

**INTELLIGENT ADAPTIVE CONTROL IN AN ON-LINE CANE
TRANSPORT SCHEDULER**

Project Number: UCQ2S

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Executive Summary

The vast majority of the Australian sugar crop is transported from the field to the sugar mill by privately owned cane railways. The total length of the permanent way exceeds 3000 km and approximately 500×10^6 tonne kilometres of cane are hauled during the crushing season, making the combined operation the third largest rail transport system in Australia

Transporting cane from the field to the factory is an expensive process. Both capital and operating costs are large and cane transport is the largest cost unit in the manufacturing of raw sugar accounting for about one third of the total manufacturing costs.

Cane railway systems perform two major tasks. Firstly, they take empty bins from the mill and deliver them to the growers where they are filled with chopped cane, and secondly, they collect the full bins from the growers and return them to the mill. At the mill, the full bins are weighed and then move onto a tip where the cane is removed. The now empty bins are ready for delivery to the growers.

The Cane Railway Scheduling Problem is to design a set of locomotive runs, or a schedule, to satisfy both the mill and the growers. A substantial set of constraints has to be considered and there's no definitive objective function that can be used to assess the merits of the schedules produced.

A system, the Automatic Cane Railway Scheduling System (ACRSS) has been developed to generate schedules solving the cane transport problem.

At the heart of ACRSS is a mathematical model of a cane transport system. This mathematical model is a simplification of an actual system and, as ACRSS has developed, extra features have been added to the model so that more realistic schedules are produced. This project improves the Automatic Cane Railway Scheduling System, ACRSS, so that the schedules generated by ACRSS more closely reflect operational schedules.

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The improvements to ACRSS include:

- Updating and improving the optimization algorithms used within ACRSS
- Allowing the harvest pattern to change from one day to the next as harvesters come on and off roster
- Improving the capabilities of ACRSS to handle load and speed restrictions in the network.

Since the conclusion of this project ACRSS has been used by over two thirds of the sugar mills that operate cane railway systems.

Background

23 out of 28 Australian sugar mills operate privately owned cane railway systems and, as a group, these systems form the third largest rail transport system in Australia.

Transporting cane from the field to the factory is an expensive process. Both capital and operating costs are large and cane transport is the largest cost unit in the manufacturing of raw sugar accounting for about one third of the total manufacturing costs.

Cane railway systems perform two major tasks. Firstly, they take empty bins from the mill and deliver them to the growers where they are filled with chopped cane, and secondly, they collect the full bins from the growers and return them to the mill. At the mill, the full bins are weighed and then move onto a tip where the cane is removed. The now empty bins are ready for delivery to the growers.

The Cane Railway Scheduling Problem, CRSP, is to design a set of locomotive runs, or a schedule, to satisfy both the mill and the growers. A substantial set of constraints has to be considered and there's no definitive objective function that can be used to assess the merits of the schedules produced.

One of the features of CRSP is that the product to be transported, harvested, chopped cane, is perishable. Because most of the cane is harvested in daylight hours (between 6am and 6pm), there is a large delay between harvesting and crushing for some cane. During this time, bacterial action occurs that not only reduces the amount of sugar that can be recovered but also produces products that cause problems in the manufacturing process. The rate of the bacterial action increases exponentially over time, and if the delay between cutting and crushing is over 18 hours, the costs associated with aging are of the same magnitude as the operating costs for the cane railway system.

When assessing schedules, mills usually attempt to minimize their operating costs while maintaining an acceptable cane age.

Sugar Research Institute, a research organization founded by the Australian sugar mills has been examining the CRSP since 1968. Considerable advances have been made in this time towards solving the CRSP but there are still areas that need further work.

A system, the Automatic Cane Railway Scheduling System (ACRSS) has been developed to generate schedules solving the cane transport problem. The problem is decomposed into separate routing and scheduling problems and these problems are solved sequentially to produce a trial schedule that is then refined iteratively.

At the heart of ACRSS is a mathematical model of a cane transport system. This mathematical model is a simplification of an actual system and, as ACRSS has developed, extra features have been added to the model so that more realistic schedules are produced. The use of ACRSS, prior to this project, indicated that the model should be again updated to consider the following:

- Harvesting patterns that vary from day to day to allow rostered harvesting and harvester migration to be incorporated into the schedules.

- Locomotive loads and speeds that vary throughout the network.
- Branch line operations that reflect operational practice.
- Shunt times at sidings that vary with the number of bins at the siding.

There have also been significant improvements in the optimization algorithms that are used in scheduling programs, and this project allowed some of these improved algorithms to be incorporated into ACRSS.

Objectives

The objectives of this project were to improve the model used by ACRSS, the schedule generating system, so that the schedules produced more closely reflected operational practices. Specifically, the ACRSS model was updated to consider the following:

- Harvesting patterns that vary from day to day to allow rostered harvesting and harvester migration to be incorporated into the schedules.
- Locomotive loads and speeds that vary throughout the network.
- Branch line operations that reflect operational practice.
- Shunt times at sidings that vary with the number of bins at the siding.
- Make provisions for locomotive passing

Additionally, the algorithms used within ACRSS to optimise the schedules that are generated have been updated to use current Operations Research techniques.

The objectives listed above, with the exception of making allowances for locomotive passing, have been achieved and incorporated into ACRSS.

The problem of locomotive passing was considered, but as ACRSS is more suited to medium and long term planning rather than everyday operations and since the problems of locomotive passing are dependent on the small disturbances to the cane transport system that occur frequently throughout the day, it was concluded that this problem was better considered in the proposed real time scheduling system.

As a separate mill funded project, ACRSS has been converted to run in a Microsoft Windows environment. This project involved:

- Converting ACRSS to the Windows environment
- Developing a user-friendly interface to ACRSS
- Integrating ACRSS and TOTools so that ACRSS accepts grower data from TOTools and exports schedules back to TOTools

The user manual attached to this document describes this interface as well as ACRSS itself.

Methodology

This project was directed by a steering committee that included the chief cane inspectors from three Mackay district sugar mills as well as representatives from CQU and SRI. The involvement of Professor JD Smith with this steering committee was very productive and the success of the project and of the related project to develop TOTools are in no small way a direct result of the involvement of this steering committee.

Since the schedule generating system ACRSS was already in existence, most of the work completed in this project involved updating the program code of this package.

Appendix A to this report is a technical description of this project and contains:

- A description of how ACRSS generates schedules,
- A comparison, in broad terms, of the ACRSS schedules and the present operational schedules,
- A description of the changes made to ACRSS from this project.

Appendix B to this report is a detailed User's manual for ACRSS.

Outputs

The modifications to ACRSS have proved successful, with the system being used in over two thirds of the mills that transport cane by rail.

In this time ACRSS has been used to examine a variety of situations including:

- Examining current operations
- Staggering the start time of locomotives to prevent congestion of the system
- The effects of extending the hours of harvesting
- The inclusion of depots to lessen the impact of small siding capacities
- Combining the transport system for a number of mills
- Examining whether an existing railway system should be replaced by a road system
- Planning for expansion

Whilst there has been some involvement by the researchers with these projects, the improvements to ACRSS have enabled mill personnel to complete significant portions of these studies.

A separate, mill funded, project to convert ACRSS to a Windows environment and to build a user-friendly interface for ACRSS has also been completed. The user manual for this interface is included in Appendix B to this report.

Intellectual Property

The initial version of ACRSS was developed in 1978 as a PhD project at James Cook University by Dr. D. Abel. In the period since then and prior to this project it was extensively redeveloped by Sugar Research Limited. This project has continued the development of ACRSS and has thus not generated an identifiable product.

Outcomes

In the period since the changes were made to ACRSS, it has been used by approximately two thirds of the mills who operate cane railways. Whilst there has been some involvement by the researchers with these projects, the improvements to ACRSS have enabled mill personnel to complete significant portions of these studies. These studies were not part of this SRDC funded project and are summarized here to illustrate how the updated ACRSS can, and has, been used by mills

The projects discussed are:

- Varying harvest patterns
- Extending the hours of harvesting
- Staggering the start time of locomotives to prevent congestion of the system.
- Using depots to lessen the impact of small siding capacities

Varying harvest patterns

The ability to handle harvester rostering and migration was one of the additional features added to the ACRSS model. A central district mill used ACRSS to produce schedules for a week of operations. The harvest patterns modelled quite different situations and varied more than would normally be expected with usual, day to day operations.

| | Shifts | Locos | Bins Used as % of Allocation | Average Cane Age | Number of Siding Capacity Violations | Average Distance of Cane to Mill | Minimum number of Shunts |
|------------------|--------|-------|------------------------------|------------------|--------------------------------------|----------------------------------|--------------------------|
| Sunday | 16 | 6 | 88 | 11:23 | 22 | | |
| Monday* | 21 | 7 | 89 | 10:45 | 20 | 36.03 | 181 |
| Tuesday | 17 | 6 | 100 | 11:52 | 20 | | |
| Wednesday | 17 | 6 | 100 | 11:25 | 18 | 35.17 | 159 |
| Thursday | 17 | 6 | 88 | 10:21 | 14 | 33.58 | 159 |
| Friday | 16 | 6 | 93 | 11:26 | 18 | | |
| Saturday | 15 | 6 | 91 | 10:36 | 15 | | |

Table 1. Schedules for varying harvest patterns

Table 1 summarizes a series of schedules that were developed to examine a number of different harvesting patterns at the mill. The total daily allotments remained constant for the seven days, with the harvesters rostered on and their locations varying from day to day. As well as showing the numbers of shifts and locomotives used, Table 1 also shows the number of bins required to implement the ACRSS schedule (as a percentage of the total daily allotment) an average cane age and the number of siding capacity violations in the ACRSS schedule. The average distance of cane from the mill and the minimum number of siding shunts are also shown if sufficient data were available to calculate these values.

This study used the modifications added to the ACRSS model to allow harvest patterns to alter and tested that the model alterations had been incorporated into the ACRSS program.

The schedules summarized in Table 1 also allow for some very general statements:

- The optimal schedules developed by ACRSS vary considerably as the harvest patterns are altered. The mill concerned did regard the harvest pattern for Monday as an extreme situation, with a large number of harvesters being placed in ‘extreme’ positions. (Smaller siding capacities, more distant from the mill) and it is thus not surprising that extra locomotive shifts are required for Monday. (There is approximately 16 hours of unused locomotive time in Monday’s schedule and it is probable that specifying different locomotive shift patterns would have reduced the number of additional shifts)
- A significant number of siding capacity violations, where the number of bins at the siding exceeds the capacity of the siding, is present in the schedules. Some actual operational practices that are not incorporated into the ACRSS model reduce this problem. For example, ACRSS provides a sufficient supply of empty bins to maintain uninterrupted harvesting. In practice, a shortage of empty bins at a siding may disrupt the harvester. Such interruptions extend the hours of harvesting and thus help to reduce the number and severity of siding capacity violations.

Extending the hours of harvesting

Within ACRSS, when the details of an individual harvesting contractor are specified, the user may ‘Fix’ the harvest start time, for example by specifying that this harvester must start harvesting at 6am or he can specify that the harvest start may ‘Float’ as long as the harvest is completed between the specified limits, for example by specifying that the harvest be completed between the hours of 6am and 6pm. If the harvest start is allowed to float, ACRSS determines the most favourable harvesting period for the contractor. (For all harvesters, the ACRSS model guarantees that, once they commence harvesting, harvesting is continuous and that there is a sufficient supply of bins to maintain this continuity)

Two distinct approaches to extending the hours of harvesting have been modelled. Firstly, a number of mills modelled extended hours harvesting by maintaining the number and allotments of the current harvesters and extending the allowable harvest period. Secondly some mills increased the allotments (and thus decreased the number) of the harvesters so that the hours of harvesting were necessarily extended.

A. Time-slice harvesting.

It is important to note that these studies were conducted only to determine the size of the benefits that could be possible by extending the harvesting period.

The existing harvesters were maintained and their harvest starts were allowed to float and the harvesting periods were extended. The term ‘Time-slice’ harvesting is an apt description for this approach.

Table 2 summarises the results obtained from some studies that looked at this option for extending the hours of harvesting. The values shown are all relative to the (then) current situation at the mills concerned.

| | Hours of Harvesting | Reduction in Locomotive Shifts | % Reduction in Average Age | % Reduction in Bins required | % Reduction in Siding Capacity Violations |
|---------------|---------------------|--------------------------------|----------------------------|------------------------------|---|
| Mill 1 | 14 | 0 | 15.00% | 0.00% | 22.00% |
| | 17 | 0 | 10.00% | 15.00% | 56.00% |
| | 24 | 1 | 29.00% | 5.00% | 56.00% |
| Mill 2 | 20 | 0 | 9.00% | 13.00% | 67.00% |
| Mill 3 | 16 | 0 | -5.00% | 9.00% | 23.00% |
| | 18 | 0 | 10.00% | 12.00% | 31.00% |
| | 24 | 0 | 20.00% | 17.00% | 50.00% |
| Mill 4 | 14 | 0 | 6.00% | 6.00% | 100.00% |
| | 16 | 0 | 11.00% | 4.00% | 100.00% |
| | 19 | 0 | 18.00% | 15.00% | 100.00% |

Table 2. Time-slice harvesting

Some notes on time-slice harvesting.

- Time-slice harvesting would be of benefit to the milling sector, but of less benefit to the harvesting and growing sectors, although it is the approach that creates less change in these sectors, particularly in the harvesting sector.
- Extending the hours of harvesting has not resulted in significant reductions in the number of locomotive shifts required. This is to be expected, since major determinants of the required haulage resources – the tonne-kilometres of cane hauled and siding capacities (and hence number of siding visits) – have not altered.
- Extended hours of harvesting allow the siding visits that are necessary to be spread over a larger time period. Hence, ACRSS is able to produce schedules that reduce the number of siding capacity violations. In all of the cases shown in Table 2, extending the hours of harvesting, has significantly reduced the number of siding capacity violations.
- As the harvesting period increases, the average cane age and the number of bins required to implement the schedule both decrease.

B. Larger harvesting groups

A number of mills have looked at this option. In most of these studies, though, the change to larger harvesting groups was combined with other changes such as rationalised rail networks and, particularly, increased siding capacities. If the siding capacities are not increased, increasing the size of the harvesting groups will increase the number of siding capacity violations because the size of the active sidings as a percentage of their allotment decreases. This means extra visits must be scheduled to the active sidings and extra locomotive shifts are required.

Table 3 summarizes one study that looked at increasing the size of harvester groups. The table compares 2 schedules produced for larger groups with a schedule produced with approximately the same harvesting period, obtained by ‘time-slice’ harvesting.

| Increase in locomotive shifts | % Change in Av Age | % Change in Bin Numbers | Change in Capacity Violations |
|-------------------------------|--------------------|-------------------------|-------------------------------|
| 0 | +1.83% | +25.47% | +5 |
| 1 | -1.31% | +14.93% | -1 |

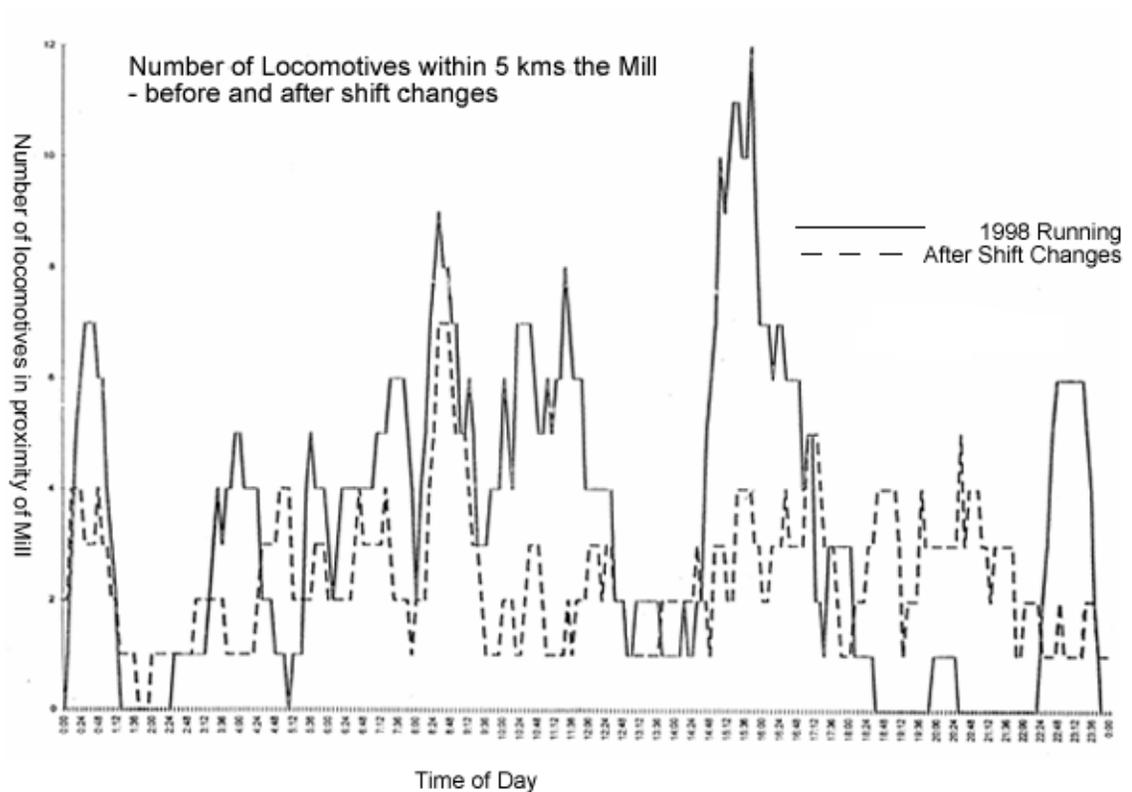
Table 3. Comparing larger harvesting groups to time-slice harvesting

Some notes:

- The first of the comparisons in Table 3 compares two schedules that haul the same amount of cane, have similar harvesting periods and require the same number of locomotive shifts. Compared with the time-sliced (base) case, the schedule for the larger group case contains significantly more siding capacity violations (up 5 to 9), and requires just over 25% more bins.
- For the second comparison shown in Table 3 an extra shift has been added. The extra shift reduces the siding capacity violations and also the number of bins required.
- Other studies have also shown that increasing the size of harvester groups without increasing the size of sidings, will increase the number of siding capacity violations.

Staggering the start time of locomotives to prevent congestion of the system

If all locomotives work standard 8am to 4pm shifts, then, particularly at the change of shift, there can be considerable congestion in the cane railway system. ACRSS allows the shift times to be specified for each individual locomotive, and one mill used this feature to investigate the benefits that it might obtain by staggering the locomotive shift times. (From 6am through to 10am). Figure 1 shows how this action could have reduced the congestion at this mill.



With the standard 8am to 4pm shifts there were, at 4pm, 12 locomotives within 5km of the mill. By staggering the locomotive start times this figure was reduced to 4 with a maximum of 7 locomotives within the 5km radius at any time of the day. Staggering the start times also added extra flexibility when it came to addressing siding capacity problems.

Using depots to overcome siding capacity violations

Siding capacity violations occur when the number of bins at a siding exceeds the capacity of that siding. ACRSS may produce schedules that contain these violations and the number and severity of these violations can be reduced by including them as a term in the objective that is considered. ACRSS allows extra locomotive shifts to be added to reduce or entirely eliminate these siding capacity violations.

Sometimes, for historical reasons, a number of smaller sidings exist in a single, geographical region. Particularly if this region is a considerable distance from the mill, it may be advantageous to service these sidings from a local depot or marshalling. ACRSS allows depot systems to be modelled and this feature has been used in a number of situations.

