its current form, it will be unable to handle the increased traffic prior to standardisation.

As indicated above, the PPBE cannot be considered in isolation. It is an important node in the Australian railway network and is affected by other parts of the network. For example, a lack of adequate marshalling facilities at major origin yards throughout Australia results in a substantial marshalling requirement at Port Pirie. On arrival at Port Pirie, all trains need to be broken into two basic categories: wagons to be exchanged and those that do not require change of gauge. Since trains are not originally marshalled into such blocks, the task must be performed within the Port Pirie yard, leading to periods of severe congestion.

The directional balance of traffic flows through Port Pirie is most significant since an imbalance can readily deplete the pool of spare bogies and hence prevent the handling of wagons arriving to be exchanged. Imbalances at Port Pirie can occur as the result of, for example, industrial stoppages, public holidays, lack of loading at the origins or non return of empty wagons from the destinations. Similarly, operations at the bogie exchange facility at Dynon in Victoria can have repercussions on the PPBE

(1) Survey conducted by S.A. Railways.

in that the circulation and distribution of bogies, necessary to maintain pool sizes at all bogie exchange depots, can very quickly be disrupted by a change in operations at any one of the depots.

The frequency of occurrence and the extent of the problems mentioned above have increased in recent times with increased traffic flows. The South Australian Railways organisation has become acutely aware of the developing situation since the operation of the PPBE is their responsibility. The problem has been raised at an ANZR Conference, and a sub-committee of that group has been formed to examine the situation. The direction taken by this committee could perhaps be seen as a short term approach aimed at operating the current facilities as efficiently as possible taking into consideration the requirements for balanced traffic flows and the establishment of adequate bogie pools. This study has been completed but it is understood that arrangements to institute the short term recommendations of the study team have been delayed.

CHAPTER 2 - STUDY OBJECTIVES

The BTE recognises the importance of examining bogie exchange operations within the context of the complete rail freight operation. This implies a need to consider all bogie exchange depots within the system. However, it has been necessary in terms of study scheduling, to limit this initial study to a detailed examination of the Port Pirie facility with some consideration of the operations of Peterborough. It is hoped to extend the study at a later date to include the other bogie exchange centres.

Therefore, within the broader context of an overall study, the BTE established the following objectives for this initial investigation:

- to define and characterise the various components of the bogie exchange operation at Port Pirie
- to measure the costs of the operation and identify those parts of the operation where a reduction in costs may be possible
- to measure the distribution of delays, identify their source and identify those sources of delay where a reduction may be possible
- to suggest and define some alternative courses of action which appear to warrant further investigation as possible longer term solutions to the problems being encountered.

CHAPTER 3 - CURRENT BOGIE EXCHANGE OPERATION

GENERAL DESCRIPTION

The Port Pirie yard is a dual gauge yard accepting standard gauge links from Port Augusta and Peterborough and a broad gauge link from Adelaide. The yard is long and narrow (approx 3 km x 80 m) with a constriction towards the middle in the form of an overhead road bridge which narrows the yard to about 30m at that point. The yard layout is further constricted in that it is doglegged and dead ended with all entries and exits taking place at the eastern end. The yard is depicted in Figure 3.1. (See Page 36).

The roadbridge divides the yard approximately in halves. The outer yard, referred to as the subsidiary sidings area, is not long enough to accept full trains arriving on standard gauge. There are too few tracks to allow storage and shunting operations to proceed unhindered. The result is periods of acute congestion, and hence a lack of ability to provide wagons to the bogie exchange facility when required. This situation is aggravated by the live-stock transfer operation which takes place in this area. Approximately three times a week stock are transferred from standard gauge wagons to broad gauge wagons. During this operation at least four of the ten roads in the subsidiary sidings area are unavailable for other uses for up to six hours at a time.

The other half of the yard, to the west and north-west of the road bridge, contains all the other yard facilities including passenger platform, engine shed and turntable, workshop, car barn, gantry transfer area, manual exchange platform and shed, and bogie exchange. As in the outer yard, there is very little track available for storage of wagons and the area becomes congested very quickly.

The bogie exchange is located towards the dead end of the yard. This location limits the storage tracks leading directly into and

out of the exchange shed to about 10-11 wagon lengths. This necessitates frequent shunting to feed and clear the exchange. While such shunting is taking place work must stop in the exchange and since the high congestion within the yard delays the shunting operation, stoppages in the exchange are frequent and often lengthy.

The exchange operation is relatively simple. A wagon is brought into the shed by a tractor and four portable jacks are positioned under special jacking plates on the wagon. The brake rods are disconnected from the bogies and the wagon is raised off the bogies. These bogies are rolled forward and the different gauge bogies, which have been placed on the track behind the wagon by a mobile crane, are rolled forward into position. The wagon is then lowered onto these bogies, the brake rods are attached, the brakes are tested and the wagon is pushed out.

CONSTRAINTS ON THROUGHPUT

The bogie exchange is a two track facility which allows two gangs to operate simultaneously. Each gang consists of seven men and includes a ganger, a crane driver, a tractor driver and four assistants.

The facility is rapidly approaching its practical capacity. This is the result of several factors which are discussed in this section.

(i) Number of Shifts

Since two crews can work simultaneously, there is the capacity to work six, 8 hour crew shifts per day i.e. 42 crew shifts per week. Currently, the facility is working 33 crew shifts per week. However, the remaining 9 crew shifts occur between Sunday and Wednesday which is that period in the week when very little traffic arrives in Port Pirie. This comes about due to the lack of loading on weekends at the origin yards.

Therefore, unless loading can be despatched from, say, Kewdale (W.A.) on Saturdays and Sundays the full shift capacity of the bogie exchange cannot be realised.

(ii) Union Darg.

Resulting from union negotiations, the throughput of wagons per crew shift is limited. With a full crew of seven the limit is set at 32 wagons; with one man down the limit is 25 and with two men down 17.

There seems little prospect of increasing these limits by negotiations if the current exchange operation is maintained.

(iii) Downtime per shift.

Examination of bogie exchange reports for May 1976 indicates that on average, over two hours per shift were lost in downtime i.e. that time per shift during which the crew were unable to work. If the crews had achieved the negotiated darg there would be little point in investigating the cause of this downtime. However, the average throughput per shift for May 1976 was 27.8 wagons indicating that 15% of available capacity was lost.

SAR officials are of the opinion that a shortage of bogies is a major cause of the loss of productive time. However, this reason is given very infrequently as a cause for delay on the daily bogie exchange delay reports. The most frequently occurring reason given on these reports is stoppages during shunting activities. This apparent discrepancy may result from the real cause of delay not being obvious to the gang in the exchange. On the other hand, it is possible that a constant shortage of broad gauge bogies might not be so great in itself to halt production in the exchange but it may give rise to a build-up of standard gauge wagons in the yard waiting to be exchanged. This would tend to increase shunting congestion in the yard and hence cause lengthy stoppages at the depot during shunting operations.

It is believed that a major contributory cause of downtime in the exchange and hence loss of capacity is the difficulty of shunting within the yard and the inability of the yard to place and clear wagons at the rate required. A shortage of bogies may also be a cause, but the BTE was unable to determine the extent of this particular problem.

(iv) Bogie Pool.

As the result of timetabling, trains generally arrive at Port Pirie from both gauges in sufficient quantities and at similar times to allow the exchange to operate in a way that approximates a one to one swap of bogies between wagons. This leads to a smaller bogie pool requirement than if trains arrived from the two gauges at staggered intervals. However, it also implies that a small imbalance in traffic flow can quickly deplete the supply of bogies of one gauge. A shortage of bogies can also occur if a large percentage of the pool is withdrawn for maintenance. Both these problems have been occurring recently and have led to an increase in delays.

The sub-committee established by ANZRC have considered this problem and have made recommendations related to increasing the pool of bogies and establishing procedures for adjusting traffic flows to maintain directional balances. Since these plans have not yet been implemented, no information is available upon which to judge their success.

TRAFFIC THROUGH THE EXCHANGE

The traffic passing through the exchange has demonstrated a steady growth over the past decade. Table 3.1 indicates annual totals of wagons and tonnages handled by the exchange since 1965-66.

As part of the East-West Rail Study, a detailed appraisal of rail traffic growth has been made and concludes that the growth of bogie exchange traffic is likely to be 4% per annum over the next

10 years and reducing to 3.5% per annum after that time. Broadly speaking, this growth is based on the expected growth of Darwin traffic as well as a growth in general traffic parallel to the general economic growth of the country as a whole. At this growth, it would appear that the current facilities at Port Pirie will be unable to handle the traffic imposed on it within the next few years and in the interim, delays could be expected to increase extensively.

REROUTING THROUGH PETERBOROUGH

Peterborough is situated at a node in the rail network with standard gauge connections to Port Pirie and Broken Hill and a broad gauge connection to Adelaide. A bogie exchange facility has been established at Peterborough primarily to accommodate traffic between Adelaide and Sydney.

At times, traffic from the West intended for the bogie exchange at Port Pirie is rerouted through the bogie exchange at Peterborough. This is usually done for one of two reasons:

. to correct an imbalance of traffic at Peterborough;
. to avoid congestion at Port Pirie.

For the period March to May 1976, approximately 10% of bogie exchange traffic arriving from the West was handled through Peterborough. About 50 per cent of the diverted wagons were required to balance loading at Peterborough. However, such an operation is only applied infrequently and on an ad hoc basis by SAR.

There are two major reasons for this. Firstly, the operation is felt to be uneconomic because of the increased mileage incurred. Secondly, such rerouting does not solve the congestion occurring at Port Pirie which is usually due to a shortage of broad gauge bogies (necessitating the storage of standard gauge wagons). If wagons from the West are diverted through Peterborough to avoid

congestion at Port Pirie, the supply of broad gauge bogies at Peterborough is reduced. Since this can lead to major problems at Peterborough if uncorrected, the inventory of broad gauge bogies must be re-instated there by diverting westbound loading from Adelaide back through Peterborough. This reduces the supply of broad gauge bogies to Port Pirie and thus the congestion in that yard is not directly reduced. However, such rerouting does prevent an increase in congestion at Port Pirie and hence buys time until other measures can be taken to restore the balance of bogies at Port Pirie by for example transferring empty wagons from broad gauge to standard gauge.

For these reasons the ad hoc rerouting of trains through Peterborough is not a practice which SAR adopts to any degree. However, intentional and scheduled rerouting through Peterborough may prove worthwhile in both economic and operational terms and is discussed later in this report.

ANALYSIS OF CURRENT OPERATIONS

One of the fundamental objectives of this study has been to determine in quantitative terms the extent of delays and costs incurred by the bogie exchange operation. This section outlines the approach taken to achieve this aim and the results obtained.

Delay Analysis

The time from the arrival of a wagon at the Port Pirie yard to its departure from the yard is called the transit time. A wagon arriving at the yard has a minimum possible transit time determined by the minimum time required for marshalling, the minimum time required to pass through the bogie exchange, and the timetable of departing trains. This minimum transit time (or service time) is not the same for all wagons as it is very dependent on timetables. Transit time in excess of the service time is called delay time.

Guards' journals for all trains into and out of Port Pirie for a given period of time formed the primary source of data. From these, details of each wagon (wagon number, contents, origin and destination) could be obtained and arrival and departure time and date could be established. Preliminary investigation of the sample size needed to assess the average transit time indicated that a sample of approximately 2000 wagons would give a 95% confidence interval of two hours. Since this form of data was likely to have legibility problems it was decided to increase the initial sample to 4000. This figure corresponds roughly to the number of wagons exchanged per month. For this reason, guards' journals were obtained from SAR and ANR for the month of May 1976. May was chosen on advice from SAR that it had been a representative period without any major departures from normal traffic movements.

Other documents recorded the wagons exchanged during each shift in the bogie exchange. These records were examined to determine those wagons which actually passed through the exchange. This record was also used to determine the approximate times between arrival and exchange and between exchange and departure.

Computer analysis was utilised to match the various records that were available for each wagon. However, prior to the analysis, the raw data had to be transcribed from the guards' journals onto easily readable forms. Since this transcription involved considerable manhours an attempt was made to limit the total numbers of records. This was done in two ways.

Firstly, it was decided to record data from the guards' journals of only 'X' class wagons.(1) In fact a quick perusal of the bogie exchange records indicated that less than 2% of wagons passing through the exchange were other than 'X' class. Therefore it was felt that the sample would not suffer from the loss of such a small number.

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(1) 'X' Class wagons are wagons designed to allow for the change of bogies and are designated by an 'X' in the alpha portion of the wagon serial number.

TABLE 3.1 - TRAFFIC HANDLED BY THE PORT PIRIE BOGIE EXCHANGE[a]

Period	Direction	Wagons	Total Wagons	Tonnes	Total Tonnes
1965-66	East	4 029		8 236	
	West	4 094	8 123	100 023	108 270
1966-67	East	6 492		23 814	
	West	6 548	13 040	148 978	172 792
1967-68	East	9 196		70 182	
	West	9 230	18 426	212 866	283 048
1968-69	East	8 471		90 259	
	West	8 535	17 006	195 648	185 907
1969-70	East	15 596		126 898	
	West	15 400	30 996	325 937	452 835
1970-71	East	16 565		131 276	
	West	16 445	33 012	349 121	480 397
1971-72	East	16 941		141 631	
	West	16 741	33 682	354 169	495 825
1972-73	East	18 175		204 105	
	West	18 267	36 432	364 222	568 327
1973-74	East	19 448		236 623	
	West	18 729	38 177	434 573	671 198
1974-75	East	20 533		239 726	
	West	19 098	39 631	432 166	671 892
1975-76	East			246 966	
	West		46 327	523 678	770 644

(a) Data supplied by SAR.

Secondly it was decided that guards' journals for only those trains on the Port Pirie to Port Augusta and Port Pirie to Adelaide links would be analysed without taking into consideration those trains on the Port Pirie to Peterborough links. This was done because the majority of wagons transferred at Port Pirie travel from Adelaide to the West and vice versa. Less than 1% of wagons exchanged at Port Pirie during the period being analysed travelled on the Port Pirie - Peterborough link.

The analysis consisted of taking the arrival records, bogie exchange records and departure records, sorting them by wagon number and in chronological order and extracting each correct grouping i.e. each set of three records for any wagon which indicated arrival, exchange and departure in correct chronological sequence.

Matching records were not found for a considerable number of wagons. This resulted from:

- errors in the guard's journals or bogie exchange records;
- errors in data transcription;
- exclusion of trains on Port Pirie - Peterborough link;
- wagons arriving before the beginning of May and departing during May;
- wagons arriving during May and leaving after the end of May.

The above then reduced the initial sample of 4000 to precisely 2134 valid records which were then analysed to obtain distributions of transit times incurred by wagons.

The data was analysed in several ways. Transit times were obtained for several catagories which are listed below. Within each category, times were assessed for all wagons and then for empty and loaded wagons. Also within each, times were assessed from arrival to bogie exchange, from bogie exchange to departure and from arrival to departure.

The basic categories are:

- all wagons
- wagons arriving on train 413 on broad gauge
- wagons arriving on train 827 or train 797 on broad gauge
- wagons arriving on train 72 on standard gauge
- wagons arriving on train 34 on standard gauge.

Wagons on the specific trains mentioned in four of the categories above are supposed to be exchanged in time to join specific trains departing Port Pirie. The analysis was performed to determine the extent to which such connections are achieved.

Results of Transit Time Analysis

The distribution of transit time for all wagons is shown in Figure 3.2. The mean transit time is 27.4 hours with a standard deviation of 15.8 hours. The analysis indicated that the mean transit time for loaded wagons was three hours less than empty wagons although a large difference between the standard deviation of these two distributions indicates that little significance can be placed on this 3 hour difference. The bulk of wagons have a transit time of between 8 and 40 hours.

The numbers of wagons with large transit times is of particular interest:

- 54 percent have transit times in excess of 1 day
- 22 percent have transit times in excess of 1½ days
- 12 per cent have transit times in excess of 2 days.

The distributions that were obtained for the specific train connections are summarised in Table 3.2.

