Relative Efficiencies in the Transportation of Commodities

Report

This Report assesses the relative efficiencies of road and rail in the transportation of several bulk commodities. The work explores potential constraints to the efficient transportation of bulk commodities, including the pricing systems applied by road and rail operators.

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RELATIVE EFFICIENCIES IN THE TRANSPORTATION OF COMMODITIES

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FOREWORD

The 1986–1988 Royal Commission into grain storage, handling and transport resulted in efficiency gains due to a wider choice of handling and transport options and greater responsiveness to market requirements. Following the Commission, the Minister for Land Transport and Shipping Support requested the Bureau to investigate the transport issues of other bulk commodities.

In response, the Bureau undertook a study of relative efficiencies in the transportation of commodities, with major emphasis being placed on export coal, Australia's leading export earner. This report presents the results of an investigation of coal transport, which are indicative for most bulk commodities with similar transport characteristics. Variations of the model developed for this analysis can be usefully applied in analogous investigations.

This report was completed by a study team comprising Mr T. Mikosza (project leader), Ms B. Dziatkowiec, and Ms O. Vaisvila with contributions from Mr G. Pickup. Dr R. Batterham of the Department of Agricultural Economics, University of Sydney developed the models used to analyse coal transport.

A. P. OCKWELL
Research Manager

Bureau of Transport and Communications Economics
Canberra

September 1992

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ABSTRACT

This report assesses the relative efficiencies of road and rail in the transportation of several bulk commodities. The work explores potential constraints to the efficient transportation of bulk commodities, including the pricing systems applied by road and rail operators.

The work is relevant to the Federal Government's micro-economic reform agenda, particularly to improving Australia's competitiveness in international bulk commodity markets through improved transportation efficiency. A case study uses mixed integer linear programming models to identify the least social cost methods of transporting New South Wales export coal from mines to ports, based on optimal utilisation of available transport resources.

The results indicate that rail is cheaper than road in social cost terms for bulk commodities characterised by large volumes, long distances and for line hauls ending in a single destination. Road better fulfils a role of delivery to railheads and is a competitive option for commodity transport involving multiple destination points.

While regulation to rail still exists in some States for a number of bulk commodities, it is highly unlikely that there would be a significant shift to road with deregulation. Grain transport after deregulation demonstrates that rail has generally retained its market share, with more competitive freight rates and a more responsive service to users.

SUMMARY

Efficiency of transportation, in terms of setting prices to reflect social costs and correctly targeted investment, has important implications for resource use in the whole economy.

As the transport industry services all other sectors of the economy, reform of transport is an important component in the Federal Government's overall approach to economic reform.

In the case of export of bulk commodities, maintaining and improving Australia's competitiveness in international markets has priority on the microeconomic reform agenda.

This Bureau study was undertaken with the following principal aims:

- to identify and document sources of inefficiency of bulk commodity transportation, with emphasis on coal transportation in New South Wales; and
- to evaluate the resource costs of transporting coal and other bulk commodities under alternative transport arrangements as a means of identifying a socially optimal transport method based on total resource costs.

Important features of the present transport arrangements are government intervention in the setting of rail charges and under-recovery of road user costs.

If regulations are not present in the market and competing modal possibilities for the transportation of commodities exist, modal choice is usually determined by lower freight charges reflecting lower private costs. However, least private costs are not necessarily the most acceptable solution from a social point of view.

Account needs to be taken of external costs of transportation which are borne by society as a whole. These are the costs of accidents, road damage, noise and air pollution, and fuel and time costs of congestion. Investigation of transport efficiency in this report includes those social costs which were quantifiable and thus were included in the analysis.

COAL TRANSPORTATION

Bulk commodities such as wheat, coal and minerals usually have to be transported long distances from their point of production (farm or mine) to a port

for export or to a processing plant. The study considered the two major surface modes of road and rail and their current transport arrangements for bulk commodities.

In particular, an investigation was conducted of the transportation of export coal from the Hunter and Newcastle Coalfields to the Port of Newcastle and from the Southern Coalfield to Port Kembla and Balmain. The coal industry plays an important role in the Australian economy, with black coal accounting for about 11 per cent of total export revenue in 1988–89.

The transport characteristics of these two coalmining areas differ significantly. The Hunter Region has relatively flat topography and is well serviced by direct road and rail connections which also carry other freight and passengers. By comparison, the Southern Coalfield has unfavourable topography for transport, leading to indirect routes, incomplete rail access and heavy suburban rail traffic on some routes.

The two coalmining areas were examined with an aim to cover a diversity of transport options and issues, so as to establish a sound base for analysing transport situations posed in other commodity markets.

METHODOLOGY

Commodity transportation networks with multiple transport choices call for the application of a specialised method. This led the Bureau to develop mixed integer linear programming models of coal transportation in the Hunter Valley and Southern Coalfield to determine the least social cost combination of transport modes.

The method involved estimating the costs of complementary road and rail options over a selection of routes to identify the optimal transport configuration in social cost terms. Account was taken of the fixed costs of transport infrastructure maintenance required to keep railway lines open. Added to this were road and rail operating costs, the costs of reloading of coal between mine-site and port and the costs of road accidents and road damage.

RESULTS

The major result of this investigation is that rail is a lower cost option than road in social cost terms. The comparative advantage of rail over road in the transportation of coal was more evident in the Hunter Valley than in the Southern Coalfield. Rail transport cost efficiency in the Southern Coalfield was somewhat constrained by limits on the size of train consists and by longer turnaround times arising from steeper ruling grades and circuitous rail routes.

The optimal transport configurations for the mines examined were generally rail only or a mix of road and rail. However, the use of road in the mixed mode configurations was usually confined to transporting coal from minesite to a rail loading facility. Rail, on the other hand, performed the role of line haul. Alternatively, optimal configurations were conveyor and rail.

A review of other commodities' transport tasks and arrangements revealed that large volume tasks such as bauxite and alumina are not directly amenable to any modal changes in transport for efficiency reasons. Other commodities such as oil, petroleum and fertiliser have their transport based on principles of distributional logistics not necessarily involving least cost transport arrangements for component tasks. Analysis did not extend to these transport networks.

CONCLUSIONS

The investigation has proved useful in a number of ways. The issue of divergence between private costs and social costs was clarified in the context of overall efficiency of resource use. Mixed integer linear programming models were developed to determine the least social cost combination of modes to meet a transport task. Similar models can be applied to review transport efficiencies of other commodities.

By way of limitations, it is important to note that the least cost solutions do not imply that the current transport activities are operating efficiently. The analysis was conducted in a static framework and, apart from the Maldon to Dombarton railway project in the Southern Coalfield, did not consider opportunities for investment in infrastructure. Nor was absolute or technical efficiency considered.

However, the technique has scope for development to a dynamic framework including investment, transport task growth and so on. The technique provides policy makers with a tool for determining transport inefficiencies and assists in policy development on key issues of reform.

CHAPTER 1 INTRODUCTION

Following the 1986–1988 Royal Commission into grain storage, handling and transport, the BTCE undertook a study of relative efficiencies in the transportation of commodities with emphasis on leading export commodities.

With black coal ranked as Australia's largest export earner, this analysis was based on a case study of efficiencies of coal transportation in New South Wales. The case study, involving the appraisal of a variety of transport configurations and issues of two coalmining areas, produced results which serve as a yardstick for comment on the relative efficiency of transport of other commodities. The study timeframe and limited research resources did not allow for detailed analyses of the transport of commodities other than coal. The coal case study demonstrated that an extensive data regime was required for such analyses.

COMMODITIES' TRANSPORT CHARACTERISTICS

Bulk commodities such as wheat, coal and minerals usually have to be transported long distances from their point of production (farm or mine) to a port for export or to a processing plant. The study considers the two surface modes, namely road and rail, which dominate in the transport of bulk commodities. Other modes, such as conveyor belts used to transport coal to power stations and bauxite to refineries, or pipelines used in oil movement, entail mostly short transport distances and are not included in this study.

The composition of the tasks performed by road and rail differs significantly. While in 1988 bulk commodities constituted only 20 per cent of total tonnes carried by road (ABS 1990a) more than 90 per cent of the rail freight (private and State) consisted of wheat, minerals and other bulk commodities (BTCE estimate, 1990).

EFFICIENCY OF TRANSPORTATION

Prices for coal and other bulk exports are set on world markets. A significant part of the f.o.b. price of bulk commodities is comprised of transport charges, estimated to be between 15 and 45 per cent for minerals, depending on the product and locality. This underscores the importance of efficiency gains in a transport system which features natural monopolies or government regulation. Other distortions in the market, such as under-recovery of road user costs (BTCE 1988a), play a significant role in setting the scenario for road-rail competition.

If regulations are not present in the market and competing modal possibilities for the transportation of commodities exist, modal choice is usually determined by lower freight charges reflecting lower private costs. However, least private costs are not necessarily the most acceptable solution from a social point of view.

Account needs to be taken of the external costs of transportation which are largely borne by society as a whole. These are the costs of accidents, road damage, noise and air pollution, and fuel and time costs of congestion. Investigation of the relative efficiency of modes in this study includes those social costs which were quantifiable, and approaches economic efficiency from a total resource cost viewpoint.

Efficiency of transportation, in terms of setting prices to reflect social costs and correctly targeted investment, has important implications for resource use. In the case of exports, efficiency of transportation is a key factor in maintaining Australia's competitiveness on international markets. Reform in transport is therefore an important component in the Federal Government's overall economic reform agenda. The development of models and their application to problems constraining the efficient transportation of goods provides policy makers with an important tool to address issues associated with reform.

STUDY AIMS

The investigation reported in this paper has the following aims:

- identify and document problems affecting the efficient transportation of bulk commodities, with an emphasis on the transportation of coal in New South Wales;
- evaluate and document the resource costs of transporting coal and other commodities under alternative transport arrangements as a means of finding the optimal transport method; and
- identify other social and environmental impacts of alternative transport options.

A secondary aim is to develop models to determine the least social cost method of transporting bulk commodities where some transport modes involve substantial fixed costs. The models are applied to determine the relative efficiencies of road and rail transportation of coal from the Hunter and Newcastle Coalfields to the Port of Newcastle and from the Southern Coalfield to Port Kembla and Balmain.

STRUCTURE OF THIS REPORT

Background information on the study's origins and its place in the Federal Government's overall reform agenda for land transport is given in chapter 2.

The methodology is discussed in chapter 3 along with model development to analyse the relative efficiency of land transport modes in carrying coal. Coal transport arrangements are discussed with the view of identifying possible constraints on efficiency and on alternative transport availability. The chapter justifies the selection of New South Wales coal transportation for a case study.

Chapter 4 describes and interprets the results obtained from the analysis of two New South Wales coalmining areas. The findings of the coal case study are applied, in relevant cases, to the relative efficiency of transportation of other commodities.

Chapter 5 deals with petroleum and minerals. The aluminium and base metals industries are described in terms of major production areas, transport tasks and patterns, to mid uses (semi-processing stage) and final destination.

In Chapter 6 an appraisal is made of post-Royal Commission grain transportation. The transportation characteristics of fertilisers and limestone are also examined.

Chapter 7 outlines the conclusions with special emphasis on the potential contribution the analysis can make to policy development in commodity transport and its social and environmental impacts.

CHAPTER 2 BACKGROUND

Transport in Australia is undergoing a transformation to make it more user responsive and efficient. The Federal and State governments have in place a series of reform measures to attain these ends. For example, the Federal Government's micro-economic reform agenda targets a number of issues in land transport, shipping and the waterfront as well as domestic and international aviation. The end objective of these reform initiatives is to develop a national transportation system.

LAND TRANSPORT REFORMS

Much of the responsibility for the land transport infrastructure rests with the States and Territories. Central to the Federal Government's land transport micro-economic reforms is the development of a more balanced and integrated approach to land transport. In 1989-90 the Industry Commission estimated that a more efficient land transport system could realise an additional $6 billion in gross domestic product every year. Of this, $4.4 billion was attributable to rail (Hansard 1992). The reforms undertaken by the Federal Government include uniformity of regulations, the setting of road funding priorities for national highways and arterials, improving rail efficiency, new measures to reduce road crashes and a more equitable system of road use charges.

Restructuring of the rail industry

As an illustration of governments' achievements in rail reform since 1983, Australian National's labour productivity in freight has more than doubled while its employment has been reduced by 33 per cent. For all systems, employment reductions have averaged 26 per cent (Industry Commission 1991).

Cost recovery

Railway efficiency has national as well as State implications. All public railway systems are operating in deficit, with the State governments cross-subsidising urban and passenger services and, to a lesser extent, the unprofitable areas within freight activities. According to the Railway Industry Council (RIC), cost recovery on freight and passenger services at the national level for non-urban rail was estimated at 76 per cent in 1986–87 (RIC 1990a). For individual systems, cost recovery for non-urban rail ranged from 97 per cent for Queensland Railways to 39 per cent for V/Line of Victoria. For individual commodities, cost recovery varies quite markedly. For non-urban rail services, cost recovery for coal and minerals in 1986–87 at the national level was 140 per cent, whereas for Less-than-Car-Load (LCL) freight it was only 24 per cent (RIC 1990a).

Railway Industry Council

Restructuring of the rail industry is being pursued through Federal and State governments' initiatives. RIC, a tripartite body comprising representatives of rail management, rail unions and relevant governments, had as its main objective the development of medium- and long-term strategies to improve the viability and competitiveness of the railway industry. RIC's recommendations are documented in RIC (1990b).

Australian Rail Industry Advisory Council

On the recommendations of RIC the Australian Rail Industry Advisory Council (ARIAC) was established to help railways maximise commercial opportunities and provide enhanced user oriented services. ARIAC comprises users of rail services, representatives of government, rail system managements and unions. It is a forum providing advice to the Federal Minister on developing an efficient and competitive rail system.

National Freight Initiative

On another front, the Federal Government pursued the establishment of the National Rail Corporation (NRC) in 1991 through the National Rail Freight Initiative (NRFI). NRFI was developed in late 1989 with the participation and support of the individual railway systems, major rail users and the Federal Government with the specific mission of establishing an efficient national rail freight enterprise providing profitable and competitive interstate services. Interstate rail freight is a growing national market and it has a direct impact on Australia's overseas trading performance in terms of its growing overseas container traffic (Booz.Allen 1990). The NRC will become operational in late 1992.

Review of road freight industry

The road freight industry is also under continuing review by the Federal and State governments. For example, the Federal Government is pursuing the issue of greater uniformity of regulations across States. Developments in regulation, registration and charging arrangements have enabled B-Doubles to be operated under nationally uniform conditions. The Inter-State Commission (1990) released a series of recommendations for road cost recovery on a user-pays approach in a report on the road freight industry.

Reforms to establish a national heavy vehicle registration scheme together with uniform technical and operating regulations and a nationally consistent road use charging regime have been pursued by the newly established National Road Transport Commission (NRTC).

Infrastructure funding

An inter-related issue of the reform process is a clearer definition of the roles and responsibilities of the various tiers of governments in the area of road funding.

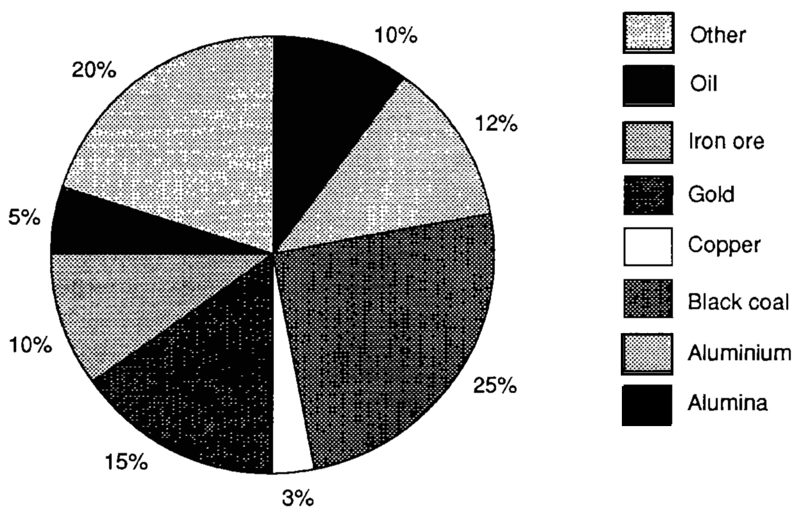
The Special Premiers' Conference of July 1991 agreed that the Commonwealth's responsibilities should concentrate on national highways and roads of national significance. The States agreed to continue to lift the efficiency of their road construction authorities.

The full program of road reforms aims to complement the rail initiatives to provide an efficient, integrated land transport system.

COMMODITY TRANSPORTATION

Transportation of commodities is an important element of the land transport system. ABARE (1990) estimated that minerals, including by-products such as alumina, pig iron and ingots, iron ore pellets and nickel matte, and bauxite represented around 47 per cent of Australia's total export earnings in 1988–89. Figure 2.1 depicts the composition of the 1988–89 export of bulk commodities.

Transportation of black coal, iron ore, wheat, alumina, mineral concentrates, crude oil and condensate, and sugar has a common feature. The transportation usually takes place from point of production/extraction to port, and the handling equipment and vehicles or rollingstock are predominantly commodity specific.



Note In 1988–89 minerals and their by products represented 47 per cent of Australia's export earnings.

Source ABARE (1990).

Figure 2.1 The composition of the 1988–89 export of bulk commodities

The costs of transport and handling of these commodities account for a significant part of the f.o.b. trimmed cost of delivery at the ports. In the case of black coal, transport and handling accounts for 30 to 45 per cent of the f.o.b. price (DPIE, pers. comm. 1990). Clearly, efficiency gains in transport and handling are vital for Australia's ability to trade in international markets. Moreover, efficiency gains generated by larger export volumes represent a favourable net impact on Australia's balance-of-payments. An efficient commodity transport system is very unlikely to facilitate imports. The primary production areas simply do not support large enough populations for significant consumer-oriented imports, nor can the commodity transport systems be readily adapted to the backloading of the imports.

ECONOMIC EFFICIENCY

Efficiency in this paper equates with economic efficiency of resource use. In a setting of competitive capital and labour markets, inefficient use of resources within one sector impinges on other sectors of the economy by means of attracting investments based on incorrect price signals. In this way, inefficiency of resource use affects the overall economic performance of the country. The relative efficiency with which transport uses resources may be gauged from a comparison of resource costs of alternative transport options after allowing for external costs relating to congestion, environment and safety.

Impediments to efficiency of resource use in the transport sector

The economic setting is constantly changing and it is important that the transport sector adjusts accordingly to minimise inefficiencies of resource use and their subsequent costs to the economy. Several situations can lead to market distortions and to transport inefficiencies.

Government regulations

An inappropriate or anachronistic regulatory framework is one set of distortions stemming from governments' intervention. Government railways have been actively pursuing efficiency gains and lowering freight charges for bulk commodities in real terms. However, any remaining regulation to rail of lossmaking operations (passenger CSOs, LCL freight) can potentially lead to inefficiencies through cross-subsidies.

Under-recovery of social costs of providing transport infrastructure

Another example of transport inefficiency can stem from a competitive market whereby freight charges do not reflect real costs of infrastructure provision. The typical inefficiency here is a misallocation of transport resources or inappropriate infrastructure resulting from lower infrastructure charges than the social opportunity costs of providing it. In the case of divergence between private and social costs of providing transport services, society bears part of the economic costs.

Problems of self-regulation

The inability of the road transport sector to be self regulating in the areas of load limits, design standards and safety provisions provides an indication of market failure which contributes to another divergence.

Externalities generated by transport

Similarly, externalities such as local air and noise pollution, accidents, congestion and environmental impacts, although incurred by users of transport services, are costs borne by society. In this case an appropriate regulatory framework may be well justified.

Road damage costs recovery

Another area which illustrates divergence between private and social costs in freight transport is that of road damage. Road user charges do not reflect closely the costs of road damage caused by vehicles. In general, operators of light vehicles are overcharged and operators of heavy vehicles are under-charged (BTCE 1988b). Failure to have markets allocate costs to individuals means that, unless other correcting mechanisms are introduced, some misallocation of resources is likely to occur, resulting in a less efficient combination of transport services to meet the freight task.

Social versus private costs

In the analysis undertaken here, private and social costs incurred by transport activities were included where possible. A few approximations exist where it was not practical to attempt to precisely isolate resource costs. Thus the rail operating costs do not include State Rail's infrastructure investment costs because the levels of investment for specific railway lines are not known. No attempt was made to net out tax and excise on fuel. However, these imprecisions are deemed to be minimal in terms of the total cost of inputs used to specify activities in the model.

For such variables as quality of life, it was not possible to obtain an estimate of the reduction of utility resulting from trucks or freight trains passing through urban areas. However, the linear programming approach does provide scope for sensitivity analysis to be conducted on the shadow prices relevant to such externalities. The purpose of using a total cost objective function was to estimate the impact of transportation activities on overall efficiency of resource use.

RESEARCH METHOD

The problem of commodity transportation resolves itself to comparing, from the point of view of the nation as a whole, the value of resources used to perform the current transportation task against the value of resources that would be used by feasible transport alternatives. As the resources consumed are being paid for by society as a whole, the object of this exercise is to find a transport configuration which minimises total social costs.

This study identifies the least cost option of coal transportation by road, rail or a combination of both. The least cost option includes the minimum private costs and the external costs for the community as a whole which arise from the transport option. Private costs include the capital and operating costs of transport operators. The common externalities of commodity transportation are road accidents, road damage, noise and air pollution, and fuel and time costs of congestion. However, incomplete data forestalled consideration of the costs of noise and air pollution, and congestion.

Finding the least social cost transport option is straightforward for a single transportation link, say, from a mine to port. However, commodity transportation networks with multiple transport choices call for the application of a specialised method. This led to the development of a mixed integer linear programming model (chapter 3). In this paper the model was applied to a case study of the transportation of coal in New South Wales.

