MODELLING GRAIN HANDLING IN VICTORIA

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Abstract:

This paper describes a computer model which is being developed at the University of Melbourne on behalf of the Victorian Grain Elevators Board. The model simulates the operations of the grain handling and transport system in Victoria and is designed to allow analysis of a range of capital investment and operational policies which may be implemented in the short or medium term. The paper outlines the framework of the model, provides details of some of its more important components and discusses the types of policies to which it will be applied.

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INTRODUCTION

The production and marketing of wheat, barley, oats and other grains is recognised as a very significant component of the Australian economy. In 1977/78, the export earnings for the state of Victoria alone of "cereal grains and their preparations" totalled $317 million (A.B.S., 1979) and it is estimated that inclusion of ancillary aspects of the grain industry, and consideration of changes since 1977/78, would bring the current annual value of the industry in this State to well in excess of $500 million.

As would be expected, a very substantial grain handling and transport task is associated with the industry and, for grain produced in Victoria and some parts of southern New South Wales, this task is the responsibility of the (Victorian) Grain Elevators Board, a statutory authority responsible to the Government of Victoria through the Minister of Agriculture. In addressing the task, important supporting roles are played by Vicrail, which provides rail transport of the majority of the grain to seaboard and inland terminals, the Australian Wheat Board, the Australian Barley Board and the Victorian Oatgrowers Pool and Marketing Co. Ltd. as marketing authorities, and grower associations, representing the producers. A small but expanding role also is played by road hauliers who in 1979/80 provided for the longer distance transport of some 100,000 tonnes of grain. This can be compared with the region's total cereal grain crop, which averaged 1.9 million tonnes per annum prior to 1978/79, but has exceeded 4 million tonnes in each of the last two years and could reasonably be expected to average around 3 million tonnes annually in the future.

The grain handling task requires a massive physical system (see map, Fig. 1), comprised of transport, storage and transfer components, together with equally extensive operational systems. Within the physical system the two principal categories of transport facilities are those for road haulage of grain by growers to local Grain Elevators Board receival points, and the rail system which provides bulk transport over long distances and includes the major part of the Victorian country rail network and more than 6300 wagons suitable for grain transport.

Provision of grain storage, a responsibility of the Grain Elevators Board, is at three levels : firstly, the local silos of which there are approximately 660 units at 240 sites providing storage for some 2.4 million tonnes of grain; secondly, the inland terminals at Dunolly and Murtoa, in which the 408,000 tonnes of storage provided is aimed at increasing the flexibility of grain handling and transport operations; and finally the three terminals - the Sunshine

