OPTIMAL SCHEDULING OF ROAD VEHICLES
IN THE MARYBOROUGH SUGARCANE
TRANSPORT SYSTEM

By

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KEYWORDS: Transport Scheduling, Optimisation, Strategic Planning.

Abstract

THE SCHEDULING of a road transport system within a sugar mill is a complex

task due to the need to effectively service several harvesters at different

locations and keep a continuous supply of cane for mill processing, given a

limited vehicle and trailer fleet. Mathematical programming methods provide a

means to assist traffic officers to schedule the pick up of full trailers from the

farms more efficiently. This reduces the time that harvesters spend waiting for

empty trailers and reduces vehicle idle time, leading to a potential reduction in

the number of vehicle shifts needed and a more reliable cane supply. A

mathematical model, which can be used on a standard PC, was applied to assess

the transport impacts of strategic options that the Maryborough region is

investigating. These options, which could not be evaluated in the past in such
detail, include transporting the cane trash to the mill for electricity co-generation

and extending the time window of harvest to improve transport efficiency. When

the model is used as an operational tool, the average vehicle idle time at the mill

is predicted to be reduced by about 90%, and the number of vehicles needed to

service the harvesters could be reduced. The model is adaptable to other sugar

mill regions based on road transport including a just-in-time harvesting to

transport to milling interface.

Introduction

Several mill regions in Australia are exploring opportunities for reduced costs of

sugar production, particularly in the harvesting and transport supply chain. One such

opportunity is a more efficient cane transport system that better integrates with harvesting

activities. In advanced sugar producing countries such as Brazil, South Africa and the United

States, sugarcane is transported from the farm to the mill via road transport, whereas in

Australia, cane is primarily transported via a narrow gauge rail system.

If the arrival time of vehicles transporting full trailers of cane to the mill were equally

spaced and aligned with the mill throughput rate, there would be no queue at the mill and no

mill idle time. It is difficult to achieve an efficient schedule using manual methods in a traffic

office due to varying travel distances between the farms and the mill, and capacities in trailer

infrastructure. Another complexity is that, in most Australian mills, harvesting is conducted
in daylight hours only while both the mill and transport operate continuously. To accommodate this, there are up to 16 hours of infield storage in the trailers when waiting for transportation to the mill. In practice, mill traffic officers prefer to have a queue of vehicles/trailers in the mill yard rather than to risk idle time, as idle time can lead to an expensive mill stoppage. If the arrival time of vehicles to the mill were better scheduled, the mill could achieve a much shorter queue at the mill with minimal risk of mill stoppages. This would also allow the mill to operate the transport system with fewer vehicles and a higher mill crush rate as a result of a more reliable cane supply.

Despite road transport being the primary means of transporting cane to the mill in major sugar producing countries, analytical tools for optimal scheduling of sugarcane transport has mainly been addressed in the case of rail transport. Abel et al. (1981) was the first to develop a sugarcane railway-scheduling model for the pick-up and delivery of cane rail wagons from the rail sidings. Pinkney and Everitt (1997) transformed this model into a user-friendly tool for traffic officers. Scheduling road transport for sugarcane has mainly been attempted using simulation (Hansen et al., 2001). Such models have been used to test different transport operation scenarios to reduce the number of vehicles required.

This paper focuses on the development of a model, through an SRDC-funded project, to schedule road transport vehicles to pick up full trailers of cane from the loading pads located on the farms. Application of the model to a range of potential strategic options is also a focus of this paper.

**Methodology**

The scheduling problem for sugarcane road transport involves the scheduling of several vehicles from the mill to pick up full trailers from the loading pads and return to the mill. Loading pads serve the same purpose as sidings in a rail transport system and are located across the cane land. In Maryborough, there is usually more than one small loading pad (capacity of 3 or 4 trailers) on each farm, whereas in NSW, the loading pads are larger and often more than one farm will share a loading pad.

In developing a model to represent the road transport system, the key decisions were to develop a sequence of loading pads that each vehicle is to visit to pick up full trailers. The model objective was to minimise a combination of vehicle idle times and queue times at the mill, which would lead to a maximum efficiency of vehicle usage. Several physical and policy constraints had to be incorporated, which are listed as follows:

- A trailer cannot be picked up until the harvester has filled it.
- A first come first served principle at the mill, in that a vehicle cannot jump the mill queue.
- Minimum and maximum operating hours for each vehicle on each day.
- Maximum number of trailers at the loading pads and in the mill yard.
- Compatibility of vehicles to trailers and to loading pads. Some vehicles are not allowed to transport b-double trailers, and some loading pads cannot accommodate b-double trailers due to road accessibility restrictions.

