ECONOMIES OF THROUGHPUT AND PEAK TRANSPORT COSTS IN THE GRAIN DISTRIBUTION SYSTEM*

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The Royal Commission into Grain Handling and Storage (RCGH) calculated that potential cost savings from deregulating the grain distribution system could be as high as $10/t (RCGH 1988). These potential savings were estimated using mathematical programming transport models, based on assumptions about the nature of handling costs at country receival points, and truck queuing costs. These models predicted that there would be an increased use of road transport in a deregulated system (currently restricted), with grain being carted greater distances from the farm to the receival point. Savings from increasing the level of centralisation (having fewer receival points) include the use of cheaper (higher throughput) receival points and subterminals, as well as the avoidance of high rail costs on branch lines.

However, these studies have focused on the spatial aspects of the grain handling system, and have failed to account for temporal aspects. As road deliveries to a site increase, there is more likelihood of truck queues forming, resulting in idle time costs. The peak load problem also limits the extent to which economies of throughput can be achieved (because it limits the amount of grain that can be railed out in the peak period), and this has not been dealt with adequately in some models. Moreover, the peak load problem on rail transport implies that efforts to increase the amount of grain railed in the peak period, by lengthening the peak period, or by reallocating rail capacity to sites where faster turnaround times can be achieved, will reduce the costs of grain handling and transport.

In this paper, the peak load problem and how it affects the nature of grain transport and handling costs, and the potential savings from centralisation, are discussed. The benefits of reducing the peak load problem by extending the receival period are also examined. Deferred delivery policies might provide a means of overcoming some of the congestion and capacity shortage problems that may result if future freight rates do otherwise favour centralisation.

The Peak Load Problem and the Shape of Transport Cost Curves

The congestion arising from increases in road deliveries can result in increased queuing costs. Kerin (1985) provided empirical evidence on the exponential nature of queuing costs at grain receival points, and found that they greatly reduced the benefits of centralisation when included in a transport model. However, his results are inconclusive because of limitations in the model he used (in particular, he used rail freight rates which bear little resemblance to rail costs, masking the high cost of using branch lines). Most other studies (eg. RCGH) include a constant queuing cost which is independent of the quantity of grain being delivered to a site, which defeats the purpose of accounting for a congestion cost.

This study also compares the effect of queuing costs on the optimal level of centralisation.

The Peak Load Problem and the Shape of Grain Handling Cost Curves

By failing to account for the peak load problem, past studies treat the observed shape of the grain handling cost curve as an efficient, immutable cost curve. A closer examination of the grain handling process reveals that the costs of country storage depend on the combination of transport and storage that is used at a site.

The cheapest method of handling the grain is to transfer it directly onto rail. Grain that is stored at the site undergoes a double handling cost, as it must be put into storage, and then transferred onto rail in the clearance period. The difference between the cost of storing and direct railing depends specifically on the type of storage technology used. For simplicity, technology can be categorized into three groups. Railing grain directly during the receival period has the lowest handling cost, storing grain in permanent storage facilities has an intermediate handling cost, whereas storing grain in temporary (bunker) storage at a site involves high costs. There is also a fixed cost of opening a site, which is independent of whether the grain is railed directly or stored at the site.

