Adequacy of Transport Infrastructure: Rail

Working Paper

This Working Paper is the second in a series of Working Papers which disseminates the results of a large research project into the adequacy of Australia's transport infrastructure over the next 20 years. The assessment covers all four modes of transport - road, rail, air and sea - with the primary focus on freight.

Bureau of Transport and Communications Economics

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Adequacy of transport infrastructure
Rail

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FOREWORD

The National Transport Planning Taskforce (NTPT) was established in October 1993 by the former Minister for Transport and Communications to report on national infrastructure needs and operational improvements required to meet future demands for freight transport.

The Bureau of Transport and Communications Economics was commissioned by the NTPT to carry out assessments of the adequacy of road, rail, seaport and airport infrastructure. In doing this it has attempted to adopt a strategic multimodal orientation. A summary of the Bureau's work is given in *Building for the Job: A Strategy for Australia's Transport Network, Commissioned Work,* vol. 1, produced by the NTPT.

The project was undertaken under the leadership of Mark Harvey and John Miller. Officers who contributed specific components included Johnson Amoako, Jane Brockington, Peter Collins, Glen D'Este, Bozena Dziatkowiec, Edwina Heyhoe and Chikkegowda Puttaswamy. Valuable guidance was provided by the BTCE director, Maurice Haddad.

Details of the research undertaken for each component of the study are provided in a series of six working papers. Each paper describes the methodology used, future demand, and results of the adequacy analysis, and gives options for future research. This paper outlines the detail on the concepts and methodology for assessing the adequacy of existing rail infrastructure and details of the basis for the conclusions regarding expenditure.

The rail adequacy work was done by Johnson Amoako and Bozena Dziatkowiec in conjunction with Maunsell Consultants Pty Ltd. The dedication of all the Bureau staff involved, the consultants and the staff of the Australian National, Westrail, Travers Morgan and the Department of Transport who cooperated in supplying considerable information, as well as the National Railways Corporation who also provided constructive comments on the rail draft paper, have been appreciated.

Russ Reynolds
Research Manager

Bureau of Transport and Communications Economics
Canberra
December 1994

CONTENTS

FIGURES

TABLES

ABSTRACT

Traditionally, rail infrastructure planning and investments have been driven by technical criteria, and usually the analysis is confined to within one or two state rail jurisdictions. This has meant, in some cases, misallocation of resources when viewed from the national perspective. The consequences in some instances are high demand corridors serviced by relatively poor infrastructure. Ideally an efficient system is one in which technical judgments are balanced with economic rationale.

The Bureau of Transport and Communications Economics, employing technical and economic methods, has evaluated the adequacy of the entire main-line rail network stretching from Cairns to Perth, thus for the first time cutting across the 'state jurisdiction syndrome'. The method used is also consistent across all four dominant modes. This paper outlines the technical and economic adequacy concepts used in the assessment of the strategic national rail infrastructure for the next 20 years. For instance, it is demonstrated in the paper that a piece of infrastructure is deemed to be technically inadequate if it provides a quality of service below some minimum acceptable level defined in terms of a number of attributes. The paper discusses two concepts of technical adequacy: that relating to the physical infrastructure characteristics, and that of the performance (output) of the infrastructure.

Technical analysis is used to screen projects, which are then subjected to economic evaluation. The evaluation establishes, for each investment scenario the optimum year of investment. The paper concludes with a list of investment projects necessary to address infrastructure deficiencies and bring rail to a par with road in terms of competitiveness. The paper also suggests areas of further research.

KEY FINDINGS

Technical assessment

- Looking at capacity, all corridors have sufficient capacity to cope with the expected demand *as at 1995-96.* If the demand increase over the 20 year period is met by increasing train numbers and keeping the trains at the same lengths as today, by 2014-15 shortages of capacity will occur on the Sydney-Melbourne, Melbourne-Adelaide, Brisbane-Cairns and Sydney-Brisbane corridors. Problem links on these corridors would be Junee-South Dynon, Tailem Bend-Adelaide, Brisbane-Nambour and Maitland-Acacia Ridge.

- Looking at the performance deficiency indicators other than capacity, the worst corridors by 2014-15 will be Sydney-Brisbane, Melbourne-Adelaide and Brisbane-Cairns.

- All multimodal terminals will have adequate capacity at both the start and end of the study period. This conclusion is conditional upon the National Rail Corporation's investment plans for terminals being implemented. These plans include projects costing $21M at Acacia Ridge, $16M at Enfield and $16M at South Dynon. Rail-port terminals at Fisherman Islands, Botany, Outer Harbour and North Fremantle will also be adequate.

- For urban areas, a serious conflict between freight and commuters currently exists in Sydney and will become greater as both passengers and freight grow. A curfew applies to freight trains during the morning and afternoon passenger peaks.

Economic assessment

- About $3B of investment in rail infrastructure is estimated to be warranted over the next 20 years. Sydney-Brisbane is estimated to warrant the greatest share of this, followed by Sydney-Melbourne and Brisbane-Cairns.

- Maintenance costs are estimated to amount to around $3B. Infrastructure projects yield savings in maintenance costs. If no investments in infrastructure are undertaken, maintenance costs are forecast to be some $1B higher over the 20 year period.

Implications

This proposed investment program is on about the same scale as One Nation funds for rail, requiring on average $150M annual expenditure over the planning period of 20 years

As with sea ports, the major factor which underlies the need for new infrastructure investments is the necessity to maintain and improve rails' level of service. Technical capacity of the rail infrastructure should handle the projected demand. This contrasts with intercity roads, urban roads, and air ports where it is the growth in projected demand which drives the need for infrastructure expansion.

CHAPTER 1 INTRODUCTION

The Bureau of Transport and Communications Economics was asked by the National Transport Planning Taskforce (NTPT) to undertake an assessment of the adequacy of transport infrastructure in Australia for the next 20 years. The assessment covers all four modes of transport - road, rail, air and sea - with the primary focus on freight. Passenger transport has to be taken account of in the analysis where it uses the same infrastructure as freight and impacts on congestion levels.

The full results of the work are presented in the Bureau's report to the NTPT. The report to the NTPT concentrates on the findings of the study, with only as much methodology provided as is necessary to understand the findings. A series of six working papers has been prepared to explain the methodology in detail as well as providing further discussion of the findings and information requirements of the study. The working papers cover each mode, and urban roads and intermodal issues.

This paper is the second in the series and contains the assessment for rail infrastructure. It examines the adequacy of rail linehaul and terminal infrastructure, identifies deficiencies and the projects necessary to address the deficiencies. Adequacy is assessed in both technical and economic terms. Although an integral part of rail systems, locomotives and rollingstock are not dealt with in this report. Adequacy is assessed only for the fixed infrastructure, that is, the substructure or foundation which makes possible the smooth and rapid movement of locomotives and rollingstock. Issues concerning the operating practices of railway systems are not considered.

In order to reduce the task to manageable proportions, the BTCE selected for examination the intercapital rail lines (excluding branch lines), Brisbane-Cairns, Canberra-Goulburn and Hobart-Burnie, and the terminals in capital cities. This infrastructure was considered to be the most significant from a national strategic economic viewpoint.

The assessment of rail infrastructure adequacy assumes that the One Nation and Queensland's Main Line Upgrade (MLU) programs of investments have been completed. One Nation is a $429M program financed by the Federal

Government being undertaken over the period 1992 to 1995 and MLU is a $580 million (revised) upgrading program financed by the Queensland State Government over the period 1992 to 1997.

NEED FOR A STRATEGIC APPROACH

The strategic nature of this study needs to be emphasised. The study puts forward dollar values of investments likely to be warranted, but these should be regarded as broad orders of magnitude only. It would be a grave misrepresentation to interpret the findings as setting out a recommended investment program. The aim was not to produce a program of specific infrastructure projects and itemised costing, but to highlight areas where a full scale cost-benefit analysis would most probably indicate that investment in additional infrastructure is warranted within the 20 year period. The study points to areas where detailed evaluations might usefully be undertaken, as well as to areas where this is not the case. The results of the study should therefore be valuable in alerting governments to parts of the national transport network infrastructure that are likely to require attention over the next 20 years, and the likely magnitude of the financial resources required.

OUTLINE OF REPORT

Chapter 2 appears in a similar form in most of the working papers in the series. It sets out the conceptual framework within which the adequacy assessments have been undertaken. Chapter 3 identifies the corridors and terminals selected for the assessment. It describes their physical attributes as they are at present. Chapter 4 discusses freight demand and projections over the 20 year assessment period. Chapter 5 discusses the technical assessment methodology and results. Chapter 6 discusses projects necessary to improve rail competitiveness, and their economic evaluation. Chapter 7 discusses the overall conclusions of the study and suggested areas of further work.

CHAPTER 2 CONCEPTS OF INFRASTRUCTURE ADEQUACY

INTRODUCTION

This chapter addresses questions of the meaning of 'adequacy' of transport infrastructure and how this might be assessed. Two definitions of adequacy have been employed by the Bureau, one technical and the other economic. How the Bureau has applied these definitions to the different transport modes has been shaped by the characteristics of the modes and availability of data and models. The depth in which the Bureau has been able to analyse adequacy is therefore very uneven between modes. Even where only a limited assessment has been possible, however, it is still important to bear in mind the ideal, and this serves as the basis for subsequent discussions about future directions that might be taken in adequacy assessment work. The first part of the chapter discusses definitions of adequacy and the second part reviews some of the practical issues faced in attempting to apply these definitions.

DEFINING ADEQUACY

The concept of adequacy

'Adequacy' of transport infrastructure refers to whether or not additional investment is required in the infrastructure. The requirement to invest is a consequence of the infrastructure providing a poor level of service, such as high operating costs, long service times or unreliability. Poor service can have a variety of causes including shortages of capacity, physical deterioration and obsolescence due to changes in technology, demand, input prices or safety requirements.

Specifying just what is meant by a 'poor' level of service is not straightforward. If efficient use of resources is the objective, whether service can be considered poor and the infrastructure requires upgrading is an economic question involving a weighing up of the capital cost of investing against the benefits in terms of improved levels of service. The technique for doing this is social cost-benefit analysis. However, undertaking a cost-benefit analysis is a complex, data intensive and time consuming task. Simpler and quicker means are needed to identify investment projects where detailed assessment is likely to be warranted, and to make decisions about smaller investments where application of cost-benefit analysis techniques would not be worthwhile. The common procedure is to employ a 'rule of thumb' whereby upgrading is considered necessary when the quality of service provided by a piece of infrastructure deteriorates below some minimum acceptable level. As an example, in the rail industry, when train 'meets', that is, trains meeting other trains, occur at more than 50 per cent of the passing loops along a corridor, some operators take this as an indication of inadequate capacity.

Technical adequacy

From the notion of 'rules of thumb' providing a rough indication of whether investment is needed, the Bureau has derived its definition of 'technical adequacy'. Transport infrastructure is deemed to be technically adequate if its physical or performance characteristics are above minimum acceptable levels. The definition can be applied either to physical or performance characteristics. Examples of physical characteristics for a railway line are axle load rating, maximum train length, track curvature and gradient, vertical clearance and rail weight. For performance characteristics, examples are capacity relative to demand, cost per net tonne kilometre, transit time, average speed and service reliability.

Given that infrastructure adequacy is essentially an economic question, determining the level of minimum technical standards should be done bearing in mind the standard that is likely to be warranted on economic grounds. One approach is to assume that, *on average across the country*, current standards for infrastructure of a given type are roughly right in economic terms. The physical or performance characteristics of a large number of sections of infrastructure can then be compared and those with the poorest standards deemed to be technically inadequate. Precisely where to draw the line between adequate and inadequate remains a matter for judgment. In the absence of information about economically warranted standards, natural breaks in the continuum of standards and perceptions about reasonable standards could be drawn upon.

Economic adequacy

An assessment of adequacy using a technical definition can only be regarded as providing a rough guide to whether upgrading is economically justified. A piece of infrastructure which is inadequate in the technical sense could be adequate in the economic sense if the cost of upgrading was high in relation to the benefits. Conversely, if the benefits of upgrading exceeded the costs, it would be economic to invest even where the infrastructure was technically adequate.

The 'economic adequacy' approach employed by the Bureau is based on social cost-benefit analysis. An investment is economically warranted at a point in time if:

1 the present value of benefits exceeds the present value of costs; *and*

2 there is no net welfare gain from delaying the investment.

The first condition is intended to ensure that the resources invested will earn at least what they could if used elsewhere in the economy and the second condition aims to ensure optimal timing. Transport infrastructure is deemed to be economically adequate at a point in time if investment to improve the level of service provided is not economically warranted.

To explain the economic concept of adequacy in more detail, figure 2.1 shows a demand curve and two 'short-run marginal social cost' (SRMC) curves for the use of a piece of infrastructure. Quantity provided or demanded per period of time is graphed on the horizontal axis and 'generalised social cost' of infrastructure use on the vertical axis. This 'generalised social cost' consists of all the costs associated with use of the infrastructure regardless of to whom they accrue. In the case of railways, generalised social costs would include the costs of track provision and maintenance, signalling, train provision and operation, time for passengers and freight including delays due to unreliability, and externalities such as delays caused to road vehicles at level crossings. Valuing freight time and costs of externalities entails significant measurement problems which are not addressed in this conceptual discussion.

The marginal cost of infrastructure use is the cost imposed by an *additional* user. The short run refers to the time frame in which it is not possible to invest to change the infrastructure. Capital costs and fixed operating costs of infrastructure are excluded because they will not be affected in the short term by infrastructure usage. The short-run marginal social cost curve, $SRMC_1$ rises as usage rises towards maximum capacity (c_1) and operating costs, delays and unreliability increase. If the maximum capacity was increased, say to c_2 the short-run marginal cost curve would shift to the right - to $SRMC_2$.

The demand curve (D) shows the quantity demanded of infrastructure usage at each level of generalised cost incurred by users. Users incur their own costs plus taxes and charges associated with use of the infrastructure. To simplify the exposition, it is assumed that taxes and charges are levied in amounts such that user pays the short-run marginal social cost of the resources consumed. This is the economically optimal price. As a result of the capacity expansion, users gain from a reduction in generalised cost from P_1 to P_2 and so increase their use from Q_1 to Q_2. The net gain to society from expanding infrastructure capacity is equal

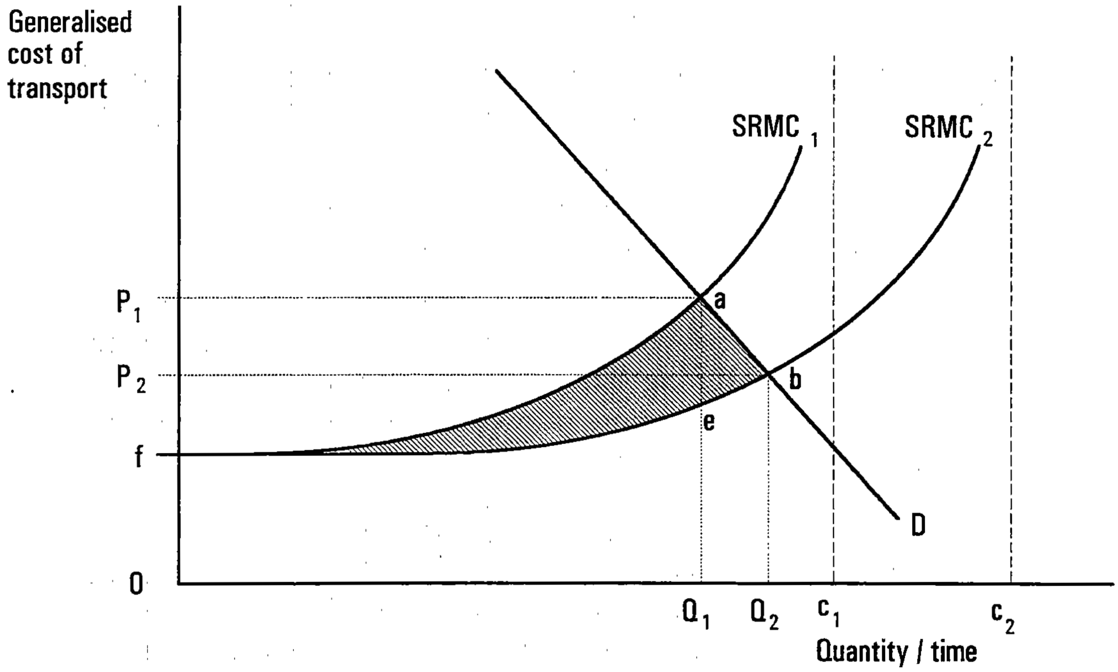

Figure 2.1 Benefits from capacity expansion

ɔ the shaded area (*abf*) in figure 2.1.[1] Clearly, the shaded area and hence the ·enefits from expanding capacity will be greater in size, the higher demand is ı relation to capacity.

ι social cost-benefit analysis would compare the capital cost of the capacity xpansion with the discounted present value of gains per period time. The first ondition in the above definition of economic adequacy requires that the latter xceed the former before capacity could be considered inadequate.

f infrastructure could be expanded in finely divisible amounts, one would :eep on adding to capacity as long as the present value of benefits from one ollar's worth of additional expenditure on capacity exceeded one dollar. In ·ractice, however, capacity can often only be expanded in sizeable lumps. In ıany cases this is due to economies of scale in construction as it is cheaper to each a given capacity level with one large capital work than to do so via a eries of smaller investments increasing capacity in steps.

The area between the two SRMC curves from *0* to Q_1 (*aef*) represents the saving in costs on existing throughput. The area from Q_1 to Q_2 (*abe*) is the gain to society associated with the generated demand. It is the difference between the gain to users represented by the height of the demand curve and the social cost of meeting the additional demand represented by the height of the $SRMC_2$ curve.

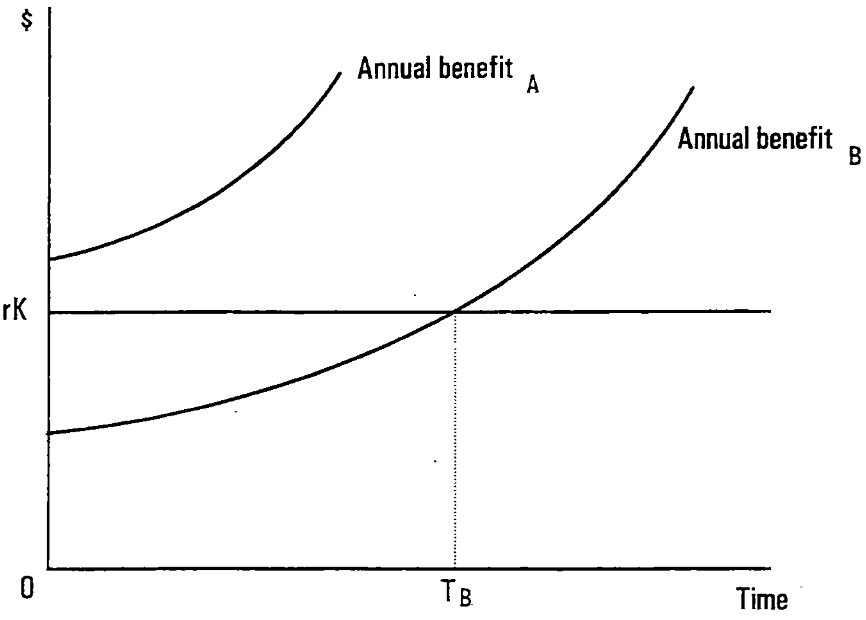

Figure 2.2 Optimal timing of investments

The optimal time to invest

Although capacity may be lumpy, the time at which to invest is divisible. This leads to the second condition in the definition of economic adequacy, which ensures optimal timing. Even when the present value of benefits exceeds costs, it may still be preferable to delay an investment. Assuming that the upgrade will be permanent, if the investment project was delayed by one year, society would forgo the benefits from the project for that year. As an offset, society could gain by investing the funds required for one year elsewhere and could earn interest. Assuming perfect capital markets, so that the interest rate equals the discount rate, which in turn equals the opportunity cost of capital, society would gain *rK*, where *r* is the discount rate and *K* the capital cost of investment. Hence an investment would be better delayed so long as $B(t) < rK$, where $B(t)$ is the benefits in year *t*.[2] If demand is growing over time, annual benefits will grow as well, so the time will eventually be reached when investment is warranted. This illustrated in figure 2.2. Time is graphed on the horizontal axis and annual benefits and costs on the vertical axis. Two annual benefit curves are shown along with the value of *rK*. The annual benefit curves have been drawn as rising at an increasing rate because, as the demand curve in figure 2.1

2 This condition is sometimes expressed as: a project should be delayed if the 'first year rate of return' is below the discount rate, that is, $\frac{B(1)}{K} < r$.

moves rightward over time, the distance between the $SRMC_1$ and $SRMC_2$ curves increases. If the annual benefit curve labelled *A* applied, the investment would be warranted immediately. In this case, the optimal time to invest occurred in the past. In the case of the *B* curve, it would be better to delay the investment until time T_B.[3]

In order to explore some of the relationships, it is assumed that annual benefits are growing at a constant rate over time, that is, $b(1+g)^t$ where b is the benefit in year zero from undertaking the investment and g is the annual growth rate in benefits.[4] Substituting the formula for annual benefit into the optimal timing condition, the optimal time to invest is $\frac{ln(rK/b)}{ln(1+g)}$. From this it can be seen that a higher discount rate and capital cost will delay the optimum time while higher benefits and growth in benefits will bring it forward.

The benefit-cost ratio (BCR) (the present value of benefits divided by the present value of capital costs) from the investment under the assumption that

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3 It is assumed that the benefit function is continuous and monotonically increasing. With investment occurring at time T and continuous compounding, the net present value of benefits and costs is: $NPV = \int_T^\infty B(t)e^{-rt}dt - Ke^{-rT}$. This equation must be differentiated with respect to T and set equal to zero to obtain the optimum time to invest: $\frac{dNPV}{dT} = -B(T)e^{-rT} + rKe^{-rT} = 0$; which reduces to: $B(T) = rK$. The second order condition for a maximum is that, in the region of the optimum: $-e^{-rt}\frac{dB}{dt} < 0$ which holds if $\frac{dB}{dt} > 0$. Thus the annual gain from implementing the project must be growing over time. The optimal timing condition derived here assumes that the project has an infinite life. There may be periodic maintenance costs and replacement costs which occur at definite times following initial construction. Deferral of the initial investment also defers these. NPV could then be expressed as:

$$NPV = \int_T^\infty B(t)e^{-rt}dt - Ke^{-rT} - k_1e^{-r(T+x_1)} - k_2e^{-r(T+x_2)} - \ldots - k_ne^{-r(T+x_n)}$$

where the *k*'s are periodic maintenance of replacement expenditures each one occurring *x* years after time *T*. The optimum timing condition then becomes: $B(T) = r\left(K + k_1e^{-rx_1} + k_2e^{-rx_2} + \ldots + k_ne^{-rx_n}\right)$. Thus one could use the simple optimal timing condition derived previously but augment *K* by an amount equal to the present value of these periodic maintenance and replacement costs. For maintenance costs which occur every year and are the same for each, it is simpler to reduce annual benefits by the amount.

