SOLVING REGIONAL INFRASTRUCTURE BOTTLENECKS: RAIL ALLOCATION POLICIES FOR A COAL TERMINAL

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ABSTRACT: The Dalrymple Bay Coal Terminal (DBCT) in Queensland, Australia is experiencing continuing pressure to increase its throughput as a result of strong demands for coal in the world market. Australia's Commonwealth Scientific and Industrial Research Organisation (CSIRO) has investigated alternative rail allocation policies and evaluated their likely impact on the terminal's throughput and stockpile levels. This paper presents a study using simulation techniques to model the DBCT coal allocation system and the Goonyella rail network. The results show that two of the rail allocation policies can provide significant reduction in stockpile levels, without significantly changing the variability in rail supply.

1. INTRODUCTION

Coal is a vital part of the Australian economy. Coal is currently Australia's top export commodity, with coal exports reaching A$21.8 billion in 2005, accounting for 15.7 percent of the country's total exports (DFAT, 2006). At the same time, Australia was also the world's largest coal exporter, accounting for 29 percent of global coal exports, and possessing nearly 9 percent of the world's total coal reserves (BP, 2006), estimated at 86.5 billion short tons. In addition, more than 70 percent of electricity generated in the country is based on coal. In 2003, for example, Australia had electricity generating capacity equal to 47.1 gigawatts, with around 75 percent produced from coal (Caslon Analytics, 2006).

There is currently a strong growth in world-wide demand for thermal coal. In 2007-08, Australia's thermal coal production is forecast to increase by 1.4 percent to 184 million tonnes. With increased export volumes and higher prices, the value of thermal coal exports is forecast to increase by 8 percent to $7.3 billion (ABARE, 2007).

Unfortunately, the industry's ability to respond to growing global demand for

Australian thermal coal is being hampered by infrastructure capacity constraints. In 2005, the Minerals Council of Australia (MCA) identified port constraints as one of the “hard” infrastructure challenges requiring attention from the government. Port constraints, particularly in the coal sector, were seen as one major cause of delays in the supply chain and reduced access to international markets (MCA, 2005). As a result, the minerals sector is upgrading its production and export infrastructure capacity and management capability while calling on the government to provide matching investment in public infrastructure, especially water, energy, ports and vital rail systems. Some recent additions to infrastructure capacity, together with more expansions planned for the next twelve months, are expected to alleviate the current problems. For example, the port of Newcastle increased its coal handling capacity by 15 percent in 2007 with further additions being planned, including a 33 million tonne-a-year third coal loading terminal scheduled for completion in early 2010. Additional expansions to the existing Kooragang Island terminal are also planned. In Queensland, expansions at the Abbot Point terminal were completed in October 2007 while expansions at the Port of Gladstone and Dalrymple Bay terminals are expected to be completed in early 2008.

Along with infrastructure improvements, management and distribution systems are being upgraded to cope with the increasing complexity of issues arising in the coal supply chain. More ports are adopting a whole of coal chain approach to allocating coal capacity by taking into account rail capacity along with port capacity. These coal allocation systems have been implemented in parts of New South Wales and Queensland to manage the overwhelming demand for coal from the Hunter Valley (New South Wales) and Goonyella (Queensland) supply chains. Without these coal allocation systems in place, it is expected that there would be longer vessel queues at Newcastle and Dalrymple Bay during the course of 2008 (ABARE, 2007).

Maintaining an efficient coal allocation system in a highly-demanding environment requires effective policies in the use of the rail networks. In one project, CSIRO Mathematical and Information Sciences (CMIS) collaborated with the terminal management company at Dalrymple Bay to develop and evaluate alternative policies for delivering coal from the mines of North Queensland to one of the largest and most efficient coal export facilities in Australia. This paper describes how simulation techniques were used to assess the impacts of different train allocation policies on the performance of the Goonyella rail network within the restrictions imposed by the contractual agreements between the different players in the coal supply chain.

1.1 Dalrymple Bay Coal Terminal (DBCT)

The Dalrymple Bay Coal Terminal (DBCT) is a port facility located in Queensland, Australia, which exports metallurgical and thermal coal mined in the Bowen Basin region of Queensland. DBCT's customers include mines owned by some of the world's largest mining companies and there are long term take-or-pay contracts in place. DBCT's capacity is being expanded to 85 Mtpa from approximately 59 Mtpa to meet ongoing customer demand (BBI, 2006).

In an average week, more than one million tonnes of coal arrive at DBCT by rail, from 15 mines throughout the Bowen Basin. The coal is either unloaded into stockpiles or transferred directly onto bulk carriers. The objective at the outset is to load the coal onto ships as quickly as possible. In order to keep the whole supply chain, from mine site to ship, operating at maximum efficiency, it is essential that all sections of the supply chain (mine, rail and port) be synchronised so that the coal coming into the terminal matches the size of ships that are scheduled to dock (Kaye, 2006).