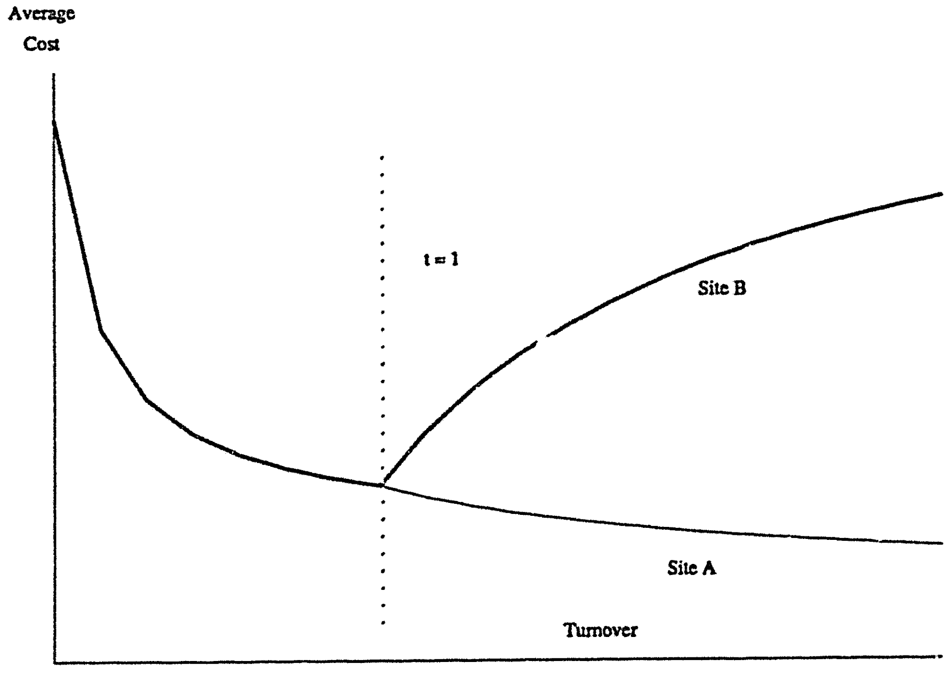


Figure 1: The Shape of Handling Costs

The allocation of scarce rail capacity in the peak period has an important effect on the shape of grain handling costs. This is illustrated in figure 1, which depicts the alternative shapes of average handling costs, expressed as a function of turnover of permanent storage capacity, for two sites which differ only in that railing grain out during the receival period is possible at site A, but not at site B. For site A, the use of rail-out allows average costs to decline when receivals exceed storage capacity (ie. turnover >1). This is because the fixed opening cost is spread over a higher throughput, and because railing of grain has lower marginal costs. Site B, which must use high cost temporary storage when permanent capacity runs out, has an upward sloping average cost curve where turnover exceeds one.

There are a number of implications. First, the estimation of grain handling cost functions (eg. Piggot and Coelli, 1988) which do not distinguish between "rail out" and other sites are mis-specified and represent a snapshot of a series of sites, whose costs are predetermined by the allocation of rail between sites. This is shown in figure 2. The optimal turnover level determined by these estimation procedures are meaningless unless considered in conjunction with peak constraints on rail capacity. Further, observed costs used in statistical estimation are based on current rail out programs, but it is possible that a reallocation of rail to sites where it can be used more productively (faster turn around time) may result in efficiency gains that cannot be represented in statistically estimated cost curves.

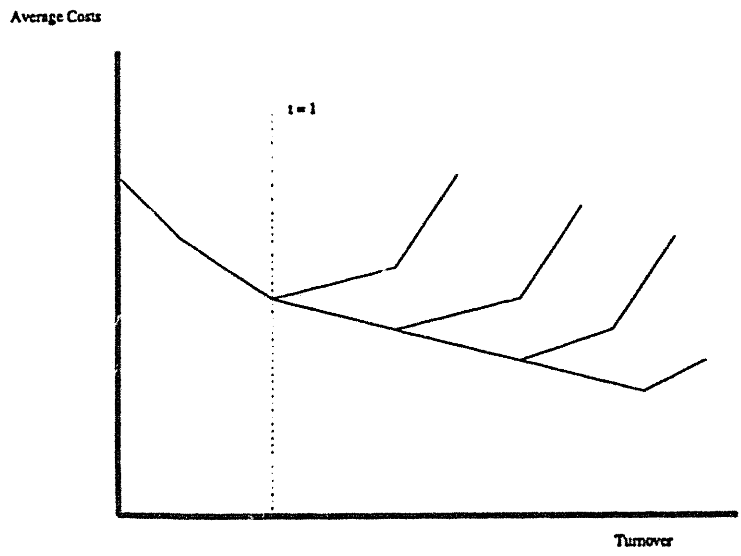


Figure 2: Locus of Possible Handling Cost Curves

This paper examines whether gains in productivity can be exploited to achieve greater economies of throughput and lower grain handling costs.

The Peak Load Problem and the Shape of Things to Come

The Royal Commission into Grain Handling and Storage recommended that the institutional constraints restricting the current grain handling and distribution system be removed. However, the enormous benefits from centralisation predicted by previous studies (which are conditional on deregulation being effective in changing freight rates to reflect social costs) may not have accounted for the associated congestion costs. In addition, large increases in deliveries at particular receival points will produce capacity shortages in the short term. Policies designed to alleviate the peak load problem may reduce some of the potential congestion and capacity shortage problems, and allow a greater degree of centralisation to be realized.

For example, a deferred delivery scheme will reduce queuing costs, because it will reduce the number of truck arrivals per day. A lengthening of the peak period will also result in an increase in peak rail capacity (expressed at available train hours). This will allow more grain to be delivered along the least cost paths, by removing the bottlenecks caused by congestion and shortages in rail and transport capacity. This study looks at the benefits of a deferred delivery scheme.

A Model of Grain Handling and Distribution in W.A.

A model of grain handling and transport for the Kwinana shipping region of W.A is used to examine these issues. The model minimizes the cost of moving the grain from the farm to the port. There are two periods, a harvest period (where all the grain is delivered from the farm to CBH storage) and a clearance period, where all grain in intermediate storage depots is moved to the port. The peak load problem exists in the harvest period, where there is a limited amount of rail and storage capacity, and congestion costs associated with road deliveries. The model is described in the appendix. The most significant features are the inclusion of detailed transport cost parameters relating to the peak load problem. An exponential queuing function is used to derive congestion penalties as road deliveries at a site increase. Detailed rail productivity parameters are also modelled, which take account of train loading rates and travelling speeds. An engineering approach is used to represent grain handling costs, according to the type of technology used at the site.