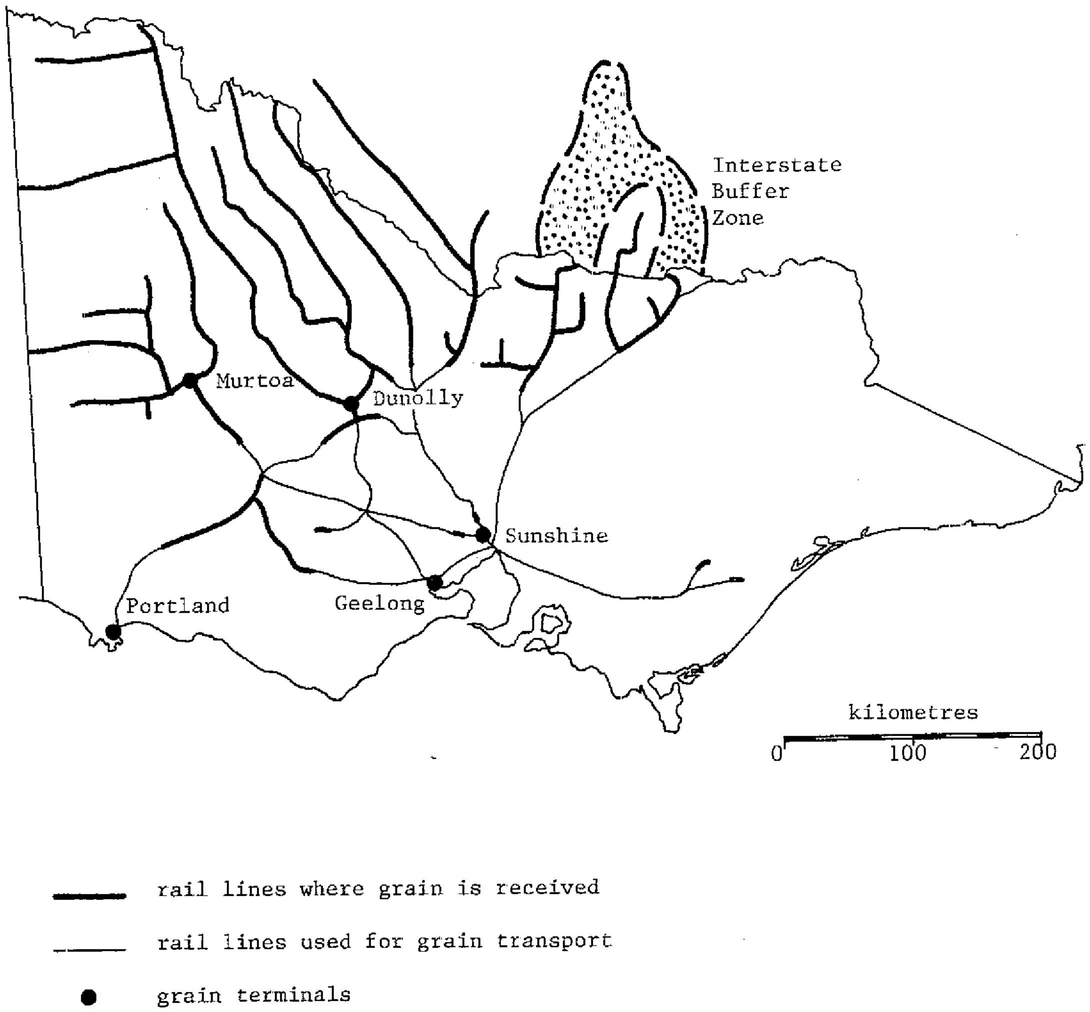

FIGURE 1 - RAIL TRANSPORT OF GRAIN IN VICTORIA

Barley Terminal with 64,000 tonnes of storage, and the seaboard terminals of Geelong and Portland which incorporate storage for 820,000 tonnes and 165,000 tonnes respectively. Whereas the Sunshine terminal receives barley by rail from all parts of the state for ultimate outloading to local maltsters and produce markets, the seaboard terminals have the primary function of handling export grain, principally wheat.

The transfer components of the physical system include elevators which handle receivals ex farm and outloading to rail trucks at local country storages, facilities for road and rail receivals at sub-terminals and terminals, and facilities for outloading to both rail and road at the inland sub-terminals and to ships at the Geelong and Portland terminals.

The operational systems include provision for inventory and control of grain held in storage at the various locations, allocation and monitoring of trains for grain transport over the rail system, and procedures for ensuring delivery to market points of the type, quality and quantity of grain required at the time it is required. Such operations require close interaction between the Grain Elevators Board, grower associations, Vicrail, the marketing authorities and shipping companies.

For some considerable time it has been recognised by the Grain Elevators Board that while the Victorian grain handling system has performed more than adequately in the past, the passage of time since the commissioning of the majority of the physical facilities and the recent significant growth of the grain handling task require that major updating of the system now be undertaken. However, it also is recognised that the complete system is a closely interwoven whole, so that changes made to the physical facilities or operational procedures in one area are likely to have repercussions throughout a major proportion of the system. Thus considerable care must be exercised in assessing the consequences of any decisions made in relation to system updating.