Unfortunately, the restricted rail capacity, coupled with strong demand for coal overseas and production delays at the mines, have combined to stretch out queues at Dalrymple Bay to 47 vessels, compared with a more normal 15-20 vessels per week. A spokesperson for Queensland Rail, the state-owned rail operator that runs the mine-to-port trains for DBCT, said improvements were needed across the supply chain to solve the problem of port bottlenecks (Trounson, 2007). As a result, CMIS has partnered with DBCT to develop a mathematical model and provide decision support tools to address DBCT's resource allocation problems and various other issues in terminal operations and management (Ernst et al., 2006). In this paper, CMIS conducts a study to investigate the implementation of a train-user allocation policy that would help reduce the port bottlenecks and continue to be fair from the stakeholders' point of view. This paper presents the results of the study and discusses the performance implications of the policies for DBCT.

1.2 DBCT Supply Chain

Supply chains are complex systems involving various stakeholders, numerous activities and large numbers of capital intensive resources to be managed over time. The coal supply chain in this study consists of the terminal operator (DBCT), terminal users, coal mines, the railing system, overseas purchasers and shipping companies. Figure 1 shows the principal players in the DBCT coal supply chain.

The coal terminal, DBCT, is a co-investment facility operated by an independent management company (DBCT Pty Ltd) for and on behalf of six mining companies and the Queensland state government. The terminal users are the mining companies that own the mines and manage the mining, production and exporting of a limited variety of coal products. Overseas purchasers generally enter into a contract with one or more of the terminal users to buy coal. Based on the amount of their investment, each terminal user gets a fair allocation (called terminal entitlement) of the terminal's throughput capacity. However, the terminal's capacity changes depending on the demand for coal products and the mix of mines to be served. Furthermore, the terminal entitlements are calculated on a monthly basis so the users engage in the trading of entitlements when they are unable to fully exploit their entitlement for any given month.

All mines are connected to the coal terminal via a rail network. The terminal users also receive railing entitlements to transport their coal products by rail to the coal terminal. The rail network is managed by Queensland Rail (QR) and provides the essential means of transporting coal in the region. QR currently supplies 8 or 9 trains for the DBCT operations. Each of these trains carry approximately 3.5 million tonnes per annum (MTPA). All trains have a capacity of 7350 to 8000 tonnes, with a cycle time of approximately 19 hours, depending on the travel distance to and from the mine (Ernst et al., 1997).

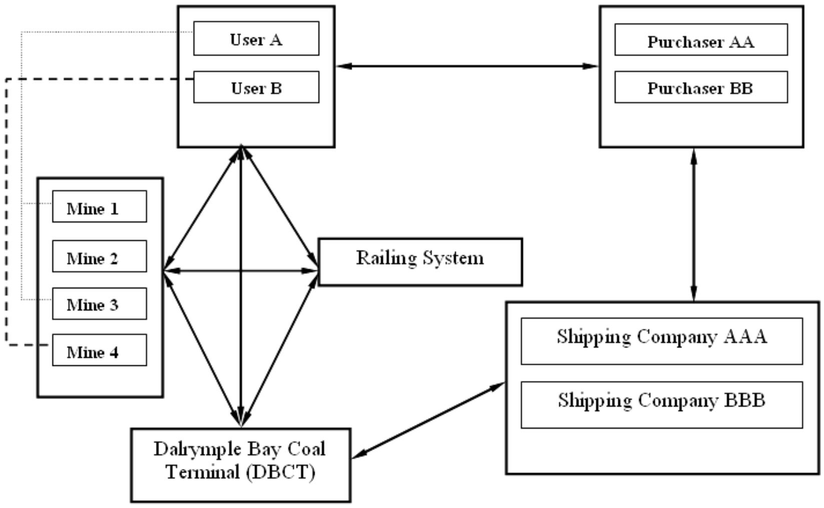

Figure 1. Components of the DBCT Coal Supply Chain

Aside from the DBCT terminal users, the rail network is also used by other terminals and mines in the region but there are no passenger trains in this system. The challenge for terminal users is to find ways to cope with fluctuations in demands for their coal products while having fixed terminal and rail entitlements over extended periods of time.

1.3 Transporting Coal

Figure 2 illustrates the process of transporting coal to DBCT. The DBCT users place orders for railing 12 days in advance in terms of consists, a group of railway wagons and engines. Consists are referred to as trains as soon as they are allocated to specific jobs. The job specifies the mine, product type and date and time for loading the coal. The trains are scheduled by Queensland Rail 48 hours in advance. Care must be taken in the scheduling to avoid train bunching and stockyard conflicts at the coal terminal.

A scheduled train waits at the main depot at Jilalan then travels to its assigned mine where it is loaded with coal. The train then leaves for DBCT where it waits to unload coal via one of two inloaders, a conveyor facility for transferring coal to the terminal. The inloaders share an access rail segment where trains queue until one of the inloaders becomes available. The inloaders work in parallel so two trains can be served at a time. After unloading, each train is sent back to the train depot to await its next assignment.