Transport of coal was examined for two coalmining areas. The first area comprised the adjoining Hunter and Newcastle Coalfields from which export coal is transported to the Port of Newcastle. The second area is the Southern Coalfield, with export outlets at Port Kembla and Port Jackson (Balmain). A detailed description of coal transportation in the two areas is found in appendix II.

The transport characteristics of the two areas differ considerably. The Hunter Region is characterised by relatively flat topography and is well serviced by direct road and rail infrastructure which also carries other freight and passengers. The Southern Coalfield by comparison has unfavourable topography for transport, leading to indirect routes, incomplete rail access, and a heavily trafficked suburban and urban rail system on some of the routes (T. Kearney, State Rail, pers. comm. 1990).

The two coalmining areas were studied with an aim to cover a diversity of transport options and issues, so as to establish a sound base for examining transport problems for other commodities. The transport tasks of other commodities outlined in this study represent similar issues to New South Wales coal in terms of their possible analysis of relative transport efficiencies.

The general approach taken to identify efficiency gains in the transport of commodities does not stop at the examination of transport efficiencies of other commodities. The study has application for more intensive investigations of land transport in a dynamic setting.

The existing transport system included the routes and modes currently used to transport coal, together with alternative routes and modes that could be used without the construction of new roads, railways (apart from the Maldon to Dombarton rail link in the Southern Coalfield), conveyor belts, slurry pipeline or coal loading facilities. In a dynamic setting, the effect of investment in such new facilities can be investigated taking into account the likely demand for transport services. A thorough analysis would also take into account a mix of commodities transported over road and rail.

The principles of the linear programming model and the detailed data input required for the specification of activities are described in chapter 3. The model is discussed in terms of its scope for enhancement to determine the land transport investment schedule to minimise net social costs.

CHAPTER 3 METHODOLOGY

The research method chosen to model the existing road and rail commodity transport arrangements, in terms of social costs they generate, is a *mixed integer linear program.* Linear programming is a standard technique for finding an optimal allocation of limited resources among competing activities (see Hillier and Lieberman (1973) and Lee, Moore and Taylor (1990) for details). The technique is ideally suited to the types of transportation problems encountered in this study. Each existing transport method and its practical alternatives can be specified in terms of a series of discrete activities for which dollar costs of resource use can be determined. The optimal use of these transport resources equates with the least resource cost incurred by society as a whole.

MIXED INTEGER LINEAR PROGRAMMING

The principle of the linear programming approach may be summarised using an illustrative example of commodity transportation, as shown in figure 3.1.

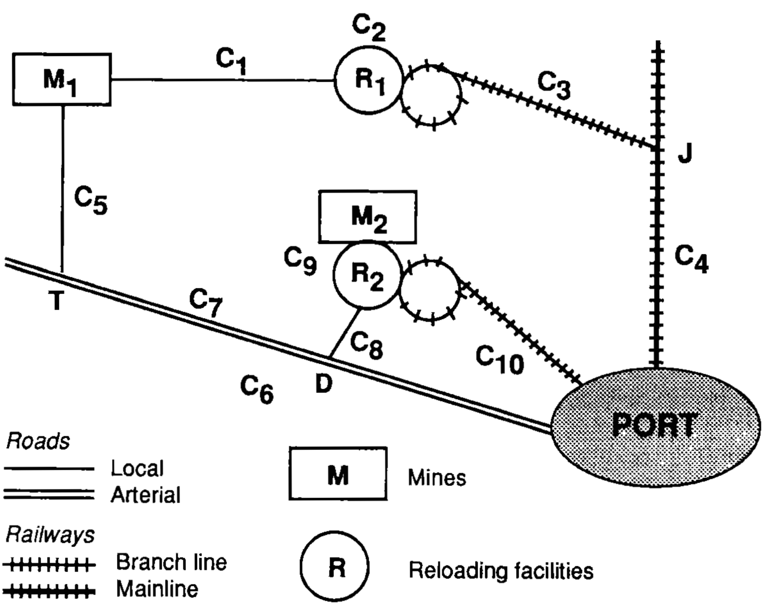


Figure 3.1 An example of a commodity transportation problem

The problem is one of choosing the least social cost method of transporting an output from mine M_1 to Port. Three transport options exist. The present option (option 1) is to take the product by truck over a local road to R_1, for reloading to rail. The product is then railed over a branch line to junction J and thereafter over mainline to Port.

Two other options exist for transport of the product from mine to port. Option 2 involves trucking of the product from M_1 to T over a local road, then over an arterial road to Port. Option 3 involves turning off from the arterial road at D to a local road leading to reloading facility R_2 next to mine M_2. The product is then railed over a minor private railway to Port.

The mathematical statement of the linear programming problem is the following. Find $x_1, x_2, ..., x_n$ which *minimise* the linear objective function,

$$Z = c_1x_1 + c_2x_2 + ... + c_nx_n$$

subject to certain restrictions or constraints.

The x_i $(i = 1, 2, ..., n)$ are so-called decision variables, and represent the value of the various discrete transport and loading activities specified in the model. Thus, the present transport method (option 1) consists of a trucking activity at cost c_1, a reloading activity at cost c_2, and two railing activities: over a branch line at cost c_3 and mainline at cost c_4. The costs comprise fixed and variable costs of transport and reloading, and external costs of these activities. The total number of discrete activities for the three transport options is ten ($n = 10$).

The constraints referred to in the linear programming problem are usually capacity constraints, in terms of an activity's throughput. Thus, the reloading facility R_2 at mine M_2 may not have sufficient spare capacity (s) to cope with all the product from mine M_1, that is, each variable

$$x_5, x_7, x_8, x_9 \leq s$$

This capacity constraint demonstrates the interdependence of the transport and loading activities. Two more sets of constraints are specified. One is the assumption that if rail branch line R_1J is to be used, that is, fixed line maintenance costs are expended on it, then these costs are also expended for the mainline from J to Port, and the use of both lines is enforced. The other constraint is that all products from mine M_1 are transported to Port.

The prefix 'mixed integer' in the linear program refers to its ability to address the fixed cost of maintenance of railway lines in terms of integer notation. Appendix I contains a full general description of the mixed integer linear programming models as they were applied to analyse transport options in the Hunter Region and Southern Coalfield.

The models were constructed on computer spreadsheets, reproduced in the appendix, which allowed the calculation of fixed line maintenance costs and variable transportation costs based on the distances and costs outlined in tables 3.2 and 3.3.

MODEL DEVELOPMENT

The models developed for the analysis of coal transportation considered investment options to improve the efficiency of meeting a given transport task in a static framework. These models may be developed further in several ways. First, the static models developed for this analysis may be extended to multi-period models that examine the dynamics of investment in transport infrastructure. Such an approach may be used to analyse the timing of investment in transport modes and the impacts of such investments on the relative efficiency of modes in undertaking transport tasks.

Second, the model developed to analyse the relative efficiency of land transport modes in carrying coal may be extended to include other freight traffics as well as passenger traffic. For example, the Maitland to Newcastle railway line also carries high tonnages of wheat traffic.

Third, demand models may be incorporated into the analysis to better reflect the demand for transport services. While long term projections of commodity flows may be used to provide indicative estimates of demand, the inclusion of demand functions in the analysis would allow the alternative social welfare maximisation objective function to be used instead of the current cost minimisation objective function.

Fourth, other transport options may be included in the analysis. For example, conveyor belts represent an option to road for the transport of coal from mine site to coal loader.

THE TRANSPORTATION PROBLEM — BLACK COAL

Queensland and New South Wales are the major coal producing and exporting States. In 1987–88 these States produced 95 per cent of the total Australian black coal output and supplied 100 per cent of export coal, amounting to 102 200 ktonnes (JCB 1989a). Coal export tonnages over six years are presented in table 3.1. The remaining five per cent of Australian black coal production was mined in Western Australia, South Australia and Tasmania (ABARE 1990) for the domestic market only.

Coal transport arrangements

Queensland

In 1987–88 the Queensland coal transport task was entirely accomplished by rail. The coal movement predominantly took place from inland coal basins to ports for export.

The Queensland Government strategy for coal and other minerals has been to raise the finance necessary for capital works, new rail infrastructure, upgrading of existing structure and purchase of locomotives and wagons, by way of an

TABLE 3.1 COAL EXPORTS FROM AUSTRALIAN PORTS

('000 tonnes)

Port	*1983–84*	*1984–85*	*1985–86*	*1986–87*	*1987–88*	*1988–89*
Newcastle	20 460	24 683	26 210	29 152	30 097	29 156
Sydney	4 634	4 111	4 773	3 513	2 529	2 285
Port Kembla	8 333	9 502	8 104	9 523	11 152	8 833
New South Wales total	33 427	38 296	39 087	42 189	43 778	40 274
Abbot Point	480	4 361	5 073	5 720	5 943	4 998
Brisbane	804	1 376	1 460	1 595	2 377	2 546
Dalrymple Bay	4 141	11 258	13 503	13 900	15 876	15 459
Gladstone	12 015	12 823	14 247	14 768	16 168	16 081
Hay Point	15 655	15 685	16 515	17 542	18 059	19 943
Queensland total	33 095	45 503	50 798	53 525	58 422	59 027
Total exports	66 522	83 799	89 884	95 714	102 200	99 301
States' percentage shares (%)						
New South Wales	50.0	46.0	43.5	44.0	43.0	40.6
Queensland	50.0	54.0	56.5	56.0	57.0	59.4

Sources Joint Coal Board (1989a); Queensland Coal Board (1990).

up-front payment from mining companies. Most of the Queensland coal railway lines are electrified and are dedicated to coal and grain.

Electrified lines include the Goonyella sub-network and the Central and West Moreton lines. Lines which are not electrified, such as the Newlands and Moura lines, complete the picture of the Queensland coal railway system. Coal traffic shares the North Coast mainline with grain, mixed freight and passenger services. It seems very unlikely that amendments to the transport regulatory setting would bring any changes to the current transport arrangements.

New South Wales

During 1987–88 in New South Wales 58 per cent of coal was carried by rail, 21 per cent by road, 20 per cent by conveyor belts and one per cent by ship (JCB 1989a). In New South Wales the transport of coal by conveyors is usually dedicated and is conducted over short distances (such as to power stations or loaders) and would thus remain unaffected by any changes to the transport system.

While there is no regulation of coal transport in New South Wales, the two main Newcastle export coal loaders have limitations on road receival, in terms of capacity limitation and lease or consent conditions (which have been waived in the past). Nevertheless, considerable scope exists for road transport of coal in the State. This analysis is directed at road and rail coal transport options in New South Wales.

The State Rail Authority of New South Wales has responsibility for rail passenger and associated road coach services and freight operations in that State. State Rail has a substantial involvement with the transportation of coal from major coalfields including the Hunter, Newcastle and Southern Coalfields.

Freight rates charged by State Rail cover capital and operating costs, except for the Ulan mine where the company participated in the capital expenditure for the railway infrastructure (IAC 1989). The approach to achieving allocative efficiency of setting prices equal to marginal costs has not been applied to the haulage of coal from New South Wales coal mines, as the system would not recover the average costs of providing the services. It has been demonstrated by Freebairn and Trace (1988a) that the typical cost structure of a dedicated line has average costs falling with greater tonnages carried and marginal cost below average cost.

When the marginal cost pricing rule is inappropriate, as with a dedicated railway, Ramsey pricing should be used. Under this approach, prices would then be inversely related to the elasticity of demand to ensure that least possible loss of social welfare occurs.

The pricing system adopted by State Rail did not seem to be based on either principle and there are debates between the railways and their customers about excessive rail freight charges (IAC 1989).

Road transport lacks an efficient pricing mechanism to ensure that all direct and indirect costs attributable to coal trucks are included in the determination of freight rates. An analysis of allocative efficiency between competing modes should take into account all costs including externalities such as air and noise pollution. However, quantitative estimates of the costs of air and noise pollution are only available as crude orders of magnitude for road and are not available at all for rail. For this reason, they have been omitted from the analysis. It is also considered that these costs would not be sufficiently large relative to other costs to affect the results in any significant way.

This chapter and appendix III present detailed treatments of road and rail transport costs from two New South Wales coalmining areas. These costs comprise direct operating costs and external costs of transport which become inputs to a linear programming model used to identify transport methods involving the least social cost (chapter 4).

Hunter and Newcastle Coalfields

A description of coal transportation in the Hunter and Newcastle Coalfields is contained in appendix II. Analysis is confined to export coal because of limited mode transfer opportunities for domestic coal in the Hunter Region . Alternative options for transporting coal from a total of 16 export mines are analysed by means of the linear programming model. These options are presented schematically in figure 3.2.

The current transport arrangements are shown in the figure as option 'a' except for mines 1 and 2. These mines use both options 'a' and 'b' as current arrangements. Thus, 1a, 1b, 2a, 2b and 3a represent current transport arrangements for mines 1, 2 and 3. Alternative transport options for the mines are indicated as 2c and 3b with no other option being available for mine 1. As may be seen, a number of collieries do not have adjacent road-to-rail reloading facilities. Consequently, two inland coal loaders serve as focal points for a number of coal export mines.

The Mount Thorley Coal Loader (MTCL) is the largest inland rail loading terminal handling some 25 per cent of Newcastle's coal exports from four mines in the surrounding area, with capacity for higher throughput. The Liddell coal loader, at point C in figure 3.2, while smaller than MTCL, transfers export coal from five mines to rail. Conveyor belts or road are used to deliver coal to rail loading facilities.

There were no capacity constraints at the inland reloading facilities. Capacity limitations on the two export coal loaders at Port of Newcastle were not imposed in the model, on the assumption that legislation could be waived and in the knowledge that the coal loaders coped with substantial road deliveries of Mount Thorley coal during a rail strike in 1985. The potential problems of having to build up truck fleets and to invest in export coal loaders, as would have resulted from a major transfer of coal from rail to road, did not arise.

The analysis detailed in this report aims at identifying the least social cost of undertaking export coal transport from the range of transport options presented in figure 3.2.

Southern Coalfield

The characteristics of the Southern Coalfield are described in appendix II. The transport logistics of the coalfield differ considerably from those of the Hunter and Newcastle Coalfields and a transport option exists involving infrastructure investment (appendix II). While domestic mines are not considered in the analysis, three of these mines are of interest because of potential mode transfer of their coal to the proposed Maldon to Dombarton railway.

The Southern Coalfield transport schematic is shown in figure 3.3.

Transport options for a total of 11 export mines are considered. A characteristic of the coalfield arising from difficult topography is having no direct rail link from inland mines to Port Kembla. This has had a number of consequences. The choice has been to transit coal by rail either via Moss Vale to Port Kembla Coal Loader, or on heavily trafficked metropolitan lines to Balmain Coal Loader. The alternative choice is road transport from Oakdale mines 1, 2 and 3 in the Burragorang Valley to Port Kembla Coal Loader. Coal from three BHP domestic mines is taken by road to O'Briens Drift at the top of the escarpment above Kemira (figure 3.3). The coal is then conveyed to a private railway at the base of the escarpment for a short transit to BHP Port Kembla steelworks.

Figure 3.3 shows the range of transport options which have been identified for the least social cost analysis. The proposed Maldon to Dombarton rail link is included as an option. A hypothetical loading site is included at Wilton (point W in figure 3.3) on the Maldon–Dombarton railway.

DATA REQUIREMENTS

Definitions

In the analysis of New South Wales coal, private costs included direct road and rail transport costs from mines to ports or domestic users and transfers from conveyor or truck to rail. The analysis excluded costs which hold constant regardless of the transport options examined. Hence, the analysis excluded the costs of coal preparation and conveyors at the minesite, and the costs which follow the discharge of coal at the port, namely stacking, blending and reclaiming. The costs of washing or preparation at the destination were likewise excluded. For example, coal from Australian Iron and Steel Pty Ltd mines is transported in its raw state and is washed at BHP's Port Kembla steelworks.

Social costs included costs of road damage arising from the passage of coal trucks and ex-post costs of fatal and injury accidents involving the trucks. These costs were ascribed a monetary value in this analysis. The costs of noise and air pollution from coal trucks have been estimated for each coalmining area.

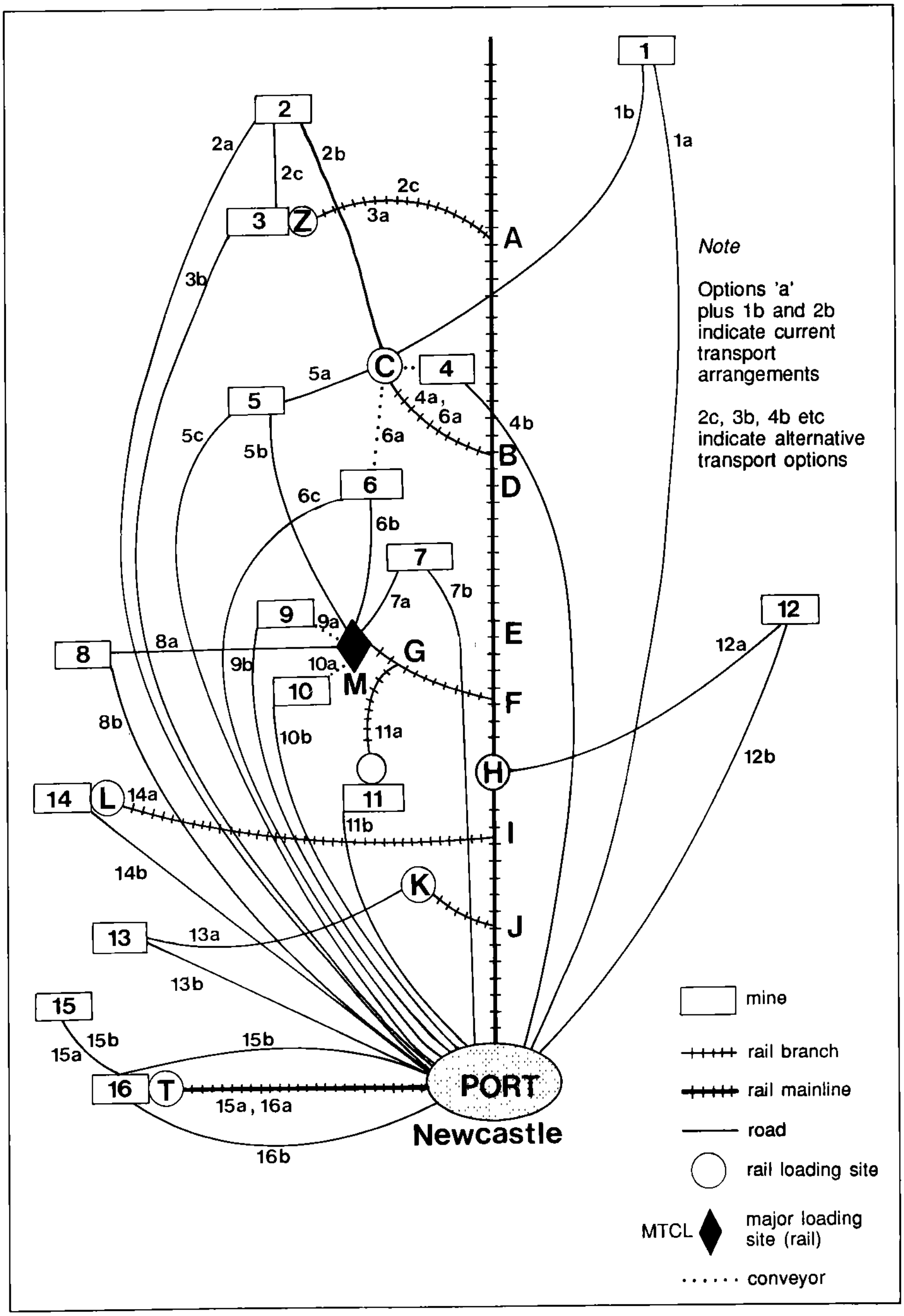


Figure 3.2 Hunter and Newcastle Coalfields transport schematic

HUNTER COALFIELD

Mines

1	Muswellbrook No. 2
2	Bayswater No. 2
3	Drayton
4	Liddell
5	Howick
6	Hunter Valley No. 1
7	Lemington
8	Wambo
9	Warkworth No. 1
10	Mount Thorley
11	Saxonvale
12	Great Greta

Rail Terminals

Z	Drayton loop (adjacent to 3)
C	Liddell loop
M	Mount Thorley Coal Loader (MTCL)
	Saxonvale loop (adjacent to 11)
H	Branxton siding
K	Thornton loop
L	Cessnock Coalfield (South Maitland Railway P/L)

NEWCASTLE COALFIELD

Mines

13	Bloomfield
14	Pelton/Ellalong
15	West Wallsend
16	Teralba

Rail Terminals

T	Teralba

PORT RAIL TERMINALS

Kooragang Island loop
Port Waratah Coal Services loop

PLACE NAMES

A	Antiene
D	Ravensworth
E	Singleton
F	MTCL branch - mainline junction
I	East Greta junction (Maitland)
J	Thornton junction
B	Newdell junction

Key to export mines, rail terminals and placenames transport schematic

Figure 3.2 Hunter and Newcastle Coalfields transport schematic (cont.)