It was to provide such assessments that development of the policy-sensitive simulation model described in this paper was initiated. The questions it seeks to answer fall into two categories : firstly, the consequences of alternative decisions with regard to capital investments, of which typical examples might be where new country storages should be located, what the effects would be of different levels of loading and unloading capacities at sub-terminals or terminals, and how the system would respond to different mixes of available rail rolling stock; and secondly, the consequences of alternative operational policies, which might be illustrated by alternative levels of use of road haulage or choices between different priority rules for allocation of trains to the various areas which require them during the harvest period.

THE GRAIN HANDLING MODEL

The priorities of Australia's grain handling authorities differ significantly between the harvest and non-harvest periods of the year. At harvest time their major concern is to receive into the system all grain growers wish to deliver and transport any local overflow to unused storage at an inland or seaboard terminal. During the rest of the year their concern is to empty the system of grain, or if this cannot be done, to minimise the quantity carried over into the next year. The grain is transported to domestic markets or to seaports for shipping overseas. These dissimilar priorities make separate analysis of the two periods essential.

As the harvest is an annual event it seems logical that the analysis cover a period of one year commencing at the start of the harvest. However, the start of harvest is subject to fluctuations, largely as a result of natural forces, and can vary by several weeks. This complicates any analysis using the start of harvest as a time datum, so for simplicity, the model adopts as its time datum a day which is just earlier than any expected start of harvest.

Using this datum, called Day One, the harvest year can be divided into three, rather than two, periods : pre-harvest, harvest and post-harvest. The pre-harvest period runs from Day One to the day when new season grain is first received. This period is analysed only when grain harvested in a previous year is still in the system at Day One. The harvest period runs from the day when grain is first received until the final delivery has been made (or alternatively, until all overflow grain has been transported from elevators) and the post-harvest period runs from this day until Day One of the following year.

Typically, models have three basic stages : input, analysis and evaluation. The input stage of the grain handling model translates the handling system into a series of links, nodes and processes. The analysis stage examines each period of the year in turn, allocating trucks and trains to elevators for loading and then to terminals for unloading. The evaluation stage produces quantitative measures for use in assessing the performance of the system infrastructure and the operating policies employed. The following sections will examine these stages in greater depth.

Input : Describing the System

The model depicts the grain handling system as a set of grain production zones, elevators, inland storage terminals, train consolidation yards and seaboard storage terminals interconnected by road and rail links.

The first role of the input stage is to describe the characteristics of these components; expressing them in terms of storage and loading capacities, grain types handled, transport link lengths, speeds and capacities and the elevator to terminal trips permitted. These data allow the model to examine the effects of transport link deletion, upgrading or addition, of increasing (or decreasing) grain storage and loading capacities and of policies affecting the grain types accepted at each terminal.

The input stage's second role is the preparation of data files specifying daily adjustments to the system; for instance, grain deliveries at elevators, shipping at seaboard terminals and alterations to the size and composition of the train fleet. These files can be read in directly or generated by a series of submodels. An example of these submodels is the one which determines the quantity of each grain delivered to an elevator on each day of harvest. It proceeds as follows:

1. the total harvest of grain A in each production zone (which corresponds to an elevator catchment) is derived from the area sown and the expected yield in the zone
2. if the zone's elevator will not receive grain A this year, all production is assigned to the nearest elevator which will
3. the maximum receival rate for the elevator and the total deliveries of grain A are used to specify a parabolic function relating daily deliveries to the number of days elapsed since the first delivery
4. the day when the first delivery is made is determined using a stochastic function, and deliveries for each day of harvest calculated.

The third and final role of the input stage is the derivation of initial values for the three "state" arrays on which analysis is based. The "state" of the system can be described as the arrangement of resources (ie. grain and trains) at a particular time. The "state" arrays describe respectively : the time every train is next available for despatch to an elevator for loading, the quantity of grain received, to come and trucked out from each elevator and the quantity of grain stored at each terminal.

