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Improving the Efficiency of Cane Harvesting in the Mackay Sugar Industry

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Abstract

The cane harvesting and transport process is a high cost activity for the Australian sugar industry. Opportunities to reduce the cost of this activity are discussed in this paper. The discussion specifically focuses on the Mackay sugar industry which, in terms of production area, is the largest single cane producing region in Australia. It is also one of the regions which could benefit most from improvements to cane harvesting and transport procedures. A review of cane harvesting and transport procedures is presented and areas where efficiency could be improved were identified using the Automatic Cane Railway Scheduling System. Cost savings appeared to be achievable in both the sugar-milling and cane-growing sectors of the industry mainly through changing the structure, size and operational basis of harvesting groups, and by upgrading mill transport infrastructure. In the Mackay sugar industry, the group enlargement process has been slow relative to other cane producing regions in Australia. The reasons for this are complex and the economic and non-economic factors which may reduce the incentive for the industry to adopt more efficient practices are discussed.

Introduction

The cane harvesting and transport process is a high cost activity for the Australian sugar industry and there appears to be scope to improve the efficiency of this process. The potential to lower cane harvesting costs has been recognised for some time, particularly during the 1980s when a number of studies examining harvest-transport efficiency were conducted (Petersen *et al.*, 1984; Page *et al.*, 1985; Ridge and Dick, 1985; Connell and Borrell, 1987; Ferguson, 1987; McWhinney *et al.*, 1988). Most recently, Ridge *et al.* (1996) and Brennan *et al.* (*in press*) have further quantified the extent of possible savings for the in-field harvesting sector. The main cost-saving measures identified by these studies are reviewed below.

Main features of cane harvest-transport systems

Cane harvesting is carried out over a 20-22 week period, commencing in June, every year. Harvesting and transport should be regarded as a single process, commencing with the cutting of cane in the field through to its arrival at the mill gate. At the interface of this process is delivery of cane by growers to a number of delivery points along the mill transport network which in Mackay, and most other Australian cane-

producing regions, is a system of narrow-gauge railways. From the delivery point (commonly referred to as a siding), the mill is responsible for transporting the cane to the mill, where it is then crushed. Cane deteriorates rapidly after harvesting, necessitating a high level of coordination between the harvesting groups and the mills. The interdependency of the in-field and mill components of this process is a key feature of cane harvesting.

Cane harvesting and transport is a capital intensive operation. Currently a harvester and two cane-hauling vehicles costs in excess of \$500 000. The mills also invest substantially in transport infrastructure. Growers form into groups for the purpose of harvesting cane. A group describes the farms, or single farm in some cases, which form a single harvesting contract. Grouping arrangements are determined by negotiations involving growers and millers, and are subject to Local Board Awards. Group sizes (the tonnes of cane harvested by a group) vary considerably in the Australian industry. In all regions group sizes have gradually increased, largely in response to the rising cost of purchasing harvesting equipment (Table 1).

Table 1. Average group size (tonnes per harvester) on a district basis and the percent increase from the previous five years.

Year	NSW	%	South	%	Central	%	Burdekin	%	North	%
1970	n/a		6,522		6,137		12,582		11,873	
1975	18,535	n/a	9,353	43	9,882	61	23,149	83	14,780	24
1980	31,465	70	10,649	13	9,814	0	25,176	8	15,742	7
1985	31,338	0	12,112	14	8,923	0	26,808	6	16,679	6
1990	37,359	19	13,895	15	12,774	43	35,827	33	23,566	41
1995	65,454	75	19,478	40	20,820	63	49,896	40	39,580	67

Source: Brennan *et al.* (in press)

In Australia, group harvesting may take on several different forms in terms of the ownership arrangements for groups, and these are often classified into five categories: (A) growers cutting their own cane, (B) growers cutting their own cane and others (farmer-contractor), (C) group of growers cutting own cane (cooperative ownership), (D) group of growers cutting own cane and others, and (E) independent contractors with no farm involvement. These categories often vary from each other with respect to the level of investment in harvesting equipment and the size of the harvesting group. Overall, the farmer-contractor (category B) and independent contractor (category E) categories have emerged as the most common arrangements, chiefly because they allow economies of scale to be realised. The size of harvesting groups falling into these two categories varies considerably, as does the type and age of harvesting equipment used by these groups. Growers who cut their own cane (category A) also operate a wide range of equipment. Second-hand harvesters, up to 20 years old, are commonly used by these growers because harvester throughputs in this category are usually too small to economically justify the use of new equipment. This harvesting category is most prevalent in the Central region. Cooperative harvesting groups (category C) dominate the NSW industry, are typically large and operate modern