A comparison of the base (social cost minimization) run, and the cost of the existing regulated system is discussed in the appendix. This paper concentrates on comparing the importance of assumptions about the peak load problem.

The Effect of Queuing Costs

The importance of accounting for the shape of queuing costs was examined by considering the predicted grain flow under the assumption that there were no congestion effects resulting from increased deliveries at a receival point. Results are shown in Table 1. It can be seen that a more grain is railed in the peak period if there are no congestion costs. This is because deliveries can be concentrated at the Avon subterminal, which is the most efficient site in terms of train turn around time. Note that peak rail transport capacity was a binding constraint in both models.The presence of congestion means that deliveries have to be more decentralized to reduce queue costs, and the resulting pattern of grain receivals means that the railing effort is allocated to less productive sites.

Thus it appears that congestion costs will have an important effect on the potential benefits of centralisation. While there is an increase in direct sub terminal deliveries (this concurs with the results of RCGH work), the presence of queuing costs reduces potential deliveries significantly (by 30%).

Table 1: Consequences of ignoring Congestion Cost

	Base Model	No Congestion Model		
Sites Open	98	93		
Grain Movements and Capacity '000t				
Peak Rail	690	784		
Clearance Rail	2342	2210		
Road X farm	3281	3281		
Central Road	1713	1642		
Capacity"	2445	2389		
Turnover	1.40	1.39		
	Average Cost		Difference	
	$/t	$/t	$/t	%
Opening	0.69	0.66	-0.04	-5
Marginal	2.00	1.98	-0.02	-1
Queuing	0.18	0.78	0.60	337
Road x farm	3.96	4.21	0.25	6
Central Road	4.06	3.94	-0.12	-3
Rail	5.98	5.87	-0.11	-2
Total	16.87	17.43	0.56	3

"available permanent storage

The net effect on total costs is quite small - total costs only increase by 55c/t (or 3.%) if delivery decisions do not account for queuing costs. However, when the absolute magnitude of costs is considered, the problem of ignoring potential queuing costs appears more significant, at $1.8 m for an average year. Consequently, future policies which do not take account of potential queuing costs (such as silo closure) may raise the overall costs of the grain distribution system.

However, it is possible that a deferred delivery policy which attempts to reduce the size of the peak load problem may be beneficial in reducing costs of using the existing system, and may avoid investment expenditure on additional transport and storage capacity in the longer term.

The Shape of Handling Costs

The differences in average operating costs in Table 1 demonstrates the importance of rail in reducing country handling costs. When there are no queuing constraints restricting deliveries, rail can be allocated to where it is most efficient, so a larger amount can be railed, and greater economies of throughput can be achieved. While this is not reflected in the *aggregated* turnover figure, but it can be seen that average handling costs are reduced by 5c/t. However, these small savings in handling costs are outweighed by the large increase in queuing costs necessary to achieve them.

Deferred Delivery Option

The importance of queuing costs and the peak load problem imply that it may be possible to reduce congestion costs by adopting a deferred delivery policy. An extended receival period will reduce the number of arrivals on a daily basis, and this will reduce queuing costs. In addition, an extended peak period will increase peak rail capacity (number of train hours available), and increase available capacity at the port (as more grain can be shipped in the peak period). An extended receival period might be achieved simply by slowing down the harvest rate, or by holding the grain on the farm in temporary storage.

The Costs of Deferred Delivery

The cost to the farmer of deferred delivery is the cost of either delaying the harvest, or of putting it into temporary farm storage. The variable costs of using a farm shed for temporarily storing the grain are about $1.37/t (Benson et al 1987), although they could be higher if insect control is necessary. The costs of more temporary farm storage (such as mesh field bins) are about $1/t.

However, the cost of slowing down the harvest rate (as a means of extending the harvest period) may be lower. The cost of using temporary farm storage is an *upper limit* on the cost of delayed harvest, because if the farmer wishes to avoid the costs of delayed harvest, he can harvest as normal and put the grain into temporary on farm storage. It is difficult to quantify the price that would be necessary to encourage farms to delay harvest. While the farmer may benefit by requiring smaller harvesting capacity, he bears a greater risk of grain damage or loss by delaying harvest (Whan and Hammer 1985). Because this risky cost of delay involves a subjective assessment, it is difficult to quantify. Further, it cannot be judged from the current farmer behavior, because there have historically been pricing incentives to encourage rapid harvest and immediate delivery (payment for grain isn't made until grain is delivered to the central system, and the price of central storage is independent of time of delivery).