Future Research Needs

Harvesting and transport operations are major cost centres for both the milling and farming sectors of the sugar industry. Cane harvesting and transport are complex systems that contain many interacting components and an integrated approach to harvesting and transport is necessary if overall costs are to be reduced or maintained.

There are a number of avenues for further research into cane transport that could prove fruitful:

- The optimum schedules as produced by ACRSS are significant improvements on the operational schedules used at most mills. In most cases, there is scope for improving the operational schedules but it is doubtful that these improvements could be realised without the provision of extra guidance for the present traffic operators.
- Real-time or residual scheduling aims to provide traffic officers with a system that produces a good pattern of actions to complete the day's operations given the current state of the system, including the stocks of full and empty bins in the mill yard and at the sidings and the positions of locomotives. At present no such residual scheduling system is available.
- Over the last couple of years, ACRSS, as refined in this project has been extensively used in many mill areas to examine harvest and transport operations. This system provides an ideal platform to examine how the combined harvest/transport costs can be minimized
- An incomplete set of investigations using ACRSS are described in the Outcomes section of this report and were not part of this project. A more complete and detailed set of investigations to determine how the cane transport costs can be minimized and what are the major determinants of this cost is warranted.
- The development and refinement of ACRSS and its model is an on-going procedure. There are indications that other intelligent searching algorithms such as the Tabu search technique would improve the performance of ACRSS.
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Publications List

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Pinkney,A.J and Everitt,P.G. (1999) An Integrated Cane Transport Scheduling System Operations Research from Theory to Real Life - Proceedings 15th National Conference of the Australian Society for Operations Research Inc,1999 (P 1039 - 1046)

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Appendix A: Overview of ACRSS

Historical Development of ACRSS

ACRSS was initially developed as a PhD thesis (Abel, 1978) and was later modified and improved extensively by the Sugar Research Institute. By the mid-eighties, ACRSS was widely used throughout the industry with many mills being able to reduce their cane transport costs by using ACRSS to investigate their cane transport systems (Pinkney, 1989; Page et al, 1985).

How ACRSS Generates Schedules

ACRSS breaks cane transport scheduling into separate routing and scheduling problems. Sequentially solving these problems produces a trial schedule that can then be refined iteratively. This approach is shown diagrammatically in Figure 1.

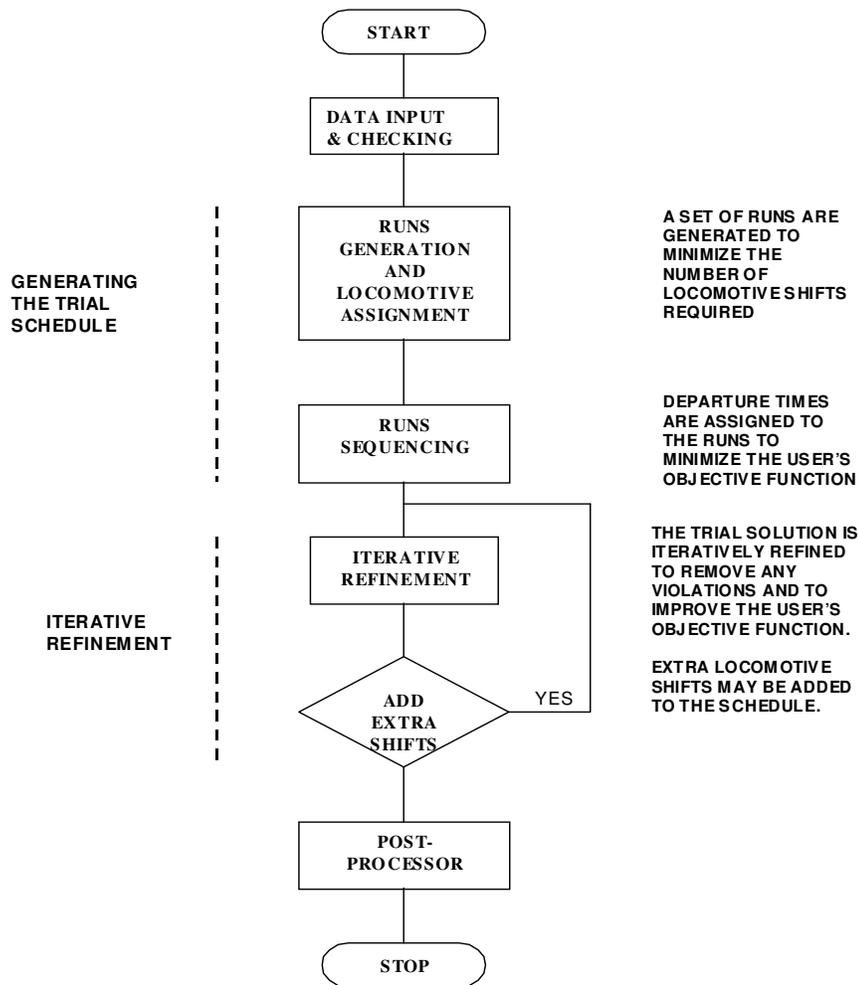


Figure 1 ACRSS Solution Algorithm

The Routing Problem

The routing algorithm breaks the network into a series of segments, where each segment is a section of track terminating at either a branch or at the end of a line. Locomotive runs are generated to service segments of the track, ie. the runs deliver empties to the growers located on the segment and collect full bins from them. The servicing needs of the segments are determined by considering both the total number of bins involved and the distance of the segment from the mill. For each locomotive run, adjacent segments are serviced until the locomotive's capacity is fully utilized or there are no further segments to be serviced before reaching the mill. Additional runs are generated for the locomotive until its available time is fully utilized.

This algorithm performs two functions - it determines the route that the locomotive runs will take and the activities they will perform and it also allocates the runs to locomotives. The objective for this module is to minimize the number of shifts required. The module's performance is shown in Table 1. This table uses data describing a case study used extensively by the Sugar Research Institute and other data from representative Australian sugar mills. The absolute minimum values are calculated by considering a much simpler situation where all the cane is collected at a single point, an average distance from the mill.

| | Absolute Minimum | | ACRSS Obtained | |
|-------------------|----------------------|-------------|----------------------|-------------|
| | Loco Run Time (mins) | Loco Shifts | Loco Run Time (mins) | Loco Shifts |
| Case Study | 1492 | 4 | 1605 | 4 |
| Mill 1 | 3122 | 7 | 3165 | 8 |
| Mill 2 | 4773 | 11 | 5095 | 12 |
| Mill 3 | 3806 | 9 | 4170 | 10 |

Table 1. Locomotive Requirements - Run Generation Module

The Sequencing Problem

The next module sequences the runs generated by the routing phase. The original sequencing algorithm used a modified tree search to locate the better schedules. Recently, a genetic algorithm has been used. Genetic algorithms are search techniques that mimic natural selection and use the operators of reproduction, crossover and mutation to move from one solution to the next. Goldberg (1989) describes how genetic algorithms can be used to locate optimal solutions. Locomotive runs are given integer identifiers and integer permutation is used to obtain the best schedule.

The schedule produced need not, at this stage, be a feasible solution. There may be harvest start violations, where the locomotive runs attempt to collect cane not yet cut, and siding capacity violations where the number of bins at a siding exceeds the siding capacity.

The results obtained have been most satisfactory and are summarized in Table 2. The times shown are the computer running times on a Sun Workstation and the violations are the total

numbers of harvest start and siding capacity violations remaining. In all instances the genetic algorithm has been able to sequence the runs in an acceptable time.

| | Tree Search | | Genetic Algorithm | |
|-------------------|-------------------|-----------------|-------------------|-----------------|
| | No. of Violations | CPU Time (secs) | No. of Violations | CPU Time (secs) |
| Case Study | 7 | 3 | 2 | 17 |
| Mill 1 | 39 | 4325 | 26 | 139 |
| Mill 2 | 44 | 16 | 28 | 39 |
| Mill 3 | ? | >24h | 35 | 120 |

Table 2. Genetic Algorithm Performance

Iterative Refinement

The iterative refinement phase improves the schedule by making a series of small changes to it. The sizes of deliveries to and collections from sidings are altered, new deliveries and collections are added, existing deliveries and collections are deleted and runs are swapped to improve the schedule. This process is used to remove violations from the schedule and to improve the schedule parameters. The user specifies which parameters are to be improved and their relative priorities. The parameters that can be considered are:

- Harvest start and siding capacity violations
- Average cane age
- Weighted cane age
- Number of bins
- Yard size

The schedules produced by ACRSS compare favourably with existing schedules. Table 3 compares the generated schedules with those in use at some mills. For all sets of data, ACRSS has been able to generate schedules using fewer locomotive shifts and for mill data, the schedules use fewer bins and improve the cane age. For the case study, improved cane age and bin fleet size could be obtained by adding an extra locomotive shift.

| | | No. of Shifts | Average Cane Age | Number of Bins |
|-------------------|-----------------|---------------|------------------|----------------|
| Case Study | Workshop | 5 | 7:45 | 942 |
| | ACRSS | 4 | 7:56 | 1000 |
| Mill 1 | Existing | 18 | 9:29 | 2956 |
| | ACRSS | 13 | 8:55 | 2143 |
| Mill 2 | Existing | 13 | 11:30 | 1543 |
| | ACRSS | 8 | 9:04 | 1545 |
| Mill 3 | Existing | 15 | 10:07 | 1983 |
| | ACRSS | 11 | 8:50 | 1823 |

Table 3. Overall System Performance

Modifications to ACRSS

At the heart of ACRSS is a mathematical model of a cane transport system. This mathematical model is a simplification of an actual system and, as ACRSS has developed, extra features have been added to the model so that more realistic schedules are produced. Recently, the model has been expanded so that:

- Harvesting patterns can vary from day to day. This allows rostered harvesting and harvester migration to be incorporated into the schedules.
- Locomotive loads and speeds can vary throughout the network.
- Branch line operations reflect operational practice.
- Shunt times at sidings can vary with the number of bins at the siding.

Changes in the Harvesting Pattern

Previously, ACRSS modelled a static situation where the number of bins delivered to and collected from a siding equalled the daily allotment at the siding. The model was also cyclical and the numbers of full and empty bins at the siding at the end of the 24 hour period were the same as those at the start of the period. This model did not allow for either rostered harvesting or harvester migration.

Daily changes in the harvesting pattern were incorporated into the ACRSS model by considering four situations:

- A harvester finished cutting at the siding yesterday.
- A harvester finishes cutting at the siding today.
- A harvester starts cutting at a siding today.
- A harvester finishes cutting at a siding tomorrow.

Table 4 summarizes the effects that these situations have on the deliveries to and collections from the sidings, eg. if a harvester is finishing at a siding today, there is no need to deliver bins for tomorrow's harvesting and the number of bins delivered today is reduced by this amount. However, in the 24 hour period being considered, a full allotment of bins must be collected.

| | Finished Yesterday | Finishes Today | Starts Today | Starts Tomorrow |
|----------------------------|---------------------------|-----------------------|---------------------|------------------------|
| No. to be Delivered | 0 | A - d | A | e |
| No. to be Collected | b | A | A - c | 0 |

A is the daily allotment.

b fulls remain at the siding from the previous day.

c fulls remain at the siding at the end of the current day.

d empties are at the siding at the start of the current day.

e empties delivered for the next day.

Table 4. Changes in the Harvesting Pattern

Varying Locomotive Loads

Variable locomotive loads and speeds are incorporated into ACRSS by :

- Increasing the length of some sections of the network when the restriction applies to individual sections of the track,
- Including a depot (or a number of depots) when the restrictions apply to whole areas of the network.

Track sections with localized load restrictions, eg. hills, are handled by hauling a complete load to the grade and then splitting the load into a series of smaller loads that can be hauled over the grade. Extra locomotive running time is used to transport the cane over the grade and increasing the length of sections of the network makes allowance for this extra running time. A post-processor programme has been developed to produce locomotive runs that reflect operational practices.

Adding depots or marshalling yards allows ACRSS to produce schedules for cane transport systems that include whole areas where locomotive loads or speeds are restricted. For some mill areas it has been necessary to include a system of depots to obtain realistic schedules. The Animated Cane Transport Scheduling System (ACTSS) has been used to verify that these techniques do allow load and speed restrictions to be handled by ACRSS.

Branch Line Operations

The ACRSS model does not allow mixed locomotive loads, ie. locomotives cannot haul empty and full bins simultaneously. This leads to some inefficient branch line operations. Figure 2 shows how the runs built by ACRSS service a branch line. As this figure shows, the requirement that mixed locomotive loads not be allowed leads to inefficient branch operations.

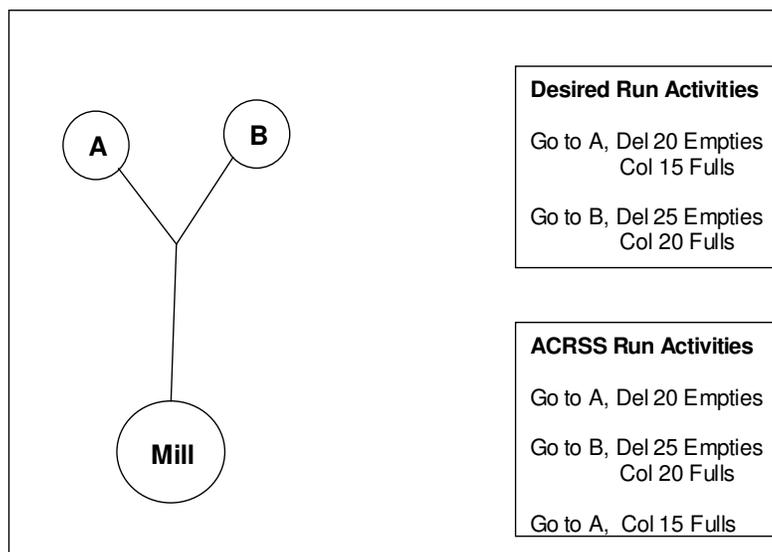


Figure 2. ACRSS branch activities

Variable Shunt Times

The ACRSS model has been expanded to allow the shunt time at sidings to vary as the number of bins at the siding increases. This allows the generated schedules to simulate the significant operator practice of using adjacent sidings. When the number of bins at the siding exceeds the original siding capacity, the shunt time is increased to allow adjacent sidings to be used. Trials with sample data have shown that ACRSS can use the increased siding capacities to produce schedules that use fewer locomotive shifts.

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Appendix B: ACRSS User's Manual

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1 SCOPE OF DETAILED MANUAL

This document is a Detailed Manual for the use of the Automatic Cane Railway Scheduling System, ACRSS. The manual provides the necessary information and guidance to prepare input data, to interpret a schedule and to appreciate the ways in which the system can be effectively and sensibly employed.

Specifically, the manual covers:

- the capabilities of the system,
- using the Windows interface,
- the input data required and the format to which the data must conform,
- the interpretation of the outputs generated, and
- the means of tailoring schedules to particular requirements.

2 SCOPE OF THE SYSTEM

ACRSS will generate a schedule for cane transport operations directly from specifications of the network geography including connections and distances as well as siding types and capacities, the locomotives' operating characteristics and the grower harvesting data such as daily bin allotments, harvesting rates and starting times where applicable. A set of schedules with varying locomotive numbers and shifts, cane age and bin fleet-size can be readily generated, leaving a mill free to choose the 'best' schedule using its own criteria. Although ACRSS was developed specifically to model cane railway transport systems, it can also be used to model road transport systems.

The major benefits to be expected from use of the scheduling system.

- the ability to generate schedules quickly makes it practicable to evaluate alternatives rapidly in planning studies, rather than relying on intuitive assessments.
- the experience to date is that the system is usually able to suggest potential savings in shifts and in cane age, and sometimes in bin fleet size.
- whilst the schedules produced do need varying amounts of changes before they could be used as operational schedules, they do provide the mills with different, advantageous ideas to incorporate into their operations.

There are, however, some limitations of which the user should be aware. The system is currently unable to consider every operational requirement for all mills, so that some revision of schedules is required to make the schedules fit all the mill's requirements. Section 3 of this manual details which conditions the system does and does not recognize. The schedule to be implemented must be carefully examined to note areas that could cause operational difficulties.

Great care should be taken in preparing data. The usual rule for computer-based systems of 'garbage in, garbage out' applies. There is little value in preparing a schedule on haphazard data. In particular, inaccurate locomotive speeds and shunt times can have a major impact on the schedules produced.

3 THE SYSTEM'S INTERPRETATION OF THE RAILWAY OPERATIONS

ACRSS uses a representation of the railway and its operation, that is, a model. ACRSS enables the user to explore the railway operations for a wide range of conditions and configurations. An understanding of the model will enable the user to detect conditions in the schedules that differ from those required at their mill.

Appendix A provides an overview of the steps that are taken by ACRSS to produce a schedule from the supplied input.

3.1 OBJECTIVE FOR SCHEDULE DESIGN

The design objective for the system is based on minimizing some or all of the following parameters:

- **The number of shifts and locomotives required.** For each set of data, ACRSS first produces a schedule requiring a minimum number of locomotive shifts. ACRSS attempts to minimize the number of locomotives required for this minimum shift schedule by operating as many locomotives, as allowed by the user, on three shifts per day. Extra shifts and extra locomotives may be added to this schedule under user control. Locomotive runtime is not conserved and the system will attempt to use any available locomotive free time to reduce weighted cane age, average cane age, zero hour, bin fleet size or total yard size.
- **The weighted cane age.** This is computed for each parcel of cane, where a parcel is a collection from a single grower. The age from cut to crush for each parcel of cane is weighted by a function of cane age, e.g. dextran level. ACRSS does not allow growers allocated to the same siding to share bins. Separate allocations must be made for each grower at a siding.
- **The average age of cane at crush.** This is computed for each parcel of cane as collected at each siding; it is not averaged by locomotive run.
- **The bin fleet size.** This does not include an allowance for paddock bins, bins under maintenance or bins otherwise unavailable for service
- **The zero hour.** This is the time when the last of the previous day's cane is crushed and is calculated in such a way that continuous crushing throughout the day is guaranteed.
- **Total yard size.** This is the total number of bins, both full and empty, in the mill yard at any time during the day.

The objective function used by ACRSS to generate a schedule is specified by the user and the user is able to assign different priorities to the objective terms listed above. Indeed, different objective functions can be set at different stages in the generation of the schedule.

3.1.1 Sets of Schedules

Once a schedule of minimum shifts has been produced, the user can add extra shifts and locomotives to this schedule until all of the locomotive resources as specified in the input data have been utilized. In general, as the number of shifts is increased the weighted age, average age, zero hour and bin fleet size will all decrease. This mechanism can be useful where, for example, the schedule with the minimum number of shifts requires too large a bin fleet.

3.2 ROLLING STOCK, YARD, SIDING AND TRACK CHARACTERISTICS

The ACRSS model allows a locomotive fleet of several types of locomotives to be used. For each type of locomotive, the maximum number of fulls and the maximum number of empties hauled in a train are specified. Mixed trains of fulls and empties are not allowed (see Section 3.3.2). A set of speeds through the network for each locomotive type are also required, (speed hauling fulls, empties or light running). A maximum of forty locomotives, possibly each of a different type, can be specified.

The ACRSS model allows only one size of bin to be used.

Siding capacities can be specified for those sidings where capacities are limited. These capacities are expressed as the maximum number of bins that can be accommodated at the siding. The capacities can be expressed as either the maximum number of fulls and the maximum number of empties at the siding (for fish tail types of sidings) or as the maximum number of bins, both full and/or empty (for loops).

Mill yard capacities are not considered but the stock yard patterns generated by the program can be used to find the yard capacities required for the schedule.