4 If the demand curve shifts rightward at a constant growth rate, benefits from infrastructure expansion will in fact rise faster because the gap between marginal costs with and without the investment rises as figure 2.1 shows.

benefits grow at a constant rate is $\frac{b(1+g)^T}{K[r-ln(1+g)]}$, where T is the time of implementation. Thus the BCR grows over time at the growth rate. If the investment is undertaken at the optimal time, the formula for the BCR reduces to $\frac{1}{1-ln(1+g)/r}$. The b and K terms drop out of the equation altogether. From this equation it can be seen that with a positive growth rate and optimal timing, the BCR can never lie below one. A project having a BCR below one would, with optimal timing, be delayed into the future, by which time its BCR would have risen above one. At the optimal time, how far the BCR lies above one will depend on the size of the growth rate relative to the discount rate. If the project has its optimal time in the past as illustrated by the annual benefit curve A in figure 2.2, the BCR will be higher still, depending on how late the project is. Application of the optimal timing criterion to identify investment projects and timings therefore means that BCRs will be above one, and significantly so where growth rates in benefits are high relative to the discount rate and where there is already substantial underinvestment.

Non-capacity expanding investments

The SRMC curves in figure 2.1 were drawn such that the investment shifts the SRMC curve to the right. Short-run marginal costs at low outputs remain unchanged. The improvements in service levels eventuate because there is more capacity to handle any given volume of demand. Some investments will shift the SRMC curve downward as well as or instead of to the right. An example would be an investment to save on variable maintenance costs. Even if there is no congestion whatsoever the principles for assessing whether the investment is warranted and estimating the optimal time are the same. In terms of figure 2.1, the demand curve would pass through the flat parts of the SRMC curves. The annual benefit would still be measured by the area bounded by the two SRMC curves and the demand curve.

Non-optimal pricing

To simplify the exposition, it was assumed in the discussion of figure 2.1 that taxes and charges were levied in the amounts such that users always paid the short-run marginal social cost. This is the optimum pricing rule to achieve economic efficiency because the marginal user, that is, the user on the borderline in deciding whether or not to use infrastructure, is faced with the full cost he or she imposes on society. In practice, prices will never perfectly reflect marginal costs and may be quite different. Where prices differ from marginal costs, measurement of benefits from infrastructure upgrading will be more complicated than just the shaded area in figure 2.1.[5] If prices are above marginal costs, infrastructure will be underutilised compared with the most efficient level, and less investment will be required. Conversely, if infrastructure is underpriced, there will be more congestion than the most efficient level and additional investment will be required.

APPLYING THE DEFINITIONS

The extent to which the Bureau has been able to apply the definitions of technical and economic adequacy to each mode of transport in the adequacy assessments described in the present series of working papers has depended on the availability of data and the availability of models to forecast future levels of service as demand grows and infrastructure is upgraded.

Demand projections

The present study aims to assess adequacy over the 20 year period 1995-96 to 2014-15 inclusive. Demand projections over this period are therefore an important first step, and this is the subject of a later chapter. Data on recent levels of utilisation are vital for making demand projections, and some forecasting techniques also require time series data.

As demand rises towards capacity, levels of service will fall, which will choke off some of the demand. Investment in new capacity can have the opposite effect, stimulating demand. In order to keep the effects of demand growth, that is, rightward movement of the demand curve, separate from effects of congestion on demand, that is, movements along the demand curve, it has been assumed when making the demand projections that service levels provided by the infrastructure remain unchanged. Figure 2.3 illustrates this. A demand curve is shown moving rightward over five time periods. The price level P represents the generalised cost at time 1 when the demand curve is at D_1. Over time, as demand grows, if the generalised cost remained at P, quantity demanded would follow the series of *Q's* along the horizontal axis. This would be the quantities the demand projections aim to estimate. If changes in service levels were taken into account, the quantities would be found at the intersections of the demand and cost curves.

5 Benefits in the form of increased willingness-to-pay would be measured with reference to the demand curve and actual generalised costs incurred including taxes and charges. Benefits in the form of net cost savings would be measured as the areas under the marginal social cost curves.

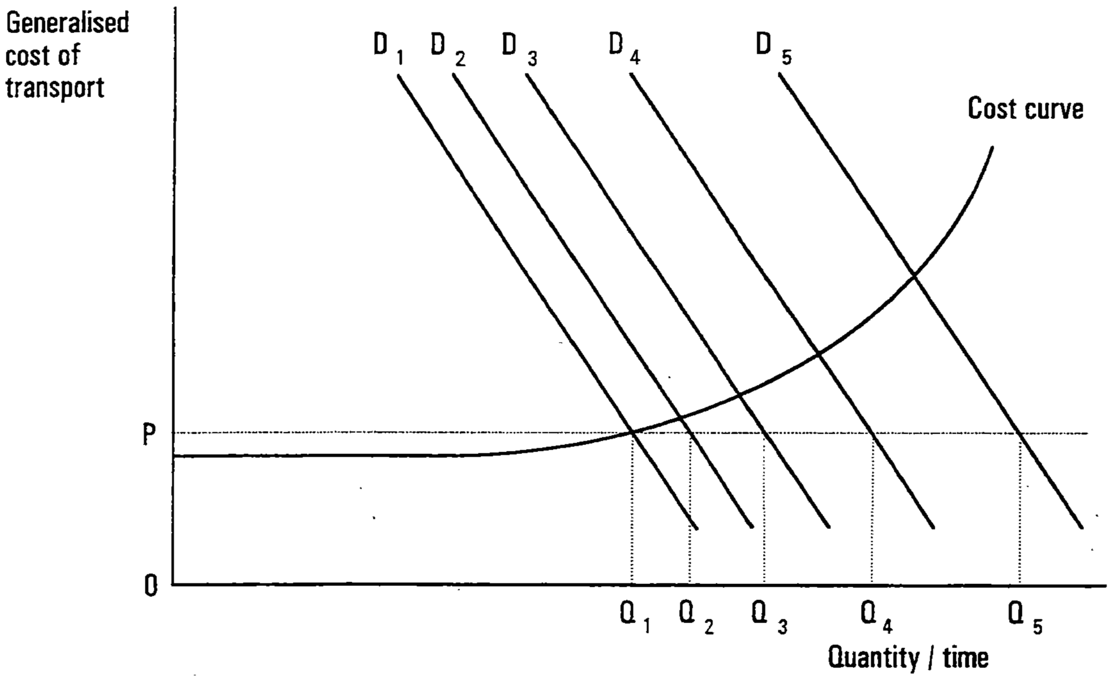

Figure 2.3 Quantity of transport demanded at a constant level of service

Data requirements

An essential component of the research has been a comprehensive program of data collection on the infrastructure being studied. The difficulties encountered by the Bureau in this part of the work have uncovered major deficiencies that exist in knowledge about the physical and performance characteristics and the usage of transport infrastructure in Australia.

Technical assessments

The basic data required are some physical characteristics of each individual piece of infrastructure and details on levels of utilisation. With this information a technical assessment can be carried out by comparing the physical characteristics of each section of infrastructure against predetermined standards or against one another to highlight the worst infrastructure. Utilisation data are essential where physical characteristics are expressed in relation to throughput, for example, trains per day per track. It might be useful to consider the results of the technical assessment alongside data on utilisation, because a piece of infrastructure of low standard but poor utilisation may not be inadequate in the economic sense.

A more sophisticated form technical assessment is based on performance characteristics such as delays, times taken, reliability or operating costs. This requires either data on current service levels or a model which will estimate them. A model normally requires much more detailed data on physical characteristics and utilisation than would be needed for a technical assessment of physical characteristics. Projection of future service levels if forecast demand was to be loaded onto existing infrastructure would also require modelling.

A technical assessment may be employed to identify investment projects and, if the projects can be costed, estimates of the costs of likely future investment needs can be derived. The investments identified would be those which would bring the level of service up to a specified level. This has been one of the approaches followed in the rail assessment. Due to lack of adequate investment in the past the current levels of service provided by most of the rail tracks examined are, on average, poor when compared to best practice benchmarks.

Economic assessments

A problem with moving from a technical to an economic definition of adequacy is that economic adequacy cannot be assessed without specifying how the infrastructure is to be upgraded in order to estimate the costs and benefits of doing so. If alternative ways of achieving the same service improvement are available, all alternatives need to be analysed and compared. As already noted, the technical assessment can assist in identifying projects.

In the present strategic exercise, full scale cost-benefit assessments of potential infrastructure investments are not feasible. The economic assessment work undertaken must necessarily be rudimentary in nature and so only provides a broad guide as to whether investments are warranted. If the data and models are available to predict levels of service provided by infrastructure such as would be required for a technical assessment of performance characteristics, a basic economic analysis is possible provided some additional information requirements are met. These additional requirements include capital costs of investment projects and data on operating costs, including values of time and reliability where these are major benefits from investment projects.

RAILWAY TRACK CAPACITY

The ability of railway authorities to meet current and future demand at reasonable levels of service and cost depends largely on their having adequate infrastructure and rollingstock capacities supported by good managerial and operational practices. Like any other production facility, railways exhibit increasing costs as output is increased beyond a certain point. This is because if more trains enter a specific segment of rail line than the line can reasonably handle at the one time, congestion develops and trains are delayed. This leads to increases in costs both to the railway operator as trains lose productive time, and to customers as delivery times become unreliable.The production process just described is common to all modes of transport. However, the rail production process has some unique characteristics.[6] Rail is fully integrated in its organisation; that is, the railway operators control both the infrastructure and the rollingstock. For other transport production processes the operators have no control or ownership of the infrastructure. They acquire transport infrastructure services on a 'pay-as-you-go' basis. This results in users absorbing the full impact of congestion. On the other hand rail operators can withhold trains (by scheduling) from entering a line to avoid severe congestion. This may result in trains queuing to enter a line and thus increase waiting times.Railway engineering literature identifies a number of definitions for railway line capacity, for example, engineering capacity, ultimate/jam/theoretical capacity and practical capacity. The use for which the definition is being put to will determine which definition is appropriate. Of particular importance to this assessment are practical and economic capacity. However, for the purpose of a broader understanding, the various capacity concepts are discussed below.

Engineering capacity

The US Department of Transportation defines engineering capacity as the maximum possible capacity (number of trains per unit of time) of a railway line under ideal conditions. By ideal conditions is meant the absence of all factors that might adversely affect throughput capability. It assumes that the system has adequate receiving and departure yard facilities. Beyond this capacity the railway line ceases to function and a complete breakdown of service occurs.

Theoretical capacity

Theoretical railway line capacity is referred to variously in some of the literature as jam or ultimate capacity. The Canadian Transport Commission (Khan 1979) defines theoretical capacity as the maximum throughput that is obtainable per unit time under prevailing track and system conditions, such as operating procedures and traffic characteristics. Theoretical capacity would occur when all available track sections, loops and sidings were occupied. For a double track for single directional movement, the condition would occur when spacings between trains are at the minimum headway.[7] Kraft (1982), on the other hand, defines theoretical capacity as the maximum short-term rate at which a rail line is capable of moving traffic, with time taken for recovering

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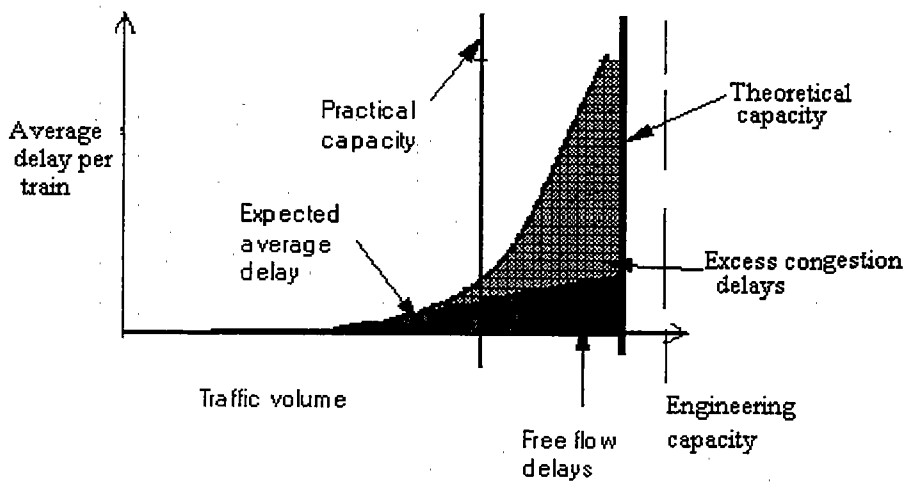
6 The process is changing with privatisation and separation of rollingstock and infrastructure ownership; an example is Swedish railways. There are also a few cases of dedicated ports where operators own or control the infrastructure utilisation.

7 Headway is the running time between separate trains moving in the same direction on a single track.

after jam conditions have developed taken into account. Traffic flow in these conditions is unstable and the slightest disruption will cause it to degenerate into high delay conditions. Yet another definition, based on the 'channel theory',[8] states that rail capacity is simply the number of channels, slots or paths available in a day.

Practical capacity

A variety of definitions for practical rail line capacity have been put forward (Khan 1979). In general terms it is a measure of rail line's capability to produce outputs at a tolerable level of service. Specifically, practical capacity is the level of traffic (number of trains per day) that a rail line can accept without exceeding a specified level of queuing time. Practical capacity is commonly considered to be 60-70 per cent of theoretical capacity.



Source Kraft (1982).

Figure 2.4 Traffic volume vs delay per train

Figure 2.4 shows the relationships between the capacity definitions discussed so far. Traffic volume is plotted on the horizontal axis and average delays per train on the vertical axis. 'Free flow' delays arise from variations in performances of different types of locomotives and rollingstock. 'Excess congestion' delays arise when trains 'meet' and one train has to wait in a

8 The theory simply stated says that trains at various speeds affect track capacity differently. It is therefore convenient to refer to capacity as being the number of train slots available in a day (Canadian National 1979).

passing loop for an opposing train to clear a single track ahead. Closer to theoretical capacity train running becomes highly unstable with associated longer delays to all trains due to domino effects.

Estimating capacity

The above definitions of railway line capacity are expressed in numbers of trains. They do not take into account situations where capacity expansion may not necessarily lead to increased train numbers, for example, raising vertical height clearances to permit double stacking. In such a situation a definition such as expressed in terms of gross tonnes that can be handled over a definitive segment of track within a given period of time may be appropriate.[9]Various studies carried out in Australia, Canada and elsewhere have identified the following as among the indicators of a railway line approaching its maximum throughput:

- decreasing ability to meet existing service specifications;
- diminishing ability to handle new traffic offered;
- increased time required to recover from disruptions;
- difficulty in maintaining the condition of the track structure due to the traffic level; and
- diminishing ability to increase daily production (for example, tonne kilometres per day).

These indicators signal that the fixed infrastructure is approaching capacity constraints, assuming that the rollingstock and other operational aspects are adequate.

The capacity of a railway line may not be uniform along all sections of a corridor. For this reason the first task in estimating capacity is to identify the specific corridor sections where bottlenecks occur. The single rail line section with the severest bottleneck can determine the capacity of the entire corridor. To illustrate this figure 2.5 shows a railway line linking towns *A*, *B*, *C* and *D*. The numbers are the maximum number of trains per day that can move between the towns. In this case the maximum number of trains per day (capacity) for through-trains between towns *A* and *D* would be that between town *B* and *C*, that is, 10 trains per day, even though the other two sections can carry more trains per day. An example is the Sydney to Melbourne rail corridor, which has higher capacity on the double track between Sydney and Junee and lower capacities on the single track between Junee and Melbourne. The Sydney to Melbourne rail corridor through-traffic capacity is determined by one of the sections of the single track links (Junee to Melbourne).

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9 Canadian National Rail definition.

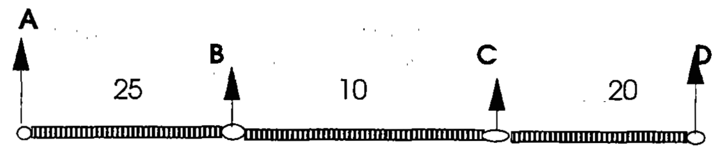

Figure 2.5 Ruling capacity

1A common method for estimating rail line capacity is via computer simulation models such as 'M-Train' used widely by consultants and rail authorities. Simulation models have their shortcomings. As pointed out by Kraft (1988), they may contain a significant amount of hidden statistical sampling error. Most simulation models follow the approach of loading the rail line to its theoretical capacity by 'flooding' the line with trains at both ends. The maximum number of trains handled per day under these conditions is the theoretical capacity. The practical capacity is derived by applying a safety factor, usually 60-70 per cent, as demonstrated in figure 2.6, which shows the impact on a line section of 650 kilometress with 19 sidings (refer appendix II).

A reasonable estimation of the theoretical capacity of a 'single' rail line can be obtained from a simple mathematical formula. In this report, capacity has been estimated by a combination of 'judgment' based on industry experience and a mathematical formula of the form

$$C = {}^{24-d}\!\Big/\!\sum t_1 t_2 w_1 w_2$$

where C = line capacity expressed as maximum number of trains in each direction per day;

t_1t_2 = the sum of running times in both direction of the slowest type of train over the longest block section, inclusive of loop crossing time;

w_1w_2 =the sum of waiting times at each end of the relevant block section; and

d = average daily downtimes due to breakdowns or maintenance.

Waiting time plus crossing time is equivalent to signal response time.

This formula assumes that all trains run over the whole length of the line for which capacity is being assessed. The 24 is the number of hours in a day.

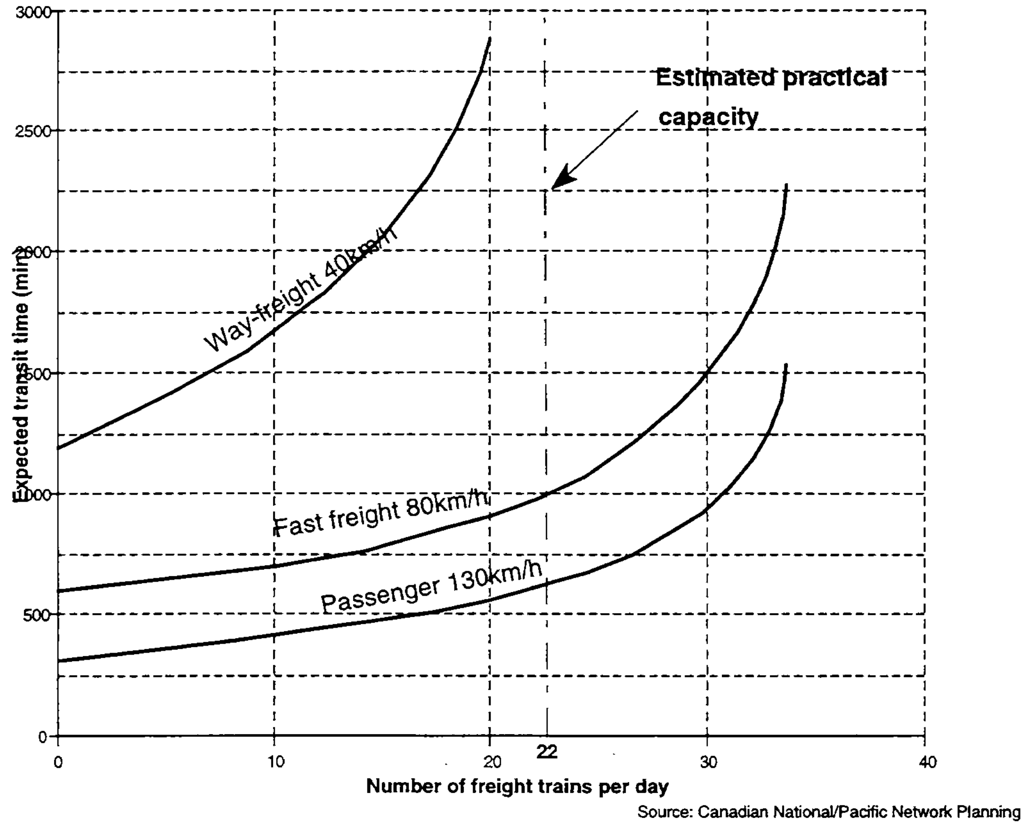

Figure 2.6 Train speeds vs practical and theoretical capacity

Double track capacities have been estimated on the assumptions that trains operate in a single direction on each track and there are no 'overtake passes'. Capacities for urban corridors were not modelled.

CONCLUSION

The approach to assessing infrastructure adequacy outlined above offers great flexibility in terms of the depth of analysis, and this is essential given the variations in degrees of data availability and ease of modelling between the modes. At the lowest level is the technical review of the physical characteristics of infrastructure. The next level is a technical assessment of adequacy based on current and projected infrastructure performance in terms of service levels. This has the advantage that it can formally incorporate demand projections. In some cases, by using the technical assessment to identify potential projects and estimating the costs of these projects, it has been possible to forecast future investment needs. Finally, if it is possible to specify investment projects and estimate costs and benefits, there is the economic assessment. This too may be undertaken in varying degrees of depth ranging from a 'back of the envelope' calculation to a major cost-benefit study. The study described in the present series of papers, with its strategic focus, would not aim to go beyond cost-benefit studies at a rudimentary level.

CHAPTER 3 CURRENT RAIL INFRASTRUCTURE

INTRODUCTION

This chapter describes the infrastructure assessed in the study. In order to assess the adequacy of rail linehaul and terminal infrastructure, the Bureau selected the rail corridors and terminals listed in table 3.1. These were selected on the grounds that they were considered to be of national strategic economic significance. Figure 3.1 maps the corridors, which total some 12 000 km in length, with 1992-93 freight carried plotted against each corridor. Most of Australia's intercapital rail network is single track at standard gauge (1435 mm). The exception is Melbourne to Adelaide, which is currently broad gauge (1600 mm), but this will soon be converted to standard gauge. The Brisbane-Cairns and Hobart-Burnie corridors are narrow gauge (1067 mm).

The remainder of this chapter consists of brief descriptions of the physical characteristics and corridor and terminal. Detailed statistics are provided in appendix tables I.1 to I.3.