The table indicates that only a small percentage of wagons on the specified trains make the connection with the intended departure train. The average transit time for loaded wagons with each of the trains considered does not differ greatly from the overall

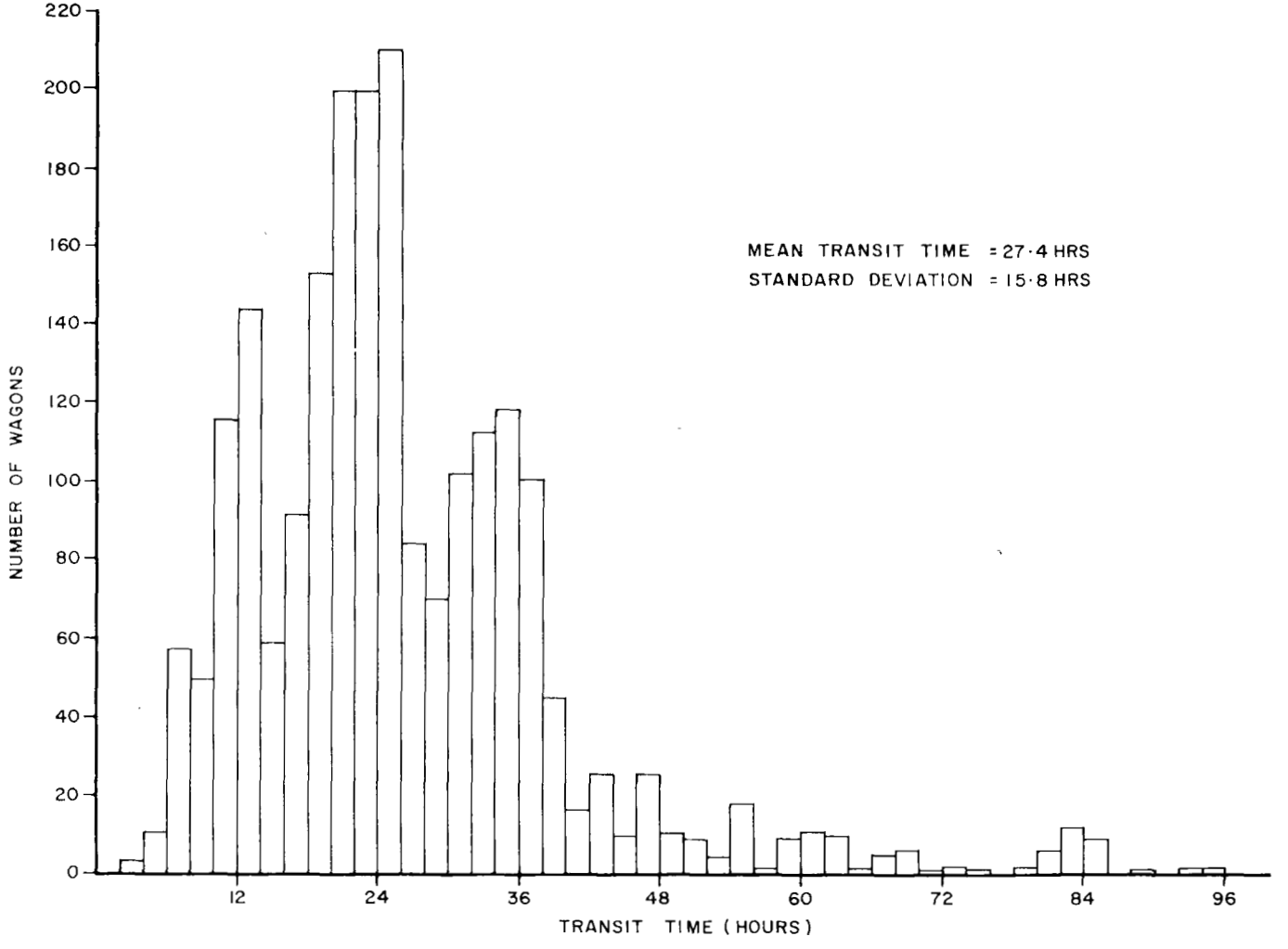


FIGURE 3·2

TRANSIT TIME DISTRIBUTION FOR ALL WAGONS

average transit time of all wagons passing through the bogie exchange. This indicates that the congestion problem occurring in the Port Pirie yard prevents intended connections from being made.

TABLE 3.2 - ANALYSIS OF TRAIN CONNECTIONS

Arrival Train	Average Transit Time for Loaded Wagons	Intended Connecting Train	% of Wagons Achieving Connection
413	26.8 hrs	23	25.5
827 or 797	22.8 hrs	73	10
72	28.9 hrs	12	2
34	31.2 hrs	730	11

Costs

The SAR keeps an account of the costs incurred directly by the bogie exchange facility. However this account does not include the cost of factors external to the bogie exchange but necessitated by the existence of it. These external costs should be included in an analysis of bogie exchange costs if a valid picture of the bogie exchange operation is to be obtained.

In the past, Port Pirie yard has been a facility shared between Australian National Railways and South Australian Railways. For the purpose of defining the apportionment of the costs of operating the yard, an agreement referred to as the Port Pirie Joint Working Agreement has been drawn up.

Apart from a few exceptions the Joint Agreement lists all facilities provided in the yard, and all operations performed, as separate items. Each cost incurred in the yard is recorded under that item for which the cost was incurred. The BTE's task therefore amounted to deciding which items could be considered to be due in whole or in part to the bogie exchange operation and if only in part, to determine the extent which could be apportioned to the bogie exchange.

The costs excluded from the Joint Agreement refer to those operations and facilities in the yard which are seen to be the sole responsibility of SAR. The only element in this category directly related to the bogie exchange operation is the cost associated with broad gauge shunt locomotives and their crews.

The costs considered in this way can be categorised into direct operating costs and depreciation costs. Another category of costs which should be considered in this analysis is the cost of delays.

(i) Direct Operating Costs

Annex B lists in detail the various costs which were included and the assumptions relating to each. The costs used were either those incurred in May 1976 or, for those costs which occur at infrequent intervals such as maintenance, the cost was considered as one twelfth the cost incurred for 1975-76 financial year.

The following bogie exchange costs were determined:

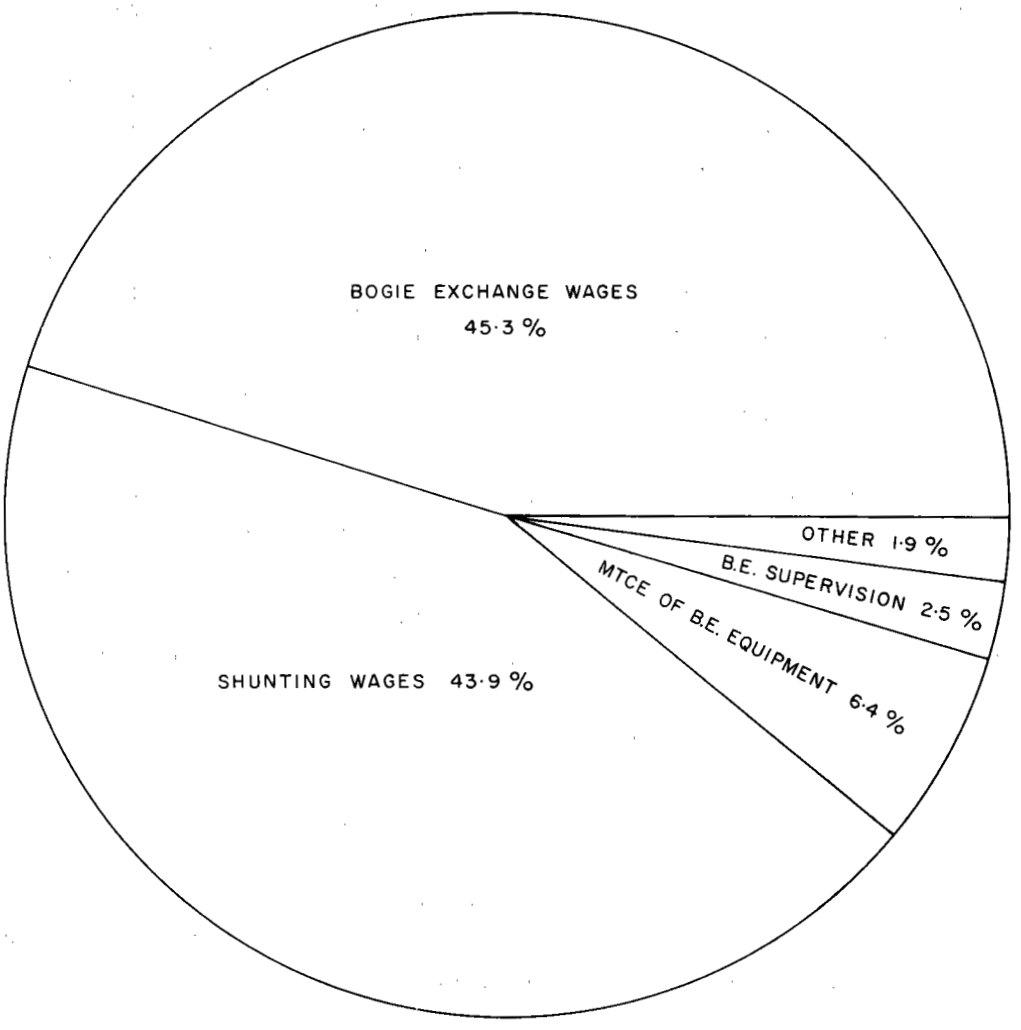
- Operating cost per wagon - $23.89
- Operating cost per net tonne - $ 1.35

Figure 3.3 illustrates the relative proportions of the items of the direct operating costs. It can be seen from the diagram that although the cost of manning the exchange is the most significant, the cost of providing shunting assistance for the exchange is also considerable.

(ii) Depreciation Costs

The SAR were able to provide data on the capital costs incurred when establishing the bogie exchange, the year of expenditure and an estimate of the life of each item.

Linear depreciation over the life of the item was assumed and all costs were converted to 1975-76 costs by utilising the Implicit



(100% = $23·89 PER WAGON)

FIGURE 3·3

DISTRIBUTION OF DIRECT OPERATING COST
PORT PIRIE BOGIE EXCHANGE 1976

GDP Price Deflater[1]. Use of these approximations was considered to be acceptable in this case since the costs involved are very small compared to the operating costs.

Annex B contains details of the depreciation costs. In summary, the depreciation cost per month was $1170.

Thus for May 1976:

. Approximate depreciation cost per wagon	$0.34
. approximate depreciation cost per net tonne	$0.02

(iii) Delay Costs

When rolling stock is delayed in transit by being held in a yard (not involving additional crew costs) two costs are incurred. The first is the cost to customers of holding extra stock. The inventory cost being considered is the cost of stocks in transit. If transit time is reduced then the quantity of stock in transit is reduced proprrtionately. The pro rata cost of delaying one tonne of cargo for one hour is Pi/8760 where P is the average value of one tonne of cargo and i is the annual inventory holding cost (including depreciation and damage). Assuming that i ranges between 10% and 15% and that P is $2000, then the holding cost of a one hour delay ranges between 2.28 and 3.42 cents per tonne. Considering the number of empty wagons returning from the west, the average wagon load is 17.69 tonnes so that the customer's inventory holding costs range from 40 to 60 cents per wagon per hour of delay.

The second aspect of delay cost is the cost to railway operators of additional rolling stock required as the result of reduced utilisation of existing wagons brought about by transit delays.

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(1) Source: Central Statistical Section, Policy Development Division, Department of Overseas Trade.

To estimate this cost it has been assumed that wagons are utilised for 8000 hours per year and that the value of a wagon in 1975-76 dollars is $28 000 and that wagons have an expected life of 25 years. Assuming a 10% discount rate, the value of one hour utilisation time and hence of one hour delay is 38.6 cents per wagon per hour.

The above two costs combined indicate a cost of between $0.79 and $0.99 per wagon per hour delay. The current delay to wagons passing through the PPBE (with delay defined as transit time in excess of minimum transit time) is approximately 15 hours.(1) This would indicate a cost of between $12 and $15 per wagon or between $0.68 and $0.85 per net tonne.

COST SUMMARY

In summary the total cost incurred by a wagon passing through the PPBE is $39.23 per wagon or $2.25 per net tonne. Figure 3.4 indicates the overall distribution of the costs involved. It is immediately obvious from this figure that substantial benefit may be realised by increased capitalisation of the operation to achieve reductions in both delays and manpower resources used. The following chapters of this report explore such possibilities.

(1) See Annex D for derivation of current minimum transit time.

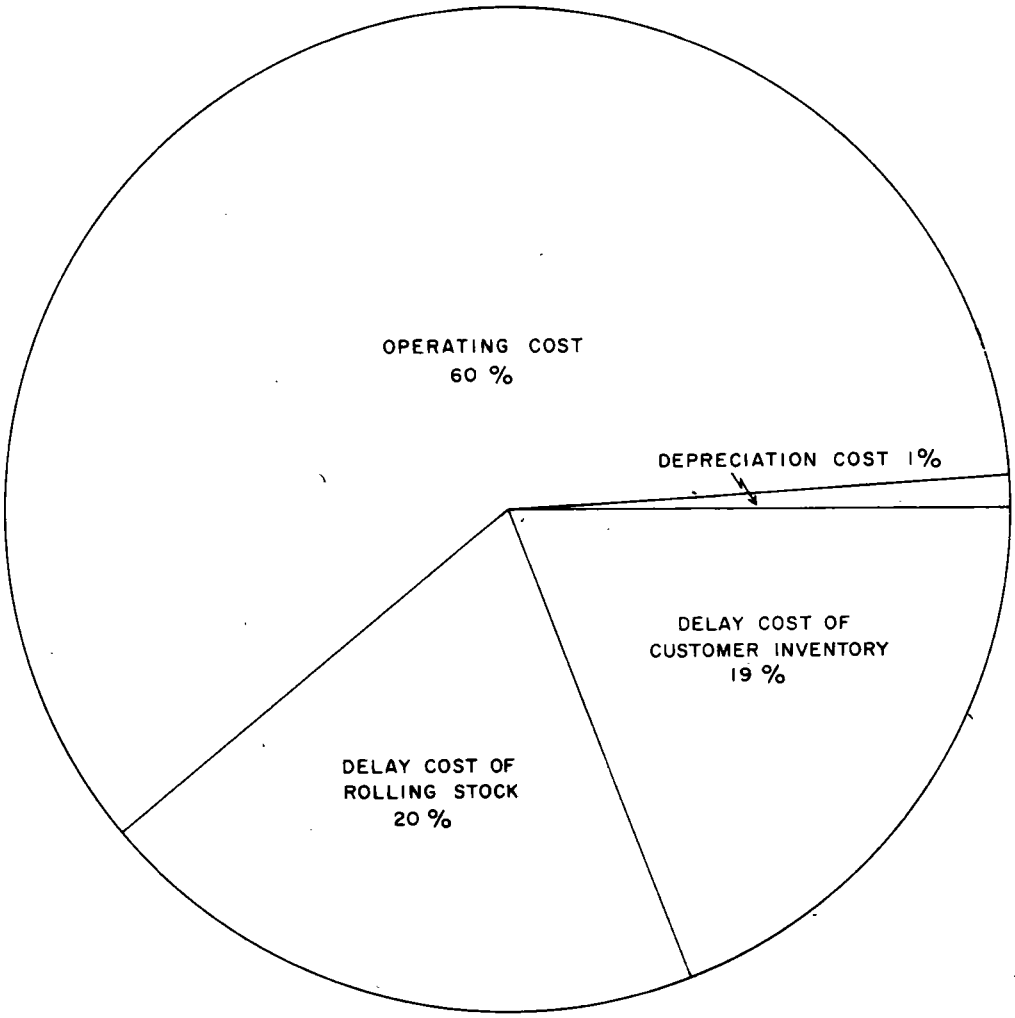


FIGURE 3·4

DISTRIBUTION OF CURRENT TOTAL COST
PORT PIRIE BOGIE EXCHANGE 1976

CHAPTER 4 - DISCUSSION OF POSSIBLE ALTERNATIVES

An objective of this study is to identify ways to reduce cost and delays at the Port Pirie facility. Having completed the investigation, three factors have become obvious.

