EVALUATION OF METHODS TO REDUCE HARVEST-TO-CRUSH DELAYS USING A SIMULATION MODEL

A BARNES [1], E MEYER [2], AND E SCHMIDT [2]

[1] *Agricultural Research Council, Institute for Agricultural Engineering, Private Bag X519, Silverton, 0127*

[2] *South African Sugar Association Experiment Station, Private Bag X02, Mount Edgecombe, 4300, South Africa*

Introduction

Long delays between the harvesting and crushing of sugarcane and the associated deterioration of cane quality have long been recognised as a major source of loss to the sugar industry. Different methods of reducing harvest-to-crush delays need to be evaluated without expensive and time consuming experimentation on real world harvesting and delivery systems. A joint project between the Agricultural Research Council, Institute for Agricultural Engineering, the South African Sugar Association Experiment Station and the School of Bioresource Engineering and Environmental Hydrology of the University of Natal was therefore initiated to develop a computer based model which could be used to evaluate different methods of reducing harvest-to-crush delays. This project was run as a Masters degree project and is documented fully in Barnes, (1999), Barnes, (1999), Barnes AJ, Hansen *et al*, (1997), Barnes *et al* (1998), Barnes *et al*, (1997), Hansen *et al*, (1998), Hansen *et al*, (1998), Barnes *et al*, (1999).

The model ,which is a simulation model, was developed using data collected from the Sezela mill area. Various strategies for reducing harvest-to-crush delays, such as altered burning and delivery schedules and implementation of harvesting groups were investigated for the mill area. Data were collected from interviews with mill, haulier and extension personnel and growers, mill records and by means of surveys of harvesting and transport systems used in the area. Detailed data on millyard operations were derived from a previous simulation model of the Sezela millyard and additional time studies that were performed in the millyard.

Model Formulation

The Arena Simulation System was chosen as the software with which to develop the model. Simulation modelling as it was used in this project, involves using time delays to describe various processes such as cutting, loading or transport and combining them in a manner, which represents the way that they interact in the real system. The time delays can be described using frequency distributions, which are sampled each time the delays are required in the model. Entities, which may represent tons of cane or trucks, are passed through the model, interacting with various system resources, such as loading and offloading equipment and space available in stockpiles. By recording statistics on times and numbers in queues, the variability and interactions in the system can be analysed. It should be noted that the figures obtained from the model are point estimates of variables that have a range of possible values, which are described by standard deviations.

The model was developed at the scale of a particular mill and the area of farms supplying it with cane, since many of the problems leading to excessive harvest-to-crush delays were thought to be the results of interactions between harvesting, delivery and milling schedules. All operations from burning or cutting up until the feeding of cane into the mill for crushing were included, since this is the time period in which deterioration of cane quality occurs. Each individual farm, or combination of farms supplying cane to the mill, with their different systems of harvesting and transport had to be represented to simulate the effect of cane being delivered from various points and at different timings. A flow diagram of some systems represented in the model and the general structure of the model is shown in Figure 1.

Data for the schedules and systems used on the individual farms were entered into an Excel spreadsheet which had macros that created text files that the Arena software read into the model. This was particularly useful in setting up the different scenarios, which were run in the model to evaluate different methods of reducing harvest-to-crush delays. Each run was set to a duration of 20 weeks so that variability in the model's output caused by the variable process times used, could be averaged out to provide a reliable estimate of average harvest-to-crush delay.

Model Validation

Validation of the model was performed by running the model with inputs set up to approximate as closely as possible the existing situation at the Sezela and then by comparing the model output with observed data. In a study performed by Illovo Sugar at the mill, the time of arrival of trucks at the mill gate was recorded over a 3-week period. This data was compared with the pattern of truck arrivals at the mill gate in the model and showed that, although some discrepancies occurred, due to the method of truck despatching used in the model, the model simulated reality reasonably well.