ACRSS assumes that maximum size locomotive loads can be hauled throughout the network and at the uniform speeds specified; that is, limiting grades or speed restrictions are not considered.

Depots may be included in the system. The locomotives that work in the depot area may be started at either the depot or the mill. A maximum of five depots may be included in the system.

3.3 CALCULATION OF RUNTIME AND PERMITTED RUNS

3.3.1 Calculation of Runtimes

Uniform speeds are assumed through the network, with transit times between two sidings given by the distance divided by the appropriate running speed. No allowance is made for time to move from a main line into a branch line, or vice versa, or to reverse the direction of a train.

Shunt times are allowed for each activity at a siding. Shunt times may be varied throughout the network. A fixed allowance is made for operations in the mill yard after each run. A run is not permitted to pass through the mill to travel from one siding to another without spending this time between runs in the mill yard.

3.3.2 Permitted Runs

The schedule will not include runs where a locomotive hauls both empty and full bins at the same time. This does not preclude a locomotive delivering its last empties for a run and collecting its first fulls from the same siding.

Optionally, in runs generation, the user can specify that empties may not be taken out of a branch line or that fulls may not be taken into a branch line. However this constraint is not observed by the system during refinement.

The passing of trains is not considered; that is, the system assumes adequate passing loops are present.

3.4 OPERATIONS AT THE MILL

The mill is assumed to crush continuously at a steady rate over a 24 hour day. Cane may also be delivered directly to the mill's cane receival station by means other than the railway operation. The crushing rate is computed as that needed to handle the sum of the growers' daily allotments and any cane delivered directly to the cane receival station in 24 hours.

Cane is considered to be available for crushing within five minutes of arrival at the mill yard. The user can specify priorities to influence the order in which the train loads of cane are crushed. Crushing order priorities may be any of the following:

- the time of arrival at the mill,
- the average age of all the fulls in the train load, or
- the age of an individual rake of cane.

(Note that a 'rake' is defined as a parcel of fulls collected from a grower by a run, rather than all fulls collected by that run.)

Buffer stocks are not considered. There will be at least one time when full stocks reach zero and at least one time when empties stocks in the mill yard reach zero.

3.5 GROWER OPERATIONS

Growers are assumed to harvest continuously at a steady rate that is specified for each individual. Growers commence harvesting from their specified harvest start times. A grower can have a 'fixed' or a 'floating' harvest start time. For a fixed start, the time is specified as input. For a 'floating' start, the system determines the best start time between specified earliest start and

latest finish times. Two harvesting periods can be specified for each grower to allow a break in harvesting for lunch.

The deliveries of empty bins can be made at any time during the day. Deliveries can be made after the end of harvesting, with those bins held over until the following day.

Growers are assumed to have on-hand at 0800 only fulls harvested that day. It is assumed that all the cane harvested the previous day has been removed from the siding by 0800. The number of empties at a siding at 0800 is determined by ACRSS to allow continuous (uninterrupted) harvesting.

If growers commence harvesting before 0800, then, in the period between harvest start and 0800, both yesterday's and today's fulls can be collected. For each individual grower, no more than one rake can contain a mixture of yesterday's and today's cane.

3.6 MISCELLANEOUS

3.6.1 Rake Ages

The system attempts to keep rake ages below a user- specified limit. There are, however, circumstances when the maximum rake age cannot be met for all rakes.

3.6.2 Meal Breaks

A meal break for each loco is placed within each shift, within the time limits specified. The break can be taken anywhere in the network.

3.6.3 Shift Start/End Times

The user may specify for each locomotive a yard start and a yard finish time. These times may vary among locomotives and may be specified on shift basis. This facility enables the user to vary the duration of shifts for locomotives and to force shift changes to be made in the mill yard.

Alternatively, the user may specify only a yard start time. In this case, the locomotive will be started from the mill yard at the specified time. If such a locomotive works one shift only, the locomotive works for the eight hour period immediately following the specified yard start time. For two shifts only the 16 hour period following the yard start time is worked. For locomotives where only a yard start time has been specified shift changes are made anywhere in the network at the end of the first and second shifts.

3.7 DEPOT OPERATIONS

Depots are incorporated into the transport system in two steps. The depot and the sidings serviced from the depot must be modelled as a separate system and then this depot system is added into the total cane railway system as a single source of supply of cane. When the depot

subsystem is being modelled as a separate system, the depot is assumed to function as a mill and the subsystem schedule meets all of the requirements outlined in Sections 3.1 to 3.6 with the exception that continuous crushing is not required. Locomotives can be started either at the mill or at the depot, and allowance can be made for these depot based locomotives to transport bins between the mill and the depot at the start and end of shifts.

If depots are to be included in the cane railway system, then the schedules for the depots must be finalized before the modelling of the entire system can proceed - the depot schedule determines the requirements for empty bins at, and the supply pattern of full bins to the depot.

For the second stage, depots are included in the entire system and are regarded as operating in a manner very similar to a siding. The demand for empty bins and the supply of full bins are determined from the schedule generated previously for the depot.

4 THE USER INTERFACE

CQU have designed and built a Windows interface to ACRSS. This section describes this interface.

4.1 Selecting an operation

The ACRSS interface maintains operations and data in an MS Access database. User assigned operation names are used throughout the interface. As well as a descriptive field that describes the operation that is being modeled, each operation contains a number of data sets. The data stored for each operation provides descriptions of :

- the physical cane transport network
- the harvesting pattern,
- the rolling stock,
- the operational parameters,
- and the ACRSS options used.

Detailed data requirements are defined in Section 4.2

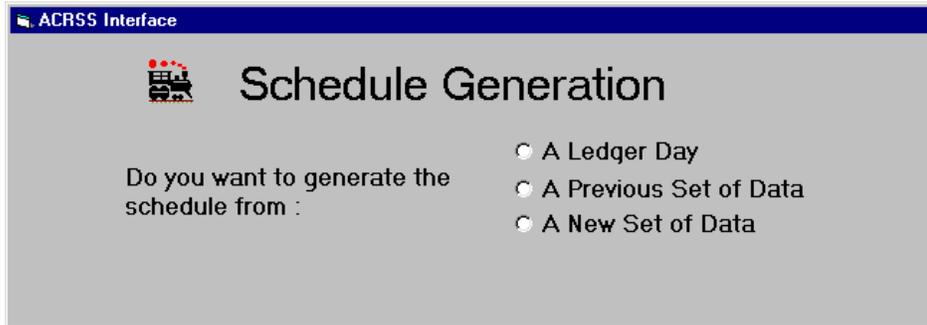


Figure 4.1 Initial Interface Screen

As shown in Figure 4.1 the user can select the operation to be modeled. If the user selects a ledger day, the harvester details are taken from a TOTools ledger. The user can choose to re-examine an existing operation or can choose to model a completely new operation, perhaps one that utilizes some parts of an existing operation.

4.1.1 Creating a new operation

When a new operation is required, a name and description for this operation are entered. Only the first 8 characters of the operation name are significant, so the name should not be longer than 8 characters. No blanks should be embedded in the operation name. Also, the operation name 'Default' has a special usage and should be avoided.

Once a name and a description for the new operation are provided, data describing the operation can be entered. If the user does not enter or alter data at this stage, the data for the new operation will be a copy the 'Default' operation data. If the user decides to alter the data, a list of the data sets that can be altered appears. Figure 4.2 shows the screen displayed at this stage.

ACRSS Interface

Schedule Generation

Do you want to generate the schedule from :

- A Ledger Day
- A Previous Set of Data
- A New Set of Data

Enter the Name of The New Operation

Run1 Run1 Mar 2001

Do you want to view or edit the data files? Yes No

Which set of data do you wish to view or edit?

- Network
- Grower
- Locomotive
- Siding Capacities
- Shunt Times
- Harvester Migration
- Operational Data
- Options
- Depot

Generate a Schedule Review Previous Schedules

Figure 4.2 Editing the data files

4.1.2 Using a Previous Operation

If the option to use a previous set of data is selected, a box will appear showing the first (alphabetically) of the existing operations. Clicking on the down arrow at the right hand end of the name will allow the user to choose any of the existing operations. The user can now examine or alter any of the existing data sets.

4.1.3 Using a Ledger Day

The user may generate a schedule based on a ledger day in the TOTools database. Once the option to generate a schedule from a ledger day is selected, the user can use the down arrow to select from the ledgers that are present in TOTools. The operation generated will use the TOTools ledger to create a grower file – the remainder of the data comes from the Default operation.

4.2 Entering Data

Each operation contains nine different sets of data. Apart from the initial use of ACRSS at a mill, it is unlikely that the user will have to generate all nine sets of data to look at a desired scenario. The sets of data describe:

- The cane railway network
- The active harvesters
- The locomotive fleet
- The capacities of the tramway sidings
- Shunt times at particular sidings that differ from the mill standard
- The migration of harvesters, either from 1 day to the next
- Operational data, such as the standard shunt time, the time spent at the mill between runs etc
- Options, that determine the particular schedule produced by ACRSS
- Depots, if there are depot subsystems present in the system being modelled.

Throughout the remainder of this manual, a test case originally developed by SRI for a Cane Inspector's course in 1973 will be used. This case has been extensively used to since 1973 to illustrate cane transport scheduling.

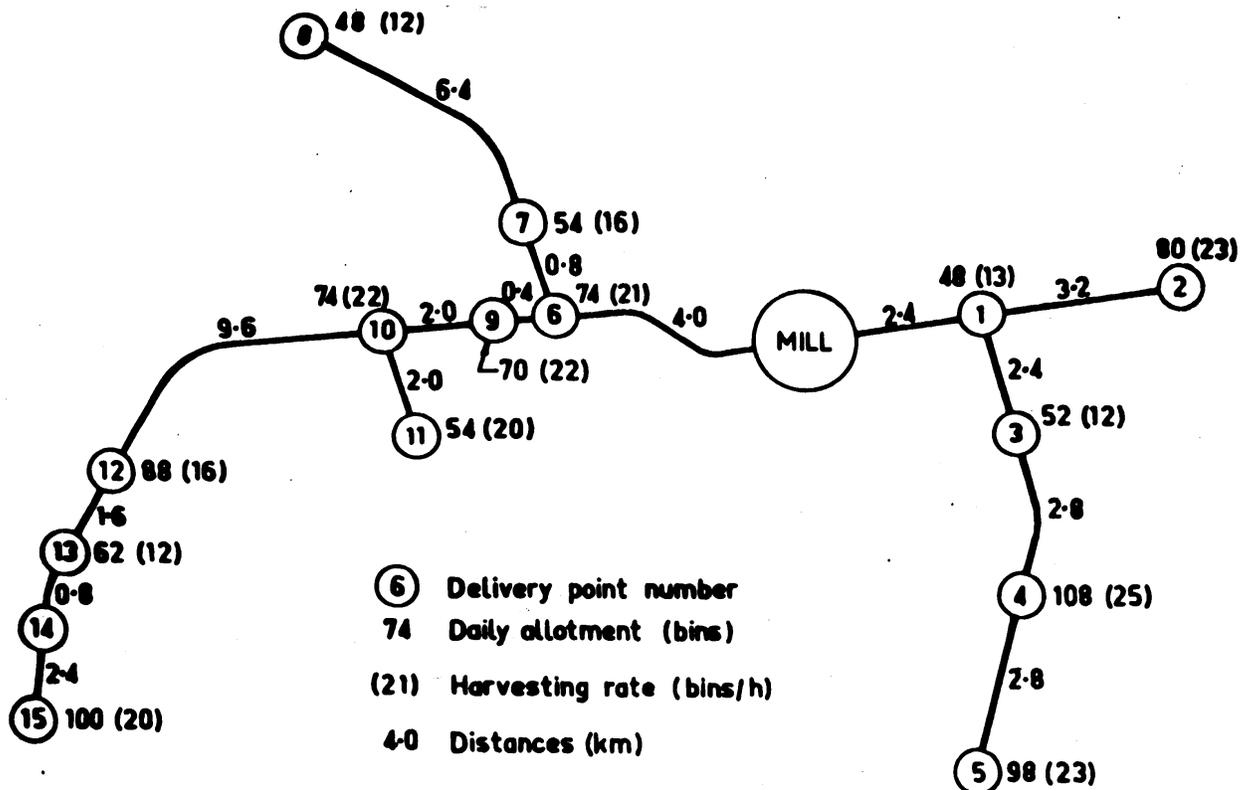


Figure 4.3 SRI sample data

4.2.1 Siding, Grower and Depot Identification

The system does not distinguish between growers (or groups) and sidings. A grower is identified by the siding to which he delivers cane.

Sidings and depots are identified by names. All names selected must conform to the following rules:

- The name must be from one to twenty characters long. A character is any character that can be entered with a single keystroke.
- Blanks (spaces) are not permitted within a name. Blanks should be replaced by hyphens (entered as a minus sign ('-')). Blanks at the beginning or end of a name are not taken to be part of the name.
- The names 'MILL', 'DEPOT' and '*' are reserved for special purposes, and cannot be used as siding names.
- The same name cannot be used for more than one siding or depot.
- Exactly the same name must be given whenever the siding or depot is mentioned on input.
- The mill must always be referred to by the name 'MILL'.
- When depot subsystems are being modelled, the depot must always be referred to by the name 'DEPOT'.

Note that numbers can be used for siding names, as they conform to these rules. It is good practice to employ the names already used in normal operation of the transport system.

Examples of valid siding names are:

SANDY-CREEK 23 8765 16A

4.2.2 Network data

4.2.2.1 The required network data

The network is described in terms of the sections of track between each pair of neighbouring sidings. All sections that can be used, including those with the mill at one end, must be included. Each section is specified by giving the sidings at each end, and the length of the track between them.

For example, the track configuration shown in Figure 4.3 would have the sections show in Table 4.1.

| | Sding 1 | Sding 2 | Distance |
|----|-------------|-------------|----------|
| 1 | Mill | BurnettJnc | 2.4 |
| 2 | BurnettJnc | DrMays | 3.2 |
| 3 | BurnettJnc | Tallons | 2.4 |
| 4 | Tallons | Maughan | 2.8 |
| 5 | Maughan | Manera | 2.8 |
| 6 | Mill | DeltaBranch | 4 |
| 7 | DeltaBranch | Maidavale.1 | 0.8 |
| 8 | Maidavale.1 | Maidavale.2 | 6.4 |
| 9 | DeltaBranch | Airdale | 0.4 |
| 10 | Airdale | RowsBranch | 2 |
| 11 | RowsBranch | RowsExt | 2 |
| 12 | RowsBranch | DAddonas | 9.6 |
| 13 | DAddonas | Hingley | 1.6 |
| 14 | Hingley | Princes | 0.8 |
| 15 | Princes | Andreassens | 2.4 |

*Section numbers are for illustrative purposes only.

They are not required on input, and must not be given.

Table 4.1 Network data for SRI test case

This scheme allows loops in the track to be specified, and the scheduling system can make use of them. The railway in Figure 4.4 would have the track description shown in Table 4.2.

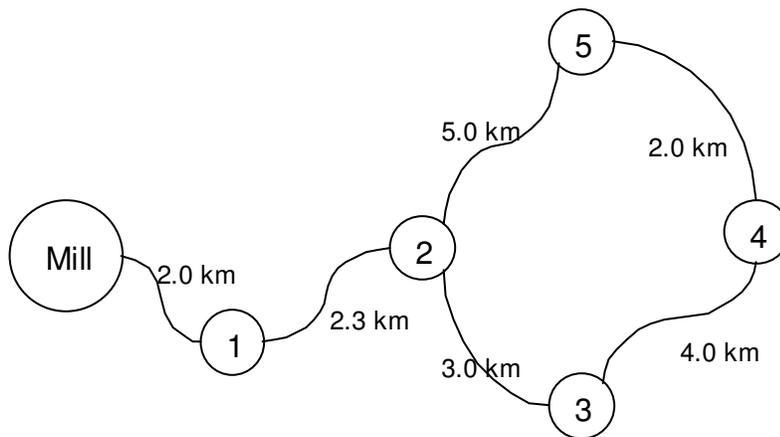


Figure 4.4. Sample Network with a loop

| Section* | Siding at One End | Siding at Other | Length |
|----------|----------------------|-----------------|--------|
| 1 | MILL | 1 | 2.0 |
| 2 | 1 | 2 | 2.3 |
| 3 | 2 | 3 | 3.0 |
| 4 | 3 | 4 | 4.0 |
| 5 | 4 | 5 | 2.0 |
| 6 | 4 | 2 | 5.0 |

Table 4.2 Network data for Loop sample

There is no required order to specify sections on input. However, it is advisable to adopt some pattern to reduce the chances of errors such as omitting sections, and to make the checking of input data easier.

The following possible pattern is recommended:

- Begin by marking on a plan of the network the siding names to be used and the distances of each from the mill.
- Calculate and mark the lengths of each section of track.
- List the section descriptions working outwards from the mill for the main line, and then for branch lines.
- For each section, give the siding closest to the mill first.

4.2.2.2 The user interface - network data

If the option to edit the network data is selected, the current network data is displayed. For the test data the display is as shown in Figure 4.5.

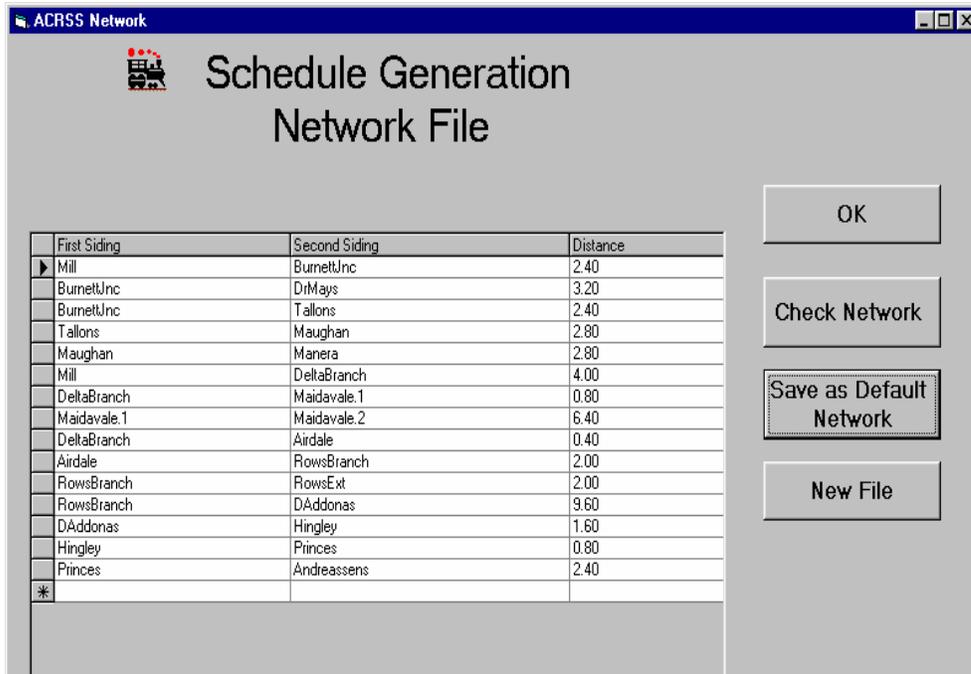


Figure 4.5 Network data entry screen

The user can now has a choice of what action should be taken. The choices are:

- Accept the network data as it is and return to the previous screen
- Edit the network data directly in the table by either altering existing entries or by adding new entries at the end of the table. Note that if a pencil remains in the right hand column, the edited data has not been saved. Move to a different row to save the data.
- Check that the network is correct. If the network data has been edited, or if a new operation has been created, possibly from a TOTools ledger, the network should be checked because checking the network also produces an intermediate file that is used to check other data sets, such as for growers.
- Use the existing network data to replace the Default network data. Unless there have been changes to the cane railway network, this option should be avoided.
- Create a new network data set, either from scratch, or from another existing network data set.