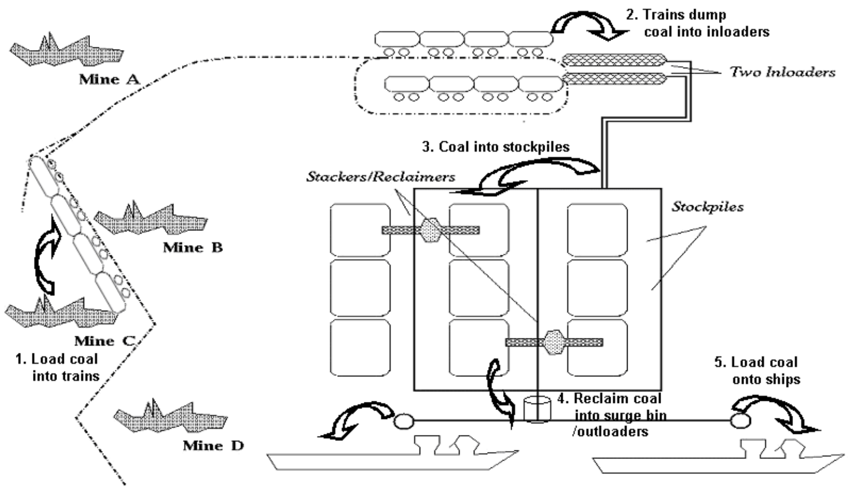

Figure 2. Transporting Coal from Mine to Ships

Inloaders transfer coal to the stockyard using a network of conveyor belts and machines. Each terminal user has a set of designated stockpiles in the stockyard. On a ship's arrival, coal is reclaimed by machines from stockpiles and sent to outloaders via conveyors and eventually to the waiting ship.

Details of the mathematical formulation and simulation program used to model DBCT's terminal operations are outside the scope of this paper. However, flow charts are presented in the Appendix that illustrate how the coal transportation processes were modelled.

2. RAIL ALLOCATION POLICIES

The process of allocating trains to users is based on users' entitlements, constraints in mine operation and train scheduling, limits on product stockpiles at the terminal, and the availability of ships to carry the orders. Historically, DBCT used an open policy of allocating trains in proportion to users' entitlements. Users are allowed to trade in current allocations for other resources or future allocations. Thus, entitlements may be exceeded, at the expense of other users, over short periods of time, but the long-term objective is to achieve each user's entitlement. There are two general conditions that may prevent the allocation of a consist to a user.

The user is said to be *stockpile bound* if there is not enough room on any of the user's product stockpiles to take the train payload.

The user is said to be mine bound if allocating the consist to the mine associated with the ordered product would violate a minimum inter-train arrival time at the mine.

The following sections describe three proposed policies for allocating railing resources to users. The three policies are referred to as "railing to entitlement", "railing to shipping" and "campaign railing".

2.1 Railing to Entitlement

Railing to entitlement represents the operating policy where users receive trains based solely on their railing entitlement, expressed as a percentage of the total trains dispatched from DBCT. This policy is just a more restrictive version of the traditional practice.

Trains are allocated to users based on the following guidelines:

- Users can only receive a train if they have sufficient stockpile capacity at DBCT to store the type of coal product to be railed.
- The inter-train arrival times and maximum train size are set for each mine and limit the size of the consist that a user receives. This is a significant factor in determining the railing capacity at the mine.
- Among all the users that are able to receive a train, priority is given to the user with the lowest percentage of achievement against entitlement (also referred to as entitlement ranking).

The diagram in Figure 3 illustrates the procedure used to assign a consist to a user based on entitlement. The procedure is summarised as follows:

- Initially, all users are considered to have stockpiles and mines available.
- The current performance against entitlement for each user who is not stockpile or mine bound is calculated using the following equation:

$$R = (T / D) - U \qquad (1)$$

  where R is the entitlement ranking, T is the number of trains received by the user, D is the total number of trains dispatched, and U is the user entitlement.
- The consist is allocated to the user with the lowest ranking. For example, from Equation 1, if user A, with entitlement 30 percent, has received 98 of 300 trains allocated to date, then user A's ranking is 0.027 (98/300 - 0.30). Similarly if user B, with entitlement 10 percent, has received 25 of the 300 trains, then user B's ranking is -0.017 (25/300 - 0.1). In this case, the consist would be allocated to user B.
- Once a user is selected, the stockpile for that user is checked. If the stockpile level is at or above capacity for the user, then this user is marked as stockpile bound and the next ranked user is selected from step 2. Otherwise, we proceed with step 4. Once marked as stockpile bound, the user is excluded from consideration until the next consist is to be dispatched.
- A mine is chosen for the user. If a mine is able to provide the product for the user, then the user and mine are assigned to the consist and the train is sent to the mine. This ends the procedure. If the mine is unavailable, then the user is marked as being mine bound and excluded from consideration. Return to step 2 to select another user.
- If all users are either stockpile or mine bound then we wait for 60 minutes and then return to step 1 above. That is, after 60 minutes we mark all users as having both mines and stockpiles available and repeat the above steps to try and find a new user and mine for the consist.