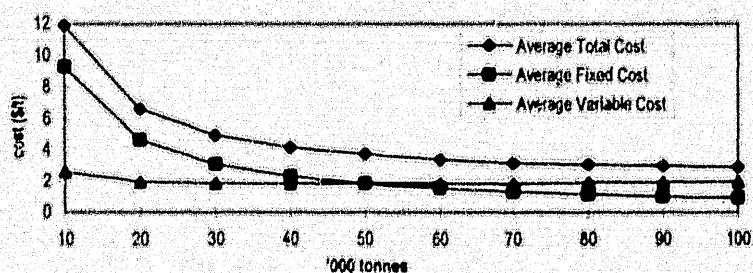
equipment. Although there are very few cooperative groups in Queensland regions, their popularity is expected to increase.

Opportunities to reduce harvesting costs

Infield harvesting costs

A number of studies have shown that group harvesting-costs can be reduced by increasing the size of harvesting groups. The behaviour of infield harvesting costs with respect to group size has been described in detail by Ridge et al (1996) and Brennan et al (in press). Figure 1 shows the response of harvesting costs to increasing group size for a harvesting group, with the fixed and variable (fuel, repairs, labour) and total cost curves. These curves describe a 'typical' harvesting group operating a new cane harvester and two cane-haulout vehicles. A large component of group harvesting-costs comprise fixed costs and increasing group size provides a means to reduce these costs, particularly the high capital costs associated with operating harvesting equipment. Cost curves differ for older equipment and an alternative strategy commonly used by group operators to reduce fixed costs is the operation of small groups using older equipment. There are, however, a number of disadvantages associated with this strategy. These include forgoing the benefits of technical advances embodied in modern harvesting equipment and reductions in efficiency of other inputs in the harvesting process, such as labour productivity. Also, the combined effect of many small groups operating at the same time imposes costs on the mill transport system, and this is discussed later in the paper.

For any given harvester-haulout arrangement there is no ideal group size for the industry because harvester operating conditions in the field, and mill transport arrangements impact strongly on the minimum costs achievable by individual harvesting groups. Mill transport arrangements which impact on group harvesting costs include the number of mill delivery points, which determines the haul distance from the farm the siding, and the mill transport schedules which determine the availability of cane bins and the ability of large groups to cut cane without interruption.



Source: Brennan et al. (in press)

Fig. 1. Cost per tonne vs seasonal throughput of cane harvester.

Cane transport to mill

There are inseparable linkages between the in-field harvesting process and the mill-operated transport system, primarily as a result of the deterioration problems associated with chopped cane. The basis of mill transport scheduling is to maintain a continuous supply of fresh cane to the mill. Furthermore, the mills endeavour to minimise the cut-to-crush delay, reflected in commercial cane sugar (CCS) values, and to lower costs by reducing number of locomotive shifts required to transport the daily allotment of cane to the mill. In addition, rationalising the numbers of locomotives, cane bins and sidings is a desirable measure to maximise the efficiency of capital. It was noted in the previous section that mill transport arrangements impact on the efficiency of harvesting groups. Similarly, grouping arrangements impact considerably on mill transport efficiency. For the mills, group amalgamation, resulting in fewer but larger groups, is desirable because a small number of groups operating in each location means fewer sidings are required and simpler transport schedules. In addition, the number of harvesters operating on any one day, their reliability, the movement of these harvesters from one transport line to another, and the spread of harvesting hours in a day affect mill transport costs.

A case study of harvest-transport arrangements in the Mackay Sugar Industry

This section of the paper quantifies the cost-reducing measures which were identified in the preceding review, including the impact of in-field group arrangements and milling transport arrangements on each others' costs. The Mackay region was chosen for this exercise because its harvesting system is dominated by small harvesting groups and there appears to be considerable scope to improve the efficiency of harvesting in this area. Along with the Plane Creek and Proserpine mills, the four mills in Mackay form the Central cane producing region.