Potential Benefits of Deferred Delivery

The benefits of extending the delivery period by 50% are shown in Table 2. Total cost savings are only $0.20/t in total, or $.60/t when expressed per tonne of grain that is delivered late. This implies that if the cost of delaying delivery is less than $0.60/t, the costs of the grain handling system could be reduced by using pricing incentives to encourage late delivery. However, from the above discussion on the costs of deferred delivery, it appears that this pricing incentive will not be sufficient to encourage farmers to delay delivery by adopting temporary storage. Whether it would provide sufficient incentive for a slower harvest rate is unclear.

It possible that the benefits of deferred delivery may have been under estimated. Most importantly, it should be noted that there appears to be a high level of excess storage capacity in some parts of WA, and this will reduce the benefits of deferred delivery policies in the intermediate term. However, greater benefits may be realised when there is a larger quantity of grain received into the system. Consequently the model was also run to examine the benefits of deferred delivery in a peak year.

Table 2: Deferred Delivery

	Base Model	Deferred Del.		
Sites Open	98	96		
Grain Movements and Capacity '000t				
Peak Rail	690	1037		
Clearance Rail	2342	2071		
Road X farm	3281	3281		
Central Road	1713	1661		
Capacity	2445	2440		
Turnover	1.40	1.38		
	Average Cost		Difference	
	$/t	$/t	$/t	%
Opening	0.69	0.68	-0.01	-2
Marginal	2.00	1.90	-0.10	-5
Queuing	0.18	0.14	-0.04	-21
Road x farm	3.96	3.94	-0.02	0
Central Road	4.06	3.99	-0.07	-2
Rail	5.98	6.01	0.03	1
Total	16.87	16.66	-0.21	-1

Total Difference $ .686 m

Difference/tonne of deferred Grain
$/t -0.63

Table 3: Peak Year -Deferred Delivery

	Base	Peak Yr.	Def. Del.(pk)		
Sites Open	98	109	105		
Grain Movements and Capacity '000t					
Peak Rail	690	824	1136		
Clearance Rai	2342	3071	2797		
Road X farm	3281	4151	4151		
Central Road	1713	2324	2110		
Capacity	2445	3132	2920		
Turnover	1.40	1.37	1.48		
		Average Cost		Difference	
	$/t	$/t	$/t	$/t	%
Opening	0.69	0.61	0.59	-0.02	-3
Marginal	2.00	2.53	2.23	-0.30	-12
Queuing	0.18	0.31	0.21	-0.09	-30
Road x farm	3.96	3.58	3.74	0.16	5
Central Road	4.06	4.39	4.01	-0.38	-9
Rail	5.98	6.00	6.39	0.39	6
Total	16.87	17.41	17.17	-0.25	-1

Total Difference $1.019 m

Difference/tonne of deferred Grain
$/t -0.75

Deferred Delivery in a Peak Production Year

The results of the peak year simulation are shown in Table 3, these are presented along with the results of the base model (average year). In a peak year, the average costs of (central) grain storage are higher. This is because of more intense use of the more costly storage technologies. The model chooses to open more sites in peak years in order to avoid the high marginal costs of grain storage at sites with labour intensive facilities. However, total country storage costs are higher. The deferred delivery policy only reduces costs by 24c, which is about 75c per tonne of grain that is delivered late. This cost saving is achieved by allowing a reduction in storage and handling costs (due to a larger amount of grain being railed in the peak period), as well as reduced queuing costs. Again, this does not appear sufficient to encourage farmers to use temporary storage to defer the delivery of grain.

It can be seen that the model chooses to open more sites in a peak year, this decentralisation of deliveries allow a reduction in queuing costs and reduced marginal storage costs, at the expense of higher opening costs. However, it is possible selective opening of receival points in peak years may be too costly due to maintenance costs. Moreover, in a longer term situation, this option of opening sunk facilities will not be available.

A run was done to test the benefits of a deferred delivery policy, when the maximum number of sites open was constrained to those chosen by the model in the base year simulation.

Table 4: Peak Year -Deferred Delivery (with constrained opening)

	Peak	Def. Del.		
Sites Open	98	98		
Grain Movements and Capacity '000t				
Peak Rail	869	1150		
Clearance Rail	3031	2741		
Road X farm	4151	4151		
Central Road	2281	2081		
Capacity	2455	2455		
Turnover	1.80	1.80		
	Average Cost		Difference	
	$/t	$/t	$/t	%
Opening	0.55	0.55	0.00	0
Marginal	2.99	2.32	-0.67	-22
Queuing	0.39	0.25	-0.13	-35
Road x farm	3.61	4.02	0.41	11
Central Road	4.24	3.91	-0.34	-8
Rail	6.02	6.39	0.36	6
Total	17.81	17.43	-0.38	-2

Total Difference $ 1.558 m

Difference/tonne of deferred Grain
$/t 1.13

Results are shown in Table 4. It can be seen that the benefits of deferred delivery are much higher, at $1.12 per tonne of deferred grain. This "constrained opening" simulation indicates that a deferred delivery option would be chosen when there is less permanent storage capacity in the system. By constraining the model to only open 98 sites, a greater use of higher cost storage technology is necessary. This means that the benefits from deferred delivery are greater, as higher marginal costs of storage are being avoided by railing the grain directly to the port.