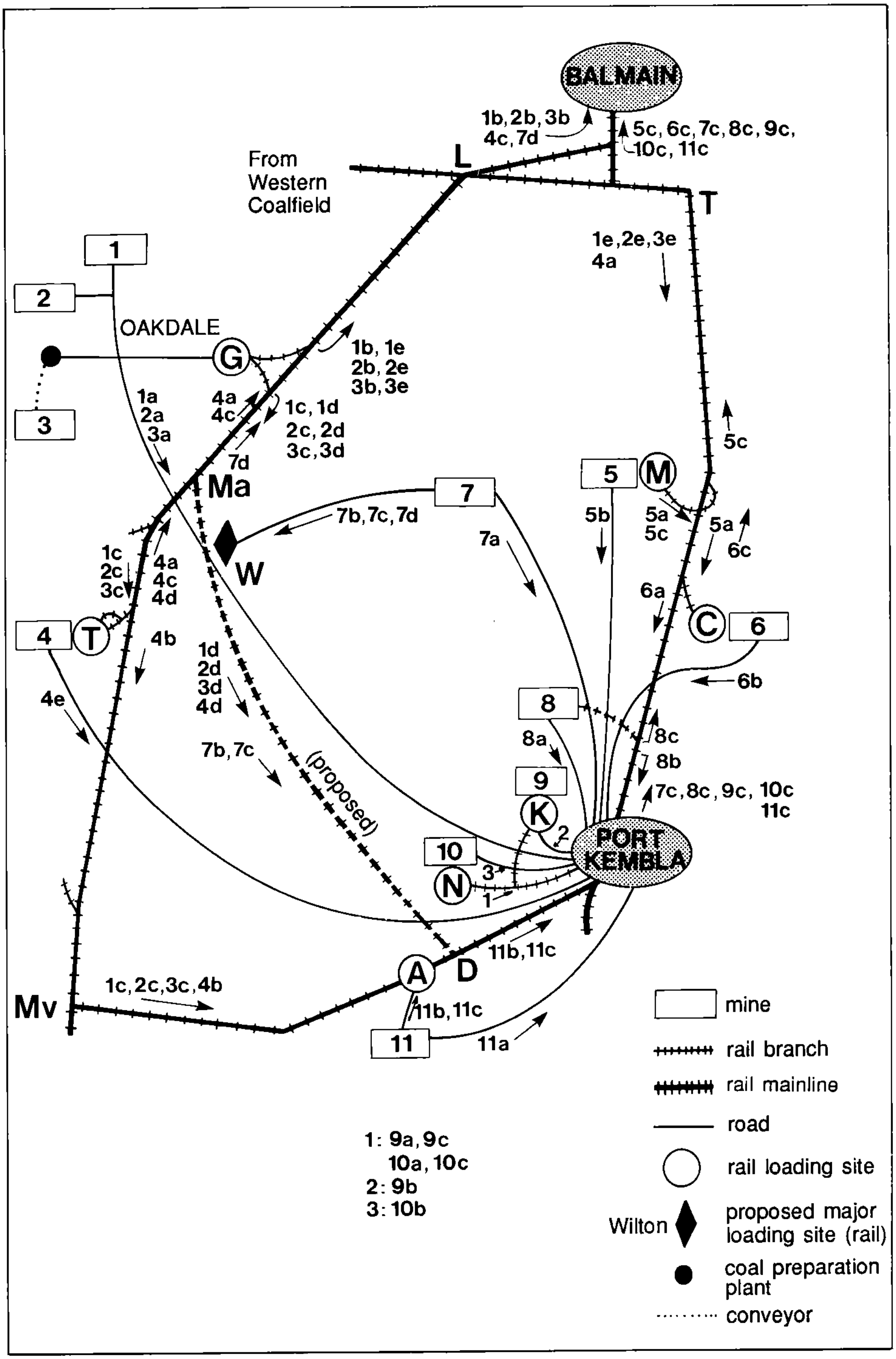


Figure 3.3 Southern Coalfield transport schematic

SOUTHERN COALFIELD

Mines

1	Brimstone No. 1
2	Oakdale
3	Nattai
4	Tahmoor
5	Metropolitan
6	Coal Cliff
7	West Cliff
8	South Bulli
9	Kemira
10	Nebo
11	Avon

PORT COAL LOADERS

Port Kembla
Balmain

PLACE NAMES

L	Lidcombe
T	Tempe
Ma	Maldon
D	Dombarton
W	Wilton
Mv	Moss Vale

Rail Terminals

G	Glenlee
T	Tahmoor
M	Metropolitan
C	Coal Cliff
K	Kemira
N	Nebo
A	Avon

Key to export mines, rail terminals and placenames transport schematic

Figure 3.3 Southern Coalfield transport schematic (cont.)

Classification of railways

For costing purposes railways were classified as mainline and branch line. Mainlines referred to the Werris Creek and Gosford railway lines in the Hunter Region. Southern Coalfields mainline railways were the Sydney to Moss Vale line, Moss Vale to Wollongong line, the Illawarra line and the proposed Maldon to Dombarton railway.

Branch lines included all railway balloon loops and rail sidings, the private South Maitland Railway extending from East Greta junction to the vicinity of Pelton/Ellalong mine and the BHP railway from Kemira and Nebo collieries to Port Kembla steelworks. Apart from a very small kilometrage, all branch lines are privately owned and operated. In the absence of data on costs of private line operation, the same maintenance costs were assumed as for mainlines.

Classification of roads

For the purpose of road damage costing, roads were classified into two categories, namely highways or arterials, and local roads (BTCE 1988a; D. P. Luck, BTCE, pers. comm. 1989).

The highway/arterial category included a majority of roads assigned to coal movements in this exercise. Leading examples of this category were the New England Highway from Muswellbrook to Newcastle and the Wilton and Mount Keira Roads between Picton and Wollongong. However, sections of other roads exceeding counts of 1000 Average Annual Daily Traffic (AADT) were also assigned to this category. The second category included all remaining roads with low traffic volumes, and were termed local.

Traffic counts for the highway/arterial road type, selected for coal transport in both the Hunter and Illawarra areas, were in excess of some 2000 AADT. Traffic counts for locals were less than 1000 AADT, with no counts encountered between 1000 and 2000 AADT (RTA 1988; DMR 1986).

More information on road classification in the coalfields is documented in appendix III.

Ports

Reference to the Port of Newcastle implies both Port Waratah Coal Loader and Kooragang Island Coal Loader. For reason of their close proximity, no differentiation was made in the analysis as to which export coal loader was used. In the case of the Southern Coalfield, the Maldon to Dombarton rail project option is considered, as is closure of the Balmain Coal Loader.

External costs of road transport

Road damage costs were computed in terms of damage estimates per Equivalent Standard Axle Load kilometre (ESAL km). All road transportation was assumed to be carried out by six-axle articulated trucks of 40 tonne Gross Vehicle Mass (GVM). It was assumed that there was no backloading of freight by these trucks.

Estimated ESALs for loaded and empty 40 tonne GVM trucks were 3.73 and 0.21 respectively. Computation of axle loads of loaded and empty trucks and the resulting damage factors was consistent with the former National Association of Australian State Road Authorities practice (NAASRA 1976a, 1976b).

Road accident costs were derived from the rates of fatalities and injuries in terms of vehicle–kilometres travelled by heavy vehicles (Federal Office of Road Safety, pers. comm. 1990). These rates were then converted into costs using estimates developed by the Bureau of Transport and Communications Economics (1988b).

Noise and air pollution costs attributable to trucks, estimated separately for the Hunter Region and the Southern Coalfield, were based on cost estimates for rural and urban areas provided by the Inter-State Commission (1990). The analysis did not attempt to estimate the fuel and time costs of congestion.

Estimating procedures

Derivations of cost estimates and further input assumptions are described in appendix III.

Sources of data

Information on current transport arrangements, coal production, export and transported tonnages was derived from a number of sources including the Joint Coal Board (JCB 1989a, 1989b, pers. comm. 1990), the Department of Primary Industries and Energy (DPIE 1989; C. Brown, DPIE, pers. comm. 1990) and the New South Wales Department of Minerals and Energy (DME 1989).

Estimates of rail operating costs were based on investigations by Freebairn and Trace (1988a), incorporating work by Easton (1988). Supplementary information was obtained from the Industries Assistance Commission (1988, 1989), Booz.Allen and Hamilton consultants to State Rail (BAH 1989) and the BTCE submission to the Royal Commission into Grain Storage, Handling and Transport (BTCE 1987b). Estimates of road operating costs were sourced from BTE (1984) and Luck and Martin (BTCE 1988a).

DATA INPUTS TO MODEL

The main inputs to the linear programming model were the total distances by railway and road types between mine and port and the tonnages transported. For most mines, saleable coal production figures for 1988–89 were used as a proxy for coal transported in that year. To complete the specification of activities, the costs of the various transport and reloading activities were presented on a per kilometre, tonne kilometre or tonne basis.

Hunter and Newcastle Coalfields

Data inputs for the Hunter and Newcastle Coalfields model are outlined in tables 3.2 and 3.3. This approach provided the flexibility to allow additional activities to

TABLE 3.2 TRANSPORT TASK DATA INPUTS TO LINEAR PROGRAMMING MODEL FOR THE HUNTER AND NEWCASTLE COALFIELDS

			Rail (km)		Road (km)	
Mine	*Tonnes 1988–89[a] ('000)*	*Transport option[b]*	*Mainline*	*Branch line*	*Highway/ arterial*	*Local*
Hunter Coalfield						
Mine 1[c]	500	1a	-	-	127	4
	250	1b	101	6	22	7
Mine 2[c]	400	2a	-	-	118	7
	250	2b	101	6	10	7
		2c	113	8	-	2
Mine 3[c]	2 250	3a	113	8	-	-
		3b	-	-	111	5
Mine 4	320	4a	101	6	-	-
		4b	-	-	105	3
Mine 5[c]	760	5a	101	6	-	4
		5b	75	11	28	21
		5c	-	-	102	4
Mine 6	3 930	6a	101	6	-	-
		6b	75	11	21	12
		6c	-	-	98	10
Mine 7	1 520	7a	75	11	17	-
		7b	-	-	93	9
Mine 8	940	8a	75	11	13	4
		8b	-	-	86	13
Mine 9	1 980	9a	75	11	-	-
		9b	-	-	76	9
Mine 10	3 060	10a	75	11	-	-
		10b	-	-	74	9
Mine 11	830	11a	75	14	-	-
		11b	-	-	70	16
Mine 12	360	12a	57	-	-	28
		12b	-	-	57	26
Newcastle Coalfield						
Mine 13	960	13a	27	3	4	-
		13b	-	-	32	-
Mine 14	1 370	14a	34	32	-	-
		14b	-	-	54	-
Mine 15	580	15a	17	-	-	6
		15b	-	-	18	8
Mine 16	750	16a	17	-	-	-
		16b	-	-	18	2

– Not applicable

a. Saleable coal production, rounded to nearest 10 000 tonnes.

b. Options 'a' plus 1b and 2b represent current transport arrangements.

c. Saleable coal transported.

Source BTCE estimates.

TABLE 3.3 COST DATA INPUTS TO LINEAR PROGRAMMING MODEL FOR THE HUNTER AND NEWCASTLE COALFIELDS

Type	*Description*	*Mainline*	*Branch line*	*Highway/ arterial*	*Local*
Rail	Maintenance ($/km)	9 200	9200	–	–
	Operating (c/tonne km)[a]	4.14	4.14	–	–
Road[b]	Damage (c/tonne km)	–	–	1.8	7.7
	Accidents (c/tonne km)	–	–	0.5	0.5
	Operating (c/tonne km)	–	–	8.33	8.33
Reloading	Conveyer or truck to rail ($/tonne)			0.60–1.00	

– Not applicable

a. Excludes State Rail's infrastructure investment costs, estimated to be 2 to 3 cents per export tonne or less than 0.1 cents per tonne km.

b. Noise and air pollution costs for road in the Hunter Region, estimated to be 0.38 cents per tonne km, are not included in the model.

Source BTCE estimates.

be incorporated into the model (such as specification of investment activities) and for data to be updated in an efficient manner.

The locations of arterial and local roads listed in table 3.2 are shown in appendix III. The rail operating costs in table 3.2 exclude State Rail's rail infrastructure capital costs on the basis of their small value when distributed on a per tonne basis and in the absence of information on how these investments were distributed over the coal railways. Noise and air pollution costs were estimated for road transport in the Hunter Region based on estimates of coal transit distances through urban and rural areas. Because no equivalent cost figure could be derived for rail transport, noise and air pollution costs were not included in the model for either mode.

Southern Coalfield

Corresponding model data inputs for the Southern Coalfield are listed in tables 3.4 and 3.5. An interesting aspect of the coalfield is the multiplicity of current transport arrangements from a number of mines and relatively few alternative transport options.

Road and rail operating costs for the Southern Coalfield differ from those in the Hunter Region. Higher costs for road operation result from higher maintenance, tyre and fuel costs on hilly terrain, partially offset by reduced maintenance resulting from fewer kilometres travelled. Adjustment of 'level terrain' truck operating costs for the Hunter Region was made by means of a World Bank model

TABLE 3.4 TRANSPORT TASK DATA INPUTS TO LINEAR PROGRAMMING MODEL FOR SOUTHERN COALFIELD

			Rail (km)		*Road (km)*	
Mine	*Tonnes 1988–89*[a] *('000)*	*Transport option*[b]	*Mainline*	*Branch line*	*Highway/ arterial*	*Local*
Mine 1	400	1a PtK	-	-	54	32
	220	1b Balm	56	4	24	12
	110	1c PtK	163	4	24	12
		1d PtK	81	4	24	12
		1e PtK	145	4	24	12
Mine 2	240	2a PtK	-	-	54	32
	130	2b Balm	56	4	24	12
	60	2c PtK	163	4	24	12
		2d PtK	81	4	24	12
		2e PtK	145	4	24	12
Mine 3	360	3a PtK	-	-	54	32
	190	3b Balm	56	4	24	12
	90	3c PtK	163	4	24	12
		3d PtK	81	4	24	12
		3e PtK	145	4	24	12
Mine 4	130	4a PtK	186	1	-	-
	440	4b PtK	122	1	-	-
	600	4c Balm	97	1	-	-
		4d PtK	68	1	-	-
		4e PtK	-	-	66	-
Mine 5	400	5a PtK	40	4	-	-
		5b PtK	-	-	43	2
		5c Balm	54	-	-	-
Mine 6	800	6a PtK	27	1	-	-
	200	6b PtK	-	-	30	1
		6c Balm	74	1	-	-
Mine 7	1 120	7a PtK	-	-	42	-
		7b PtK	49	-	24	-
		7c Balm	143	-	24	-
		7d Balm	90	-	24	-
Mine 8	1 880	8a PtK	-	-	13	2
		8b PtK	15	2	-	-
		8c Balm	79	2	-	-
Mine 9	1 010	9a PtK	-	12	-	-
		9b PtK	-	-	10	-
		9c Balm	94	12	-	-
Mine 10	650	10a PtK	-	10	-	-
		10b Pt	-	-	10	
		10c Balm	94	10	-	-
Mine 11	190	11a PtK	-	-	14	8
		11b PtK	20	-	-	5
		11c Balm	114	-	-	5

– Not applicable

a. Saleable coal production, rounded to nearest 10 000 tonnes.

b. Destination port: Port Kembla or Balmain.

Source BTCE estimates.

TABLE 3.5 COST DATA INPUTS TO LINEAR PROGRAMMING MODEL FOR SOUTHERN COALFIELD

Type	*Description*	*Mainline*	*Branch line*	*Highway/ arterial*	*Local*
Rail	Maintenance ($/km)	9 200	9 200	-	-
	Operating (c/tonne km)[a]	6.62	6.62	-	-
	Operating (c/tonne km)[b]	6.35	6.35	-	-
Road[c]	Damage (c/tonne km)	-	-	1.8	7.7
	Accidents (c/tonne km)	-	-	0.5	0.5
	Operating (c/tonne km)	-	-	9.14	9.14
Reloading	Conveyor or truck to rail ($/tonne)	1.00			

– Not applicable

a. Excludes State Rail's infrastructure investment costs, estimated to be 2 to 3 cents per export tonne or less than 0.1 cents per tonne km.

b. Proposed Maldon–Dombarton railway. Cost includes amortisation of capital, but is lower than for other Southern Coalfield lines. If capital costs were excluded, the operating cost would be 4.35 cents per tonne km.

c. Noise and air pollution costs for road are not included in the model.

Source BTCE estimates.

(Watanatada, Dhareshwar & Rezende Lima 1987), which takes into account the cost impacts of road gradients and curves.

Results

The results of the modelling exercises are outlined in the next chapter, along with inferences for other commodities.

BROWN COAL

Australia's brown coal mines are located in Victoria, in the Latrobe Valley, 130–200 kilometres east of Melbourne. In 1987 the State Electricity Commission of Victoria produced almost 97 per cent of the State's total output of 43.5 million tonnes. The remaining output of 3 per cent was produced by Alcoa of Australia Limited. All brown coal output produced in Australia is domestically consumed for electricity generation or for the manufacture of briquettes. Transport of brown coal is regulated to rail by the Victorian Government, the largest single domestic consumer of this coal. This transport task does not appear to be vulnerable to an optional modal shift thus it was excluded from the analysis of alternative transport options used for black coal.

CHAPTER 4 RESULTS

The empirical results generated from the mixed integer linear programming model were computed as two separate sets of values for the Hunter and Newcastle Coalfields and for the Southern Coalfield respectively. Each set contains the social marginal costs of transporting a tonne of coal from each mine by the optimal mode or a mixture of modes. The model also computed the social opportunity cost of transporting coal using any sub-optimal mode within these two coalmining areas.

HUNTER AND NEWCASTLE COALFIELDS

The results generated for the Hunter and Newcastle Coalfields are presented in table 4.1.

Table 4.1 enumerates the current and alternative transport modes from the export mines in the second column. The optimal transport modes are shown in terms of tonnages carried in the third column. The corresponding social marginal costs of transporting a tonne of coal from each mine by the optimal modes are also listed.

These calculations hold for one thousand tonnes of coal only, but they may be assumed to hold, in this case, for up to the capacity of the rail lines, coal loaders, and similar equipment.

Table 4.1 also shows the social opportunity cost of transporting coal using any sub-optimal mode in the last column. This opportunity cost quantifies the cost of not using resources in an efficient way.

The results presented in the table indicate that optimal modes are mostly road–rail (RR) options. Road in these options is used entirely for the purpose of short haul to a rail loading point, followed by main haul by rail to port. Alternatively, optimal modes are also represented by rail only (RL) with coal commonly being loaded to rail from conveyors.

Social opportunity costs

An interesting result from the analysis is that of high social opportunity costs incurred by mines 1 and 2 using a road transport mode to haul coal to port (options

TABLE 4.1 OPTIMAL TRANSPORT MODES, OPPORTUNITY COSTS AND SOCIAL MARGINAL COSTS — HUNTER AND NEWCASTLE COALFIELDS

Mine	*Mode (current mode in bold)*	*Optimal mode and quantity ('000 tonnes)*	*Social marginal costs of transporting by optimal mode ($ per tonne)*	*Opportunity cost of using a sub-optimal mode ($ per tonne)*
Mine 1	**RD1A**	0		14.74
	RR1B	750	11.88	
Mine 2	**RD2A**	0		11.21
	RR2B	0		0.30
	RR2C	650	13.53	
Mine 3	**RL3A**	250	10.02	
	RD3B	0		12.85
Mine 4	**RL4A**	320	8.86	
	RD4B	0		12.33
Mine 5	**RR5A**	0		2.39
	RR5B	760	8.74	
	RD5C	0		12.13
Mine 6	**RR6A**	930	9.86	
	RR6B	0		5.27
	RD6C	0		12.14
Mine 7	**RR7A**	520	11.03	
	RD7B	0		14.22
Mine 8	**RR8A**	940	11.80	
	RD8B	0		13.49
Mine 9	**RL9A**	980	7.12	
	RD9B	0		9.39
Mine 10	**RL10A**	60	7.12	
	RD10B	0		9.80
Mine 11	**RL11A**	830	8.37	
	RD11B	0		10.32
Mine 12	**RR12A**	360	12.82	
	RD12B	0		5.37
Mine13	**RR13A**[a]	0		0.00
	RD13B	960	5.64	
Mine 14	**RL14A**[a]	0		0.00
	RD14B	370	10.51	
Mine 15	**RR15A**	0		1.00
	RD15B	580	5.59	
Mine 16	**RL16A**[a]	0		0.00
	RD16B	750	4.07	

a. Indicates that this is an alternative optimal mode.

Source BTCE estimates.

RD1A and RD2A in table 4.1). For mines 1 and 2 they are over $14.70 per tonne, and over $11.20 per tonne respectively. The social costs are probably significantly higher than the private freight costs paid to transport coal from these mines. Unfortunately, it was not possible to collect data on the actual freight costs paid by the various mines, for the various transport modes, as this is regarded as commercially sensitive information.

Sub-optimal choices

The reasons for the sub-optimal transport choices for mines 1 and 2 were investigated, and it transpired that road transportation of coal from these mines was being phased out with gradual transfer to rail over a three year period. That is, transfer was being made to transport options RR1B and RR2B. An agreement to this effect is in place between State Rail, mine proprietors and Transport Workers Union and is aimed at providing some 80 affected truck owner drivers with ample time to trade out of their vehicles and to find alternative employment.

The modal shift to rail for mines 1 and 2 coincides with the development of coal loading facilities at Liddell (figure 3.2). The choice of the Liddell loader for mine 2 over the Drayton rail loop facility is marginally more expensive. However, it appears that mine 2 is currently using rail transport through Liddell as part of a medium term goal to substitute rail for road transport of coal.

All other mines, with the exception of mine 5, were using transport modes which minimised net social cost. Mine 5 was using a sub-optimal mix of road and rail with an opportunity cost of $2.39 per tonne. The optimal mode for this mine would be road transport to the Mount Thorley Coal Loader for subsequent rail transport to the port.

SOUTHERN COALFIELD

Results obtained for the Southern Coalfield transport tasks, using a similar model, are presented in tables 4.2 and 4.3. It was assumed that the proposed Maldon to Dombarton rail line was available for use.

The results for the Southern Coalfield support the finding of the Hunter and Newcastle Coalfields analysis that rail is the optimal mode for the main haul of coal. However, in the case of the Southern Coalfield the results differ for a number of mines, either because there is no close rail access to mines (such as for Oakdale mines 1, 2 and 3) or because rail services do not exist (mines 7 and 8).

It was determined that six out of eleven mines would need to use road only or a mixture of road and rail services to minimise social costs. Where a choice exists between road and rail main haul, road and rail offer services at equal social costs for mines 8 and 10 which are located 15 and 10 kilometres respectively from port. For mines 5 and 6, located some 40 and 30 kilometres respectively from Port Kembla, rail is clearly the optimal mode.