4.2.2.3 The user interface – checking data sets

As each of the data sets are created, they can be progressively checked to ensure their accuracy. To check the network data, click on the “Check Network” button. If there are errors such as sidings that cannot be reached, a message box stating that there are errors will appear and the user can then check where the error has occurred and make the corrections.

When ACROSS can interpret the data as a network, the message changes to indicate that no errors were detected. At this stage, another check can be performed on the network data because

ACRSS produces a listing showing the distances of each siding from the mill. These distances should be checked. Table 4.3 shows the output obtained when the sample data was checked

Base.7

| Line as input | Siding at one end | Siding at other | Interpreted as Length |
|-----------------------------|-------------------|-----------------|-----------------------|
| Mill BurnettJnc 2.4 | Mill | BurnettJnc | 2.40 |
| BurnettJnc DrMays 3.2 | BurnettJnc | DrMays | 3.20 |
| BurnettJnc Tallons 2.4 | BurnettJnc | Tallons | 2.40 |
| Tallons Maughan 2.8 | Tallons | Maughan | 2.80 |
| Maughan Manera 2.8 | Maughan | Manera | 2.80 |
| Mill DeltaBranch 4 | Mill | DeltaBranch | 4.00 |
| DeltaBranch Maidavale.1 0.8 | DeltaBranch | Maidavale.1 | 0.80 |
| Maidavale.1 Maidavale.2 6.4 | Maidavale.1 | Maidavale.2 | 6.40 |
| DeltaBranch Airdale 0.4 | DeltaBranch | Airdale | 0.40 |
| Airdale RowsBranch 2 | Airdale | RowsBranch | 2.00 |
| RowsBranch RowsExt 2 | RowsBranch | RowsExt | 2.00 |
| RowsBranch DAddonas 9.6 | RowsBranch | DAddonas | 9.60 |
| DAddonas Hingley 1.6 | DAddonas | Hingley | 1.60 |
| Hingley Princes 0.8 | Hingley | Princes | 0.80 |
| Princes Andreassens 2.4 | Princes | Andreassens | 2.40 |

Title: Base

| Calculated distances of sidings from mill | |
|---|----------|
| siding | distance |
| mill | 0.00 |
| BurnettJnc | 2.40 |
| DrMays | 5.60 |
| Tallons | 4.80 |
| Maughan | 7.60 |
| Manera | 10.40 |
| DeltaBranch | 4.00 |
| Maidavale.1 | 4.80 |
| Maidavale.2 | 11.20 |
| Airdale | 4.40 |
| RowsBranch | 6.40 |
| RowsExt | 8.40 |
| DAddonas | 16.00 |
| Hingley | 17.60 |
| Princes | 18.40 |
| Andreassens | 20.80 |

Table 4.3 Checking the sample data

Checking the network data also produces a file that is used by the other programs that check the other data items.

4.2.2.4 Creating network data for new operations

New data sets can be created either from a blank data set or from the network data set of an existing operation. If the new network data set is to be created from an existing file, a pull down list of the existing data is created for the user to select from.

It is likely that each mill will create a new network file from scratch only for the initial operation and that this data set will form the basis of the network modelled in future operations.

4.2.3 Grower data

4.2.3.1 The required grower data

One line is required for each grower. There is no required order for this input, although it is advisable to use some convention to ensure all growers are included.

The scheduling system can consider only one morning grower and/or one afternoon grower for a siding. A grower harvesting throughout the day should be shown as a morning and an afternoon grower to allow for the harvester's lunch break. A morning and an afternoon grower can be allocated to the same siding, but not two morning or two afternoon growers. At a siding, morning harvesting must be completed before afternoon harvesting commences.

The harvesting periods for each grower are either 'fixed start' where harvesting starts at the specified time, or 'floating starts' where the harvesting occurs between the start and finish times that are given. ACRSS guarantees that the harvesting will not be delayed because of a lack of empty bins and that for floating start harvesters, the entire allotment will be cut between the specified start and finish times.

Where the same siding is used for a morning and an afternoon grower, separate details (on one line each) must be given for the two periods. For each grower with a floating harvest start time, the data required are as shown below, and must be given in the order shown:

- the siding allocated. Use exactly the same name as used in the network data set.
- the daily allotment (in tonnes, or bins if the bin capacity is 1),
- the harvesting rate (in tonnes per hour, or bins per hour if the bin capacity is 1),
- allocation to morning or afternoon harvesting. The code 'AM' must be used for morning harvesting, and 'PM' for afternoon harvesting.
- the earliest harvest start time (if this is not 0600),
- the latest harvest end time (if this is not 1800).

The earliest start and latest end times can both be omitted if these are 0600 and 1800 respectively.

Specifying a grower as a morning or an afternoon loader is used only to separate the two harvesting periods that can be worked at a siding. If there is only one grower at a siding and that grower does not have a specified meal break, then the ACRSS schedule will be the same regardless of whether the harvester was specified as 'morning' or 'afternoon'. Also, if harvest start times are allowed to float, ACRSS makes no attempt to start the morning harvesters before the afternoon ones, unless the times for the harvesting periods ensure this happens.

For growers with fixed harvest start times, the latest harvest end time is replaced with the word 'Fixed'.

The data for the SRI test case growers are as shown below in Table 4.4. For this data set, there is no sharing of sidings and all growers have been designated ‘morning’ harvesters, even though some don’t start until the afternoon.

| Harvester | Allotment | Harvest Rate | AM/PM | Harvest Start | Harvest Finish |
|--------------|-----------|--------------|-------|---------------|----------------|
| BurnettJnc | 48 | 13 | AM | 1300 | 1800 |
| DrMays | 80 | 23 | AM | 0600 | 1800 |
| Tallons | 52 | 12 | AM | 1300 | 1800 |
| Maughan | 108 | 25 | AM | 1300 | |
| Manera | 98 | 23 | AM | 1300 | |
| Delta Branch | 74 | 21 | AM | 0600 | |
| Maidavale.1 | 54 | 16 | AM | 0600 | 2200 |
| Maidavale.2 | 48 | 12 | AM | 0600 | fixed |
| Airdale | 70 | 22 | AM | 0600 | fixed |
| RowsBranch | 74 | 22 | AM | 1200 | fixed |
| RowsExt | 54 | 20 | AM | 1300 | fixed |
| DAddonas | 88 | 16 | AM | 0800 | fixed |
| Hingley | 62 | 12 | AM | 0645 | fixed |
| Andreassens | 100 | 20 | AM | 0900 | fixed |

Table 4.4 Grower details – SRI test case

4.2.3.2 The user interface - grower data

The interface to allow the grower data to be edited is very similar to that used to edit the network data. Again the user can :

- Accept the data
- Edit the data
- Check the grower data. Before grower data can be checked, the corresponding network data must have been checked
- Save the grower data as ‘Default’
- Create a new grower data set either from scratch or from an existing data set.

The output obtained when the grower data is checked is shown in Table 4.5. Note that the program to check the grower data uses an internal file produced by the network checking program and that the network data for an operation must be checked prior to checking the grower data.

Title: Base

| Siding | Allotment (tonnes) | Harvesting rate (tonnes/hr) | Harvesting period | earliest start | latest end | |
|-------------|-----------------------|--------------------------------|----------------------|-------------------|---------------|-------|
| BurnettJnc | 48 | 13 | 1 | 1300 | 1800 | float |
| DrMays | 80 | 23 | 1 | 600 | 1800 | float |
| Tallons | 52 | 12 | 2 | 1300 | 1800 | float |
| Maughan | 108 | 25 | 1 | 1300 | 1800 | float |
| Manera | 98 | 23 | 1 | 1300 | 1800 | float |
| DeltaBranch | 74 | 21 | 1 | 600 | 1800 | float |
| Maidavale.1 | 54 | 16 | 1 | 600 | 2200 | float |
| Maidavale.2 | 48 | 12 | 1 | 600 | | fixed |
| Airdale | 70 | 22 | 1 | 600 | | fixed |
| RowsBranch | 74 | 22 | 1 | 1200 | | fixed |
| RowsExt | 54 | 20 | 1 | 1300 | | fixed |
| DAddonas | 88 | 16 | 1 | 800 | | fixed |
| Hingley | 62 | 12 | 1 | 645 | | fixed |
| Andreassens | 100 | 20 | 1 | 900 | | fixed |

Table 4.5 Checking the grower data

4.2.4 Locomotive data

4.2.4.1 The required locomotive data

These records describe the hauling capacity and running speeds of the various locomotives. Speeds and loads are treated as uniform throughout the network.

Locomotive characteristics

- The name of the locomotive. The name should match the locomotive description specified in the TOTools database.
- The order in which locomotives should be used by ACRSS
- The maximum size of a train of empties (in bins) for this locomotive. This will be treated as constant throughout the network for this particular locomotive type.
- The maximum size of a train of fulls (in bins) for this locomotive type. Again this is treated as uniform throughout the system.
- The speed for a locomotive with empties only. This will be treated as a uniform speed throughout the network.
- The speed for a locomotive with fulls only. This will be treated as a uniform speed throughout the network.
- The speed of a locomotive running light engine. Again this is treated as a uniform speed.
- The total number of locomotives in the system cannot exceed 40.

The data for the SRI test case locomotives are as shown in Table 4.6.

| LocoName | LocoOrder | Load - Fulls | Load - Empties | Speed - with Fulls | Speed - with Empties | Speed - Light Engine |
|----------|-----------|--------------|----------------|--------------------|----------------------|----------------------|
| Moreton | 1 | 100 | 130 | 10 | 16 | 16 |
| Thomas | 2 | 100 | 130 | 10 | 16 | 16 |
| Sandy | 3 | 100 | 130 | 10 | 16 | 16 |

Table 4.6 Locomotive data – SRI test case

4.2.4.2 The user interface - locomotive data

This interface is similar to that described when the network data was being discussed. The output obtained when the locomotive data is checked is shown in Table 4.7.

| Locomotive | Order | Maximum Loads | | Locomotive Speeds | | |
|------------|-------|---------------|-------|-------------------|-------|--------------|
| | | Empties | Fulls | Empties | Fulls | Light Engine |
| Moreton | 1 | 130 | 100 | 16 | 10 | 16 |
| Thomas | 2 | 130 | 100 | 16 | 10 | 16 |
| Sandy | 3 | 130 | 100 | 16 | 10 | 16 |

Table 4.7 Checking the locomotive data

4.2.5 Siding Capacity data

One line is required for each siding with limited capacity. There is no required order for this input, although it is advisable to use some convention to ensure that all desired sidings are included. When entering the initial set of siding capacities, it is worthwhile entering the capacities of all sidings, including those not active in the current operation. This way should mean that all future operations consider correct the siding capacities.

For each siding the information required is as below:

- The siding considered. Exactly the same name as given in the track configuration and grower details data sets must be used.
- The first siding capacity (in bins). If the capacity is specified as a total number of bins (as for a loop), then the total siding capacity is entered. If the capacity is specified as a maximum number of empties and a maximum number of fulls, then the maximum number of empties which can be accommodated is used.
- The second siding capacity (in bins). This information is not required for loop type of sidings where only an overall siding capacity is required. For the fish-tail type of siding where capacities are defined as a number of empties and a separate number of fulls, then the maximum number of fulls is entered here.

The data for the SRI test case siding capacities are as shown in Table 4.8. The first four sidings are fish tail type sidings and have separate empty and full areas.

| Siding | Empty Capacity | Full Capacity |
|---------------|-----------------------|----------------------|
| BurnettJnc | 38 | 38 |
| DrMays | 64 | 64 |
| Tallons | 41 | 41 |
| Maughan | 86 | 86 |
| Manera | 78 | |
| DeltaBranch | 59 | |
| Maidavale.1 | 43 | |
| Maidavale.2 | 38 | |
| Airdale | 56 | |
| RowsBranch | 59 | |
| RowsExt | 43 | |
| DAddonas | 70 | |
| Hingley | 49 | |
| Andreassens | 80 | |

Table 4.8 Siding Capacities for the SRI test case

Again, siding capacity data can be checked. The output obtained when the capacities shown in Table 4.8 were checked is shown in Table 4.9. The errors located at this stage usually indicate differences in the names of the sidings as used here and as specified in the network data.

| siding | capacities | | |
|-------------|------------|-------|-------|
| | empties | fulls | total |
| BurnettJnc | 38 | 38 | 76 |
| DrMays | 64 | 64 | 128 |
| Tallons | 41 | 41 | 82 |
| Maughan | 86 | 86 | 172 |
| Manera | 0 | 0 | 78 |
| DeltaBranch | 0 | 0 | 59 |
| Maidavale.1 | 0 | 0 | 43 |
| Maidavale.2 | 0 | 0 | 38 |
| Airdale | 0 | 0 | 56 |
| RowsBranch | 0 | 0 | 59 |
| RowsExt | 0 | 0 | 43 |
| DAddonas | 0 | 0 | 70 |
| Hingley | 0 | 0 | 49 |
| Andreassens | 0 | 0 | 80 |

Table 4.9. Checking siding capacities

4.2.6 Shunt time data

One line is required for each siding when the shunt time differs from the previously defined default value. There is no required order for this input.

For each siding where shunt time is different from the default value, the information required is as below, and must be given in the order shown:

- The siding considered. Again, exactly the same name as used in the track configuration and grower details data sets must be used.
- The shunt time (in minutes) applicable to each activity at the siding. Note that simultaneous deliveries and collections are considered as two activities and a time of twice the specified shunt time will be allowed for such events.

The data for the SRI test case shunt times are as shown in Table 4.8. For all other sidings, the shunt time per activity is the mill standard shunt time of 5 minutes.

| Siding | Shunt Time |
|---------------|-------------------|
| Maidavale.1 | 20 |
| DrMays | 15 |

Table 4.9. Checking siding capacities

The shunt times data can be checked. Again, spelling differences account for the majority of errors.

4.2.7 Harvester migration data

Four different types of migration (finished yesterday, finishes today, starts today and starts tomorrow) are allowed for harvester migration. For each of the four types extra information is required specifying the number of bins at the siding at the start/ or end of the day.

For each siding of the harvester migration, the information required is as below.

- The siding considered. Exactly the same name as given in the track configuration and grower details data sets must be used.
- Type of migration. (finished yesterday, finishes today, starts today and starts tomorrow)
- The extra data required is dependent on the type of migration
 - For finished yesterday the first data field is number of fulls left at the siding at midnight that were cut yesterday, and the second data field is the time at which yesterday's harvesting finished (2 pm is to be specified as 1400)
 - For finishes today the first and only field specifies the number of empties that were delivered after harvesting yesterday.

- For harvesting starts today the first field specifies the number of empties left at the siding before midnight and the second field specifies the number of full bins that will not be collected by midnight tonight.
- For starts tomorrow the extra data field specifies the number of empties that are to be delivered before midnight tonight for tomorrow's harvest.

Table 4.11 shows some typical harvester migration data. Note harvesters that are active today cannot also be either 'finished yesterday' or 'starts tomorrow' migrators. Migration data can also be checked.

| Harvester | MigrationType | MigrationData1 | MigrationData2 |
|-----------|---------------|----------------|----------------|
| Princes | Fin_Yes | 25 | 1400 |
| Manera | Fin_Tod | 10 | 0 |
| Maughan | Str_Tod | 15 | 20 |

Table 4.11 Migration data .. SRI test case

4.2.8 Operational data

Various operating parameters are required to describe the cane transport operations. The required information is:

- Bin size. Bin size is specified by this record. A uniform bin fleet is allowed and only one bin size can be specified. If harvesting rates and daily allotments are given in bins, rather than tonnes, specify a bin capacity of one tonne.
- Shunt times. This is a default value and is applied to those sidings not specifically entered in the shunt time data. The time must be given in minutes.
- Yard delays. The allowance for time in the mill yard for a locomotive between runs. This should include an allowance for shunting, maintenance, delivering consignment notes, etc. It is applied to all runs and must be given in minutes.
- Crib break – start time. The minimum time, in hours, between the start of a locomotive shift and the start of the crew's crib break.
- Crib break – finish time. The maximum time, in hours, between the start of a locomotive shift and the end of the crew's crib break.
- Crib break –duration. The length of a crib break (in minutes).
- Desired maximum cane age. The user can specify a desired maximum age for a rake of cane. Whilst the program attempts to reduce the age of all rakes below this maximum age, extra shifts will not be added solely to make all rake ages less than the

desired maximum. An age of 17 hours 30 minutes should be given as 1730. Remember a 'rake' is a collection from a single grower, rather than all cane on a train.

- **Road Details.** These records describe the cane transported to the mill cane receiving station by means other than the cane railway, for example, by road transport. These lines specify the number of tonnes of cane tipped in each period and the duration of the periods. The lines describing the quantity and timing of this cane must be arranged in time order starting at 0800 hours. If a period extends over 0800, then it must be split into two separate periods, one up to 0759 and the other from 0800 onwards. The period ending at 0759 would be the last period described in the data records. The data required is:
 - The number of tonnes of cane delivered directly to the cane receiving station in the period being considered.
 - The starting time for the delivery of cane directly to the cane receiving station.
 - The finishing time for the delivery of cane directly to the cane receiving station.

If there is more than one period when cane arrives at the cane receiving station by means other than the cane railway, the additional periods are also entered in this format.

A pull down list has been provided to assist the user prepare the operational data. The pull down list has an associated set of help notes that explain the data required.

A typical screen display is shown in Fig 4. 6. Table 4.12 shows the output obtained when this data set is checked.

| Operational | Value | Comments |
|------------------|--------------|---|
| Shunt Time | 5 | Shunt time at a siding |
| Yard Delay | 30 | Time spent in the mill yard between runs |
| Crib Break | 20 | Length of the crib break |
| Crib Start | 3 | Earliest crib start time. |
| Crib Finish | 5 | Latest crib finish time. |
| Maximum Cane Age | 1800 | Maximum desired cane age |
| Bin Size | 5.6 | Bin size, in tonnes. |
| Road Details | 30 0900 1000 | Details of when road transported cane is received |
| * | | |

Bin size is specified by this record. Only one bin size is allowed. The information is: The capacity of a bin, in tonnes. If harvesting rates and daily allotments are given in bins, rather than tonnes, specify a bin capacity of one tonne.

Figure 4.6 Operational data input

```

Shunt Time      5           Shunt time at a siding
Yard Delay     30           Time spent in the mill yard between runs
Crib Break     20           Length of the crib break
Crib Start     3           Earliest crib start time.
Crib Finish    5           Latest crib finish time.
Maximum Cane Age 1800       Maximum desired cane age
Bin Size       5.6         Bin size, in tonnes.
Road Details   30 0900 1000 Details of when road transported cane is received
  
```

Data interpreted as :-

```

Shunt time at a Siding 5 minutes
Minimum time at the mill after a run 30 minutes
Length of a meal break 20 minutes
Meal breaks are taken between hours 3 and 5 of the shift
Desired maximum cane age for a parcel of cane 1800
Bin Size 5.6 tonnes
  
```

```

No. of periods of Road Transported Cane 1
30 tonnes between 900 and 1000
  
```

Table 4.12 . Checking the operational data

4.2.9 ACRSS Options

The system provides some options by which the schedules generated can be influenced. A number of options can be specified in any order. If the option requires a number of values, these values must be separated by at least one space.

If an option is not specified, the default condition for that option is assumed.

The available options are :

DEBUG This option is to apply self-consistency checks at many points. It has been incorporated for debugging purposes. Routine use is not recommended as voluminous output is produced and solution times are substantially increased. Note that self-consistency checks are always applied at the end of execution of each program. The default is not to apply self-consistency checks during execution of a program.