Firstly, the current exchanging operating is labour intensive in terms of the costs incurred. Secondly, the operation and capacity of the bogie exchange is limited greatly by the layout and size of the Port Pirie yard, and finally the capacity of the facility is rapidly being approached. This chapter considers, in general terms, various ways that might overcome these problems and Chapter 5 discusses in greater detail, four of the more promising alternatives.

ANZRC STUDY

The ANZRC study, mentioned previously in this report, considered in detail the problems associated with the size of bogie pool and the balancing of traffic flows. The BTL has therefore not considered these problems at this stage of the study.

AUTOMATED FACILITY

Analysis of bogie exchange costs reveals that the labour cost of manning the exchange is the most significant cost incurred. Therefore it appears likely that further mechanisation may be justified in economic terms if such mechanisation achieved a reduction in crew size.

The task performed within the bogie exchange depot has been examined and a more automated process than is currently used has been proposed. The details of this process are discussed in Annex C. Since no detailed design has been undertaken at this stage, the scheme should be considered as conceptual only and the costs approximate.

In summary, the automated process should reduce crew requirements from 7 to 4 per gang, cost between $500,000 and $800,000 to build and install and should be able to handle 56 wagons per shift, provided wagons could be placed and cleared by shunters at this rate.

SCHEDULED REROUTING THROUGH PETERBOROUGH

The bogie exchange facility at Peterborough is currently operating with sufficient reserve capacity to handle a significant increase in traffic. As mentioned previously, the ad hoc rerouting of trains through Peterborough rather than through Port Pirie can lead to problems. However, it may well prove economical to reroute through Peterborough on a regular scheduled basis and thus utilise the available capacity of that facility even though such rerouting involves an additional 144km. The construction of a bypass loop (so that trains do not have to enter the Port Pirie yard) may improve the attractiveness of the rerouting option. Evaluation of the alternatives proposed in the next chapter will attempt to determine whether or not such rerouting is effective, and if so, to what extent.

ESTABLISHMENT AT PORT PIRIE OF A SECOND BOGIE EXCHANGE OF CURRENT DESIGN

One possible method of increasing the capacity of the Port Pirie facility is to provide a second bogie exchange shed. This additional facility could be placed in series or in parallel to the existing shed, or both the new and old sheds could be positioned at some other location in the yard.

If the first of these options was adopted, one of the major operational problems of the current facility would be aggravated. The present location of the exchange, close to the dead end of the Port Pirie yard, creates difficulties for shunting operations and introduces a requirement for frequent shunting during each bogie exchange shift since only about ten to twelve wagons can

be stored on the exchange entry and exit roads. The provision of another exchange shed in the same area increases the shunting requirements in this area substantially and it is considered that very little capacity increase would be realised.

If the old and a new shed were sited at a different location in the yard, the most likely location would be at the eastern extremity of the yard, and probably within the present railway reservation. This location is suggested because it is easily accessible from both the broad gauge and standard gauge areas of the yard and is removed from other areas of activity in the yard. However, there are two major factors which militate against such a proposal.

Firstly, it would not appear feasible to position two bogie exchange sheds in parallel at this site since there is insufficient width of reservation. The two facilities would therefore have to be positioned in series. Such an arrangement would be undesirable from an operational viewpoint since on each side of the exchange two separate gangs would have to co-ordinate operations. This means that any hold-up experienced by one gang would stop operations of the other gang. For this reason it is most unlikely that such a duplication of facilities would in fact achieve a doubling of throughput.

Secondly, the shunting assistance required by this facility would be similar in nature to the current facility but at a much higher rate and it is not believed that the existing yard could handle such a shunting demand.

It is concluded, therefore, that this approach does not offer a reasonable solution.

RELOCATION OF THE BOGIE EXCHANGE

The existing yard at Port Pirie suffers from operational problems due to poor layout. It is often congested with current traffic loads and it lacks adequate wagon storage areas. Such problems

lead to an inability to provide a 'place and clear' service to the bogie exchange without causing frequent and lengthy delays in the exchange itself. This problem will only be aggravated by any traffic growth unless action is taken to overcome it.

The yard itself is not amenable to expansion since it is constricted on all sides. It therefore appears reasonable to remove the bogie exchange and at least some of the current yard functions to a new location outside, but reasonably close to the existing Port Pirie yard. It is felt that such an approach would lead to a substantial increase in capacity of bogie exchange operations at Port Pirie as well as a reduction in delays to all rail traffic in the area.

CHAPTER 5 - ALTERNATIVES EVALUATED

An objective of this study has been to provide details of some possible alternatives to the current Port Pirie bogie exchange to enable their evaluation within the context of the East-West Rail Link study.

An attempt has therefore been made to define alternatives which cover a wide range of investment. The evaluations indicate the extent of investment warranted as well as when investment should be made.

The alternatives presented here therefore should not be considered as recommended alternatives, but should be considered as possible alternatives which warrant further detailed investigation.

The four alternatives presented here each achieve different levels of capacity and throughput. Each may be considered a separate proposal with unique characteristics. The performance of each alternative is depicted in transit time curves which indicate transit time per wagon for any given traffic flow. On the other hand, alternatives may be considered as separate stages of development with the first alternative being a base case, i.e. the current situation with some operational changes and no capital investment, and the other alternatives representing improvements to the current situation through capital investment. The evaluations of these alternatives compare Alternatives 2, 3 and 4 against Alternative 1, to determine whether or not the proposals are economically justified and if so at what traffic flow.

It is not possible at this stage to determine the optimum extent of facilities that are required for bogie exchange in the Port Pirie area because of the uncertainties of both future traffic growth and the construction of the Adelaide to Crystal Brook standard gauge. The evaluations will therefore indicate the level of expenditure which would be warranted for different levels of traffic.

ALTERNATIVE ONE - SCHEDULED REROUTING

This case is essentially the continuation of the use of existing facilities with some operational changes.

The operational changes involve an examination of the possible benefits which could be derived by the scheduled rerouting through Peterborough of Melbourne and Adelaide traffic.

Analysis of transit times through Peterborough has not yet been performed. However, an estimate has been made of the transit time curve for this yard. Details of the assumptions used in the derivation of this curve are listed in Annex D and the curve is presented in Figure 5.1. It had been suspected that the transit time through Peterborough would be less than for Port Pirie and the theoretical analysis has in fact indicated this. This is probably because the analysis is largely dependent on train timetabling and the current timetabling at Peterborough appears to be more consistent in terms of coordinating with the bogie exchange operations than is apparent at Port Pirie.

It is also suspected that the costs incurred at Peterborough are less than for Port Pirie, although the extent of the difference is not known. For this reason, the analysis will assume that the direct operational costs of the bogie exchange operation are the same for both depots.

As traffic is diverted through Peterborough, the costs of bogie exchanging (including train operating and delay costs) would decrease at Port Pirie and increase at Peterborough. Assuming that initially the costs via Peterborough are lower than the costs via Port Pirie it would be economical to divert traffic until the marginal costs of the two possible routes were identical.

Rerouting of Sydney-Adelaide traffic is also possible. Currently this traffic changes gauge at Peterborough. An alternative route via Dynon is only marginally longer. This rerouting possibility

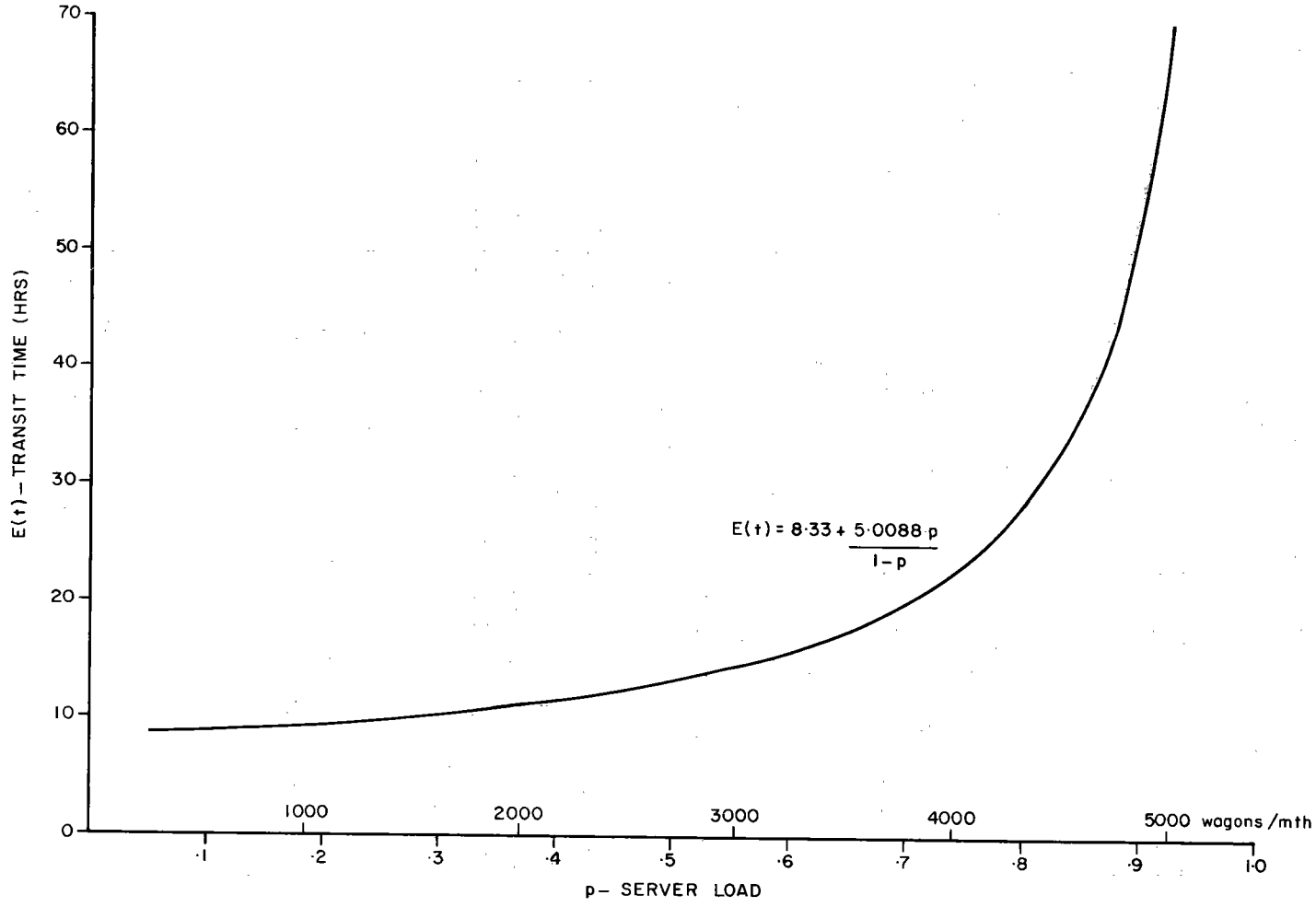


FIGURE 5·1
TRANSIT TIME CURVE FOR CURRENT SITUATION
WAGONS PASSING THE B.E. IN PETERBOROUGH

is included in this alternative. Again the optimum traffic balance between the two routes occur when the marginal costs are equal.

The analysis identifies the extent of rerouting required to achieve this balance. The costs used for Port Pirie are those presented in Chapter 3, and the transit time curves are shown in Figures 5.2 and 5.3. The derivation of these curves is given in Annex D.

ALTERNATIVE TWO - SCHEDULED REROUTING PLUS PORT PIRIE BYPASS

This alternative has been established to consider the possible benefits that might eventuate from the construction of a loop connection between the two standard gauge lines entering Port Pirie at a cost of approximately $200,000.

This would enable standard gauge trains, and in particular those trains which have been scheduled for rerouting through Peterborough to travel directly between Port Augusta and Peterborough, bypassing Port Pirie entirely. Such rerouted trains, when arriving from the west would be sorted into standard gauge and broad gauge destinations at Peterborough.

A loop of this nature was planned some years ago but was never built, apparently due to opposition to the proposal by various sectors of the Port Pirie community. SAR officials feel that due to changed circumstances, such objections probably would not be raised if the loop was proposed now.

Another objection to the loop is that currently a change of locomotive, guard's van and crew occurs at Port Pirie because the train would be passing from the ANR to the SAR system or vice versa. With the impending incorporation of SAR into ANR this objection should be removed.

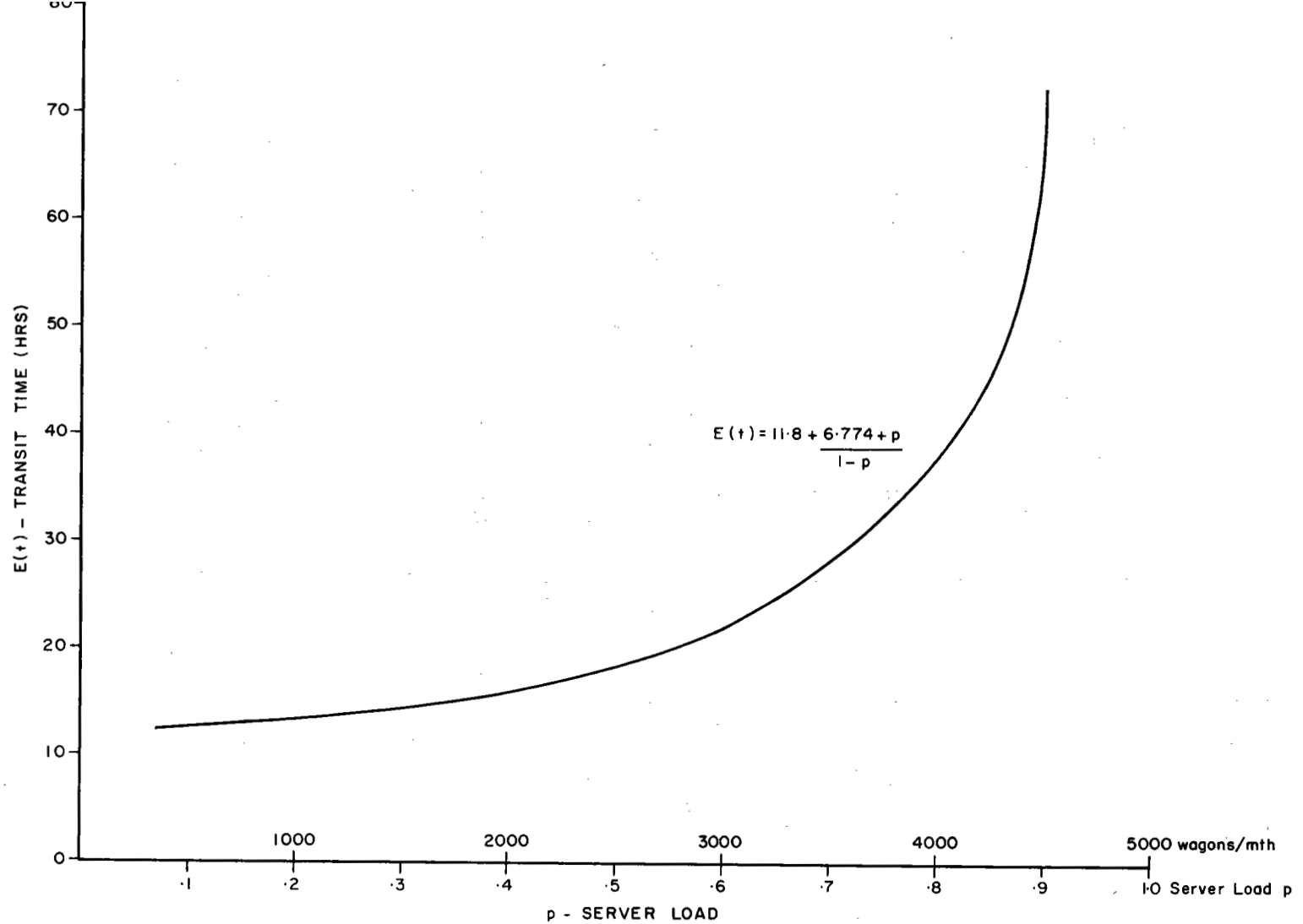


FIGURE 5·2
TRANSIT TIME CURVE FOR CURRENT SITUATION
WAGONS PASSING THROUGH PORT PIRIE B.E.

