Coal Transportation in NSW: a programming analysis of road and rail options[1]

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Introduction

Bulk commodities such as wheat, coal or 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. Usually there are competing modal possibilities for the transportation of these commodities, with modal choice being determined by minimisation of private costs. However, minimising private costs does not necessarily provide the most acceptable solution from a social point of view.

Efficiency of transportation has important implications for resource use and, in the case of exports, for maintaining Australia's competitiveness on international markets. Hence, reform of transport is an important component in the Federal Government's overall approach to economic reform. 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.

The problem reported in this paper is that of transporting coal from the Hunter and Newcastle Coalfields to the Port of Newcastle, and from the Southern Coalfield to Balmain and Port Kembla. The investigation has two aims. The first is to develop a model to determine the least cost method of transporting bulk commodities where some transport modes involve substantial fixed costs. The second aim is to apply the model to select the least social cost method of transporting export coal from the coalfields.

A mixed integer linear programming model was developed to determine the least social cost combination of transport modes. The method involves estimating the costs of competing road and rail transport options over a selection of routes to determine the optimal modal configuration in social cost terms. Account is taken of the fixed costs of transport infrastructure maintenance required to keep railway lines open. Added to this are road and rail operating costs (which vary with the tonnages of coal transported), the costs of reloading of coal between minesite and port and the costs of road accidents. If data were available to value general environmental impacts such as noise pollution, dust pollution and greenhouse gas emissions, then the model could be extended to take these social costs into account.

Background

Federal and State Governments have in place a series of reform measures to improve the efficiency of transportation. These measures are part of governments' aims to improve efficiency of resource use through economic reform. However, this process of economic reform places additional pressure on the transport sector as a service industry responsible for the movement of freight and people across sectors.

Railway efficiency has national, as well as State implications. All public railway systems are operating in deficit, with the States using rail subsidies to cover the costs of urban and passenger services and, to a lesser extent, the unprofitable areas among freight activities. Cost recovery rates for non-urban rail at the national level in 1986-87 ranged from 24 per cent for 'less than car load' freight to 140 per cent for coal and minerals (Railway Industry Council 1990).

Restructuring of the rail industry is being pursued through Federal and State government initiatives. The objective of such restructuring is to develop medium and long term strategies to improve the competitiveness of rail.

The road freight industry is also under continuing review by Federal and State governments. For example, the Federal Government is pursuing the issue of greater uniformity of regulations across States. Recently, the Inter-State Commission (1990) released a series of recommendations for road cost recovery in a report on the road freight industry which, if adopted, will affect the relative cost efficiency of road freight transport.

The coal industry plays an important role in the Australian economy, with coal accounting for 12.7 percent of Australia's commodity export earnings in 1988-89. Given the economic significance of coal, it is important to maintain its export share in an increasingly competitive world market. Because the costs of handling and transporting export coal are prominent in the supply chain, amounting 30 to 45 per cent of the f.o.b. trimmed cost of delivery, it is appropriate to examine the transport configurations which minimise land transport costs.

Export rather than domestic coal has been chosen for the analysis because it offers more scope for modal transfer. Domestic coal is typically short-hauled by road or taken by conveyor from minesite to consumer (such as a power station). The volumes of coal exported from New South Wales are substantial, providing measurable externality effects arising from modal shifts.

The Hunter Region coal transportation network

The Hunter and Newcastle Coalfields are served by the Port of Newcastle, the largest coal port in New South Wales. A total of 16 export mines is under review, 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 are estimated to be 21.0 million tonnes. Total exports from the Port of Newcastle in 1988-89 were actually 29.2 million tonnes, including the production from Ulan mine in the Western Coalfield, from Gunnedah Coalfield, and from Wallarah mine to the south of Newcastle whose output is transported by sea to Newcastle.

The main transport links for all Hunter Coalfield mines 1 to 12 and two Newcastle Coalfield mines 13 and 14 are either the Newcastle-Werris Creek main railway line or the New England Highway. The railway line also carries export coal from Ulan and from Gunnedah. Ulan and Gunnedah rail movements are not directly considered because both are sufficiently distant from port for rail to be clearly the optimal mode. However, the use of road transport from the nearby mines 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 and the Hunter Regional Association of Councils. Community concerns regarding 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). 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.

In this paper, a number of road and rail transport options have been identified for each of the Hunter and Newcastle Coalfields' export mines. These include road options which could be regarded as unacceptable from the community viewpoint, but are assessed (below) to be sub-optimal. The transport alternatives are shown schematically in Figure 1. Although reloading costs at rail terminals may affect modal choice, these costs do not represent a high proportion of total transport costs.

The current transport arrangements are shown in Figure 1 as option 'a' except for mines 1 and 2. These mines use both options 'a' and 'b' as the 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. 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 export mines.

The Mount Thorley Coal Loader (MTCL) is the largest 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 1, while smaller than MTCL, transfers to rail export coal from five mines. Conveyor belts or road are used to deliver coal to rail loading facilities.

The Southern Coalfield transportation 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 Balmain Coal Loader. The remaining 1.4 million tonnes was domestic coal, the majority of which 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 Coalfields deliveries, Port Kembla exported 8.8 million tonnes and Balmain 2 million tonnes, in 1988-89.