Longer Deferred Delivery

Longer deferred delivery policies (extending the peak period by several months) have not been considered in this study. This is because the cost (to the farmer) of delayed delivery is likely to be an increasing function of the length of delay. As the time the grain is held on the farm is increased, there will be increasing need for more "permanent" farm storage, with better insect control measures. In addition, a major benefit of deferred delivery is a reduction in truck queuing costs, and the apparent exponential nature of truck queues implies that there will be declining marginal benefits associated with extending the receival period for a longer time.

Summary

It appears that substantial savings could be made from a more centralized grain distribution system, one of the main savings results from reduced branch line movements, with more grain being carted from the farm to main line receival points and sub-terminals. Another saving is the closure of some receival points - there appears to be an oversupply of receival points in the existing infrastructure - these impose high opening costs (and suggest that there must have been over expenditure historically). These results concur with a number of previous studies (eg. RCGH 1988)

However, the congestion effects arising from increasing road receivals at particular receival points and subterminals will limit the gains from centralisation. These congestion effects have not been considered in most other studies. Policies that are based on the results of these studies, which do not account for the potential congestion costs (such as extensive silo closure or pricing policies that encourage an excess concentration of grain deliveries) will impose unnecessary costs on the industry.

A deferred delivery policy may provide a means of reducing congestion costs and allowing greater economies of throughput while allowing the transport cost savings from centralisation to be achieved. However, because of the high level of over capacity in the current system, the savings from a deferred delivery policy may not be as significant as they would be in an optimally adjusted system.

In the longer term, a deferred delivery policy may provide a cost effective means of dealing with receivals in years of high production, so that excess capital expenditure on grain storage infrastructure can be avoided. Other policies that reduce queuing costs, such as longer opening hours, time of day/season incentives for delivery policies, or investment in additional receival capacity, might be a means of allowing the potential benefits from centralisation to be realised.

APPENDIX

The short run cost minimisation model considers the flow of grain from the farm to the port in a single year. The supply of grain at the farm level and the demand for grain at the port/domestic market are assumed to be exogenous. The model considers the intermediate process of getting the grain from the farm to the port. The cost of handling grain at the port and shipping costs are assumed to be independent of the time of delivery and are therefore not included. The determination of the demand for grain handling and storage facilities at particular locations is endogenous, and depends on the cost of delivering to the site, the cost of handling at the site, and the cost of clearing the grain from the site to the port. The "supply" of grain handling services at particular locations can also be altered within the model, according to decisions made about the opening of sites, as well as the allocation of rail to particular sites in the harvest period, and the possibility of relocating existing bunker storage to areas where there is a shortage of storage capacity.

The analysis was limited to the Kwinana Shipping Zone in order to limit the size of the model. About half of the grain produced in WA is stored and distributed in this zone. The Kwinana was chosen because it contained sites with a range of alternative technologies, as well as two transfer depots, similar to the subterminals that have been the focus of attention in previous studies. While changes in cost and pricing arrangements may attract some grain from fringe areas, it is assumed that this will be a small effect.

The Network

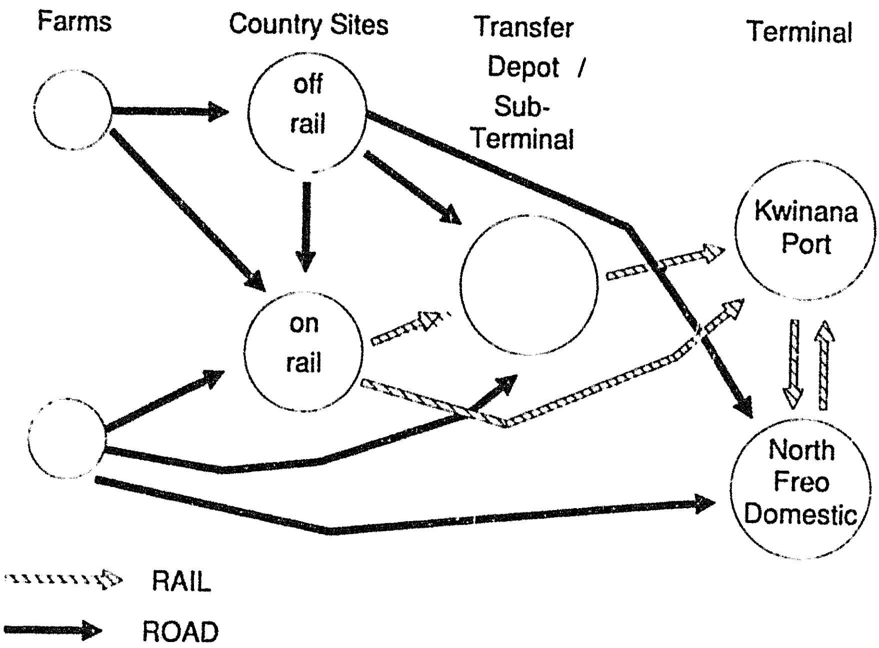
The spatial flow of resources is depicted by figure A.1. The possible links and modes of transport allowed in the network, represent those options available in a free environment, not the historically constrained one. There are 112 country receival points in the zone, of which 96 are currently located on rail lines. The existing rail network is shown in figure A.2.