For miller-cum-planter (MCP) cane at Sezela, records showed that the average harvest-to-millgate delay was of the order of 57 hours. MCP cane mostly falls into the category of cane offloaded directly onto the spiller tables and thus this harvest-to-millgate delay would be very close to its harvest-to-crush delay. The harvest-to-crush delay simulated by the model for cane offloaded directly onto the spiller tables was of the order of 35 hours. This discrepancy was attributed to the fact that mill and harvesting and transport equipment breakdowns, weather stoppages and delays due to managerial discretion, were not allowed for in the original model.

In a follow up project, the model was altered to try and allow for breakdowns and weather stoppages (Barnes, 1999). Although the simulated delay for spiller offloaded cane could only be

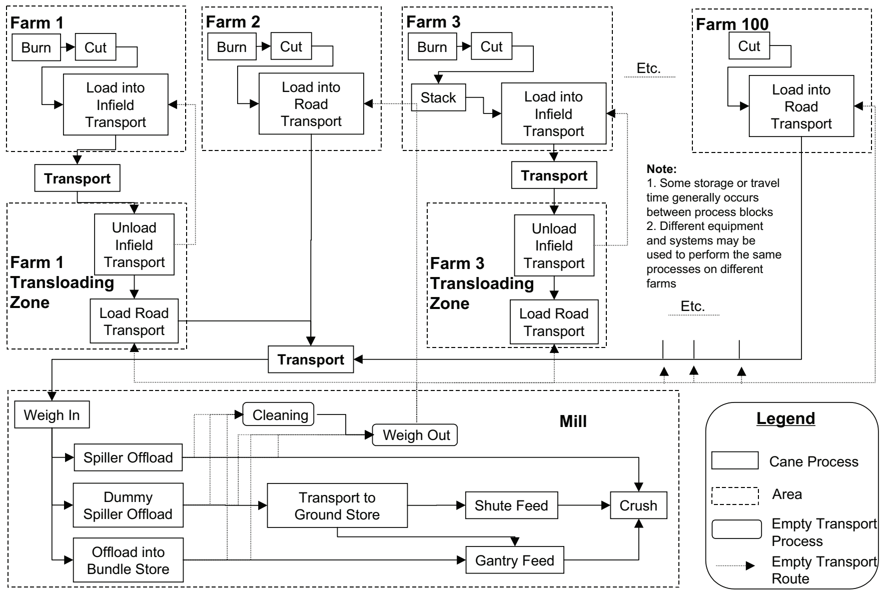

Figure 1. Structure of harvesting and delivery system in model.

increased to 40 hours, it was shown that the percentage changes in overall average weekly harvest-to-crush delays from the existing situation, for the various scenarios that were investigated, were very similar to those obtained with the original model. This demonstrated that the trends indicated by the model were valid, despite the fact that it under-simulated harvest-to-crush delays. The under-simulation can be attributed to the fact that a way was still not found to model the influence of managerial discretion on the harvesting and transport system. There was also a significant increase in the variability of the results obtained with the altered model due to the random nature of breakdowns and weather stoppages that were modelled.

Scenario Runs and Results

Various scenarios were run to evaluate the effect of different proposed methods of reducing harvest-to-crush delays. The results of these scenarios, in terms of average weekly harvest-to-crush delays are given in Table 1.

Existing Situation

Under the existing situation in the Sezela Mill Supply area the average weekly harvest-to-crush delay was estimated by the model to be 38,2 hours. Point estimates of the average weekly delays incurred by cane in the various stockpiles in the existing system is given in Figure 2. The long delays incurred in the NightBurntCut and BurntCut (burnt cane waiting to be cut) stockpiles are due to the practice of only burning cane every second or third day that occurs on many farms in the Sezela mill area. Cane burnt on a Monday morning may have to wait until Tuesday or Wednesday afternoon before it is cut, thus incurring an additional 24 to 48 hour delay. The long delays in the transloading zone stockpiles (Bundle Transload and Spiller Transload) are caused by the differences in harvesting and delivery schedules. Harvesting occurs Monday to Saturday and on some farms, delivery occurs Tuesday to Sunday or seven days a week, so stockpiles have to be built up in the transloading zones during the week to ensure that there is cane to transport on a Sunday. A similar reasoning can be applied to the long delays in the millyard stockpiles (BundleStore and GroundStock). The mill crushes Monday to Sunday and the bulk of deliveries to the mill arrive from Monday to Saturday, and so cane has to be built up in the millyard stockpiles during the week to supply the mill on a Sunday

Balanced Delivery Plan

The principle of balancing deliveries of cane through the course of the week was to try and reduce periods of congestion at the mill, decrease vehicle turnaround times and therefore make vehicles available again more quickly. The model indicated that this strategy would not be particularly effective, only reducing

Table 1. Results of scenario runs.