The Southern Coalfield operations centred on Port Kembla and Balmain differ considerably from the Hunter Region in a number of ways. The topography in Southern Coalfield is not as favourable to road and rail transport and coal trains share a very heavily trafficked suburban and interurban rail system. The schematic representation of the transport options is shown in is Figure 2.

Road transport features prominently in the Southern Coalfield, with over 8.6 million tonnes being carried predominantly by road in 1988-89. The Coal Resources Development Committee (1989) reported in a study of the Southern Coalfield that the high volume of coal hauled through commercial and residential areas gave rise to much criticism from residents and local councils. The amenity of the commercial centres of Picton, Corrimal and Fairy Meadow and of residential areas in the vicinity of the transport routes was adversely affected.

There are few direct links between mines and Port Kembla. Coal can be transported by rail either via Moss Vale to Port Kembla Coal Loader, or on the metropolitan lines to Balmain Coal Loader. It is also possible to use the metropolitan lines, and interurban lines to transport coal to Port Kembla. The proposed Maldon to Dombarton rail link is included as an option in the analysis. A hypothetical loading site is included at Wilton on the Maldon-Dombarton railway.

Two further problems affect rail transportation from the Southern Coalfield. They are limitations on train capacity due to steep gradients on the existing lines. In addition, no coal trains are permitted on Sydney metropolitan lines during commuter peak periods, namely 5.30AM - 9.30AM and 2.30PM - 6.30PM. For these reasons higher operating costs prevail for most rail coal transportation in the Southern Coalfield, than in the Hunter Region.

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 operated on a seven day a week basis, but closes between 6pm and 7am. 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.

Social versus private costs

Failure to develop freight services in response to a changing economic environment, or to provide a regulatory framework which allows adjustments to occur will inevitably reduce efficiency of resource use with subsequent costs to the economy. Transport, like any other sector of the economy, competes for resources within competitive capital and labour markets. Inefficiency in one sector has important implications for the competitiveness of other sectors of the economy, and for overall economic performance.

In some cases, market failure may result in society bearing part of the economic costs causing a divergence between the private and social costs associated with the provision of transport services. The inability of the road transport sector to achieve acceptable outcomes in the areas of load limits, design standards and safety provisions is one example of market failure which contributes to such divergence. Similarly, externalities such as accidents, local air and noise pollution, and other environmental impacts, although generated by users of transport services, are costs borne by society.

Another area which illustrates divergence between private and social costs in freight transport is that of road damage. For the most part, road damage costs caused by freight vehicles and coaches are borne by other road users. Failure of road charges to properly reflect costs to private 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.

In the analysis undertaken here, private and social costs incurred by transport activities were included where possible. For some variables such as quality of life, it was not possible to obtain an estimate of the reduction in 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 existing transport system was modelled using mixed integer linear programming. 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), conveyor belts, slurry pipes or coal loading facilities. The effect of constructing such new facilities can be included in the model relatively easily, but data collection and the calculation of the present value of costs and returns associated with these investment alternatives is quite demanding.

Mixed integer LP model

Mixed integer linear programming was chosen because of its ability to model the fixed cost of the maintenance of rail lines. The linear programming model can be stated algebraically (see Lee, Moore and Taylor (1985) for details) as

Minimise (or maximise)

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

subject to

$$a_{i1}x_1 + a_{i2}x_2 + \ldots + a_{ij}x_j + a_{ij+1}x_{j+1} + \ldots + a_{in}x_n \ (\leq, =, \geq) \ b_i \quad \text{for} \quad i=1,2,\ldots,m \tag{2}$$

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

The x's in all the above equations represent the value of the various 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 rail mainlines and branch lines. Each segment is either maintained at a given fixed cost and therefore usable having a value of 1 in the linear programming solution, or it is not maintained and is therefore unusable, and has a value of 0 in the solution. The maintenance of segments is defined in such a way that if, for example, the segment from Singleton to Antiene junction is maintained and therefore usable, all other segments from Antiene to Port Waratah 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 right hand side of the equation system, the b coefficients in equations (2).

The fixed costs associated with the maintenance of mainline and branch line segments were calculated using various assumptions detailed in Table 1 and amplified in the discussion of results. The fixed costs are specified in the linear programming model as the $c_1, \ldots, c_j$ coefficients in equation (1).

The free variables $x_{j+1}, \ldots, x_n$ represent the 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 transshipped from road to rail, a reloading cost was used in the cost calculations. The $c_{j+1}, \ldots, c_n$ 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 $a_{ij+1}, \ldots, a_{mn}$ coefficients in the equations labelled (2).

The constraint relationships and the right hand side coefficients b ensured th[illegible]e assumption that the rail 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 a port. Matrix 'pictures' of the completed models for the Hunter Valley and the Southern Coalfield are shown in Figures 3 and 4.

The linear programming models were constructed in computer spreadsheets which allowed the calculation of the fixed line maintenance costs and the variable transportation costs based on the distances and costs outlined in Tables 1, 2, and 3. A FORTRAN programme was written to read the spreadsheet file, and to translate it into standard MPS format. This approach provides flexibility to allow additional activities to be incorporated into the model and for data to be updated in an efficient manner. The linear programming models were solved using a mixed integer version of MINOS (see Murtagh and Saunders 1987) on a Macintosh computer.