TABLE 3.1 CORRIDORS AND TERMINALS EXAMINED

Corridors - linehaul	*Corridors - urban*	*Terminals*
Brisbane-Cairns	Acacia Ridge-Fisherman Islands	Acacia Ridge
Sydney-Brisbane	Chullora-Botany	Chullora
Sydney-Melbourne	Islington-Port Adelaide	South Dynon
Melbourne-Adelaide	Kewdale-Fremantle	Islington
Adelaide-Perth		Alice Springs
Adelaide-Alice Springs		
Sydney-Adelaide		Hobart, Burnie
Hobart-Burnie		Fyshwick
Canberra-Goulburn		

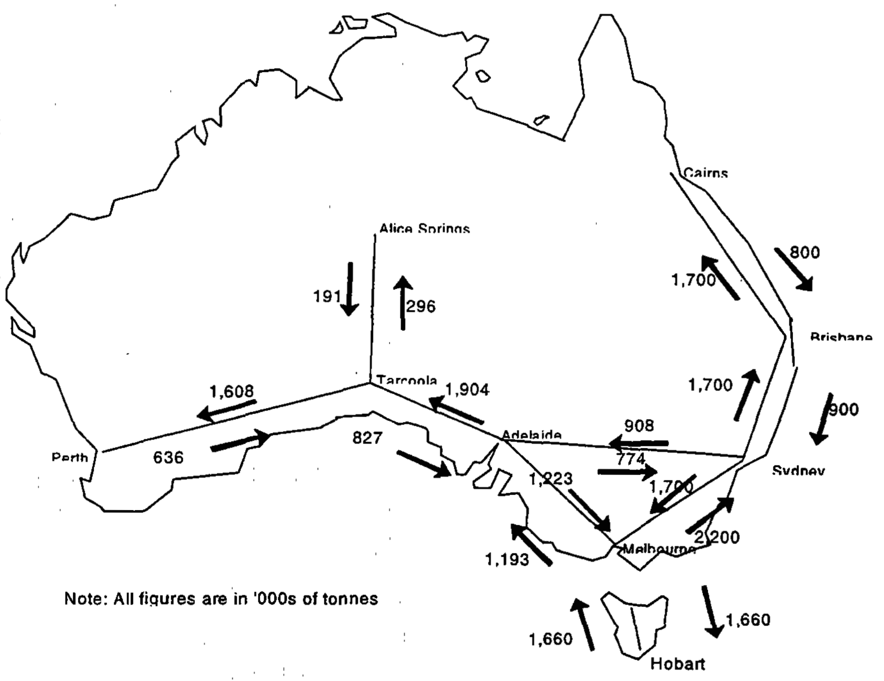

Figure 3.1 Rail corridors examined and annual tonnages carried 1992-93

LINEHAUL CORRIDORS

Brisbane-Cairns

This corridor is one of the longest in Australia (1680 km), equivalent to the Brisbane-Sydney and Sydney-Melbourne corridors combined. The track between Brisbane and Rockhampton is high quality continuous welded rail (CWR), mostly on concrete sleepers, and is electrified to 25 kV with a nominal contact wire height of 4.7 m and a minimum wire height of 4.4 m. Although the contact wire constrains the system, tunnels and bridge structures above the wire and less than 4.8 m in height are the real vertical clearance constraints. There are also 367 turnouts that are at a standard less than 1 in 16 with 60 kg/metre rail. The track section between Rockhampton and Cairns is comprised of 41 kg rail supported on timber sleepers. Queensland Railway's Main Line Upgrade Program of investment (MLU) is replacing and upgrading bridges to 20 tonne axle loads and M160 loadings.[1] Signalling consists of Centralised Traffic Control (CTC) between Brisbane and Townsville and Train Order between Townsville and Cairns.

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1 A load rating based upon a theoretical steam locomotive with driving wheels of 16 tonnes (M220 is 22 tonnes; M270 is 27 tonnes).

Sydney-Brisbane

This corridor is 970 km long in total. It consists of double track from Chullora to Maitland, and single track from Maitland to Acacia Ridge. Loops are 1500 m long with spacing at 25 to 30 minutes of running time. The corridor track is in 53 kg rail laid on timber sleepers, with a small proportion of the track on concrete sleepers, mainly in some areas of tight radius curves. This corridor also has some of the lowest average speeds on the network due to the steep gradients (Chullora-Newcastle) and level crossings. The major clearance constraint is the clearance of approximately 4.1 m on a number of structures. There are 158 structures less than the State Rail Authority standard of 4.88 m height. In addition the section between Chullora and Newcastle is wired, with a minimum wire height of 4.57 m. CTC signalling is employed between Chullora and Grafton, with Grafton to Acacia Ridge consisting of electric staff system.

Sydney-Melbourne

This is the most heavily trafficked rail corridor in the rail network. The corridor is approximately 960 km long. The route consists of double track between Chullora and Junee, and the rest is single track with loops up to 900 m in length spaced at 20 minutes of sectional running time. The major clearance constraint is the clearance of approximately 4.1 m on a number of structures. A 32 km section of the Chullora to Goulburn sector is steeper than the standard of the remaining links of 1 in 50. The track generally has been in poor condition. However, some investment has been made under the One Nation program to raise speeds and axle loads between Melbourne and the Victorian border, through re-railing in 60 kg/m into continuous welded rail (CWR) and re-ballasting the track. The Bethungra spiral between Cootamundra and Junee has been upgraded and re-laid in 60 kg rail on concrete sleepers. Signalling is mostly CTC (Chullora-Goulburn has CTC and automatic block signalling; Goulburn-Junee has CTC and block telegraph for 22 km; Junee-South Dynon has CTC).

Sydney-Broken Hill-Adelaide

This corridor is approximately 1635 km and is single track outside the Sydney Cityrail area. Loops are 800 m long east of Broken Hill at 20 minute intervals, and 990 m long west of Broken Hill at 30-50 minute intervals. The line between Chullora and Parkes is characterised by very large gradients and high curvatures which impact heavily upon train lengths and trailing tonnages. The track consists of timber sleepers east of Broken Hill and concrete sleepers west of Broken Hill to Crystal Brook and Adelaide. Rail size is generally 47 kg or greater. All turnouts west of Broken Hill are 1 in 9, requiring 35 km/hr speed. The track and bridges permit 19 tonne axle loads east of Broken Hill and 23 tonne axle loads west of Broken Hill. Tunnels and overhead structures cause a height restriction of 4.1 m between Chullora and Parkes as distinct from 5.9 m height clearance for the rest of the corridor. Various signalling systems are being used, with the very inefficient staff and ticket (manual) system, on the Parkes-Broken Hill section.

Melbourne-Adelaide

The new route through Geelong is approximately 796 km. It follows the existing Sydney-Melbourne standard gauge track between the South Dynon yard as far as Tottenham (outer Melbourne suburb), and then dual standard gauge track to Newport. From Newport to North Geelong the track is new standard gauge (under construction and due for completion in late 1995). The remainder of the track to Adelaide is broad gauge, and is currently being converted to standard gauge as part of the One Nation investment program. The completion of One Nation funded projects on this corridor will complete the last link in the standard gauge network, to connect Brisbane, Sydney, Melbourne, Adelaide and Perth.

Adelaide-Perth

This is the longest corridor in Australia, totalling 2627 km. The route has the lowest grades and curvatures in the rail network. The corridor's clearances of 6.7 m height permit double stacking of containers, improving its capacity and efficiency. The high standard of track and the low number of trains, all carrying heavier loads than elsewhere, combine to give this corridor very low costs per tonne of freight compared with the eastern corridors.

Adelaide-Alice Springs

This corridor shares the same track as Adelaide-Perth as far as Tarcoola, about 711 km north-west of Adelaide. The Tarcoola to Alice Springs railway is the newest section of railway line in the rail network, having been completed in the early 1980s. However, it carries the lightest traffic of any corridor, with only 296 000 tonnes north and 191 000 tonnes south in 1992-93. As the corridor has a minimum clearance of 6.5 m, it is suitable for double stacking.

Hobart-Burnie

This corridor carries 1.6M tonnes annually, mainly in bulk commodities. The corridor has very steep ruling grades and low maximum trailing loads, with maximum permissible speed for the corridor of 70km/hr. Average speeds performed are very low, 37km/hr between Hobart and Devonport and 50km/hr between Devonport and Burnie.

Goulburn-Canberra

The Goulburn-Canberra line is 100 km, and links Canberra with the main Sydney to Melbourne line. The track is single with 526 m long loops spaced at intervals 40-50 minutes running time. Three passenger trains and one freight train carrying fuel and parcels traverse the branch line daily. A bulk train carries concentrate from a mine siding at Tarago. Annual tonnages on the line are comprised of 180 000 tonnes of bulk fuel and 117 000 tonnes of concentrate.

URBAN CORRIDORS

In a number of cities, corridors through urban areas connect the main rail terminal with the local port. The key physical attributes of the significant urban corridors are shown in appendix table I.3 and are briefly described below.

Chullora-Botany

This corridor is a freight line and is not affected by passenger train activities. Passenger and freight trains mix, however, over other parts of the Sydney urban network. The State Rail Authority of New South Wales is constructing two 1500 m and two 800 m tracks at Port Botany, to enable freight trains to be held and to be run through the Sydney urban area at times of lowest passenger train activity.

Acacia Ridge-Fisherman Islands

A standard gauge track is currently being constructed between Dutton Park and Fisherman Islands and is expected to be available for the first train in mid-1995. This will have the effect of completely separating freight traffic from the suburban passenger system apart from some express passenger trains to the Gold Coast. Although the axle loading of the track is at 20 tonnes, it could be upgraded at relatively low cost by the replacement of understrength bridges on the existing standard gauge line. The dominant freight activity on this corridor (2.7M tonnes) is the coal traffic from the West Moreton collieries (on narrow gauge).

Islington-Port Adelaide

This corridor is separated from the passenger traffic. A full 6000 tonne train can access the terminal. There is very little rail traffic (100 000 tonnes per annum) accessing this port.

Kewdale-Fremantle

The major user of this corridor is the Kwinana steel plant. Full size trains of up to 9000 tonnes can access the Fremantle terminal. However, very little rail traffic utilises this corridor.

URBAN FREIGHT TERMINALS

Terminal characteristics are set out in detail in appendix table I.2. Brief descriptions are provided below.

Chullora

This terminal has the most restrictive infrastructure of all the major terminals. There is only one arrival/departure track, of 700 m, which limits train length, and only two handling tracks under the gantries. The storage capacity to throughput ratio for containers is very low compared with other terminals. Interstate traffic at Chullora will use Enfield in the longer term when National Rail Corporation's (NRC) upgrading works, due to start in 1995, are completed.

South Dynon

South Dynon is the most heavily used terminals and has undergone a major extension under One Nation. Phase One of NRC's upgrading program will provide two new tracks capable of handling 1200 m trains. Ultimately, five tracks of up to 1500 m in length are planned.

Acacia Ridge

The terminal at Acacia Ridge has a single 1200 m track (dual gauge) for container handling and two 400 m long tracks under the gantry. This terminal has a similar loading and unloading capacity to Chullora in relation to throughput, but has a wider area and storage capacity than Chullora.

Fyshwick

The Fyshwick terminal only handles a small amount of parcel freight and one bulk fuel train per day. The freight is not time sensitive and therefore does not have capacity problems of significance.

Islington

Islington is being developed to four 1200 m tracks with an adjacent storage area.

Kewdale

This terminal has arrival/departure tracks which provide a large capacity.

Hobart and Burnie

These terminals have less space and lower crane and loading capacity compared with mainland terminals, but this is commensurate with the small intermodal traffic task in Tasmania.

Alice Springs

Alice Springs terminal has adequate intermodal storage given the light density of traffic.

CHAPTER 4 DEMAND

INTRODUCTION

Assessing infrastructure adequacy involves comparing future demands with existing infrastructure capacity. This chapter sets out the demand projections for rail infrastructure usage and describes the methodology and assumptions behind them. The period covered is the 20 years from 1995-96 to 2014-15 inclusive.

Adequacy needs to be assessed on a link by link basis taking into account not only freight travelling from one end of a corridor to the other, but also freight entering and leaving at intermediate points as well as passenger trains. The demand projections are summarised below as corridor averages, but actual capacity assessments are undertaken using link projections and these are presented in the final section of the chapter.

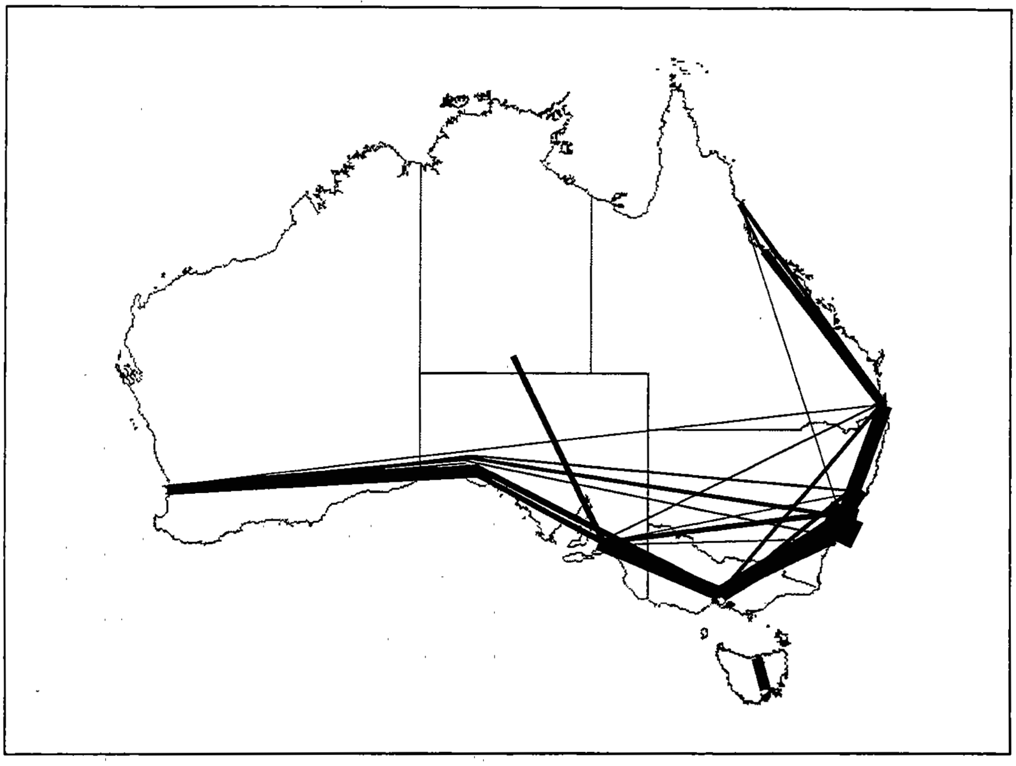
Interstate rail freight in Australia tends to be primarily general freight capable of unitisation. The major industrial freight movements on most corridors are currently steel products, but in the future they may include chemicals, petroleum and other bulk products. Other bulk freight such as coal or grain is usually short-haul intrastate traffic.

Corridor end-to-end rail freight projected to 1994-95 is plotted in figure 4.1. In contrast to road interstate freight flows (see Working Paper no. 14.1), the rail freight flows are much more uniform around the coast. Compared to road freight flows, rail has greater shares of the market between Adelaide and Perth and Adelaide and Alice Springs, reflecting rail's advantage over long distances and the quality of the rail infrastructure on those routes.

FUTURE DEMAND

Methodology and assumptions

The rail demand growth forecasts for interstate freight were derived by firstly examining National Rail Corporation's (NRC) five year projections and



Source Derived from figures supplied by the Centre for Transport Policy Analysis Wollongong.

Figure 4.1 Rail freight task 1994-95

reviewing the long-term impact of route changes, such as for the Sydney-Adelaide rail corridor. Once the Melbourne-Adelaide standard gauge track is opened in 1995, most Sydney-Adelaide freight will travel via Melbourne. The implications of lower density freight and lighter trains were also considered. The Bureau accepted the NRC's growth rates to 1997-98. These rates are high because they reflect service improvements arising as the One Nation package of investments is implemented and NRC's establishes itself in the market. It was considered that these high growth rates could not be sustained into the future if service levels remain constant. Hence lower growth rates were adopted for the period 1997-98 to 2014-15.

It was assumed that passenger traffic will continue to grow at a rate less than population growth. For the non-NRC corridors, Brisbane-Cairns, Adelaide-Alice Springs and Hobart-Burnie, growth rates were obtained by adjusting past trends to reflect future expectations. Intrastate freight estimates were derived from the database used in railcost model developed by Travers Morgan. The database provides estimated gross tonne kilometres and train kilometres per year for each link, broken down into interstate and intrastate freight and passenger movements. The intrastate freight projections were made with reference to crude material, food and livestock trends and and past intrastate

TABLE 4.1 RAIL DEMAND

Corridor	1995-96 freight volumes (million tonnes) Average	Corridor	2014-14 freight volumes (million tonnes) Average	Corridor	Change 1995-96 to 2912-15 (%) Average	Corridor	Average annual growth rate (%) Corridor
Melbourne-Adelaide	6.5	5.2	8.8	7.5	35	44	1.9
Sydney-Melbourne	7.5	5.1	11.4	8.0	52	57	2.4
Sydney-Brisbane	5.0	3.9	8.2	5.5	64	41	1.8
Brisbane-Cairns	4.5	2.7	5.7	3.1	27	13	0.6
Adelaide-Perth	na	2.6	na	4.0	na	54	2.3
Hobart-Burnie	1.6	na	1.8	na	13	na	na
Sydney-Adelaide	1.1	na	1.3	na	18	na	na
Adelaide-Alice Springs	0.8	0.8	0.9	0.9	13	13	0.6
Canberra-Goulburn	0.3	0.3	na	na	na	na	na

na Not available or not applicable

Source BTCE estimate, Travers Morgan consultants; Maunsell consultants.

freight trends generally. It was assumed the growth would be modest. These are the dominant commodities that drive the intrastate freight market.

Tonnage projections

The demand projections for freight on rail corridors are summarised in table 4.1. The tonnages shown in the 'average' column are distance weighted averages along corridors, that is, tonne kilometres divided by kilometres. The corridor tonnages are freight travelling the entire length of each corridor.

In terms of distance weighted averages, Sydney-Brisbane and Sydney-Melbourne have the highest growth rates. Brisbane-Cairns also is expected to grow relatively fast (a total growth of 27 per cent is expected, mainly in the intrastate tonnages, in particular coal and ores between Gladstone and Rockhampton). With road freight forecast to grow at 3 per cent (see Working Paper no. 14.1), rail is expected to lose market share to road, on the assumption that service levels provided by the infrastructure remain unchanged after 1996-97.

Sydney-Melbourne and Adelaide-Perth have the highest growth rates for corridor traffic, reflecting rail's advantages over road on high volume and long distance routes.

TABLE 4.2 RAIL TRANSPORT DEMAND: TRAINS PER DAY

	Average freight trains trains per day total both directions						*Average passenger trains per day total both directions*	
	1995-96		*2014-15*		*% change in corridor 1995-96 to 2014-15*	*Average annual corridor % growth rate*		
Corridors	*Average*	*Corridor*	*Average*	*Corridor*			*1995-96*	*2014-15*
Melbourne-Adelaide	9	7	12	10	25.0	1.2	2	2
Sydney-Melbourne	15	10	23	16	50.0	2.2	10	10
Sydney-Brisbane	10	8	17	11	37.5	1.7	4	4
Brisbane-Cairns	15	9	19	10	11.1	0.6	4	4
Adelaide-Perth	na	3	na	5	66.7	2.7	2	2
Hobart-Burnie	4	na	4	na	na	na	na	na
Sydney-Adelaide[4]	2	na	2	na	na	na	2	2
Adelaide-Alice Springs	na	2	na	2	0.0	0.0	1	1
Canberra-Goulburn	2	2	na	na	na	na	6	na

Notes 1. Average train numbers are corridor and intrastate trains combined.
2. Corridor columns include trains travelling the ull length of the corridor.
3. Passenger trains are interstate trains only.
4. Sydney-Adelaide corridor assumes no freight traffic between Parkes and Broken Hill.

Source BTCE; Travers Morgan (1994).

Train numbers projected

Table 4.2 shows the forecast freight tonnages converted into train numbers, and also passenger train numbers. These are distance weighted average train numbers, that is, train-kilometres divided by track kilometres. The numbers for passenger trains are interstate trains and do not include the large numbers of urban services at corridor ends. Growth rates for train numbers on most corridors are well below those for freight, because they are adjusted for expected use of longer, heavier trains.

Tonnage projections by link

Figures 4.2a to 4.2f present the demand in tonnages by corridor-links for 1992-93 and as projected to 1995-96 and 2014-15. The link tonnages are themselves distance weighted averages. All figures are on the same scale. A general observation is that links closer to Sydney have the highest demands compared to links closer to other capital cities. Brisbane-Cairns tonnages peak between Gladstone and Rockhampton due to the large tonnages of coal moving along this link. The Melbourne-Adelaide corridor shows a near even flow due to the high proportion of freight having origins or destinations beyond the corridor ends (Sydney-Adelaide, Sydney-Perth and Melbourne-Perth traffics).