Analysis : Handling and Transporting the Harvest

The analysis stage of the model simulates the processes involved in handling the harvest.

The model deals individually, and in chronological order, with the three periods of the year : pre-harvest, harvest and post-harvest. During the pre-harvest period transport is provided whilst grain remains in the system and no new season grain has been delivered. Once all carryover grain has been removed or deliveries start, the period is evaluated and harvest period transport commences. This continues until all grain has been delivered into the system (or all overflow trucked out), when the period is evaluated. Post-harvest transport is allocated until all storages have been emptied or the year finishes. The period is then evaluated prior to examination of overall system performance (see Fig. 2).

An important benefit of this format is that different operating policies can be simulated in each period, within a common model structure. For example, during the harvest period trains may be allocated to elevators according to the probability of the elevator filling before all grain has been delivered, but at other times allocated to elevators in a prearranged order. The common model structure is examined in detail in the following sections.

The model combines event-based and time-based simulation methods in a hybrid structure whose cornerstone is allocating empty trains to elevators to load grain. The trains are despatched to elevators in the order in which they become available. The grain loaded is then used to adjust the inventories of the elevators and terminal served by the trip. However, prior to despatch, the train's departure time is checked to determine whether a new day has started. If it has, the complete system is updated. Grower deliveries to elevators and out-road deliveries to terminals are received, grain is out-loaded to ship at the seaboard and the size and composition of the train fleet adjusted. The next available train is then despatched to the next elevator. (See Fig. 3).

The Train. Trains are described in terms of their locomotive and wagon type and by the type of load which may be carried (ie. single or mixed grains destined for one or more terminals). Together with the time when the train is next available for despatch, these data are included in the train fleet matrix. The trains are ordered from first available to last.

When a train is to be allocated, the earliest available (ie. the first in this matrix) is selected. As described above, if the train is available during the present day a trip is selected for it; otherwise, the system is updated for the change of day.

The Daily System Update. The size and composition of the train fleet is assumed to be fixed throughout each day, any changes being made at the change of day. Trains added to the system are made available immediately but those returned to general use are the next available which suit. This allows great freedom in simulating policies of train provision.