No	Scenario	Original Model	
		Average Weekly Delay (h)	% Change from Existing Situation Scenario
1	Existing Situation	38.2	
2	Balanced Delivery Plan	39.7	3.9
3	Daily Burn Schedule	29.7	-22.3
4	Cutting Green Cane	25.8	-32.5
5	More Farms on Direct Delivery	35	-8.4
6	Mon-Sun Harvesting	19.4	-49.2
7	Mon-Sat Crushing	27.4	-28.3
8	Single Central Haulier (100 Vehicles)	39.2	2.6
9	Single Central Haulier (80 Vehicles)	39.8	4.2
10	Harvesting Groups	26.3	-31.2
11	Idealised System	12	-68.6

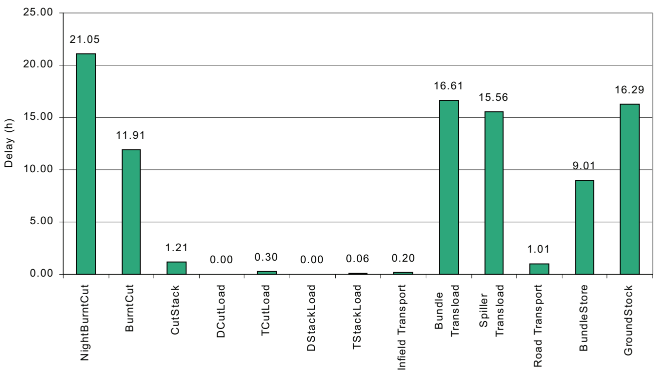

Figure 2. Average stockpile delays for existing situation scenario.

delays by approximately 3% (Table 1). One possible explanation is that, although the truck dispatching algorithm in the model ensures that the day-night and weekday distribution of deliveries to the mill is balanced, it does not ensure that the deliveries are evenly distributed within a particular 12 hour period and therefore congestion may still occur at periods of peak arrivals

Improved management of burning schedules

A daily, mornings only burn schedule should decrease delays by ensuring that no cane stands in the field overnight, waiting to be cut. The model indicated that such a strategy would decrease delays by approximately 22%. One problem with this scenario is that, on farms with Daily Required Deliveries (DRD) less than approximately 30 tons, cane will have to wait a day or two in the field or transloading zone, after being cut, until sufficient cane has been accumulated to provide a full load for a truck. Therefore, for the full effect of better management of burning schedules to be useful, farms with smaller DRD's need to practise some sort of group harvesting. By wholly eliminating burning from the harvesting system, delays in the model were decreased by approximately 32% (Table 1, scenario 4).

Farms Delivering Direct to the Mill

In this scenario, 34% of the tonnage delivered to the mill was delivered without transloading, thus eliminating delays on the transloading zones for that cane. This strategy only produced an approximately 8% decrease in overall average harvest-to-crush delay, since relatively little of the total tonnage could be delivered direct. In Figure 3 the point estimate of overall average weekly harvest-to-crush delays is broken down into the average weekly delays for components of cane that are transloaded or delivered directly to the mill as well as the components of cane that are offloaded by the various offloading facilities in the millyard.

- BTIS refers to the time in system or harvest-to-crush delay for bundle cane offloaded into the bundle stockpile.
- GTIS refers to loose cane offloaded into the ground stockpile by the dummy spiller.
- STIS refers to loose cane offloaded directly onto the mill table by the spillers.

For the other offloading techniques, however, it can be seen that the delays for direct delivered cane are significantly less than those for transloaded cane, especially if the cane is delivered in loose form. The difference in delays for ground stockpiled cane and cane offloaded by spillers onto the mill tables is of the order of 15 hours.