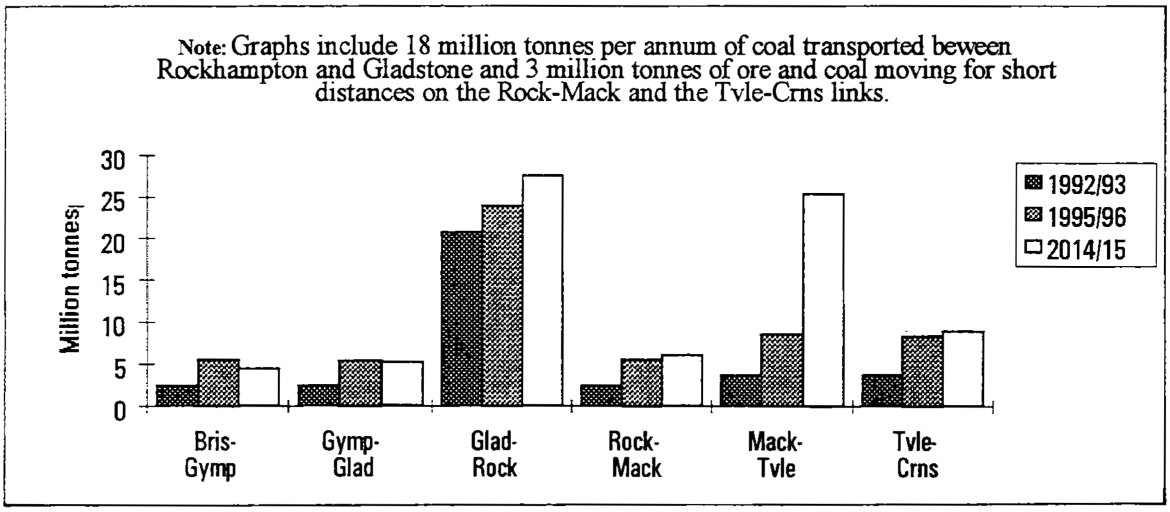


Figure 4.2(a) Corridor-links demand Brisbane-Cairns

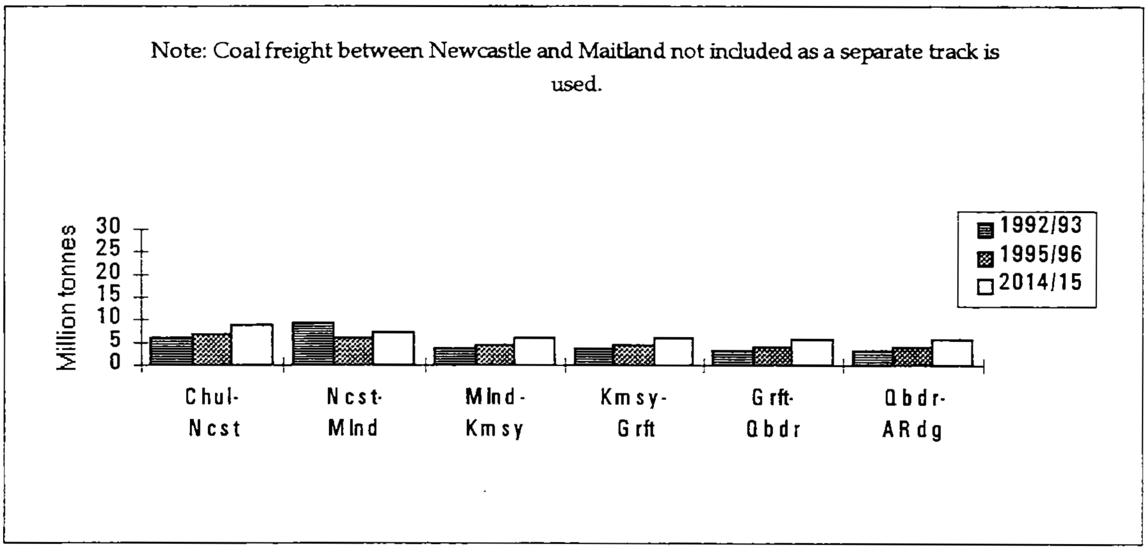


Figure 4.2(b) Corridor-links demand Sydney-Brisbane

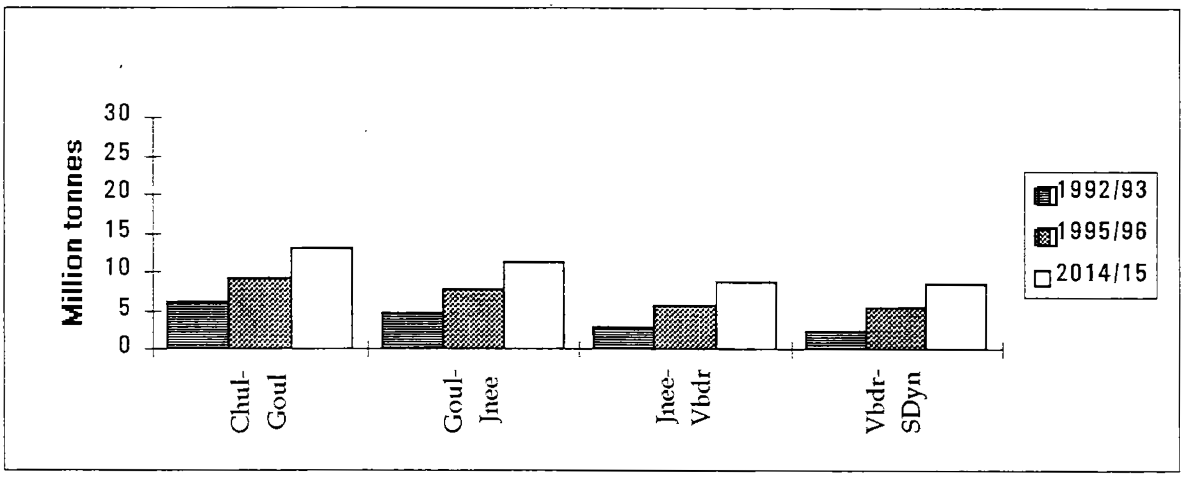


Figure 4.2(c) Corridor-links demand Sydney-Melbourne

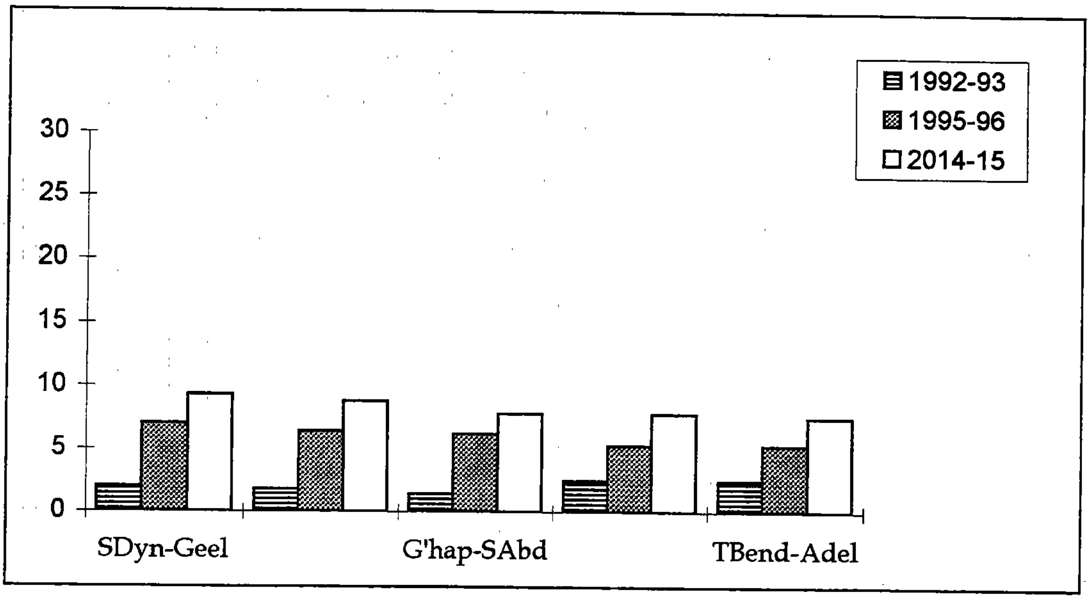


Figure 4.2(d) Corridor-links demand Melbourne-Adelaide

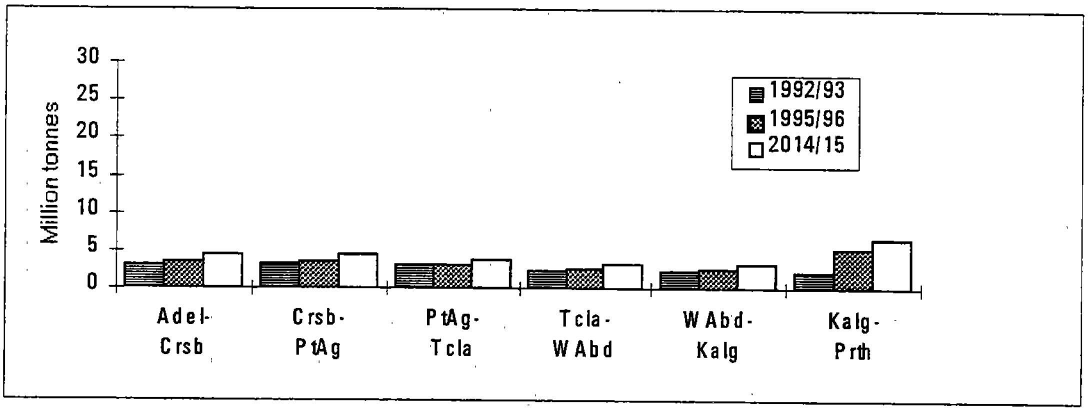


Figure 4.2(e) Corridor-links demand Adelaide-Perth

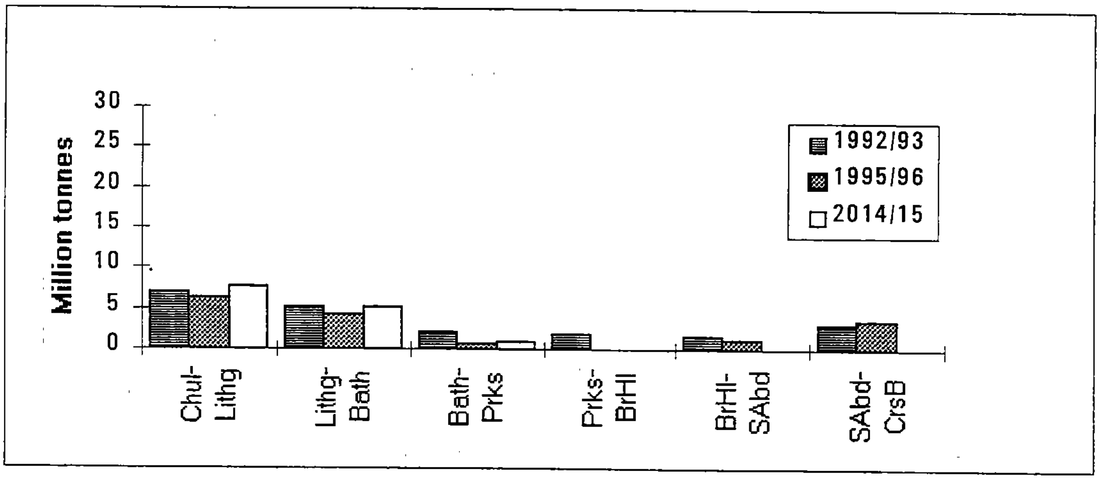


Figure 4.2(e) Corridor-links demand Sydney- Adelaide

CHAPTER 5 TECHNICAL ASSESSMENT OF ADEQUACY

INTRODUCTION

As discussed in chapter 2, the Bureau's assessment methodology involves technical and economic stages. For rail it has been possible to undertaken both types of assessment. This chapter deals with the technical assessment covering linehaul corridors, terminals and urban corridors. The technical assessment has been undertaken in the most detail for linehaul infrastructure, where both physical and performance characteristics are compared against benchmarks to enable sections to be ranked against one another in relative terms. Practical capacity levels are compared with demands for both tracks and terminals.

LINEHAUL CORRIDORS

Methodology

Technical assessment of the adequacy of intercity rail infrastructure was undertaken by comparing actual infrastructure characteristics and performance with benchmarks set to represent best practice standards. It is not suggested that these standards are appropriate targets for an investment program to achieve. The standards only serve to facilitate comparisons between sections of rail track.

Two sets of standards were devised, the first specifying physical characteristics and the second, performance characteristics. For physical characteristics the target standards are shown in table 5.1. For performance characteristics, the target standards were capacity relative to demand, cost per net tonne kilometre, transit time, average speed and service reliability.

The maximum practical capacities have been estimated for each corridor. As explained in chapter 2, the practical capacity of a corridor is governed by the link with the least capacity. The amount of capacity available in the corridor in trains per day for interstate traffic was obtained after taking out intrastate freight and passenger trains. 1995-96 and 2014-15 demand projections were

TABLE 5.1 BENCHMARK DESIGN STANDARDS

Attribute	*Target Standard*	
Axle load	23 tonne at 110 km/hr (1995) 25 tonne at 160 km/hr (2014)	
Clearance	Horizontal 2600 mm vertical 6 825 mm	
Gradient	Maximum 1 in 50 preferred 1 in 100	
Gauge	1 435 mm tolerance -0 + 3 mm	
Level crossings	Paving concrete slabs Protection booms and flashing lights Signage to AS 1743 and 1744	
Signalling	Advanced Train Control System (ACTS) (type to be determined)	
Track structure	Rail weight	53 and 60 kg/m
	Sleepers	concrete
	Sleeper spacing	670 mm tangent track
	Fasteners	resilient
	Ballast depth	300 mm
	Sub-ballast depth	- 150 mm
Track curvature	Railways of Australia *Manual of Engineering Practice* (min 800 m radius)	
Maxm train speeds	115 km/hr by 1997 (23 tonne axle), 160 km/hr by 2014 (25 tonne axle)	
Maximum train length	1800 m western corridors, 1500 m eastern corridors	

Source Maunsell Consultants 1994.

converted into trains per day. It is widely accepted that practical capacity is some 60-70 per cent of the theoretical maximum and this represents the level of utilisation at which a line can provide a tolerable level of service (Kraft 1988).

Two types of production cost have been used as a performance measure, fully distributed and avoidable.. They were estimated using a spreadsheet rail costing model. In the estimation of the avoidable costs, it was assumed that a standard train moves a specified load, for example 3M tonnes, per annum. For each trip, the train is assumed to be loaded and operated at the maximum practical level within the constraints imposed by the track and the need to maintain a reasonable speed given engine power. The physical characteristics of the track affect the performance of trains via the average speed, fuel consumption, train freight carrying capacity, train maintenance costs, and fixed infrastructure costs. For the purpose of setting the cost per tonne kilometre benchmark, the best practice cost was taken as that for the least cost corridor under these assumptions (refer table 5.6).

TABLE 5.2 ROAD AND RAIL MARKET STANDARDS

	Road actual 1992/93			*Rail actual 1992/93*			*Rail expectation 2014/15*		
Corridor	*A*	*B*	*C*	*A*	*B*	*C*	*A*	*B*	*C*
Brisbane-Cairns	2	22	75	2	30	60	1	18	100
Brisbane-Sydney	1	13	75	1	14	80	1	12	100
Sydney-Melbourne	1	12	80	1	14	80	1	12	100
Sydney-Adelaide	1	20	85	2	30	60	1	18	100
Melbourne-Adelaide	1	10	80	1	12	80	1	10	100
Adelaide-Perth	2	30	85	2	36	80	2	30	100
Adelaide-Alice Springs	1	18	85	1	22	80	1	18	100

A Morning of delivery. Example overnight = 1
B Hours from acceptance closure to delivery available
C Average train/truck speed

Source Maunsell Consultants 1994.

Transit time standards were set with reference to the times road transport can achieve including allowance for improvements in road performance over the next 20 years. That is not to say that rail is expected to achieve the same transit times as road, but that rail will not be so far behind road as to make it an unacceptable alternative in the eyes of its customers. Table 5.2 lists the market standards for transit and delivery times set by road transport as at 1992-93 and compares these to actual rail standards in that year and the rail benchmarks set for 2014-15. The 2014-15 standard for rail is overnight delivery for all corridors except for Adelaide-Perth, where two days are allowed.

Reliability is the ability of rail to consistently deliver freight within the contracted variances of the service plan for a particular freight client. Generally, the timetable and service plans will include some allowance for delays. Ideally reliability would be assessed from the variability of arrival times, but the data are not available. As a proxy, the difference between the actual and maximum possible transit times was employed. The standard was set at five minutes difference per 100 kilometres.

Some of the standards described above are higher for 2014-15 compared to 1995-96. This is because best practice rail standards and the performance of the competing road mode are both expected to improve over the period.

The assessment of rail infrastructure adequacy assumes that the One Nation and Queensland's MLU programs of investments have been completed. One Nation is a $429M program financed by the Federal Government being undertaken over the period 1992 to 1995 and MLU is a $580 million (revised) upgrading program financed by the Queensland State Government over the period 1992 to 1997.

Deficiencies are indicated below for the Sydney-Adelaide corridor, but these can be ignored, because once the One Nation project to provide a standard gauge line between Melbourne and Adelaide has been completed, most of the interstate freight on the Sydney-Adelaide line will presumably switch to the route via Melbourne.

Results

Assessment based on physical characteristics

The results of the technical assessment using physical indicators are summarised in table 5.3 using unweighted average deficiency ratings for corridors and links. Components of the averages are set out in appendix table III.1. The ratings are simply the ratios of actual infrastructure measurement to the benchmark standard. For example, if a corridor or link has a ruling vertical clearance of say 4.1 m and the benchmark for clearance is 6.8 m, the deficiency rating for the corridor for clearance will be 0.6. The arithmetic mean is then taken for all the attributes of the corridor or link. The picture that clearly emerges is that the deficiencies occur along corridors east of Adelaide. The worst links in 2014-15 according to this assessment, with scores of 0.5 and below, are Goulburn-Junee, Grafton-Acacia Ridge, Chullora-Broken Hill and Hobart-Burnie.

Other findings of the technical assessment using physical indicators are that:

- Rail weights along most of the lengths of all corridors are below the benchmark;
- The greater part of most corridors have timber sleepers, which results in greater speed restrictions and higher maintenance costs;
- All corridors east of Adelaide are deficient in clearances. These restrict loading heights;
- Some gradient deficiencies exist on all eastern state corridors. Steep grades necessitate greater loco power, restrict trailing loads, and add to fuel consumption.;
- Outdated train control and signalling systems exist on the Parkes-Adelaide, Townsville-Cairns and Port Augusta-Kalgoorlie links;
- Curves are particularly bad on the Brisbane-Cairns and Sydney-Brisbane corridors and the Sydney-Junee link. Tight curves restrict speed and increase resistance and wear and tear on track and rollingstock.

Assessment based on performance characteristics

Results of the technical assessment using performance indicators are summarised for corridors and links as unweighted averages in table 5.4.

TABLE 5.3 CORRIDOR AND LINK PHYSICAL DEFICIENCY RATINGS

Rail corridors and links	Average rating 1995-96	Average rating 2014-15
Sydney-Melbourne	**0.6**	**0.5**
Chullora-Coulburn	0.6	0.6
Goulburn-Junee	0.6	0.5
Junee-Vic border	0.6	0.6
Nsw border Seymour	0.6	0.6
Seymour-South Dynon	0.6	0.6
Sydney-Brisbane	**0.7**	**0.5**
Chullora-Newcastle	0.6	0.6
Newcastle-Maitland	0.7	0.6
Maitland-Kempsey	0.7	0.6
Kempsey-Grafton	0.6	0.6
Grafton-Qld border	0.5	0.5
Nsw border-Acacia-Rdg	0.5	0.5
Canberra-Goulburn	**0.5**	**0.5**
Melbourne-Adelaide	**0.8**	**0.6**
Melbourne-Nth-Geelg	0.9	0.9
North gel- Gheringhap	0.8	0.8
Gheringhap-SA border	0.8	0.7
Vic border-Tailem bend	0.8	0.8
Tailem bend-Adelaide	0.7	0.6
Sydney-Adelaide	**0.6**	**0.5**
Chullora-Parkes	0.5	0.4
Parkes-Broken hill	0.6	0.5
Broken hill-SA border	0.9	0.8
Nsw border-Crst Brook	0.9	0.8
Brisbane-Cairns	**0.7**	**0.6**
Brisbane-Gympie	0.8	0.8
Gympie-Gladstone	0.8	0.8
Gladst-Rockhampton	0.8	0.8
Rockhampton-Mackay	0.7	0.7
Mackay-Townsville	0.7	0.7
Townsville-Cairns	0.6	0.6
Adelaide-Perth	**0.9**	**0.8**
Adelaide-Crystal Brook	0.9	0.8
Crystal brk-Prt Augusta	0.9	0.8
Port Augusta-Tarcoola	0.9	0.8
Tarcoola-WA border	0.9	0.8
SA border-Kalgoorlie	0.9	0.9
Kalgoorlie-Perth	0.9	0.9
Adelaide-Alice Springs	**0.8**	**0.8**
Tarcoola-NT border	0.8	0.8
SA border-Kalgoolie	0.8	0.8
Hobart-Burnie	**0.5**	**0.5**
Hobart-Western Juct	0.5	na
Western Juct-Devport	0.5	na
Devonport-Burnie	0.5	na

Note Rating of 1.0 is the highest level of adequacy.

Source BTCE estimateMaunsell consultants (1994);

Melbourne-Adelaide, Sydney-Brisbane, and Brisbane-Cairns have the lowest ratings in 2014-15. Looking at individual link ratings, the worst links on these corridors would be respectively, Tailem Bend-Adelaide, Maitland-Kempsey, and Brisbane-Gympie/Townsville-Cairns.

Table 5.5 shows estimated practical capacities for corridors in trains per day after taking out trains entering and leaving corridors at intermediate points. These are compared in the table to estimated numbers of corridor trains, both passenger and freight. The 1995-96 infrastructure is post One Nation and assumes that trains are at the maximum possible lengths given passing loop lengths. Train numbers are assumed to increase over the period in proportion to freight volume.

The table shows that all corridors have sufficient capacity to cope with the expected demand at both 1995-96 and 2014-15 levels. However, for a given level of demand a trade-off exists between train length and service frequency. It is possible that, in the coming years, freight markets will demand more frequent services. As a sensitivity test, table 5.5 shows the demand for capacity at 2014-15 assuming a 20 per cent increase in daily train numbers. A shortage of capacity would then be expected to exist on the Sydney-Melbourne corridor, the problem being on the single track section south of Junee. Figures 5.1(a) to 5.1(f) show estimated link capacities against expected demand in 2014-15. The only link where demand is forecast to exceed capacity (subject to MLU) is the Brisbane-Gympie link. This was omitted from table 5.5 because of uncertainty about the extent to which MLU would address the cpacity constraint.

Estimated costs per kilometre and percentages by which they exceed the cost for the 'best practice' corridor, Adelaide-Alice Springs, are shown in table 5.6 for corridors and links. Brisbane-Cairns is the most expensive of the major corridors at 82 per cent above best practice, followed by Sydney-Brisbane (56 per cent) and Sydney-Melbourne (45 per cent). The Brisbane-Gympie and Townsville-Cairns links show up as particularly deficient.

Corridor summaries

Brisbane-Cairns. There are deficiencies in curvature, track structure, and clearances and, in the long term, in passing loop lengths. Average speeds and transit times are currently deficient and will become more so by 2014-15. The Brisbane-Gympie link was not included in table 5.2. Congestion currently occurs north of Brisbane (Caboolture-Nambour) where freight trains encounter large numbers of commuter passenger trains. Queensland's Main Line Upgrade program of investments will substantially remedy this.

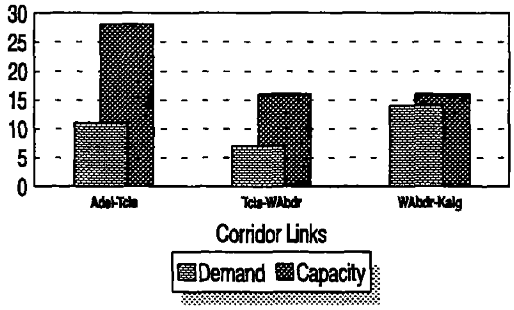
Sydney-Brisbane. The corridor is generally deficient on all physical and performance measures except for train length and weight of rail. Correction of

TABLE 5.4 CORRIDOR AND LINK PERFORMANCE DEFICIENCY RATINGS

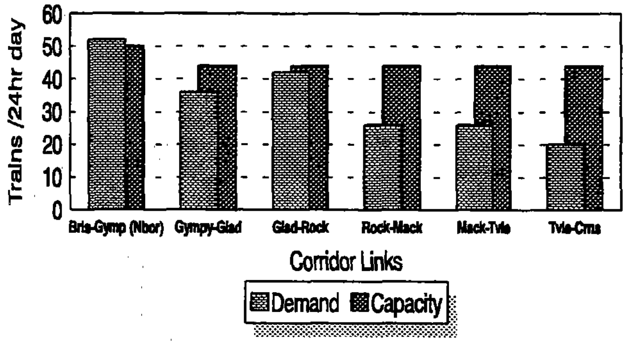
Rail corridors and links	*Average rating 1995-96*	*Average rating 2014-15*
Sydney-Melbourne	**0.9**	**0.7**
Chullora-Coulburn	0.7	0.6
Goulburn-Junee	0.9	0.7
Junee-Vic border	1.0	0.7
Nsw border Seymour	1.0	0.7
Seymour-South Dynon	1.0	0.8
Sydney-Brisbane	**0.7**	**0.6**
Chullora-Newcastle	0.7	0.6
Newcastle-Maitland	0.6	0.6
Maitland-Kempsey	0.7	0.5
Kempsey-Grafton	0.8	0.6
Grafton-Qld border	0.7	0.6
Nsw border-Acacia-Rdg	0.8	0.6
Canberra-Goulburn	**0.9**	**0.9**
Melbourne-Adelaide	**0.8**	**0.6**
Melbourne-Nth-Geelg	1.0	0.7
North gel- Gheringhap	1.0	0.7
Gheringhap-SA border	1.0	0.8
Vic border-Tailem bend	0.7	0.6
Tailem bend-Adelaide	0.5	0.5
Sydney-Adelaide	**0.8**	**0.7**
Chullora-Parkes	0.6	0.5
Parkes-Broken hill	0.7	0.7
Broken hill-SA border	1.0	0.8
Nsw border-Crst Brook	0.7	0.6
Brisbane-Cairns	**0.7**	**0.6**
Brisbane-Gympie	0.5	0.5
Gympie-Gladstone	0.7	0.6
Gladst-Rockhampton	0.9	0.6
Rockhampton-Mackay	0.8	0.7
Mackay-Townsville	0.8	0.7
Townsville-Cairns	0.8	0.5
Adelaide-Perth	**1.0**	**0.8**
Adelaide-Crystal Brook	0.9	1.0
Crystal brk-Prt Augusta	0.9	0.6
Port Augusta-Tarcoola	1.0	0.7
Tarcoola-WA border	1.5	0.8
SA border-Kalgoorlie	1.1	0.8
Kalgoorlie-Perth	0.9	0.6
Adelaide-Alice Springs	**1.0**	**0.8**
Tarcoola-NT border	0.9	0.8
SA border-Kalgoolie	1.0	0.8
Hobart-Burnie	**0.6**	**NA**
Hobart-Western Juct	0.6	NA
Western Juct-Devport	0.6	NA
Devonport-Burnie	0.7	NA

Note Rating of 1.0 is the highest level of adequacy.