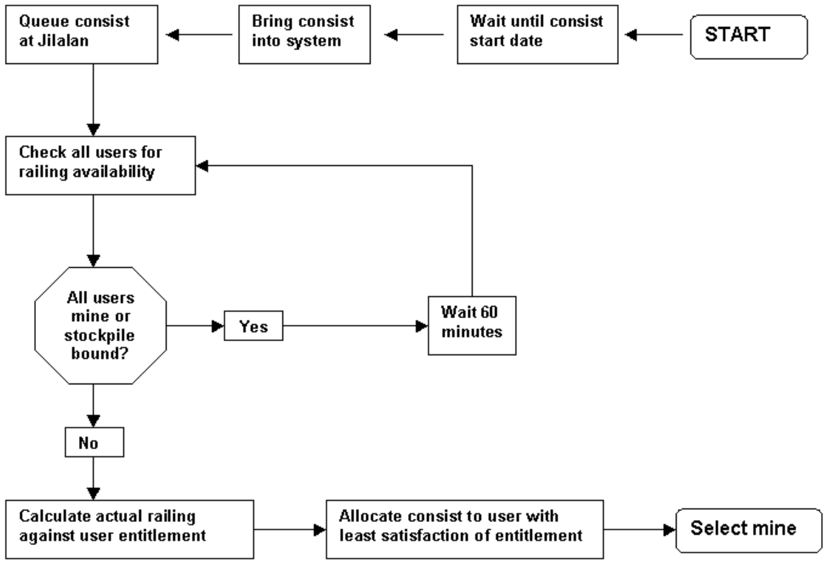

Figure 3. Allocation of Railing based on Entitlement

2.2 Railing to Shipping

The railing to shipping policy essentially prohibits users from building up their stockpile of products beyond what is actually needed for shipping. In this policy, coal can only be railed when there is a ship scheduled to load the coal within the rail allocation window, currently set at 12 days.

The allocation of consists to users and mines follows essentially the same procedure as railing to entitlement with the exception of step 1. This step is modified with eligible users limited only to those that require coal to be loaded onto ships immediately (within the next 12 days). The coal requirement is calculated as in Equation 2:

$$C = P - S - E \qquad (2)$$

where C is the amount of coal required, P is the sum of all user parcels to be loaded in the next 12 days, S is the user stockpile level, and E is the quantity of coal en route.

Here the coal en route refers to the amount scheduled to arrive on all trains already dispatched by the system. If the coal required is positive, the user is considered for the allocation of the consist, otherwise the user is ignored. The choice among the eligible users is again based on the entitlement ranking given in Equation 1.

The result of this policy is that users receive trains according to their entitlements but are not allowed to build up stockpiles at DBCT beyond what they require for their immediate shipping needs.

2.3 Campaign Railing

The campaign railing policy allows the allocation to be driven purely by the shipping requirements.

Only coal that is required for shipping in the next 12 days may be railed to DBCT and trains are allocated using a First-Come-First-Serve rule based on the ship loading sequence. The campaign railing policy closely resembles the railing to shipping policy except that the choice of user is made without reference to entitlement. In particular, step 1 of the procedure is replaced by:

- For each user that has a positive coal requirement, as given by Equation 2, select the user that is not stockpile or mine bound with the earliest ship arrival date. For example, if a user has an 80,000-tonne stockpile limit at DBCT and expects two 50,000 tonne ships arriving in the 12 day window, then this user will be stockpile bound with the arrival of the second ship. For ships with multiple users, the order is determined by the order of parcels on the ship (For the purposes of this study, each user has only one parcel per ship).

This policy determines rail priorities solely by shipping requirements thus preventing users from stockpiling coal at DBCT beyond their immediate shipping needs. In principle, this dispatch rule may lead to a large number of consecutive trains being sent to the same user. However, the enforcement of minimum inter-train arrival times at the mines prevents this from happening, ensuring that different mines (and hence different users) are generally selected for consecutive consists. In addition, only enough trains for a single shipment are sent to a user, after which a different user receives usually the highest priority since consecutive shipments tend to be for different users.

Since only products that are to be shipped in the next 12 days can be brought to DBCT, longer term storage must occur at the mines. With less coal stored at the terminal, there will be greater stockpile capacity available at DBCT resulting in less stockpile-bound users.

3. POLICY SCENARIOS

3.1 Simulation Scenarios

Simulation scenarios were created whereby each of the three policies where applied to a common set of demand, supply and entitlement data. The scenario implementing the rail to entitlement policy will be referred to as the entitlement scenario. Similarly, shipping scenario and campaign scenario were used to refer to the implementation of the rail to shipping and campaign railing policies, respectively.

The simulation runs were performed using the Terminal Operations Model (TOM) developed by CMIS for DBCT (Ernst et al., 2000). TOM was run under the Arena/Siman package using historical data for the simulation period 30 June 1998 to 7 April 2000, although only the period July 1998 to March 2000 inclusive was considered for reporting. For a detailed discussion of the simulation parameters, please refer to Ernst et al. (2000).

For the purpose of simulation, ship loading was assumed to occur unchanged irrespective of the railing activity. In other words, it was assumed that the ship arrival sequence, berth times and loading times occurred as given by the historical data. As a consequence, no direct measurement can be made of the effect of the railing policies on dispatch and demurrage. To do so would have required detailed modelling of the berthing process and stockyard operations which were beyond the scope of this study.