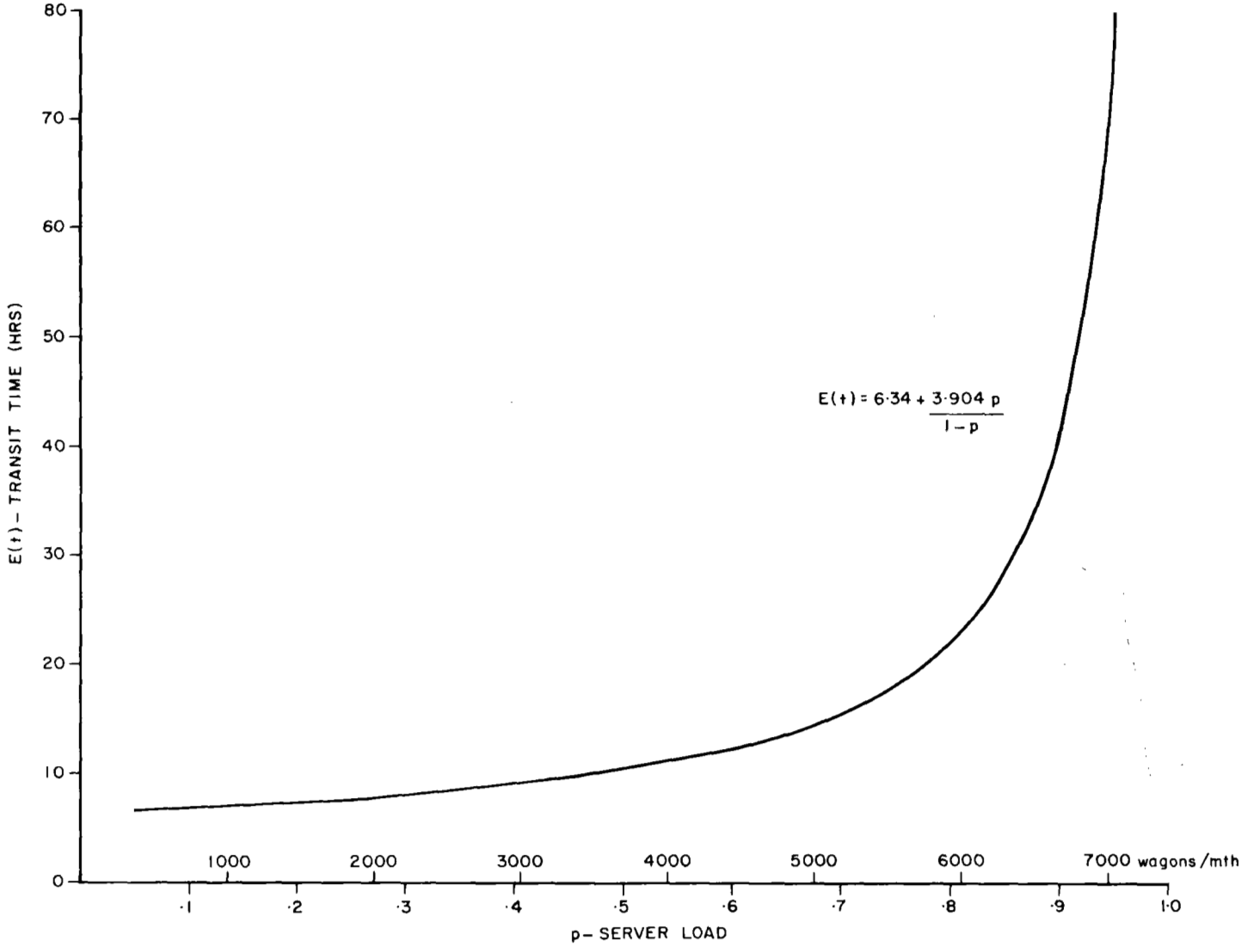


FIGURE 5·3

TRANSIT TIME CURVE FOR CURRENT SITUATION

WAGONS PASSING STRAIGHT THROUGH PORT PIRIE ON S.G.

This alternative does not include the provision of sorting roads that were envisaged when the loop was originally planned some years ago. This is because the bypass is only intended to be used by trains which are scheduled to bypass Port Pirie without stopping. This may give rise to a small number of loaded wagons from the west destined for Port Pirie being taken to Peterborough. However, it is felt that this problem could be overcome by including such wagons on trains which are scheduled to stop at Port Pirie.

ALTERNATIVE THREE - AUTOMATED EXCHANGE IN EXISTING LOCATION

The basis of this alternative is the construction of an automated bogie exchange facility at Port Pirie combined with scheduled rerouting through Peterborough.

A description of the concept of the automated depot can be found in Annex C. This new depot achieves some significant improvements over the current depot including a reduction in crew size from 7 to 4, increased throughput and the ability to place and clear wagons in entry and exit roads to the depot without interrupting the actual exchanging operation. It is estimated that the cost of providing a depot of this nature in the Port Pirie yard would be of the order of $500,000 to $800,000, and further details of these costs are provided in Annex C.

If an automated depot of this type was established in the current Port Pirie yard it would not be able to operate at peak efficiency. The limitation of the yard in terms of marshalling and storage space would limit the rate at which wagons could be placed and cleared at the depot. In other words the yard would not be able to feed the depot at the rate at which the depot could exchange bogies.

For the purpose of the derivation of the transit time curve for this situation, it has been assumed after consultation with SAR that the yard could supply wagons to the depot at a rate 30%

higher than the current situation. In determining the transit time curves for the current situation the rate at which the depot could handle wagons was used as the determing factor. However, in this alternative it was necessary to use the rate at which the yard could supply the depot as the determining rate. Further details of the derivation of the transit time curve are given in Annex D and the curve thus derived is presented in Figure 5.4.

The direct operating cost of bogie exchange per wagon was calculated on the basis of the increased throughput and the reduction in gang size. The shunting costs have been assumed to remain the same as have all other costs. On this basis the operating cost per wagon has been assessed as $17.82.

As with Alternatives 1 and 2, this case will possibly warrant some rerouting through Peterborough. In this instance the transit time curves to be used for Peterborough are the same as those used in Alternative 1.

ALTERNATIVE FOUR - AUTOMATED EXCHANGE IN NEW LOCATION

With this alternative an attempt has been made to define the extent of facilities that would be required to cater for any likely increase in traffic in the forseeable future.

In concept the alternative considers:

- relocation of the bogie exchange outside the existing yard;
- provision of an automated exchange depot;
- provision of adequate storage for wagons at the depot;
- provision of additional marshalling facilities.

Suitable sites for such a facility exist reasonably close to the existing yard. One such site is a large open area to the north-west of Warnertown and adjacent to the standard gauge line between Port Pirie and Crystal Brook.

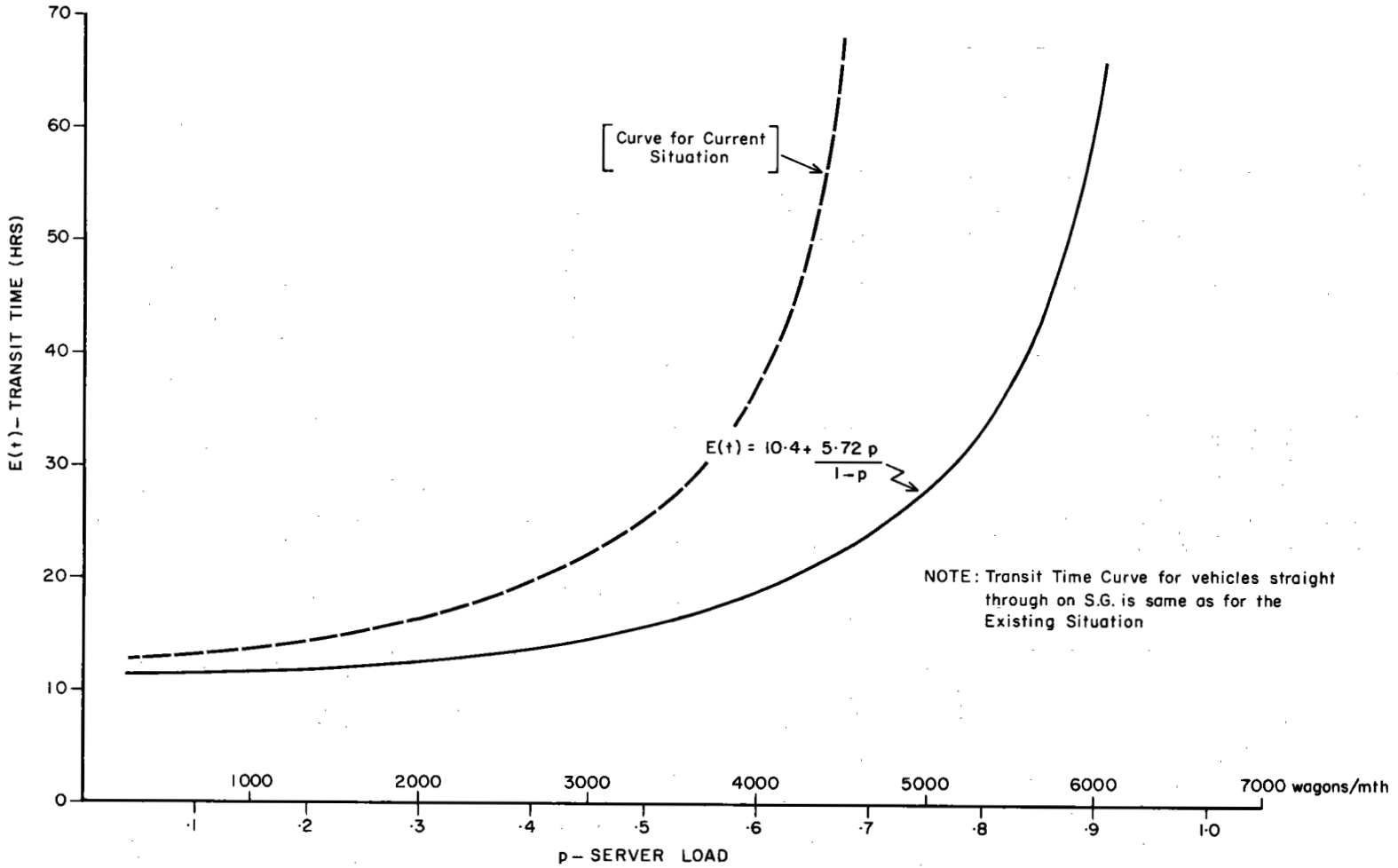


FIGURE 5·4
TRANSIT TIME CURVE FOR ALTERNATIVE THREE
WAGONS PASSING THROUGH PORT PIRIE B.E.

It would seem desirable to utilise the existing Port Pirie yard as much as possible. This alternative therefore considers relocating most of the broad gauge marshalling areas to the new site and converting the existing yard to basically a standard gauge facility with only those broad guage functions not related to bogie exchange such as stock transfer and passenger movements remaining in the existing yard.

Figure 5.5 illustrates the concept. A broad gauge link approximately 9 km in length would have to be provided from the existing broad gauge line to the Warnertown site. Trains from Adelaide with loading requiring bogie exchange would proceed directly to the Warnertown site rather than Port Pirie. Here, the wagons would be sorted into bogie exchange and non bogie exchange. Those to be bogie exchanged would be stored here, the remainder would be taken into the Port Pirie yard. After the broad gauge wagons are converted to standard gauge, they would be removed to the Port Pirie yard for marshalling into west bound trains.

Trains arriving from the West would enter the Port Pirie standard gauge yard where they would be broken into exchange and non exchange wagons. Those to be exchanged would be moved in a block to the Warnertown site. After being exchanged they would be marshalled into southbound trains which would depart directly from Warnertown.

This alternative would allow the proposed automated bogie exchange to operate at peak efficiency allowing the conversion of approximately 55 to 60 wagons per shift. In the derivation of the transit time curve for this alternative, as with Alternative 1, the rate at which the bogie exchange depot can handle wagons has been the determining rate. Details of the derivation of the transit time curves for both bogie exchange and straight through standard gauge wagons are presented in Annex D and the curves themselves are presented in Figures 5.6, and 5.7.

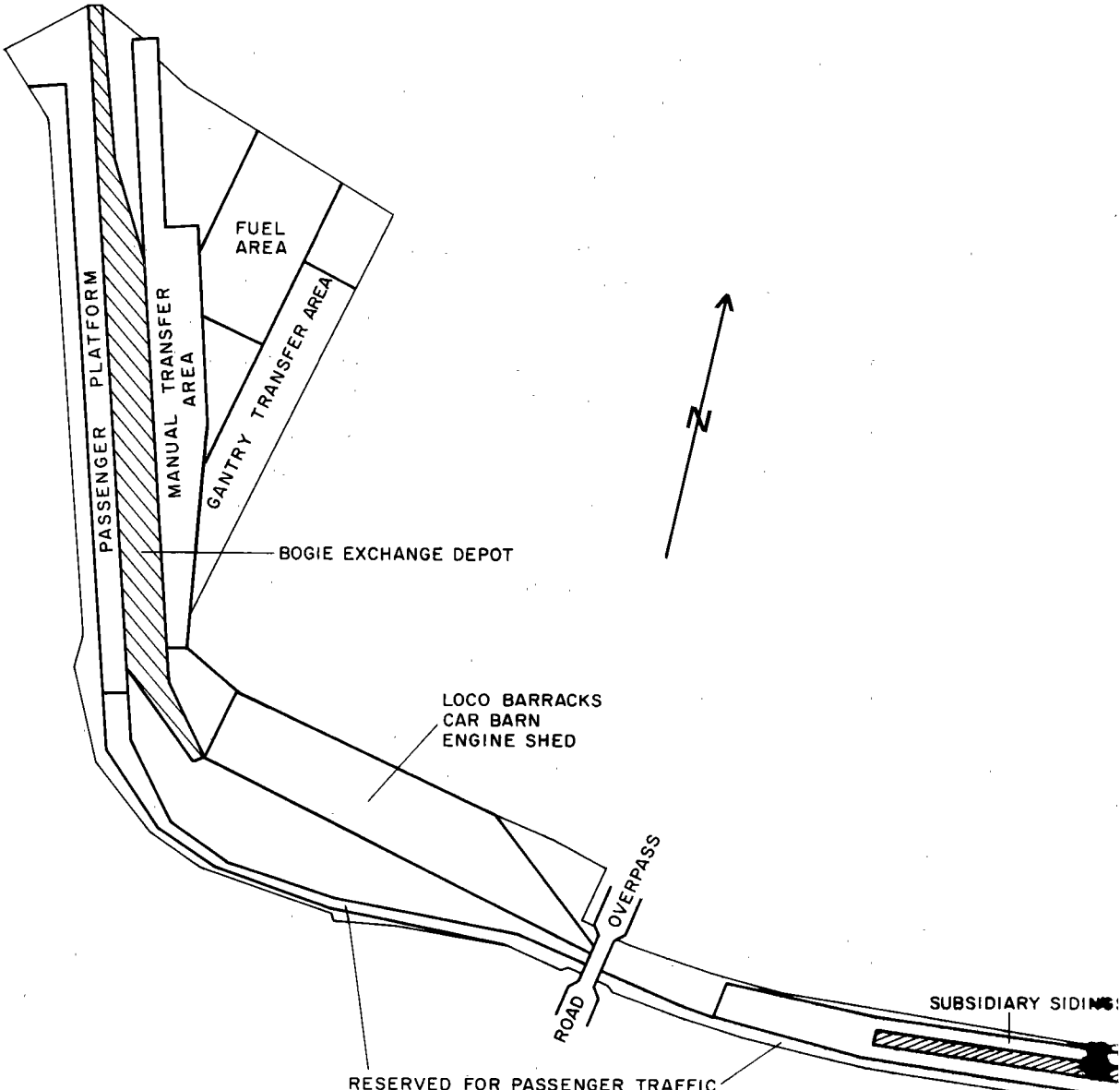
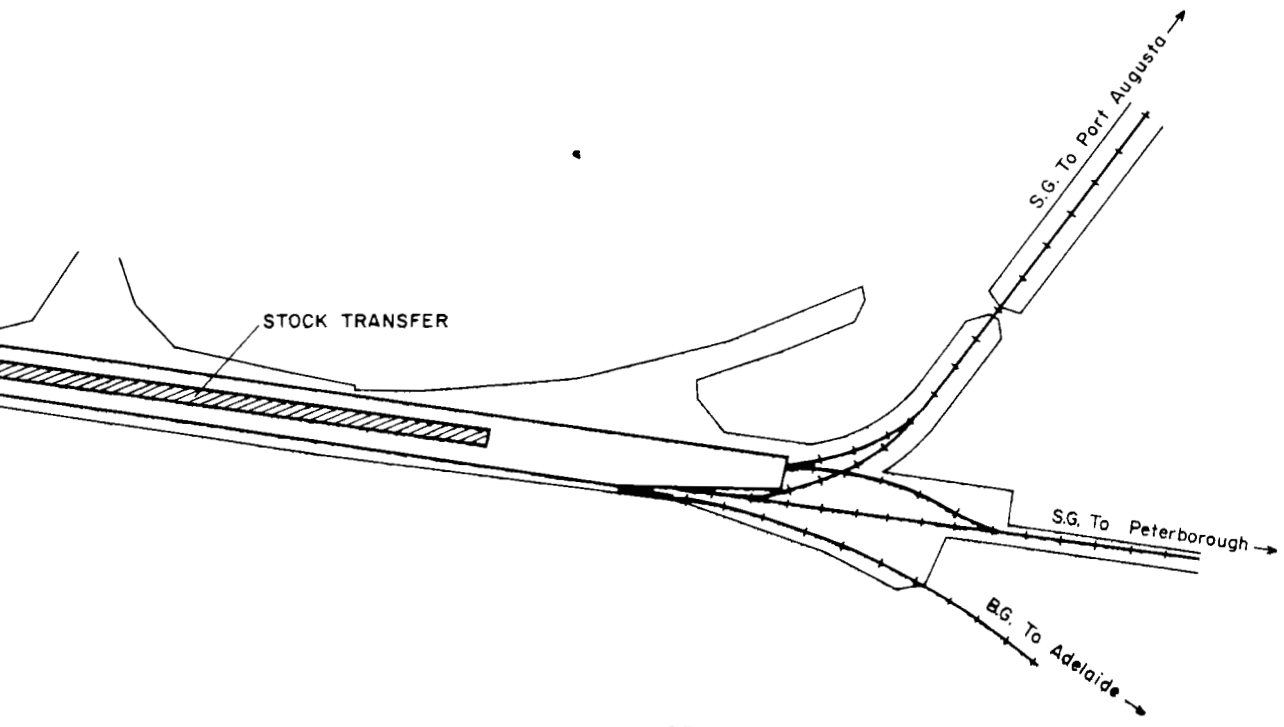