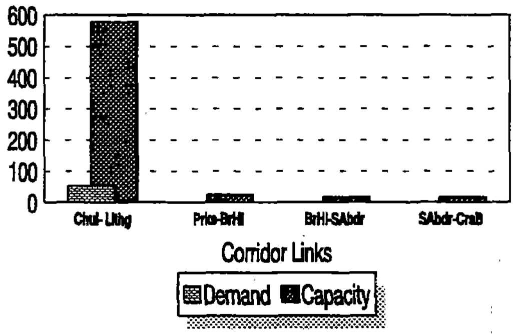
Sources BTCE ESTIMATE; Maunsell consultants (1994).



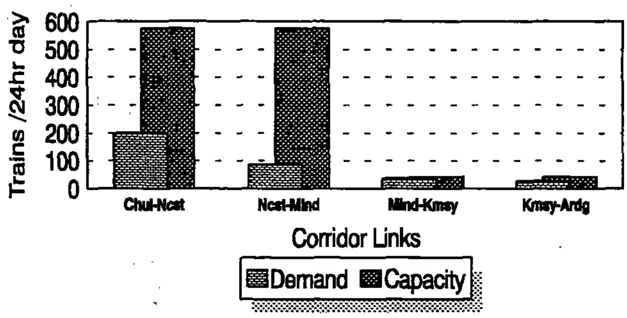
Adelaide-Perth



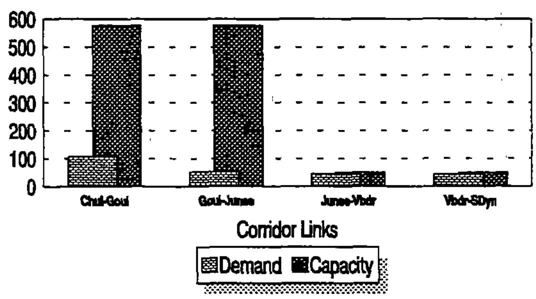
(b) Brisbane- Cairns



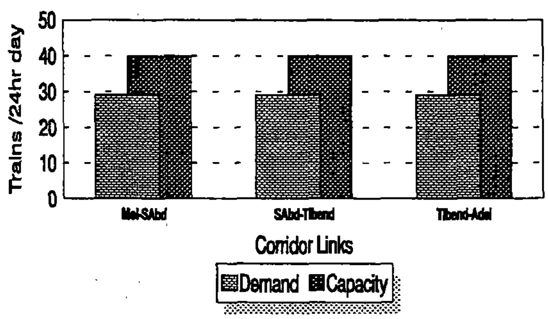
Sydney-Adelaide



(d) Sydney-Brisbane



Sydney-Melbourne



(f) Melbourne-Adelaide

ure 5.1 Link capacity vs 2014 demand

These scenarios assume there is no further investment after One Nation.

Brisbane-Gympie link capacity assumes MLU would not make significant improvement on capacity.

TABLE 5.5 SUMMARY OF SERVICE LEVEL ASSESSMENT

		1995-96				*2014-15*				
		Demand			*Overall service*	*Demand*				*Overall service*
		Million net tonnes[2]				*Million net tonnes[2]*			*20%[3]*	
Corridor	*Capacity[1]*	*Average*	*Corridor*	*Daily trains[3]*	*deficiency*	*Average*	*Corridor*	*Daily trains*	*increase[4]*	*deficiency*
Melbourne-Adelaide	22	6.5	5.2	9	0.8	8.8	7.5	12	16	0.6
Sydney-Melbourne	26	7.5	5.1	20	0.9	11.4	8.0	26	29	0.7
Sydney-Brisbane	22	5.0	3.9	12	0.7	8.2	5.5	15	21	0.6
Brisbane-Cairns[5]	24	4.5	2.7	13	0.7	5.7	2.6	14	17	0.6
Adelaide-Perth	12	na	2.6	5	1.0	na	4.0	7	10	0.8
Hobart-Burnie	12	1.6	1.6	4	na	1.8	1.8	4	5	na
Sydney-Adelaide	13	1.1	na	2	0.8	1.3	na	2	5	0.7
Adelaide-Alice Springs	10	0.8	0.8	3	1.0	0.9	0.9	3	4	0.8
Canberra-Goulburn	12	0.3	0.3	8	0.9	na	na	na	na	na

na Not available

Notes 1 Capacity is train paths available through the corridor remaining after allowing for trains travelling over only part of the corridor, that is, intrastate except for Brisbane-Cairns.

2 Average tonnes are distance weighted averages over corridor lengths. Corridor tonnes refer to end-to-end freight.

3 Daily trains are passenger trains plus estimated corridor freight trains except for Hobart-Burnie and Sydney-Adelaide where freight train numbers were estimated from the average freight tonnages. It has been assumed that trains are at the maximum lengths permitted by passing loop lengths. Train numbers increase over time in proportion to freight volume.

4 A 20 per cent increase in freight train numbers was assumed as a sensitivity test to higher demand or an increase in service frequency.

5 The Brisbane-Gympie link is not included because the impact of MLU on capacity was unable to be assessed.

Source BTCE estimates; Travers Morgan; Maunsell Consultants (1994).

TABLE 5.6 CORRIDOR BY LINK COST PERFORMANCE

Corridor by links	Per cent above base	Corridor by links	Per cent above base
Sydney-Melbourne	**45**	**Brisbane-Cairns**	**82**
Chullora-Goulburn	58	Brisbane-Gympie	111
Goulburn-Junee	45	Gympie-Gladstone	82
Junee-Vic border	46	Gladstone-Rockhampton	66
NSW border-Seymour	38	Rockhampton-Mackay	74
Seymour-South Dynon	38	Mackay-Townsville	71
Sydney-Brisbane	**56**	Townsville-Cairns	87
Chullora-Newcastle	64	**Adelaide-Perth**	**5**
Newcastle-Maitland	56	Adelaide-Crystal Brook	5
Maitland-Kempsey	50	Crystal Brook-Port Augusta	5
Kempsey-Grafton	50	Port Augusta-Tarcoola	5
Grafton-Qld border	50	Tarcoola-WA border	5
NSW border-Acacia ridge	60	WA border-Kalgoorlie	5
Canberra Goulburn	337	Kalgoorlie-Perth	5
Melbourne-Adelaide	**23**	**Adelaide-Alice Springs**	Base
Melbourne-North Geelong	17	Tarcoola-NT border	Base
North Geelong-Gheringhap	17	SA border-Alice Springs	Base
Gheringhap-SA border	3	**Hobart-Burnie**	**na**
Vic border-Tailem Bend	19	Hobart-Western Junction	na
Tailem Bend-Adelaide	61	Western Junction-Devonport	na
Sydney-Adelaide	**33**	Devonport-Burnie	na
Chullora-Parkes	56		
Parkes-Broken Hill	16		
Broken Hill-SA border	30		
NSW border-Crystal Brook	30		

na Not appliclable

Notes 1. The costs (not shown owing to confidentiality) are avoidable costs derived from ideal situation scenario for comparative purpose only.

2. The percentage 'above' column refers to how much each links cost differ from the base, which is the best cost corridor, Alice Springs-Tarcoola, based on the ideal scenario described above.

Source BTCE estimate.

curve and sleeper deficiencies is important for reducing the service deficiencies. Transit times, reliability and costs are so poor that the corridor may not survive as a commercial freight alternative unless improvements are implemented.

Sydney-Adelaide. Gradients, curves and clearances are very deficient east of Parkes, but the Blue Mountains crossing is difficult and expensive to improve. The rail weight of 47 kg over 75 per cent of corridor is below standard. The 68 per cent of the track which is on timber sleepers would require large investment to upgrade to concrete. Average speed is low due to track, signalling, curvature, and gradient deficiencies and the need to deliver trains in two parts between Sydney and Parkes. These deficiencies have a considerable impact on costs.

Sydney-Melbourne. The corridor currently performs relatively satisfactorily in terms of transit time but not so well on reliability and costs. A deficiency in corridor capacity could occur towards 2014-15. The most pressing problem is the single line sections south of Junee, which require long bi-directional passing loops. These loops may be acquired south of Albury by taking over and converting the largely redundant adjacent broad gauge track. Improvements are also required to ease very poor gradients and tight curves between Chullora and Junee.

Melbourne-Adelaide. Gradient and curvature deficiencies exist in the Adelaide Hills area but the remainder of the corridor is effectively high speed track. Double stacking would be particularly advantageous, especially for Perth traffic as the benefits would be delivered over a journey of 3400 km. The main impediments are the Bunbury Street tunnel in Melbourne and tunnels in the Mount Lofty ranges. The corridor has relatively high costs, reflecting a perceived market requirement for many trains of small size.

Adelaide-Perth. The corridor performs well and has adequate capacity. Transit times will become deficient as competitors' times improve. Improvements in transit time and reliability could be achieved by new rollingstock technology and track/rail quality management. An improved signalling system and longer crossing loops would allow trains to pass without stops.

Adelaide-Alice Springs. Capacity is adequate and reliability and transit times are the best in Australia.

Hobart-Burnie. Tasrail is a short intrastate railway and has adequate capacity to carry the relatively low traffic volumes. Assessed against the benchmark standards used for mainland corridors, this corridor appears quite deficient. However, the current infrastructure is considered adequate for the commercial environment in which the railway operates.

Goulburn-Canberra. The corridor has adequate capacity but, however, performs poorly against all the other measures. The low volume of traffic dictates that no investment is required.

TERMINALS

Methodology

Shortages of terminal capacity force trains to be dispatched at inopportune times or incoming trains to be delayed while waiting for trains occupying terminal track to be unloaded or loaded. Terminal capacity can be measured in terms of numbers of trains the terminal track can hold at the same time, container storage capacity, or terminal throughput in trains, TEU or tonnages handled per day.

Throughput capacity is determined mainly by the handling equipment used, numbers of platforms and the capacity of the entrance and exit to the terminal for trucks. The assessment of terminal adequacy has been undertaken considering numbers of tracks, lengths of tracks, daily track utilisation, truck turnaround times, and storage space availability.

The terminals covered are intermodal terminals for general freight and not terminals for specific products. In 1992 the NRC commissioned consultants to examine the requirements for terminals to the year 2003-04 and to develop a 'master plan'. (The plan has since been superseded by NRC Corporate Plan 3 (CP3). However, the revised figures were not received in time for analysis.) In making adequacy assessments it has been assumed that all the investments contained in the master plan will have been implemented by 2014-15.

Results

Figures 5.2a and 5.2b sum up the position for the major terminals for 1995-96 and 2014-15 by comparing projected annual throughputs in TEUs with capacity.

The graphs show that all terminals will have adequate capacity at both the start and end of the study period. This conclusion is conditional upon master plan investments of $21M at Acacia Ridge, $16M at Enfield and $16M at South Dynon taking place to ensure adequate capacity to 2014-15.[1] The study also assessed the rail-port terminals at Fisherman Islands, Botany, Outer Harbour and North Fremantle and found no deficiencies.

Terminal summaries

Acacia Ridge (Brisbane). Investments in the terminal currently under way will increase capacity to an estimated 300 000 TEU per annum subject to changes in operating methods being implemented. The next two phases of development under the master plan involve construction of three 1500 m tracks at an estimated total cost of $21M. Half of this cost is associated with grade separation of Beaudesert Road. The terminal would then have a potential capacity estimated at 550 000 TEU.

Chullora (Sydney). This terminal has inadequate track length, track numbers and container storage space. It has been a major constraint to the development of intermodal business.

1 CP3 revised investment includes $49M for Melbourne intermodal, $6M for Melbourne steel, $46M for Sydney intermodal, $5M for Brisbane intermodal and $3M for other terminals.

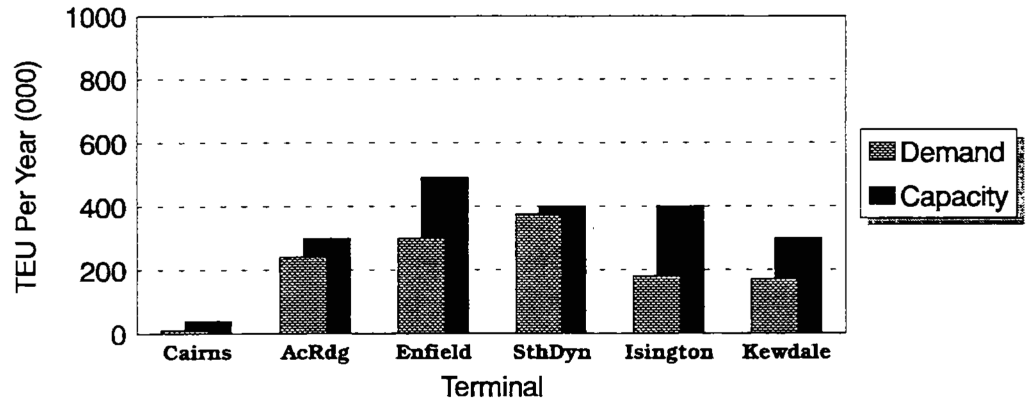


Figure 5.2a Terminal demand versus capacity: 1995-96

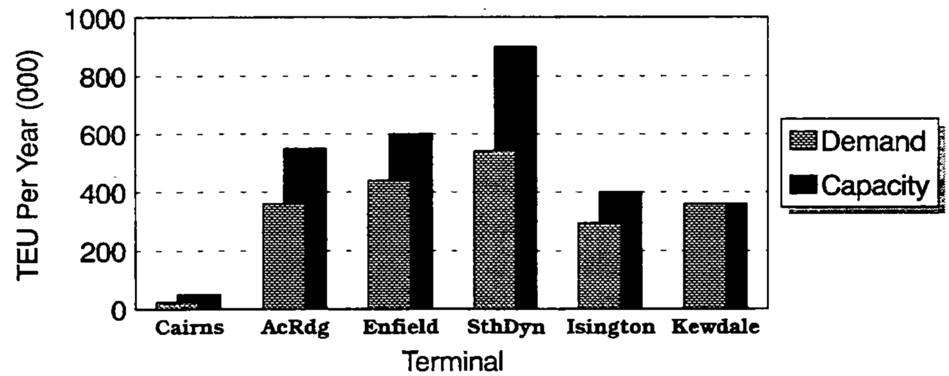


Figure 5.2b Terminal demand versus capacity: 2014-15

Enfield (Sydney). is being redeveloped as the replacement for Chullora, and the first phase is being funded by NRC. It is likely that this phase will add sufficient new capacity to meet the immediate demand. Part of this process is the consolidation of fragmented intermodal operations at Chullora, Cooks River and Clyde into Enfield. The consolidation process will improve costs and performance, but it will also absorb the capacity from the first phase of infrastructure improvements. The first phase of the Enfield terminal involves construction of three tracks of 900 m length and associated hardstand. Construction has been delayed by community opposition, and completion of phase one is now expected in 1996. This delay represents a significant constraint on National Rail's capacity and is restricting recovery of benefits from complementary investments in the Sydney-Melbourne corridors and terminals at Acacia Ridge and South Dynon. Further development will be progressively required to meet future growth. Infrastructure under phase 2 of the master plan estimated to cost $16M will increase the capacity to more than 600 000 TEU.

South Dynon (Melbourne). Following the implementation of phase 1 of the master plan, and the Dock Link road project, the terminal now serves both domestic and port traffic. The current estimated throughput capacity is over 400 000 TEU. However, capacity is limited by the fact that only two tracks exceed 600 m. As a result of standardisation, in 1995 South Dynon will take over the function of gauge transfer for one million tonnes of steel product from Western Port. It will also start direct Perth train services from that time. This, along with the consolidation of the rail-port operations, will utilise the new capacity created by phase 1. The master plan recommends an immediate progression to phase 2 with completion by 1996. As yet this has not been committed. Phase 2, costing $16M, is estimated to provide a throughput of 600 000 TEU and is considered essential to allow efficient train sizes on all corridors. Looking further ahead, the master plan provides for the site to be extended and developed as a terminal of 900 000 TEU capacity.

Islington (Adelaide). The terminal has a capacity of about 400 000 TEU. The only deficiency is the track length of 1200 m, which is less than potential maximum train length of 1800 m. This deficiency is currently overcome by operating procedures, at relatively little cost.

Kewdale (Perth). A minor capacity deficiency has been identified near the end of the study period, which may be corrected by additional full length tracks or improved methods. The terminal's 1300 m tracks are shorter than the train length potential, but operating procedures can accommodate larger trains. The site area limits extension of length.

URBAN CORRIDORS

Historically freight has had to compete with commuter services in some urban areas, and freight has been the loser. A serious conflict between freight and commuters currently exists in Sydney and will become more so as both passenger and freight traffics grow. It does not automatically follow, however, that infrastructure investments are needed to solve the problem. Initiatives on the demand side such as congestion pricing and traffic management may be more economic alternatives. The other urban rail corridors examined are between terminals and ports; these were found to be generally adequate.

Corridor summaries

Acacia Ridge-Fisherman Islands (Brisbane). Narrow gauge track on this corridor has been in place since 1976 and a standard gauge track is currently under construction. The majority of freight on this corridor will continue to be coal traffic from the West Moreton collieries. The freight demands to 2014-15 on the standard gauge track for interstate import/export containers or other general freight are not expected to exceed its capacity. The potential for growth in urban commuter traffic is significant and may limit freight capacity at points of conflict. However, there are no significant deficiencies foreshadowed over the study period.

Enfield/Chullora to Port Botany (Sydney). The connection between Enfield and Port Botany is a separate freight line. The dominant traffic is coal from east of Sydney to Port Kembla, which uses the section of double track from Enfield to Marrickville. The line has adequate capacity for the forecast freight to 2014-15. Most freight is intrastate.

Enfield-Outer Sydney. Freight trains arriving at Enfield from the north, south and west share tracks with the fast growing urban commuter system. Both urban passenger and interstate freight are expected to expand on the corridors to the north and south. One Nation projects have alleviated some of the conflict between freight and passenger traffic, by the addition of a 1500 m passing siding to the north and some separation of tracks to the south. The technical deficiencies that existed on these sections have only been partially addressed. Remaining deficiencies will become more acute as both users expand their markets. The NSW Environment Protection Authority has imposed noise level restrictions for locomotives between Sydney and Newcastle, which has resulted in a curfew between the hours of 2200 and 0600 on diesel locomotives working on this corridor. This measure has prevented NRC from achieving some crew and operating efficiencies in respect of one service.

Islington to Port Adelaide (Adelaide). This corridor consists of low traffic density freight lines with few points of urban conflict. The urban passenger rail system services a peninsula with limited potential for growth. No deficiency currently exists or is likely.

Kewdale to Fremantle (Perth). This corridor is deemed to include North Fremantle and Kwinana. Kwinana is the main terminal for interstate steel freight and is likely to continue to develop. A separate freight line meets design standards and no deficiency exists. The line to North Fremantle shares the Swan River bridge with urban passenger services. Little interstate freight is presently generated at Fremantle or North Fremantle. If North Fremantle become an international container landbridge terminal, track overhead electric cables would restrict double stacking, but a minor investment in track separation for freight and passenger services could overcome this.

CHAPTER 6 ECONOMIC ASSESSMENT OF ADEQUACY

METHODOLOGY

In order to undertake an economic assessment, it is necessary to identify potential investment projects and to estimate their costs and benefits. NRC put forward a set of infrastructure projects for a five year period and these are listed in table 6.1. The projects have the potential to cut journey times in each corridor by approximately 30 minutes. However, because the NRC projects only relate to the next five years, they were not considered adequate to constitute a basis for an economic assessment over a 20 year period. A much more extensive list of needed projects was developed for this purpose. These are summarised in table 6.2.

The technical standards were used to develop the list of projects necessary for the economic assessment to proceed. The projects were selected so that, in each corridor, their combined effect is to attain the level of service performance targets developed for the technical assessment. Implementation of these projects would bring the average level of service benchmark ratings up to approximately one. Note that this is only an average of the deficiency ratings - some individual targets would be overshot and others not met by a considerable margin. The impacts of projects on deficiency ratings are discussed further below. Once the list of projects has been established using technical criteria, the role of the economic assessment is to pare the list back by removing unwarranted projects.

The 'goal 1' set of projects includes the NRC list and extends beyond it. The 'goal 2' projects are treated as *additional to,* not *instead of* the goal 1 projects.

The goal 1 projects would achieve:

- delivery day matching road as at 1995-96 (for example, if road can deliver next day so will rail);
- an average speed of 80 km/hr;
- transit time from acceptance to delivery similar to road as at 1995-96;
- reliability based on 5 minutes deviation per 100 km; and

- average total (fully distributed) cost of production of 3.0 cents per net tonne kilometre.

The goal 2 projects would, if implemented after goal 1 projects, achieve a higher level of service:

- delivery day matching road as expected in 2014-15;
- an average speed of 100 km/hr;
- transit time from acceptance to delivery similar to road as expected in 2014-15;
- reliability based on 5 minutes deviation per 100 km;
- an increase in the axle loadings to 25 tonnes on most corridors; and
- average total (fully distributed) cost of production of 2.0 cents per net tonne kilometre.