SIDSIZ The default is that no delivery or collection at a siding will exceed the sidings capacities. **SIDSIZ** overrides this.

BRANCH The default is that the initial set of runs will not include cases where fulls are taken into a branch or empties from a branch. **BRANCH** overrides this. This parameter applies to an intermediate phase of ACRSS only.

MINCOL The argument is the minimum collection size required. The default is a minimum collection size of five bins. This parameter applies to an intermediate phase of ACRSS only.

MINDEL The argument is the minimum delivery size required. The default is a minimum delivery size of five bins. This parameter applies to an intermediate phase of ACRSS only.

LOCO This option enables the user to specify shift times and yard start times for the individual locomotives. (Yard start times are the times when the user wishes the locomotive to be in the mill yard.) For example, if the user wishes to utilize the available locomotives in the manner shown below in Table 5.20, the required options are shown in Table 5.21.

| LOCOMOTIVE | SHIFTS WORKED | YARD TIMES |
|------------|-------------------|--------------------------|
| 1 | All three | Midnight |
| 2 | All three | Midnight 8 am 4 pm |
| 3 | Day and Afternoon | 6 am 2 pm 10 pm |
| 4 | Day Work | 7 am 4 pm |

Table 4.13 Sample Locomotive Utilization

```

LOCO 1 1 0000
LOCO 2 1 0800
LOCO 3 1 0600 1400
LOCO 3 2 1400 2200
LOCO 4 1 0700 1600

```

Table 4.14 Prepared Locomotive Options

The default is that all locomotives are required to be in the mill yard at 0800.

YARD This option enables the user to specify priorities to be used to determine the order in which the train loads of cane are crushed. The priorities and their codes are:

- time of arrival in mill yard, code 1,
- average age of the train load of cane, code 2,
- age of the oldest rake of cane in the train load, code 3.

A sample entry is

YARD 2

which specifies that the next train load of cane to be crushed is the one with the highest average age of all those available in the mill yard. The default is as shown in the example.

OBJFUN This option specifies the objective function for the runs sequencing phase only. The user has the option of including violation indices, weighted cane age, average cane age, zero hour, bin fleetsize and total yard size, or some combination of these in an order of priority. The components to be used with their codes are:

- average cane age, code 1,
- zero hour, code 2,
- bin fleetsize, code 3,
- weighted cane age, code 4,
- harvest start and siding capacity violations, code 5,
- total yard size, code 6.

A sample OBJFUN entry is

```
OBJFUN 2 5 4
```

This record specifies that two items are in the objective and that violations are to be removed, if possible, and then the weighted cane age is to be minimized. This is the default.

AGEF This option specifies the ageing function to be used in calculating the weighted cane age. The ageing function is defined by specifying the required weighting at hourly intervals from 0 to 24 hours. 25 values are required and these are input in three lines with nine values on the first line and eight on each of the other two lines. Each line must begin with AGEF.

The default ageing function is shown as Figure 5.3. This approximates CSR's dextran function. The required entries to specify this function are:

```
AGEF 8 10 12 15 19 23 28 34 42
AGEF 52 64 79 97 119 146 180 221
AGEF 271 333 410 504 619 761 935 1150
```

LOG This option allows key parameters for each solution to be noted as an improvement. It is useful in gaining a "feel" for the operation of the refinement procedure but increases the volume of output obtained. The default is not to log.

OBJREF This option applies only to the final, refinement phase. It specifies the objective for refinement. The user has the option of including the violation indices, cane ages, the zero hour, the bin fleetsize and the total yard size, or some combination of these, in an order of priority. The components to be used, with their codes, are:

- average cane age, code 1,
- zero hour, code 2,
- bin fleetsize, code 3,

- weighted cane age, code 4,
- harvest start and siding capacity violations, code 5,
- total yard size, code 6.

A sample OBJREF entry is

OBJREF 3 5 4 3

This record specifies that three items are in the objective and that violations are to be removed and then the weighted cane age and the bin fleetsize are to be minimized, in that order of priority. This is the default.

TITLE The TITLE entry allows specification of a title used for annotating output generated by the reports generation program and which is embedded in the file of schedules produced by the refinement program. It is included as probably useful in identifying schedules when the RESTART option is used. Sample format is:

TITLE RUN OF 21/3/80 MIN AGE REQUIRED 9 HOURS

A maximum of 80 characters may be given as a title. The default is the date of running the program Phase4.

MINAGE A MINAGE entry specifies a threshold for the average cane age, the level below which all average cane ages are taken as being of equal merit. A sample entry is

MINAGE 945

which specifies the age limit as 9 hours 45 minutes. The default is not to apply a threshold on average cane age.

MINBIN A MINBIN entry specifies a threshold for the bin fleetsize, the level below which all bin fleetsizes can be taken as being of equal merit. A sample entry is

MINBIN 1000

which gives the minimum bin fleetsize required as 1000 bins. The default is not to apply a threshold on bin fleetsize.

MINWT A MINWT entry specifies a threshold for the weighted cane age, the level below which all weighted ages are taken as being of equal merit. A sample entry is

MINWT 50

which specifies the limit as 50 units. (If the default AGEF is used, 50 units corresponds to about nine hours.) The default is not to apply a threshold on weighted cane age.

MINYD A MINYD entry specifies a threshold for the total yard size, the level below which all total yard sizes are taken as being of equal merit. A sample entry is

```
MINYD 500
```

which specifies the limit as 500 bins. The default is not to apply a threshold on total yard size.

MINZRH A MINZRH entry specifies a threshold for the zero hour. For example,

```
MINZRH 0930
```

gives 9.30 am as the minimum zero hour of interest. The default is 8 am.

To illustrate the use of the options, consider the case of a mill which allows full bins to be taken into a branch line and wishes to develop a schedule with minimum shifts. This mill has set as its principal requirement the reduction of weighted cane age and is also desirous of reducing the total number of bins used. For this mill, the option file would be:

```
BRANCH
OBJFUN 2 5 4
OBJREF 3 5 4 3
```

The options not specified would take their default values as described above.

From experience gained in operating ACRSS, the following set of options have been found to be most suitable for most scheduling applications and it is recommended that these options be used unless there is a particular reason for varying them. The default options are:

```
LOG
BRANCH
OBJFUN 2 5 4
OBJREF 3 5 4 3
```

The LOG option produces a summary of the optimization process which assists the user if, for some reason, the program does not successfully complete execution.

The BRANCH option enables full bins to be taken into branch lines and this is in line with normal practice.

Specifying that the run sequencing phase remove harvest start and siding capacity violations and then optimize only on weighted average cane age by using the option OBJFUN 2 5 4 succeeds in producing a schedule with minimum shifts and with a low average cane age.

OBJREF 3 5 4 3 specifies that the refinement phase (Phase4) removes harvest start and siding capacity violations and then reduces weighted cane age first and then bin fleet size.

The options used for this example are shown in Figure 4.7.

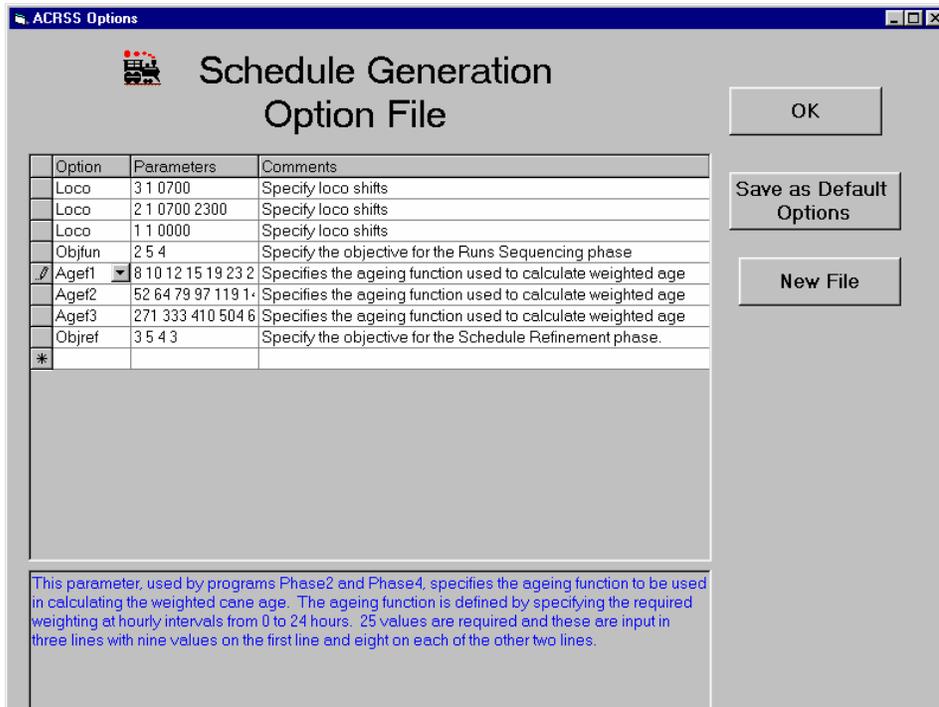


Figure 4.8 Options used

4.2.10 Depot data

This section allows the user to specify any depots that are in the system. Depots in ACRSS can cater for a wide range of operational practices including

- A fully functional depot where the depot locomotives are based and serviced at the depot and never return to the mill
- A depot where the locomotives start each day at the mill, have crew changes in the depot system and return to the mill at the end of their day
- An operation similar to a marshalling yard, where the locomotives start each shift at the mill, travel to the marshalling area, assemble one or more loads of full bins at this area and then return to the mill for the change of shift

Section 5 of this report describes in detail how a depot can be incorporated into ACRSS.

For this test example, there are no depots in the system and the input screen is as shown in Figure 4.8. The option buttons selected show that the system being modelled is not a depot system itself and that it does not include any depots

The screenshot shows a window titled "ACRSS Depots" with a sub-dialog titled "Schedule Generation Depots". The dialog contains two radio button questions:

- "Is this a Depot System ?" with radio buttons for "Yes" and "No". The "No" option is selected.
- "Does this system contain depot subsystems?" with radio buttons for "Yes" and "No". The "No" option is selected.

On the right side of the dialog, there are three buttons:

- "OK"
- "Check Depot Locomotive Details"
- "New File for Depot Locomotives"

Figure 4.8 Depot Input

4.3 Generating a Schedule

When all the input data has been entered and checked, a schedule can be generated. By default, ACRSS initially generates a minimum shift schedule that uses as many locomotives as possible on an around the clock (3 shift basis).

The ACRSS interface allows the user to generate a schedule by clicking on the “Generate a Schedule” button as shown in Figure 4. 9. The actual steps that ACRSS takes to produce a schedule are described in Appendix A.

Figure 4.9 Generating a Schedule

When the schedule has been produced, a summary screen as Shown in Figure 4.10 is displayed, showing the key parameters of the schedule that has been produced. If, for one reason or another, ACRSS does not produce a schedule a blank summary screen appears. Some of the reasons why ACRSS may not produce a schedule are discussed later in this section.

The summary screen displays:

- The sequence number for this schedule. A number of schedules can be produced from a set of data. This sequence number describes the position of a schedule in this sequence.
- The number of locomotives used for this schedule. For the test example, ACRSS has produced a schedule using 2 locomotives.
- The number of locomotive shifts in the schedule. Here, the ACRSS schedule uses 5 shifts, with the first locomotive working 3 shifts and the second only 2. Because of the options entered, the first locomotive starts its first shift at 0000 (midnight) and ACRSS guarantees that it will be back in the mill yard at midnight the next day. The second locomotive works 2 shifts, starting at 0700 and finishing 16 hours later at 2300.
- The total free time in the schedule. A total of 223 minutes of free time is spread over the 2 locomotives (& 5 shifts)

- The average cut-to-crush age of the cane is 9 hours 21 minutes
- The weighted age is 102. This is an average figure and estimates the dextran level of the cane. The function used to calculate the weighted age uses a relationship that increases very rapidly if the cut-to-crush age of a rake of cane exceeds 18 hours.
- The zero hour for associated with the schedule. The zero hour is the time when the last of yesterday's cane is crushed.
- The number of bins required to implement the ACRSS schedule.
- The number of harvest start violations. These occur if the ACRSS schedule attempts to collect cane that has not been cut.
- The number of siding capacity violations. These occur if the schedule attempts to place more bins at the siding than the siding can accommodate.

The screenshot shows a window titled "ACRSS Summary" with a sub-header "Schedule Generation Summary". Below the header is a table titled "Key Statistics for Schedules". The table has 10 columns: Sequence No, No. of Locos, No of Shifts, Free Time, Average Age, Weighted Age, Zero Hour, No of Bins, Harvest Viols, and Siding Viols. The first row contains the following data: Sequence No 1, No. of Locos 2, No of Shifts 5, Free Time 203, Average Age 09:20:00, Weighted Age 102, Zero Hour 09:36:00, No of Bins 836, Harvest Viols 0, and Siding Viols 4. Below the table are six buttons: "Add Extra Loco Shifts", "View Report", "View Violations", "Remove Violations", "Restore Siding Capacities", and "Export to TOTools".

| Key Statistics for Schedules | | | | | | | | | |
|------------------------------|--------------|--------------|-----------|-------------|--------------|-----------|------------|---------------|--------------|
| Sequence No | No. of Locos | No of Shifts | Free Time | Average Age | Weighted Age | Zero Hour | No of Bins | Harvest Viols | Siding Viols |
| 1 | 2 | 5 | 203 | 09:20:00 | 102 | 09:36:00 | 836 | 0 | 4 |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |

Figure 4.10 Schedule Summary Display

The user can now either return to the main ACRSS screen by closing this summary window or he can:

- Produce additional schedules for this operation
- Examine one of the schedules that ACRSS has produced in more detail
- Examine the harvest start and siding capacity violations associated with one of the ACRSS schedules
- Remove the siding capacity violations from one of the ACRSS schedules. Essentially, this option removes the violations by increasing the siding capacities to accommodate the number of bins that the schedule has placed at the siding.

- After the siding violations have been removed, the user may wish to restore the siding capacities to their actual values for reporting purposes
- If the operation reflects TOTools ledger, then one of the schedules that ACRSS has generated can be exported back to the TOTools ledger for inspection, display using the ACTSS program and possible modification.

4.3.1 Adding Extra Shifts

This option allows the user to add extra shifts to the existing ACRSS schedules. The display screen that appears when this action is selected is shown in Figure 4.11.

| Key Statistics for Schedules | | | | | | | | | |
|------------------------------|--------------|--------------|-----------|-------------|--------------|-----------|------------|---------------|--------------|
| Sequence No | No. of Locos | No of Shifts | Free Time | Average Age | Weighted Age | Zero Hour | No of Bins | Harvest Viols | Siding Viols |
| 1 | 2 | 5 | 203 | 09:20:00 | 102 | 09:36:00 | 836 | 0 | 4 |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |

Select the Starting Schedule: Schedule 1 2 Locos & 5 shi

How many extra shifts are required? 0

How many extra locomotives are required? 0

Extra Shift Allocation

Add extrashifts to new locomotives (Shfdis = 1)

Add extra shifts to existing locomotives (Shfdis = 2)

Generate Extra Schedules

Figure 4.11 Adding Extra Shifts

The user begins by selecting the schedule to be used as the starting point. The pull down selection box that appears allows the user to select one of the schedules from the summary as the starting point for the extra schedules that use extra locomotive shifts. The selection list shows the sequence number, number of locomotives and the number of shifts for each existing schedule.

Once the starting schedule has been selected, the user now indicates how many shifts and locomotives are to be added. For the test case, where the existing schedule uses two locomotives, working 3 and 2 shifts respectively and where the options specify that a third locomotive, starting at 0700 is available, the user has the following options available:

- Don't use the third locomotive but add an extra, third shift to the second locomotive. For this scenario, choose to add 1 extra shift and no extra locomotives. (Finish with 2 locomotives & 6 shifts, with each locomotive working all 3 shifts.)
- Introduce the third locomotive and use it for 1 shift. For this scenario, choose to add 1 extra shift and 1 extra locomotive. (Finish with 3 locomotives and 6 shifts, with the locomotives working 3, 2 and 1 shifts respectively)
- Add 2 extra shifts to the existing schedule. This results in a 7 shift schedule and necessitates the use of the third locomotive. The extra shift allocation option allows the user to select how the shifts are to be spread across the available locomotives. If the extra shifts are allocated to the new locomotive, the locomotives will work 3, 2 and 2 shifts respectively. If the extra shifts are first allocated to the existing locomotives, the locomotives will work 3, 3 and 1 respectively.
- Add 3 extra shifts to give an 8 shift schedule, using all 3 locomotives. Regardless of the shift allocation option selected the final schedule will require the locomotives to work 3, 3 and 2 shifts respectively.

When the extra shifts and locomotives have been chosen, the extra schedules may be produced. ACRSS will not produce the extra schedules if the user has not specified sufficient locomotives in the locomotive input data. The extra schedules that are produced by this action are then displayed in the summary screen.

The action to add extra shifts and locomotives can be repeated a number of times with any of the existing schedules used as a starting point.

4.3.2 Viewing a Report

By choosing to view a report, the user can examine, in detail, any of the schedules contained in the summary. The report contains the following sections:

- The key parameters of the schedule. This includes the parameters such as weighted and average cane age, zero hour and bin fleet requirements (as shown in the summary), the distribution of the free time over the locomotives and the distribution of the cane age by hour.
- A summary of the runs completed by each locomotive, showing the start and finish times of runs for each locomotive.
- Detailed description of each locomotive run. This shows the sidings visited and the activities at the siding. The duration of the run and the time when the activity actually occurred are also shown.
- The activities at the mill. There are separate reports for the empty and full yards and this part of the report shows the stock patterns in these yards throughout the day.
- Detailed list of activities at each siding. For each active siding, a list of the deliveries and collections made are shown along with a indication of the maximum number of bins that were located at the siding.
- A report showing how the bins in the transport system were utilized throughout the day.

Section 6 of this document contains the report obtained from the test case schedule.

4.3.3 View the Violations

This action allows the user to view the violations associated with a particular schedule. This report shows, for the selected schedule:

- Any harvest start violations where the schedule attempts to collect cane before it is harvested
- Any siding capacity violations where the schedule leaves more than the allowable number of bins at a siding. Note that the schedule as generated will restrict the size of deliveries and collection to the siding capacity and that these violations occur because the timing of the activities cannot be adjusted to meet all competing needs and avoid the violations. Quite often, it is found that a core group of siding violations occur in a number of operations modeled at a mill and these correlate well with the sidings that cause problems in the actual operations. Adding extra shifts in the hours of harvesting will remove the majority of the siding violations.
- Any rake of cane older than the age limit specified in the operational parameters will also be displayed. This shows the origin of any stale cane.

Table 4.13 below shows the violations for the 2 locomotive, 5 shift schedule.

| | | | | |
|-------------------|-----------------------|---------|----------------------|----|
| Grower Airdale | total siding capacity | 56 | maximum no. of bins | 70 |
| Grower RowsBranch | total siding capacity | 59 | maximum no. of bins | 74 |
| Grower DAddonas | total siding capacity | 70 | maximum no. of bins | 88 |
| Grower Hingley | total siding capacity | 49 | maximum no. of bins | 62 |
| Grower DAddonas | rake 2 age 22: 1 | outside | the max age of 18: 0 | |

Table 4.13 Violations for the 2 locomotive, 5 shift schedule

4.3.4 Removing Violations

This action allows the user to remove the siding violations. It acts by increasing the size of the sidings where there are siding violations so that they will accommodate the maximum number of bins that the ACRSS schedule wishes to leave at the siding. The sizes of other sidings are not affected by this action. The action will not remove harvest start violations.