PASSENGER PLATFORM
MANUAL TRANSFER AREA
FUEL AREA
GANTRY TRANSFER AREA
BOGIE EXCHANGE DEPOT
LOCO BARRACKS
CAR BARN
ENGINE SHED
OVERPASS
ROAD
SUBSIDIARY SIDI
RESERVED FOR PASSENGER TRAFFIC

FIGURE 3·1

PORT PIRIE STATION YARD

APPROX SCALE

0 300 METRES



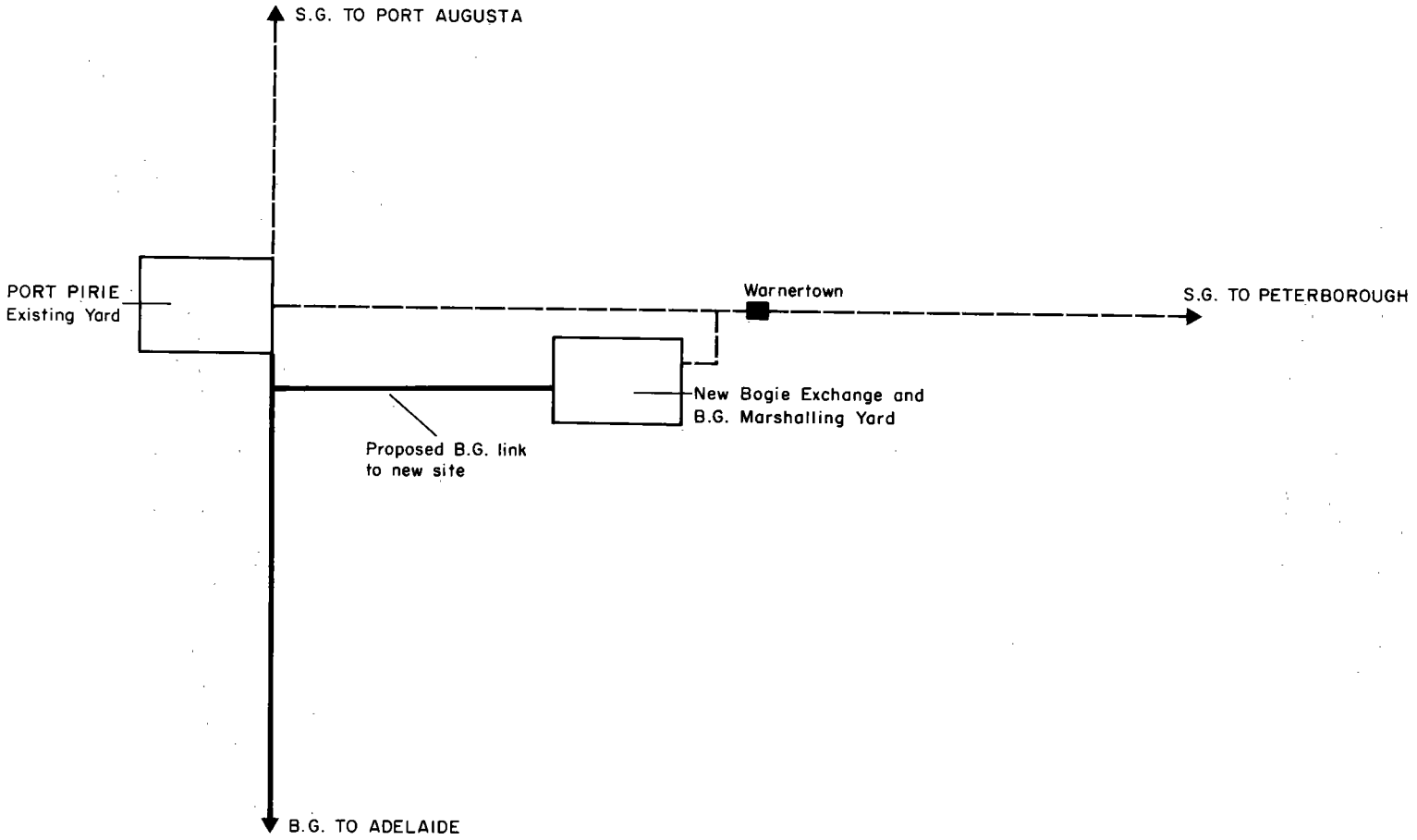


FIGURE 5·5
CONCEPTUAL LAYOUT FOR ALTERNATIVE FOUR

It should perhaps be noted at this stage that the theoretical derivation of the transit time curves is considerably influenced by the timetabling of trains. As can be seen from Annex D the current timetable is assumed in this analysis. However, this new facility would often allow the conversion of complete trains in a single 8 hour shift, depending of course on the length of trains. Therefore it would appear that considerable benefit in terms of a reduction in delays would result from a rescheduling of trains departing from the Port Pirie area.

The alteration of timetables is not being considered at this stage in the study, since it involves several factors outside the scope of this study. The reduction in transit times and hence delays depicted in the analysis of this alternative are based on the existing timetable and therefore can be considered as a conservative estimate of the transit times that could be achieved by the provision of facilities of the nature of those described.

The estimated capital cost of this alternative is approximately $7.2 million and Annex D presents details of the costs considered. Costs of operating the bogie exchange are the same as used in Alternative Three, although the cost per wagon is lower ($16.13), reflecting the higher throughput of the automated exchange in the new location. Other unit operating costs are the same as for all the previous cases.

The capital cost estimate must be considered as approximate only for a number of reasons. As mentioned previously, the costs are based on facilities shown in Figure D.1. The unit rates used in the estimate need to be verified. The exact location of the most desirable site would require extensive investigation of all possible sites in the area and this would obviously effect the extent of track work required to link the new site to existing system. Other factors which affect the costs and which would require more detailed consideration include the extent of marshalling facilities and storage required, whether or not facilities

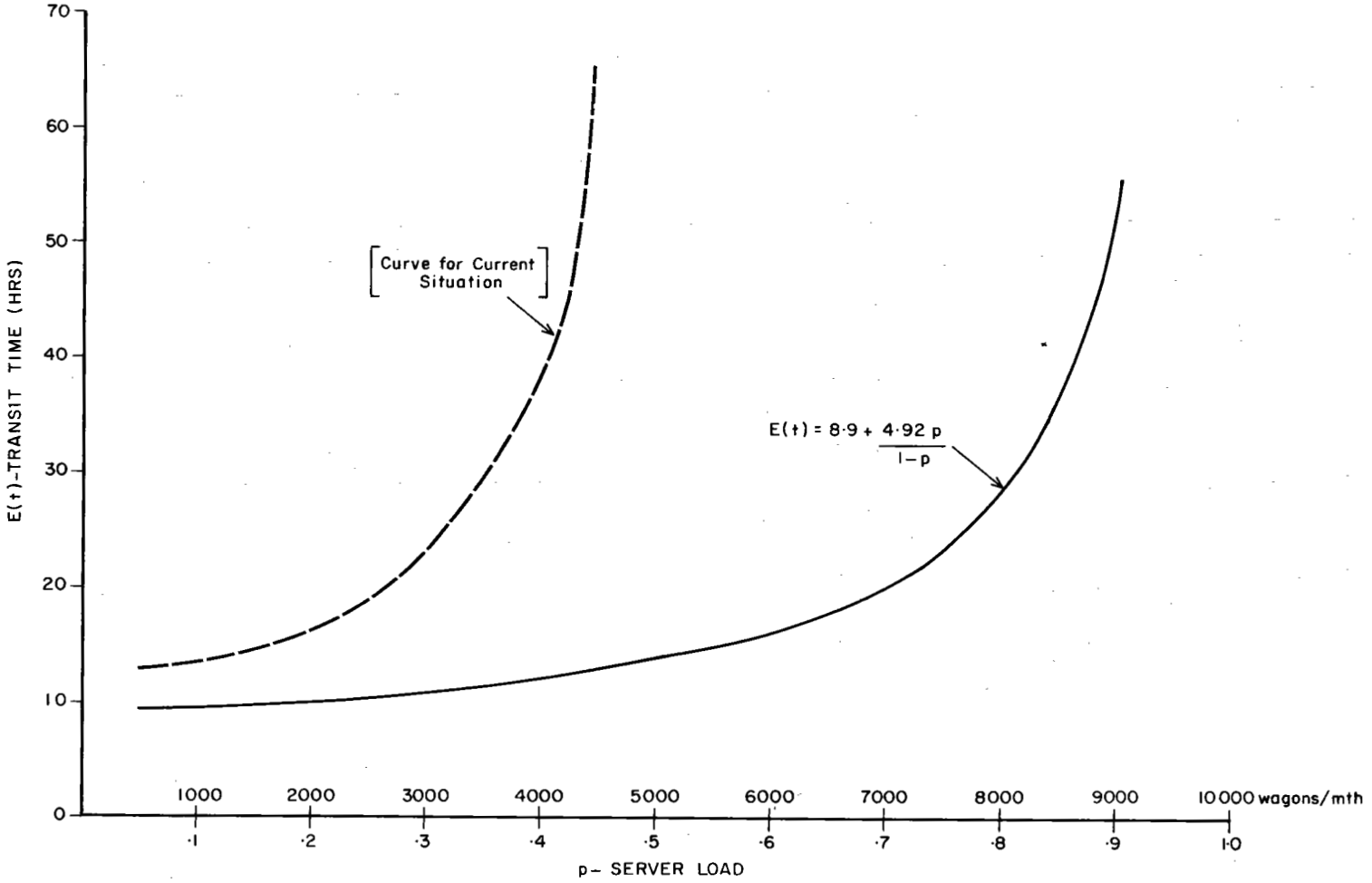


FIGURE 5·6
TRANSIT TIME CURVE FOR ALTERNATIVE FOUR
WAGONS PASSING THROUGH PORT PIRIE B.E.

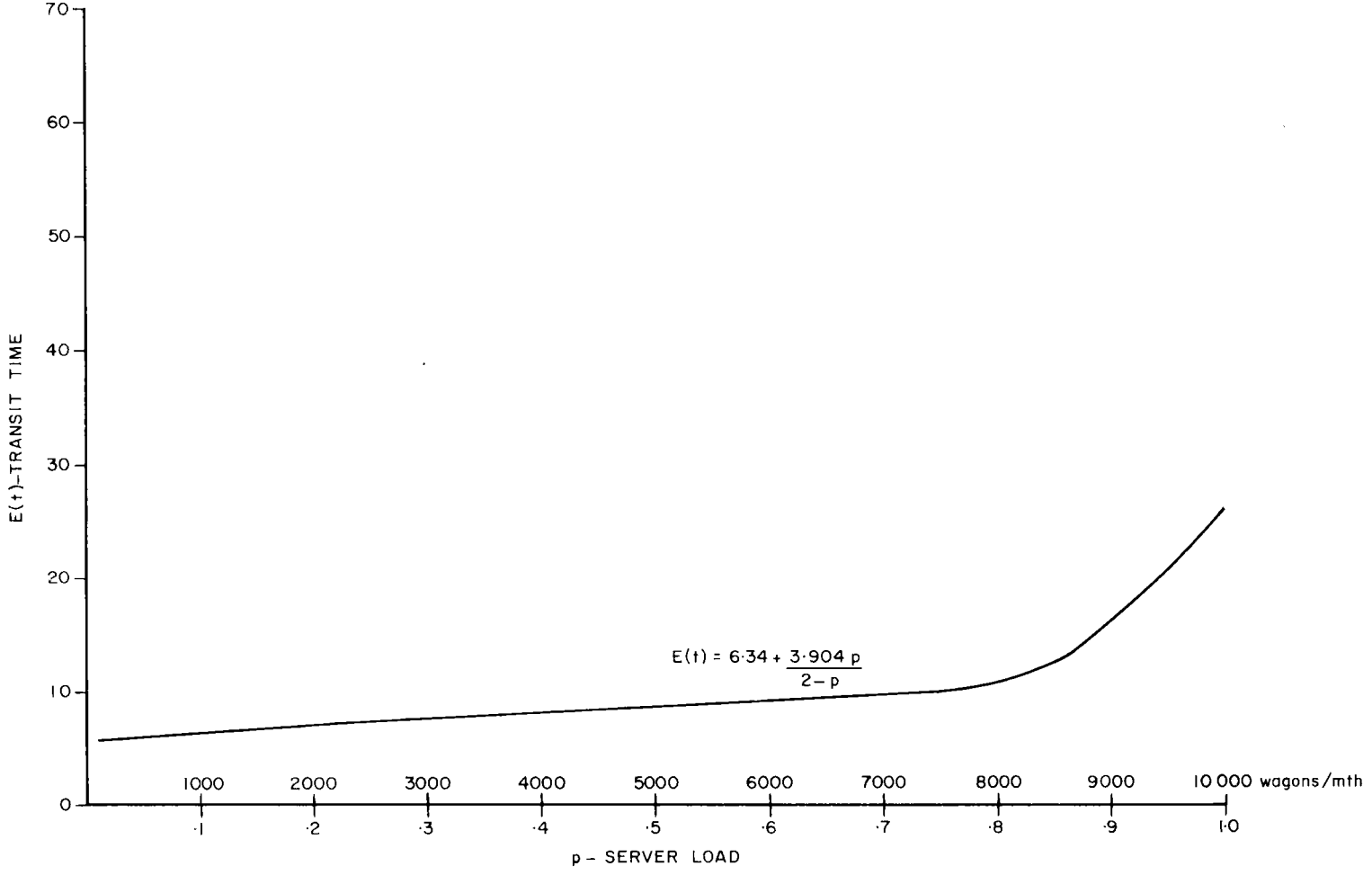


FIGURE 5·7

TRANSIT TIME CURVE FOR ALTERNATIVE FOUR
WAGONS PASSING STRAIGHT THROUGH PORT PIRIE ON S.G.

would need to be provided for priority marshalling at the exchange, what are the signalling requirements, what is the most suitable layout for the new yard and what changes would be desirable in the existing yard.