Data requirements

In this analysis, private costs included direct road and rail transport costs from mine to port 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.

Social costs included costs of road damage arising from coal trucks and costs of fatal accidents and injury involving the trucks. These costs were ascribed a monetary value in this analysis.

For costing purposes railways were classified as mainline and branch line. Mainlines referred to are the Werris Creek and Gosford lines in the Hunter region. The 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 rail loops and rail sidings. 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.

For the purpose of road damage costing roads were classified into two categories, viz highways and arterials, and local roads (Bureau of Transport and Communications Economics 1988a; D P Luck, personal communication, 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, highly-trafficked sections of other roads were also included. The second category included all remaining roads with low traffic volumes, and were termed local. Traffic counts for arterials in the Hunter and Illawarra areas, selected for coal transport options, were in excess of 2000 Average Annual Daily Traffic (AADT). Traffic counts for locals were less than 1000 AADT, with no counts encountered between 1000 and 2000 AADT (Roads and Traffic Authority 1988, Department of Main Roads 1986).

Road damage costs were computed in terms of damage estimates per Equivalent Standard Axle Load kilometre (ESALkm). 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 is 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 National Association of Australian State Road Authorities practice (National Association of Australian State Road Authorities 1976a; 1976b).

Road accident costs were derived from the rates of fatal accidents and injuries in terms of vehicle-kilometres travelled by heavy vehicles and the average number of fatalities per accident (Federal Office of Road Safety, personal communication, 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 for trucks were estimated, based on rural and urban cost estimates in Inter-State Commission (1990). However, these costs were not included in the model in the absence of similar estimates for rail. The analysis did not attempt to estimate the fuel and time costs of congestion.

Data inputs to the model

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

Estimates of rail operating costs were based on Monash University, Centre of Policy Studies investigations by Freebairn and Trace (1988), incorporating work by Easton (1988). Supplementary information was obtained from the Industries Assistance Commission (1988; 1989), Booz.Allen and Hamilton (1989) consultants to State Rail and the BTCE submission to the Royal Commission into Grain Storage, Handling and Transportation (Bureau of Transport and Communications Economics, 1987). Estimates of road operating costs were sourced from Bureau of Transport Economics (1984) and Luck and Martin (Bureau of Transport and Communications Economics, 1988a). The road operating costs for the Southern Coalfield were adjusted from the 'level terrain' truck operating costs for the Hunter Region by means of a World Bank model (Watanatada et al, 1987), which takes into account the cost impacts of road gradients and curves.

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 tonnes transported in that year. To complete the data input specification the costs of the various transport and reloading activities were presented on a per kilometre, tonne kilometre or tonne basis. These figures are presented in Table 1 and 2. The cost data inputs to the model are itemised in Table 3, including the fixed and variable costs of road transport, variable costs of road transport, reloading costs and externality costs.

Results

Initially, the analysis was to be based on three assumptions: rail transport incurs the total fixed cost of maintenance, rail transport incurs part of that cost, and rail transport does not contribute to maintenance cost.

The empirical results generated from the mixed integer linear programming models are presented in Tables 4, 5 and 6. The tables show the optimum transport modes and the social marginal costs of transporting an extra tonne of coal from each mine by the optimal modes. The calculations hold for one thousand tonnes of coal only, but they may be assumed to hold, in this case, for tonnages up to the capacity of the rail lines, coal loaders, and similar equipment. The optimal transport modes are derived under the assumption that coal transport is required to pay the entire fixed cost of rail mainline maintenance, as well as the same cost for the 'coal only' branch lines. Tables 4 to 6 also show the social opportunity cost of transporting coal using any sub-optimal mode.

The assumption that coal transport be required to pay all of the fixed costs of mainline maintenance is obviously unrealistic. It was used as a 'higher cost' assumption. A more realistic assumption is that coal transport would pay a share of the fixed costs in proportion to the total freight volume on the various mainline segments, and that passenger services would also pay a 'fair' proportion of these fixed costs. In overstating the fixed costs of rail maintenance properly attributable to coal transport, the model underestimates the opportunity costs of non-optimal road, or mixed road and rail transport modes. It proved difficult to collect data on the volume of coal versus other commodities transported by rail, on some lines. Thus an alternative assumption that coal transport would not be required to pay any of the fixed costs of rail mainline maintenance, but would be required to pay these costs on the branch lines, was run in a modified model. The difficulties in allocating fixed costs points to the need to include all transport tasks (eg wheat transport) in the model.

Hunter Valley

An interesting result from the analysis is the high social opportunity costs incurred by mines 1 and 2 using a road transport mode to haul coal to port (options RD1A and RD2A in Table 4). For mine 1 they are about $14.70 per tonne, and over $11.20 per tonne for mine 2. The social costs are probably higher than the private freight costs paid to transport coal from these mines. Unfortunately, it was impossible 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. The development of coal loading facilities at Liddell has resulted in mine 1 phasing in rail transport at the expense of road over a three year period. Similarly, while the loop line to Drayton has been completed only recently, 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 of the other mines (with the exception of mine 5) were using transport modes that minimised net social cost. These modes were mixed road and rail (RR), or rail only (RL). Mine 5 was using a sub-optimal mixed road and rail mode with an opportunity cost of about $2.40 per tonne. The optimal mode for this mine would be to transport coal to the Mount Thorley Coal Loader, for subsequent rail transport to the port.