Matching Harvesting, Delivery and Milling Cycles

Changing to a Monday to Sunday harvesting schedule produced a 49% decrease in delays in the model. It must be noted that this includes daily burn schedules which from scenario 3 (Table 1) are shown to contribute 22,3 % of this decrease in delay. The additional decrease in delays can be attributed to the fact that cane does not have to be accumulated in the transloading zone and ground stockpiles to supply cane for deliveries and crushing on Sundays.

Changing to a Monday to Saturday crushing schedule (which did not require daily burn schedules) produced a 28% decrease in delays which means that the decrease in delays due to matching harvesting, delivery and milling cycles in this scenario was similar to that in the Monday to Sunday harvesting scenario.

Use of a Single Central Haulier to Minimise Vehicle Numbers

Using a single central haulier for the entire mill area so that vehicle numbers could be reduced produced very little change in harvest-to-crush delays simulated by the model. This demonstrated that having more vehicles in the system did not cause a significant amount of congestion in the model, which would have increased overall delays. The model indicated that a minimum of 80 vehicles was required to be able to transport all the cane to the mill. This was also a result of the idealised conditions of the model – the lack of delays due to factors such as managerial discretion in the model meant that all the cane could be comfortably transported with fewer vehicles than are used in reality.

Organisation of Farms into Harvesting Groups

Organisation of farms within their areas into harvesting groups with combined DRD's of at least 100 tons made it practical for all farms to be on daily burning schedule. The decrease in delays simulated in the model produced by this strategy was of the order of 31% which is approximately 8% more than that produced with conversion of all farms to a daily burn schedule alone. The extra decrease was attributed to the fact that no

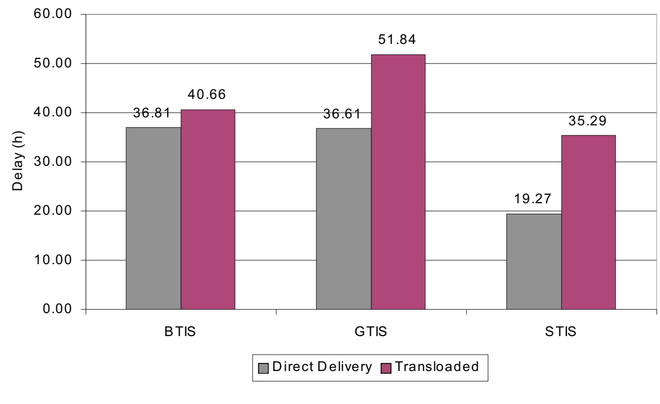

Figure 3. Point estimates of average weekly delays for different off-loading systems in the farms on direct delivery scenario.

farms had to incur overnight delays on the transloading zones while waiting to accumulate full truckloads.

Idealised System

In the idealised system scenario the model was set up with all of the most effective of the previously investigated strategies. All farms were organised into harvesting groups and assigned to cut green cane, Monday to Sundays. The farms that could deliver direct to the mill with their current harvesting systems were assigned to do so and all farms were set to deliver cane 7 days a week. This scenario produced a decrease in delays in the model of approximately 68%.

Figure 4 shows that the average weekly harvest-to-crush delay can be as low as 4.7 hours for direct delivered cane offloaded by the spillers directly onto the mill tables. Direct delivered cane stored in the bundle or ground stockpiles before being crushed incurs an average weekly delay of the order of 11.5 hours. This is approximately 7 hours greater than the delay for cane offloaded directly onto the mill tables which is same duration as is incurred in the ground stockpile. In a similar way, the delays for transloaded cane are approximately 8 hours greater than those for direct delivered cane which is the duration of delays incurred in the spiller cane transloading zone stockpiles.