Once a train has been allocated to a particular user, priority is given to products required for shipping in the next 12 days. However any product for which there is stockpile and mine availability is considered. The mine from which the product is to be sourced, where there are multiple mines for a product, is determined randomly based on the historical distribution of trains for that product. Mines are assumed to have sufficient coal available whenever a train is allocated to them.

3.2 Performance Measures

For each scenario, five performance measures were created to analyse the impacts of the policies. The first three measure the effects on the rail system while the last two indicate effects on stockpile levels. The five measures calculated based on the final 12 months of the simulation horizon, are described as follows:

- ***Trains per week:*** The average number of trains arriving at the terminal per week.
- ***Min-max trains per week:*** The minimum and maximum of weekly train numbers. This gives one measure of the variability in railing requirements.
- ***Rail top-up variability:*** The rail top-up variability provides a measure of the difficulty in scheduling trains by looking at the variability in additional weekly trains required to supplement typical weekly numbers. It considers the number of additional trains that are required each week for a user over and above a baseline that might be satisfied by a typical train schedule. For the purposes of this performance measure, the number of trains allocated to nine of the mines in a 'typical' or baseline schedule is given in Table 1. DBCT’s standard three letter codes are used to identify the mines.

  The number of trains in each week above this baseline is aggregated over all users. The top-up variability is then defined as the standard deviation of this excess number of trains as a percentage of the total average scheduled number of trains (74 from Table 1). For example, if BAC was allocated 25 trains in one week, it would contribute 25 to the total for that week. However if it only required 18 in the next week, then BAC would still be credited with 23 (from Table 1) for the purpose of calculating the top-up variability. The top-up numbers for BAC would then be 2 in the first week and 0 in the second week.
- ***Stockpile average:*** The average tonnage stored in the stockpiles at

the coal terminal.

- ***Stockpile standard deviation:*** The standard deviation of the stockpile levels at the terminal.

Table 1. Typical weekly schedule of trains to users

User*	BAC	BCP	CCP	FOX	GMK	MBN	NGY	OCJ	RSD
Trains per week	23	8	3	1	9	8	6	10	6

Notes: *User mines: BAC = Blair Athol, BCP = Burton Downs, CCP = Coppabela Coal, FOX = Foxleigh, GMK = German Creek, MBN =Moranbah North, NGY = North Goonyella, OCJ = Oaky Creek, RSD = Riverside

4. DISCUSSION OF RESULTS

Table 2 provides a comparison of the three policies against historical data using the above performance measures.

Table 2. Comparative performance of policies versus historical data.

Measure	Train Allocation Policies			Historical Data
	Rail to Entitlement	Rail to Shipping	Campaign Railing	
Trains per week	76.00	75.77	75.66	75.70
Min-Max Train/Week	49 - 96	37 – 97	58 - 98	42 – 94
Rail Top-up Variability	10.66%	11.95%	9.58%	8.55%
Stockpile Tonnage: Average Standard Deviation	 1,301,044 111,738	 847,932 143,487	 898,762 165,860	 1,351,334 259,929

Table 2 shows that all three policies produced similar average weekly train numbers, as well as maximum train numbers, as those from historical data. However, the three scenarios showed significantly higher rail top-up variability over historical data. This means that although the weekly number of trains allocated may be the same (around 76), the three policies had more variable numbers above the weekly average indicating a greater flexibility to respond to excess rail requirements. This flexibility is supported by data showing that the three policies have significantly lower stockpile levels and stockpile variability than historical data.

The shipping and campaign scenarios showed reductions in average stockpile level of 33 percent or more, and reductions in stockpile variability of 36 percent or more as compared to historical data. Although the entitlement scenario showed the lowest stockpile variability, its stockpile levels were the same as historical data, and 30 percent more than those of the shipping and campaign scenarios. This implies that the shipping and campaign scenarios provide flexible and responsive rail allocation policies that meet weekly rail demand and result in significantly lower stockpile levels at DBCT.

From historical data, the variability in outloading was found to be 23.39 percent, as calculated from the standard deviation over the mean of the weekly number of tonnes shipped. This compares favourably with the variation in inloading of 14-17 percent for the three scenarios (computed similarly as the standard deviation over the mean of the weekly number of tonnes unloaded). Hence the terminal stockpiles provide significant smoothing of the weekly throughput variability with most of the rail variability being directly attributable to fluctuations in the shipping requirements.

Figure 4 presents a comparison of the monthly train allocations under the three scenarios against those historically achieved. The curves follow a cyclical pattern where the minimum and maximum points generally occur in the same month every year. The graph shows the curves for the shipping and campaign scenarios behaving closely to each other, except for Dec 99-Jan 00, where the campaign scenario was significantly lower, and Feb 00 when campaign scenario was higher.