Potential projects on the Sydney-Adelaide corridor have been omitted from table 6.2 because interstate freight is expected to go via Melbourne. No goal 2 projects were identified for Brisbane-Cairns. In cost terms, goal 1 adds an additional $1B to NRC's projects, and when goal 2 is added on, the total

TABLE 6.1 NRC PROPOSED INVESTMENT PROJECTS

($ million)

Location	*Project*	*Cost*
Brisbane to Sydney	Concrete sleepers and track improvements	150
	First level automatic train control system	13
Melbourne to Adelaide	Concrete sleepers and track improvements	91
	First level automatic train control system	11
	Improve overhead clearance for double stack	50
Joppa Junction to Albury	Concrete sleepers and track improvements	140
	Improve restrictive gradients	75
	First level automatic train control system	13
Albury to Melbourne	Concrete sleepers and track improvements	57
	Renew weak old rail	48
	Relocate track to expand Melbourne terminal	4
	First level automatic train control system	10
Adelaide to Kalgoorlie	Track improvements	2
	First level automatic train control system	11
Kalgoorlie to Kewdale	Track improvements	15
Tarcoola To Alice Springs	First level automatic train control system	11
Sydney Metropolitan	Provide power to One Nation 1500 loop	5
Region	Freight line separation south of Sydney	9
	Sydney bridges to freight axle loads	7
Total		722

Source National Rail Corporation.

TABLE 6.2 INVESTMENT PROJECTS

($ million)

	B-C	S-B	S-M	M-A	A-P	A-ASP	Total
Goal 1							
Realignments	80	300	35		18		433
Track/concrete	140	150	200	90	10		590
Control systems		15	25	10	10		60
Passing loops and sidings			100	20			120
60 kg rail	140		45				185
Clearances	5			50			55
Urban access	80	70	50				200
Terminals		20	25	20			65
Total goal 1	445	555	480	190	38		1708
Goal 2							
60 kg rail		195	110	115	500	170	1090
Clearances (4.8 m)		75	40				115
Bridges			10	10			20
Gradients			170	55			225
Passing loops and sidings		50	75	50	100		275
Control systems		40	40	40	50	15	185
Terminals		10	15	35	15	5	80
Grade separation/improvement		75	80	100	100	15	370
Total goal 2		445	540	405	765	205	2360
Grand total	445	1000	1020	595	803	205	4068

Note The goal 2 projects enclosed in boxes are the selected projects which, with the addition of all the goal 1 projects, were used to produce the goal 1 & 2 results in table 6.5.

Source Maunsell Consultants (1994); BTCE.

reaches \$4.1B. The first four lines of the goal 2 investments bring the tracks up to the standard where they can handle 25 tonne axle loads, and the others, excluding terminals, are to reduce transit times. NRC informed the Bureau that it would not seriously consider the speed related items.[1]

The Bureau undertook cost-benefit analyses of the projects. The evaluations were rudimentary in that they were based solely on estimated operating cost savings. A project or group of projects was counted as being warranted if its benefit-cost ratio (BCR) exceeded unity. An 8 per cent discount rate was employed. Taking into account only operating cost savings will usually lead to an understatement of benefits since the values of improvements in transit times and reliability are not taken into account. The exception is projects which enable trains to increase their loads, namely longer passing loops, which permit longer trains, and higher clearances and increased axle loads, which increase wagon carrying capacity. Such projects allow the same freight task to be performed with fewer trains and so save on operating costs.[2] Whether these benefits can be realised depends on whether the market will tolerate a reduction in service frequency, or alternatively will grow sufficiently so that the trains with higher carrying capacity can be fully utilised without sacrificing too much frequency.

Another set of benefits excluded from the analysis is the gains accruing to *new* traffic generated by improved service levels and by price reductions if the railways pass on part or all of the cost savings to customers. Figure 6.1 illustrates this. Net tonne-kilometres (ntk) carried per annum on a corridor is plotted along the horizontal axis and cents per ntk on the vertical axis. For a forecast quantity of freight carried in a particular year of Q_1, an investment in rail infrastructure reduces the cost per ntk from C_1 to C_2. The methodology employed is the present assessment is to measure the annual benefit as $(C_1 - C_2)Q_1$, the saving in operating costs represented by the shaded rectangle in figure 6.1. If the railway operator were to pass on the full saving in costs to customers and the demand curve was D as represented in the figure, an

1 Other views put to the Bureau by the NRC are that the 60 kg rail included in goal 2 is probably needed particularly on curves. All replacement track will be 60 kg and much of this would be included in their maintenance. NRC doubts the \$500M identified for 60 kg rail for the Adelaide-Perth track and thinks this is more likely to be \$100M, and that less than \$100M would be needed for passing loops on the Adelaide-Perth track. NRC also felt that more investment on bridges would be warranted.

2 If there was a shortage of capacity and this was causing reliability problems, these investments would also yield benefits in the form of improved reliability. However, as shown by the technical assessment, demand is likely to be below practical capacity in all corridors for the next 20 years. The savings in operating costs would therefore be the only benefits from investments that increase train capacities.

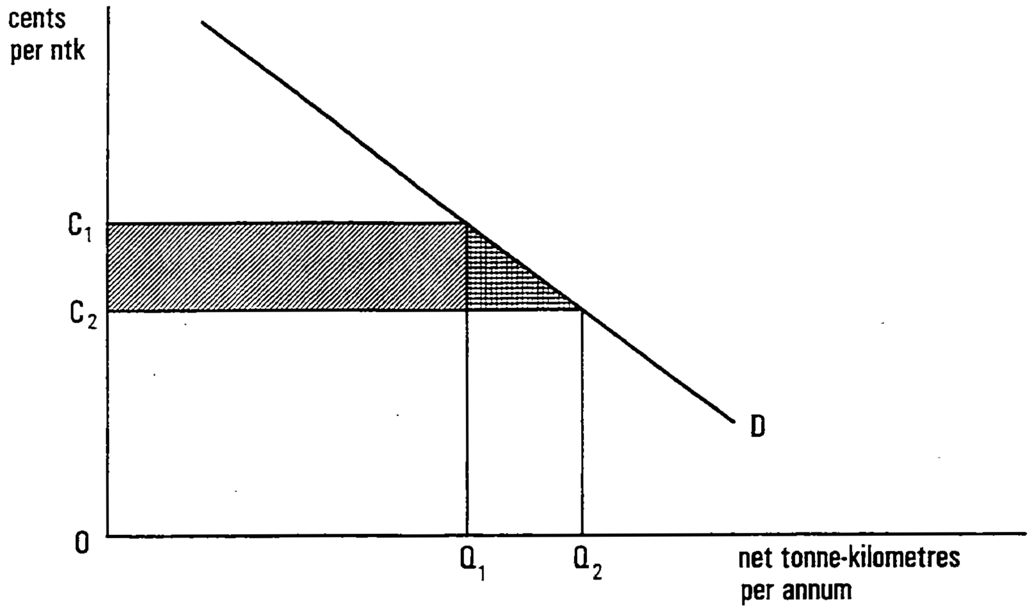


Figure 6.1 Benefit-cost analysis model

additional quantity demanded would be generated of Q_1Q_2. The benefit to society from this would be measured as the area of the hatched triangle.

Another assumption of the simple cost-benefit analysis methodology employed is that railway costs are constant over the relevant range. Thus as demand grows over time, operating costs with and without the investments not adjusted to allow for economies of scale or better utilisation of infrastructure.

Savings on roads arising from diversion of freight from rail to road only need to be taken into account if the road haulage industry is being over- or under-charged for the costs it imposes on society or if the diversion of freight reduces congestion on roads. For purposes of the strategic assessment being undertaken here, it was assumed that neither of these were of sufficient magnitude to warrant inclusion.

RESULTS

The benefits from implementing a number of projects in combination on the same corridor are not the same as the sum of benefits from each project considered in isolation. For each corridor, the projects were evaluated firstly in small groups such as would logically go together, and then all together.

Table 6.3 provides the details of strategic project groupings formed to explore the interrelationships between projects. Where a project would fit into two categories, the project has been included in the category that stands to gain the most from the project. For example, re-railing with 60 kg rail has been included

TABLE 6.3 STRATEGIC PROJECT GROUPINGS

Grouping	*Project types*	*Operating cost savings*
Consolidation	Passing loops and siding projects	Allows the same quantity of freight to be carried in smaller numbers of longer trains
Transit times	Realignment and grade easing projects	Saves on time related rollingstock capital and running costs and fuel
Maintenance	Concrete sleepers and 60 kg rail projects	Reduces costs of keeping tracks operational
Load flexibility	Clearance, 60 kg rail and bridge projects	Permits wagons to be loaded to greater heights and weights reducing wagon numbers and, if desired, train numbers as assumed in these evaluations
Operations	Control systems	Saves running costs of signalling system and may improve transit times by reducing waiting times

Source Maunsell Consultants (1994); BTCE.

under transit time for Brisbane-Cairns as rail size limits speed (and to a lesser extend axle loads) for much of the corridor.

The BCRs are shown in table 6.4. As this is a social cost-benefit analysis rather than a financial analysis, fuel excise has been excluded from both costs of project construction and benefits. The reason behind this is that fuel excise is a transfer from railways to the government and so does not represent a cost on society. It has been assumed that fuel excise comprises 8 per cent of the costs of rail construction projects.

For each corridor, the groups are arranged in descending order of BCR. Load flexibility and consolidation projects generally perform well in terms of BCRs. As noted already, benefits from these types of projects will only be realised if either users will tolerate a drop in service frequency or market demand will grow sufficiently to limit the reduction in frequency. The benefits from these projects must therefore be regarded as less certain than for the other project types which save railway operating costs while at the same time increasing or at least not reducing service levels (saving transit times and saving maintenance costs respectively).

In the second set of evaluations undertaken, projects were grouped as follows: NRC projects, the goal 1 projects, and goals 1 and 2 combined. The results are set out in table 6.5. Terminal projects have been excluded and are dealt with separately below. The $205M of Adelaide-Alice Springs goal 2 projects were not considered because, with the low freight volumes, these are not likely to be warranted. In undertaking the evaluations it was assumed that the goal 1 projects would be completed in mid-1997 and the goal 2 projects in mid-2007. Costs and benefits were discounted to mid-1997.

TABLE 6.4 PROJECTS STRATEGIC GROUPING EVALUATION RESULTS

($ million)

Corridor	*Initiative*	*Financial capital cost*	*BCR*
Melbourne-Adelaide	Consolidation	20	4.1
	Load flexibility	230	2.4
	Maintenance	90	2.4
Sydney-Melbourne	Maintenance	200	3.2
	Consolidation	100	1.7
	Transit times	205	1.6
	Load flexibility	160	1.5
Sydney-Brisbane	Consolidation	50	2.7
	Load flexibility	270	2.4
	Maintenance	150	1.5
	Operations	15	1.4
	Transit times	205	0.9
Brisbane-Cairns	Load flexibility	5	14.0
	Transit times	220	2.5
	Maintenance	140	2.0
Adelaide-Perth	Maintenance	10	5.3
	Operations	10	2.6
	Transit times	18	1.6

Source Maunsell Consultants (1994).

The NRC and goal 1 projects taken as groups for all corridors were found to be justified in that they produced BCRs in excess of one. However, this was not the case for the goal 2 projects. For each corridor all possible combinations of goal 2 projects were tested and combinations yielding BCRs below unity were eliminated. Of the remaining combinations, the combination having the largest net present value was selected.

Of the $2.08B goal 2 projects (excluding terminal and Adelaide-Alice Springs investments), $1.58B were retained and these are the projects shown in the boxes in table 6.2. All three groupings of projects produce respectable BCRs. The overall result suggests that some $3.2B could be invested in railways in the corridors studied over the coming 20 years, with benefits exceeding costs.

Looking at individual corridors, Sydney-Melbourne and Sydney-Brisbane have the greatest spending needs, each accounting for 30 per cent of the total financial capital costs. Melbourne-Adelaide clearly offers the best returns, while Brisbane-Cairns appears to be marginal. However, the analysis here is partial in that it only includes operating cost savings. Brisbane-Cairns investments mainly decrease transit time as this is the main type of deficiency for this

TABLE 6.5 PROJECT EVALUATION RESULTS[1]

($ millions)

Corridor	Financial capital costs	Resource capital costs[2]	Present value of benefits[3]	NPV	Benefit-cost ratio
NRC projects[4]					
Sydney-Melb	364	310	403	93	1.3
Melbourne-Adel	151	129	507	379	4.0
Adelaide-Perth	28	24	64	40	2.7
Sydney-Brisbane	163	139	145	6	1.1
Total	706	602	1 119	518	1.9
Goal 1 projects including NRC					
Sydney-Melb	455	419	584	165	1.4
Melbourne-Adel	170	156	495	339	3.2
Adelaide-Perth	38	35	66	32	1.9
Sydney-Brisbane	535	511	575	64	1.1
Brisbane-Cairns	445	409	459	49	1.1
Total	1 643	1 530	2 179	649	1.4
Goal 1 & 2 projects[5]					
Sydney- Melb	980	626	1 101	475	1.8
Melbourne - Adel	540	302	795	495	2.6
Adelaide -Perth	288	134	218	84	1.6
Sydney - Brisbane	970	682	905	223	1.3
Brisbane-Cairns	445	409	459	49	1.1
Total	3 223	2 153	3 478	1 326	1.6

Notes 1. Terminal investment projects are excluded but urban corridor projects are included.

2. Resource capital costs are less than financial capital costs because of the exclusion of fuel excise in rail construction projects and discounting of goal 2 projects from 2007 to 1997.

3. It is assumed that the goal 1 projects are implemented in 1997 and the goal 2 projects in 2007. All costs and benefits are discounted to 1997.

4. NRC projects exclude Adelaide to Alice Springs and the provision of power to the 1500 m loop in Sydney

5. Goal 1 & 2 consists of goal 1 projects plus goal 2 projects judged to be economic.

Source BTCE estimates.

corridor. If the benefits to customers of time savings could be valued and included in the benefits, the relative position of the Brisbane-Cairns corridor might be improved.

It should be remembered that these results are effectively weighted averages for each corridor group of projects and the evaluations of strategic groupings of projects have shown that, within each corridor group, there are subsets of projects yielding higher returns, as table 6.2 showed. It might also be noted that these results assume that the projects are implemented in 1997 for goal 1 and 2007 for goal 2. BCRs may be improved by delaying projects until demand has grown more.

Financial analyses were not undertaken. However, the main difference would be the inclusion of fuel excise charges. Inclusion of fuel excise would increase both benefits and costs, but the amounts would not be great, so it can be inferred that the financial net present values and BCRs would not be very different from the social values.

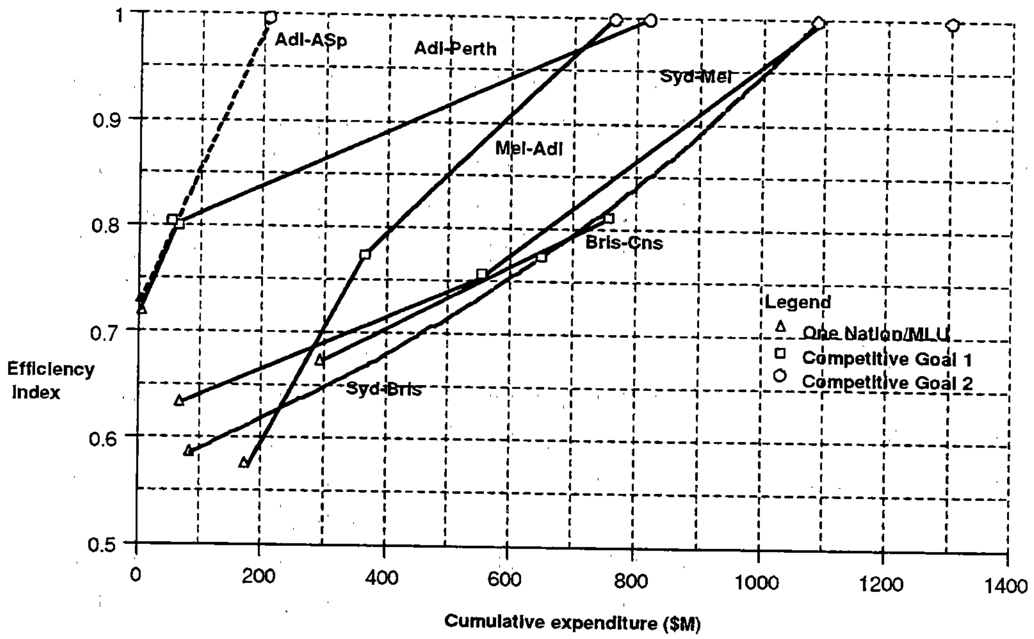
In addition to the investments in linehaul infrastructure in table 6.5 there are $145M of terminal investments included in the goal 1 and goal 2 sets of projects. The greater part of this is already included in the NRC's corporate plan and so is likely to proceed. As shown in the technical assessment, much of this investment is needed, to ensure there is adequate capacity for the next 20 years.

Combining the terminal investments with the linehaul investments considered as warranted, the total estimated investment needs over the next 20 years for the rail infrastructure studied is expected to be of the order of $3.4B. It is emphasised that these results are only indicative and any actual investment decisions should be based on much more detailed and comprehensive analyses which would fully take into account the effects of the investments on rail's customers. Actual investment decisions would also need to take account of the interrelationships between investments in fixed infrastructure and investments in rollingstock and the efficiency of operational procedures.

INVESTMENT IMPACTS

It was found in chapter 5 that all corridors show some degree of deficiencies when assessed against the performance benchmarks. Figures 6.2 and 6.3 illustrate the expected impacts of the various corridor investment proposals presented in table 6.2 on unweighted performance deficiency ratings. In figure 6.2 the cost of the investments are graphed on the horizontal axis, and unweighted performance deficiency ratings calculated against 2014-15 standards are graphed on the vertical axis. For each corridor, three points are shown: post One Nation or, in the case of Brisbane-Cairns, post Mainline Upgrade; goal 1; and goals 1 and 2 combined. The One Nation/MLU points are plotted horizontally at the relevant expenditure levels for those investment programs. The goal 1 projects lead to ratings of 0.75 to 0.82 because the ratings are calculated using 2014-15 standards. On the basis of 1995-96 standards, goal 1 would achieve ratings around one.

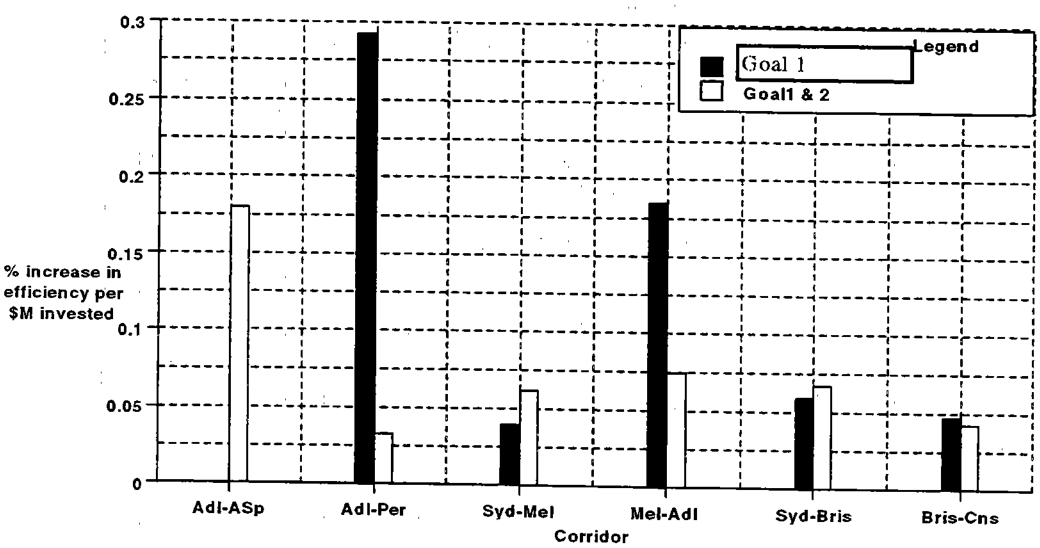
The slopes of the lines connecting the points indicate the effectiveness of a dollar of investment in improving a corridor's rating. To facilitate corridor comparisons figure 6.3 graphs the percentage increases in ratings per million dollars invested for goal 1 and goals 1 and 2 combined. Considering goal 1 by itself, the greatest efficiency gains per million dollars invested would be



Vote Goals 1 and 2 include all project costs, unlike the economic evaluation, which excludes projects found to be uneconomic.

Source Maunsell Consultants 1994, BTCE.

Figure 6.2 Cumulative investments and efficiency ratings



Source Maunsell Consultants 1994.

Figure 6.3 Impact of investments

realised by upgrading the Adelaide-Perth and Melbourne-Adelaide corridors. Adelaide-Alice Springs is well ahead of the others for goal 1 and 2 combined. Comparing the rankings of the corridors in figure 6.3 with those from the cost-benefit analyses in table 6.5, there are some similarities which suggests that this technique of figures 6.2 and 6.3 is a reasonable method of technical assessment. However, in common with other forms of technical assessment, it fails to take account of differences in volumes of throughputs. Hence Adelaide-Alice Springs and Adelaide-Perth do far better in technical than in economic assessments.

Corridor summaries

Sydney-Melbourne. The competitiveness of this corridor is expected to decline following One Nation because of the additional traffic introduced following standardisation of the Melbourne to Adelaide track which will take up the existing spare capacity.The critical requirements are to improve the train performance south of Junee by the introduction of long, moving pass, crossing loops. This can be done by converting the adjacent redundant broad gauge track. A concurrent upgrade of Melbourne and Sydney terminals will then allow larger trains to run more freely. Track improvements and concrete sleepers are also needed. The Sydney to Melbourne rail corridor is a prime candidate for infrastructure investment.

Melbourne-Adelaide. Investment is required for passing sidings to accommodate the additional traffic from the Broken Hill route and for track improvements, including concrete sleepers and clearance for double stack from Melbourne to Perth. Demand growth over the next 20 years combined with the diversion of traffic to this route will mean a threefold increase in annual tonnage, from about 2.5M to 7.5M by 2014-15. This volume will utilise about 45 per cent of available practical capacity, assuming that trains carry 75 per cent of the maximum possible tonnage, given clearances and passing loop lengths. The route density of 9200 tonnes per route kilometre will be the highest on the network. The Adelaide to Melbourne corridor is also a prime candidate for further infrastructure investment.

Adelaide-Perth. Rail's market share on this corridor is declining as a result of superior road transit performance and superior sea cost performance. The critical requirements are improvements in average speed and reliability. This can be achieved by introducing long, moving pass, crossing loops at strategic locations and by a comprehensive control system together with effective quality control. A concern is the $0.5B required for rail upgrade to 60 kg, which was shown to be uneconomic investment. It may be cost effective to selectly implement parts of this investment. There is a synergy from improvements to other corridors that will impact positively on this corridor. For example, double stack standardisation from Melbourne will make double stacking possible all the way from Melbourne to Perth, and improved transit times from Brisbane and Sydney could lead to increased Brisbane-Perth freight.

The predicted Adelaide-Perth volume will utilise about 45 per cent of corridor capacity capacity, assuming that trains carry 75 per cent of the maximum possible tonnage, given clearances and passing loop lengths. Based on the demand forecasts of this study, route density is predicted to improve from about 800 to 1500 tonnes per route kilometre over the next 20 years. Generally at this density 'on train' investment will give better returns than infrastructure investment. The Adelaide to Perth corridor is substantially adequate and will only require a small amount of infrastructure investment over the planning period.