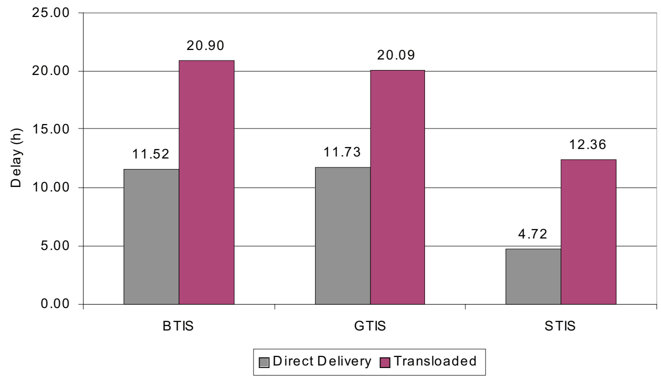

Figure 4. Point estimates of average weekly delays for different off-loading systems in the idealised harvesting and deliver scenario.

Conclusions

The application of simulation modelling to the investigation of harvest-to-crush delays in the sugarcane harvesting and transport system was reasonably successful. The use of simulation modelling made it possible to model what is a complex system which would have been very difficult to realistically represent using other analytical techniques such as linear programming, scheduling algorithms or queuing theory. Another advantage of using simulation modelling was that all the components of the harvesting and delivery system could be integrated, so that a holistic view of the system could be obtained to address the interests of both growers and millers. It also made it possible to represent the variability inherent in the system by including frequency distributions to describe different process times. One drawback of the complexity of the model was the long runtime that it required. The variability inherent in the system also means that the results of the model are variable, which has to be taken into account when considering their implications for a harvesting and delivery system. When looking at the results, it should also be remembered that some factors such as management discretion could not be included in the model.

The results of the experimental runs performed with the model indicated that the largest delays occur where burnt cane is waiting to be cut, in the transloading zones and in the millyard stockpiles. The delays in the stockpiles were the result of differences in harvesting, delivery and milling cycles and it was evident that the most significant decreases in harvest-to-crush delays can be brought about by matching these cycles as closely as possible. Changing to daily burn schedules had a marked effect on delays and was the major source of decreases in delays when individual farms were converted to harvesting groups, enabling larger areas of cane to be burnt at one time.

The model could now be reasonably easily applied to other mill areas. It would be necessary to perform a survey of the harvesting and delivery systems used in the particular area and to obtain records from the mill on information such as farm DRD's, delivery periods and hauliers, which could then be used to set up the input spreadsheets for the model. If harvesting and delivery systems were encountered that are not used in the Sezela mill area (such as mechanical harvesting), these would have to be added to the model. Furthermore, a study of the particular millyard would have to be performed to provide the information required to adjust the millyard section of the model.

REFERENCES

Barnes AJ, (1999). Simulation Modelling of sugarcane harvest-to-crush delays. MSc Eng. Thesis, School of Bioresources Engineering and Environmental Hydrology, University of Natal Pietermaritzburg, South Africa.

Barns AJ, (1999). Alterations to harvest-to-crush delay simulation model. SASEX Internal Report.

Barnes AJ, Hansen AC, de la Harpe ER and Lyne PWL, (1997). Simulation modelling of sugarcane harvesting and transport delays. Agricultural Engineering in South Africa, Vol 29, p57-68.

Barnes AJ, Hansen AC and Lyne PWL, (1998). Investigation of sugarcane harvest-to-crush delays using a simulation model. Agricultural Engineering in South Africa, Vol 30, p96-99.

Barnes AJ, Meyer E, Hansen AC, de la Harpe ER and Lyne PWL, (1997). Simulation modelling of sugarcane harvesting and transport delays. Proc S Afr Sug Technol Ass 72: p18-23.

Barnes AJ, Meyer E and Schmidt E, (1999). Evaluation of methods to reduce harvest-to-crush delays – Sezela case study. S Afr Suc Ind Agron Assoc. AGM. p56-63.

Hansen AC, Barnes AJ and Lyne PWL, (1998). An integrated approach to simulating sugarcane harvest-to-mill delivery systems. Proc Am Soc Agric Eng, An Int meeting, Orlando, Florida USA. Paper No 986099.

Hansen AC, Barnes AJ and Lyne PWL, (1998). Using computer simulation to evaluate sugarcane harvest-to-mill delivery systems. Proc Am Soc Agric Eng, Conf on Computer in Agriculture, Orlando, Florida USA. P98-107.