A number of harvest-transport scenarios were designed to examine the impact of changing the number of groups in the system, as well as the spread of hours over which these groups operate, and to investigate the effects of manipulating mill transport arrangements. These scenarios were generated using the Automatic Cane Railway Scheduling System (ACRSS). ACRSS will generate a schedule for railway operations directly from specifications of railway distances, siding capacities, locomotive operating characteristics and the grower delivery data such as daily bin allotments, harvesting rates and starting times. The output is a set of computer-generated schedules.

For this exercise, five mill transport-schedules were generated. Schedule 1 acted as a control schedule, closely resembling the harvest-transport situation of a Mackay mill with 46 harvesting groups operating in morning harvesting hours. This involved modelling a 'typical' day using data from a Mackay sugar mill. Schedule 2 was generated from the same input data used in Schedule 1, with the exception of the starting times of the harvesting groups. Schedule 2 allowed ACRSS to choose or 'float' these times. For a floating start ACRSS determines the best starting times for

the groups according to the objective function¹. Schedule 3 varied from Schedule 2 to the extent that all limits on siding capacities were removed. In Schedule 4, the 45 active groups operating in the first three schedules were amalgamated to form 23 large groups with floating start times. The number of active sidings in the system was also reduced to 23. Some sidings were extended to have a capacity around equal to that of the largest sidings in the existing system (from 60 to 100 bins), which is realistic given that the mill regularly assesses and gradually upgrade siding capacities. Schedule 5 used the same input data as Schedule 4, except siding capacity was unlimited. The results of these schedules are discussed below and Table 2 presents a summary of these results.

Results

Table 2. Summary of results from five harvest-transport schedules.

Schedule ID	1	2	3	4	5
Number of groups on day	46	46	46	23	23
Total allotment (bins)	2362	2362	2362	2346	2346
Shifts operated	16	16	9	10	7
Locos. needed	7	7	3	4	3
Average run distance (km)	17.78	17.78	17.78	16.71	16.71
Average run time (h)	3.13	3.3	2.8	2.55	2.38
Total loco. time (h) ²	72.3	73.3	57.3	53.75	50.1
-running time	31.1	31.1	31.1	29.25	29.25
-shunting time	30.6	31.6	15.6	14	10.3
-yard delays	10.5	10.5	10.5	10.5	10.5
Number of shunts	146	151	94	84	62
Average cane age	9.26	7.56	10.42	9.44	10.40
Bins required	1899	1742	2808	1815	2691
Ratio of total bin capacity to daily allotment (%)	80	73	118	77	114
Adjusted zero hour	7:46	7:31	10:51	9:48	11:10

Extending the hours of harvest. (Schedule 2)

The number of shifts required was the same as for Schedule 1 and locomotive running and shunting (attaching cane bins to the locomotive) times were also unchanged. Schedule 2 is preferable to Schedule 1 because the average cane age was reduced by 1h 30 mins. Also less bins were required to run this schedule, with the ratio of total bin capacity to the daily cane allotment falling from 80% to 73%. The implementation of this schedule would be relatively simple, with no requirement to undertake major restructuring of infield sector. Groups would only need to alter their starting time.

¹ The design objective for the system is based on minimising some or all of the following six parameters: a) the number of shifts required, b) the zero hour, c) the average cane age at crush, d) the weighted cane age, e) the bin fleet size and f) total yard size.

² Note that locomotive time and the number of shunts are only minima values obtained by locating cane at a single point corresponding to the average distance from the mill.

Extending the hours of harvest and no siding capacity limits. (Schedule 3)

This schedule required fewer locomotive shifts than the previous two schedules because there was no limit to siding capacity; locomotives only needed to make one delivery and collection of empty bins each day. The number of shifts was reduced from 16 to 9 and was reflected by reductions in both average run time and total shunt time. The results suggest that the minimum number of locomotive shifts and minimum cane age are goals which cannot be achieved simultaneously, as demonstrated by higher average cane age for this schedule. More bins were also required because, with fewer visits to sidings, full bins spend extra time on the rail network waiting for collection. Consequently, they are not 'turned around' as quickly. This was also reflected in the ratio of bin capacity to daily cane allotment which was 118% compared to only 73% for Schedule 2. The zero hour, which is the time the mill commences crushing the current day's allotment, was also very high at 10:51 am and would be unacceptable to the mill.