An additional complexity in the Maryborough transport system is the need for quick hitching, which is the dropping off of a full trailer at the mill and proceeding to pick up the next full trailer. The full trailer will sit at the mill yard for processing at night. Quick hitching
is required to provide the capacity to quickly relocate trailers in the event of a harvester disruption or breakdown. The optimisation model developed is formally called a mixed-integer linear programming problem, and the reader is referred to Higgins (2005) for a complete mathematical description of the model.

In practice, vehicles also transport empty trailers back to the farms after they have been processed at the mill. When harvesters operate during daylight hours only, as in the Maryborough case study, the transport of empty trailers is not an issue, because there will usually be enough supply of empty trailers at the farm to prevent delays to harvesters waiting for trailers. However, if the harvesters operate continuously, and a just-in-time system is incorporated, then harvesters will need to receive empty trailers in a timely manner to prevent them from being delayed. This situation would require some modifications to the model presented here.

The model was far too complex to be solved using commercial software packages dedicated to optimisation. Instead, a heuristic was coded in FORTRAN to find a near optimal solution. For the Maryborough case study, a good solution could be achieved within about 15 minutes CPU time on a fast Pentium 4 PC.

Application to the Maryborough Case Study

The Maryborough sugar region contains 15 600 hectares of land under sugarcane, about 144 farming enterprises and 25 harvesting groups. Currently, about 24 vehicles are operating to transport the trailers of cane to the mill each day. The mill has about 128 physical trailers with a capacity of 25 tonnes of cane and 21 trailers with a capacity of 40 tonnes of cane, giving a total of 149 trailers. While this represents the physical fleet, many trailers will be transported to and from the farms more than once per day, since the mill processes about 220 full trailer loads of cane per day.

The Maryborough region has 960 loading pads spread across the cane land. The average distance of a pad to the mill by road is 25.4 kilometres with an average one-way travel time of 57 minutes.

For the analysis, a 48 hour planning horizon was selected using the actual trailer demands by harvesters of the 15th and 16th of July 2003 within the Maryborough region. There were 445 trailers transported to the mill during that period, though without any mill stoppages or slow crush rate, the mill would average about 520 trailers.

Maryborough Sugar Factory has records of all delivery of trailers from the farms to the mill, as well as the actual schedule of vehicles, which shows the queue times at the mill. From the recorded data, the average queue time of trailers at the mill was 38 minutes for the 15th and 16th July 2003, compared to about a 40 minute average for the entire harvest season.

Traditionally in Maryborough, a vehicle will usually service a designated harvester while the harvester is operating. This means that a vehicle will continuously travel between the mill and the farm where the harvester is located, until the last trailer at that location has been transported to the mill, after which, the vehicle may transport full trailers from another harvester.

The main advantage of this method of scheduling is that the driver of the vehicle does not require new instructions on travel routes until the full trailers of the current harvester(s) being served by that vehicle, have been transported to the mill. The main disadvantage is that it leads to irregular arrival of full trailers back at the mill, which produces
queues. This irregularity is increased because of differences in vehicle routes and average round trip time, which are attributed to harvester operators starting and finishing at different times of the day.

Figure 1 shows the actual queue time for each of the 445 trailers scheduled over the 48 hour planning horizon. The average queue time was 38 minutes, which varied depending upon the time of the day.

Many harvesters start operations between 5 a.m. and 8 a.m. and finish between 4 p.m. and 6 pm. In Figure 1, these were the times of the day with the longest queues. It is very expensive for the mill to be idle, and the manual method of scheduling the pick up of full trailers leads to highly variable queue time as shown in Figure 1. As a result, the traffic officer aims to have a queue time of about 20 minutes to minimise the risk of idle time.

![Fig. 1—Actual queue time (h) recorded for each of the 445 trailers scheduled during the planning period](image)

Application of the model produced a schedule with queue times shown in Figure 2. The average queue time is about 3 minutes and the variability was much less than the manual method (Figure 1). While the Maryborough Sugar Factory would warmly welcome the shorter queue times shown by the model, they would still want a minimal level of stock queued at the mill to minimise the risk of mill stoppage.

In Figure 2, 30% of trailers have a queue time of less than 2 minutes at the mill. If vehicles have no unexpected delays (e.g. slow traffic on roads), such a low level of queue time would be low risk.

However, the model results of Figure 2 do not account for unexpected delays such as wet weather stops, whereas the actual queue times in Figure 1 do.