An exception which shows rail transport inefficiency is the current haulage of a relatively small tonnage of coal from mines 1, 2 and 3 over the circuitous route

TABLE 4.2 OPTIMAL TRANSPORT MODES, OPPORTUNITY COSTS AND SOCIAL MARGINAL COSTS — SOUTHERN COALFIELD

Mine	*Mode (current mode in bold)*	*Optimal mode and quantity ('000 tonnes)*	*Social marginal costs of transporting by optimal mode ($ per tonne)*	*Opportunity cost of using a sub-optimal mode ($ per tonne)*
Mine 1	**RD1A**	0		2.45
	RR1B	730	17.05	
	RR1C	0		14.20
	RR1D	0		3.10
	RR1E	0		11.79
Mine 2	**RD2A**	0		2.45
	RR2B	430	17.05	
	RR2C	0		14.20
	RR2D	0		3.10
	RR2E	0		11.79
Mine 3	**RD3A**	0		2.45
	RR3B	640	17.05	
	RR3C	0		14.20
	RR3D	0		3.10
	RR3E	0		11.79
Mine 4	**RL4A**	0		15.84
	RL4B	0		7.40
	RL4C	0		4.06
	RL4D	1 170	8.92	
	RD4E	0		4.99
Mine 5	**RL5A**	400	5.83	
	RD5B	0		3.75
	RL5C	0		2.80
Mine 6	**RL6A**	1 000	3.71	
	RD6B	0		2.87
	RL6C	0		6.24
Mine 7	**RD7A**	1 120	8.85	
	RR7B	0		2.51
	RR7C	0		14.96
	RR7D	0		16.94
Mine 8	**RD8A**	1 880	3.25	
	RL8B[a]	0		0.00
	RL8C	0		9.42
Mine	**RL9A**	0		0.27
	RD9B	1 010	2.11	
	RD9C	0		14.03
Mine 10	**RL10A**[a]	0		0.00
	RD10B	650	2.11	
	RL10C	0		13.77
Mine 11	**RD11A**	0		0.06
	RR11B	190	4.92	
	RR11C	0		17.36

a. Indicates that this is an alternative optimal mode.

Source BTCE estimate.

TABLE 4.3 OPTIMAL TRANSPORT MODES, OPPORTUNITY COSTS AND SOCIAL MARGINAL COSTS — SOUTHERN COALFIELD (WITH NO COAL LOADED AT BALMAIN)

Mine	*Mode (current mode in bold)*	*Optimal mode and quantity ('000 tonnes)*	*Social marginal costs of transporting by optimal mode ($ per tonne)*	*Opportunity cost of using a sub-optimal mode ($ per tonne)*
Mine 1	**RD1A**	730	19.50	
	RR1C	0		11.76
	RR1D	0		0.65
	RR1E	0		9.35
Mine 2	**RD2A**	430	19.50	
	RR2C	0		11.76
	RR2D	0		0.65
	RR2E	0		9.35
Mine 3	**RD3A**	640	19.50	
	RR3C	0		11.76
	RR3D	0		0.65
	RR3E	0		9.35
Mine 4	**RL4A**	0		15.86
	RL4B	0		7.40
	RL4D	1170	8.92	
	RD4E	0		4.99
Mine 5	**RL5A**	400	5.83	
	RD5B	0		3.75
Mine 6	**RL6A**	1000	3.71	
	RD6B	0		2.87
Mine 7	RD7A	1120	8.85	
	RR7B	0	11.36	2.51
Mine 8	RD8A	1880	3.25	
	RL8B [a]	0		0.00
Mine 9	**RL9A** [a]	0		0.00
	RD9B	10	10	2.11
Mine 10	**RL10A** [a]	0		0.00
	RD10B	650	2.11	
Mine 11	**RD11A**	0		0.06
	RR11B	190	4.92	

a. Indicates that this is an alternative optimal mode.

Source BTCE estimate.

through Moss Vale to Port Kembla. The opportunity cost for this route is $14.20 per tonne.

At present, mines 9 and 11, located close to Port Kembla, are using inefficient modes, namely rail or road, but at very low social opportunity costs. The distant mine 4 incurs high social opportunity costs ranging from $4.06 to $15.84 using rail, however the circuitous rail routes are some 50 per cent to 180 per cent longer than the road distance.

Alternative transport options

Rail transport to Balmain

The rail or road–rail transport to Balmain (denoted as option C for mines 4, 5, 6, 7, 8, 9, 10 and 11; option B for mines 1, 2 and 3; and option D for mine 7) generates opportunity costs ranging from $2.80 to $17.36 per tonne except for the Oakdale mines (option B). Option B is the optimum for these mines.

Maldon to Dombarton railway

Other transport options, denoted by option D for mines 1, 2, 3, 4 and 7 and options B and C for mine 7, over the proposed railway line from Maldon to Dombarton, were also evaluated.

The input to the model included an operating cost of $0.0635 per tonne kilometre, $1.00 per tonne reloading cost at Glenlee and $0.02 per tonne kilometre replacement cost for the Maldon–Dombarton project.

After allowing for the capital costs of constructing the new railway, the results indicated transport via that route was the cheapest for mine 4 (discussed above) while the Oakdale mines would incur a small social opportunity cost of $0.65 per tonne. Mines 1, 2 and 3 in the Oakdale area provide interesting problems for analysis. As indicated earlier, the optimal transport mode for them is by road and then rail to port at Balmain. However, if Balmain was closed to coal export then the optimal transport route for these mines would be by road to Port Kembla.

Balmain closure

Table 4.3 presents the results assuming Balmain was to be closed for coal loading.

Under the Balmain closure option, the cheapest transport alternative is road for mines 1, 2, 3, 7, 8, 9 and 10 while for mines 4, 5 and 6 rail is the preferred mode. For mine 4 the cheapest alternative is the proposed Maldon to Dombarton railway. The preferred transport options for mine 11 are a rail–road mixture irrespective of Balmain closure.

OVERALL RESULTS

Hunter and Newcastle Coalfields

The major results of this study indicate that rail transport is much cheaper than road as a principal means of transporting export coal in the Hunter Region, in terms of net social cost. It appears that in the Hunter and Newcastle Coalfields there is no outcome which favours a road only option, clearly indicating that rail transport is more efficient in social cost terms.

This result is strengthened given that the analysis used the assumption that coal transport by rail is required to pay all of the fixed cost of mainline maintenance, while normally other commodities and passenger traffic would be expected to share that cost. This 'higher cost' assumption overstates rail transport costs in the sense that other commodities would be expected to pay their share of rail maintenance costs. However, the cost assumption was deliberate in the absence of data on the other traffics.

Southern Coalfield

The results obtained for the Southern Coalfield also demonstrate that rail is a cheaper option than road for the main haul component, in social cost terms. However, for a number of mines, road becomes the only feasible option where no nearby rail access to mines exists, where no rail services exist or at best a circuitous route may be used.

A number of factors affect the transportation of coal by rail in the Southern Coalfield:

Rail transport to Balmain

Coal transport shares the railway line with Sydney commuter trains, and hence coal trains face time constraints during the morning and afternoon commuter peak hours. A turnaround time for a coal train can lengthen to 48 hours, imposing extra penalties, such as crew costs, on operating costs.

Maldon–Dombarton alternative

The results indicate an unexpectedly small penalty for using the new Maldon to Dombarton railway line for the Oakdale mines. The opportunity costs for these mines can be explained by the combined effect of including the reloading and capital costs in the computation. The reloading costs constitute a high proportion of the operating cost incurred on the relatively short distance, while a full allocation of the replacement cost of infrastructure to coal only amplifies this effect. The replacement cost was computed on the basis of additional domestic coal and the Western Coalfield (Lithgow–Kandos area) export coal being carried on the Maldon to Dombarton link.

More analysis needs to be conducted on the question of the merits of constructing the Maldon to Dombarton line, given the sensitivity of these results. Such analysis of options for investment in transport infrastructure would require the extension of the current single period static model to a multi-period model.

Closure of Balmain

The social cost of closing the Balmain coal loader can be estimated by comparing the objective function values for models with and without coal loading permitted. The cost was estimated at $3.86 million per year. If, for example, the social costs of noise, dust and congestion at Balmain were greater, then it may be reasonable to close the coal loader.

Attributable costs allocation

Assumptions regarding attributable costs were an important factor for the determination of optimal transport modes. Three alternative assumptions were possible for fixed rail maintenance costs: rail transport incurs the total fixed cost of maintenance, rail transport incurs part of that cost, or rail transport does not contribute to maintenance cost. The chosen assumption was that coal transport would constitute a high proportion of the operating cost incurred on the relatively short Maldon to Dombarton line. The full allocation to coal of the project's replacement costs further raises unit costs. The Maldon to Dombarton line has the potential to carry other traffics, possibly including grain, steel and mineral products (this may assume closure of the Moss Vale–Unanderra line). An allocation of capital costs over the full range of traffics would lower the cost for the Oakdale area mines.

Road transport to Port Kembla

Road transport faces steeper grades and curves in the Southern Coalfield as well as time constraints on truck operations. The down time results in uneven demand for services and increases truck operating costs. Despite the higher operating costs, road or road–rail mixture are preferred transport alternatives from the social viewpoint for mines located close to Port Kembla or for road delivery to a railhead. This result reiterates the findings obtained for the Hunter and Newcastle Coalfields.

CHAPTER 5 PETROLEUM AND MINERALS

This chapter provides an overview of petroleum and mineral production and their respective transport arrangements. The transport characteristics of petroleum products from refineries are largely dictated by the marketing and distributional arrangements of major oil companies.

Minerals typically undergo stages of processing and transport and, unlike petroleum, are produced mainly for export. Issues encountered in the transportation of minerals are therefore of particular interest to this investigation, as with export coal.

The mining sector is a significant contributor to Australian Gross Domestic Product (GDP) and an important export revenue earner. In 1989–90 the coal and minerals mining sector contributed 4.6 per cent to the Australian GDP, while basic metal production alone amounted to around 1.5 per cent of GDP (ABARE 1991a).

Bulk minerals have similar characteristics to coal, in terms of relatively low price and large volumes transported, which incurred a high proportion of transport costs expressed in f.o.b. values. Although crude oil, petroleum and metallic minerals often do not have the same transport arrangements as coal in New South Wales, the possibility of their modal transfer has been examined.

CRUDE OIL AND PETROLEUM

An efficient and reliable source of energy is a vital pre-requisite for economic performance. Petroleum products are still the most important source of energy commonly used in Australia and throughout the world. In the early 1980s Australia's self-sufficiency in petroleum was some two-thirds of domestic consumption, reaching around 85 per cent in 1984–85 (*Petroleum Gazette* 1987a).

Forecasts have shown that Australia's self-sufficiency will continue to decline as existing oilfields, particularly Bass Strait, become exhausted. Australia's self-sufficiency could be expected to decline to 42 per cent if new oilfields are not discovered or brought into production. Consequently, Australia's net petroleum imports are expected to more than treble by the year 2000 as the consumption of crude oil has outstripped additions to reserves annually for at least the last ten years (*Petroleum Gazette* 1988). Thus, a large oil import bill is a real possibility for Australia in the 1990s.

In Australia there were one hundred and six oil producing wells at the end of 1987 and oil refinery output increased by 5 per cent over the previous year, as did the output of marketable products (DPIE 1989). In 1987 Australian exports of petroleum products increased by 19 per cent to $2155 million. Imports of petroleum products were valued at $1758 million in 1987 while expenditure on exploration, development and production amounted to $2421 million (DPIE 1989).

Transport fuels (automotive gasoline, aviation gasoline, aviation turbine fuel, automotive diesel oil) accounted for about 80 per cent of petroleum product sales in 1987. It may be argued that the demand for transport fuels is relatively inelastic and therefore the marketing and distribution arrangements of petroleum products are an exercise in operational strategy. However, some substitution has occurred, but on the whole not in the transport fuels area.

An important event for Australia's oil industry was the Federal Government's decision to deregulate the industry from 1 January 1988. Basically, the changes brought about by this decision mean that there is no guaranteed market for indigenous crude oil. That is, the sale of indigenous crude oil on an allocation basis to Australian refiners no longer applies. This has enabled producers and refiners to make economic decisions based on responses to market forces. It is expected that, as a result of this decision, a more efficient allocation of resources should occur.

Responses to market forces in the crude oil trade may also extend to trade in refined petroleum products. The proximity of a number of new state-of-the-art refineries in Singapore, the Middle East and the Far East is likely to lead to additional importation of products into Australia, particularly to Northern Australia.

Distributional issues

Although deregulation in crude oil allocation has occurred, the oil industry has stated that the products market has not been deregulated as 'it remains heavily regulated in such areas as price control' (*Petroleum Gazette* 1987b). This stated 'regulation and price control' refers to the activities of the Prices Surveillance Authority (PSA) in setting common prices for Australian capital cities.

It has been stated that the PSA system of determining maximum wholesale petrol prices creates some major distortions. The main distortions are that this system fails to take into account freight costs and other supply costs. Therefore these costs do not necessarily fall where they are incurred. These distortions also occur in the freight differentials determined for prices in country towns away from seaboard terminals. The Australian Institute of Petroleum stated that there is a substantial variation between the freight differential and actual supply costs ex-refinery or ex-seaboard terminal (Nicholson 1987).

Transportation arrangements

The transport of petroleum features the supply of crude feedstocks to refining centres by sea or pipeline, followed by the distribution of refined products over State marketing areas by road, sea and rail. Pipelines and road dominate the combined crude oil and petroleum products transport task. Pipelines carry some 42 per cent of crude feedstocks and refined products, road transport some 40 per cent, coastal ship 15 per cent, and rail only 3 per cent (BTCE 1989a).

The petroleum products distribution network is organised by the oil companies themselves, usually through a system of main depots and agents who control certain geographical areas. These areas of control are part of larger State marketing areas. With some exceptions State marketing areas usually coincide with State boundaries. Exceptions occur where the logistics of the operation make it more feasible, for example, to supply some parts of northern New South Wales from the Queensland State marketing area.

There are no modal regulations governing the distribution of petroleum products in New South Wales, Queensland, South Australia and Tasmania. Six major oil companies control the distribution and marketing of petroleum products in Australia. For example, in Queensland the transportation arrangements are driven by market forces only, whereby a combination of road and rail is used with line haul generally by rail and local distribution by road.

The main emphasis is on the use of the most efficient mode or combination of modes. For instance, in the case of one major company, a combination of road and rail is used from Brisbane, Gladstone, Mackay and Townsville, with long haul transport tasks being performed by rail. Therefore, both road and rail are used, together with some use of sea transport if convenient.

In Western Australia the marketing and distribution arrangements of petroleum products were deregulated from 1 July 1992. In that State the transport of bulk fuel is in a transition period, in which negotiations are being carried out between the oil companies and the transport providers. The oil industry's recent rationalisation has resulted in four major companies handling the main distribution task in Western Australia.

The distribution is organised around a rail network which has contracted to less than twenty main centres that are located almost entirely on main line services. These centres coincide with the oil companies' depot towns and agencies (Department of Transport WA 1987). The State railway network for bulk fuel distribution may need to be rationalised further to mirror the industry's re-arrangement of its transport services and distribution agencies as a result of deregulation.

Rail tankers are owned by the oil companies, and block trains are expected to be introduced to the main distribution centres, where economically warranted. The local distribution of petroleum products is undertaken by road transport, by the company agents, either on behalf of their parent company or in their own right as direct purchase agents.

The rationalisation of both rail services and the industry's delivery outlets has resulted in the emergence of larger agent outlets. Smaller depots and sub-agencies are serviced by road transport by these agents. This development has led to a reduction in agent numbers, with fewer agents servicing larger areas. The Western Australian Department of Transport (1987) has stated that even under deregulation rail could be expected to still hold the fuel traffic.

Petroleum products are a bulk commodity and thus rail transport does seem to offer some advantages, especially for long haul. The marketing and distribution of crude oil and petroleum products is an exercise in determining the best operational transport strategy. In States where the transport of petroleum is unregulated, the companies themselves determine the optimum mode and route combination. Where regulations exist, it seems that rationalisation has occurred both on the part of oil companies and on the part of the State rail authorities.

IRON ORE

The Australian iron ore industry is characterised by the large scale nature of its operations. Iron ore is mined, crushed and screened on site and then railed to one of several ports where blending takes place.

In 1989, mine production of iron ore exceeded 104 000 kilotonnes (ABS 1990d). About 96 per cent of iron ore, valued at around $2 billion, was exported to Asian countries (ABS 1990d). The biggest production and export shipments occur in Western Australia's Pilbara mines and ports. The largest iron ore producers such as Hamersley, Mount Newman, Robe River and Goldsworthy operate their own railways, served by their own rollingstock. These railways are characterised by very high utilisation and productivity rates. In the absence of a road option to undertake these large railway tasks, hence the possibility of mode transfer was not examined in relation to iron ore transport.

BAUXITE, ALUMINA, ALUMINIUM AND BASE METALS

Transport issues in bauxite, alumina, aluminium and base metals are presented in this chapter in the form of an overview only rather than in terms of a detailed analysis. All these products or semi-processed products go through similar stages of processing and transport, as depicted in figure 5.1.

Volumes of production and exports of bauxite, alumina, aluminium and base metals are shown in table 5.1.

Australian minerals, sold on competitive world markets, require attention being given to the costs incurred at all stages of mining, transportation and marketing. Transport charges represent a significant proportion of the minerals' f.o.b. values. The land transport costs represent 15 per cent of iron ore f.o.b. values; 10 per

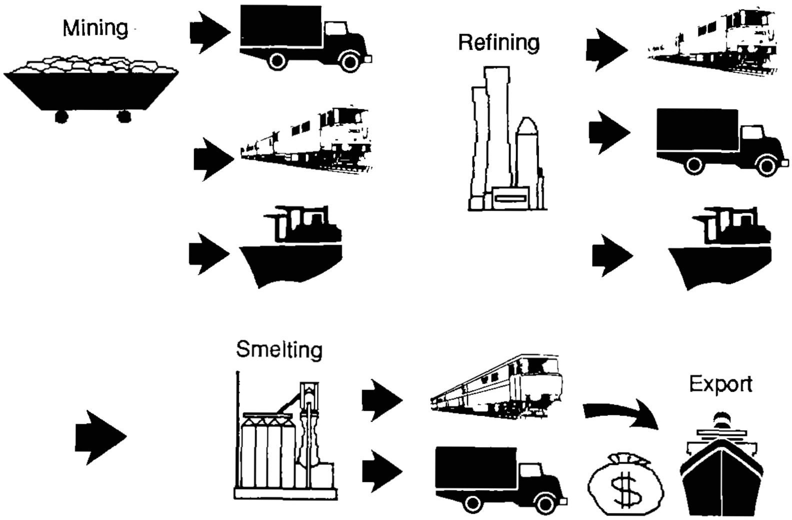


Figure 5.1 The production and handling of bulk minerals

TABLE 5.1 PRODUCTION AND DISPOSAL OF BULK MINERALS, 1987–1988

(kilotonnes)

Mineral	*Mine production*	*Export*	*Export share (per cent)*
Bauxite	35 161	3 838[a]	11
Alumina	10 330	8 541	83
Aluminium	1 074	747	70
Copper[b]	225	150	67
Lead[b]	483	406	84
Zinc[b]	763	718	94
Silver	1 143	919	80
Tin	6 938	6 723	97
Nickel[b]	69	39	57

a. 1987 export data are not complete for confidentiality reasons.

b. Metallic content of ores and concentrates, blister copper, lead bullion and nickel matte.

Source Compiled from *1989 Commodity Statistical Bulletin* and *Quarterly Mineral Statistics*, September Quarter 1989 (ABARE 1989).

TABLE 5.2 MOVEMENTS OF MINERALS BY MODE, 1987[a]
(kilotonnes)

Minerals	*Rail*	*Road*
Bauxite and alumina	13 725	380[b]
Nickel	97	21
Lead, zinc and copper	2 582	318

a. Several aluminium and base metals transport tasks have not been included in total task for confidentiality reasons.

b. This figure includes only aluminium transported from Kurri-Kurri and Tomago smelters.

Sources BTCE 1987a; BMR 1989.

cent of lead, zinc and silver f.o.b. values; while in the case of nickel and tin exports, 7 and 2 per cent of f.o.b. values were represented by the land transport costs respectively (Freebairn & Trace 1988b).

Examination of relative cost efficiencies of road and rail for export coal resulted in rail being identified as a preferred mode on long distances. This overview of mineral transportation attempts to verify the results achieved for coal.

Mineral movements by mode

Rail performs an important mineral transportation task. While later movement statistics are unavailable, rail in 1987 accounted for 96 per cent of total tonnes of minerals moved by road and rail in Australia.

Selected mineral movements are shown in tables 5.2, 5.4, 5.6 and 5.7.

The main components of rail mineral movements were bauxite and alumina which together accounted for around 14 million tonnes.

Bauxite, alumina and aluminium

Australia is the world's biggest producer of bauxite, alumina and aluminium. F.o.b. value of alumina and aluminium exceeded $4.7 billion in 1990–91 (ABARE 1991a). Aluminium produced in Australia derives from bauxite mined at Gove, Northern Territory, in the Darling Ranges, Western Australia and at Weipa, Queensland.

Large scale bauxite mining operations in the three States are presented in table 5.3 in terms of quantities of bauxite mined. The aluminium industry transport task entails large shipments of bauxite to refineries and of alumina to smelters. However, part of the bauxite output from Weipa and Gove is exported in raw form.

The large task of transporting bauxite and alumina is accomplished by coastal shipping on two routes: from Western Australian ports to Victoria and from

TABLE 5.3 PRODUCTION OF BAUXITE BY STATE, 1987

State	*Tonnes*
Queensland	7 924 577
Western Australia	20 925 911
Northern Territory	5 244 698
Victoria[a]	6 535
Total	34 101 721

a. Victorian production of bauxite is for domestic consumption only.