The major result of the empirical study is quite clear. Rail transport is much cheaper than road as a means of transporting export coal in the Hunter Valley, in terms of net social cost. This result is strengthened, given that the analysis used the unrealistic assumption that coal transport using the rail mode is required to pay all of the fixed cost of main rail line maintenance. The solution to the modified model gave exactly the same transport mode choice as the original model. The only difference was in the value of the objective function. This result also strengthens the model results, as this solution was expected.

Southern Coalfield

The results for the Southern Coalfield are little different from those of the Hunter Valley (see Tables 5 and 6). A mixture of road and rail transport is used, and most mines are transporting coal by the least social cost method, or a method close to the optimum. An exception is the transport of a relatively small tonnage of coal from mines 1, 2 and 3 through Moss Vale to Port Kembla. The opportunity cost for this route is $14.20 per tonne.

It was assumed in the model that the proposed Maldon to Dombarton line was available for use. The results indicated transport via that route was the cheapest for Mine 4.

The mines in the Oakdale area provide interesting problems for analysis. The optimum transport mode for them is by road and then rail to port at Balmain. If Balmain were closed for coal export, then the optimum transport route for these mines would be by road to Port Kembla. This is a somewhat surprising result, given that the model indicates that the Maldon to Dombarton line should be open to transport coal from Mine 4. The opportunity cost of using the Maldon to Dombarton line, for coal from the Oakdale mines, would be $0.65 per tonne, with an operating cost of $0.0635 per tonne km assumed on that line, including a $0.02 per tonne km replacement cost for the Maldon-Dombarton project. This replacement cost is computed on the basis of additional domestic coal and Western Coalfield export coal being carried on the Maldon to Dombarton link. The Maldon to Dombarton line has potential to carry other traffics, including grain and mineral products. An allocation of capital costs over the full range of traffics would lower the cost for the Oakdale area mines. More analysis needs to be conducted on the question of the advisability 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 multiperiod model.

The social cost of closing the Balmain port 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 would be reasonable to close the coal loader.

Conclusions

The analysis of transportation problems usually involves a range of options that need to be considered simultaneously. In addition, given the structure of the transport industry and possibilities for substitution and complementary relationships between transport modes, it is necessary to analyse the interactions that occur in meeting a given transportation task. Finally, given the divergence between private and social costs that arises in transportation activities, any assessment of the performance of sectors in the industry needs to evaluate the effects of their conduct on overall efficiency of resource use.

The issue of coal transportation from the Hunter and the Southern Coalfields is characterised by such problems. In attempting to determine the least cost combination of modes to meet the transportation task, a mixed integer linear programming model was developed. Its application to the coal transportation issue illustrates the potential use of such a technique for examining transportation problems.

The results generated by the analysis generally highlighted the comparative advantage of rail relative to road in transporting bulk commodities. This comparative advantage was based on a model that incorporated social costs incurred in meeting the task. While some components of social cost are difficult to quantify, the use of the approach does provide for some evaluation to be made of the impact of such social costs on the combination of modes.

Finally, while a least cost combination may be determined in a static framework, such an optimal solution does not mean that current activities are operating optimally. The technique does provide policy makers with a tool for determining current inefficiencies in the system and options for investment in infrastructure to improve efficiency. Ideally, such an extension of the current model would incorporate investment options within a dynamic framework.

References

Booz. Allen and Hamilton Inc (1989) *Diagnostic Review and Strategic Priorities for Freight and Country Passengers*, unpublished.

Bureau of Transport and Communications Economics (1987) *Competition and Regulation in Grain Transport*, submission to Royal Commission, Occasional Paper82, AGPS, Canberra.

____ (1988a) *Review of Road Cost Recovery*, Occasional Paper 90, AGPS, Canberra.

____ (1988b) *Costs of Road Accidents in Australia*, Occasional Paper 91, AGPS, Canberra.

Bureau of Transport Economics (1984) *Transport Cost Compendium*, unpublished.

Coal Resources Development Committee (1989) *A Strategic Study of the NSW Southern Coalfield*, DME 89/200, July 1989.

Department of Main Roads (1986) *Traffic Volumes and Supplementary Data 1986: Illawarra Division*, DMR, Sydney.

Department of Minerals and Energy (1989) *New South Wales Coal Industry Profile 1989: Statistical Information to June 1988*, Department of Minerals and Energy, Sydney.

Department of Primary Industries and Energy (1990) *Open Cut Mine Survey; Longwall Mine Survey; Non-Longwall Mine Survey*, unpublished.

Easton, E (1988) *Charges and Costs of Rail Transport of Coal, Lead and Zinc Concentrate: Summary*, Centre of Policy Studies, Monash University, Melbourne.