Enlarged groups, extended harvesting hours, fewer sidings. (Schedule 4)

The number of shifts were reduced from 16 (in Schedule 2) to 10, with the number of groups operating accounting for the key difference between these two schedules. However, some siding capacities were increased in order to realistically accommodate the larger groups. Therefore, the reduction in shift numbers could be attributable to both the group amalgamation and siding extensions. Further research would be required to assess the precise individual contribution of these factors on the locomotive shift requirements. Again, the trade-off between shift numbers and cane age was apparent. Compared to Schedule 2, the average cane age rose by just over one hour and 30 minutes and the bin requirement increased by 73 bins with the ratio of bin capacity to daily allotment four per cent higher at 77%.

The average distance for each locomotive run fell compared to the previous three schedules because several sidings at the end of branch lines were removed. This schedule was also characterised by fewer shunts because there were fewer active sidings in use and the cane supply at these sidings was concentrated, meaning more cane was taken away per shunt as a result of enlarged groups.

Enlarged groups, extended harvest hours, fewer sidings, unlimited siding capacity. (Schedule 5)

As a result of the removal of restrictions on siding capacity the number of locomotive shifts required was reduced to seven, the lowest of all five schedules. The average run time was also the lowest for the five schedules, resulting from the elimination of return visits by locomotives to sidings. The average run distance remained the same as for Schedule 4 because there was no change in the location of active sidings. Comparing Schedules 3 and 5 indicates that harvest group rationalisation is likely to reduce the number of shifts by about one or two. The reduction in the average distance of the cane from the mill also accounts for some of the difference between Schedules 3 and 5.

Both Schedules 3 and 5 show that the removal of siding capacity restrictions has a large impact on shift requirements, and this demonstrates that the reduction in shift

numbers evident in Schedule 4 is also at least partly due to siding extensions. As with Schedule 3, the cane age and zero hour of this schedule would not be acceptable if implemented and extra shifts would have to be included to improve these parameters.

Impact of modifying harvest-transport arrangements on cost

This section discusses the costs associated with operating each schedule. Costs were assigned to both the in-field and mill-transport sectors; for in-field costs the model described in Ridge *et al.* (1996) was used and a similar spreadsheet model was developed to examine mill-transport costs. Table 3 presents a summary of these costs.

Table 3. Summary of costs for Schedules 1 to 5.

Schedule	Total in-field cost (\$)	Total mill-transport cost (\$)	Total mill area cost (\$)
1	6 762 425	3 542 145	10 304 570
2	6 762 425	3 496 802	10 259 227
3	6 762 425	3 600 860	10 363 285
4	5 936 930	3 144 962	9 081 892
5	5 936 930	3 353 424	9 290 354

Schedules 2 and 3 did not require any adjustments to grouping arrangements and were therefore assigned the same in-field cost as Schedule 1. Schedules 4 and 5 involved changes to the in-field grouping arrangements, with the 74 harvesting groups belonging to Schedules 1,2 and 3 amalgamated to form 37 groups. The number of groups actively harvesting on the day corresponding to the schedules was reduced from 46 to 23.

The in-field costs allocated to Schedules 4 and 5 were based on the assumption that the amalgamated groups would retain only enough harvesting equipment necessary to carry out harvesting at an acceptable delivery rate. The amalgamation of groups resulted in surplus equipment; therefore only the latest-model equipment from each amalgamated group was used in the calculations. All other variables used to provide in-field-cost estimates for groups in Schedules 4 and 5 were held constant from Schedules 1,2 and 3.

Cart distances were assumed to remain constant for all groups in all schedules. Although the number of sidings available for use on any particular day would be reduced by about half for Schedules 4 and 5, it was assumed that most sidings in the system would be retained. This would allow groups to access other sidings depending on where the group was harvesting its daily allotment, meaning that, in most cases, cart distances would not significantly change. In reality, if Schedule 4 or 5 was implemented, all groups would experience reductions and increases in cart distance to varying degrees depending on the combination of farms making up each amalgamated group, although the overall net change in cart distances would probably be small.