Source BMR 1989.

Queensland and the Northern Territory to New South Wales and Tasmania. These movements represent about 95 per cent of the total transport task in terms of tonne kilometres carried (BTCE 1987a). Bauxite mined near Weipa (Queensland), amounting to eight million tonnes per annum, was transported by rail to the port. A Bureau of Mineral Resources (BMR 1989) estimate for 1987 showed that 25 per cent of bauxite output was exported and 75 per cent of it was shipped to Gladstone for further processing.

In Western Australia bauxite output of around 17 million tonnes in 1987 (BMR 1989) from the Darling Ranges (Jarrahdale, Del Park and Huntly) was transported to Pinjarra refinery by conveyor belt, where it was refined to alumina. From Pinjarra, alumina is transported by rail to Bunbury or Kwinana for export or further processing in Victorian smelters (Portland and Port Henry). Bauxite output from Willowdale is taken by conveyor belt to the Wagerup refinery for processing and exported as alumina through the port of Bunbury. Bauxite from Jarrahdale mine is railed to Kwinana refinery and exported as alumina.

The remaining Western Australian mine, Mount Saddleback (output of about 4 million tonnes) uses conveyors to transport bauxite to its own refinery at Worsley for alumina production of about 1 million tonnes per annum. Rail is used to carry the alumina from Worsley to Bunbury and Kwinana for export or interstate for smelting.

Some 2 million tonnes of bauxite mined at Gove (Northern Territory) is exported each year in raw form (Nabalco 1990). In 1987 a further 3.2 million tonnes of bauxite was refined on site into alumina and exported. Otherwise, the alumina was shipped to Newcastle and hauled by road to the Tomago smelter in the Hunter Valley for further processing to aluminium. The aluminium from the Tomago smelter is road hauled back to Newcastle for export or domestic use.

Data availability

For confidentiality reasons, data on volumes of bauxite exports are not available (ABS 1990d). Data are unavailable on the magnitudes of tonnages

TABLE 5.4 TRANSPORT TASK OF ALUMINA AND ALUMINIUM, 1987

Product	Origin	Destination	Distance (km)	Mode	Total tonnage ('000)
Bauxite	Andoom	Weipa	19	Rail	7 925
Aluminium	Newcastle	Kurri-Kurri	42	Road	na
Aluminium	Newcastle	Tomago	50	Road	na
Bauxite	Jarrahdale[a]	Kwinana	51	Rail	na
Alumina	Wagerup[a]	Fremantle	109	Rail	4 800
Alumina	Pinjarra[a]	Fremantle	80	Rail	na
Alumina	Wagerup	Bunbury	65	Rail	na
Alumina	Worsley	Bunbury	57	Rail	1 000
Alumina	Pinjarra[a]	Bunbury	101	Rail	na

na Not available

a. Figures are unavailable ex Jarrahdale and Pinjarra origins. Wagerup to Fremantle represents the total transport task. A breakdown of tonnes of alumina transported to different ports in Western Australia from the Alcoa refineries is not available.

Sources BTCE 1987a; BMR 1989.

transported to the Tomago and Kurri-Kurri smelters. Nor are back tonnages of aluminium from Bell Bay, Kurri-Kurri and Tomago smelters for domestic destinations known. All production figures for alumina and aluminium of given refineries and smelters were estimated by the Bureau of Mineral Resources. The transport tasks are based on the assumption that production throughputs were transported by appropriate transport modes.

Road services in the alumina and aluminium industry are limited to an auxiliary cartage of bauxite from a mine pit to an enrichment plant (Jarrahdale in WA) and to short distances from the port of Newcastle to Hunter Valley smelters. Rail and road involvement on selected routes are shown in table 5.4.

Alumina produced at the Gladstone refinery (about 2.8 million tonnes) is either exported from Gladstone or shipped to one of three smelters: Boyne Island (210 000 tonnes of output in 1987 was exported), Bell Bay (122 900 tonnes of alumina was produced in 1987) or Kurri-Kurri (150 000 tonnes of aluminium was produced in 1987). The products from these smelters were destined for domestic or export markets.

All aluminium produced in Portland (100 000 tonnes per annum) was exported while Point Henry smelter production of about 177 000 tonnes in 1987 was sold to domestic or export markets.

Scope for mode transfer

Although there are large volumes of bauxite and alumina transported to ports in Western Australia, Queensland and the Northern Territory there seems to be very little scope for transfer to alternative modes.

TABLE 5.5 PRODUCTION OF LEAD, ZINC AND COPPER BY STATE, 1987
(tonnes)

State	*Lead*	*Zinc*	*Copper*
Queensland	213 035	253 004	171 710
New South Wales	229 758	401 673	31 014
Tasmania	35 969	86 142	27 061
South Australia	3	17 419	na
Northern Territory	10 385	20 077	na
Western Australia	na	na	2 910
Total	489 150	778 386	232 695

na Not available

Source BMR (1989).

Regulatory measures

Regulations governing the transport to rail of major bulk commodities (coal, mineral sands, bauxite, alumina and woodchips) are currently under review. To date, the regulatory measures used in Western Australia have usually been long term contracts (3 to 5 years) between the government and mines, which also provide for up-front capital payment for rollingstock. The up-front capital paid by the mines has been reimbursed by a freight rate rebate. In Western Australia most of the bauxite mined is transported by conveyor belts to refineries (Pinjarra, Wagerup and Worsley) or by rail from Jarrahdale to Kwinana. Rail transports alumina from refineries to ports as the commodity is regulated to the mode by way of long term agreements between companies and Westrail (Department of Transport WA pers. comm., 1990).

The Queensland Government has used regulatory measures to allocate mineral transport to rail. The private rail transport task of almost 8 million tonnes over a 19 kilometre distance from Andoom to Weipa does not have a feasible transport alternative because of the large volume involved.

Road is only involved in hauling alumina from the port of Newcastle to the Hunter Valley smelters of Tomago and Kurri-Kurri, and in back haulage of aluminium to the port for export on distances of around or less than 50 kilometres. As transport of bulk minerals is not regulated to rail in New South Wales, modal shift is possible given sufficient volume.

Ship and conveyor belt transport tasks, which contribute mostly to movement of bauxite and alumina, are not covered in this analysis as alternatives to other surface transport.

Base metals

Lead, zinc, copper and nickel, valued above $1 billion of f.o.b. value in 1987–88 (ABS 1990c) are mostly mined in Queensland, New South Wales, Tasmania and to a lesser extent in the Northern Territory, South Australia and Western Australia (table 5.5).

Production of lead, zinc and copper

Major lead, zinc and copper producing States are Queensland and New South Wales although some production comes from Tasmania and the Northern Territory. To a certain extent silver is a by-product of lead-zinc-copper production. Most of the lead and zinc production comes from a separation process of lead-zinc-copper or silver ore during which zinc and lead concentrates are obtained.

The Queensland metals output comes from the Mount Isa zinc-lead-copper mine in the north-west of the State. This represents the largest lead and copper mine in Australia. Sulphide zinc-lead-copper ore is concentrated on site and is separated to lead concentrate and zinc concentrate roughly in proportion of 55 per cent of lead and 45 per cent of zinc (BMR 1989). In 1987 the Mount Isa mine produced about 6 million tonnes of copper ore, which was later condensed to 670 202 tonnes of concentrate and refined into 153 777 tonnes of blister for export and domestic markets. Other States share the total Australian copper output, but rather as a by-product in lead or zinc production.

Major New South Wales production of lead is from mines located at Broken Hill, Woodlawn and Cobar and is obtained from zinc-lead-silver ores. Production of zinc by several mines in the Broken Hill area increased steadily year by year, with the largest zinc production increase of 25 per cent occurring from 1986 to 1987. Other zinc ore and concentrate producers are located in New South Wales at Woodlawn, Elura and Cobar; in Queensland at Mount Isa; in Tasmania at Que River, Rosebery and Hellyer; and in the Northern Territory at Woodcutters. Some production also occurs at Beltana in South Australia.

In 1987 the Cobar mine produced 54 900 tonnes of zinc concentrate and 5200 tonnes of lead concentrate while Elura mill, located some 40 km from Cobar, produced 106 491 tonnes of zinc and 184 182 tonnes of lead concentrate from its zinc-lead-silver mine.

Transportation of base metals

Transportation volumes and distances of base metals are presented in table 5.6. The table shows that rail predominated for all transport tasks except those over short distances of 80 kilometres or less, for which road transport was used. Road transportation of minerals from Woodcutter to Darwin (over 80 kilometres), from Teutonic Bore to Leonora (60 kilometres), from Mt Lyell to Rosebery (60 kilometres) and from Puttapa to Copley (20 kilometres), represented cases where alternative rail services did not exist. Similarly, the rail option did not exist for movements by road of zinc primary ore from the Que River mine area to the Rosebery concentrator (over 42 kilometres), leaving no significant examples for base metals of short-haul by road in a road–rail competitive situation.

TABLE 5.6 LEAD, ZINC AND COPPER TRANSPORT TASKS, 1987

Origin to destination	Distance (kilometres)	Mode	Lead and zinc (tonnes)	Copper (tonnes)
Mount Isa to Townsville	981	Rail	758 058	153 777
Teutonic Bore to Leonora	60	Road	61 000	
Leonora to Esperance	645	Rail	61 000	48 000
Elura to Port Pirie	826	Rail	na	
Broken Hill to Port Pirie	363	Rail	690 000	
Broken Hill to Adelaide	514	Rail	na	
Broken Hill to Newcastle	1 349	Rail	na	
Woodlawn to Newcastle	406	Rail	107 888	
Woodlawn to Port Kembla	253	Rail		39 578
Elura to Cockle Creek	892	Rail	290 673	
Puttapa to Copley	20	Road	38 000	
Copley to Port Pirie	321	Rail	38 000	
Que River to Rosebery[a]	42	Road	152 850	
Rosebery to Burnie	119	Rail	371 000	120 000
Cobar to Newcastle	881	Rail	54 900	56 900
Beltana to Port Pirie	287	Rail	17 490	
Woodcutter to Darwin	80	Road	36 199	
Mount Lyell to Rosebery	60	Road		90 649

na Not available

a. Figure includes only zinc content.

Sources BMR (1989); BTCE (1987a).

The foregoing observations about the respective roles of road and rail are entirely consistent with results obtained for coal transport in chapter 4.

Rail transport of lead, zinc and copper

Rail transport conducts the major lead, zinc and copper transport tasks over a wide range of distances (see table 5.6). The output from mines in Mount Isa taken by rail over nearly 1000 kilometres to Townsville, represented almost a billion tonne-kilometre task. In 1987 the transport task included zinc (414 200 tonnes), lead concentrates (343 858 tonnes) and copper anodes. These mineral products were smelted at Townsville and exported (excluding small quantities which were shipped to Risdon in Tasmania for smelting treatment). Several Broken Hill area mines sent their lead concentrate by rail to Port Pirie for smelting and subsequent export of the smelted product.

From the Elura mill near Broken Hill lead concentrate was transported by rail to Port Pirie smelter and then for export; but some lead was domestically consumed. The nearby Elura mine sent its zinc concentrate by rail to the Port Kembla smelter and refinery for the export and domestic markets.

Most of the zinc concentrate produced by Broken Hill Mines was exported, the rest was sent either to Tasmania (Risdon), Cockle Creek or Port Pirie for refining and smelting. However, Broken Hill Holdings Ltd sent its concentrate by rail to

Port Pirie or Cockle Creek for smelting or refining and exported zinc metal only rather than a concentrate. Further information on the production and transport of zinc and lead concentrates from Broken Hill to different refineries and smelters is unavailable (BMR 1989).

Other transport logistics for lead, zinc and copper were as follows:

- From the New South Wales Cobar copper-zinc-lead-silver mine output, lead concentrate was railed to Cockle Creek for smelting while a small amount of the concentrate was exported. The Cobar mine produced copper concentrate of around 57 000 tonnes annually and sent it over 881 kilometres to Newcastle by rail .
- The Woodlawn zinc-lead-copper-silver mine in New South Wales, located 48 kilometres southwest of Goulburn, produced concentrate of both zinc and lead. The bulk of the zinc concentrate was railed over 406 kilometres to Cockle Creek for smelting, though some concentrate of zinc, copper and lead was exported without further processing via Port Kembla or Newcastle. Woodlawn mine sends its copper concentrate product by rail over 253 kilometres to a smelter at Port Kembla for further processing.
- Beltana mine in South Australia sent zinc concentrate over 287 kilometres by rail for export through Port Pirie.
- Tasmanian mines, Rosebery and Que River, export only the concentrates of lead, zinc and copper. After further processing the concentrate is transported over the longer distance of 119 kilometres by a private railway (Emu Bay) to Burnie for export.
- Tasmania's Mount Lyell Mine & Private Railways produced copper concentrate amounting to 23 000 tonnes and transported it by private railway to Burnie for export.
- In Western Australia copper is obtained as a by-product of nickel production from the Kambalda and Windarra fields and processed at the Kalgoorlie refinery or is railed to Kwinana refinery or despatched from Kwinana to Port Kembla for refining. In 1986 copper was produced by the Teutonic Bore mine (BMR 1988) and the transport tasks involved were road and rail haulage of copper concentrate on two transport routes. Rail haulage involved 48 000 tonnes of concentrate from Leonora to Esperance, a distance of over 645 kilometres.
- In 1987 most of the mines in the Kambalda fields did not produce copper. The only amount produced in the Kwinana nickel refinery as a by-product was shipped to the Port Kembla smelter.

Nickel

Nickel production is very sensitive to world price fluctuations for this metal. In 1986 the depressed world prices resulted in the closure of seven nickel mines, mainly in Western Australia (Agnew, Windarra and Kambalda fields). As nickel prices remained depressed in 1987, production of concentrate, matte and oxide was low.

TABLE 5.7 NICKEL ORE AND CONCENTRATE TRANSPORT BY ORIGIN AND DESTINATION, 1987

Origin to destination	*Distance (kilometres)*	*Mode*	*Tonnes*
Nepean to Kambalda	50	Road	20 621
Kambalda to Perth	750	Rail	7 550
Kambalda to Kalgoorlie	46	Rail	39 384
Agnew to Leonora	133	Road	na
Leinster to Leonora	188	Road	na
Leonora to Kalgoorlie	180	Rail	na
Windarra to Malcolm	na	Road	na
Malcolm to Kalgoorlie	257	Rail	na
Kalgoorlie to Perth	706	Rail	47 834
Greenvale to Yabulu	225	Rail	2 117
Windarra to Malcolm	na	Road	7 550

na Not available

Sources BMR (1989); BTCE (1987a); Reader's Digest (1982).

Western Australia is the biggest nickel producer, followed by Queensland. In 1988–89 Western Australia produced 40 000 tonnes of nickel ore and concentrate from nickel sulphide, while Queensland produced 24 000 tonnes from laterite ore at Greenvale.

In Western Australia the transport tasks for nickel ore and concentrates involve road from Agnew to Leonora then rail to Kalgoorlie for smelting or to Kwinana for refining. Windarra ore is carried to Malcolm by road and then to the Kalgoorlie smelter by rail (table 5.7).

From the Kambalda mine, nickel is transported to the Kambalda concentrator and later sent by rail to the Kalgoorlie smelter. From the Nepean mine, nickel ore is transported to Kalgoorlie smelter over the short distance of 50 kilometres by road for further processing.

Silver

Silver is produced as a co-product with lead, zinc, copper and other metals (BMR 1989), but only in small quantities. Total production for Australia amounted to 1119 tonnes in 1987 (BMR 1989) and these quantities are not sufficient to be further analysed.

Tin

Tin production quantity for 1987 was 14 944 tonnes in concentrates and 7691 tonnes metal content. The biggest producer, Renison Ltd (Tasmania), exported 87 per cent of total Australian production of all concentrates. Smaller amounts of tin were produced in Western Australia and Queensland in the range of 100 to 400 tonnes.

CONCLUSIONS

An overview of the minerals production and processing chain and the transport logistics for mineral ore enhancement and its subsequent movement to port for export has proved instructive in the examination of commodity transportation by road and rail.

Role of road and rail

In the major minerals producing States, Queensland and Western Australia, the predominant transport mode for base metals (lead, zinc and copper) and nickel is rail. This confirms the results obtained from the analysis of coal transportation options where rail dominates in the market of long distances and large volumes moved. These results are presented in chapter 4.

For the mineral transport tasks listed in tables 5.6 and 5.7, rail is always used where rail infrastructure exists. Road transport is confined to instances where there is no rail infrastructure.

Queensland

The largest minerals producer, Mount Isa, uses rail to transport large volumes of lead, zinc and copper over 1000 kilometres to Townsville.

Western Australia

It is highly unlikely that any shift from rail to road transport would eventuate under deregulation in Western Australia. Road transport is used to transport metal ores from Nepean, Windarra and Leinster, where rail links do not exist, and road performs a feeder service to rail heads at Malcolm and Leonora. Nickel moves by road on the long distance of 188 kilometres from Leinster to Leonora over a route where rail infrastructure is not provided.

South Australia and New South Wales

The deregulated environments of the Broken Hill to Port Pirie or Adelaide, and Cobar to Newcastle rail transport tasks may warrant some investigation. Research done by Easton (1988) on rail pricing policy and costs indicated that Australian National and State Rail are exerting their monopoly power in charging for mineral haulages. While these commodities are not subject to regulation the companies claim that rail is the only viable mode because of the long distances involved (IAC 1989). Further examination of these transport tasks was constrained by lack of information.

Tasmania and Northern Territory

Tasmania and the Northern Territory use road services to complement rail long distance haul on distances of 100 kilometres or less. Lack of rail services in the mining areas of Tasmania (Que River and Mt Lyell) and also in the Northern Territory (Woodcutters) determined the use of road.

CHAPTER 6 OTHER COMMODITIES

This chapter gives an overview of the transport arrangements for three more bulk commodities: grains, fertilisers and limestone. The object is to define the post Royal Commission changes to grain transport arrangements and to identify potential areas for improved transport efficiency in the other two commodities.

GRAIN TRANSPORT POST ROYAL COMMISSION

The Royal Commission into Grain Storage, Handling and Transport (1988) recommended changes to the then existing grain marketing and transport arrangements leading to a more efficient system with greater capacity and increased benefits to grain growers.

Background

The recommended changes have generated more flexible and responsive transport and distribution systems to meet changing domestic and export market requirements with a continuing effort towards reduction of transport and distribution costs.

The one major change addressed by the Royal Commission was to remove restrictions related to transport of grain by road. The reforms aimed at achieving an integrated and efficient rail and road transport system that would promote competition and provide a more efficient market based allocation of resources.

Recommendations concerning operational transport system

The following recommendations relating to grain transport were specified by the Royal Commission (1988):

1) Discriminatory restrictions on road's capacity to service grain growers should be removed, that is:

- The States of Victoria and Queensland, where distance limits precluded road from hauling grain to ports, were asked to remove the limits to which road transport was restricted;
- Western Australia was asked to allow for road service operations in areas reserved to rail only;

- New South Wales was to provide road receival facilities at the ports of Newcastle and Port Kembla; and
- South Australia was to lift the surcharge imposed on road operators between rail served silos.

2) Railway systems should be able to act commercially in their pricing and investment decisions without being constrained by non-commercial objectives. Of particular importance is the separation of commercial and non-commercial activities.

3) The benefits of the recommended reforms would be greatest if financial costs faced by alternative modes accurately reflected the resource and social costs of providing the services (inefficiencies are related to under-recovery of road costs).

Wheat production and transport

In both quantity and value terms, wheat is the largest grain crop produced in Australia. Gross value of wheat production approached $3 billion in 1989–90 and generated more than $2.4 billion in export revenue (ABARE 1991a). In the following year these values were reduced to around $2 billion and more than $1.7 billion respectively. Wheat export revenue represented around 4 per cent of Australia's total exports of goods and services in 1989–90, falling to 3 per cent in 1990–91. Wheat export revenues constituted 80 per cent and 69 per cent respectively of all grain exports in 1989–90 and 1990–91.

The reduction in the 1990–91 export revenues was caused by the erosion of wheat prices on the international market. World wheat prices continue to be distorted by export subsidies of the United States, Canada and the European Community. Although Australia is the fourth largest world wheat exporter, Australia's share of the international wheat market represented only 12.7 per cent in 1989–90 and 13.3 per cent in 1990–91 by volume (ABARE 1991a). In effect, Australia is a price taker on the international wheat market.

The wheat industry's annual land transport costs are of the order of $250 million in an 'average' year's production of around 14–15 million tonnes, equivalent to 8 to 10 per cent of the gross value of production (AWB 1990). Hence, the role of transport in conveying wheat from farm to port represents an important factor in maintaining Australia's competitiveness on international markets. The efficiency with which such a task is undertaken has strong implications for net returns to growers.

Post-Royal Commission changes to grain transport

There have been major changes in transport infrastructure and practices arising from the recommendations of the Royal Commission (ABARE 1991b). The changes include the deregulation of the domestic wheat market, the closure of a number of high cost railway branch lines in New South Wales, Victoria and South Australia, and the opening of new port facilities at Port Kembla and Fisherman Islands.

Oats and barley

The handling, transport and marketing of oats has been deregulated totally following the bankruptcy of the New South Wales and Victorian Oats Boards. Barley exports were still regulated to State Barley Boards in early 1992. Domestic barley sales have been deregulated in all States except Queensland, where a permit fee of $1.50 per tonne of feed barley is required for its handling and marketing. The issue of further deregulation of barley handling, transport and marketing is currently under review with discussions (on appropriate future arrangements) taking place between farmers and the newly formed GrainCo Queensland Cooperative Limited (GrainCo, pers. comm. 1992).

Wheat

The Commonwealth Wheat Marketing Act 1989, effective from 1 July 1989, reinforced the Australian Wheat Board's (AWB) sole responsibility for marketing wheat exports and enhanced the Board's charter to cover other grain exports. The Act contains provisions to override certain State regulations with respect to marketing, storage, handling and transport of wheat. The enabling regulations were enacted in February 1990 and deregulated the transport of wheat across Australia.