With the variability of queue times produced by the model (Figure 2) being substantially less than using the manual method (Figure 1), the traffic officer would be able to aim for a much shorter minimal queue time at the mill than the current goal of 20 minutes.
Given that 445 trailers were scheduled over the two-day planning period, a reduction in average queue time of eight minutes would reduce the total queue time per day by over 24 hours, which is equivalent to reducing the number of vehicles by one.

In 2005, the Maryborough Sugar Factory plan to use the model to schedule the pick up of full trailers from the loading pads during the night. A night schedule will be more reliable than a day one as it will less prone to disruptions (e.g. harvesters), and should need minimal rescheduling. Anticipated benefits will be shorter vehicle queues in the mill yard and better forward knowledge of stocks of cane in the yard throughout the night.

![Queue time (h) for the 445 trailers when the transport schedule was produced by the model.](image)

**Fig. 2—Queue time (h) for the 445 trailers when the transport schedule was produced by the model.**

**Application of model for strategic scenarios**

The sugar industry at Maryborough is considering the option of producing electricity from the cane trash, which meant that the whole crop had to be harvested and transported to the mill. As one would expect, transporting the whole crop to the mill would require increased capacity in vehicles and trailers. However, modelling such a scenario does not produce one single solution, since the length of time harvesters are waiting for trailers can be traded off against investment in extra capacity. This is considered in the following list of scenarios formulated by the Maryborough region:

1. Model the existing system.
2. Transport the whole crop to the mill.
3. Transport the whole crop to the mill with harvesting conducted over a 20 hour period each day.

In the existing system, the 25 harvesters operate within daylight hours (between about 4 a.m. and 6 p.m.) as shown in Figure 3 (left), which also shows that most of the harvesting is conducted between 6 a.m. and 4 p.m. The hours of operation per day does vary
across harvesters and it depends upon the amount of cane each harvester harvests per day. In Figure 3 (right) the harvesting is staggered over a 20-hour time period. Table 1 shows the key model inputs for each harvester for the base case and full trash scenarios.

Average trailer weights vary considerably across harvesters, with some harvesters using a combination of 25 tonne and 40 tonne trailers. Under a full trash scenario, there is 11% more material being transported to the mill as a result of the extra trash.

The average trailer weight in full trash is 69% of that of the base case. This leads to the increase in trailers filled per hour and loads per day for each harvester (Table 1).

![Fig. 3—Hours of harvest for the base (left) versus the 20-hour time window scenario (right).](image)

The sugarcane road transport model was applied to produce a schedule for each of the scenarios and the results are shown in Table 2. The number of vehicles used is a set parameter for the model, and Table 2 shows the impact on each scenario for two different numbers of vehicles.

Table 2 shows that reducing the number of vehicles by 1 in the base case leads to a substantial increase in delays to harvesters waiting for empty trailers. Using 37 vehicles leads to a total of 50 hours of harvester waiting time, which is about 25% of the total harvest hours. Under the full trash scenario, there is a major increase in the number of vehicles and trailers used.

The total delays-to-harvesters are also much larger than the base case, which was reduced by adding more vehicles. These long delays to harvesters are also attributed to limited capacities in the loading pads and the faster filling of trailers under a full trash scenario.

With full trash harvesting, several more quick hitches are required, which means the mill yard would need an extended capacity to hold the additional full trailers. This extended capacity may require capital investment or land acquisition.

Increasing the time period of harvesting when transporting full trash to the mill is one opportunity for reducing the extra transport costs under a full trash scenario.

A harvesting time period of 20 hours would remove the transport congestion during the daytime, which would lead to reductions in trailers, vehicles and quick hitches required.

A further analysis would be required to look at whole-of-system solutions that balance the costs of transport with the costs of harvesters waiting for trailers.
Table 1—Changes in model inputs from base case to full trash.

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<th>Harvester Number</th>
<th>Start time</th>
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<th>Average trailer weight (t)</th>
<th>Trailers per hour</th>
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Table 2—Impacts on transport for the different scenarios.

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Acknowledgements

The authors acknowledge Mr Glyn Peatey of the Maryborough Sugar Factory Ltd along with other members of the steering group, for their contributions in helping to formulate the real life system, evaluating the model outputs, and progressing the research towards implementation.

Thanks also go to Mr Luis Laredo of CSIRO Sustainable Ecosystems for the production of the GIS maps and to the Sugar Research and Development Corporation for their major financial contribution through project CSE005 and CSE010. Figure 1 incorporates data that is © Commonwealth of Australia (Geoscience Australia) 2002.
REFERENCES