Freebairn, J W and Trace, K (1988) *Rail Transport of Bulk Minerals: Study Perspective*, Centre of Policy Studies, Monash University, Melbourne.

Industries Assistance Commission (1988) *Assistance to Mining: Some Issues and Preliminary Analysis*, AGPS, Canberra.

____ (1989) *Government (Non-tax) Charges Vol 4: Studies - Public Rail Freight, Electricity and Workers Compensation Arrangements*, AGPS, Canberra.

Inter-State Commission (1990), *Road Use Charges and Vehicle Registration: A National Scheme* (Vol. 1), AGPS, Canberra.

Jakeman, A J and Simpson, R W (1987) *Air Quality and Resource Development*, Centre for Resource and Environmental Studies CRES Monograph 16, Australian National University, Canberra.

Joint Coal Board (1989a) *Black Coal in Australia 1987-88, A Statistical Yearbook*, Joint Coal Board, Sydney.

____ (1989b) *New South Wales Coal Yearbook 1988-89*, Joint Coal Board, Sydney.

Lee, S M, Moore, L J and Taylor, B W (1985) *Management Science*, second edition, Allyn and Bacon, Needham Heights.

Murtagh, B A and Saunders, M A (1987) *Minos 5.1 User's Guide*, Stanford University, Stanford.

National Association of Australian Road Authorities (1976a) *A Study of the Economics of Road Vehicle Limits: Transport Operations*, Study Report T2, February 1976, NAASRA.

____ (1976b) *A Study of the Economics of Road Vehicle Limits: Pavements*, Study Report T4, February 1976, NAASRA.

Railway Industry Council (1990), *Rail into the 21st Century*, AGPS, Canberra.

Roads and Traffic Authority New South Wales (1988) *Traffic Volumes and Supplementary Data 1988: Newcastle and Districts (Urban Areas of Hunter Valley Division)*, RTA.

Watanatada, T, Dhareshwar, A M and Rezende Lima, P R S (1987) *Vehicle Speeds and Operating Costs: Models for Road Planning and Management*, John Hopkins University Press, Baltimore.

Table 1 Transport Task Data Inputs to Linear Programming Model — Hunter Valley

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

(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 2 Transport Task Data Inputs to Linear Programming Model — Southern Coalfield

Mine	Tonnes 1988-89[a] ('000)	Transport option	Rail (km) Mainline	Rail (km) Branch line	Road (km) Highway/ arterial	Road (km) Local	Destination Port
Mine 1	400	1A	-	-	54	32	Kembla
	220	1B	56	4	24	12	Balmain
	110	1C	163	4	24	12	Kembla
		1D	81	4	24	12	Kembla
		1E	145	4	24	12	Kembla
Mine 2	240	2A	-	-	54	32	Kembla
	130	2B	56	4	24	12	Balmain
	60	2C	163	4	24	12	Kembla
		2D	81	4	24	12	Kembla
		2E	145	4	24	12	Kembla
Mine 3	360	3A	-	-	54	32	Kembla
	190	3B	56	4	24	12	Balmain
	90	3C	163	4	24	12	Kembla
		3D	81	4	24	12	Kembla
		3E	145	4	24	12	Kembla
Mine 4	130	4A	186	1	-	-	Kembla
	440	4B	122	1	-	-	Kembla
	600	4C	97	1	-	-	Balmain
		4D	68	1	-	-	Kembla
		4E	-	-	66	-	Kembla
Mine 5	400	5A	40	4	-	-	Kembla
		5B	-	-	43	2	Kembla
		5C	54	-	-	-	Balmain
Mine 6	800	6A	27	1	-	-	Kembla
	200	6B	-	-	30	1	Kembla
		6C	74	1	-	-	Balmain
Mine 7	1 120	7A	-	-	42	-	Kembla
		7B	49	-	24	-	Kembla
		7C	143	-	24	-	Balmain
		7D	90	-	24	-	Balmain
Mine 8	1 880	8A	-	-	1[illegible]	2	Kembla
		8B	15	2	-	-	Kembla
		8C	79	2	-	-	Balmain
Mine 9	1 010	9A	-	12	-	-	Kembla
		9B	-	-	10	-	Kembla
		9C	94	12	-	-	Balmain
Mine 10	650	10A	-	10	-	-	Kembla
		10B	-	-	10	-	Kembla
		10C	94	10	-	-	Balmain
Mine 11	190	11A	-	-	14	8	Kembla
		11B	20	-	-	5	Kembla
		11C	114	-	-	5	Balmain

(a) Saleable coal production, rounded to nearest 10 000 tonnes.
Source: BTCE estimates.

Table 3 Cost Data Inputs to the Linear Programming Models

Type	Description	Mainline	Branch line	Highway	Local
Rail	Maintenance ($/km)	9 200	9 200	-	-
	Operating (c/tonne km)[a,b]	4.14	4.14	-	-
	Operating (c/tonne km)[a,c]	6.62	6.62	-	-
	Operating (c/tonne km)[d]	6.35	6.35	-	-
Road[e]	Damage (c/tonne km)	-	-	1.8	7.7
	Accidents - (c/veh km)	-	-	0.5	0.5
	Operating (c/tonne km)[a]	-	-	8.33	8.33
	Operating (c/tonne km)[c]	-	-	9.14	9.14
Reloading	Conveyor or truck to rail ($/tonne)	1.00			

(a) Excludes SRA's rail infrastructure investment costs, estimated to be 2 to 3 c/export tonne or less than 0.1c/tonne km.