The introduction of the revised Commonwealth Wheat Marketing Act has resulted in fragmentation of the domestic market for wheat in Australia, which accounts for 15 to 20 per cent of total production (AWB 1990). Basically, the Act terminated the compulsory acquisition and administration of pricing arrangements under the so called 'pooling' concept, bringing about changes from centralised distribution to direct transport of wheat from farm to mill (Grain Elevators Board, pers. comm. 1990).

The AWB negotiated rail freight contracts for the 1989 crop year (1 October 1988 to 31 September 1989) with State rail authorities. The crop year involved rail services to the same extent as in previous years' harvests in all States except for South Australia where some areas shifted to road services.

A poor wheat harvest in the 1989 crop year, caused by adverse weather conditions (drought in South Australia and floods in New South Wales), resulted in a decrease in the transport task. The 1989 export tonnages from Australia are presented in table 6.1.

Other post-Royal Commission changes include the greater use of price signals to reflect market values, whereby the AWB is now paying growers on the basis of protein content of wheat. Port costs are no longer pooled regardless of the port of export. Overall, these changes have led to a more efficient and flexible grain transport and marketing system (ABARE 1991b).

TABLE 6.1 WHEAT EXPORTS FROM AUSTRALIA BY STATE AND PORT, 1989[a]

State/port	Tonnes ('000)
NSW	1 876.2
Newcastle	1 345.7
Port Kembla	290.9
Sydney	239.5
Victoria	1 330.3
Geelong	698.6
Melbourne	31.4
Portland	600.4
Queensland	1 422.0
Brisbane	966.6
Gladstone	288.2
Mackay	167.2
South Australia	1 156.6
Ardrossan	6.6
Port Adelaide	362.3
Port Giles	133.8
Port Lincoln	261.4
Port Pirie	165.7
Thevenard	62.3
Wallaroo	164.5
Western Australia	5 410.7
Albany	789.7
Esperance	401.0
Kwinana	3 337.0
Geraldton	883.0
Australia	11 195.9

a. The 1989 crop year, covering 1 October 1988 to 30 September 1989.

Note Figures may not add to totals because of rounding.

Source *WA Co-operative Bulk Handling Newsletter* 1990.

Broad assessment of deregulation impacts

South Australia

In the 1989 crop year nine silos in South Australia converted from rail to road transport. This move resulted in a decrease of freight rates for those silos and attracted more grain to them. A further eight silos were planned to change to road. Block trains have been used for grain cartage, except for the narrow gauge line in the Port Pirie division, resulting in favourable freight rates being negotiated by the industry.

The ongoing programme to upgrade road weighbridges to 60 tonnes capacity has been carried out in order to cope with the increasing number of road based silos (SACBH 1990).

New South Wales

In New South Wales road facilities at the ports of Newcastle and Port Kembla were completed in 1990 to enable road to deliver grains in larger quantities.

The 1989 wheat transport task was carried out by State Rail Authority in the same way as before. State Rail won the contract for the task arranged by the Grain Handling Authority (ABARE, pers. comm. 1992; Grain Handling Authority of NSW 1989). The Grain Handling Authority was corporatised on 1 October 1990 and re-instituted as the Grain Corporation. The Corporation arranges for grain to be transported from northern New South Wales to Fisherman Islands (Brisbane) and from the Riverina to Geelong, rather than to New South Wales ports (Grain Corporation, pers. comm. 1992).

Queensland

The former agreement between Queensland Railways and Bulk Grains expired at the end of the 1989 season. Queensland Railways carried the 1989 wheat harvest at the renewed concessional rates offered to farmers under the unit trains transport arrangement (Bulk Grains Queensland 1990). AWB (1990) expects that the new agreement will provide greater opportunity for road transport although most of the wheat for export will continue to be transported by rail.

Victoria

In Victoria grain transport to port is still regulated to railways when the distance exceeds 60 kilometres. New arrangements have been negotiated between AWB and V/Line for the transport of export wheat.

Western Australia

In Western Australia the five year agreement between Co-operative Bulk Handling Limited and Westrail lapsed in 1989 and a new one-year agreement was signed between the parties. This ensured rail services for the next grain harvest at much lower rail freight charges, comparable to road freight charges (Co-operative Bulk Handling Limited 1990).

Conclusion

Although the full impact of the deregulation of grain transport is not yet assessable (such as barley in Queensland and wheat in Victoria) it is apparent that most of the bulk grain export task on long distances will remain with railways for cost efficiency reasons (BTCE 1987b). Nevertheless some domestic wheat transport, already deregulated by the Commonwealth Act, has been taken over by road transport to local mills.

FERTILISER

The Australian fertiliser industry has an annual turnover of approximately $800 million from the production of around 4.0 million tonnes of phosphate and nitrogenous fertilisers (AFMC 1987). Some 4000 persons are directly employed in the manufacture of fertilisers and additional employment is provided by distribution and other allied activities. In 1987 the assets used in fertiliser and allied manufacture had an estimated replacement value of $1390 million.

The outlook for the Australian fertiliser industry is one of continuing viability as world shortages of nitrogen are forecast in the 1990s. The Australian Fertilizer Manufacturers' Committee (AFMC) has stated that the domestic industry has, and will maintain, the capacity to supply all Australia's fertiliser requirements. World trade prices for fertilisers are linked to movements of the international grain market. Furthermore, given the importance of fertilisers to agriculture, the Australian fertiliser industry is an important sector of the Australian economy. As at July 1990 there were seventeen fertiliser manufacturing establishments operating in Australia.

Transportation arrangements

All fertiliser plants in Australia are located near a port, due to their bulky raw material input requirements which are shipped to these plants. These raw materials for the manufacture of fertilisers are mainly imported, although phosphate deposits which exist at Duchess (Mount Isa) in Queensland and Mount Weld (Laverton) in Western Australia may be exploited in the future.

In New South Wales, there are three fertiliser plants operating and each plant handles the distribution of the finished product according to the needs of its customers. That is, the mode of transport used for the distribution of fertiliser is based on the most effective way to serve the particular clients. One firm (pers. comm. 1990) stated that it uses railways where they exist, as railways are an efficient way of carrying their bulk commodity.

Transport arrangements in Victoria and Western Australia are similar to those in New South Wales, that is, the mode of transport used for distribution is based entirely on operational considerations and client requirements. The situation is similar in South Australia. Queensland fertiliser manufacturers also use whatever mode of land transport best suits their needs.

Transport regulations governing the carriage of fertilisers exist in Tasmania only.

Conclusion

Fertiliser distribution inland from port fertiliser manufacturers to numerous points of sale involves intricate transport arrangements, usually based on the commercial decisions of the manufacturers. The only potential market distortions are in Tasmania where fertilisers are regulated to rail. However, the AFMC perceives that any distortions in Tasmania were not major (AFMC, pers. comm.

1990) and fertiliser manufacturers were quite satisfied with the rail services provided.

LIMESTONE

In 1986–87, the Australian ex-mine value of limestone was some $63.4 million from the production of approximately 10.8 million tonnes of limestone (BMR 1989). About 65 per cent of the limestone produced in Australia is used in the manufacture of cement. A further 14 per cent is consumed as quicklime and hydrated lime, and some 10 per cent as metallurgical flux. Some 5 per cent is consumed as agricultural limestone dust, and an additional 4 per cent is used for the manufacture of chemicals. The final 2 per cent is used as various filler-grade products.

Transportation arrangements

Limestone for cement production

The carriage of limestone for cement production is confined to short distances from quarries to cement plants, and is usually conducted by conveyors or road trucks. The plants are located in close proximity to quarries as the process of cement manufacture requires large quantities of limestone. Only one dedicated railway exists for the carriage of limestone and it is located in New South Wales between the Marulan quarry and a cement factory at Berrima.

Limestone for other uses

The transportation arrangements for the distribution of limestone tend to vary according to customer and company needs and the quantities to be transported in any one movement. Rail tends to be favoured for long haul movements and for larger quantities of limestone as it offers cheaper freight rates than road.

Some clients prefer to make their own transport arrangements, often using their own trucks and/or contractors. Limestone producers often operate their own road transport fleet, usually from mine to mill.

Conclusion

The transport of limestone is a matter of choice for the producers who base their mode/route combinations on the needs of clients and on the principles of efficient production and distribution methods.

CHAPTER 7 CONCLUSION

This study of relative efficiencies of road and rail explored potential constraints affecting the efficient transportation of a range of commodities.

The study established a useful technique to evaluate relative efficiencies of road and rail, although data were often of inferior quality or were unavailable for the task being undertaken. Much of the transport and handling cost information was commercially sensitive and unavailable, prompting best estimates to be made and imposing a limitation on the accuracy of the results.

The linear programming technique used in the case study was based on a static approach, involving a 'snapshot' of a timeframe. Detailed analysis of investment options such as the Maldon to Dombarton rail project would require a dynamic approach. In that approach models would need to be extended to determine both the optimal mode split and an investment schedule over a study timeframe (say 20 years) to minimise net social costs over the period. This study has given weight to the potential application of such an approach.

A preliminary investigation of Maldon–Dombarton has found that if the costs of completing the rail link were amortised over the estimated coal tonnages during a 50-year project life, the link was close to being feasible. Given the sensitivity of this result to cost assumptions, the Maldon to Dombarton option, or else an overland conveyor from Wilton (e.g. the Alf Critcher proposal) warrants further investigation.

It is important to note that the relative efficiency solutions derived from the models do not suggest that current road and rail activities are necessarily being managed and operated efficiently. Nor does the investigation address transport efficiency in the absolute sense, that is, no consideration was given to technical efficiency.

SOCIAL VERSUS PRIVATE COSTS

While modal choice is usually determined by minimisation of private costs, this does not necessarily provide the most acceptable solution from a social point of view. A case study of the transportation of New South Wales export coal identified the least social cost transport methods in terms of total resources consumed, with some externalities being taken into account.

An efficiency comparison of a transport system should focus on the extent of the divergence between private and social costs. With reference to export coal, this study concluded that there was wide divergence between private and social costs, on the basis of factors which determine transport prices.

As far as practicable, correct pricing should attempt to internalise externalities generated by transport. An examination of pricing policies used by road and rail demonstrated that neither mode applies efficient resource cost based pricing principles.

PRICING

Road

An efficient road use charging system should take account of the full external cost generated by vehicles, including pavement damage, congestion, accidents, noise, and environment damage including air pollution. If road freight rates reflect only part of these costs, distortions in resource allocation occur resulting in these externalities being produced in quantities above the economic optimum. For production of units of externalities in excess of the optimum, the cost incurred by society exceeds the associated benefits.

Rail

From the analysis of coal transportation it appears that the State Rail Authority of New South Wales charges a single tariff which does not seem to be based on marginal cost pricing or Ramsey pricing. The final impact on efficiency of resource use by State Rail Authority's pricing practice is difficult to determine without further analysis.

REGULATION

New South Wales, Victoria, Queensland, Western Australia and Tasmania still apply a range of regulatory instruments to the transportation of coal, minerals, petroleum and grain. In States where transport of bulk commodities is regulated to railways, rail has a monopoly on the provision of services. In some cases, State governments raise additional revenue from rail freight by means of extracting royalties in the form of excess freight rates.

Deregulation which allows road to compete may not significantly reduce rail freight rates, if a task could not feasibly be undertaken by road owing to the large volumes and distance involved. Coal and mineral transportation exemplifies this situation in most instances.

However, in other instances transport deregulation may not only result in a reduction of rail freight charges (and thus an increase in consumers' surplus) but also would provide more incentive for efficiency gains to be made in rail. The introduction of open competition suggests also the lifting of unnecessary restrictions on B-doubles and road trains allowing for efficiency gains to be made by that mode.

Supporting evidence of allocative efficiency improvement has been obtained from the grain handling authorities and co-operatives. After the legislative deregulation of grain, it appears that rail has retained its dominant position with only small tonnages of grain having transferred from rail to road in South Australia. Although rail remains the major carrier of grain, it has to compete for tonnages by offering lower freight rates and better quality of service than it did before deregulation.

TRANSPORT EFFICIENCIES

The export coal case study, and a review of other bulk commodities, led to a number of conclusions about road and rail transport of bulk commodities.

Road

Road has a competitive advantage in transporting commodities involving distribution systems with multiple customers or destination points. Bulk commodities in this category include petroleum products, fertilisers and limestone. Typical examples are the inland distribution of petroleum products ex-refinery, or fertilisers from manufacturing plants. Distribution is often guided by logistics pertaining to an oil or fertiliser company's marketing strategy.

Rail

Rail represents the lowest cost method of transporting bulk commodities which are characterised by:

- high volumes;
- long distances;
- line hauls ending in a single destination (such as a port); and
- substantial economies of scale.

Bulk commodities falling into this category include black and brown coal, iron ore, minerals and grain. Road has limited scope for competing for a greater market share of these commodities.

APPENDIX I MIXED INTEGER LINEAR PROGRAMMING MODELS

Linear programming (LP) models are perhaps the best known *deterministic models* available to management, applied under conditions of assumed certainty (as opposed to *probabilistic models* in conditions of uncertainty). LP is a mathematical method of allocating scarce resources to achieve an objective, such as maximising profit (Lee, Moore & Taylor 1990). For example, management decision problems such as production planning, capital budgeting, transport resource allocation or advertising are concerned with the achievement of a given objective (profit maximisation or cost minimisation) subject to limited resources (money, equipment, labour, time, etc.). LP involves the description of real world decision situation as a mathematical model that consists of a linear objective function and linear resource constraints. The general LP model described in this appendix formed the basis of this analysis, namely to identify least social cost transport methods for New South Wales export coal. The analysis was conducted in a static framework without account being taken of the most efficient infrastructure investment schedule necessary for future transport demand (see Model Development section of chapter 3).

THE GENERALISED LINEAR PROGRAMMING MODEL

A distinct pattern exists in the formulation of each LP problem. First, *decision (or solution) variables* are defined. These variables, which typically represent the basis of the management decision, are expressed as mathematical symbols. Second, an *objective function*, and *system constraints* are defined, which together form a mathematical model of a real-world-type situation.

Decision variables

Decision variables, denoting a level of activity or quantity produced, are defined. For the general model, n decision variables are defined as:

x_1 = quantity of activity 1
x_2 = quantity of activity 2
x_n = quantity of activity n

or

$$x_j = \text{quantity of activity } j$$

where $j = 1, 2, ..., n$.

Objective function

The objective function represents the sum total of the contributions of each decision variable in the model towards an objective. It is represented as:

Minimise (or *maximise*)

$$Z = c_1x_1 + c_2x_2 + ... + c_jx_j + ... + c_nx_n$$

where Z is the total value of the objective function and c_j is the contribution per unit of activity j (j=1, 2, ..., n).

System constraints

The constraints of an LP model represent the limited availability of resources in the problem. Let the amount of each of m resources available be defined as b_j (for i=1, 2, ..., m). Thus, the constraint equations can be defined as:

$$a_{i1}x_1 + a_{i2}x_2 + ... + a_{ij}x_j + ... + a_{in}x_n\ (<, =, >)\ b_i$$

$$\text{for} \quad i = 1, 2, ... , m \quad \text{and} \quad x_1, x_2, ..., x_j, ..., x_n > 0$$

The coal transportation problem

Hunter and Newcastle Coalfields transportation

LP models of this type were applied to the coal transportation problems of the Hunter and Newcastle Coalfields, and of the Southern Coalfield. A further extension of the models was that they were of the *mixed integer* form, so chosen for their ability to model the fixed cost of maintenance of railway lines.

The mathematical statement was:

Minimise

$$Z = c_1x_1 + c_2x_2 + ... + c_jx_j + c_{j+1}x_{j+1} + ... + c_nx_n \tag{1}$$

subject to

$$a_{i1}x_1 + a_{i2}x_2 + ... + a_{ij}x_j + a_{ij+1}xj+1 + ... + a_{in}x_{in} > b_i \tag{2}$$

$$\text{for} \quad i = 1, 2, ..., m$$

where

$$x_1, x_2, ..., x_j = 0 \text{ or } 1 \qquad x_{j+1}, x_{j+2}, ..., x_n > 0 \tag{3}$$