Sydney-Brisbane. The Sydney to Brisbane corridor is the least competitive of all rail corridors. Market share is comparable with Sydney to Melbourne because road transport is also hampered by poor infrastructure. There is a major requirement for realignment of the route and associated track improvements. The goals 1 and 2 investments for this corridor would improve the running time for high priority freight from the existing 19 hours to about 10 hours, and reduce estimated costs from about 5.5 cents to 2.0 cents per net tonne kilometre.

The increased freight tonnages are estimated to utilise about 50 per cent of available capacity if efficient train services predominate. The estimated 5600 tonnes per route kilometre enters the the lower end of the range of best practice for railway density.

Brisbane-Cairns. The Brisbane to Cairns corridor currently competes well on price. However, additional curve easing and reduced terminal times, particularly at Rockhampton and Townsville, are required to bring the line closer to competing with road.

Terminals

Terminals need to be considered separately from the corridors as their operations and cost structures are very different. Terminal capacity can limit corridor capacity just as track capacity. Terminals will influence the cost of a rail freight in three ways:

- the cost incurred by the freight client interfacing to rail from another mode;
- the terminal freight handling costs;
- effects on linehaul costs where there is a shortage of terminal capacity affecting train scheduling.

TABLE 6.6 EFFECTS OF TERMINAL INVESTMENT

		Terminal				
Scenario	***Attribute***	***Acacia Ridge***	***Enfield***	***South Dynon***	***Islington***	***Kewdale***
Base case	Volume handled ('000 TEU/yr)	110	105	220	180	120
	Total cost ($M)	4.4	4.2	12.1	8.1	4.8
	Cost/TEU ($)	40	40	55	45	40
	Track capacity (no x length)	1 x 1200 2 x 600	3 x 900	2 x 1100 4 x 600	4 x 1200	2 x 1300 1 x 900
	Average delay per truck (h)	0.5	0.5	0.6	0.3	0.3
	Delay cost ($M)	2.7	2.6	6.6		1.8
Goal 1	Volume handled ('000 TEU/yr)	240	300	375	180	170
	Investment ($M)	20	25	20	-	-
	Total cost ($M)	8.4	10.5	16.9	8.1	6.8
	Cost/TEU ($)	35	35	45	45	40
	Track capacity (no x length)	3 x 1200	4 x 1200	5 x 1200	4 x 1200	2 x 1300 1 x 900
	Average delay per truck (h)	0.4	0.4	0.4	0.3	0.3
	Delay cost ($M)	4.8	6.0	7.5	2.7	2.5
Goal 2	Volume handled ('000 TEU/yr)	360	440	862	294	360
	Investment ($M)	10	15	35	15	5
	Total cost ($M)	9.0	11.0	30.1	9.3	9.0
	Cost/TEU ($)	25	25	35	25	25
	Track capacity (no x length)	4 x 1500	4 x 1500	5 x 1500	4 x 1700	3 x 1300
	Average delay per truck (h)	0.3	0.3	0.3	0.3	0.3
	Delay cost ($M)	5.4	6.6	12.9	4.4	5.4

Notes 1. Track capacity is the number of length of tracks provided at the terminal after the investment. Each track may turn trains (in and out) two or more times per 24 hours.

2. Truck delay is the expected average delay of road vehicles per TEU delivered or collected, from the time of arrival at the terminal until departure from the terminal.

3. Delay cost is the cost of delays to the road trucks on an annual basis. It is based on a rate of $50 per truck hour.

Source Maunsell Consultants 1994.

Control and operating equipment, service planning, work practices and other factors affect the competency and operations at terminals. For example, the National Rail Terminal Master Plan recommended standardisation through exclusive use of top lift containers and trailer chassis to avoid multiple handling of containers as two critical elements contributing to best practice results.

In this study costs to clients are indicated by estimating truck delay costs. In the absence of actual cost data, terminal operations costs are based on adjusted pre-National Rail and the Terminal Master Plan estimates of best practice costs. It should be noted that terminals become more complex as volumes increase and large terminals may have higher unit costs than smaller terminals. However, the penalty in increased terminal costs may be offset by cost savings in train operations arising from economies of scale. Table 6.6 shows the expected impacts on the five main terminals of the goal 1 and goal 1 and 2 combined investment packages. The South Dynon terminal stands out as having by far the highest volume and cost per TEU. Truck delay costs are forecast to reach $12.9M by 2014-15, but this is on account of the sheer number of trucks as the average delay per truck is no higher than for the other terminals.

MAINTENANCE

The cost of maintaining (including renewalsing) fixed rail infrastructure (track, sleepers, signalling, communications, etc) on the mainline rail network studied is estimated to be some $220M per annum, or about $20 000 per kilometre, assuming that the One Nation investments have been carried out. By 2014-15, assuming that the warranted goal 1 and goal 2 projects have been carried out, annual maintenance costs are estimated to be of the order of $130M. These estimates should be considered as indicative only. When summed over the next 20 years it is likely that the maintenance warrant is around $3.5B.

It is clear from the magnitude of the yearly saving in maintenance that, if some of the infrastructure projects are not undertaken, then maintenance costs will be higher. It is estimated that if no investment in infrastructure were undertaken, maintenance costs over the period would be some $1B greater.

CHAPTER 7 CONCLUSIONS

SUMMARY OF FINDINGS

Physical deficiency indicators show that most of the deficiencies in track infrastructure occur along corridors east of Adelaide. Performance deficiency indicators show Melbourne-Adelaide, Sydney-Brisbane and Brisbane-Cairns as the worst corridors by 2014-15. All corridors have sufficient capacity to cope with the expected demand over the coming 20 years.

All multimodal terminals will have adequate capacity at both the start and end of the study period. This conclusion is conditional upon NRC's investment plans for terminals being implemented. Rail-port terminals at Fisherman Islands, Botany, Outer Harbor and North Fremantle will also be adequate.

As for urban areas, a serious conflict between freight and commuters currently exists in Sydney and will become greater as both passengers and freight grow.

About $3B of investment in rail infrastructure is estimated to be warranted over the next 20 years. Sydney-Melbourne ($1.0B) and Sydney-Brisbane ($1.0B) are each estimated to warrant some 30 per cent of this. Melbourne-Adelaide ($0.5B), Brisbane-Cairns ($0.4B) and Adelaide-Perth ($0.3B) require lesser amounts. This proposed investment program is on about the same scale as One Nation funds for rail, requiring on average $150M annual expenditure over the planning period of 20 years. The One Nation rail investment program amounted to $429M over a 3 year period, representing on average of $142m expenditure per year.

Maintenance costs are estimated to amount to around $3.5B over the 20 year study period if the infrastructure projects suggested as warranted in this study are implemented. If no investments in infrastructure are undertaken, maintenance costs are forecast to be some $1B higher over the period.

AREAS OF FURTHER RESEARCH

The key objective of the study was to assess the adequacy of rail fixed infrastructure now and in the future. The experience gained through the course of the study has reinforced the view that greater benefits and a much broader insight into the industry as a whole can be gained if operational issues are considered in parallel with any infrastructure assessment. This is not to say that this study has failed, the sudy was purposefully targetted to consider infrastructure. The importance for considering operational and infrastructure issues stems from the fact that traditionally rail transport has been managed as 'vertical integration', unlike road transport and the other modes. Although operational issues such as rollingstock capital requirements are not the responsibility of the Federal Government, a national strategic assessment of transport need not exclude private capital.

This paper has made some advances in developing ways to assess rail infrastructure adequacy and has identified potential investment needs at a strategic level. The most obvious area for future work is developing a database on the current rail infrastructure. It might be possible to collect data on rail infrastructure on a section basis with each section being several kilometres long as is the case for road databases. However, in the time available for the study it was only possible to assemble data on much longer lengths of track (so called 'links'). Some disaggregation of those links would be desirable.

A significant area where further work may be profitable is in the cost-benefit analysis of investment projects. The analysis employed in this study was rudimentary in that it assumed constant costs and counted only operating cost savings as benefits. There are several fronts where research could take place to improve project evaluations.

- A better understanding how railway costs are affected by investments in infrastructure and changes in freight volumes is one of these.

- Benefits in the form of time savings to freight were not included in the study (nor were they for the road project evaluations) on the grounds that they are not likely to be very important compared to time savings for passengers and vehicles. However, differences in times taken between the transport modes are a significant determinant of modal shares.

- Benefits in the form of improved reliability are likely to be important for rail because this is an area where rail's performance can be considerably improved. However, the data do not exist at present to permit objective measurement of current levels of reliability. Thus it was difficult to predict how various investments would affect reliability, and to put dollar values on the improvements.

- For investments which reduce unit costs at the expense of service frequency, such as investments permitting longer trains or loading to greater heights, it was assumed that freight markets would either tolerate the drop in frequency, or grow sufficiently so that existing frequencies could be maintained. A better knowledge of freight markets is needed here.
- A greater awareness of rollingstock and operational issues and how these relate to infrastructure would also be useful.
- Finally, benefits from additional freight generated by improvements in service quality and by any cost reductions passed onto customers were ignored in the analysis. Again, more knowledge of freight markets and of values of time and reliability are required.

Making headway in the areas identified above will at the very least require close consultation with rail system operators and with some of their customers. Models may be developed to assist with costing and capacity assessment. Discussions with and possibly surveys of customers could increase knowledge of freight markets. Rail systems might be persuaded to assist with the development of databases on infrastructure. If they are unwilling to collect and provide information on reliability, surveys might be a substitute. Through increasing our understanding and analytical capabilities in respect of the rail industry, this research should have wider benefits than just improving assessments of infrastructure adequacy; it will enable us to provide a better range and quality of advice on railway issues in general.

Further detailed research in the areas outlined above would be beneficial to rail operators and governments rail policy makers and for the BTCE, would enhance the capability of its research staff. Of particular importance is the emerging debate on the merits and demerits of separation of control and management of rail operations from fixed infrastructure, such work would provide the necessary information and data for an informed debate.

APPENDIX I CORRIDOR AND TERMINAL CHARACTERISTICS

Table I.1 ROUTE STRUCTURES CHARACTERISTICS

Rail corridors and links	*Link length kilometres*	*Axle load tonnes*	*Vertical Clearance metres*	*Ruling gradient Per cent*	*Signalling system*	*60 Kg Rail Per cent*	*Concrete sleepers Per cent of link length*	*Curves Per cent*	*Maximum passing loop lengths metres*	*Maximum trailing load tonnes*
Sydney-Melbourne	960	19	4.1	..	..	..	5	..	900	..
Chullora- Goulburn	225	19	4.1	2.5	Ctc&abs	2	Na	70	Unlimited	4275
Goulburn-Junee	261	19	4.1	2.0	Ctc&block telegraph	0	6	70	Unlimited	6515
Junee-Vic border	160	19	4.1	2.0	Ctc	0	14	98	900	6515
NSW border- Seymour	193	19	na	2.0	Ctc	0	0	98	900	4275
Seymour-South Dynon	120	19	na	2.0	Ctc	14	0	98	900	4275
Sydney-Brisbane	970	19	4.1	..	..	..	10		1500	..
Chullora- Newcastle	153	19	4.56	2.0	Ctc	4	30	40	1500	4110
Newcastle- Maitland	29	19	4.56	1.2	Ctc	4	24	40	1500	7585
Maitland- Kempsey	320	19	4.56	1.2	Ctc	4	24	40	1500	7585
Kempsey-Grafton	183	19	4.1	1.2	Ctc	7	2	40	1500	7585
Grafton-Queensland border	179	19	4.1	2.0	Ecs	7	2	40	1500	5180
NSW border- Acacia Ridge	105	19	4.1	2.0	Ecs	7	2	40	1500	5180
Goulburn-Canberra	100	19	na	2.5	Ecs	50	0	27	526	1130
Melbourne-Adelaide	796	23	4.1	..	..	..	40	..	1500	..
Melbourne-North Geelong	71	23	4.1	1.2	Ctc	100	100	100	1500	5000
North Geelong- Gheringhap	11	23	4.1	1.2	Ctc	100	0	100	1500	5000
Gheringhap-SA border	442	23	4.1	1.2	To	50	10	85	1500	5000
Vic border-Tailem Bend	193	23	4.1	1.2	Ctc	0	90	100	1500	5000
Tailem Bend- Adelaide	128	23	4.1	2.1	Ctc	3	5	70	1500	4000
Sydney-Adelaide	1635	20	5.9	1.2	..	..	32	..	900	..
Chullora-Parkes	433	19	4.1	2.0	Ctc&staff	0	0	30	800	2000
Parkes-Broken Hill	679	19	5.9	1.0	Staff	0	0	95	990	6000
Broken Hill-SA border	48	23	5.9	1.2	To	0	100	95	990	6000
NSW border- Crystal Brook	322	23	5.9	1.2	To	25	100	95	1800	6000

Rail corridors and links	*Link length kilometres*	*Axle load tonnes*	*Vertical Clearance metres*	*Ruling gradient Per cent*	*Signalling system*	*60 Kg Rail Per cent*	*Concrete sleepers Per cent of link length*	*Curves Per cent >800 m*	*Maximum passing loop lengths metres*	*Maximum trailing load tonnes*

Table I.1 Continued

Rail corridors and links	*Link length (kilometres)*	*Axle load (tonnes)*	*Vertical Clearance (metres)*	*Ruling gradient (Per cent)*	*Signalling system*	*60 kg rail (Per cent)*	*Concrete sleepers Per cent of link (length)*	*Curves Per cent >800 m*	*Maximum passing loop lengths (metres)*	*Maximum trailing load (tonnes)*
Brisbane-Cairns	1680	20	4.3	..	..	..	39	..	750	
Brisbane-Gympie	173	20	4.4	1.0	CTC	35	100	31	750	2650
Gympie- Gladstone	356	20	4.4	1.0	CTC	35	100	31	750	2650
Gladstone- Rockhampton	109	20	4.4	1.0	CTC	35	70	31	1500	2140
Rockhampton- Mackay	325	20	4.4	1.0	CTC	35	3	31	750	2650
Mackay- Townsville	378	20	4.4	1.0	CTC	35	3	31	750	2650
Townsville- Cairns	339	20	4.4	1.0	TO	35	3	31	750	2740
Adelaide-Perth	2627	23	6.8	..	..	..	93	..	1800	..
Adelaide-Crystal Brook	190	23	6.8	1.0	CTC	0	100	99	1800	6000
Crystal Brook-Port Augusta	109	23	6.8	1.0	CtC & TO	0	93	99	1800	6000
Port Augusta- Tarcoola	412	23	6.8	1.0	CtC	0	100	99	1800	6000
Tarcoola-WA border	546	23	6.8	1.0	CtC	0	100	99	1800	6000
SA border- Kalgoorlie	731	23	6.8	0.7	CtC	0	100	99	1800	6000
Kalgoorlie-Perth	683	23	6.8	0.7	CtC & ABS	15	100	100	1800	6000
Adelaide-Alice Springs	820	23	6.8	..	..	..	..	..	1800	6000
Tarcoola-Nt border	518	23	6.8	1.2	TO	0	100	99	1800	6000
SA border-Alice Springs	313	23	6.8	1.2	TO	0	100	99	1800	6000
Hobart-Burnie	360	18	4.1	2.2	..	..	..	..	1000	..
Hobart-Western Junction	199	18	4.1	2.2	TO	0	0	na	1000	1450
Western Junction-Devonport	111	18	4.1	2.2	TO	0	0	na	1000	2000
Devonport- Burnie	50	18	4.1	2.2	TO	0	0	na	1000	2000

.. Not applicable

na Not available

Notes: On the Sydney - Adelaide corridor the steepest grade occurs between Lithgow to Bathurst (1 in 33). The rest of corridor has 1 in 50 grade. On the Sydney - Brisbane corridor there is one section at 1 in 32 south of the Hawkesbury River.

Maximum passing loop length dictates the maximum length of a train. A passing loop is a siding that allows a train to pull off the line that it is travelling on to allow another train to pass.

Axle load determines the maximum carrying capacity of a wagon, for example, a wagon with 4 axles of 20 tonnes each would carry a max load of 80 tonnes.

Ruling gradient is the maximum gradient (steepness eg 1 in 40=2.5 per cent) of a section of a rail line. This controls the load able to be pulled on a train. grade as a percentage can be converted to a fraction by dividing 100 by the percentage and expressing the nominator as 1 (eg 2% is 2/100=1/50 or 1 in 50)

Clearances determine the size of loads that can be taken through a corridor

CTC = Centralised traffic control, ABS = Automatic block signalling, TO = Train Order, ES = Electric Staff, ST = Staff and ticket, and BT = Block telegraph

Source: Maunsell Consultants (1994)

TABLE I.2 TERMINAL CHARACTERISTICS

City	*Sydney*		*Melb*	*Brisb*	*Adel*	*Cairns*	*perth*	*Hobart*	*Burni*	*Alice-Sp*
Terminal	*Chul*	*Enfield*	*Sth -Dyn*	*A.ridge*	*Islingt*	*Cairns*	*Kewdale*	*Hobart*	*Burni*	*Alice Sp*
Area	*2*		*2*	*4*	*15*	*5*	*15*	*1*	*1*	*4*
Storage capacity (TEU)	100		300	300	300	100	500	50	50	100
Cranes total	5		6	4	8	1	5	1	1	3
Number	2/3		2/4	1/3	1/2/5	1				1/2
Type	RM/SL		RM/SL	RM/SL	RM/SL	RT	SL	SL	SL	RM/SL
Arrival/departure roads										
Number	1	3	7	9	7	3	4			2
Total length(metres)	700	900	5000	6000	4600	3000	6000			2600
Holding/loading roads										
Number	3		4	3	4	6	3	5	5	1
Total length(metres)	1200		2400	1300	4800	2800	3900	1500	1500	1000
Throughput/year										
TEU (000's)	140		230	110	170		150	20	10	40
Reefers (%)	5		5	5	10		10			10
Trains (arrive&dep)	2400		3600	3000	1300		1300	400	300	500
Gates										
Number in	1		3	2	3		2	1	1	1
Number out	1		1	1	1		1	1	1	1
Weighbridge yes/no	y		y	n	y		n	y	y	n
Delays										
Average time truck is in terminal(min)	20									
Time from terminal cutoff to train (min)	30				20		10			
Deficiency										
Problems areas	Area, train length, storage, capacity		Area, train length, storage, capacity	Area, train length, storage, capacity	no	no	no	no	no no	no

Note: RM-Rail mounted

TR-Rubber tyred

SL-Side loader

Note:Although delay times, where available, have been given as averages, there is a wide variability in times. Therefore, averages are indicative

Table I.3 Urban Freight Corridors

Urban Freight Corridors				
City	*Sydney*[1]	*Brisbane*	*Adelaide*[2]	*Perth*[3]
Corridor	*Chullora - Botany*	*Acacia Ridge - Fisherman Isl*	*Islington - Port Adelaide*	*Kewdale - Fremantle*
Physical Attributes				
Route length (km)	24	31	19	20
Base tonnage	1018(to) 786(from)	149(from) 3422(to)	1000	350
Which terminals serve these corridors	Botany/CookR .	Murrarie/Fisherman Is	Outer harbour/ Oil	Kwinana Steel/Nth Fremantle Cont
Interaction with urban passenger network	Yes	No	Very little	Very little
Congestion problems	Yes	No	None	None
Priority for freight trains	low	N/A	High	High
Ruling grade	1 in 80	1 in 75	1 in 80	1 in 125
Speed limit	115 down to 30	80 down to 40	80	90
Axle load	22t	20t	23t	24t
Weight limit (trailing load)	3000t	2000t	6000t	9000t
Height limit	4.8	5.4	5.9	4.3
Signalling type	CTC/ES	CTC	TO	CTC
Travel time				
Terminal to main line (h)	0.1	N/A	0.1	0.1
Port to terminal (h)	0.5	0.7	0.5	0.5
Variability in travel time (%)	20	20	20	20

Note 1: Botany Yard will consist of 2*1500m and 2*900m holding tracks and will relieve congestion with urban passengers.

Note 2: Outer harbour terminal provides for landbridge from Adelaide.

Note 3: North Fremantle terminal is primarily for interstate freight but has the potential to be expanded if markets so demand.

Source: Maunsell Consultant (1994)

APPENDIX II DERIVATION OF PRACTICAL CAPACITY

The practical capacity is derived by applying a safety factor to estimated theoretical capacity. The safety factor may be determined by the distribution of the probability of a certain number of train dispatchments. Kraft (1982) suggests that train dispatches follows the Poisson distribution concept (figure II.1). Kraft found that the probability distribution of actual train dispatchment would have a tail area of about 15 per cent, suggesting the jam capacity would be exceeded 15 per cent of the time. Kraft then deduced that the mean of the probability distribution is equivalent to the practical capacity, which is usually between 60 and 70 per cent of theoretical capacity.

Mathematically, the Poisson probability distribution is expressed as:

$$Pr(0) = e^{-\mu} \mu^{r} / r!$$

Where μ is the mean dispatching rate and r the time constraint event (train dispatches).

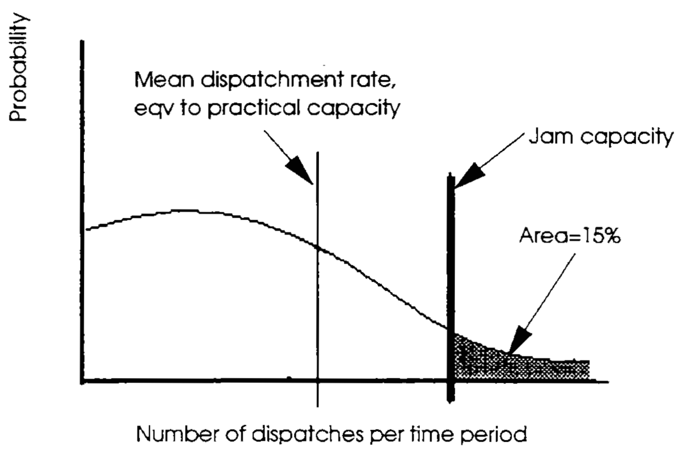


Figure II.1 Plot of probability distribution of actual dispatchment rate given the average dispatchment rate

The maximum number of trains (theoretical capacity) is influenced mainly by traffic distribution over the various sections between crossing sections. The crossing section most heavily used (with greatest accumulation of running times in both directions) determines the through traffic capacity of the total line. Each of the corridors defined in this study has at least one link or section that is a single line, which constrains and determines the overall capacity of the corridor's through traffic, assuming that the urban double track sections of the corridor are not saturated with local traffic, in which case the urban sections would be the main constraint.

Further issues on capacity.

There are a number of factors that have been identified by railway operators and empirical research as bearing on a rail line capacity. These can be grouped broadly under two headings:

- physical characteristics of the line including controls; and
- train characteristics including trains interaction.

Physical line characteristics which constrains a single line theoretical capacity includes crossing loops spacing and length, signal block length, track maintenance, grade, alignment, degree of double or multiple track, degree and nature of signalisation, and terminal capacity.