For this reason the analysis includes a test of the sensitivity of the results to variations in capital costs over the range of $5m to $10m.

CHAPTER 6 - EVALUATION RESULTS

The evaluation of the alternatives was conducted as part of the East-West Rail Link study. The methodology is discussed in the BTE report[1] on that study and will not be discussed further here. The evaluation was for a time span of 20 years and for a 10 per cent discount rate. Based on the expected forecast of traffic through the Port Pirie bogie exchange the following results were obtained:

- Automation of the existing exchange in the Port Pirie yard gave a benefit-cost ratio of thirteen. This option should be implemented in 1975-76 to maximise the benefits. Obviously it is not possible to design and install an automated exchange in 1975-76, however installation at the earliest possible time is warranted.
- The option of automating the existing facility followed by a relocation of the automated facility gave a benefit-cost ratio of 3. Again, automation of the existing facility should occur in 1975-76 and the relocation at an assumed cost of $7.0 million should occur in 1983-84. The timing of the relocation was not particularly sensitive to capital cost in the range of $5.0 million to $10.0 million.
- If physical constraints do not permit the automation of the existing facility then an automatic exchange in a new location is warranted in 1976-77. Again, such timing is not possible but to obtain maximum benefits the facility should be constructed as soon as possible.
- The construction of the bypass loop could not be justified. The saving of two hours on rerouted trains was insufficient to make this option attractive.

The optimum amount of rerouting was calculated for each of the alternatives evaluated. The rerouting strategy has been to reroute normal Port Pirie bogie exchange traffic through Peterborough.

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(1) Not yet published.

Consideration was also given to rerouting some of the Adelaide-Sydney traffic through Dynon. This traffic would normally pass through the depot at Peterborough and, if sent through Dynon, the ability of the Peterborough exchange to accept rerouted traffic from Port Pirie is increased.

Rerouting was found to be beneficial in both the current situation and for the alternative which considered automating the exchange in the existing yard. The extent of rerouting required in each case to minimise total costs is shown in Figures 6.1 and 6.2.

The best rerouting under the existing conditions can be seen in Figure 6.1. During 1975-76 approximately 46 300 wagons were transferred at Port Pirie. At this level of traffic, Figure 6.1 indicates that about 6800 wagons should be diverted through Peterborough, which is considerably more than was done in 1975-76.

For Alternative Four which considered the provision of an automated exchange in a new location, no rerouting need take place once the new facility becomes operational. Until that time, the extent of rerouting would depend on the facilities available.

The results, in summary, are that rerouting is economically worthwhile now, and that the concept of an automatic exchange is worthy of development into a firm design. Further investigations of the practicability of automating the existing exchange are required.

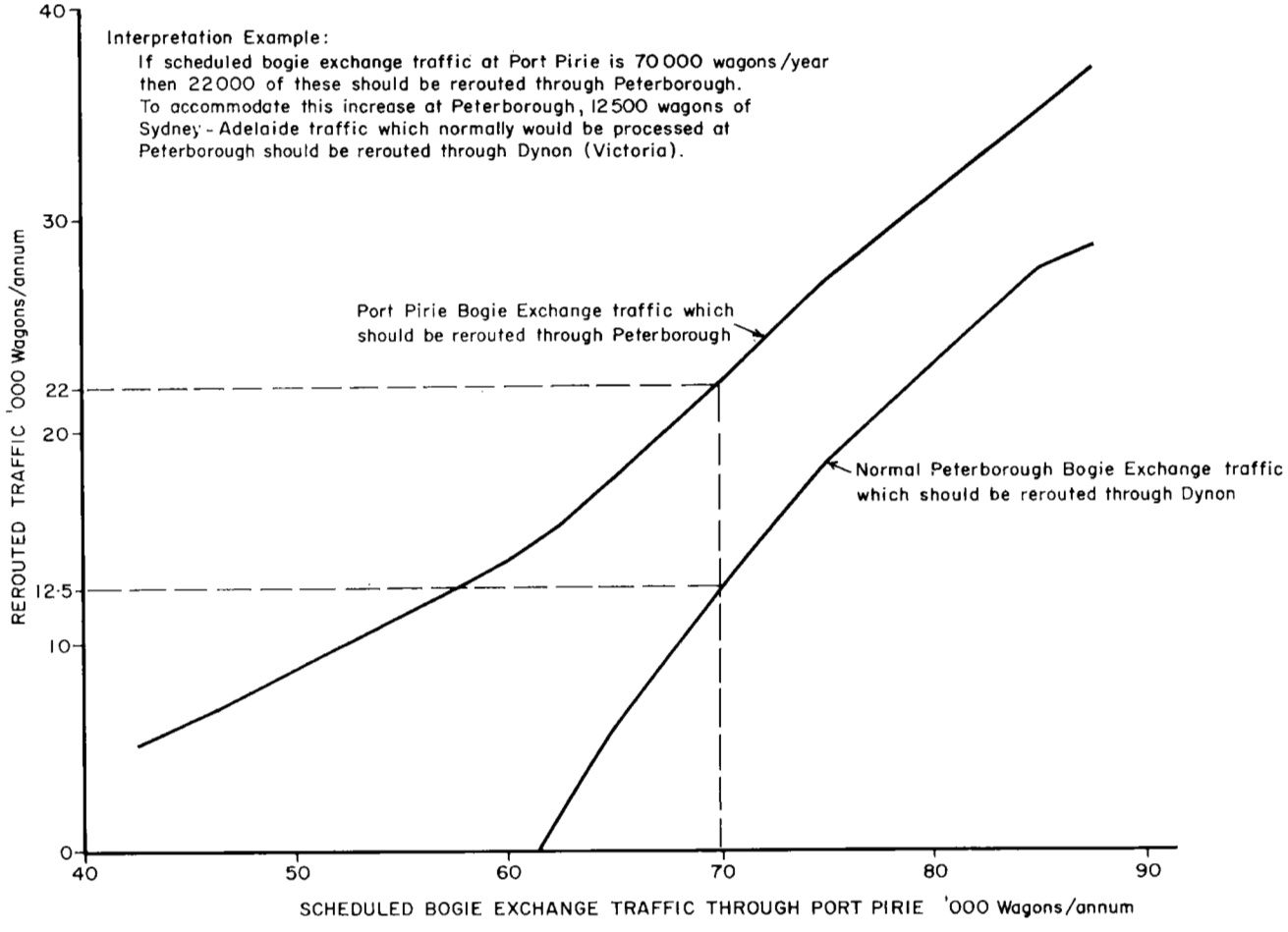

FIGURE 6·1
OPTIMUM REROUTING-EXISTING FACILITIES

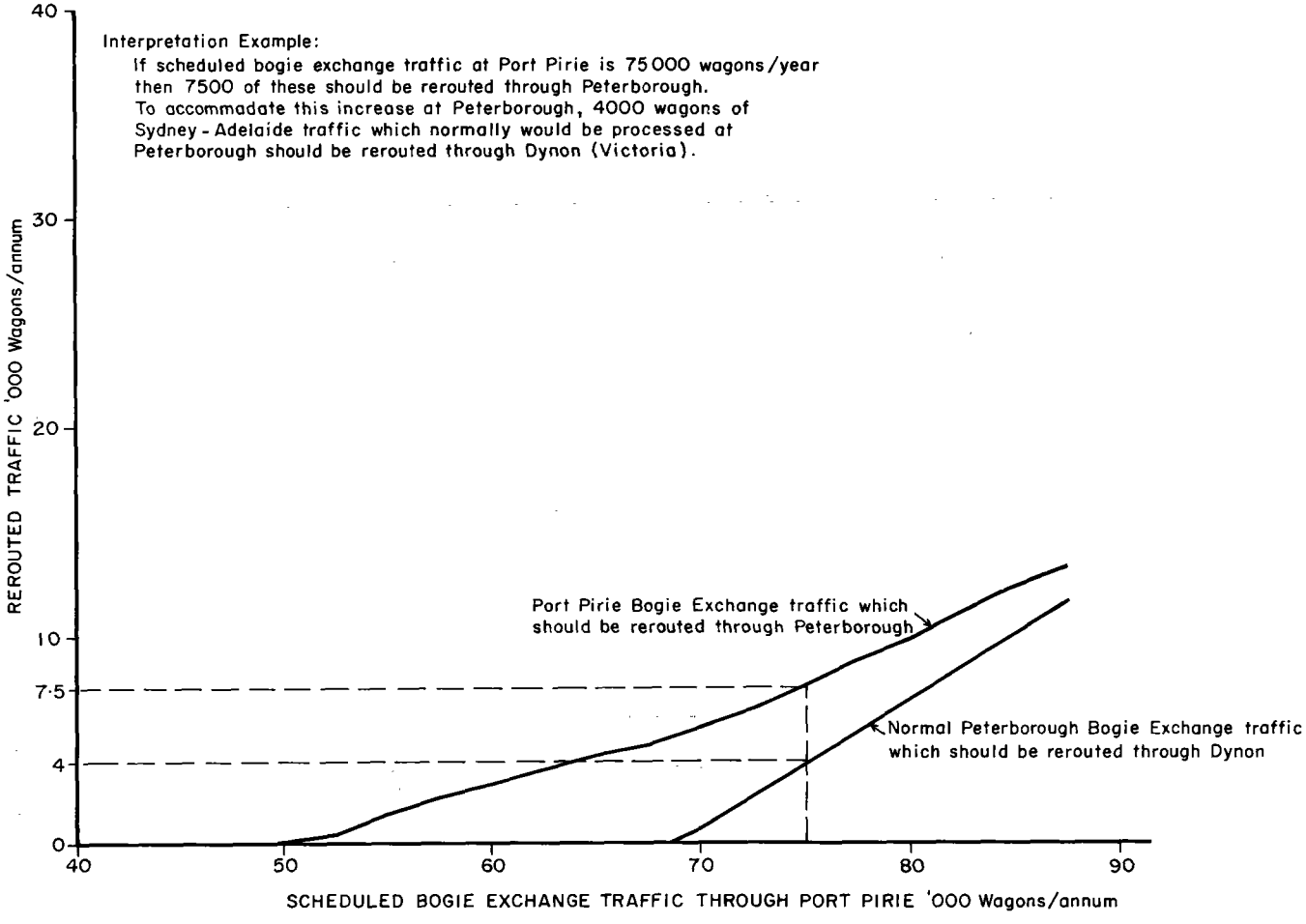

FIGURE 6·2
OPTIMUM REROUTING AUTOMATED EXCHANGE IN EXISTING YARD - NO BYPASS LOOP

CHAPTER 7 - CONCLUSIONS

The operational cost currently incurred by the bogie exchange in Port Pirie has been estimated at $23.89 per wagon or $1.35 per net tonne.

The cost attributable to the depreciation of capital assets associated with the bogie exchange has been estimated at $1170 per month. For the month of May 1976 this averaged at $0.34 per wagon or $0.02 per net tonne.

The average transit time incurred by wagons passing through the Port Pirie exchange during May 1976 was 27.4 hours. It would appear that such lengthy transit times are the result of a combination of factors including -

- inability of the yard to handle traffic imposed on it
- restrictive location of the bogie exchange depot
- lack of wagon storage space both at the depot and in the yard.

Considerable scope exists for reducing these delays and costs. This report proposes four upgrading options ranging in cost from $200,000 to $7.2m. which the BTE considers should be investigated further. These alternatives have been proposed in detail in this report and include -

- rerouting of traffic through Peterborough
- construction of a bypass loop outside Port Pirie
- provision of an automated exchange depot in the existing yard
- provision of an automated exchange depot on a site removed from the existing yard together with the provision of additional marshalling facilities.

All of these options except the construction of the bypass loop have considerable economic merit on the data so far available. The economic attractiveness of these options depends mainly on the reduction of delays and in the lower operating costs in the case of automated facilities. Further investigation is required to determine the practicability of the automated exchange in the existing location and further work is required to develop the concept of an automatic exchange into a practical working design.

The analysis also indicates that an expenditure of approximately $7.2 million could provide facilities which would be capable of handling all traffic expected to require bogie exchange in the Port Pirie area over the next twenty years. With such an option the average transit time for wagons passing through the exchange is expected to be at least 9 hours less than at present, with traffic flows more than double what is currently handled.

It is recommended that this study be extended to examine bogie exchange operations at Peterborough, Wodonga and Dynon. This further study should also consider the interaction between the four depots particularly in relation to bogie pool size, traffic flow balancing and block marshalling of trains.

ANNEX A - YARD DELAY CURVE

The operations of a yard such as Port Pirie can be quite complex. What might happen in the future can best be predicted by means of a simulation model. The BTE does not possess a suitable model nor was there sufficient time to develop one. A simplified approach was adopted which would give a reasonable idea of how the yard performance would respond to increasing traffic.

The yard performance was assumed to be described by Pollaczek's formula which is given below[1].

$$E(t) = B + \frac{P\,B\,(1 + C^2)}{2\,(1 - P)}$$

where $E(t)$ = mean transit time

B = mean service time

C = coefficient of variation of service time distribution (ratio of standard deviation to mean)

A = arrival rate

P = server load

$= A.B$

$= 1.0$ when server is operating at capacity.

The transit time is defined to be the time from the arrival of a wagon in the yard to its departure. The service time is the time a wagon would take to pass through the yard if there were no delays. It is made up of the following components:

- marshalling time at train arrival;
- time to pass through the bogie exchange;
- marshalling time after bogie exchanging;
- time from completion of marshalling to departures of next train.

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(1) D.R. Cox and W.L. Smith, Queues, Methuen, London, 1961, pp. 50-58.

The service time is obviously very dependent on the train time-table. Delay time is the difference between transit time and service time.

Pollaczek's formula assumes that the arrival rate is random. This is not the case in this application since wagons obviously arrive in groups. However, the service time distribution can be quite general, only the mean and standard deviation need to be specified. To have a general distribution for both arrival rates and service times would present severe analytical difficulties. It was considered that assuming a random arrival rate would not significantly affect the usefulness of the approach while allowing the analysis to be much simpler.

The values of E(t) and all of the independent variables were estimated for May 1976. Using the formula, a value of 28.4 hours was obtained for E(t). This compares very well with the measured mean transit time of 27.4 hours. The method therefore gives good results, at least for the current situation.

On this basis it is reasonable to assume that the method will give satisfactory results for a modest increase in traffic. For large increases in traffic there may be significant changes in operating practices which would detract from the accuracy of the prediction. However, under those circumstances, the method would predict that the transit time would be very sensitive to traffic levels and this is what would be experienced in practise.

Prediction of future transit times was based on the assumption that the service time distribution would not alter. The only other variable required in the formula is the arrival rate and this can be calculated directly from the predicted traffic levels. Curves of transit time as a function of traffic can then be drawn. These are the transit time curves presented in Chapter 5 of this report.

ANNEX B - COSTS OF CURRENT SITUATION

OPERATING COSTS

The following is a list of items from the Port Pirie Joint Working Agreement which were considered in determining current operating costs. Schedule and Item numbers are those used in the working agreement.