After viewing the violations, the user might conclude that the violations that are still in the schedule are manageable in practice. Eg the capacity may be only exceeded by a small number and it might be possible to store an extra bin or two at the siding, or it may be an existing practice to use an adjacent siding to complement the active siding, or it may be possible to leave the extra bins on the branch line or ...

While violations are present in the schedule ACRSS will not use any locomotive free time to reduce schedule parameters such as cane age or bin numbers. Removing the violations (by allowing siding capacities to increase) allows ACRSS to use the available free time to reduce these values. The reductions are often quite significant and it is recommended that violations should be removed before various alternative operations are compared as the presence of violations could mask the differences between the schedules that have been produced.

Figure 4.12 shows the summary screen after the violations have been removed from the 2 locomotive, 5 shift schedule. Note that the locomotive free time has been significantly used to make some improvements in cane age and bin numbers. Note also that the siding violations have been removed in both schedules shown.

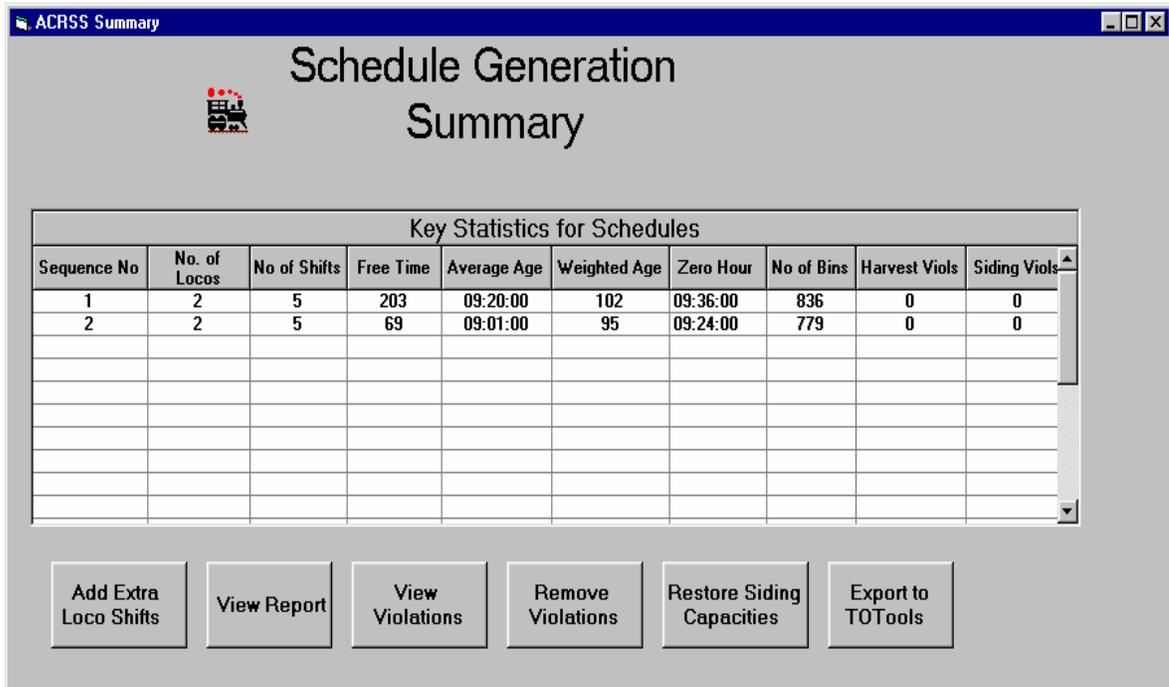


Figure 4.12 Removing the siding violations

4.3.5 Restoring the siding capacities.

Removing the siding violations has effectively hidden any siding violations that may be present. Restoring the siding capacities will restore the sidings to their existing capacities and enable a more accurate picture to be obtained. Figure 4.13 shows the summary screen after the siding capacities have been restored.

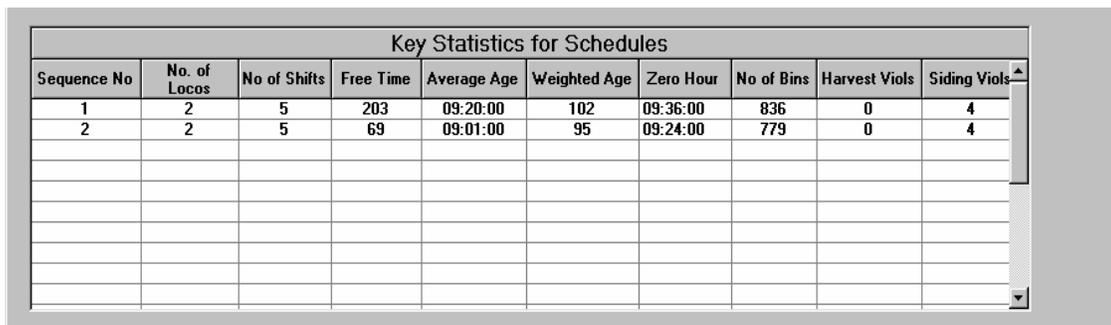


Figure 4.13 Restoring the Siding Capacities

4.3.6 Exporting to TOTools

If the schedule was originally developed from a TOTools ledger, it can be exported back to the TOTools ledger. Once it has been exported back to the ledger, it can be examined from TOTools or used as the basis of an ACTSS schedule and displayed using the ACTSS simulator.

Some aspects to consider if the ACRSS schedule is to be written back to TOTools are:

- There should be agreement in the names of the sidings used in TOTools and throughout ACRSS (network, growers, siding capacities etc). Any discrepancies are flagged by ACRSS when then runs are being exported to TOTools.
- Any existing locomotive runs in the TOTools ledger for the day modeled in ACRSS are deleted before the ACRSS schedule is exported back to TOTools.
- The ACRSS runs may span up to 3 days allowing for runs that commenced yesterday afternoon to deliver empty bins for today's harvest and for runs that start tomorrow morning to collect today's full bins.
- An extra field labeled 'Depot' has been added to the 'Siding' table in the TOTools database. This field allows the transfer of harvester details and locomotive runs between TOTools and ACRSS to occur if depots are present. If no depots are present, this entry should be 'Mill' for all sidings in the TOTools database table.
- If the TOTools ledger is to show the correct locomotives making the runs added by ACRSS the locomotive names in TOTools and ACRSS should agree. If ACRSS cannot match its locomotive name with one in TOTools, it will show the run as being made by the first of the TOTools locomotives.

4.3.7 When ACRSS doesn't produce a schedule

Sometimes ACRSS fails to produce a schedule and most often this is caused by problems with the input data. This section describes some of the data problems that may result in no schedule being generated.

ACRSS uses a series of intermediate files as it generates schedules. These files are stored in the active directory and are called operation.xx, where operation is the name of the currently selected scheduling operation and xx is an integer value. The contents of these files are:

- File extension .7. This file contains the network distances and is produced when the network data is correct. It is used when grower data is analyzed.
- File extensions .8 and .9. These files are produced when the grower data is successfully processed. These files are used by ACRSS to develop a set of locomotive runs.
- File extension .10. This file is produced when ACRSS has developed a set of locomotive runs. The sequencing phase of ACRSS uses this file.
- File extension .12. This file is produced by the sequencing phase of ACRSS. This sequencing phase takes a set of locomotive runs and sequences them in time order by locomotive.

- File extension .13. This file is also initially produced by the sequencing phase and contains the schedule data. Schedules that are refined and generated by the refinement phase of ACRSS are also stored in this file.

Checking which of the intermediate files exist can help isolate the reason why ACRSS was unable to generate a schedule. For example, if the .7 extension file is not present, ACRSS encountered problems analyzing the network data and it's likely that there are errors in the network data that should be corrected. Missing .8 and/or .9 files indicate errors with the grower data.

If the .10 file is missing, ACRSS has been unable to produce a set of locomotive runs for this operation. This is associated with a lack of locomotive hauling capacity but this lack of locomotive capacity can be caused by data input errors. Some of the errors that have been witnessed are:-

- Excessively large allotments for a grower, perhaps caused by an extra digit in the allotment. This won't cause an error when the grower data is checked, but may necessitate a large amount of locomotive activity to service the siding
- Inaccurate bin weights. The mill average bin weight is specified as an operational parameter. If the bin weight is not correctly specified or not specified at all (it defaults to 1 tonne) then ACRSS may run out of locomotive capacity because of the excessive bin allotment.
- Inaccurate siding capacities. If very small siding capacities are specified, extra locomotive runs will be required to service sidings and this can exhaust the locomotive resources. In particular, when specifying siding capacities for loop-type sidings, ensure that the second capacity is blank, rather than 0 or 1.
- ACRSS expects locomotives to travel at their highest speeds when traveling light and to travel faster (or at the same speed) when hauling empties compared to when they are hauling fulls.

If ACRSS is able to generate a set of locomotive runs, and produces the .10 intermediate file, it will very likely go on to generate a schedule.

5 ACRSS Depots

There are a number of reasons why depots may be used in a cane railway system including:

- Efficient servicing of a region where there are extensive load and speed restrictions,
- Dealing with small sidings that are a considerable distance from the mill,
- To marshal the cane from regions to a central location before it is transferred to the mill,
- To increase the productivity of larger locomotives that can efficiently transfer large rakes of cane to the mill, but are inefficient when at shunting sidings,
- To transport increased tonnages from a region without unduly increasing the problems associated with locomotive passing.

Within ACRSS, depots are taken to include:

- The traditional depots where locomotives are based at the depot and start and end their working day at that depot.
- Marshalling yard operations, where the locomotive starts at the mill, travels to the marshalling yard, uses the marshalling yard as a base to service the neighboring sidings and to possibly collect a load(s) of full bins for transfer to the mill, and completes its working period by returning to the mill, possibly with a load of full bins.

Locomotive shift changes may or may not occur in the depot region.

Depots are incorporated into the transport system in two steps. The depot and the sidings serviced from the depot are modelled as a separate system and then this depot system is added into the total cane railway system as a single source of supply of cane.

When the depot subsystem is being modelled as a separate system, the depot is assumed to function as a mill and the subsystem schedule meets all of the requirements outlined in Sections 3.1 to 3.6 with the exception that continuous crushing is not required.

Locomotives can be started either at the mill or at the depot, and allowance can be made for these depot-based locomotives to transport bins between the mill and the depot at the start and end of shifts.

If depots are to be included in the cane railway system, then the schedules for the depots must be finalized before the modelling of the entire system can proceed - the depot schedule determines the requirements for empty bins at, and the supply pattern of full bins to the depot.

For the second stage, depots are included in the entire system and are regarded as operating in a manner very similar to a siding. The demand for empty bins and the supply of full bins at the depot are determined from the schedule generated previously for the depot.

For the remainder of this Chapter, the test case used in Chapter 4 will be expanded to include a depot. Figure 5.1 shows the depot system that has been included and Table 5.1 shows the names of the sidings.

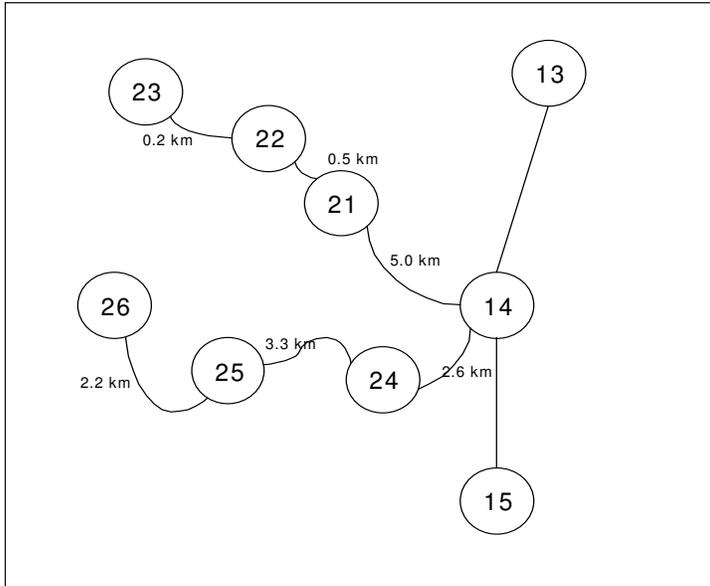


Figure 5.1 Princes depot

| <i>Number</i> | <i>Name</i> |
|---------------|----------------------|
| 14 | Princes |
| 21 | Matsens |
| 22 | Keilbach (Transload) |
| 23 | Keilbach (Right) |
| 24 | Kings |
| 25 | Parkers |
| 26 | Scarpis |

Table 5.1 Names of depot sidings

The change to the base system as modelled in Chapter 4 has been the addition of a depot based at the previously unused siding 14 (Princes). For the depot region based at Princes, the locomotive loads have been halved and the shunt times at the sidings doubled. The total daily allotment for all the growers in the depot system is 290 bins. One locomotive is based at the depot and one starts and finishes at the mill.

5.1 MODELLING THE DEPOT SYSTEM

5.1.1 Input data requirements

Initially, a new operation must be created for the depot system. This will involve entering the nine sets of data detailed in Section 4.2. If it is intended to use the interface between ACRSS and TOTools, the name of the depot system initially entered should be set to XXDefault, where

the first 2 letters of the depot name replace the XX. For this example, naming the depot PRDefault will allow for the successful transfer of data between ACRSS and TOTools.

Once the depot operation has been created, it should be declared as a depot system. Selecting the option to edit the ‘Depot’ data set leads to the Depots screen being displayed. The Depots screen is shown in Figure 5.2.

| Locomotive | Order | Load - FU | Load - MT | Speed - FU | Speed - MT | Speed - LT | Depot - Empties | Depot - Fulls | Time to Depot | Time from Depot |
|------------|-------|-----------|-----------|------------|------------|------------|-----------------|---------------|---------------|-----------------|
| Homebush | 1 | 50 | 65 | 10 | 16 | 16 | 0 | 0 | 0 | 0 |
| Lacey | 2 | 50 | 65 | 10 | 16 | 16 | 130 | 100 | 68 | 108 |
| DH10 | 3 | 50 | 65 | 10 | 16 | 16 | 130 | 100 | 68 | 108 |

Figure 5.2 Editing the Depot data

Since this is a depot system, the option to model a depot system is selected. The user can now enter a name for this depot to use as a link to the mill system. In this instance the name used is the same as the operation name – PRDefault. For exporting data to and from TOTools, the TOTools name for the siding must also be entered – in this case Princes.

Locomotive details can also be entered from this screen. In addition to the loads and speeds for the locomotives, the user also specifies whether or not the locomotive is based at the depot or the mill and for locomotives that are based at the mill, the travel time and loads that the locomotive hauls between the mill and the depot are shown. In this instance, the first loco is based at the depot whilst the other 2 locomotives that could be used in the depot system are based at the mill and are capable of hauling 130 empty bins from the mill to the depot in 68 minutes and of returning to the mill with 100 full bins in 108 minutes. Apart from the data that describes the travel between the mill and the depot, the locomotive data could have been entered using the standard locomotive data entry screen as detailed in Section 4.4.

Figures 5.3 to 5.7 show the other data entered for the depot system. Some areas to note in these files are:

- In the network data, the name 'Depot' has replaced 'Mill'. You cannot have a 'Mill' in a depot system,
- The shunt time at a siding and the time spent in the mill yard (actually at the depot) have been altered in the operational data,
- The shifts worked by the locomotives are specified in the options file. Loco 1, the locomotive based at the depot works an 8 hour shift from 0600, whilst locomotive 2, based at the mill, works a 10 hour shift starting at 0800. Included in the 10 hours is the travel to and from the depot to the mill.

| First Siding | Second Siding | Distance |
|---------------------|---------------------|----------|
| ▶ Depot | Matsens | 5.00 |
| Matsens | Keilbach(Transload) | 0.50 |
| Keilbach(Transload) | Keilbach(Right) | 0.20 |
| Depot | Kings | 2.60 |
| Kings | Parkers | 3.30 |
| Parkers | Scarpis | 2.20 |
| * | | |

Figure 5.3 Network data for depot system

| Harvester | Allotment | Harvest Rate | AM/PM | Harvest Start | Harvest Finish |
|---------------------|-----------|--------------|-------|---------------|----------------|
| ▶ Matsens | 50 | 15 | AM | 0600 | 1800 |
| Keilbach(Transload) | 80 | 12 | AM | 0400 | fixed |
| Keilbach(Right) | 20 | 5 | PM | 1300 | fixed |
| Kings | 50 | 15 | AM | 0700 | 1800 |
| Parkers | 30 | 10 | AM | 0900 | fixed |
| Scarpis | 60 | 12 | AM | 0800 | fixed |
| * | | | | | |

Figure 5.4 Grower data for depot system

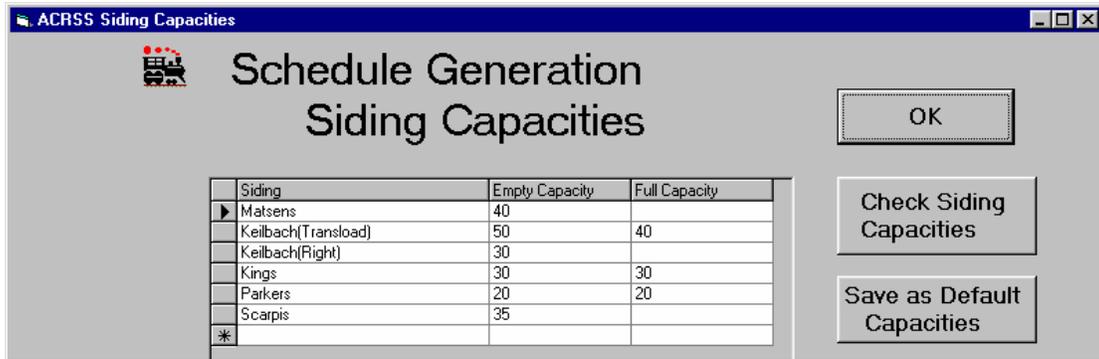


Figure 5.5 Siding capacity data for depot system

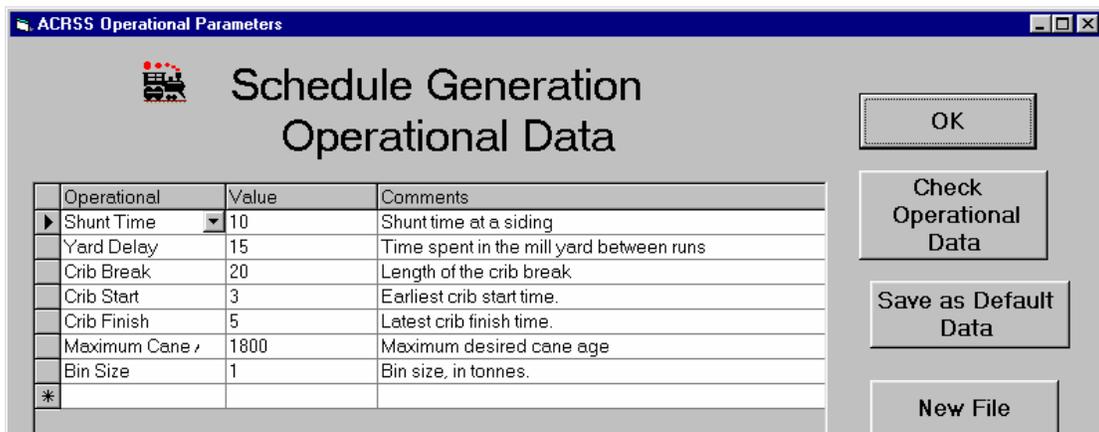


Figure 5.6 Operational data for depot system

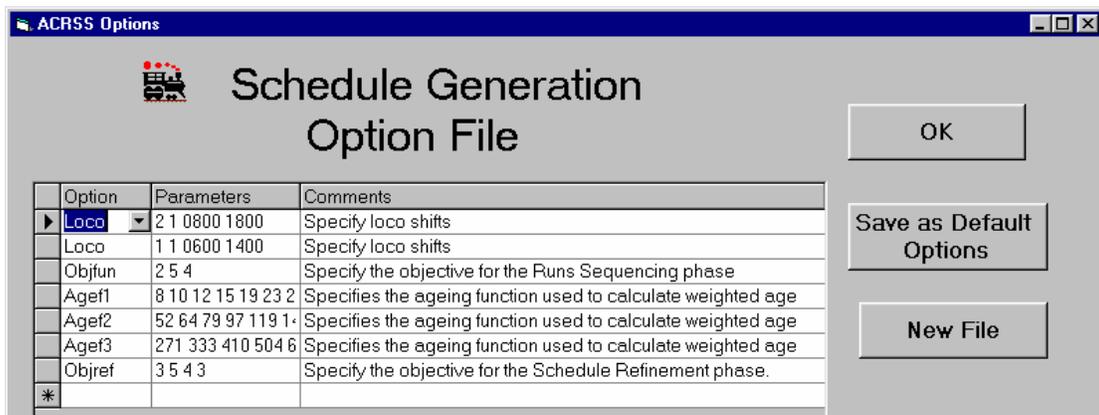
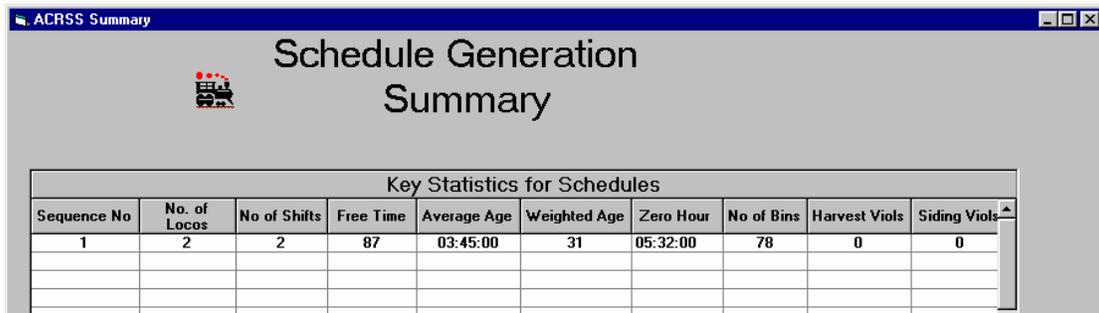


Figure 5.7 Options for depot system

5.1.2 Generating a schedule for the depot

When the depot data has been entered, a schedule for the depot system can be generated. Figure 5.8 shows the summary of this schedule.