Grain may move from the farm to a number of intermediate nodes, including country receival points and sub terminals. The Kwinana port has no road receival facilities, all grain that is transported by road to the metropolitan area must be delivered to North Fremantle (an abandoned export site) then railed to Kwinana (30 km away) . North Fremantle is also the domestic market outlet. There are two inland "sub terminals", Merredin and Avon, which are used as transfer depots in the current system, for shifting grain from narrow gauge to standard gauge trains. Although there are transfer costs involved in unloading the narrow gauge trains and reloading the grain into standard gauge trains, they are outweighed by the lower costs of hauling grain in standard gauge trains.

Two Period Representation

The model is divided into two periods, the harvest and clearance periods. The harvest period is 50 days long, and defines the time during which grain is delivered from the farm to the central system. The rest of the year is called the clearance period, when all the grain from intermediate nodes is cleared to the port. There are no ex farm movements

Fig. A.1 The Grain Distribution System



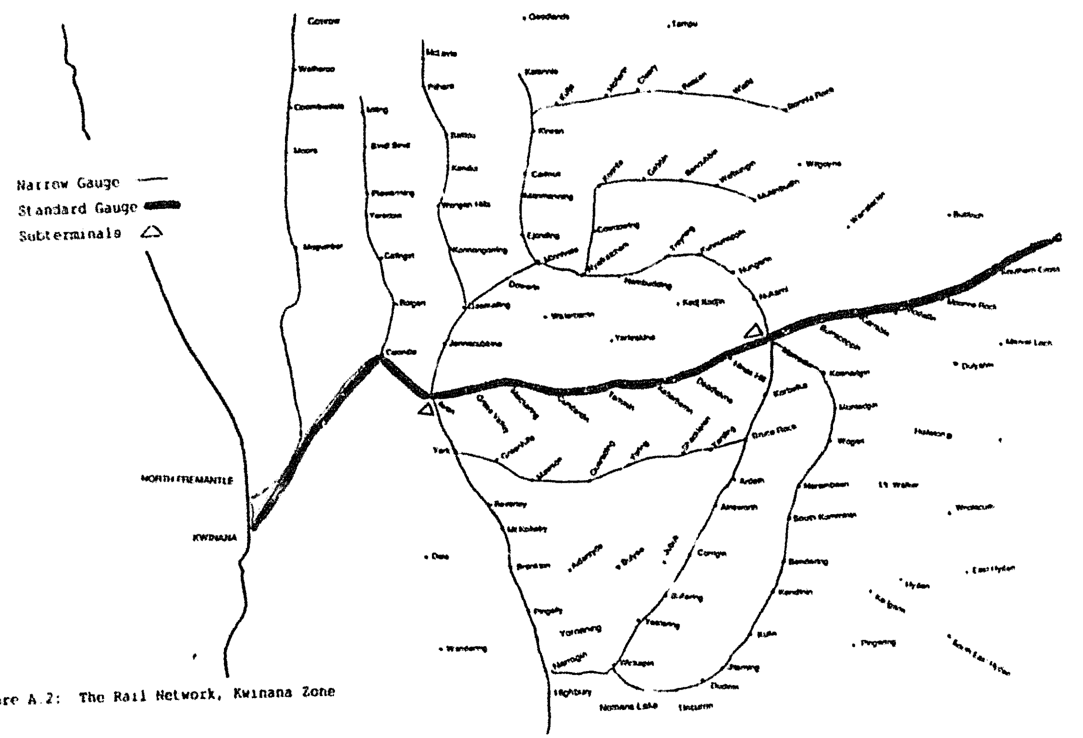


Figure A.2: The Rail Network, Kwinana Zone during this period. All the transport options (modes and links) between the receival points, subterminals and port are possible in either period.