(b) Hunter Region

(c) Southern Coalfield

(d) Proposed Maldon-Dombarton line. Includes amortisation of capital cost, but cheaper operating costs than other Southern Coalfield lines. If the capital costs were excluded, the operating cost would be 4.35c/tonne km.

(e) Noise and air pollution costs for road, estimated to be 0.38c/tonne km, are not included in the model.

Source: BTCE estimates.

Table 4 Optimum transport modes — Hunter Valley

Mine	Mode (current mode in *italics*)	Optimal mode and quantity ('000 tonnes)	Social marginal costs cost of transporting by optimal mode 1 tonne of coal	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
Mine 13	*RR13A**	0		$0.00
	RD13B	960	$5.64	$0.00
Mine 14	*RL14A**	0		$0.00
	RD14B	370	$10.51	
Mine 15	*RR15A*	0		$1.00
	RD15B	580	$5.59	
Mine 16	*RL16A**	0		$0.00
	RD16B	750	$4.07	$0.00

* indicates that this is an alternative optimum mode

Table 5 Optimum transport modes — Southern Coalfield

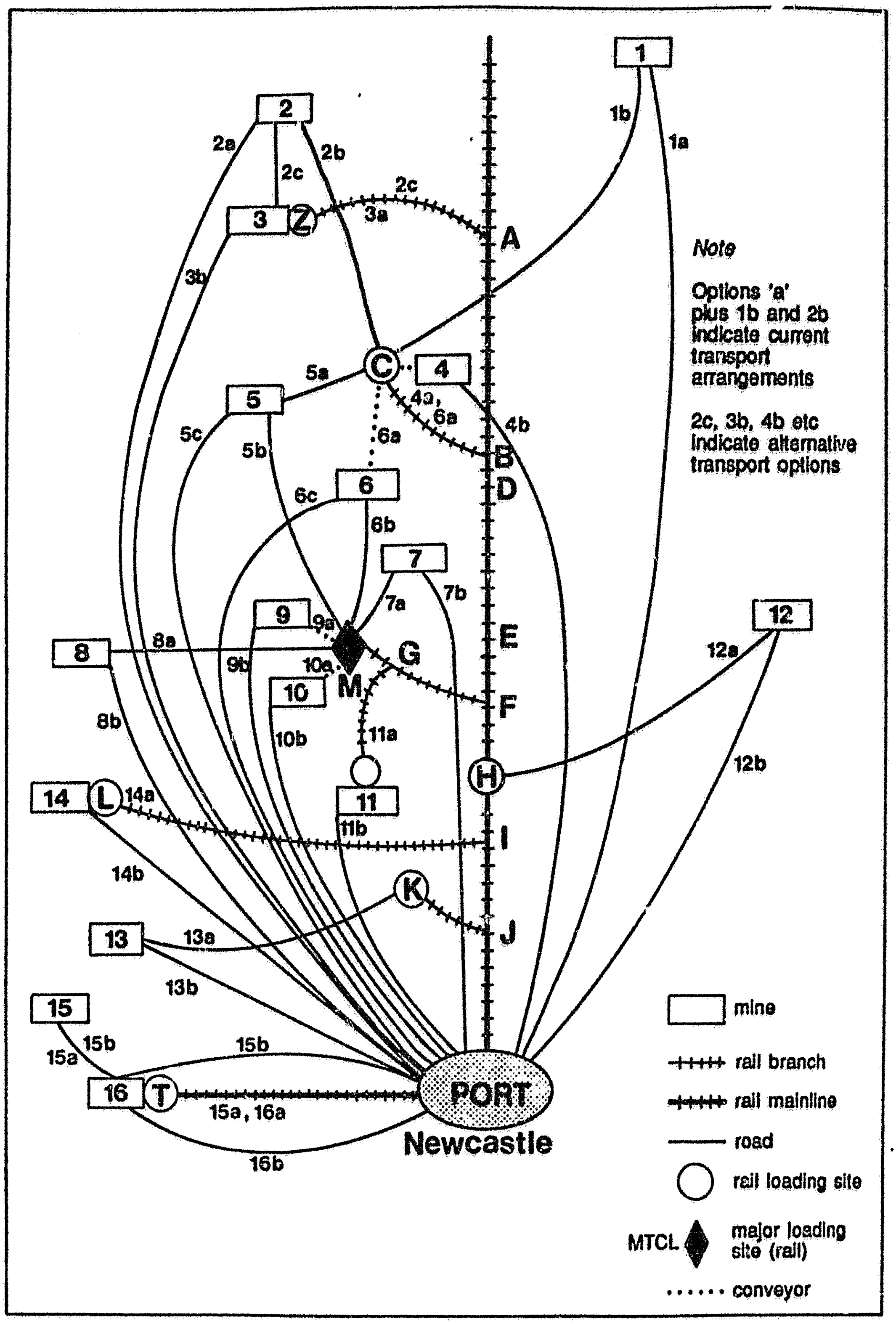
Mine	Mode (current mode in *italics*)	Optimal mode and quantity ('000 tonnes)	Social marginal costs cost of transporting by optimal mode 1 tonne of coal	Opportunity cost of using a sub-optimal mode ($ per tonne)
Mine 1	*RD1A*	0		$2.45
	RR1B	730	$17.05	
	RR1C	0		$14.20
	RR1D	0		$3.10
	RR1E	0		$11.79
Mine 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	1170	$8.92	
	RD4E	0		$4.99
Mine 5	*RL5A*	400	$5.83	
	RD5B	0		$3.75
	RL5C	0		$2.80
Mine 6	*RL6A*	1000	$3.71	
	RD6B	0		$2.87
	RL6C	0		$6.24
Mine 7	*RD7A*	1120	$8.85	
	RR7B	0		$2.51
	RR7C	0		$14.96
	RR7D	0		$16.94
Mine 8	*RD8A*	1880	$3.25	
	RL8B*	0		$0.00
	RL8C	0		$9.42
Mine 9	*RL9A*	0		$0.27
	RD9B	1010	$2.11	
	RD9C	0		$14.03
Mine 10	*RL10A**	0		$0.00
	RD10B	650	$2.11	
	RL10C	0		$13.77
Mine 11	*RD11A*	0		$0.06
	RR11B	190	$4.92	$0.00
	RR11C	0		$17.36