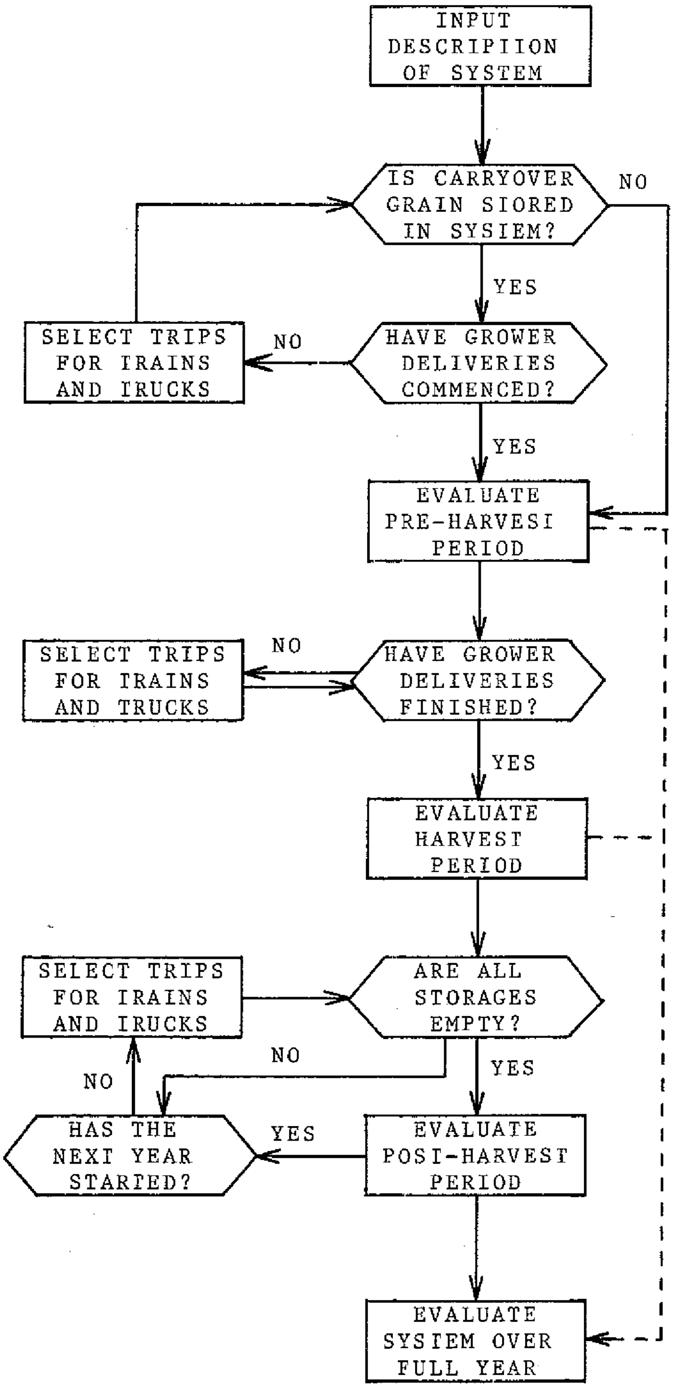

FIGURE 2 - AN OVERVIEW OF THE GRAIN HANDLING MODEL

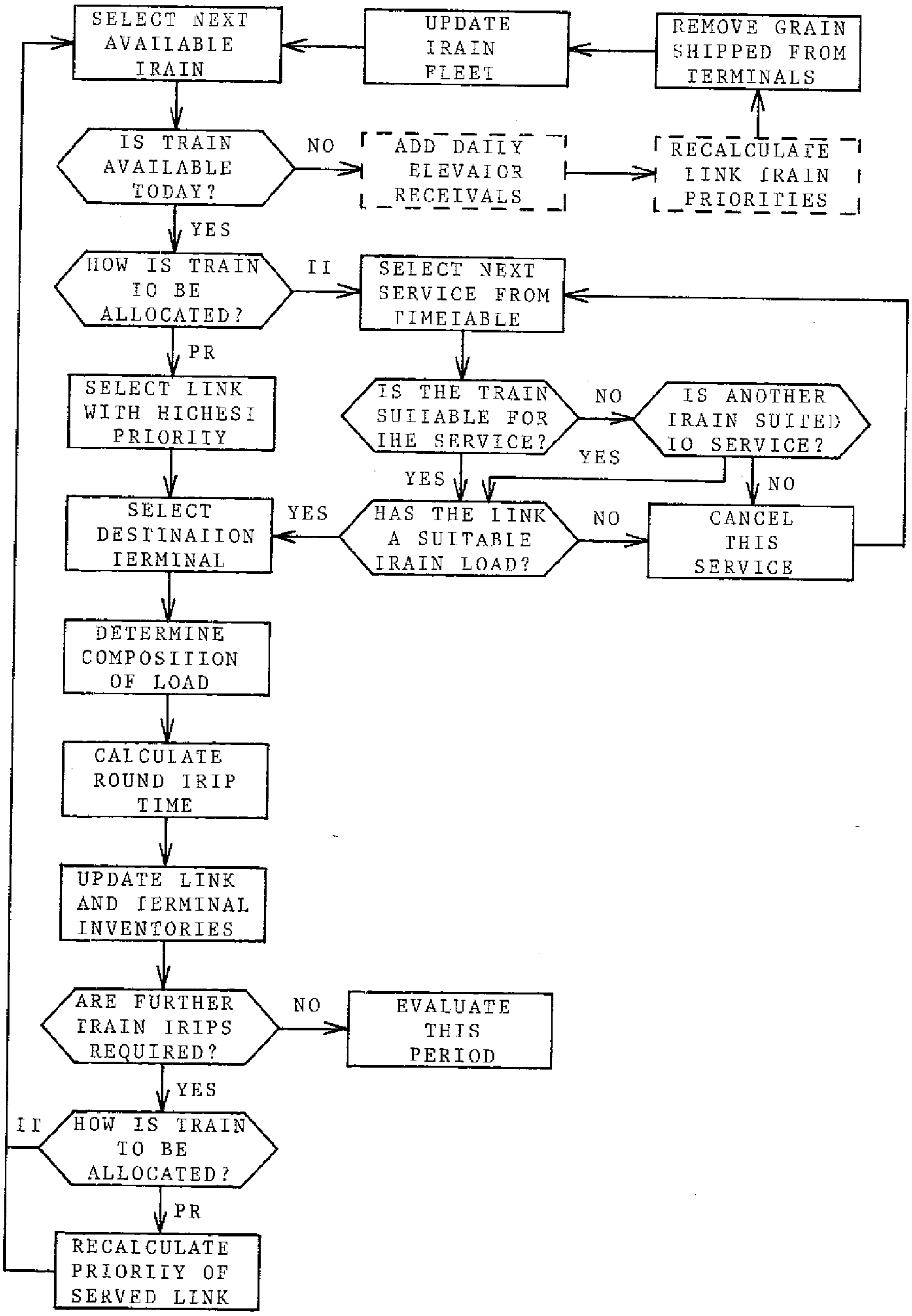

FIGURE 3 - THE ANALYSIS STAGE OF THE GRAIN HANDLING MODEL

Grower deliveries to elevators and road deliveries to and shipping from terminals are included as inventory adjustments made each day. Throughout the year grain shipped at seaboard terminals is subtracted from their inventories, whilst during the harvest period grain received at elevators from growers or delivered by road to terminals is added to the appropriate inventory.

Should an elevator have insufficient unused storage to accept all grain delivered on a day, the excess is recorded as not delivered and a penalty cost applied. This cost is selected to reflect the reduced yield which may be the result of delayed harvesting or the cost of providing temporary on-farm storage. During the harvest period the adjustment of elevator inventories is followed by calculation of revised elevator priority values (unless trains are allocated according to a timetable).

Trip Origin and Destination. Due to a number of factors, but particularly the limited siding capacity at many elevators, trains are rarely despatched to single elevators; rather, they are sent to a group of elevators located on a 40-50 km link of the rail network. The destination link for the train can be selected on the basis of the link's need (or priority) for trains relative to all other links or according to a previously specified timetable or plan.

The basis of the link priority method is the priority matrix, which lists the priority value for each link for each train fill type. If the link cannot supply a suitable train load the priority value is set to zero.

The train's destination is the link having the highest priority value for the train's fill type, which is also capable of carrying the locomotive and wagons making up the train. The priority matrix also includes the destination terminal for the trip, so the train's journey is fully specified.

Calculation of the priority value differs between periods of the year; during the harvest period it is a function of the quantity of overflow grain still to be received at each elevator on the link and the corresponding volume of unused storage; at other times it is related to the order in which storages are to be emptied.

The timetable method allows not only the destination link to be specified, but also other parameters including the required locomotive and wagons, the latest permitted arrival time at the link and departure and destination terminals. This permits the simulation of policies ranging from specifying the service order for links to a full timetable.

This method uses a trip specification procedure which differs slightly from the priority method. The earliest available train is selected and compared with the next service to be provided. If the train is not suitable, the train fleet is searched for one that is. Should one not be found the service is cancelled and the procedure restarted. When a suitable train has been identified, the link is checked to confirm that a load is available. Again, if the answer is no, the service is cancelled and the procedure restarted. The destination terminal, if not specified, is then determined on the basis of travel or trip time.