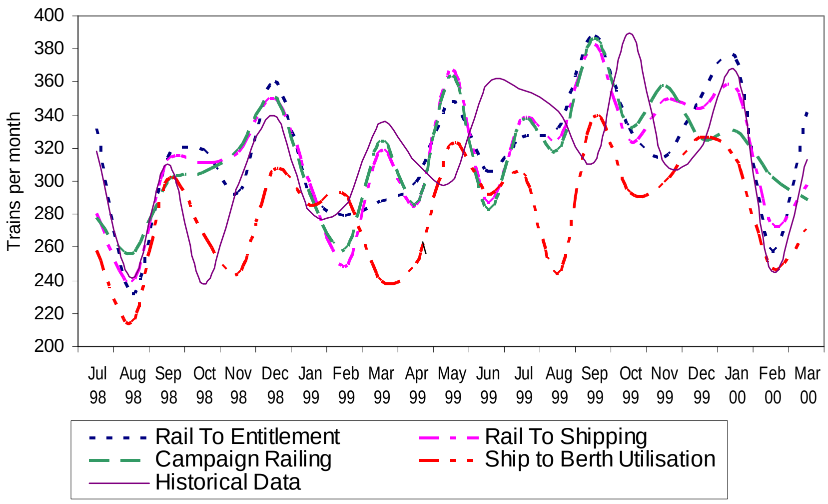

Figure 4. Comparison of Monthly Train Numbers

The entitlement curve generally follows the peaks and troughs of the shipping and campaign curves with the shipping values usually falling between the entitlement and campaign values. This comes as no surprise since the shipping policy basically represents a compromise between the extremes of allocating railing based solely on entitlement (entitlement scenario) and solely on shipping demand (campaign scenario). The historical pattern shows a similar cyclical pattern as the simulation results although shifted backward slightly by a month.

For Oct 98, Feb 99, Jun 99, and Jan 00, one can clearly see how railing to entitlement anticipates future demand. These points show more trains being allocated than required in one month (when entitlement value is significantly higher than the campaign value) to build the coal stockpiles and then have less trains than required in the next month (when entitlement value is significantly less than the campaign value) to use up the stockpile.

4.1 Variants of the Scenarios

To gain a better understanding of the impacts of the policies, two variants of the original simulation were performed. The first variant examined the effect of increasing the rail allocation window from 12 days to 15 days while the second fixed the number and capacity of consists used.

The results of the first variant are shown in Table 3. With an additional three days in the rail allocation window, more ships will be included in the time window and therefore more coal were expected to be stockpiled at the terminal. This is confirmed by the significant increase in average stockpile levels for the three scenarios, as compared to those in Table 2. The average stockpile level for the entitlement scenario was up by 9 percent, 34 percent for the shipping scenario, and 25 percent for the campaign scenario. Compared with the stockpile levels from historical data, the entitlement scenario was now 5 percent higher, as opposed to just level in the 12-day case. Similarly, the shipping and campaign scenarios were now only 15 and 11 percent lower respectively for the 15-day window, as compared to 30 percent lower in the 12-day window.

Table 3. Performance when rail window is increased to 15 days

Measure	Train Allocation Policies		
	Rail to Entitlement	Rail to Shipping	Campaign Railing
Trains per week	75.75	75.55	75.42
Min-Max Train/Week	40 – 97	33 - 100	37 - 99
Rail Top-up Variability	11.22%	11.00%	11.54%
Stockpile Tonnage: Average Standard Deviation	 1,418,542 130,035	 1,141,605 153,536	 1,201,818 140,532

The same weekly average number of trains were being allocated but with greater variability (higher maximum and lower minimum). The top-up variability was also higher. This implies that in order to reduce variability in the train numbers, it is desirable to reduce the rail window as much as possible. This would lead to 'just in time (JIT) railing' where trains with coal earmarked for a particular ship are scheduled as late as possible. The disadvantage of the JIT policy is that there is a higher risk of having to delay ships if there is a breakdown or delay to railing. Thus, a balance needs to be struck between efficiency and reliability.

The second variation limited the number of available consists at Jilalan to 16 with each consist having a uniform capacity of 8200 tonnes each. In addition, the same minimum inter-train arrival time of 60 minutes was applied to all mines. The results showed a slight reduction in top up variability by 2.5 percent for the shipping scenario and approximately 1 percent for the other two. These small reductions imply that the majority of the variability in rail numbers is attributable to the variability in the ship arrival stream.

4.2 Effects on Mines

Table 4 shows the impact of the scenarios on the weekly train numbers assigned to the mines. For each mine and scenario, the number of trains arriving from the mine at DBCT per week is analysed. The table contains the average weekly train assignments (Avg), the standard deviation (SD) and maximum value (Max) of weekly train assignments. As in Table 1, DBCT's standard three letter codes are used to identify the mines.

Table 4. Impact of scenarios on weekly number of trains from mines.