Crossing loop spacing and length affect transit times and train lengths, and in turn the total throughput of a rail line. Prolonged train delays would affect the total number of trains a line can carry in a day, while shorter train lengths due to shorter crossing loops would constrain total tonnage carried per train and in effect increase the number of trains required for the same freight. A study by the Federal Railroad Administration in the USA (P Marwick 1975) indicates average elasticity for crossing loop spacing to be 0.5; that is, a 1 per cent increase in crossing loop spacing results in about a 0.5 per cent increase in train delays. With regards to loop lengths, train scheduling might be designed in such a way that loop lengths do not impose restrictions on train lengths. This could be achieved by sending the shorter trains via the crossing loops while the longer trains use the straight, through line, and by timing longer trains to meet at meet at loops where the loop length can accomodate the longer trains Industry practice, however, indicates that such a system is difficult to achieve on a system-wide basis since it places constraints on effective utilisation of rolling stock and by itself constrains capacity.

Horizontal alignment or curvature and grades affect average train speeds, and in turn capacity. Tight curves, such as say a radius of 200 metres, impose severe speed restrictions for high speed trains. The effect is increased transit times (lower capacity utilisation) and higher operating cost. With regard to grades more powerful locomotives have reduced the influence of this factor in constraining train trailing load. However, steeper grades (eg 1 in 40) influence the load trains can pull.

The primary role of the train control system is to improve safety by ensuring that trains are separated by reasonably safe distances however, in performing this function it affects rail line capacity. The type of signal system, its nature and turnout speeds are the key factors. Control systems that allow for minimum headways based on train speed and breaking performance, for instance, would allow for greater practical capacity.

Operating characteristics that constrain capacity include average speeds, train speed distribution due to multiple train interaction, and power to weight ratio. Speed is a critical factor in the determination of capacity. It determines the time a section of a track is occupied by a train. The faster the train the more other trains can use the same track and thus enhance the track capacity. The study referred to above (P. Marwick 1975) also found that a 1 per cent decrease in speed results in a 2 per cent increase in average delay. This relationship holds for both uniform and non-uniform speeds. Higher amount of interaction between trains on a line affects average speeds. The train power to weight ratio may affect average speeds, especially where higher grades are involved.

Further issues on line performance measures

Measures of physical capacity expressed in number of trains per day tend to underplay the significance of quality of service or the performance of the rail line, particularly when the rail line's capacity exceeds current demand. Capacity definition conveys greater meaning when it is related to the performance of the rail line. Rail line performance may be measured by the following, they are additional to those discussed in the text:

Acceptable delay is defined to be the difference between maximum time allowable (scheduled time) for a train to move from an origin to a destination and a minimum time (free flow time) required for the movement (Khan 1979). Infrastructure related delays are primarily caused by speed restrictions, for example approaches to weak bridges, on tight curves and due to multiple train interaction on a single rail line, (As trains 'meet' one usually slows down to turn into a passing loop). Estimating delays above the levels of acceptable delays allows for direct comparison of the performance of different single track links (or comparison of double track against double track). Delays caused by multiple train interaction on a single line may be estimated by a mathematical model, originally formulated by E R Petersen (1974) and enhanced by BTE (1975) and Kraft (1982);

The basic functional form of the model (1) is:

$$D = N_A N_B /24 (W_A /2 (R_B + ADV)^2 + W_A(R_B + ADV)P_{minA} + W_B /2 (R_A+ ADV)^2 + W_B(R_A - ADV)P_{minB})$$

The model collapses to simply (2)

$$N^2R^2/24$$

if it is assumed that:

dollar values per hour of trains in both directions are equal to 1.0 then (W_A=W_B= 0.0),

pullout and acceleration time in both directions are equal to 0.0 that is

(P_{minA}= P_{minB}= 0.0) and train dispatching priority is first come first served, that is, ADV= 0., and

when R_A, R_B and $N_A N_B$ are represented by R and N respectively;

and where

D =dollar cost of total train delay along segment A-B or Total time delay;
N = number of trains per day;
W = dollar value per hour of trains;
R = train running time;
P = pullout and acceleration time for restarting a delayed train; and
ADV = dispatching priority expressed as time advantage.

The subscript A denotes trains from direction A to B, and B trains from direction B to A, 'min' denotes time. 24 represents 24 hour day.

$$P = (V_2-V_1)^2/(2(SV_2) \qquad 3$$

Where: V_2 and $V_1$are train final and initial speeds, respectively, as a result of train 'meet' interaction;

S is acceleration of 0.1m/sec^2 (State rail estimate).

$$ADV_{opt} = W_A(R_A+P_{minB})-W_A(R_B+P_{minA})/(W_A+W_B) \qquad 4$$

The subscript 'opt' denotes optimal.

It should be noted that when 'time advantage'(ADV) = 0 it indicates that when two trains meets enroute the preferred dispatching method is first come first served, while If ADV = 4, say, it would indicate that when two trains meet, one train is time disadvantaged by a delay of 4 minutes.

It should be noted that when W_A = W_B = 1, then the model's output D is total train delay in hours.

The estimated delays are those due to train interactions rather than those of the physical characteristics of the line such as curves and gradients. They therefore measure the effects of capacity utilisations.

Ratio of tonne kilometres and train hours (tkm/T-hr). This measure shows the amount of total output (tonne-km) of a link per average input (train hours) per train at any given level of traffic. It measures the joint performance of the link and trains under operating conditions involving congestion, and is an appropriate unit for the comparison of performance of links.

APPENDIX III EFFICIENCY TARGETS

TABLE III.1 Technical Standards ratings

Rail Corridors by Links	*Axle load:- Bmrk-25 t*		*Clearance:- Bmrk-6.8 m*		*Gradient:- Bmrk1.0 per cent*		*Signalling sys: Bmrk -CTC*		*Rail weight: Bmrk-60 kg rail*		*Sleepers: Bmrk concrete*		*Curves*		*Max Speed: - Bmrk 160 km/h*	*Passing loops: Bmrk 1500 m*		*Train Load (Tonnes)*	*Overall Effcy ratio*
	Current	*Effcy ratio*	*Current*	*Effcy ratio*	*Current*	*Effcy ratio*	*Current*	*Effcy ratio*	*Coverage (Per cent)*	*Effcy ratio*	*Cover age (Per cent)*	*Effcy ratio*	*Per cent of total length*	*Effcy ratio*	*Effcy ratio*	*Current max lgth*	*Effcy ratio*	*Max train load*	
Syd-Mel	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Chul-Goulb	19	0.8	4.1	0.6	2.0	0.5	CTC&ABS	0.9	2	0.0	na	na	70	0.7	0.7	na	na	4275	na
Goulb-Jun	19	0.8	4.1	0.6	2.0	0.5	CTC&BT	0.7	0	0.0	6	0.1	70	0.7	0.7	na	na	6515	na
Jun-Vicbder	19	0.8	4.1	0.6	2.0	0.5	CTC	1.0	0	0.0	14	0.1	98	1.0	0.7	900	0.6	6515	0.6
NSWbd-Seym	19	0.8	na	na	2.0	0.5	CTC	1.0	0	0.0	0.0	0.0	98	1.0	0.7	900	0.6	4275	na
Seym-S Dn	19	0.8	na	na	2.0	0.5	CTC	1.0	14	0.1	0.0	0.0	98	1.0	0.7	900	0.6	4275	na
Syd-Brisb	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Chul-Nectl	19	0.8	4.56	0.7	2.0	0.5	CTC	1.0	4	0.0	30	0.3	40	0.4	0.7	1500	1.0	4110	0.6
Nectl-Maitl	19	0.8	4.56	0.7	1.2	0.8	CTC	1.0	4	0.0	24	0.2	40	0.4	0.7	1500	1.0	7585	0.6
Maitl-Kmp	19	0.8	4.56	0.7	1.2	0.8	CTC	1.0	4	0.0	24	0.2	40	0.4	0.7	1500	1.0	7585	0.6
Kmp-Grfln	19	0.8	4.1	0.6	1.2	0.8	CTC	1.0	7	0.1	2	0.0	40	0.4	0.7	1500	1.0	7585	0.6
Grfn-Qld bd	19	0.8	4.1	0.6	2.0	0.5	ECS	0.5	7	0.1	2	0.0	40	0.4	0.7	1500	1.0	5180	0.5
NSWbd-Ac Rg	19	0.8	4.1	0.6	2.0	0.5	ECS	0.5	7	0.1	2	0.0	40	0.4	0.7	1500	1.0	5180	0.5
Can Con	**19**	**0.8**	**na**	**na**	**2.5**	**0.4**	**ECS**	**0.5**	**50**	**0.5**	**0**	**0.0**	**27**	**0.3**	**0.7**	**526**	**0.6**	**1130**	**na**
Melb-Adle	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Melb-Nth Glg	23	0.9	4.1	0.6	1.2	0.8	CTC	1.0	100	1.0	100	1.0	100	1.0	0.7	1500	1.0	5000	0.9
Nth Glg-Gheg	23	0.9	4.1	0.6	1.2	0.8	CTC	1.0	100	1.0	0	0.0	100	1.0	0.7	1500	1.0	5000	0.8
Gheg-SAbd	23	0.9	4.1	0.6	1.2	0.8	TO	1.0	50	0.5	10	0.1	85	0.9	0.7	1500	1.0	5000	0.7
Vicbd-Tim Bd	23	0.9	4.1	0.6	1.2	0.8	CTC	1.0	0	0.0	90	0.9	100	1.0	0.7	1500	1.0	5000	0.8
Tim Bd-Adl	23	0.9	4.1	0.6	2.1	0.5	CTC	1.0	3	0.0	5	0.1	70	0.7	0.7	1500	1.0	4000	0.6

TABLE III.1 (CONTINUED)

Rail Corridors by Links	*Axle load:- Bmrk-25 tonnes*		*Clearance:- Bmrk-6.8 metres*		*Gradient:- Bmrk-1.0 per cent*		*Signalling sy:- Bmrk-CTC*		*Rail weight: Bmrk-60 kg rail*		*Sleepers: Bmrk concrete*		*Curves*		*Max Speed: - Bmrk 160 km/h*	*Passing loops Bmrk 1500m*		*Train Load (Tonnes)*	*Overall Effcy ratio*
	Current	*Effcy ratio*	*Current*	*Effcy ratio*	*Current*	*Effcy ratio*	*Current*	*Effcy ratio*	*Cover age (Per cent)*	*Effcy ratio*	*Cover age (Per cent)*	*Effcy ratio*	*Per cent of total length*	*Effcy ratio*	*Effcy ratio*	*Current Max lgth*	*Effcy ratio*	*Maximum train load*	
Syd-Adl	..	..	..	..	..	..	..	..	..	..	..	..	..	..		..	..	..	..
Chul-Prkes	19	0.8	4.1	0.6	2.0	0.5	CTC&St 0.6	0	0	0	0.0	30	0.3	0.7		800	0.4	2000	0.4
Prkes-Bkn Hill	19	0.8	5.9	0.9	1.0	1.0	Staff 0.0	0	0.0	0	0.0	95	1.0	0.7		990	0.6	6000	0.5
Bkn Hill-SAbd	23	0.9	5.9	0.9	1.2	0.8	TO 1.0	0	0.0	100	1.0	95	1.0	0.7		990	0.6	6000	0.8
NSWbd-Cr Bk	23	0.9	5.9	0.9	1.2	0.8	TO 1.0	25	0.3	100	1.0	95	1.0	0.7		1800	1.0	6000	0.8
Brisb-Crns	..	..	..	..	..	..	..	..	..	..	..	..	..	..		..	..	..	..
Brisb-Gypie	20	0.8	4.4	0.6	1.0	1.0	CTC 1.0	35	0.4	100	1.0	31	0.3	0.7		700	0.9	2650	0.8
Gypie-Glad	20	0.8	4.4	0.6	1.0	1.0	CTC 1.0	35	0.4	100	1.0	31	0.3	1.0		700	0.9	2650	0.8
Glad-Rokn	20	0.8	4.4	0.6	1.0	1.0	CTC 1.0	35	0.4	70	0.7	31	0.3	1.0		1500	1.0	2140	0.8
Rokn-Macy	20	0.8	4.4	0.6	1.0	1.0	CTC 1.0	35	0.4	3	0.0	31	0.3	1.0		700	0.9	2650	0.7
Macy-Tville	20	0.8	4.4	0.6	1.0	1.0	CTC 1.0	35	0.4	3	0.0	31	0.3	1.0		700	0.9	2650	0.7
Tville-Crns	20	0.8	4.4	0.6	1.0	1.0	TO 0.5	35	0.4	3	0.0	31	0.3	1.0		700	0.9	2740	0.6
Adle-Perth	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Adle-Cryst Brk	23	0.9	6.8	1.0	1.0	1.0	CTC	1.0	0	0.0	100	1.0	99	1.0	0.7	1500	0.8	6000	0.8
Crys Brk-Pt Ag	23	0.9	6.8	1.0	1.0	1.0	CTC&TO	1.0	0	0.0	100	1.0	99	1.0	0.7	1800	1.0	6000	0.8
Pt Ag-Tarc	23	0.9	6.8	1.0	1.0	1.0	CTC	1.0	0	0.0	100	1.0	99	1.0	0.7	1800	1.0	6000	0.8
Tarc-SAbd	23	0.9	6.8	1.0	1.0	1.0	CTC	1.0	0	0.0	100	1.0	99	1.0	0.7	1800	1.0	6000	0.8
SAbd-Kalg	23	0.9	6.8	1.0	0.7	1.4	CTC	1.0	0	0.0	100	1.0	99	1.0	0.7	1800	1.0	6000	0.9
Kalg-Perth	23	0.9	6.8	1.0	0.7	1.4	CTC&ABS	1.0	15	0.15	100	1.0	100	1.0	0.7	1800	1.0	6000	0.9
Adl-A Sps	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Tarc-NT bd	23	0.9	6.8	1.0	1.2	0.8	TO	1.0	0	0.0	100	1.0	99	1.0	0.7	1800	1.0	6000	0.8
SAbd-A Sps	23	0.9	6.8	1.0	1.2	0.8	TO	1.0	0	0.0	100	1.0	99	1.0	0.7	1800	1.0	6000	0.8

na not available not applicable Bmrk = bench mark

Notes: On the Sydney - Adelaide corridor the steepest grade occurs between Lithgow and Bathurst (1 in 33). The rest of corridor has 1 in 50 grade. On the Sydney - Brisbane corridor there is one section at 1 in 32 south of the Hawkesbury River.

Maximum passing loop length dictates the maximum length of a train. A passing loop is a siding that allows a train to pull off the line that it is travelling on to allow another train to pass.

Axle load determines the maximum carrying capacity of a wagon, for example, a wagon with 4 axles of 20 tonnes each would carry a max load of 80 tonnes.

Ruling gradient is the maximum gradient (steepness eg 1 in 40) of a section of a rail line. This controls the load able to be pulled on a train

Clearances determine the size of loads that can be taken through a corridor.

Source: Maunsell Consultants (1994)

TABLE III.2 Targets and Expected Investment Impact on Service level Attributes

Corridor	Attribute	Post OneNat /MLU			Targets Goal-1			Goal-2		
		A	B	C	A	B	C	A	B	C
BNE-CNS	Capacity (trains/24h)	13	24	1.00	13	24	1.00	na	na	na
	Delivery Day	2	2	1.00	2	2	1.00	na	na	na
	Transit hours	22	30	0.73	22	22	1.00	na	na	na
	Average Speed	80	40	0.5	80	80	1.00	na	na	na
	Reliability	na	na	na	n/a	n/a	n/a	na	na	na
	Costs (cents/ntk)	3.4	5.5		3	3	1.00	na	na	na
	Average			0.76			1.00			
SYD-BNE	Capacity (trains/24h)	13	13	1.00	13	22	1.00	15	22	1.00
	Delivery day	1	1	1.00	1	1	1.00	1	1	1.00
	Transit hours	14	19	0.74	13	13	1.00	10	10	1.00
	Average speed	80	50	0.64	80	80	1.00	100	100	1.00
	Reliability	50	168	0.30	49	49	1.00	20	20	1.00
	Costs (cents/ntk)	3.4	5.6	0.61	3	3	1.00	2	2	1.00
	Average			0.71			1.00			1.00
SYD-MEL	Capacity (trains/24h)	20	26	1.00	20	26	1.00	26	26	1.00
	Delivery day	1	1	1.00	1	1	1.00	1	1	1.00
	Transit hours	14	15	0.93	13	13	1.00	10	10	1.00
	Average speed	80	70	0.88	80	80	1.00	100	100	1.00
	Reliability	48	95	0.51	48	48	1.00	19	19	1.00
	Costs (cents/ntk)	3.8	5.8	0.66	3	3	1.00	2	2	1.00
	Average			0.82			1.00			1.00
MEL-ADL	Capacity (trains/24h)	9	22	1.00	9	22	1.00	12	22	1.00
	Delivery day	1	1	1.00	1	1	1.00	1	1	1.00
	Transit hours	12	14	0.86	12	12	1.00	9	9	1.00
	Average speed	80	65	0.81	80	80	1.00	100	100	1.00
	Reliability	40	58	0.69	40	40	1.00	16	16	1.00
	Costs (cents/ntk)	3.5	4.8	0.73	3	3	1.00	2	2	1.00
	Average			0.85			1.00			1.00
ADL-PER	Capacity (trains/24h)	5	12	1.00	5	12	1.00	7	12	1.00
	Delivery day	2	2	1.00	2	2	1.00	2	2	1.00
	Transit hours	36	45	0.80	33	33	1.00	26	26	1.00
	Average speed	80	66	0.83	80	80	1.00	100	100	1.00
	Reliability	132	199	0.66	132	132	1.00	53	53	1.00
	Costs (cents/ntk)	2.5	2.5	1.00	2.5	2.5	1.00	2	2	1.00
	Average			0.88			1.00			1.00
ADL-ASP	Capacity (trains/24h)	3	10	1.00	na	na	na	3	10	1.00
	Delivery day	1	1	1.00	na	na	na	1	1	1.00
	Transit hours	22	26	0.85	na	na	na	15	15	1.00
	Average speed	80	75	0.94	na	na	na	100	100	1.00
	Reliability	77	58	1.00	na	na	na	31	31	1.00
	Costs (cents/ntk)	3	3	1.00	na	na	na	2	2	1.00
	Average			0.96						1.00

Notes A relates to the market requirement B relates to what the authority can deliver
. C is the competitiveness rating.

Market costs (A) are based on market expectations, and are fully distributed cost

Supply costs (B) are costs for rail services but without any further reform in work practices.

Reliability= minutes deviation per 100km with five and two minutes allowance for goal 1 and 2 respectively.

Capacity is assigned 1.0 if supply is greater than or equal to demand, and it is interstate train path only

GLOSSARY

Automatic Block Signalling (ABS) Similar to CTC but without a central controller. Coloured lights are used to merely keep trains separated from each other.

Axle loads determine the maximum capacity of a wagon.

Ballast provides the cushioning and drainage needed to support a long life railway track.

Block Telegraph A mechanical system of safeworking where trains are protected by signals controlled from local signal boxes at stations. The signal boxes communicate with each other on the movement of trains.

Clearances (horizontal and vertical) are important as they determine the size of loads that can be taken through the corridor.

Continuous Welded Rail (CWR) The track where the running rail is welded into very long lengths to form a continuous running surface without joints. Expansion and contraction is resisted by the sleepers pushing against the ballast around them. To enable this the rail is fastened to the sleeper with a resilient fastener that does not allow any longitudinal movement. If the rail is simply spiked down to a timber sleeper, rail anchors have to be used to resist the movement.

Centralised Traffic Control (CTC) The system by which trains are controlled from a central point through a system of coloured lights. The location of a train is indicated to the controller on a board (or computer screen) by the train tripping a circuit on the track. The controller can also control turnout settings.

Double Stack The method of loading where one container is placed on top of another on a special railway wagon called a well wagon. Additional operational efficiencies can be derived from double stacking by enabling twice the number of containers to be carried for the same length of train.

Dual Gauge A section of track which has three running rails to allow access by different gauge trains.

Electric Staff (ES) A form of safeworking where the train driver carries an authority to travel over a certain section of the railway (the staff). Only one authority is released at a time and thus only one train is allowed on a section between staff stations at any one time.

Fastener The component that attaches the rail to the sleeper. The most common fastener is the dographic which is driven in a pre-drilled hole in the sleeper. However, this has the weakness that it can come loose under traffic, and need to be re-spiked.

Gauge The distance between the running rails on a railway track. Most of the national rail system is Standard Gauge (1435 mm), except for Melbourne to Adelaide which is currently Broad Gauge (1600 mm) - soon to be converted to standard gauge - and Brisbane to Cairns which is Narrow Gauge (1067 mm). The Hobart to Burnie corridor is also narrow gauge.

M160, M220, M270 Load ratings based upon a theoretical steam locomotive with driving wheels of 16 tonnes, 22 tonnes and 27 tonnes, respectively. The actual axle load of a train is different to the 'M' rating as the axles are spaced differently. For example a bridge rated as M160 can carry wagon gross axle loads up to 20 tonnes. This means that a two-bogie (4 axle) wagon can weigh up to 80 tonnes. Depending upon the tare weight of the wagon normally (about 15 to 20 tonnes), this would mean a maximum payload of 60 tonnes.

Passing (crossing) Loop A siding that allows a train to pull off the line that it is travelling on, to allow another train to pass. The length of a passing loop is major constraint to the length of the train.

Ruling Gradient The maximum gradient (steepness) on a section of line, which therefore controls the load able to be pulled on a train.

Safeworking The management of trains to ensure that they are kept separated and do not collide. Unlike cars and trucks, trains can take up to two kilometres to stop in an emergency.

Staff and Ticket A method of safeworking whereby the train driver needs to have a 'staff' issued by a stationmaster to travel to the next station. There is only one staff for a section and the stationmaster cannot let another train onto the section unless the staff has been returned either to himself or to the next station up the line. If the next train is allowed to go on the section, it either picks up the staff (in the case of a returning train) or uses its previous staff to unlock a security box to get a 'ticket' to authorise travel to the next station.

TEU A standard size shipping container which is 20 feet (6.1 m) long.

Trailing Load The maximum load that can be pulled on a train. It can dictate how long a train can be, not taking into account passing loops.

Train Order A method of safeworking that operates through train drivers following a set of instructions called Train Orders from a central traffic controller. This is the cheapest form of safeworking.

Turnout A point where one railway track diverges into two. Whether a train follows one track or the other is determined by which way the movable parts (called switches) are positioned. In CTC territory the switches are set by the traffic controller. The type of turnout is defined by the angle (expressed as a ratio) and by the weight of rail used in its construction. The speed of a train passing through a turnout is determined by the angle of the turnout. For instance a 1 in 16 turnout has a speed of 55km/hr.

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ABBREVIATIONS

AN	Australian National Railways Commission
ARRDO	Australian Railway Research and Development Organisation
BIE	Bureau of Industry Economics
BTE	Bureau of Transport economics
BTCE	Bureau of Transport and Communications Economics
CTC	Canadian Transport Commission
NRC	National Rail Corporation

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