Diverse Technology Representation

Possible activities at each receival point are modelled in detail with identification of the costs of using different types of grain storage facility at each site (vertical, horizontal and bunker) and their available capacity at each site. The cost of constructing additional temporary storage is also incorporated. The costs of opening receival points (mainly the costs of a skeleton labour force) are modelled separately by using binary variables.

Single Grain Type

The grain flowing through the system is assumed to be homogeneous. While the existence of multiple types and grades of grain may have an effect on operating decisions and costs (particularly because of segregation requirements which reduce effective storage capacity) the homogeneity assumption was necessary for simplicity. Physical storage capacities were reduced to effective storage capacities, to represent segregation needs.

Data Used in the Model

Physical Data

The quantity of grain delivered from each farm supply node is based on historical receival point deliveries. An examination of the past 10 years receivals indicated that the 1986/7 season represented an average year, and 1984/5 a peak year. The receival data from these years are used in the model. In addition to delivering to country receival points, farm supply zones had the option of delivering to one or both subterminals (depending on their relative proximity), all farms had the option of direct delivery to North Fremantle.

The capacity of each type of storage at each receival point, subterminal and the port were supplied by CBH. Because total clearance of country sites in the post harvest period is assumed (CBH 1987), the physical storage capacity of the site measures the available storage space in the harvest period, but effective storage capacity is reduced by 15% for horizontal storages, and 5% for vertical structures to allow for segregation.

The amount of grain that can be stored at a receival point is limited, but additional grain can be delivered to the receival point and transported to a sub terminal or port. There is no capacity limit assumed of the operation of road transport (ex receival points) in the peak period.

The amount of grain carried over from the previous season varies substantially from year to year, depending on shipping demands and the volume of harvest, a net carryover figure of 0 (carryover minus amount shipped in the peak period) was used in the base model, based on an historical average.

Costs

The marginal costs of storing grain using the various technologies were obtained from the CBH submission into RCGH. Opening costs are also included, with dummy variables on marginal sites to allow selective closing on receival points. The cost of transporting grain in the peak period are higher than in the clearance period, for rail and road. Queuing costs are incorporated as they may be particularly important factor affecting the cost of road deliveries in the peak period. Road transport costs were derived on RCGH publications. Rail costs were obtained from an engineering type study of rail transport costs in WA. The costs of branch line maintenance are highly disaggregated, reflecting the high maintenance costs of very lightly trafficked segments. These costs are shown in Tables A.1 and A.2.

Table A:1 Costs used in Model

Storage and Handling	$/t
Technology	
Modal Transfer	0.74
Vertical Storage	1.01
Horizontal Storage	1.65
CLS Storage	5.25
Bunker Storage	6.68
Mobile Storage	8.28
Fixed Costs (avg)	21300

Table A:2 Transport Costs used in Model

Road	$/t	
Peak	.93 + .135D	if D < 20
	6.4 + .0753(D-20)	if 20 < D < 100
	12.41 + .0631(D - 100)	if D > 100
Clearance	1.07 + .0631D	
Rail		
Narrow Gauge		
Peak	8.37 + .0317D - 6.69S - 3.341V	
Clearance	4.9 + .0138D - 4.17S - 1.97V	
Standard Gauge		
Peak	2.29 + .0181D - 4.2S - .862V	
Clearance	1.86 - .0181D - 3.8S - .862V	

Where D = distance Km, S = train size '000t,
V = presence of vertical technology

Maintenance (Range) $/t .22 to 16.02

Rail Productivity

Detailed rail productivity parameters were obtained from the engineering study, which took account of the outloading rates, train configurations and speeds for different sites. Previous studies have used only net tonne km to represent rail productivity, while this alternative representation allows the model to select sites according to train turnaround time. In WA, only a limited number of sites have rapid (vertical) rail loading technology (which can take an hour), and grain that is railed other sites may take all day to load in the harvest period. It is possible that a reallocation of rail to vertical technology sites would allow a more productive use of rail and therefore allow greater economies of throughput to be achieved.

Queuing Costs

There are a number of problems associated with the inclusion of queuing costs in the model, including the fact that the potential changes in grain flow may result in queuing problems that are unprecedented in WA. However, Kerin (1985), analyzed the relationship between truck arrivals and queues in South Australia. His model was of the form

$$TQC = 4.363 \times 10^{-6} . QR^{2.3386} . NH^{-1.6092}$$

where TQC is total queuing costs, QR is total grain receivals, NH is a measure of road receival capacity (number of hours).

The exponential form of the model implies that increases in arrival rates at high levels are likely to have a greater effect on the waiting time than increases at low levels, because of the congestion effect it creates on all the other trucks arriving in that time period. The exponential relationship between queuing and arrival rates, and the negative exponential one between queuing and departure (service rates) concur with conventional queuing theory (Gross and Harris 1974).