To be considered as a contributory cost, any cost must be directly attributable to the bogie exchange and must be necessarily incurred by the existence of the exchange. For example, the wages paid to bogie exchange staff are obviously included. However, wages paid to signalmen are not included even though part of their task may be caused by the existence of the exchange because it is considered that such wages would have to be paid even if there was no bogie exchange.

For some of the items mentioned below it was apparent that only some portion of the cost could be attributed to the exchange. The apportionment used and the assumptions in relation to that apportionment are given.

Costs were compiled in general on a monthly basis. Costs which are incurred on a regular basis such as wages to bogie exchange staff were obtained for the month of May 1976. Other costs which occur less frequently but are related to the traffic flow such as maintenance costs were considered as one twelth of the cost incurred for those items for the financial year 1975-76.

Schedule	Item	
1	516	The cost of labour and materials involved in the maintenance of the bogie exchange building, pavement, office and amenities room. Full cost considered.

Schedule	Item	
1	532	The cost of labour and materials involved in the maintenance of the joint Permanent Way within the Port Pirie station yard. Full cost considered.
6	401-1	Salaries for Yardmasters and Assistant Yardmasters. These staff spend approximately 25% of their time involved directly with the bogie exchange and a further large proportion of their workload involved with operating the yard to accommodate the exchange. It has been conservatively estimated that the numbers of such staff and hence their salaries could be reduced by 25% if the bogie exchange did not exist.
6	402-1	Wages for Supervising Shunters and Assistant Shunters. These staff spend approximately 50% of their time supervising shunting for the bogie exchange. It has been assumed that 50% of these staff are required by the existence of the exchange.
6	405	Maintenance of electric hoists, mobile cranes, shunt tractors and other equipment employed at bogie exchange. Full cost considered.
6	409	Cost of Electricity. It has been estimated that one fifth of electricity consumed in the Port Pirie yard is consumed in the bogie exchange depot. Since the jacks used in the depot are electrically operated, the amount of electrical energy consumed in the depot would be considerable and the estimate of one fifth is seen as conservative.
6	413	Cost of wages etc., of Drivers and Firemen of standard gauge shunt locomotives. 50% of the shunting operations in the Port Pirie yard relate either directly or indirectly to the bogie exchange. It is therefore assumed that

Schedule	Item	
		the cost of shunting could be reduced by 50% if the exchange did not exist.
6	414	Fuel and supplies for standard gauge shunt locomotives. For the reasons stated in the previous item, 50% of this cost is considered.
6	415	Repairs and renewals to standard gauge shunt locomotives. For the reasons stated in item 413, 50% of this cost is considered.
6	418	Wages of staff engaged in the operation of the bogie exchange, also stores, stationery and supplies used. Full cost considered.

The Joint Working Agreement does not include consideration of the broad gauge costs analagous to Schedule 6 Items 413, 414, and 415 mentioned above. This is because as far as the sharing of functions in the yard is concerned, these broad gauge activities were seen to be wholly the responsibility of SAR. However, for the purposes of this study such costs were required but were not readily available. After discussions with SAR, it was agreed that the assumption be made that the broad gauge shunting costs would be the same as for standard gauge

Table B.1 summarises the operating costs considered.

The accounting procedures used by SAR involved the accumulation of accounts on a fortnightly basis which are then rounded off to monthly totals. The accounts considered as being for May 1976 actually cover the period 1st May to 28 May inclusive. Therefore, in this section where the aim is to determine costs on a per wagon and per net tonne basis the figures considered are the numbers of wagons and net tonnes that were handled in the above period i.e. 3461 wagons and 61348 net tonnes.

TABLE B.1 - OPERATING COSTS OF THE PORT PIRIE BOGIE EXCHANGE

Schedule and Item Number from Port Pirie Yard Joint Working Agreement		Proportion assumed applicable to Bogie Exchange	Amount in 1975-76	Amount in May 1976	Average Monthly Cost
Schedule	Item		$	$	$
1	516	Full	4075	-	340
1	532	Full	10156	-	846
6	404-1	25%	-	8391	2098
6	402-1	50%	-	35260	17630
6	405	Full	64816	-	5401
6	409	20%	18096	-	302
6	413	50%	-	15219	7610
6	414	50%	-	2081	1040
6	415	50%	15591	-	650
6	418	Full	-	37454	37454
Broad gauge shunting[(a)]					9300
Total					$82671

(a) Broad gauge shunting costs are assumed equal to standard gauge shunting costs i.e. equal to the sum of items 413, 414 and 415 of Schedule 6.

These totals are less than the actual totals for the complete month which are used elsewhere in this report. On this basis then the following costs were derived:

Operating cost per wagon = $82,671/3461
= $23.89 per wagon
Operating cost per net tonne = $82671/61348
= $1.35 per net tonne

DEPRECIATION COSTS

The SAR were able to supply details of the original capital cost of the plant and equipment used in the bogie exchange depot, as well as the estimated life of each item.

The procedure adopted to arrive at a cost per month applicable to the exchange as a result of capital expenditure is described below. This procedure is very approximate in nature. However, it is considered that such approximations are justified since these costs are very small in relation to other costs incurred by the exchange.

The procedure is simply to assume a linear depreciation over the estimated life of each item and convert the prices to 1975-76 prices by means of the Implicit GDP Price Deflator(1).

Table B.2 lists the costs considered and the figures used to arrive at the monthly depreciation.

This monthly depreciation cost is a cost which is independent of traffic flow. Therefore as traffic increases the depreciation cost per wagon decreases. Thus the following unit costs are applicable only to the traffic flow in the period 1 May to 28 May.

---

(1) Central Statistical Section, Policy Development Division, Department of Overseas Trade.

Depreciation Cost per wagon = $1169.56/3461
= $0.34 per wagon
Depreciation Cost per net tonne = $1169.56/61348
= $0.02 per net tonne.

TABLE B.2 - DEPRECIATION OF CAPITAL COSTS

Item	Original Cost $	Year of Expenditure	Ratio for 1975-76 price	Estimated life (years)	Monthly Depreciation $
Four Hoists	11431	65-66	213.2/96.8	20	104.90
B.E. Bldg, pavement & amenities	28000	66-67	213.2/100.0	50	99.49
	33150	71-72	213.2/125.0	50	994.23
Track & 2 leads	20587	66-67	213.2/100.0	50	733.15
Spare Hoist & Fire Extinguisher	2326	67-68	213.2/102.7	20	20.12
Air Compressor	395	67-68	213.2/102.7	20	3.41
Shunt Tractor	6053	68-69	213.2/106.2	10	101.26
Mobile Crane	10597	68-69	213.2/106.2	10	177.28
Four Hoists	15389	69-70	213.2/111.0	20	123.16
Shunt Tractor	6313	69-70	213.2/111.0	10	101.04
Shunt Tractor	7248	71-72	213.2/125.0	10	103.02
Mobile Crane	20220	76-77	213.2/213.2	10	168.50
Total					1169.56

ANNEX C - THE CONCEPT OF AN AUTOMATED EXCHANGE

Analysis of the costs incurred by the current bogie exchange indicates that the major cost is the cost of manning the depot. As a means of reducing those costs an attempt has been made to conceive of a bogie exchange system which would substitute a higher degree of capital investment than is currently used for some of the labour.

This problem has been considered and a new system is suggested which is more automated than the present system and which achieves a reduction in crew size from 7 men to 4 men per gang. This system is referred to as the 'automated exchange' throughout this report and is presented in detail in this annex.

It should be noted that the operation described in this annex is an attempt to propose a workable alternative to the existing practice. The BTE does not claim that this method is the best way to achieve the desired goals of increased throughput with a reduced labour force. It is possible that the process as proposed could be refined or that an entirely different process may prove beneficial. However, this proposal has been defined in some detail to demonstrate that a process could be adopted to achieve the desired goals and to estimate the likely order of capital cost, labour reduction and throughput which could be achieved.

THE PROCESS

The operation of this new facility is based on the use of a mechanised "beetle" i.e. a frame mounted on wheels between the tracks which can hook onto the bogies of a wagon from beneath, and move the wagon along the track. Approximately one wagon length from the entry into the exchange is a mechanical block on the rails which prevents the movement of wagons towards the shed. This block would be locked and unlocked by the beetle which

would have a length of travel of approximately two wagon lengths from the shed. The beetle is operated by the leading hand of the gang from a special console within the shed.

Prior to the start of operations, wagons to be converted are shunted onto the entry road and moved down to a position just short of the safety block. The wagons are still coupled at this stage. The leading hand activates the beetle which travels out past the safety block and takes up a position beneath the first wagon. As the beetle passes the safety block it activates a lever which opens the block to allow the movement of wagons past it. The beetle then drags all the wagons forward one wagon length such that the safety block is between the first and second wagon. The beetle then activates the safety block, a second operator uncouples the first wagon from the others, and the beetle drags the first wagon into the exchange shed.

In the shed are four jacks similar to those currently used except that two are in a fixed position and the other two are moveable over a prescribed range controlled by the leading hand from his console. By controlling the beetle, he positions the wagon such that the two front jacking plates are in position in relation to the fixed jacks. He then adjusts the position of the moveable jacks from his console until their position corresponds to the other jacking plates. He then commences to raise the wagon.

When the wagon has been raised a sufficient height the two assistants move under the wagon and, using specially designed hydraulic tools, remove the pins to disconnect the brake rods from the bogies. The wagon is then raised to the necessary height.

At this point the leading hand activates the beetle to move the bogies out from under the wagon. It is envisaged that the beetle would be of sufficient length to allow the crane driver to place the two new bogies at approximately the correct separation onto that part of the beetle which protrudes behind the wagon. In

this way, when the leading hand mobilises the beetle to bring the spent bogies forward from beneath the wagon the new bogies are at the same time positioned appropriately beneath the wagon and the spent bogies can be removed by the crane driver onto the reserve stack.

The crane used in this operation would differ from that currently used. The major disadvantage with the current type of mobile crane is that assistance is required to set the hooks over the bogie prior to raising, to position the bogie over the track prior to lowering and to release the hooks after lowering. It is envisaged that a specialised mobile crane could be obtained which would allow the crane operator to perform the required functions without assistance. Such a crane would probably take the form of a large forklift truck with positive grappling controls which would allow accurate positioning control when lowering.

When the beetle has correctly positioned the bogies under the wagon, the wagon is lowered and the two assistants recouple the brake rods using the hydraulic tools. The brakes can then be tested and the balance of the wagon on the bogies checked. If all is satisfactory, the beetle is once again activated and the wagon is moved out of the shed, past the safety block on the exit side. The operation can then be repeated.

THE ADVANTAGES

The advantages that this process has over the current practice can be summarised as offering increased throughput with a reduction of labour. In an attempt to estimate the time required to convert one wagon, time estimates have been made for the sequence of activities which are seen to lie on the critical path of the process. Table C.1 lists these activities and time estimates.

For this analysis it was assumed that the beetle could travel at an average speed of 1 m/sec when dragging loaded wagons and 2 m/sec when empty or moving bogies, and that the jacks could raise a fully loaded wagon at the rate of 1.5 m/min.

TABLE C.1 - ANALYSIS OF WAGON TRANSFER TIME

ACTIVITY	ASSUMPTIONS	TIME (secs)
Beetle moves out to queueing wagons	36m @ 2m/sec	18
Beetle drags all wagons forward 1 wagon length	27m @ 1m/sec	27
First wagon is uncoupled		5
Beetle moves wagon into positon in depot	36m @ 1m/sec	36
Jacks are positioned		15
Wagon raised to allow access to brake rods	0.3m @ 1.5m/min	12
Uncouple brake rods		10
Wagon raised to full height	0.75m @ 1.5m/min	30
Beetle moves bogies	28m @ 2m/sec	14
Wagon lowered partially	0.75m @1.5 m/min	30
Couple brake rods		15
Wagon lowered fully	0.3m @ 1.5m/min	12
Check for level		30
Beetle moves wagon out of depot	63m @ 1 m/sec	63
Beetle returns to start	90m @ 2 m/sec	45
	TOTAL	362 Secs.

This analysis indicates that the time required to convert a wagon is just over six minutes. For the purposes of establishing throughput, an average time of eight minutes per wagon has been allowed, suggesting that a total of 56 wagons per 8 hour shift could be converted, provided that wagons could be supplied to the depot at this rate.

With the current procedure, work in the depot must stop while shunting movements are occurring on the entry and exit roads to the depot, i.e. while the safety blocks at the ends of the roads are open. With this new process it is envisaged that by utilising a new type of safety block and locating it close to the depot, work in the depot will not have to stop whilst shunting is occurring on the entry and exit roads.

The other major advantage of the new system is that the size of gang required could be reduced from 7 to 4. This new gang would comprise

- a leading hand who controls the beetle and the jacks
- a crane operator to handle bogies
- two assistants to uncouple wagons, couple/uncouple brake rods, check for faults, fine adjust position of bogies when lowering wagons etc.

CAPITAL COSTS

Estimates have been made of the equipment required for the automated exchange. These are summarised in Table C.2 and it can be seen that the total cost for a 2 track automated depot would be about $500,000.

TABLE C.2 - ESTIMATE OF EQUIPMENT COSTS - SINGLE TRACK FACILITY

ITEM	ESTIMATED RANGE $
2 x Fixed Jacks	20 000 - 25 000
2 x Mobile Jacks	30 000 - 36 000
Cable Operated Beetle	75 000 - 110 000
2 Hydraulic Pin removing tools	1 000 - 1 500
Operators Console	10 000 - 12 000
Large Forklift with Rotating Head and side clamps	50 000 - 60 000
TOTAL	$186 000 - 244 500

PRELIMINARY EVALUATION OF BENEFITS OF NEW PROCESS

The following is a brief evaluation of the benefits resulting from the labour savings of the proposed process. The evaluation is performed by comparing the performance of the proposed process with that currently in use.

Two evaluations are performed. The first compares both processes on the basis of maximum throughputs. The second compares the current average throughput of the existing depot with a reduced throughput for the new process which is thought to reflect the possible throughput of the new process if installed in the existing yard and subject to the constraints of this yard mentioned in the text of this report.

Evaluation 1

Productivity of existing facility:

1 gang (7 men) can theoretically convert 32 wagons per shift and work 11 shifts per fortnight.
Assume 6 weeks per annum lost through holidays etc.
∴ No. of wagons per annum per gang
= 32 x 11 x 23
= 8096 w.p.a.

Productivity of proposed facility:

1 gang (4 men) can convert 56 wagons per shift and work 11 shifts per fortnight.
Assume 23 fortnights per year (as above).
∴ No. of wagons per annum per gang
= 56 x 11 x 23
= 14168 w.p.a.

Assume a traffic flow through the depot of 50,000 wagons per annum.

$$\text{Labour required for existing facilities} = \frac{50\,000}{8\,096} \times 7$$
$$= 43.2 \text{ man years.}$$

$$\text{Labour required for new process} = \frac{50\,000}{14\,186} \times 4$$
$$= 14.1 \text{ man years.}$$

The saving for the new facility would be

43.2 - 14.1 = 29.1 man years per year.

If it is assumed that 1 man year costs $20 000 then this saving represents approximately $580,000 per annum, which indicates that over a 25 year period at 10% discount rate an expenditure of approximately $5.2m can be justified on labour savings.

Evaluation 2

Productivity of existing facility:

1 gang (7 men) currently convert on average 27.8 wagons per shift for 11 shifts per fortnight.
Assume 23 fortnights per year
∴ No. of wagons per annum per gang = 27.8 x 11 x 23
= 7033 w.p.a.

Productivity of proposed facility installed in existing yard:

1 gang (4 men) could convert 36 wagons per shift i.e. an increase of 30% over what is currently achieved for 11 shifts per fortnight.
Assume 23 fortnights per year
∴ No. of wagons per annum per gang = 36 x 11 x 23
= 9108 w.p.a.

Assume a traffic flow through the depot of 50,000 wagons per annum.

Labour required for existing facilities $= \frac{50\ 000}{7\ 033} \times 7$

= 49.8 man years.

Labour required for new process $= \frac{50\ 000}{9\ 108} \times 4$

= 22.0 man years.