Mine	**Train Allocation Policies**									**Historical Data**		
	Rail to Entitlement			**Rail to Shipping**			**Campaign Railing**					
	Avg	**SD**	**Max**	**Avg**	**SD**	**Max**	**Avg**	**SD**	**Max**	**Avg**	**SD**	**Max**
BAC	23.7	6.9	35	23.7	8.2	36	23.8	7.6	36	23.8	5.2	33
BCP	9.4	4.0	18	9.5	4.7	19	9.7	4.5	18	9.3	3.5	18
CCP	4.7	3.4	15	4.5	3.7	15	4.5	3.6	16	4.4	1.7	8
FOX	0.3	1.2	7	0.3	1.4	7	0.3	1.3	7	0.3	1.1	5
GMK	10.6	3.8	18	10.6	4.1	18	10.7	4.0	18	10.5	3.7	17
GNY	1.3	1.3	6	1.3	1.3	5	1.5	1.4	6	0.2	0.6	3
GRS	0.3	0.6	2	0.2	0.5	2	0.2	0.4	1	0.1	0.4	3
KES	0.2	0.5	2	0.2	0.5	3	0.2	0.4	2	0.1	0.5	3
MBN	7.9	3.6	16	7.7	4.0	17	7.8	3.6	15	6.9	3.7	14
NGY	3.5	2.2	9	3.8	2.8	11	3.8	2.4	9	3.8	2.4	8
NPK	0.1	0.3	1	0.1	0.3	2	0.1	0.3	1	0.0	0.0	0
OCJ	11.6	3.7	19	11.5	4.3	20	11.1	4.3	19	12.9	3.9	25
PDN	0.3	0.5	2	0.2	0.5	2	0.2	0.5	2	0.0	0.0	0
RSD	1.9	1.7	5	2.0	2.2	8	1.9	1.8	6	2.5	2.6	10
SWC	0.1	0.2	1	0.1	0.3	2	0.0	0.1	1	0.8	2.0	8

Notes:
1) BAC = Blair Athol, BCP = Burton Downs, CCP = Coppabela Coal, FOX = Foxleigh, GMK = German Creek, GNY = Goonyella, GRS = Gordonstone, KES = Kestrel, MBN =Moranbah North, NGY = North Goonyella, NPK = North Park, OCJ = Oaky Creek, PDN = Peak Downs, RSD = Riverside, SWC = South Water Creek.
2) Avg = average weekly train assignments, SD = standard deviation of weekly train assignments, MAX = maximum of weekly train assignments.

Compared with historical data, the policies generally had minimal impact on the train numbers assigned to the mines with the notable exception of Oaky Creek (OCJ), Goonyella (GNY), South Walker Creek (SWC) and Riverside (RSD). GNY showed a significant increase in average weekly train assignments while OCJ, RSD and SWC had a notable decrease. There was increased variability for Blair Athol (BAC), Coppabella (CCP), and GNY, while the standard deviation for RSD and SWC decreased. The scenarios increased the maximum train numbers for Foxleigh (FOX) and CCP but decreased those for OCJ, RSD and SWC.

5. CONCLUSION

Three rail allocation policies have been evaluated using scenarios that implement the policies on rail demand provided by historical data. Simulation results show that two policies, railing to shipping and campaign railing, produce a significant reduction in average stockpile levels when compared with the third policy, railing to entitlement, and historical data. Although much of the variability in train numbers can be traced to the ship arrival stream, the railing to shipping policy and campaign railing policy offered the most consistent yet flexible option for meeting excess train requirements and minimizing the instances of stockpile bound users. All three policies appear to have minimal impact on the consists supplied by Queensland Rail, as shown by the same total weekly train numbers produced with historical data. With respect to individual mines, the policies had significant impacts only for Oaky Creek (OCJ), Goonyella (GNY), South Walker Creek (SWC) and Riverside (RSD). Overall, railing to shipping appears to offer the flexibility required by the users, meet the pattern of efficiency sought by the coal terminal and maintain the level of stability accepted by the mines.

If the railing to shipping policy is to be adopted, it is recommended that close attention be paid to the length of the rail allocation window to minimise the risk of having insufficient stock at the port when the ships are ready to berth and ensure that users with small entitlements can meet large shipments. The allocation window for railing may be allowed to vary depending on the entitlement of the user or the size of the scheduled shipment. Another option is to allow users to maintain some minimum stock levels at the coal terminal even when they have no immediate shipment planned. This would provide a safety buffer to guard against unexpected breakdowns and delays.