The mill transport cost for Schedule 2 was slightly lower than Schedule 1 because less bins were required, resulting in a small saving in capital costs and materials costs for repairs. Despite lower labour costs resulting from fewer shifts and a reduction in

the number of locomotives required, Schedule 3 was more expensive than Schedules 1 and 2 because the provision of extra siding capacity increases capital and maintenance costs. The additional bin requirements also resulted in higher capital and maintenance costs.

Schedules 4 and 5 were less expensive than Schedules 1,2 and 3. Savings could be attributed to the slight reduction in the number of sidings maintained in the system and a reduction in the number of locomotive shifts necessary to support these schedules. Schedule 5 was more expensive than Schedule 4 because of its extra bin requirements and siding extensions.

Although the cost trade-off between the number of shifts and cane age was not analysed in this exercise, Schedule 4 appears to be the best schedule because it has the lowest cost and an acceptable cane age.

Impediments to improving harvest-transport efficiency in Mackay

Despite the economic advantages of a harvest-transport system comprising fewer harvesting groups and a rationalised mill-transport network, the Mackay sugar industry has moved only very slowly towards this type of system. One contributing factor is the reluctance of many growers and harvester operators to amalgamate harvesting groups, and this has also been the case, but to a lesser extent, in other regions. A number of factors can explain the aversion towards large harvesting groups and these are reviewed in Brennan *et al.* 1996 (in press). Wet-weather risk appears to be a major deterrent to the formation of large groups. Smaller groups can generally recover time lost to wet-weather disruptions more quickly than large groups and ensure their cane allotments are supplied on time. In the Mackay region, a significant proportion of the crop is burnt prior to harvesting. Large groups harvest large areas at a time and for many growers there is a risk of losing large proportions of burnt cane, unable to be harvested because of wet weather. There are measures, however, to reduce wet-weather risk and include harvesting cane green and using harvesting equipment designed to operate in wet weather conditions.

Other major factors explaining why small groups are preferred include lifestyle considerations and differences in the perception of harvesting costs. In addition, in some areas there are physical traits preventing the operation of large harvesting groups. Decisions relating to harvesting are not based entirely on economic motives and harvesting-group structures in Mackay may reflect a preference to combine lifestyle choices with harvesting. In a recent survey conducted by the author to investigate the attitudes of cane harvesting-contractors and growers in Mackay, many harvester operators revealed that although they wanted to achieve low harvesting costs, they did not believe that there were major advantages from operating large harvesting groups. Furthermore, they thought that increasing group size would not be rewarded by cost savings. Typically, some costs are treated by harvester operators as farm costs, thereby reducing the perceived cost of harvesting for these operators. Also, it was revealed that there were small variations in harvesting price, with only a very weak correlation between harvesting price charged in the region and group size. This may further reduce the incentive for the region to adopt large groups. Mackay harvester operators who responded to this survey did not display any clear intention to enlarge their group size. This suggests that it is not reasonable to assume that

individuals will continue on a steady path of adjustment out of harvesting, and some form of intervention may be necessary to ensure that groups continue to amalgamate.

Concluding remarks

Overall, extending the duration of the harvesting period by floating the starting times of harvesting groups is a better strategy than allowing a concentration of starting times in the early morning period. While there is no improvement in terms of shift requirements, the main benefit of spreading the hours of harvesting is the lowering of the average cane age and bin fleet numbers. Increasing siding capacities reduces the number of shifts required. Decreasing the number of shifts, however, has the disadvantage of significant increases in cane age and bin requirements, and a compromise must be reached between these parameters. Introducing fewer, but larger, groups to the system reduces the harvesting costs of the in-field sector. Mill transport costs are also reduced by less time spent shunting at sidings and fewer locomotive shifts required to transport cane to the mill.

To achieve these reductions in cane harvesting costs, the mutually dependent relationship between growers and millers must be recognised and the harvest-transport system managed as a single entity, commencing from the cutting of cane in the field through to its delivery to the mill gate. In addition, the factors mitigating against the in-field sector's acceptance of large-group harvesting systems must be considered when addressing future directions for the harvest-transport sector.

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