The screenshot shows a window titled 'ACRSS Summary' with a sub-header 'Schedule Generation Summary'. Below the header is a table titled 'Key Statistics for Schedules'. The table has 10 columns: Sequence No, No. of Locos, No of Shifts, Free Time, Average Age, Weighted Age, Zero Hour, No of Bins, Harvest Viols, and Siding Viols. The first row of data shows: Sequence No 1, No. of Locos 2, No of Shifts 2, Free Time 87, Average Age 03:45:00, Weighted Age 31, Zero Hour 05:32:00, No of Bins 78, Harvest Viols 0, and Siding Viols 0.

| Key Statistics for Schedules | | | | | | | | | |
|------------------------------|--------------|--------------|-----------|-------------|--------------|-----------|------------|---------------|--------------|
| Sequence No | No. of Locos | No of Shifts | Free Time | Average Age | Weighted Age | Zero Hour | No of Bins | Harvest Viols | Siding Viols |
| 1 | 2 | 2 | 87 | 03:45:00 | 31 | 05:32:00 | 78 | 0 | 0 |
| | | | | | | | | | |
| | | | | | | | | | |

Figure 5.8 Summary of depot schedule

The user can now either return to the main ACRSS screen by closing this summary window or :

- Produce additional schedules for this operation
- Examine one of the schedules that ACRSS has produced in more detail
- Examine the harvest start and siding capacity violations associated with one of the ACRSS schedules
- Remove the siding capacity violations from one of the ACRSS schedules. Essentially, this option removes the violations by increasing the siding capacities to accommodate the number of bins that the schedule has placed at the siding.
- After the siding violations have been removed, the user may wish to restore the siding capacities to their actual values for reporting purposes

When a depot system is modelled, the schedule cannot be returned to TOTools. The depot runs can , however, be returned to TOTools after schedules have been generated for the entire mill system.

Once the user is satisfied with the depot schedule, a report of the schedule should be produced and viewed by choosing to view the report of the desired schedule. VIEWING THE REPORT PRODUCES A FILE CONTAINING THE LIST OF ACTIVITIES AT THE DEPOT. THIS FILE IS USED WHEN THE MILL SYSTEM IS MODELLED.

5.2 MODELLING THE ENTIRE SYSTEM

5.2.1 Mill data requirements

Once the depot system has been modelled and a suitable ACRSS schedule generated, the depot can be incorporated into the mill system. The network and depot data have to be altered.

Firstly, the depot data for the mill has to be altered to show that a depot system is included in the mill system. Figure 5.9 shows that the option to include a depot system has been selected and

that the name of the depot system included is PRDefault, the name specified when the depot operation was generated. Note the warning that the depot system must be modelled first.

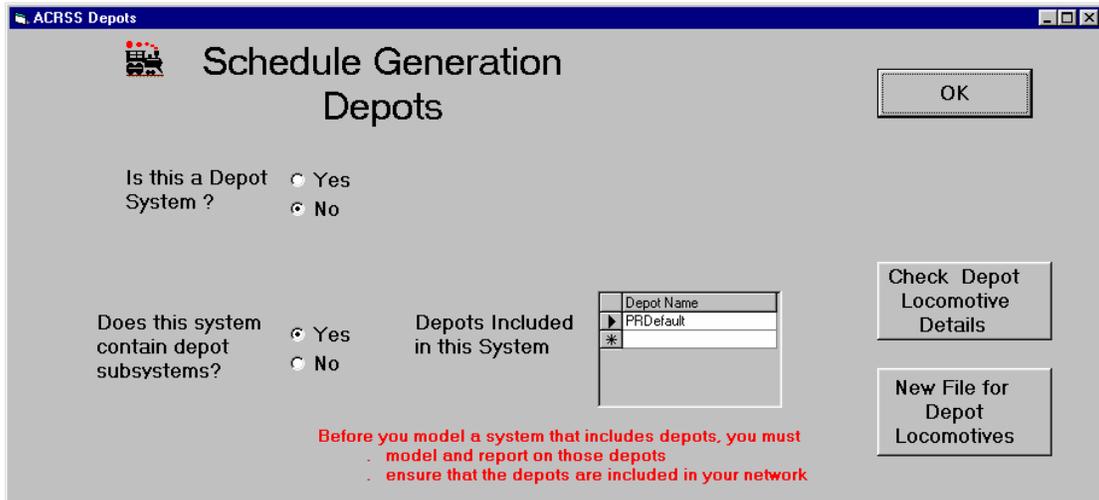


Figure 5.9 Incorporating a depot system into a mill system

The network data must also be modified to include the depot. Figure 5.10 shows the modified network data. Note that the name of the siding, Princes, has been changed to the name of the depot – PRDefault.

| First Siding | Second Siding | Distance |
|--------------|---------------|----------|
| Mill | BurnettJnc | 2.40 |
| BurnettJnc | DrMays | 3.20 |
| BurnettJnc | Tallons | 2.40 |
| Tallons | Maughan | 2.80 |
| Maughan | Manera | 2.80 |
| Mill | DeltaBranch | 4.00 |
| DeltaBranch | Maidavale.1 | 0.80 |
| Maidavale.1 | Maidavale.2 | 6.40 |
| DeltaBranch | Airdale | 0.40 |
| Airdale | RowsBranch | 2.00 |
| RowsBranch | RowsExt | 2.00 |
| RowsBranch | DAddonas | 9.60 |
| DAddonas | Hingley | 1.60 |
| Hingley | PRDefault | 0.80 |
| PRDefault | Andreassens | 2.40 |
| * | | |

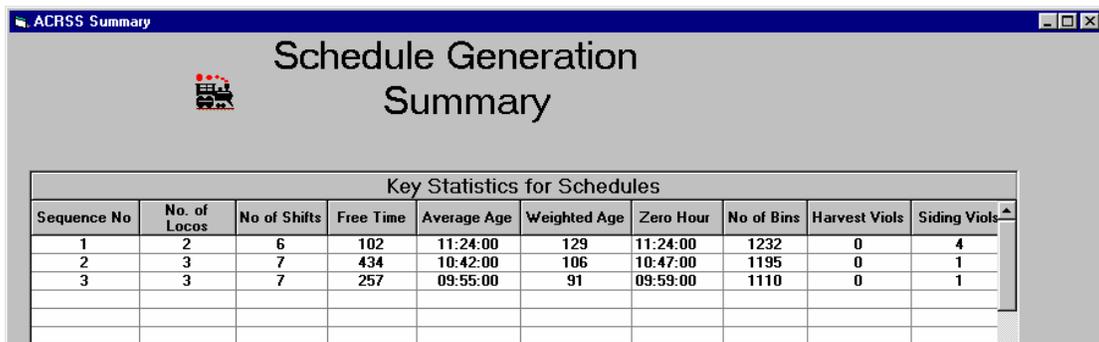
Figure 5.10 Incorporating a depot. Changes to the network data

5.2.2 Completing the schedule

Schedules for the complete system can now be generated. Figure 5.11 shows the summary obtained after:

A starting schedule using 2 locomotives and 6 shifts was obtained
 An extra locomotive and shift was added to remove all but 1 siding capacity violation
 The siding capacity violation was removed and the available locomotive free time was used to reduce cane ages and bin numbers
 The siding capacities were restored to their original values to give a true representation of the system

The locomotives and shifts shown in this summary do not include the locomotives and shifts that were used at the depot.



The screenshot shows a window titled "ACRSS Summary" with a sub-header "Schedule Generation Summary". Below this is a table titled "Key Statistics for Schedules".

| Sequence No | No. of Locos | No of Shifts | Free Time | Average Age | Weighted Age | Zero Hour | No of Bins | Harvest Viols | Siding Viols |
|-------------|--------------|--------------|-----------|-------------|--------------|-----------|------------|---------------|--------------|
| 1 | 2 | 6 | 102 | 11:24:00 | 129 | 11:24:00 | 1232 | 0 | 4 |
| 2 | 3 | 7 | 434 | 10:42:00 | 106 | 10:47:00 | 1195 | 0 | 1 |
| 3 | 3 | 7 | 257 | 09:55:00 | 91 | 09:59:00 | 1110 | 0 | 1 |
| | | | | | | | | | |
| | | | | | | | | | |

Figure 5.11 Summary of the ACRSS schedules produced for the combined system

5.3 CHANGES TO THE REPORT

There are some changes to the report to reflect the inclusion of the depot in the system.

Firstly, the depot is referred to by its specified TOTools name throughout. Table 5.2 shows the details of a locomotive run that delivers and collects from the depot at Princes

```
run 4
  loco allocated 1 shift 1
  run duration 4: 2
  meal break taken within run at 11:32

  leaves mill at 10:18 with 130 empties

  siding      time empties  empties  fulls  cumulative  fulls left
              delivered on train collected  fulls    at siding
Princes      11:52    110     20
Andreassens  12: 6     20      0
Andreassens  12:11           20     20     36
Princes      12:30           80    100     94

  run returns to mill at 14:20 with 100 fulls
```

Table 5.2 Run visiting the depot

Table 5.3 summarizes the activities at the depot. Included in this summary are the activities by the locomotive that starts and finishes at the mill, but spends most of its time working in the depot system. The runs, in this case runs 19 and 20 where the depot locomotive travels between the mill and the depot are not included in the run details portion of the report. (For this case the

run details shows only 18 runs). The report generated for the depot system shows the complete set of locomotive runs for the depot system.

```

grower Princes
daily allotments requested morning      afternoon
actual 160 tonnes 290 tonnes requested 0 tonnes
harvesting rate 0 tonnes/h 0.1 bins/h actual 190 tonnes 190 bins
harvest start 7:29 7:29
harvest end 8:0 8:0
av. age at crush 11:26

delivery at 8:0 by run 20 of 130 bins
delivery at 11:52 by run 4 of 110 bins
collection at 12:30 by run 4 of 80 bins, bins left 94, crush at 9:59
collection at 16:10 by run 19 of 100 bins, bins left 90, crush at 8:56
delivery at 22:45 by run 13 of 50 bins
collection at 22:50 by run 13 of 90 bins, bins left 0, crush at 13:37
collection at 7:56 by run 3 of 20 bins, bins left 0, crush at 20:4

```

Table 5.3 Activities at the depot

If the schedules for the mill and the depot are based on a TOTools ledger, both can be exported back to TOTools by choosing the 'Export to TOTools' action from the mill's summary screen.

5.4 DEPOT NAMING CONVENTIONS FOR USE WITH TOTOOLES

The following naming conventions when used for depot systems facilitates the use of TOTools to define the harvesting pattern to examine the resulting schedules exported back from ACRSS. Most of the data for the depot system named XX... is generated from the XXDefault operation. (XX are the first two characters of the depot's name.) The exception is the grower data, which is generated from the relevant TOTools ledger. The ACRSS interface names the depot operation generated from a TOTools ledger Xxddmmyy, where ddmmyy is the TOTools ledger date. Eg an operation generated for Princes' depot for 1st July 2002 would be named Pr010702. Most of the data for the mill system is generated from the default operation. The grower data is generated from the relevant TOTools ledger. The operation is named ddmmyy, where ddmmyy is the date of the TOTools ledger.

The parts of the program that import and export the data from TOTools, use an additional field in the TOTools siding table that shows whether the particular siding is part of the mill system or a part of the depot system. For the case considered, the sidings in the Princes depot system would have an entry of 'Princes' in this field and the other sidings would have an entry of 'Mill'. The program that imports the TOTools data updates the mill's depot data and the mill's network data to show that the depot name has changed from XXDefault to Xxddmmyy.

6 ACRSS reports

These provide the user with detailed descriptions of the schedules generated by ACRSS and are only obtained after the entire suite of programs has successfully executed.

The first part of this output (Table 6.1) lists the key parameters of the schedule for assessment. These parameters are:

- the number of shifts and locomotives used,
- the running time for these locomotives,
- cane ages, both average and weighted, the total amount of cane collected and the crushing rate calculated,
- the number of bins required,
- empties and fulls carryovers, and
- a distribution of cane ages by time.

By examining this part of the report, a user can determine whether or not the schedule meets his requirements.

The second section of this report (Table 6.2) is the summary of locomotive activity. This report shows for each locomotive what maximum loads have been specified, the number of shifts worked and the number and duration of the runs made. The number of empties delivered and fulls collected is also shown for each locomotive run. The locomotive activity report for the test case is shown as Table 6.2.

The next section of this report contains the detailed information on the individual runs. The sidings visited by each run and the locomotive activities at these sidings are shown. Note that the run duration does not include the time spent at the mill between runs. Table 6.3 shows the locomotive runs for the test case.

Activities in the mill yard are listed in the next section of the computer output as shown in Table 6.4. There is a summary of the activities in the fulls yard which shows the number of fulls in the fulls yard before and after the various runs have finished. The fulls carryover, that is the number of fulls in the yard at 0800 is also shown in this report. There is also a very similar summary of the activities in the empties yard. The yard activities for the sample case are shown as Table 6.4.

The next section of the report gives details of grower activities in which the allotments, harvesting rates, start and finish harvest times are shown for each grower. This report also shows, for each active siding, when bins are delivered to or collected from the siding. The age of each individual rake at crushing is shown as well as an average age calculated on a grower basis. Table 6.5 shows the activities by grower for the test case.

The last section of the report lists the numbers of full and empty bins in the transport system at hourly intervals, starting from 0800. Table 6.6 shows the numbers of bins at sidings, on locomotives and in mill yards at hourly intervals throughout the day.

```

*****
* Refined - Schedule 2 *
*****

Shifts operated 6
Locos needed 3

Loco   Shifts   Total   Total   Free
       operated runs    runtime time

   1     3       8    20:19   0: 1
   2     2       6    13:13   0: 7
   3     1       3     5: 8    1:31
Total    6      17    38:40   1:39

Average cane age           8: 0
Estimated Dextran level    62 ppm on brix
Crushing rate              43 tonnes/h
Bin weight                 1.00 tonnes
Bins required              715 tonnes
Total daily allotment      1010 tonnes

Ratio of total bin capacity to daily allotment 70%

Road transported cane :-
                        30 tonnes between 9. 0 and 10. 0

At 08:00:
  Fulls in yard      8 tonnes  Empties in yard  211 tonnes
  Todays cane that has arrived at the yard      0 tonnes
  Yesterdays cane still to arrive at the yard  0 tonnes

Adjusted zero hour 8:11

Distribution by ages
Age at crush tonnes  %    % over

1:00 to 1:59    36    3.56  96.44
2:00 to 2:59    80    7.92  88.51
3:00 to 3:59    53    5.25  83.27
4:00 to 4:59   250   24.75  58.51
5:00 to 5:59    65    6.44  52.08
6:00 to 6:59    48    4.75  47.33
7:00 to 7:59    89    8.81  38.51
10:00 to 10:59  15    1.49  37.03
12:00 to 12:59  140   13.86  23.17
13:00 to 13:59  77    7.62  15.54
14:00 to 14:59  157   15.54   0.00

```

Table 6.1 Key Schedule Parameters

loco 1 shift 1 maximum loads.. 130 empties and 100 fulls
 no.of shifts 3 starting time 0: 0 finishing time 24: 0

| run | leaves | empties | returns | fulls | meal breaks |
|-----|--------|---------|---------|-------|-------------|
| 1 | 0: 0 | 127 | 2:40 | 61 | |
| | | | | | 3: 0 |
| 2 | 3:20 | 117 | 5: 2 | 3 | |
| 3 | 5:22 | 66 | 8: 7 | 36 | |
| 4 | 8:28 | 125 | 12:15 | 100 | |
| | | | | | 12:35 |
| 5 | 12:55 | 104 | 14:47 | 20 | |
| 6 | 15: 7 | 76 | 17: 8 | 88 | |
| 7 | 17:28 | 20 | 21:26 | 100 | |
| | | | | | 19:20 |
| 8 | 21:46 | 0 | 23:40 | 100 | |

loco 2 shift 1 maximum loads.. 130 empties and 100 fulls
 no.of shifts 2 starting time 7: 0 finishing time 23: 0

| run | leaves | empties | returns | fulls | meal breaks |
|-----|--------|---------|---------|-------|-------------|
| 9 | 7: 0 | 64 | 10:20 | 82 | |
| | | | | | 10:42 |
| 10 | 11: 2 | 18 | 13:15 | 97 | |
| 11 | 13:35 | 58 | 15:11 | 26 | |
| 12 | 15:36 | 69 | 17: 8 | 100 | |
| 13 | 17:28 | 20 | 19: 2 | 75 | |
| | | | | | 19:22 |
| 14 | 19:42 | 46 | 22:40 | 50 | |

Table 6.2 Summary of Locomotive runs .. (continues)

loco 3 shift 1 maximum loads.. 130 empties and 100 fulls
 no.of shifts 1 starting time 7: 0 finishing time 15: 0

| run | leaves | empties | returns | fulls | meal breaks |
|-----|--------|---------|---------|-------|-------------|
| 15 | 7: 1 | 40 | 8:40 | 31 | |
| 16 | 9:26 | 60 | 12: 8 | 0 | 10:37 |
| 17 | 13:24 | 0 | 14:31 | 41 | |