* indicates that this is an alternative optimum mode

Table 6 Optimum transport modes — Southern Coalfield (with no coal loaded at Balmain)

Mine	Mode (current mode in *italics*)	Optimal mode and quantity ('000 tonnes)	Social marginal costs cost of transporting by optimal mode 1 tonne of coal	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
	RL4C	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*	0		$0.00
Mine 9	*RL9A**	0		$0.00
	RD9B	1010	$2.11	
Mine 10	*RL10A**	0		$0.00
	RD10B	650	$2.11	
Mine 11	*RD11A*	0		$0.06
	RR11B	190	$4.92	

* indicates that this is an alternative optimum mode



Note

Options 'a' plus 1b and 2b indicate current transport arrangements

2c, 3b, 4b etc indicate alternative transport options

Figure 1 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 1)

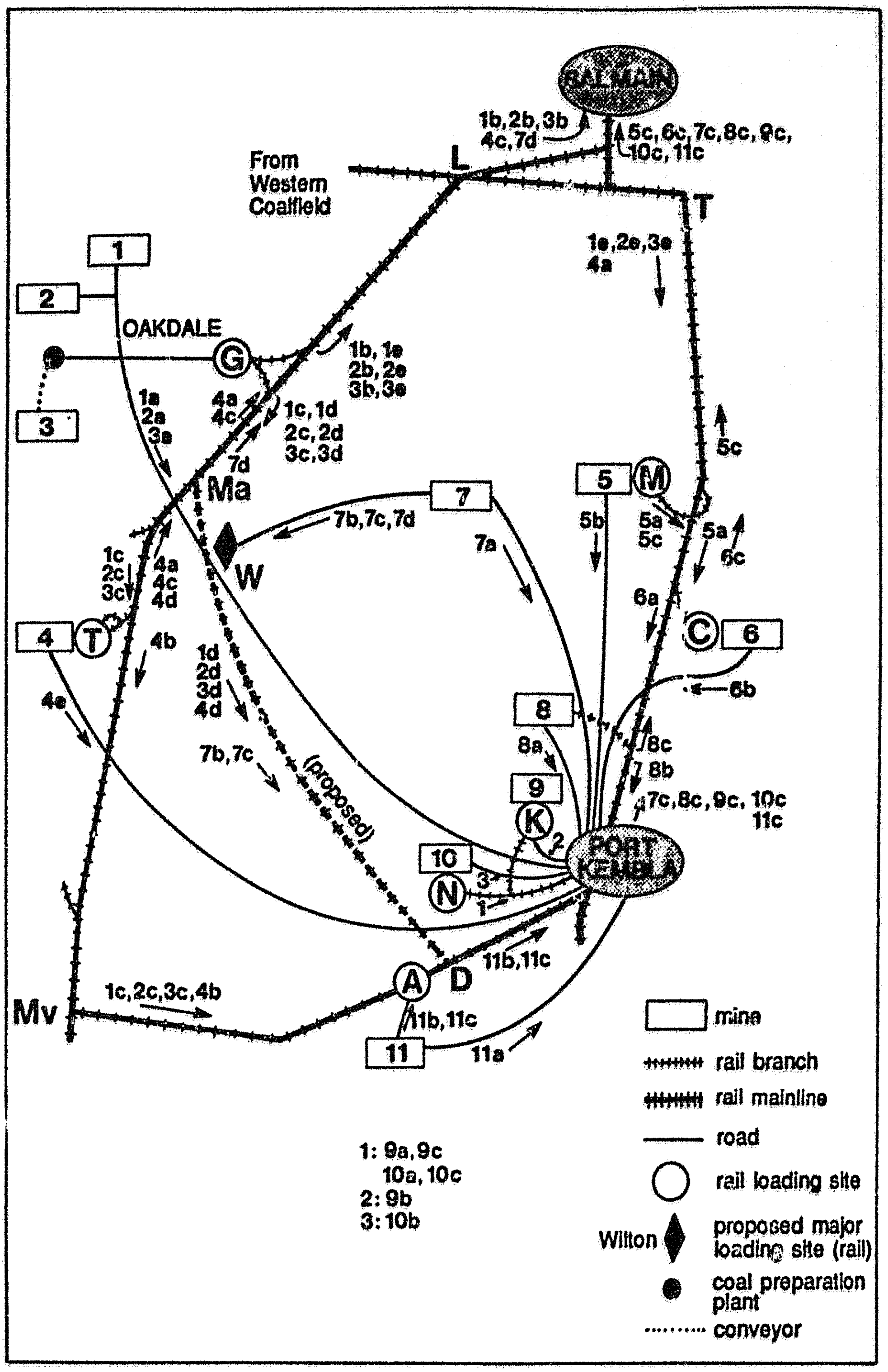


Figure 2 Southern Coalfield transport schematic

SOUTHERN COALFIELD

Mines

1	Brimstone No. 1
2	Oakdale
3	Nattal
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 2)

```
         M M M M M M M M B B B B B B B M R R R R R R R R R R R R R R R R R R R R R R R R R R R R R R R R R R R   R
         N N N N N N N N R R R R R R R N D R D R R L D L D R R D R R D R D R D L D L D L D R D R D L D R D L D   H
         L L L L L L L L L L L L L L L L 1 1 2 2 2 3 3 4 4 5 5 5 6 6 6 7 7 8 8 9 9 1 1 1 1 1 1 1 1 1 1 1 1 1 1   S
         A B D E F H I J Z C M N G L K T A B A B C A B A B A B C A B C A D A B A B 0 0 1 1 2 2 3 3 4 4 5 5 6 6
         B C E F H I J P A B G G F I J P                                           A D A B A B A B A B A B A B
OBJ      C C C C C C C C B B B B B C B C B B B B B B D A B B A B A B B B B B B A B A B A B B B A A A B A A A A ≤ 0
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 3 The linear programming model for the Hunter Region transportation network

	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	RD1A	RR1B	RR1C	RR1D	RR1E	RD2A	RR2B	RR2C	RR2D	RR2E	RD3A	RR3B	RR3C	RR3D	RR3E	RL4A	RL4B	RL4C	RL4D	RD4E	RL5A	RD5B	RL5C	RL6A	RD6B	RL6C	RD7A	RR7B	RR7C	RR7D	RD8A	RL8B	RL8C	RL9A	RD9B	RD9C	RL10A	RD10B	RL10C	RD11A	RR11B	RR11C	ROWTYPE	RHS
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	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	A	D	A	A	A	A	A	A	A	B	B	B	A	A	B	A	A	B	A	A	B	A	A	B		0
RCAPMVTA	-B																													V					V					V				V																										≤	0
RCAPTAMA		-B																												V					V					V			V		V	V																									≤	0
RCAPMAG1			-B																											V	V				V	V				V	V		V		V											V															≤	0
RCAPG1G2				-B																																							V		V											V															≤	0