The Train Load. Irrespective of the train allocation procedure, the load carried is always that having the highest priority value for the train configuration and destination. The priority for loading each grain at all elevators on the link is evaluated, then the highest priority are loaded, then the second etc until the train is full. Elevator siding capacity is used to limit the quantity of grain outloaded.

Trip Time. The three components of round trip time : travel time, loading time and unloading time, are calculated separately.

Travel time between each permissible link-terminal pair is determined for a normal goods train running at scheduled speeds. Times for those trains allowed to operate at higher speeds, ie. fast and express goods, are factored from the normal goods time. The non-travelling component of the scheduled time, ie. stops on passing loops and at stations, provides an estimation problem due to its wide fluctuation. It appears unrelated to journey length, time of day etc. so the ratio of non-travelling to travelling times is assumed stochastic. Travel time, and also loading and unloading times, is multiplied by a stochastic factor to allow for unscheduled delays.

Travel time is taken to exclude all time the train spends on the destination link, so loading time includes travel time on the link, shunting time at elevators and any time spent waiting for wagons to be loaded. Travel time is determined from average speeds and shunting time using a stochastic function. Loading time is zero if the locomotive is permitted to drop empty wagons and pick up full ones or is the actual time the locomotive must wait at the farthest elevator if the train cannot be split.

On reaching the terminal the train joins the unloading queue to wait its turn at an unloading bay. The time required to empty the train is a function of the capacity of the unloading facility and the size and composition of the load and train. Following cleaning and inspection the train is again ready for despatch.

This approach permits simulation of many possible changes to terminal operation ie. increasing elevator and conveyor capacities, providing more unloading bays and lengthening terminal working hours, and is sensitive to small time savings. This is a significant advantage over model structures using daily allocation of trains where time savings from incremental improvements are not perceived.

Updating Grain Inventories. In the final phase of the train allocation procedure the train's load is used to update grain inventories at the elevators served and the destination terminal. This is a straightforward process of deduction at the elevators and addition at the terminal.

The inventory at each elevator on the link is then examined to determine whether more train trips are needed to transport overflow or empty the facility. If no trains are required, the rest of the system is checked and if no more trips are needed throughout the system, the particular period of the year is evaluated.

When further trips are necessary the next available train is selected and the allocation procedure repeated. If link priority is used to allocate the trains, the priority value for the link just served is recalculated using the new elevator inventories.

Evaluation : Assessing System Performance

System performance during each period of the year is assessed before the next period begins, whilst the complete year is evaluated at its end.

The aim of the evaluation is to provide quantitative data for assessing alternative system configurations and operating policies. Due to the number of community groups and operators involved in handling grain the range of performance measures used is diverse, covering the cost and efficiency of grain handling facilities, farm to elevator delivery, transport from inland facilities to the seaboard and shipping and marketing. The succeeding sections discuss the more important measures.

Grower Delivery Costs. A brief examination of the grain handling system emphasises that, at least in the short term, policies benefitting one group in the system invariably place extra costs on some others. This is particularly true of grower delivery costs. Any reduction in the number of points where grain can be delivered, as a result of closing elevators or restricting the grain types received, will increase the average delivery distance for growers. This may not only affect delivery costs, but may upset the nexus between harvesting and delivery labour on the farm and so require upgrading of harvesting or delivery equipment.

The model uses average delivery distances for each grain and elevator to calculate delivery costs. Each elevator is assigned an average delivery distance which is applied to each grain. Should the elevator not accept a particular grain, it is diverted to the nearest one which does, and the delivery distance increased by the distance between the two elevators. Delivery cost is the generalised cost of the trip, including vehicle running and standing costs and the labour cost of the driver.