The saving for the new facility would be

49.8 -22.0 = 27.8 man years per year.

If it is assumed that 1 man year costs $20 000, then this saving represents approximately $556 000 per year, which indicates that over a period of 25 years at 10% discount rate an expenditure of approximately $5m could be justified on labour savings.

ANNEX D - DETAILS OF ALTERNATIVES

This annex contains the assumptions in relation to, and the details of, the various alternatives which have been evaluated in the East-West Rail Link study. These alternatives have been discussed in Chapter 5 of this report and consist of -

- Alternative 1, which is a continuation of current practices without capital investment but incorporating the principle of rerouting to utilise available capacity at the Peterborough bogie exchange.
- Alternative 2 which involves the provision of a bypass loop outside Port Pirie.
- Alternative 3 which is the upgrading of the bogie exchange depot in the existing Port Pirie yard.
- Alternative 4 which includes the relocation of the exchange to a site outside the existing yard in conjunction with the provision of an upgraded depot and additional marshalling facilities.

It was necessary to determine the following information for each case:

- general description;
- capital works required and an estimate of costs;
- transit time curves depicting each case;
- estimates of through puts and hence bogie exchange operational costs on a per wagon basis.

Depending on the outcome of the evaluations, any of the cases may consider rerouting through Peterborough. The transit time curves and cost for the Peterborough situation are presented in Chapter 5 for Alternative 1. If rerouting is considered in the other alternatives the Peterborough details will be assumed to remain the same as those used in Alternative 1.

The alternatives presented here are in no way proposed as recommended alternatives. As explained in Chapter 5 they have been proposed in order to evaluate the affect of varying degrees of capital investment.

ALTERNATIVE ONE - SCHEDULED REROUTING

General Description

As mentioned previously, this case involves the continuation of the use of current facilities. Consideration is given in the evaluation to rerouting wagons through Peterborough until the marginal cost incurred by either route is identical. Even so, in future years delays experienced by wagons requiring bogie exchange would be substantial.

Capital Works

This case does not involve the expenditure of any additional capital.

Transit Time Curves - Port Pirie

a) Bogie Exchange Vehicles

The theoretical approach adopted to derive the transit time curves has been presented in Annex A. The procedure used in the actual derivation is presented here in some detail.

It is necessary to initially determine the average time taken for a wagon to pass through the yard (and the standard deviation of this average) given the condition that wagons can be 'served' without delay after arriving in the yard. The procedure adopted to determine this average was:

- Determine the average number of wagons which require bogie exchange on the various trains arriving in Port Pirie.
- For each train determine the average time of arrival.

- Assume a period of two hours elapses between time of arrival and the time at which wagons become available at the exchange depot.
- Determine the time of departure of the first train to leave Port Pirie on the appropriate gauge.
- Allow a transfer rate through the exchange of 3.7 wagons per hour i.e. the average rate achieved during May 1976 and allow a further two hour period after exchanging to enable wagons to be taken from the depot to the subsidiary siding and marshalled onto a train. Then determine the number of wagons which could be exchanged in time to depart on the first available train.
- Determine the time of departure of the second available train.
- Determine the number of wagons which could be exchanged in time to depart on the second available train.
- Repeat procedure until all wagons have departed.
- By repeating this complete procedure for each train arriving over a prescribed period of time, a frequency distribution of wagons vs transit time can be drawn up.

For this alternative, the analysis of the frequency distribution determined, for wagons requiring bogie exchange, that the mean no- delay service time was 11.82 hrs. with a standard deviation of 4.54 hours.

Insertion of these figures into Pollaczek's Formula defines the transit time curve for the existing situation i.e.

$$\text{Mean Transit Time, } E(t) = 11.8 + \frac{6.774P}{1-P} \quad \text{hours}$$

where P = server load
This curve is presented in Figure 5.2.

b) Vehicles Passing Straight Through on Standard Gauge.

To obtain a complete picture of wagon transit times in Port Pirie yard it was necessary to determine a transit time curve for wagons arriving on standard gauge which are to continue past Port

Pirie also on standard gauge. A procedure similar to that outlined above was used except that rather than use a bogie exchange service rate to determine a frequency distribution of transit times, two simple assumptions were adopted:

(i) on trains arriving from the west there are a mixture of wagons which are to either proceed past Port Pirie on standard gauge or are destined for the broad gauge. It was therefore assumed that four hours after the arrival of a train from the west, those wagons which are to proceed on standard gauge could have been separated from the others and would be available to leave on the next east bound train.

(ii) Trains arriving from the east would be less affected by mixed destination loading, and hence it was assumed that wagons continuing westbound on standard gauge would be available for departure 2 hours after arrival.

Using these assumptions, the following were obtained:

Mean Service Time = 6.34 hrs.
Standard Deviation = 3.05 hrs.

Hence, Mean Transit Time, $E(t) = 6.34 + \frac{3.904P}{1-P}$ hours

This Curve is presented in Figure 5.3.

For the purpose of the evaluations it was necessary to assess mean transit time as a function of traffic volume. This was achieved by determining the current value of P from the ratio between the known average arrival rate and the assumed transfer rate. This value of P then corresponded to the existing traffic flow.

Transit Time Curves - Peterborough

It was necessary to establish transit time curves for the Peterborough yard and bogie exchange in order to make estimates of time penalties incurred at Peterborough when traffic is rerouted through that exchange rather than through Port Pirie. In the derivation of the curves a service rate of 4.3 wagons per hour was assumed i.e. 32 wagons per 7.5 hour shift.

a) Bogie Exchange Vehicles

Mean Service Time = 8.33 hours
Standard deviation = 3.75 hours

Hence, Mean Transit Time, $E(t) = 8.33 + \frac{5.009P}{1-P}$ hours

b) Vehicles Passing Straight Through on Standard Gauge.

Mean Service Time = 6.34 hours
Standard deviation = 3.05 hours

Hence, Mean Service Time, $E(t) = 6.34 + \frac{3.904P}{1-P}$ hours

These curves are presented in Figures 5.1 and 5.3.

Operational Costs

The costs of operating the bogie exchange in Port Pirie for this case are the same as those presented in Chapter 3 of the text. Although it is expected that the costs incurred at Peterborough are less than for Port Pirie the BTE has at this stage been unable to ascertain the actual costs. Hence for the evaluations it is assumed that the cost incurred by a wagon at the Peterborough exchange is the same as that incurred at Port Pirie.

ALTERNATIVE TWO

General Description

This alternative is simply the provision of a bypass loop outside Port Pirie so that standard gauge trains can travel between Port Augusta and Peterborough without entering the Port Pirie yard. The intention is to evaluate the effect of this loop in conjunction with the rerouting options included in the other alternatives.

Capital Works

It is estimated that the cost of constructing this loop would be approximately $200,000.

Transit Time Curves and Operational Costs

It was not necessary to define new trarsit time curves for this alternative since yard performance at either exchange depot remains unchanged.

Similarly, the operational costs to be used in this alternative would depend on the particular alternative to be considered in conjunction with this alternative.

ALTERNATIVE THREE

General Description

This alternative involves upgrading the existing facilities in Port Pirie by the provision of a new automated exchange depot. The evaluation of this case will also consider rerouting traffic through Peterborough to utilise the available capacity of that depot.

Capital Works

The cost of converting the existing depot to one such as that described in Annex C is estimated as ranging between $500,000 and $800,000.

Transit Time Curves

The transit time curves were established for this case by utilising a similar procedure as for Alternative One. However, as explained in Chapter 5, the yard becomes the determining factor of capacity for this alternative.

The Port Pirie yard is currently feeding the existing bogie exchange at the average rate of approximately 7 wagons per hour. SAR officials feel that the ultimate capacity of the yard to feed the existing exchange is perhaps 20% above the existing rate. The new bogie exchange depot would allow a slight increase on this rate due to the possibility of a continuous feeding facility. It has been assumed that this would allow a further increase of the feeding rate of 10% and hence the rate used in the derivation of the transit time curve is 30% greater than the current feeding rate to the depot i.e. 9 wagons per hour.

Other assumptions required for the derivation of the curve were the same as for the previous alternatives. Analysis of the frequency distribution this obtained revealed the following -

Mean Service Time = 10.4 hours
Standard Deviation = 3.3 hours
Hence, Mean Transit Time, $E(t) = 10.4 + \frac{5.72P}{1-P}$

This curve is presented in Figure 5.4.

It was assumed that the movement of straight through standard gauge trains would be unchanged from the existing situation. The

transit time curve therefore for such trains is the same as that determined in Alternative One.

Operational Costs

Alternative Three achieves a reduction in the cost of converting wagons due to a combination of increased throughput and reduced crew size in the exchange.

The cost of manning the exchange in the current situation averages at $10.82 per wagon and the average throughput per crew shift is 27.8 wagons. For this alternative productivity is increased by 30% and crew size is reduced from 7 to 4. This reduces the average cost per wagon of manning the exchange to $4.76 per wagon.

The other direct operating costs incurred are considered to remain constant at $13.07 per wagon.

Hence the average operating cost of converting wagons in this alternative is $17.83 which is a reduction of $6.06 per wagon.

ALTERNATIVE FOUR

General Description

This alternative involves the provision of adequate facilities in the Port Pirie area to handle all traffic which is expected to pass through that area over the next twenty years. The proposal outlined here involves considerable expenditure and has been proposed to examine whether or not such expenditure is warranted economically.

It should be noted that the BTE does not suggest that this proposal is the most desirable even if it proves to be economically justifiable. If such a result is forthcoming the conclusion to be drawn would be that in economic and operational terms at

least one feasible solution exists. It would then be necessary to determine what the most appropriate solution would be.

The basis of this alternative includes -

- relocate Bogie Exchange to a site near Warnertown
- provide broad gauge access to this site from the main Port Pirie-Adelaide broad gauge line.
- provide broad gauge marshalling facilities at Warnertown.
- convert existing yard at Port Pirie to a predominantly standard gauge yard.
- provide an automated Bogie Exchange depot.

A description of the operational aspects of this alternative is given in Chapter 5.

Capital Works

The capital works included in this alternative consist of the development of the Warnertown Complex as shown in Figure D.1, the provision of 9km of broad gauge track linking the new site to the existing broad gauge system and the conversion of the existing yard in Port Pirie to standard gauge. Table D.1 lists the various component costs.

TABLE D.1 - COST ESTIMATE FOR ALTERNATIVE FOUR

	$
Land Compensation	50 000
Earthworks	600 000
Trackwork	5 400 000
Signals	200 000
Bogie Exchange Depot	800 000
Conversion of Existing Yard	150 000
Total	$ 7 200 000

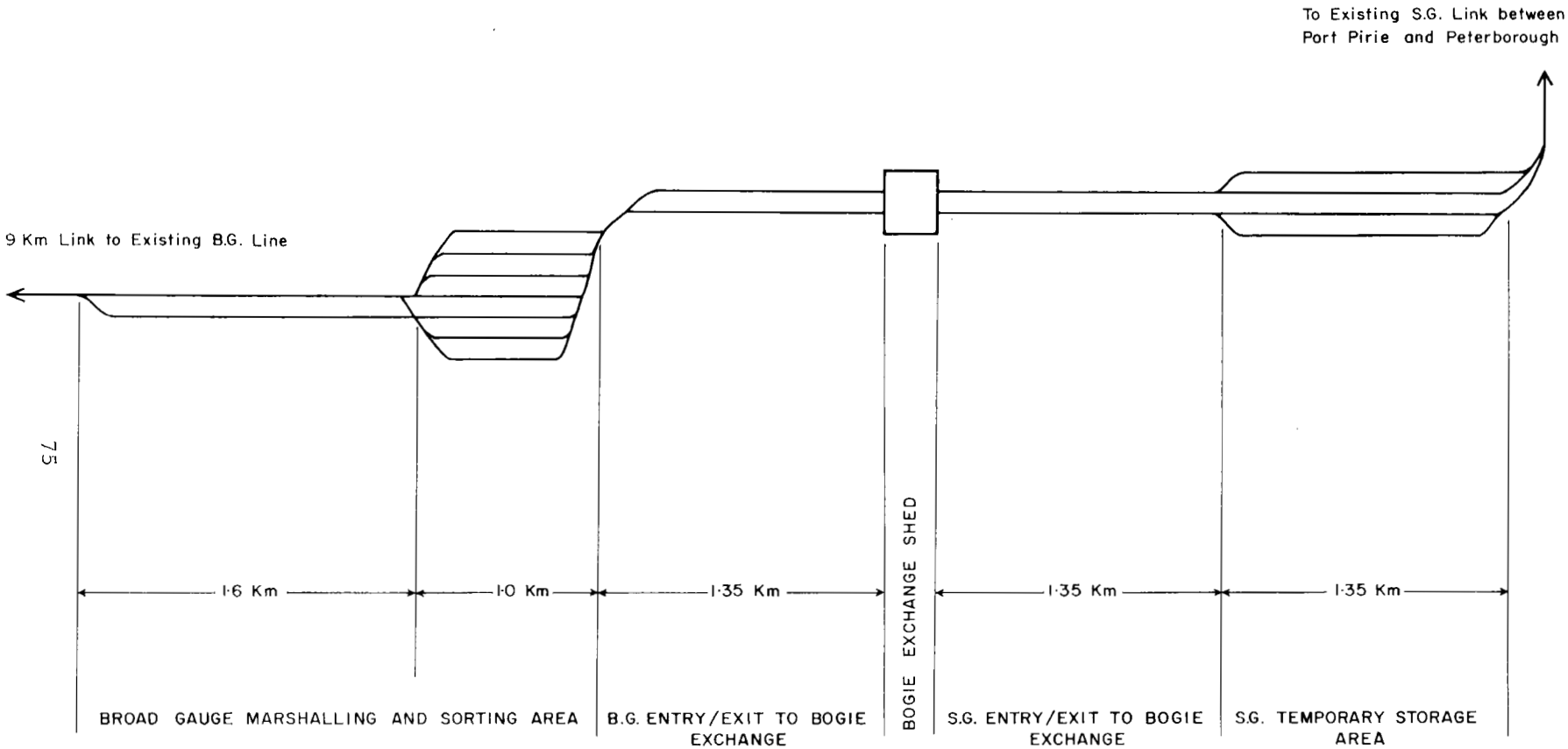

FIGURE D·1

CONCEPT OF WARNERTOWN COMPLEX FOR ALTERNATIVE FOUR

Transit Time Curves

A similar procedure to that used for the other alternatives was adopted to determine the transit time curves.

The following assumptions were made for wagons requiring change of gauge.

a) For Broad Gauge arrivals -

- wagons available at the exchange one hour after arrival
- service rate in depot 7.5 wagons/hour
- wagons available for despatch 1 hour after transfer.

b) For Standard Gauge Arrivals

- Wagons available at the exchange two hours after arrival
- service rate in depot, 7.5 wagons/hour
- wagons available for despatch 1 hour after transfer.

Analysis of the frequency distribution obtained using these assumptions revealed the following for wagons requiring transfer -

Mean Service Time = 8.9 hours
Standard Deviation = 2.9 hours
Hence, Mean Transit Time, $E(t) = 8.9 + \frac{4.92P}{1-P}$ hours

For vehicles passing straight through on the standard gauge, the assumption was made that twice the number of wagons could be handled in the same time as currently since approximately twice the existing amount of marshalling and sorting track would be available with this alternative. It was therefore assumed that the transit time curve for these wagons in this alternative would take the same shape as the curve for the existing situation with the traffic flow axis halved in scale.

The above curves are presented in Figures 5.6 and 5.7.

Operational Costs

As for Alternative Three, this proposal achieves a reduction in the cost of converting wagons due to a combination of increased throughput and reduced crew size in the exchange compared to the existing facility.

The effect of increasing productivity from an average of 27.8 per shift to 56 per shift and reducing crew size from 7 to 4 results in a reduction in the cost per wagon of manning the exchange from $10.82 per wagon to $3.07 per wagon. The other direct operating costs incurred are considered to remain constant at $13.07 per wagon.

Hence the average cost of converting wagons in this alternative is $16.14 per wagon which is a reduction of $7.75 per wagon.