This model was tested in WA during a 1987/8 survey of truck queues. It was found that queuing costs were generally less than 50c per tonne, whereas Kerin's model predicted queuing costs to be 3 or 4 times higher. However, the proxy used to reflect receival capacity (number of hoppers) doesn't allow for the existence of faster inloading rates in WA (they are generally twice as fast). When the size of the receival capacity variable was doubled, the model performed much better, and was considered to provide a reasonable approximation for queue costs in WA.

In order to keep the model simple, some ballpark estimates were derived using the model, as well as observations made during the survey. First, it was assumed that, provided turnover levels of grain at the site were less than one, the average costs of queuing would be about 50c/t. This assumption is based on the observed queuing costs in the survey. This average queuing cost was incorporated into road transport costs, assuming an average wait of 15 minutes per truck.

To represent the extra costs of queuing that may arise as a result of an increased concentration of receivals at particular sites (represented by increased turnover) a penalty cost was derived, using Kerin's model. This penalty cost is calculated by examining the increase in total queuing cost as turnover increases above one. Turnover is increased above one by using rail outloading, or by using bunker storage. A linear approximation was used to represent the increase in total costs as turnover increases above one.

Extended Delivery Period

One of the benefits of extending the harvest period will be that the reduction in queuing costs that comes from spreading out road deliveries over a longer time period. The base assumption is that receival period at individual sites is 40 days. For the deferred delivery runs, it is assumed that the receival period is increased by 50% to 60 days. It is assumed that the effect of extending the harvest period are the same as the benefits of increasing the road receival capacity. A 50% increase in hopper capacity is therefore assumed in calculating reduced queuing costs.

Peak rail capacity and net carryover were also adjusted to allow for the longer receival period. (Net carryover declines because more grain can be shipped from the port).

Model Results

The costs of using the existing system was simulated by taking actual receival point deliveries as exogenous (they are based on current freight rates, and restrictions), and considering the least cost method of grain storage and distribution, assuming that CBH minimize perceived costs.

Results of the comparison are shown in table A.3. It is seen that the potential saving from deregulation (ie. social costs cf. existing costs) are $3/t. This is lower than estimates provided by the RCGH. However, several qualifications must be made when comparing between studies. First, this model treats only intermediate storage and transport costs, excluding all port and shipping charges. This accounts for much of the differences. For example, net of savings in shipping costs, the Eastern Australian model predicted savings of $5.31/t. Some resource costs savings in transport were also assumed in this model, whereas this model uses costs calculated on current operational practices.

There are a lot of data differences that imply that between model comparisons cannot be used to examine alternative modelling assumptions about the peak load problem, which is the issue here. The modeling work discussed in the text of this paper concentrates on comparing the importance of the peak load problem using the social cost minimisation model.

Other significant points from Table A.3 are that there are 14 sites (12.5%) closed in the social cost minimisation model, compared with the existing system. However, the savings in opening costs are more than compensated for by the increase in marginal storage costs associated with using fewer sites (more intense use of labour intensive facilities at opened sites). Consequently, average operating costs of country storage are higher. It appears that silo closure is a consequence of more intense use of subterminals, which allows gains in transport costs by avoiding branch line movements and the cost of intermediate transfers.

Savings from deregulation are mainly due to transport costs savings, there are significant reductions in rail costs (56%) avoiding branch line maintenance costs, and a substitution toward road transport. In terms of expenditure on transport, the modal mix is considerably higher for road in

Table A.3: Comparison of Existing and Least Cost System

	Existing	Least Cost		
Sites Open	112	98		
Grain Movements and Capacity '000t				
Peak Rail	903	690		
Clearance Rail	3712	2342		
Road X farm	3281	3281		
Central Road	359	1713		
Capacity	2661	2445		
Turnover	1.30	1.40		
	Average Cost		Difference	
	$/t	$/t	$/t	%
Opening	0.79	0.69	0.10	14
Marginal	1.79	2.00	-0.21	-10
Queuing	0.27	0.18	0.09	52
Road x farm	2.81	3.96	-1.15	-29
Central Road	0.57	4.06	-3.49	-86
Rail	13.65	5.98	7.67	128
Total	19.89	16.87	3.02	18
MODAL MIX % $RD/$TRANS	20	57		

the social cost minimum case (20 to 58%).

Total savings from "deregulation" are about 18%.

Another point that is worthy of note is that the most important savings from deregulation are due to reduced transport costs, and most importantly, reduced branch line maintenance costs. These savings will only be realized if deregulation results in significant branch line closure. However, given the potential for cross-subsidization between different lines and services in a rail network, (as well as distortions in the road transport market (eg road damage)), some of measured potential benefits of deregulation (which compare the social cost minimum with the existing system) will not be realised.

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