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RCAPA       -C                                       V V                                                           ≤ 0
RCAPB       -C-C                                     V V                                                           ≤ 0
RCAPD       -C-C-C                             V   V V V   V   V     V                                             ≤ 0
RCAPE       -C-C-C-C                           V   V V V   V   V     V                                             ≤ 0
RCAPF       -C-C-C-C-C                         V   V V V   V   V V   V V   V   V   V   V   V                       ≤ 0
RCAPH       -C-C-C-C-C-C                       V   V V V   V   V V   V V   V   V   V   V   V   V                   ≤ 0
RCAPI       -C-C-C-C-C-C-C                     V   V V V   V   V V   V V   V   V   V   V   V   V       V           ≤ 0
RCAPJ       -C-C-C-C-C-C-C-C                   V   V V V   V   V V   V V   V   V   V   V   V   V   V   V           ≤ 0
RCAPZ                       -A                       V V                                                           ≤ 0
RCAPC                         -A               V   V       V   V     V                                             ≤ 0
RCAPM                           -A                               V     V   V   V   V   V                           ≤ 0
RCAPN                             -A                                                       V                       ≤ 0
RCAPG                               -A                           V     V   V   V   V   V   V                       ≤ 0
RCAPL                                 -A                                                               V           ≤ 0
RCAPK                                   -A                                                         V               ≤ 0
RCAPT                                     -A                                                               V   V   ≤ 0
MINE1                                        1 1                                                                   ≥ C
MINE2                                            1 1 1                                                             ≥ C
MINE3                                                  1 1                                                         ≥ D
MINE4                                                      1 1                                                     ≥ C
MINE5                                                          1 1 1                                               ≥ C
MINE6                                                                1 1 1                                         ≥ D
MINE7                                                                      1 1                                     ≥ D
MINE8                                                                          1 1                                 ≥ C
MINE9                                                                              1 1                             ≥ D
MINE10                                                                                 1 1                         ≥ D
MINE11                                                                                     1 1                     ≥ C
MINE12                                                                                         1 1                 ≥ C
MINE13                                                                                             1 1             ≥ C
MINE14                                                                                                 1 1         ≥ D
MINE15                                                                                                     1 1     ≥ C
MINE16                                                                                                         1 1 ≥ C
PORT                                        -1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1 ≤ 0
----------------------------------------------------------------------------------------------------------------------
```

Range Table

Symbol		Value
Z	>	.0000001
Y	>	.0000010
X	>	.0000100
W	>	.0001000
V	>	.0010000
U	>	.0100000
T	>	.1000000
1	>	.9999990
A	>	1.0000000
B	>	10.0000000
C	>	100.0000000
D	>	1000.0000000
E	>	10000.0000000
F	>	100000.0000000
G	>	1000000.0000000
H	>	10000000.0000000

Legend

Symbol	Meaning
Columns	
MNLij	Fixed cost of maintaining main line segment i to j
BRLij	Fixed cost of maintaining branch line segment i to j
RDxy	Road transport from mine x using option y
RLxy	Rail transport from mine x using option y
RRxy	Road and rail transport from mine x using option y, including a reloading charge from road to rail
Rows	
RCAPi	Rail capacity "produced" by rail maintenance and "used" by rail transport options
MINEj	Mine from which coal is required to be transported
PORT	Transport destination

Figure I.1 The linear programming model for the Hunter Region transportation network

The x's in all the above equations represent the value of the various transport activities specified in the model. The integer variables represented by $x_1, x_2, \ldots, x_j$ are, in this case, the segments of the railway mainlines and branch lines. Each segment is either maintained at a given cost and is therefore usable, having the value 1 in the LP solution, or it is not maintained and is therefore not usable, and has the value 0 in the solution.

The maintenance of segments is defined in such a way that if, for example, the segment from Antiene junction to Singleton is maintained and therefore usable, all other segments from Antiene to the Port of Newcastle must also be maintained. In the model the inclusion of an activity in the optimum solution provided for an arbitrarily high volume of coal to be carried. This was reflected in the a_{ij} coefficients in the model which were negative to provide transport capacity in the righthand side of the equations, the b coefficients in equation 2.

	MNLMVT	MNLTM	MNLMG1	MNLG1G2	MNLG2L	MNLLB	MNLMVWO	MNLWOD	MNLDPK	MNLBTJ	MNLLT	MNLTJT	MNLTMET	MNLMETCC	MNLCCSB	MNLSBPK	MNLMD	MNLWD	BRLGG1	BRLGG2	BRLTT	BRLKK1	BRLNK1	BRLK1PK	BRLMM	BRLCCCC	BRLSBSB
OBJ	C	C	C	B	C	C	C	A	C	B	B	B	C	C	C	C	B	C	B	B	A	B	B	B	B	A	B
RCAPMVTA	-B																									
RCAPTAMA		-B																								
RCAPMAG1			-B																							
RCAPG1G2				-B																						
RCAPG2LI					-B																					
RCAPLIBA						-B																				
RCAPMVWO							-B																			
RCAPWODO								-B																		
RCAPDOPK									-B																	
RCAPTJB										-B																
RCAPLTJ											-B															
RCAPTJTE												-B														
RCAPTEME													-B													
RCAPMECC														-B												
RCAPCCSB															-B											
RCAPSBPK																-B										
RCAPMAWI																	-B									
RCAPWIDO																		-B								
RCAPGG2																			-A							
RCAPGG1																				-A						
RCAPTT																					-A					
RCAPKK1																						-A				
RCAPNK1																							-A			
RCAPK1PK																								-A		
RCAPMM																									-A	
RCAPCCCC																										-A
RCAPSBSB																											-A
MINE1																										
MINE2																										
MINE3																										
MINE4																										
MINE5																										
MINE6																										
MINE7																										
MINE8																										
MINE9																										
MINE10																										
MINE11																										
PORTB																										
PORTK																										

	RD1A	RR1B	RR1C	RR1D	RR1E	RD2A	RR2B	RR2C	RR2D	RR2E	RD3A	RR3B	RR3C	RR3D	RR3E	RL4A	RL4B	RL4C	RL4D	RD4E	RL5A
OBJ	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	A	B	A
RCAPMVTA			V					V					V				V				
RCAPTAMA			V					V					V			V		V	V		
RCAPMAG1			V	V				V	V				V	V		V		V			
RCAPG1G2																V		V			
RCAPG2LI		V			V		V			V		V			V	V		V			
RCAPLIBA		V					V					V						V			
RCAPMVWO			V					V					V				V				
RCAPWODO			V					V					V				V				
RCAPDOPK			V	V				V	V				V	V			V		V		
RCAPTJB																				
RCAPLTJ					V					V					V	V					
RCAPTJTE																				
RCAPTEME																				
RCAPMECC					V					V					V	V					V
RCAPCCSB					V					V					V	V					V
RCAPSBPK					V					V					V	V					V
RCAPMAWI				V					V					V					V		
RCAPWIDO				V					V					V					V		
RCAPGG2		V			V		V			V		V			V						
RCAPGG1			V	V				V	V				V	V							
RCAPTT																V	V	V	V		
RCAPKK1																				
RCAPNK1																				
RCAPK1PK																				
RCAPMM																					V
RCAPCCCC																				
RCAPSBSB																				
MINE1	1	1	1	1	1															
MINE2						1	1	1	1	1										
MINE3											1	1	1	1	1					
MINE4																1	1	1	1	1	
MINE5																					1
MINE6																				
MINE7																				
MINE8																				
MINE9																				
MINE10																				
MINE11																				
PORTB		-1					-1					-1						-1			
PORTK	-1		-1	-1	-1	-1		-1	-1	-1	-1		-1	-1	-1	-1	-1		-1	-1	-1

	RD5B	RL5C	RL6A	RD6B	RL6C	RD7A	RR7B	RR7C	RR7D	RD8A	RL8B	RL8C	RL9A	RD9B	RD9C	RL10A	RD10B	RL10C	RD11A	RR11B	RR11C	ROWTYPE	RHS
OBJ	A	A	A	A	A	A	B	B	B	A	A	B	A	A	B	A	A	B	A	A	B		0
RCAPMVTA																					≤	0
RCAPTAMA																					≤	0
RCAPMAG1								V													≤	0
RCAPG1G2								V													≤	0
RCAPG2LI								V													≤	0
RCAPLIBA								V													≤	0
RCAPMVWO																					≤	0
RCAPWODO							V														≤	0
RCAPDOPK							V												V		≤	0
RCAPTJB		V			V							V									≤	0
RCAPLTJ																					≤	0
RCAPTJTE		V			V							V									≤	0
RCAPTEME		V			V							V									≤	0
RCAPMECC					V							V									≤	0
RCAPCCSB			V									V									≤	0
RCAPSBPK			V								V										≤	0
RCAPMAWI								V													≤	0
RCAPWIDO																					≤	0
RCAPGG2																					≤	0
RCAPGG1																					≤	0
RCAPTT																					≤	0
RCAPKK1													V								≤	0
RCAPNK1																V					≤	0
RCAPK1PK													V			V					≤	0
RCAPMM		V																			≤	0
RCAPCCCC			V		V																≤	0
RCAPSBSB											V	V									≤	0
MINE1																					≥	C
MINE2																					≥	C
MINE3																					≥	C
MINE4																					≥	D
MINE5	1	1																			≥	C
MINE6			1	1	1																≥	C
MINE7						1	1	1													≥	D
MINE8										1	1	1									≥	D
MINE9													1	1							≥	D
MINE10																1	1				≥	C
MINE11																			1	1		≥	C
PORTB		-1			-1			-1				-1									≤	0
PORTK	-1		-1	-1		-1	-1			-1	-1		-1	-1		-1	-1		-1	-1		≤	0

Figure I.2 The linear programming model for the Southern Coalfield transportation network

The fixed costs associated with the maintenance of mainline and branch line segments were calculated using various assumptions detailed in Methodology chapter 3 and Data Input Assumptions appendix III. *Fixed costs* are specified in the LP model as the $c_1, ..., c_j$ coefficients in equation 1.

The free variables $x_{j+1}, ..., x_n$ represent transport activities. The costs of these activities are calculated by multiplying the variable cost by the distance of each of the transport methods used for each segment of the trip. Provision was made for the use of different loaded and unloaded variable costs for each transport method. Alternatively, average variable costs may be used for both the forward and return trip for each transport segment. Where coal had to be transhipped from road to rail, a reloading cost (/tonne) was used in the cost calculations.

The $c_{j+1}, ..., c_n$ coefficients in equation 1 are the *variable costs* associated with each transport activity. Each transport activity was specified in 1000 tonne units. Transport of coal was represented by a series of ones and minus ones in the $a_{ij+1}, ..., a_{mn}$ coefficients in equation 2.

The constraint relationships and the righthand side coefficients b ensured that the assumption that the railway lines were maintained, if they were to be used, was enforced. The other significant set of constraints in the model was that all coal produced had to be transported to Port of Newcastle. A diagram of the completed model input is shown in figure I.1.

The LP model inputs were constructed in a computer spreadsheet which allowed the calculation of fixed railway line maintenance costs and the variable transportation costs based on distances outlined in chapter 3, table 3.1.

Southern Coalfield transportation

The corresponding model input specification for the Southern Coalfield is at figure I.2

The computer spreadsheet approach provides flexibility to allow additional activities to be incorporated into the model (for example, specification of investment activities) and for data to be updated in an efficient manner.

APPENDIX II COAL TRANSPORTATION IN NEW SOUTH WALES

The case study addressed coal transportation in two coalmining areas: firstly, the Hunter and Newcastle Coalfields; secondly, the Southern Coalfield.

THE HUNTER AND NEWCASTLE COALFIELDS TRANSPORT NETWORK

The Hunter and Newcastle Coalfields are served by the Port of Newcastle, the largest coal port in New South Wales (figure II.1). The Hunter Coalfield is easily the largest of the State's coalfields, with 19 operating mines and an output of 25.6 million tonnes of saleable coal in 1988–89. The Newcastle Coalfield's 18 operating mines produced 15.5 million tonnes of saleable coal in 1988–89.

This study reviews coal deliveries from 16 *export* mines only, 12 in the Hunter Coalfield and four in the Newcastle Coalfield. Total coal deliveries from these mines to the Port of Newcastle in 1988–89 were estimated to be 21.0 million tonnes. Total exports from the Port of Newcastle in 1988–89 were actually 29.2 million tonnes, including inland production from Ulan mine in the Western Coalfield, four Gunnedah Coalfield mines and from the coastal Wallarah mine to the south of Newcastle. The output from Wallarah mine was transported by MV *Wallarah* to Port of Newcastle for transhipment overseas.

The Port of Newcastle has two modern coal receiving, storage and blending facilities: Port Waratah Coal Services Ltd (PWCS) and Kooragang Coal Loader Ltd (KCL). PWCS handled almost 17 million tonnes and KCL some 12.2 million tonnes of Newcastle's total exports of 29.2 million tonnes in 1988–89. The combined nominal throughput capacity of PWCS and KCL is considerably greater at 46.0 million tonnes per annum (PWCS 28.0 million tonnes and KCL 18.0 million tonnes).

The main transport links for all twelve Hunter Coalfield mines and Newcastle Coalfield mines 13 and 14 are either the mainline Werris Creek to Newcastle railway or the New England Highway. The railway line also carries export coal from Ulan in the Western Coalfield and from mines in the Gunnedah Coalfield. Ulan and Gunnedah rail movements are not directly considered because both are sufficiently distant from port for rail to be clearly the optimal mode. This is not

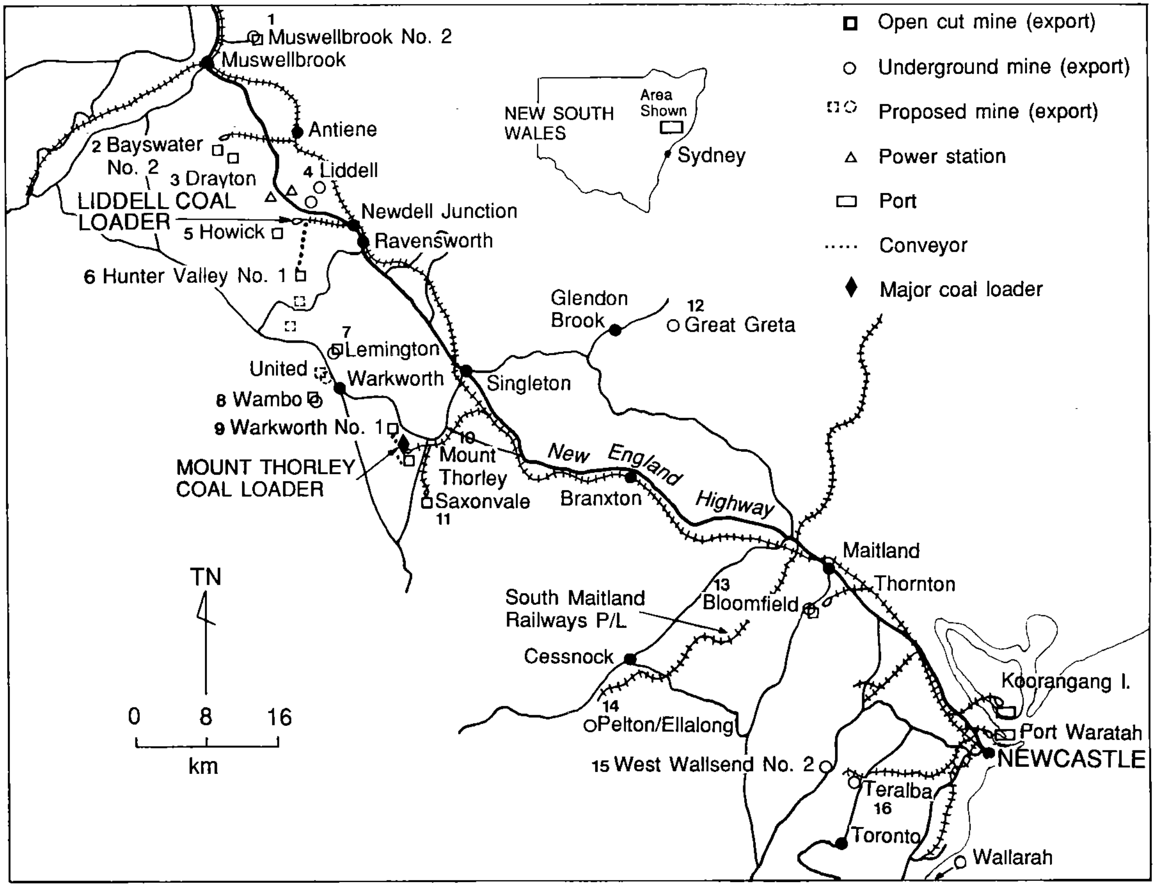

Figure II.1 Hunter and Newcastle Coalfields export mines

the case for the Lower Hunter and Newcastle areas where a competitive regime exists for road and rail options.

The Mount Thorley Coal Loader is the largest rail loading terminal in the region handling some 7.5 million tonnes of coal in 1988–89 from mines 7, 8, 9 and 10 (see figure II.1). The Liddell coal loading facility in the Upper Hunter handled over 5.5 million tonnes of coal in 1988–89 from mines 1, 2, 4, 5 and 6. The throughput of this facility is being expanded with a plan to transfer to rail transport almost 1 million tonnes of coal output from mines 1 and 2 which are presently carried by road. A large proportion of the Liddell throughput in 1988–89 (over 3.9 million tonnes) was coal received by conveyor from mine 6.

Other loading terminals on railway loops were at mines 3 and 11 at Branxton (for mine 12) and at mines 13 and 16. The private South Maitland Railway conveyed coal from mine 14 to East Greta junction near Maitland on the mainline Werris Creek to Newcastle railway.

Social and environmental impacts of Hunter Valley coal transport

Any intensification of road transport of coal has important implications for funding construction and maintenance of road infrastructure. Coal-induced infrastructure demands and their funding are leading concerns of the Association of Coal Related Councils (ACRC), a State body representing the interests of 22 affected councils with a population of over 1 million, and its regional offshoot, the Hunter Regional Association of Councils.

Councillor Vitnell (1990) of the ACRC advocated a levy on road transport of coal and a wider use of offroad transport options. Community concerns about the high incidence of heavy vehicles travelling through towns in the Hunter Region have been identified by the Associations and by Jakeman and Simpson (1987). The downstream Lower Hunter councils have voiced specific concerns about the rates of road deterioration arising from truck haulage of coal and the potentially adverse impacts this haulage may have on tourism.

Large contributors to dust-fall are open cut coal mining operations in the Upper Hunter. Air and noise pollution are attributed to mining operations and to transport (Jakeman, Parker et al. 1987).

THE SOUTHERN COALFIELD TRANSPORT NETWORK

Transport options are considered for 11 export mines in the Southern Coalfield which accounted for 9.2 million tonnes of coal in 1988–89. Some 6.6 million tonnes were loaded at Port Kembla Coal Loader and 1.2 million tonnes at Sydney's Balmain Coal Loader. The remaining 1.4 million tonnes was domestic coal, of which the majority was transported from mines 9 and 10 to the Port Kembla steelworks. The steelworks had a total coal intake of 7 million tonnes. Including Western Coalfield deliveries of over 3 million tonnes (other than Ulan coal which is transported to Newcastle), Port Kembla exported 8.8 million tonnes and Balmain 2 million tonnes in 1988–89.

Both the Port Kembla and Balmain coal loaders were owned and operated by the Maritime Services Board in 1988–89, but negotiations were under way in 1990 to lease the Port Kembla operations to a private sector consortium. A second export coal loader in Sydney, the Coal & Allied Industries Ltd Balls Head Coal Loader (0.34 million tonnes throughput in 1988–89), served Coal & Allied's Chain Valley mine in the Newcastle Coalfield. Export coal from Chain Valley is carried by ship to Balls Head and thus is beyond the scope of this analysis.

The Southern Coalfield operations centred on Port Kembla and Balmain differ considerably from the Hunter Region in a number of ways. The topography in the Southern Coalfield is unfavourable to transport and coal trains share a very heavily trafficked suburban and inter-urban rail system. Rail transport is less efficient than in the Hunter Region as a result of few direct links between mines and Port Kembla and limitations on train consists over the steep gradients. In addition, no coal trains are permitted on Sydney metropolitan lines during commuter peak periods, namely 5.30 a.m. – 9.30 a.m. and 2.30 p.m. – 6.30 p.m. For these reasons higher operating costs prevail for most rail coal transportation in the Southern Coalfield.

Roads also have steeper grades and curves than are encountered in the Hunter Region, resulting in higher operating costs for trucks. The Port Kembla Coal Loader is restricted to a seven day a week operation between 7.00 a.m. and 6.00 p.m. The resulting down time for coal trucks also increases operating costs, while limited stockpile capacity at Port Kembla results in an uneven demand for transport services.

The Southern Coalfield area map is at figure II.2. Deliveries of saleable coal from 17 Southern Coalfield mines (including raw coal for the steel industry which was washed at Port Kembla steelworks) amounted to 14.7 million tonnes in 1988–89. While domestic mines are excluded from the analysis the transport characteristics of three (out of six) domestic mines are described. This is done to demonstrate the potential for a mode transfer of coal sourced from domestic mines 12, 13 and 14 from road to the Maldon to Dombarton rail link. The proposed rail link has potential to carry both export and domestic coal.

The main transport characteristics of the Southern Coalfield are as follows:

- The output from Burragorang Valley mines 1 and 2 was transported by road to Wollondilly Coal Preparation Plant, and that from mine 3 by conveyor. A portion of the saleable coal from the plant was then transported by road, via Oaks and Mount Keira Roads, to Port Kembla Coal Loader. The remainder of the coal was transported on Burragorang Road to the Glenlee rail terminal near Campbelltown, and thence by rail either north via Lidcombe to the Balmain coal loader, or south via Moss Vale to the Port Kembla coal loader.

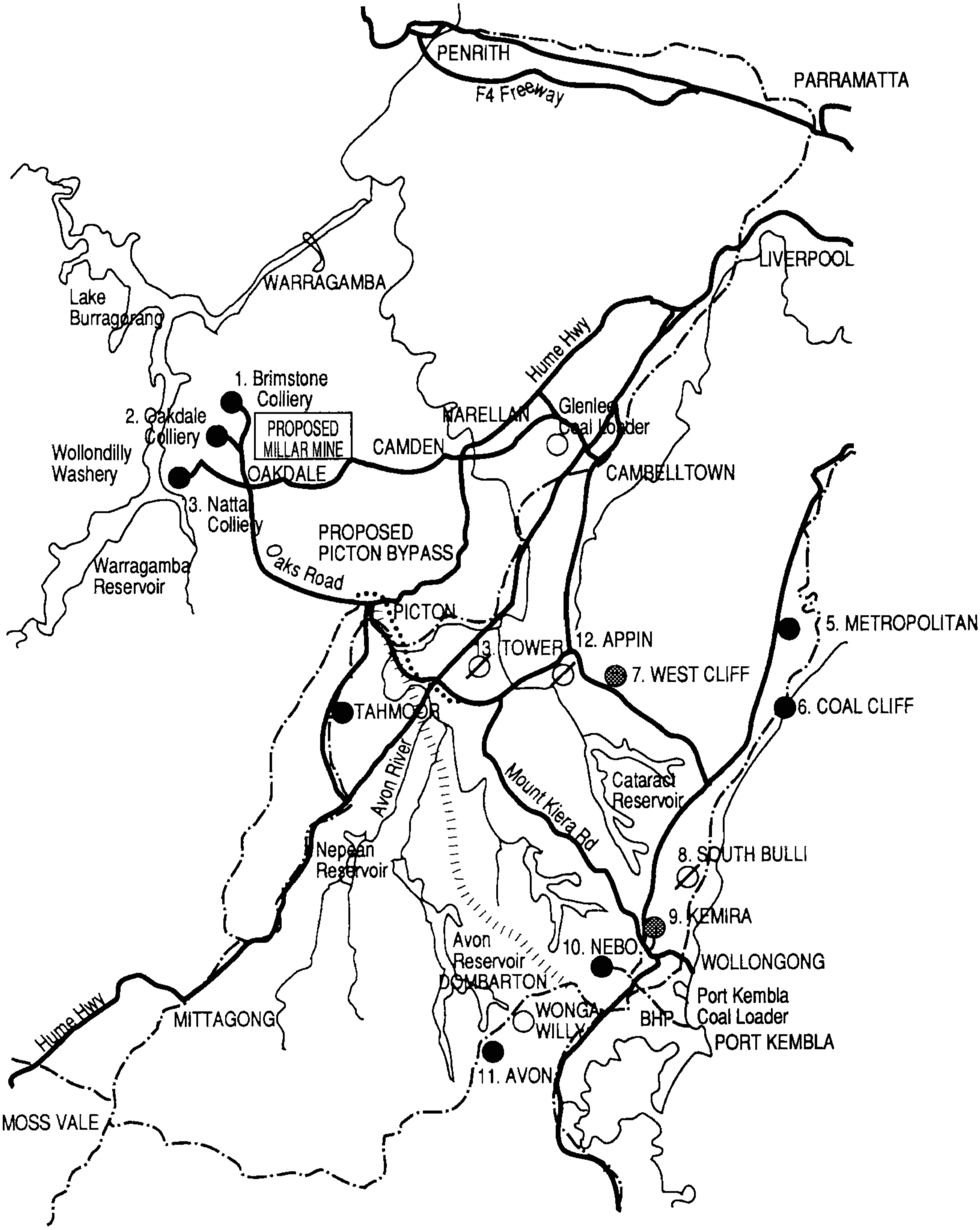

Figure II.2 Southern Coalfield mines

- A major transfer point for almost 4.3 million tonnes of coal in 1988–89 from domestic mines 12, 13 and 14 was at O'Briens Drift at the top of the escarpment at Mt Keira. The method is to bottom dump the coal from trucks onto an underground conveyor. The coal is reloaded to BHP's private railway at the base of the escarpment near mine 9 and transported to the BHP Port Kembla steelworks.
- Over 1.1 million tonnes of coal was transported from mine 7 over Mount Ousley Road to the Port Kembla Coal Loader. Lesser quantities of coal and coke were transported by truck from mine 6 to domestic users, mainly in the Wollongong area.
- Another major coal movement (1.8 million tonnes) by road within the Wollongong urban area to Port Kembla coal loader was from mine 8.
- Additional rail loading facilities were available for mines 4, 5 and 6. While the rail link to mine 8 was closed, the link was considered as a transport option.

The analysis includes the Maldon to Dombarton rail link as an option (see figure II.2). The Maldon–Dombarton project involves the building of a 40 kilometre railway including the 4 kilometre Avon tunnel at the south end, providing a direct link from inland mines to Port Kembla (Railway Digest 1985). The project was advanced some 20 to 25 per cent to completion with most earthworks, some bridgework and tunnel portals completed, when it was cancelled in June 1988 (Railway Digest 1988). Reasons for cancellation were stated to be reductions in funding and a significant decline in tonnages from those originally forecast. In mid 1988, completion of the project was costed at $150 million (Baird 1988).

There are compelling reasons for inclusion of the Maldon–Dombarton option. Based on a 50 year project life and some reasonable assumptions of 1988–89 coal tonnage (some 12.4 million tonnes), export growth (a conservative 1.6 per cent per annum) and discount rate (10 per cent), the project's amortisation cost translates to 6.35 cents per tonne kilometre. The estimated 1988–89 coal tonnage over the railway consists of:

- Western Coalfield traffic: 4 million tonnes (assumes closure of Balmain Coal Loader);
- Burragorang Valley mines 1, 2 and 3: 1.80 million tonnes; mine 4: 1.17 million tonnes; and
- Export mine 7: 1.12 million tonnes, and domestic mines 12, 13 and 14: 4.26 million tonnes.

The Maldon–Dombarton transport option assumes a road-to-rail loading point in the vicinity of Wilton, chosen on grounds of road access and proximity of mines. The choice of this site for a terminal coincides with the Critcher (1990) proposal for a major loading facility near Wilton for coal transport via an overland conveyor to Port Kembla.

Social and environmental impacts of Southern Coalfield coals' transport