The Cost of Delayed Deliveries. The daily delivery function for elevators represents the rate at which growers wish to deliver grain. If the elevator storage fills before all overflow has been received restrictions are usually placed on the delivery rate for the remainder of the harvest. The grower then has three options : to continue harvesting and store grain on the farm as best he can, to continue harvesting and lease or hire more on-farm storage or to reduce his harvesting rate and risk weather damage and the expected reduction in yield. In each case he bears some cost, so the model uses the hire temporary storage alternative to provide a reasonable estimate of this cost. A unit charge ($/tonne day) is applied to all grain not received on the correct day on every day until it can be accepted at the elevator.

Handling Facility Costs. There are two categories of elevator costs : the cost of providing and maintaining the facility and the cost of receiving and outloading grain. The opportunity cost of elevators and silos is assumed to be zero, so capital costs are ignored. Maintenance costs are broken into two components; the first, covering painting, rates etc. being proportional to silo capacity and the second, covering electrical and mechanical work, proportional to elevator lifting capacity. Operating costs include labour, motive energy and pest control fumigants. Labour cost during the harvest period is a direct function of the time the elevator is open, number of employees and the average wage rate. At other times during the year employment is casual, so outloading is costed on a per wagon loaded basis. Motive energy and fumigants represent a small proportion of the cost and are assumed proportional to elevator throughput.

Terminal costing is similar, the exception being labour costs. At terminals, unloading rates do not vary greatly between shifts so the cost of receiving grain can also be calculated on a per-unit basis.

Grain Handling Efficiency. Efficiency is measured in terms of facility throughput for each unit of cost. Whilst it is unfair to compare facilities outright, due to the effect of grain mix and delivery patterns, this measure can be used to identify facilities warranting closer investigation.

The Transport Task and Costs. Road and rail transport of grain between elevator and terminal is considered separately. There are very few elevators which outload to road and they require a small proportion of the available road haulage fleet, so there is little difficulty in providing sufficient transport regardless of the size or duration of the harvest. Because of this, efficient scheduling is much less important than for rail transport, so total distance travelled and tonne-km are the only operational measures required. Transport costs in the road industry are well defined and readily available so both costs and charges are easily calculated.

Rail transport of grain, unlike road transport, consumes a very significant proportion of rail system resources, particularly in the harvest period. Consequently efficient operation of the system is important, with time savings of hours significantly increasing the carrying capacity of the system. The model prepares average values of each component of round trip time as well as ratios between them. The size of the rail transport task is measured by train-km and tonne-km travelled, the number of trains required each day and the tonnage and number of trains carried on each link. Rail charges are readily available, however costs are difficult to identify because of the joint use problem and the difficulty of obtaining accurate and suitable data.

CONCLUSION

The discussion above has outlined the concepts and structure of the policy-sensitive model of the Victorian grain handling system. The model is now in the final stages of being coded for the University of Melbourne VAX computer and will be ready for full-scale testing using data for the 1980/81 harvest year. This testing will consist of two phases.

Firstly, model verification will be undertaken involving input data corresponding to existing physical facilities and current operating policies to confirm that model outputs correspond with what is observed in the real system. In this phase, it is anticipated that data for previous years also will be utilised.

Secondly, the model will be operated under a large number of different sets of input data, reflecting alternative capital investment and operating policy options which may include, for example, the following.

Capital Investment Options.

Location of new country storages.
Improvement of loading/unloading facilities at terminals.

Quantity and type of new rail rolling stock.
Increases in rail siding capacity at country storages.
Rail network changes.

Operational Options

Priority rules for allocation of trains to links.
Restriction of grain types received at specific locations.
Grain carry-over storage : quantity by location.
Use of on-farm storage.
Wagon type restrictions at terminals.

This second phase will serve to test methods of representing policy options in input data as well as the validity of the model's analysis and evaluation procedures. The different computer runs undertaken in this phase will exemplify the manner in which the validated moded will ultimately be applied in practice.

REFERENCE

Australian Bureau of Statistics - Victorian Office (1979). Victorian Year Book, No. 93, 1979.