RCAPG2LI					-B																								V			V		V			V		V			V	V		V											V															≤	0
RCAPLIBA						-B																							V					V					V						V											V															≤	0
RCAPMVWO							-B																							V					V					V				V																										≤	0
RCAPWODO								-B																						V					V					V				V											V																≤	0
RCAPDOPK									-B																					V	V				V	V				V	V			V		V									V														V		≤	0
RCAPTJB										-B																																								V			V							V												≤	0
RCAPLTJ											-B																					V					V					V	V																													≤	0
RCAPTJTE												-B																																						V			V							V												≤	0
RCAPTEME													-B																																					V			V							V												≤	0
RCAPMECC														-B																		V					V					V	V					V					V							V												≤	0
RCAPCCSB															-B																	V					V					V	V					V			V									V												≤	0
RCAPSBPK																-B																V					V					V	V					V			V								V													≤	0
RCAPMAWI																	-B														V					V					V					V										V															≤	0
RCAPWIDO																		-B													V					V					V					V																									≤	0
RCAPGG2																			-A										V			V		V			V		V			V																												≤	0
RCAPGG1																				-A										V	V				V	V				V	V																												≤	0
RCAPTT																					-A																						V	V	V	V																									≤	0
RCAPKK1																						-A																																							V									≤	0
RCAPNK1																							-A																																									V						≤	0
RCAPK1PK																								-A																																					V			V						≤	0
RCAPMM																									-A																							V		V																						≤	0
RCAPCCCC																										-A																									V		V																			≤	0
RCAPSBSB																											-A																																V	V											≤	0
MINE1																												1	1	1	1	1																																						≥	C
MINE2																																	1	1	1	1	1																																	≥	C
MINE3																																						1	1	1	1	1																													≥	C
MINE4																																											1	1	1	1	1																							≥	D
MINE5																																																1	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					-1			-1			-1				-1										≤	0
PORTK																												-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

Figure 4 The linear programming model for the Southern Coalfield transportation network