Road transport features prominently in the Southern Coalfield, with over 8.6 million tonnes of coal *predominantly* carried by road in 1988–89, or some 62 per cent of total deliveries. *A Strategic Study of the NSW Southern Coalfield* (New South Wales Department of Minerals and Energy 1989) reports that the high volume of coal being hauled by road through commercial and residential areas has given rise to much criticism from residents and local councils. The amenity of commercial centres such as Picton, Corrimal, Fairy Meadow and residential areas along and adjacent to the transport routes is adversely affected.

The criticism of road transport is mostly directed at the noise and air (coal dust) pollution problems. Coal dust and amenity loss are the main problem areas identified in a one-quarter kilometre section of Picton's main business district which coal trucks traverse. A proposed Picton bypass to resolve these problems has not yet been built.

Another coal dust pollution problem arises at road receival stations and at satellite stockpiles, with emissions from direct dumping by trucks and front end loaders to reclaim, and from trucks on access roads (Laird 1988).

The Strategic Study identifies safety aspects and the effect of coal trucks on other road users as a significant issue. The concentration of coal trucks travelling along two-lane rural roads and down Mt Ousley Road is often found to be intimidating by both local and visiting drivers in the region.

The Coal Resources Development Committee (CRDC), charged with the Strategic Study, identifies the problem that producers would not support off-road haulage of coal if it led to higher costs. On the other hand, road freight rates do not reflect the direct costs of increased road wear and tear and the intangible costs in the areas of safety, noise, dust and traffic congestion borne by the community. The committee puts forward certain transport strategies which encourage transfer to off-road options. On present trends, up to 3 million more tonnes of coal would be hauled on Wollongong roads by 1995 (*Illawarra Mercury* 1989).

Interestingly, CRDC recommends that the State government maintain the integrity of the Maldon–Dombarton railway corridor for possible future resumption of the project in the event of significant increases of tonnages from mines which could be serviced by the railway. Mines at West Bellambi and East Bargo may be developed, thus giving weight to a joint user facility being developed in conjunction with mines 12, 13 and 14, and to the resumption of the Maldon–Dombarton project.

APPENDIX III DATA INPUT ASSUMPTIONS

Estimates of rail and road social marginal operating costs were used as input to the mixed integer model. The estimates were built on several conceptual models and assumptions. This appendix provides insight into these models, assumptions and sources involved in generating these estimates.

GENERAL APPROACH

The main features of the existing coal transport infrastructure and the composition of capital and operating costs are detailed below.

Rail and road classification

Railway lines are classified into two categories, mainlines and branch lines, due to different traction volumes and the usual dedication of branch lines to one commodity. Mainlines and branch lines in the Hunter Valley and Illawarra are depicted in figures 3.2 and 3.3.

Almost all branch lines in both areas are privately owned and maintained while mainline maintenance is a responsibility of State Rail.

To simplify cost estimates of road damage, roads are classified into two categories only, highways or arterials as the first category and local roads as the second category. Arterials are marked by higher than 2000 Average Annual Daily Traffic (AADT) counts while local roads have lower traffic volumes. For both the Hunter Valley and Illawarra there were no roads traversed by coal trucks with AADT counts between 1000 and 2000.

Table III.1 presents roads used as coal routes in this study by category for estimating pavement damage costs.

Rail operating costs

Rail operating costs are based on estimates of marginal operating costs by Freebairn and Trace (1988b), incorporating work by Easton (1988). These operating costs used the original Easton estimates of train operational parameters and costing practices used by the State Rail Authority of New South Wales. Exceptions were made in the treatment

TABLE III.1 ROAD CATEGORIES FOR PAVEMENT DAMAGE COSTING

Highway/arterial	*Local*
Hunter and Newcastle Coalfields	
New England Highway	All other roads
Pretty Road (MR 503)	
Mine 13 to Maitland	
Mine 14 to Hexham	
Mine 16 to Port (except for 2 km of local road near mine 16)	
Various Port of Newcastle roads	
Southern Coalfield	
Burragorang Road (MR 259) (Oakdale to Narellan)	All other roads
Appin Road (MR 1770)	
Remembrance Drive (Old Hume)	
Wilton Road/Mount Keira Road	
Road (MR 95)	
Mount Ousley Road	
Southern Expressway	
Princes Highway	
Lawrence Hargrave Drive	
Various Port Kembla roads	

Source BTCE estimates.

of infrastructure and rollingstock capital costs and in allocation of infrastructure maintenance costs.

Capital costs of rollingstock and infrastructure maintenance

Capital assets are valued at their opportunity costs, measured by replacement costs of an equivalent unit of capacity, assuming no excess capacity exists within the coal transport system.

The following parameters were selected for the capital cost estimates:

- Rather than the historical value of rollingstock proposed by Easton (1988) and used by State Rail for accounting purposes, replacement values were adopted. Replacement values have adjusted the historic costs for the effects of inflation and they represent real costs of rollingstock.
- Straight line depreciation method was used over the effective life of assets to estimate the annualised capital costs.

  The following effective asset lives were used:

Locomotives	22 years for diesel power, or 30 years for electrical power
Wagons	25 years
Infrastructure	50 years

- Zero resale value was assigned at the end of the asset lives.
- A discount rate of 8 per cent per annum was chosen to estimate the real long term cost of capital.
- In case of multi-use lines the unattributable costs of track maintenance were allocated to coal only. While track maintenance costs could have been allocated to all traffics on a basis of traffic shares, a commonly used allocation method, no information was available on other traffics sharing the common rail infrastructure.

Other rail operating cost components

Estimates of other avoidable rail operating costs consist of the following components:

- Crew costs comprise basic pay, all allowances, bonuses, taxes and on-costs. Although in the short run workforce levels can not be adjusted, it was assumed that changes such as retraining and natural wastage can occur during a year.
- Fuel or electricity usage costs are estimated as a function of several operational parameters such as locomotive power, load, speed, distance, number of axles, ruling grades and fuel price.
- Locomotive servicing and maintenance costs reflect age and a high utilisation rate in the coal export task. Wagon servicing and maintenance costs depend on high wagon kilometre intensity of use and the nature of coal loads.
- Infrastructure maintenance costs include maintenance of permanent way and works, maintenance of signalling equipment and overhead wires, and cost of operating signalling equipment. These costs vary depending on routine and unscheduled maintenance and repairs.
- CPI annual inflation rates (ABS 1990a) were used to update the 1986 Easton, and Freebairn and Trace estimates of operating costs.

The marginal rail operating cost for a coal train operating in the Hunter Valley amounted to $4.14 per tonne or 4.14 cents per tonne kilometre, expressed in December Quarter 1988 prices.

Track maintenance costs

An allowance of $9200 per track kilometre was added to take into account the fixed track maintenance cost, inflated from $7500 in 1986 (BTCE 1987b).

Loading costs

Variable operating costs at rail terminals consisted of all operating costs including the cost of maintaining the private loops and sidings. These ranged from $0.60 to $1.00 per tonne (coal industry sources, pers. comm. 1990).

Economic costs of past expenditure on railway infrastructure

Capital expenditure on track improvements and other infrastructure used in the haulage of export coal in New South Wales amounted to $1 billion in the period 1978 to 1989 (State Rail Authority 1989). Since past expenditure does not exert any influence on future cash flows from coal exports, it can be treated as a sunk cost, irrelevant in an economic analysis.

Applying the sunk cost formula to $1 billion capital expenditure, discounted by 10 per cent real discount rate together with an assumption of 50 years infrastructure life, and 1.6 per cent estimated annual rate of coal export growth, based on the annual growth in the last decade (Joint Coal Board 1989a), a minor cost of $0.014 per tonne was derived.

However, if the capital replacement formula is used to calculate annual capital charges, similar to current rollingstock values, the annual cost of capital expenditure to a user is much higher and amounts to $1.62 per tonne or $0.02 per tonne kilometre.

Neither of the latter estimates has been used as an input to the model.

ROAD OPERATING PARAMETERS AND COSTS FOR HUNTER AND NEWCASTLE COALFIELDS

The updated BTE Cost Compendium (1984, unpublished) was used for estimating the marginal cost of hauling coal by road.

The following truck technical and operational data were used:

- 6-axle articulated coal truck of 40 tonnes GVM and 25 tonnes payload capacity.
- An assumed trip length of 80 kilometres, which represents an average road distance in the Hunter Coalfields.
- Operational pattern designed for the 1989 annual output of 915 000 tonnes of saleable coal for export, transported from the Wambo mine to Newcastle with the following technical details:
  - annual transport task of 36 600 tonnes per truck;
  - annual distance of 266 000 kilometres per truck;
  - 329 days of truck operation during a year with ten per cent extra capacity for down-time was included;
  - average truck speed of 60 kilometres per hour;
  - turnaround time of 4 hours 40 minutes (including 2 hours for loading and unloading);
  - an eight hour daily shift, five days a week and 48 weeks a year, were assumed together with an earning rate of $12.80 per hour in the transport and storage sector (ABS 1989) to arrive at the total labour costs;
  - fuel usage of 50 litres per 100 kilometres for a loaded truck and 40 litres per 100 kilometres for an unloadedtruck was assumed (BTCE 1987b); this translated to 119 000 litres per annum for the task;
  - a new set of 22 tyres per truck with a life of 90 000 kilometres on sealed roads at $400 per tyre; and

TABLE III.2 ESTIMATES OF TRUCK OPERATING PARAMETERS AND COSTS — HUNTER VALLEY, 1988

Truck type	6-axle articulated
Trailer	Triaxle tipping
Gross vehicle mass	40 tonnes
Average payload	25 tonnes
Average distance per year	266 000 kilometres
Average fuel consumption	2.2 kilometres per litre
Distance related costs	
Fuel and oil[a]	26 cents per kilometre
Tyres	10 cents per kilometre
Maintenance	8 cents per kilometre
Time related costs	
Depreciation[b]	$21 860
New prime mover	$150 000 purchase price
New trailer	$45 000 purchase price
Life of vehicle	4 years
Real interest rate	5 per cent
Residual value	60 per cent
Registration and insurance	$9 630
Labour[c]	42 cents per kilometre
Total operating costs	$253 674
Operating costs per tonne	$6.93
Operating costs per tonne with licence and insurance costs deducted[d]	$6.67

a. At $0.58 per litre (BTCE 1989b).

b. Annual cost of capital was estimated for 5 years asset life and 60 per cent residual value (BTCE 1987b).

c. Drivers wages and on-costs plus 2 per cent on-costs were added to earnings (including overtime).

d. To avoid double counting of road damage costs.

Source BTCE estimates.

- a maintenance requirement for 479 units per truck was assumed depending largely on annual vehicle kilometres and labour at $45 per hour.

• Capital costs of $150 000 for a new prime mover and $45 000 for a new trailer.

These truck operating costs (table III.2) are comparable to other truck operating costs generated by commercial models recently available to the BTCE.

External costs of road transport

Two externalities' costs have been included in the model which were ascribed a monetary value. These are social costs of road damage arising from the passage of coal trucks, and costs of fatal and serious injury accidents involving the trucks.

Road damage costs: These were computed in terms of damage estimates per Equivalent Standard Axle Load (ESAL) kilometre, consistent with NAASRA (1976a, 1976b).

ESALs for loaded and empty 6-axle articulated 40 tonne GVM trucks were estimated from the following axle-loads:

- 5.0 tonnes for steer axle;
- 16.0 tonnes for dual drive axle; and
- 19.0 tonnes for trailing tri-axle.

The estimates were obtained from NAASRA (1976a) for a loaded truck. Corresponding axle loads of 3.5 tonnes, 5.7 tonnes and 5.8 tonnes applied for an unloaded truck (tare 15 tonnes).

Computed road damage factors were 3.73 for loaded trucks and 0.21 for unloaded trucks, using the fourth-power rule (NAASRA 1976b). With no backloading for coal trucks, the pavement damage costs based on BTCE estimates were calculated to be 7.7 cents per tonne kilometre for local roads and 1.8 cents per tonne kilometre for arterial roads or highways.

Road accident costs for 6-axle articulated trucks were derived from the number of fatalities and severe injuries sustained from accidents by heavy vehicles in 1988 and average costs of all accidents in Australia in 1985.

In 1990 *fatalities and severe injuries* amounted to 291 and 854 respectively (Federal Office of Road Safety, pers. comm. 1990).

Average *costs per accident* category were estimated at (BTCE 1988b):

- $380 087 per critical injury;
- $177 707 per severe injury (life threatening); and
- $46 135 per severe but not life threatening injury.

These estimates, adjusted for inflation to 1988 dollars using CPI rates (ABS 1990b), were converted into costs per vehicle kilometre travelled in 1988. The total of 3835.7 million vehicle kilometres travelled in 1988 was used for the conversion (ABS 1990a). The corresponding unit costs per tonne and per tonne kilometre were developed for a coal truck payload of 25 tonnes. The aggregated unit costs of fatalities and severe injuries amounted to 0.5 cents per tonne kilometre.

Air and noise pollution evaluation involved the determination of an urban/rural split for coal truck transits. The proportion of road transits through urban areas was estimated by the BTCE to be about 30 per cent based on a weighted average incorporating Upper Hunter mines and Newcastle Coalfield mines. Applying the ISC (1990) estimates of noise and atmospheric pollution costs for urban and rural areas of 8.680 and 2.184 cents per kilometre respectively to annual distances travelled by a coal truck, average costs of around 0.38 cents per tonne kilometre were arrived at.

Noise and air pollution costs attributable to trucks were estimated separately for the Hunter Region and the Southern Coalfield, based on cost estimates for rural and urban areas of ISC (1990). However, these costs were not included as data inputs to the model as no corresponding estimates were available for coal trains.

Costs of congestion

This analysis did not attempt to estimate the congestion costs generated by coal trucks and the resultant higher fuel consumption and time costs from congestion. Although congestion costs seem to have an impact on other road users, particularly in urban areas, it was beyond the scope of this analysis to estimate marginal and average costs of road use. Reloading costs ranged from $0.60 to $1 per tonne depending on the type of reloading facilities in use.

RAIL AND ROAD COSTS FOR SOUTHERN COALFIELD

Due to different terrain and distances in Southern coal areas, both costs were recomputed to reflect longer turnaround times for trains and steeper gradients and more curves for trucks.

Rail operating parameters

Adjustment was made to the train operating costs used for the Hunter Valley rail system to reflect longer turnaround times (24 to 48 hours) and shorter train consists of 27 to 32 wagons used in the Southern Coalfield.

Major adjustments to rail operating costs

Major increases in crew costs due to threefold turnaround time were assumed in addition to increases arising from longer average distances such as fuel, maintenance of locomotives and wagons and use of an extra locomotive in the hilly area. Rail operating costs increased by 60 per cent from 4.14 cents per tonne kilometre to 6.62 cents per tonne kilometre.

Maldon to Dombarton railway option

For the proposed Maldon to Dombarton railway, operating costs have been adjusted to 4.35 cents per tonne kilometre to take account of electricity costs and locomotive maintenance cost savings. The net cost savings on diesel fuel replaced by electricity and locomotive maintenance were based on Travers Morgan estimates made for the Sydney–Melbourne Railway Electrification Study (1980).

TABLE III.3 ESTIMATES OF TRUCK OPERATING PARAMETERS AND COSTS — SOUTHERN COALFIELD, 1988

Truck type	6-axle articulated
Trailer	Triaxle tipping
Gross vehicle mass	40 tonnes
Average payload	25 tonnes
Average distance per year	137 200 kilometres
Average fuel consumption	2.0 kilometres per litre
Distance related costs	
Fuel and oil[a]	30 cents per kilometre
Tyres	11 cents per kilometre
Maintenance	11 cents per kilometre
Time related costs	
Depreciation[b]	$25 740
New prime mover	$150 000 purchase price
New trailer	$45 000 purchase price
Life of vehicle	5 years
Real interest rate	5 per cent
Residual value	40 per cent
Registration and insurance	$9 630
Labour[c]	42 cents per kilometre
Excess weight permit	$3 300
Total operating costs	$318 411
Operating costs per tonne	$7.55
Operating cost per tonne with licence and insurance costs deducted[d]	$7.32

a. 5 years asset life and 60 per cent residual value was assumed (BTCE 1987b).

b. At $0.58 per litre (BTCE 1989b).

c. 2 per cent for on-costs were added to earnings (including overtime).

d. To avoid double counting of road damage costs.

Source BTCE estimates.

Maintenance costs of infrastructure

Fixed maintenance costs of infrastructure remained at the same level as for the Hunter Valley case study and amounted to $9200 per kilometre per annum.

Reloading costs

Variable reloading costs at rail terminals were assumed at $1.00 per tonne.

Capital cost of Maldon to Dombarton railway

The capital replacement formula was used to compute the annual capital charge. The straight line depreciation method over assumed effective asset life of 50 years and 10 per cent discount rate was chosen for the formula. The resultant annual capital charge, converted to unit cost per tonne kilometre using estimated future annual coal export volumes, amounted to $0.90 per tonne or $0.02 per tonne kilometre. An annual rate of increase of 1.6 per cent was used to estimate future coal exports. This estimate was based on statistics of coal export trends in the last decade, provided by Joint Coal Board (1989a).

Truck operating parameters

The road operating costs used in the Hunter Valley were adapted to the Illawarra area using the following operational parameter changes:

- An average gradient of 2.2 per cent and 1.67 road curves per kilometre on the escarpment; and
- 13 truck operating hours per day due to the imposed time limits in the Port Kembla urban areas.

The cost model by Watanatada et al. (1987) for trucks operating in different gradients was used to estimate increases in fuel and tyre usage and maintenance costs. Truck operating costs rose by 9.7 per cent, or from $6.67 to $7.32 per tonne as a result of steeper gradients, more curves and lesser average distances (table III.3).

External costs of road damage and accidents

Estimates of the external costs of road damage and fatal and serious injury accidents were arrived at in the same way as for the Hunter Valley. These estimates were applicable to specific road operations in the Southern Coalfield.

Unit *costs of road damage* of 1.8 cents per tonne kilometre for highways and arterials and 7.7 cents per tonne kilometre for local roads were the same as for the Hunter Valley.

Costs of fatal and severe accidents were also the same at 0.5 cents per tonne.

Noise and air pollution costs attributable to trucks were estimated separately for Southern Coalfield, based on the cost estimates for rural and urban areas of ISC (1990). However, these costs were not included as data inputs to the model as no corresponding estimates were available for coal trains.

REFERENCES

Abbreviations

ABARE	Australian Bureau of Agricultural and Resource Economics
ABS	Australian Bureau of Statistics
AGPS	Australian Government Publishing Service
AIP	Australian Institute of Petroleum
AWB	Australian Wheat Board
BAH	Booz. Allen and Hamilton
BMR	Bureau of Mineral Resources
BTCE	Bureau of Transport and Communications Economics
BTE	Bureau of Transport Economics
CRES	Centre for Resource and Environmental Studies, Australian National University
DME	Department of Minerals and Energy NSW
DMR	New South Wales Department of Main Roads
DPIE	Federal Department of Primary Industries and Energy
IAC	Industries Assistance Commission
IC	Industry Commission
JCB	Joint Coal Board
NAASRA	National Association of Australian State Road Authorities
RIC	Railway Industry Council
RTA	Road Traffic Authority
SACBH	South Australian Co-operative Bulk Handling Limited

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ABBREVIATIONS

AADT	Annual Average Daily Traffic
ABARE	Australian Bureau of Agricultural and Resource Economics
ABS	Australian Bureau of Statistics
ACRC	Association of Coal Related Councils
AFMC	Australian Fertilizer Manufacturers Committee
AGPS	Australian Government Publishing Service
AIP	Australian Institute of Petroleum
ANU	Australian National University
ARIAC	Australian Rail Industry Advisory Council
AWB	Australian Wheat Board
BAH	Booz.Allen and Hamilton
BHP	The Broken Hill Proprietary Co. Ltd
BMR	Bureau of Mineral Resources, Geology and Geophysics
BTE	Bureau of Transport Economics
BTCE	Bureau of Transport and Communications Economics
CPI	Consumer Price Index
CRES	Centre for Resource and Environmental Studies, Australian National University
CRDC	Coal Resources Development Committee
CSO	Community Service Obligations
DME	Department of Minerals and Energy NSW
DMR	New South Wales Department of Main Roads
DPIE	Federal Department of Primary Industries and Energy
ESAL	Equivalent Standard Axle Load
f.o.b.	free on the board
GDP	Gross Domestic Product
GVM	Gross Vehicle Mass
HVCCC	Hunter Valley Coal Chain Council
IAC	Industries Assistance Commission
IC	Industry Commission

ISC	Inter-State Commission
JCB	Joint Coal Board
KCL	Kooragang Coal Loader Ltd
km	kilometre
LCL	Less-than-Car Load
LP	Linear Programming
MR	Main Road
MTCL	The Mount Thorley Coal Loader
MV	Motor Vessel
NAASRA	National Association of Australian State Road Authorities
NRC	National Rail Corporation
NRFI	National Rail Freight Initiative
NRTC	National Road Transport Commission
NSW	New South Wales
ntkm	net tonne–kilometres
pers.comm.	personal communication
PSA	Prices Surveillance Authority
PWCS	Port Waratah Coal Services Ltd
RD	Road only
RIC	Railway Industry Council
RR	Road–Rail
RL	Rail only
RTA	Road Traffic Authority
SACBH	South Australian Co-operative Bulk Handling Limited
SRA	State Road Authority
State Rail	State Rail Authority of New South Wales
tkm	tonne–kilometres
vkm	vehicle–kilometres
WA	Western Australia