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APPENDIX: ADDITIONAL FLOWCHARTS FROM THE TERMINAL OPERATIONS MODEL

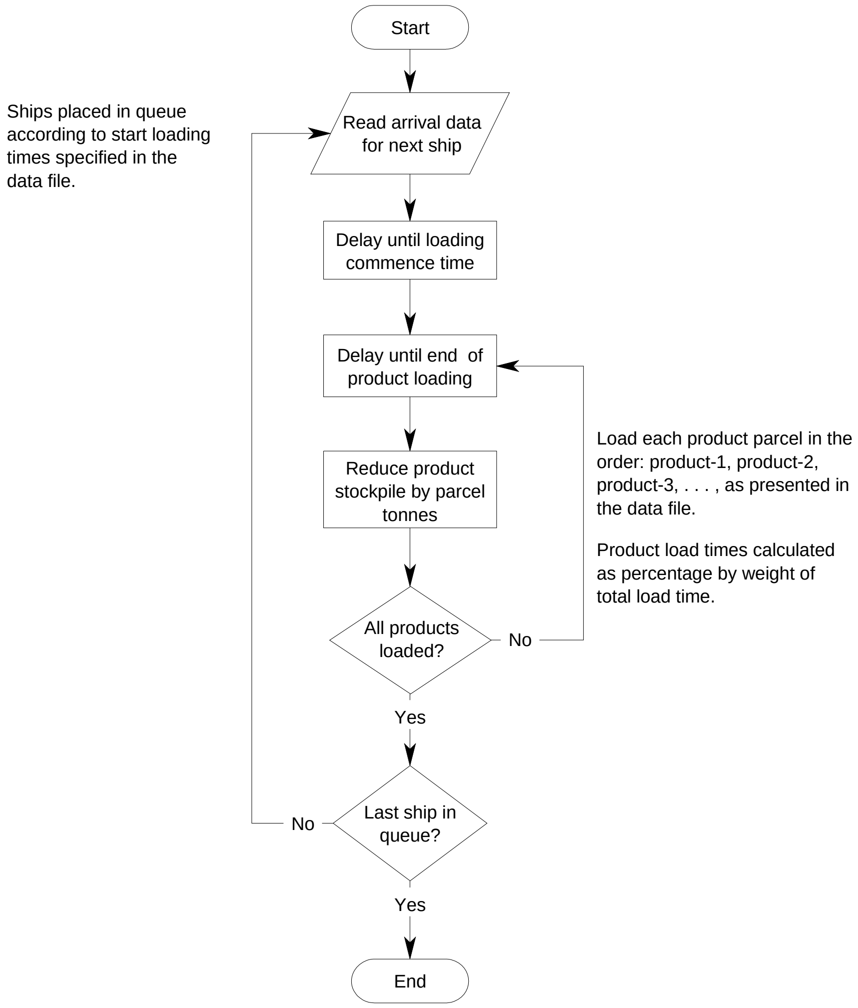

Figure A1. Flowchart for loading ships

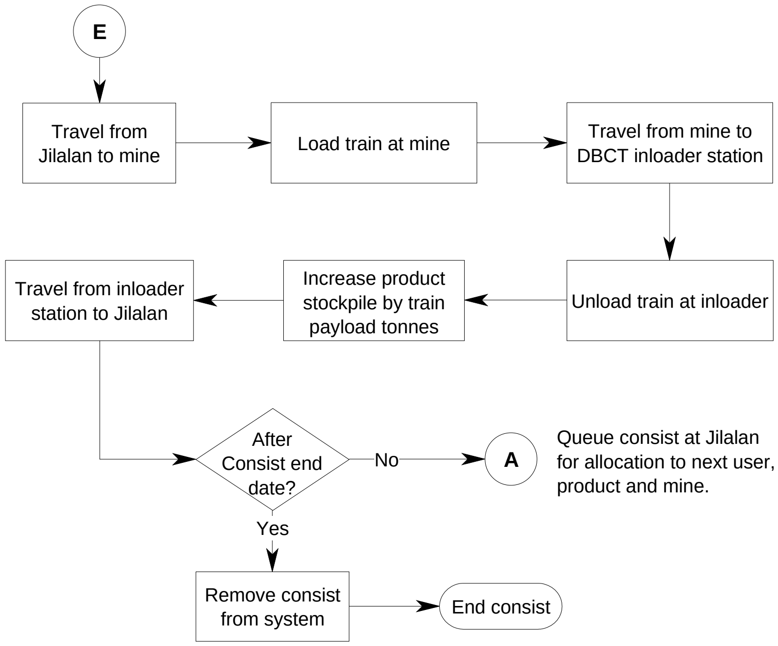

Figure A2. Flowchart for sending a train to a mine

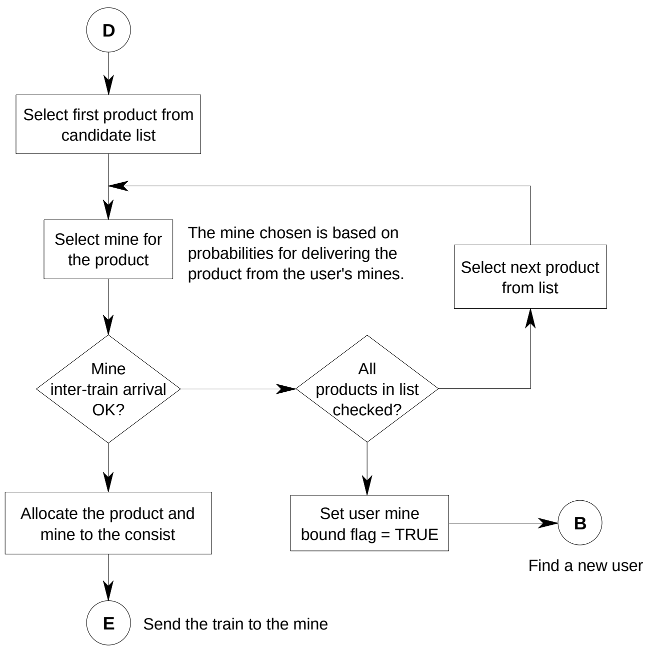

Figure A3. Flowchart for allocating a mine to a consist