Table 6.2 Summary of Locomotive runs

LOCOMOTIVE RUNS

run 1
 loco allocated 1 shift 1
 run duration 2:40
 leaves mill at 0: 0 with 127 empties

| siding | time | empties | empties | fulls | cumulative | fulls |
|-------------|------|---------|--------------------|-----------|------------|-------|
| left | | | delivered on train | collected | fulls | at |
| siding | | | | | | |
| Maidavale.2 | 0:47 | 32 | 95 | | | |
| DeltaBranch | 1:19 | 56 | 39 | | | |
| Airdale | 1:25 | 39 | 0 | | | |
| RowsExt | 1:45 | | | 28 | 28 | 0 |
| RowsBranch | 2: 2 | | | 33 | 61 | 0 |

run returns to mill at 2:40 with 61 fulls

run 2
 loco allocated 1 shift 1
 run duration 1:42
 leaves mill at 3:20 with 117 empties

| siding | time | empties | empties | fulls | cumulative | fulls |
|---------|------|---------|--------------------|-----------|------------|-------|
| left | | | delivered on train | collected | fulls | at |
| siding | | | | | | |
| Maughan | 3:53 | 64 | 53 | | | |
| Manera | 4: 8 | 53 | 0 | | | |
| Tallons | 4:34 | | | 3 | 3 | 0 |

run returns to mill at 5: 2 with 3 fulls

Table 6.3 Details of Locomotive runs .. (continues)

```

run 3
  loco allocated 1 shift 1
  run duration 2:45
  leaves mill at 5:22 with 66 empties

siding      time empties  empties  fulls  cumulative  fulls
left
                                     delivered on train collected  fulls  at
siding
Maidavale.1 6: 0      22      44
DAddonas    6:53     44      0
Airdale     7:41
                                     36      36      0

run returns to mill at 8: 7 with 36 fulls

run 4
  loco allocated 1 shift 1
  run duration 3:47
  leaves mill at 8:28 with 125 empties

siding      time empties  empties  fulls  cumulative  fulls
left
                                     delivered on train collected  fulls  at
siding
RowsBranch  8:57     45      80
Andreassens 9:56     80      0
Andreassens 10: 1
Hingley    10:25
DAddonas   10:39
                                     20      20      0
                                     42      62      2
                                     38      100     4

run returns to mill at 12:15 with 100 fulls

run 5
  loco allocated 1 shift 1
  run duration 1:52
  leaves mill at 12:55 with 104 empties

siding      time empties  empties  fulls  cumulative  fulls
left
                                     delivered on train collected  fulls  at
siding
Tallons     13:18     27      77
BurnettJnc  13:32     13      64
DrMays      13:59     64      0
DrMays      14:14
                                     20      20      0

run returns to mill at 14:47 with 20 fulls

```

Table 6.3 Details of Locomotive runs .. (continues)

```

run 6
  loco allocated 1 shift 1
  run duration 2: 1
  leaves mill at 15: 7 with 76 empties

siding      time empties  empties  fulls  cumulative  fulls
left
                                     delivered on train collected  fulls  at
siding
BurnettJnc  15:21      31      45
Manera      15:56      45      0
Manera      16: 1                    55      55      0
BurnettJnc  16:54                    33      88      0

run returns to mill at 17: 8 with 88 fulls

run 7
  loco allocated 1 shift 1
  run duration 3:58
  meal break taken within run at 19:20
  leaves mill at 17:28 with 20 empties

siding      time empties  empties  fulls  cumulative  fulls
left
                                     delivered on train collected  fulls  at
siding
Andreassens 18:51      20      0
Andreassens 18:56                    80      80      0
Hingley     19:40                    20      100     0

run returns to mill at 21:26 with 100 fulls

run 8
  loco allocated 1 shift 1
  run duration 1:54
  leaves mill at 21:46 with 0 empties

siding      time empties  empties  fulls  cumulative  fulls
left
                                     delivered on train collected  fulls  at
siding
Manera      22:30                    43      43      0
Maughan     22:51                    43      86      0
Tallons     23:12                    14      100     3

run returns to mill at 23:40 with 100 fulls

```

Table 6.3 Details of Locomotive runs .. (continues)

```

run 9
  loco allocated 2 shift 1
  run duration 3:20
  leaves mill at 7: 0 with 64 empties

left siding      time empties  empties  fulls  cumulative  fulls
                                delivered on train collected  fulls  at
siding
RowsExt          7:36         25       39
Maidavale.1     8:15         23       16
Maidavale.2     8:44         16        0
Maidavale.2     8:49                33      33      0
Maidavale.1     9:47                23      56      0
DeltaBranch     9:56                26      82      0

run returns to mill at 10:20 with 82 fulls

run 10
  loco allocated 2 shift 1
  run duration 2:13
  leaves mill at 11: 2 with 18 empties

left siding      time empties  empties  fulls  cumulative  fulls
                                delivered on train collected  fulls  at
siding
DeltaBranch     11:22        18        0
Maidavale.2    11:54                15      15      0
DeltaBranch     12:42                48      63      0
Airdale        12:49                34      97      0

run returns to mill at 13:15 with 97 fulls

run 11
  loco allocated 2 shift 1
  run duration 1:36
  leaves mill at 13:35 with 58 empties

left siding      time empties  empties  fulls  cumulative  fulls
                                delivered on train collected  fulls  at
siding
RowsBranch     14: 4         29       29
RowsExt        14:16         29        0
RowsExt        14:21                26      26      0

run returns to mill at 15:11 with 26 fulls

```

Table 6.3 Details of Locomotive runs .. (continues)

```

run 12
  loco allocated 2 shift 1
  run duration 1:32
  leaves mill at 15:36 with 69 empties

siding      time empties  empties  fulls  cumulative  fulls
left
                                     delivered on train collected  fulls  at
siding
Tallons      15:59      25      44
Maughan      16:14      44      0
Maughan      16:19
Tallons      16:40
                                     65      65      1
                                     35      100     1

run returns to mill at 17: 8 with 100 fulls

run 13
  loco allocated 2 shift 1
  run duration 1:34
  leaves mill at 17:28 with 20 empties

siding      time empties  empties  fulls  cumulative  fulls
left
                                     delivered on train collected  fulls  at
siding
BurnettJnc   17:42      4      16
DrMays       18: 9      16      0
DrMays       18:24
BurnettJnc   18:48
                                     60      60      0
                                     15      75      0

run returns to mill at 19: 2 with 75 fulls

run 14
  loco allocated 2 shift 1
  run duration 2:58
  leaves mill at 19:42 with 46 empties

siding      time empties  empties  fulls  cumulative  fulls
left
                                     delivered on train collected  fulls  at
siding
Hingley      20:53      46      0
DAddonas     21: 4
                                     50      50      0

run returns to mill at 22:40 with 50 fulls

```

Table 6.3 Details of Locomotive runs .. (continues)

```

run 15
  loco allocated 3 shift 1
  run duration 1:39
  leaves mill at 7: 1 with 40 empties

left siding      time empties  empties  fulls  cumulative  fulls
                                delivered on train collected  fulls  at
siding
Maidavale.1      7:39      9      31
Airdale          7:48     31      0
Maidavale.1      8:12      31     31      31      0

run returns to mill at 8:40 with 31 fulls

run 16
  loco allocated 3 shift 1
  run duration 2:42
  meal break taken within run at 10:37
  leaves mill at 9:26 with 60 empties

left siding      time empties  empties  fulls  cumulative  fulls
                                delivered on train collected  fulls  at
siding
Hingley         10:57     16     44
DAddonas        11: 8     44      0

run returns to mill at 12: 8 with 0 fulls

run 17
  loco allocated 3 shift 1
  run duration 1: 7
  leaves mill at 13:24 with 0 empties

left siding      time empties  empties  fulls  cumulative  fulls
                                delivered on train collected  fulls  at
siding
RowsBranch       13:53      41     41      41      0

run returns to mill at 14:31 with 41 fulls

```

Table 6.3 Details of Locomotive runs

FULLS CARRYOVER AND SUMMARY

| Arrival time | run | fulls before arrival | fulls in run | fulls after run | time crush starts | time stock exhausted | cum.av.age col. | at crush |
|--------------|-----------|----------------------|--------------|-----------------|-------------------|----------------------|-----------------|----------|
| 8: 0 | carryover | 8 | | | | | | |
| 8:12 | 3 | 0 | 36 | 36 | 8:12 | 9:13 | 36 | 1:48 |
| 8:45 | 15 | 12 | 31 | 43 | 9:15 | 10:27 | 67 | 2:39 |
| 10:25 | 9 | 1 | 82 | 83 | 10:26 | 12:19 | 149 | 2:57 |
| 12:20 | 4 | 0 | 100 | 100 | 12:20 | 14:38 | 249 | 4:30 |
| 13:20 | 10 | 56 | 97 | 153 | 14:40 | 16:53 | 346 | 5:54 |
| 14:36 | 17 | 99 | 41 | 140 | 16:52 | 17:49 | 387 | 4:23 |

| | | | | | | | | |
|-------|----|-----|-----|-----|-------|-------|------|-------|
| 14:52 | 5 | 128 | 20 | 148 | 18:26 | 18:53 | 407 | 4:51 |
| 15:16 | 11 | 131 | 26 | 157 | 17:49 | 18:25 | 433 | 4:27 |
| 17:13 | 6 | 72 | 88 | 160 | 21:13 | 23:15 | 521 | 7: 9 |
| 17:13 | 12 | 160 | 100 | 260 | 18:54 | 21:13 | 621 | 5: 1 |
| 19: 7 | 13 | 178 | 75 | 253 | 2:42 | 4:26 | 696 | 11:40 |
| 21:31 | 7 | 149 | 100 | 249 | 23:15 | 1:33 | 796 | 12:34 |
| 22:45 | 14 | 196 | 50 | 246 | 1:31 | 2:40 | 846 | 14: 8 |
| 23:45 | 8 | 202 | 100 | 302 | 5:51 | 7:57 | 946 | 13:57 |
| 2:45 | 1 | 172 | 61 | 233 | 4:26 | 5:51 | 1007 | 14:21 |
| 5: 7 | 2 | 131 | 3 | 134 | 8:13 | 8:13 | 1010 | 14:28 |

EMPTIES CARRYOVER AND SUMMARY

| time | run | empties before departure | empties in run | empties after run | cumulative deliveries |
|-------|-----------|-----------------------------|-------------------|----------------------|--------------------------|
| 8: 0 | carryover | 211 | | | |
| 8:28 | 4 | 231 | 125 | 106 | 125 |
| 9:26 | 16 | 135 | 60 | 75 | 185 |
| 11: 2 | 10 | 127 | 18 | 109 | 203 |
| 12:55 | 5 | 190 | 104 | 86 | 307 |
| 13:35 | 11 | 115 | 58 | 57 | 365 |
| 15: 7 | 6 | 124 | 76 | 48 | 441 |
| 15:36 | 12 | 69 | 69 | 0 | 510 |
| 17:28 | 7 | 81 | 20 | 61 | 530 |
| 17:28 | 13 | 61 | 20 | 41 | 550 |
| 19:42 | 14 | 137 | 46 | 91 | 596 |
| 0: 0 | 1 | 278 | 127 | 151 | 723 |
| 3:20 | 2 | 295 | 117 | 178 | 840 |
| 5:22 | 3 | 266 | 66 | 200 | 906 |
| 7: 0 | 9 | 271 | 64 | 207 | 970 |
| 7: 1 | 15 | 208 | 40 | 168 | 1010 |

Table 6.4 Mill Yard Activities

ACTIVITIES BY GROWERS

grower BurnettJnc

siding capacity empties 38 bins fulls 38 bins
maximum empties 31 bins fulls 33 bins

| | morning | | afternoon | |
|----------------------------|-----------|-----------|-----------|--------|
| daily allotments requested | 48 tonnes | requested | 0 tonnes | |
| actual | 48 tonnes | actual | 0 tonnes | 0 bins |

harvesting rate 13 tonnes/h 13.0 bins/h 0 tonnes/h 0.0 bins/h

harvest start 14:17 0: 0
harvest end 18: 0 0: 0
av. age at crush 7:45

delivery at 13:32 by run 5 of 13 bins
delivery at 15:21 by run 6 of 31 bins
collection at 16:54 by run 6 of 33 bins, bins left 0, crush at 6:40
delivery at 17:42 by run 13 of 4 bins
collection at 18:48 by run 13 of 15 bins, bins left 0, crush at 10: 8

Table 6.5 Details of Grower Activities .. (continues)

grower DrMays

| | | | |
|-------------------------|---------|-------|---------|
| siding capacity empties | 64 bins | fulls | 64 bins |
| maximum empties | 60 bins | fulls | 60 bins |

| | | | | |
|----------------------------|-----------|-----------|-----------|--------|
| | morning | | afternoon | |
| daily allotments requested | 80 tonnes | requested | 0 tonnes | |
| actual | 80 tonnes | actual | 0 tonnes | 0 bins |

| | | | | |
|-----------------|-------------|-------------|------------|------------|
| harvesting rate | 23 tonnes/h | 23.0 bins/h | 0 tonnes/h | 0.0 bins/h |
|-----------------|-------------|-------------|------------|------------|

| | | |
|------------------|-------|------|
| harvest start | 13:21 | 0: 0 |
| harvest end | 16:50 | 0: 0 |
| av. age at crush | 10:14 | |

delivery at 13:59 by run 5 of 64 bins
collection at 14:14 by run 5 of 20 bins, bins left 0, crush at 4:51
delivery at 18: 9 by run 13 of 16 bins
collection at 18:24 by run 13 of 60 bins, bins left 0, crush at 12: 2

grower Tallons

| | | | |
|-------------------------|---------|-------|---------|
| siding capacity empties | 41 bins | fulls | 41 bins |
| maximum empties | 27 bins | fulls | 36 bins |

| | | | | |
|----------------------------|----------|-----------|-----------|---------|
| | morning | | afternoon | |
| daily allotments requested | 0 tonnes | requested | 52 tonnes | |
| actual | 0 tonnes | actual | 52 tonnes | 52 bins |

| | | | | |
|-----------------|------------|------------|-------------|-------------|
| harvesting rate | 0 tonnes/h | 0.0 bins/h | 12 tonnes/h | 12.1 bins/h |
|-----------------|------------|------------|-------------|-------------|

| | | |
|------------------|------|-------|
| harvest start | 0: 0 | 13:40 |
| harvest end | 0: 0 | 18: 0 |
| av. age at crush | 7:52 | |

delivery at 13:18 by run 5 of 27 bins
delivery at 15:59 by run 12 of 25 bins
collection at 16:40 by run 12 of 35 bins, bins left 1, crush at 4:55
collection at 23:12 by run 8 of 14 bins, bins left 3, crush at 13:50
collection at 4:34 by run 2 of 3 bins, bins left 0, crush at 14:28

grower Maughan

| | | | |
|-------------------------|---------|-------|---------|
| siding capacity empties | 86 bins | fulls | 86 bins |
| maximum empties | 64 bins | fulls | 66 bins |

| | | | | |
|----------------------------|------------|-----------|-----------|--------|
| | morning | | afternoon | |
| daily allotments requested | 108 tonnes | requested | 0 tonnes | |
| actual | 108 tonnes | actual | 0 tonnes | 0 bins |

| | | | | |
|-----------------|-------------|-------------|------------|------------|
| harvesting rate | 25 tonnes/h | 25.0 bins/h | 0 tonnes/h | 0.0 bins/h |
|-----------------|-------------|-------------|------------|------------|

| | | |
|------------------|-------|------|
| harvest start | 13:40 | 0: 0 |
| harvest end | 18: 0 | 0: 0 |
| av. age at crush | 8:34 | |

Table 6.5 Details of Grower Activities .. (continues)

delivery at 16:14 by run 12 of 44 bins
 collection at 16:19 by run 12 of 65 bins, bins left 1, crush at 5: 4
 collection at 22:51 by run 8 of 43 bins, bins left 0, crush at 13:53
 delivery at 3:53 by run 2 of 64 bins

grower Manera

siding capacity total 78 bins maximum at siding 53 bins

| | morning | | afternoon | |
|----------------------------|-----------|-----------|-----------|--------|
| daily allotments requested | 98 tonnes | requested | 0 tonnes | |
| actual | 98 tonnes | actual | 0 tonnes | 0 bins |

harvesting rate 23 tonnes/h 23.0 bins/h 0 tonnes/h 0.0 bins/h

| | | |
|------------------|-------|------|
| harvest start | 13:37 | 0: 0 |
| harvest end | 17:53 | 0: 0 |
| av. age at crush | 10:19 | |

delivery at 15:56 by run 6 of 45 bins
 collection at 16: 1 by run 6 of 55 bins, bins left 0, crush at 7:25
 collection at 22:30 by run 8 of 43 bins, bins left 0, crush at 14: 3
 delivery at 4: 8 by run 2 of 53 bins

grower DeltaBranch

siding capacity total 59 bins maximum at siding 56 bins

| | morning | | afternoon | |
|----------------------------|-----------|-----------|-----------|--------|
| daily allotments requested | 74 tonnes | requested | 0 tonnes | |
| actual | 74 tonnes | actual | 0 tonnes | 0 bins |

harvesting rate 21 tonnes/h 21.1 bins/h 0 tonnes/h 0.0 bins/h

| | | |
|------------------|-------|------|
| harvest start | 8:41 | 0: 0 |
| harvest end | 12:13 | 0: 0 |
| av. age at crush | 3:46 | |

collection at 9:56 by run 9 of 26 bins, bins left 0, crush at 2: 3
 delivery at 11:22 by run 10 of 18 bins
 collection at 12:42 by run 10 of 48 bins, bins left 0, crush at 4:42
 delivery at 1:19 by run 1 of 56 bins

grower Maidavale.1

siding capacity total 43 bins maximum at siding 31 bins

| | morning | | afternoon | |
|----------------------------|-----------|-----------|-----------|--------|
| daily allotments requested | 54 tonnes | requested | 0 tonnes | |
| actual | 54 tonnes | actual | 0 tonnes | 0 bins |

harvesting rate 16 tonnes/h 16.0 bins/h 0 tonnes/h 0.0 bins/h

| | | |
|------------------|------|------|
| harvest start | 6:15 | 0: 0 |
| harvest end | 9:39 | 0: 0 |
| av. age at crush | 2:33 | |

Table 6.5 Details of Grower Activities .. (continues)

delivery at 7:39 by run 15 of 9 bins
 collection at 8:12 by run 15 of 31 bins, bins left 0, crush at 2:39
 delivery at 8:15 by run 9 of 23 bins
 collection at 9:47 by run 9 of 23 bins, bins left 0, crush at 2:27
 delivery at 6: 0 by run 3 of 22 bins

grower Maidavale.2

siding capacity total 38 bins maximum at siding 32 bins

| | morning | | | | afternoon | | | |
|----------------------------|---------|--------|-----------|------|-----------|---|--------|--------|
| daily allotments requested | 48 | tonnes | requested | 0 | tonnes | | | |
| actual | 48 | tonnes | 48 | bins | actual | 0 | tonnes | 0 bins |

harvesting rate 12 tonnes/h 12.1 bins/h 0 tonnes/h 0.0 bins/h

| | | |
|------------------|-------|------|
| harvest start | 6: 0 | 0: 0 |
| harvest end | 10: 0 | 0: 0 |
| av. age at crush | 4:44 | |

delivery at 8:44 by run 9 of 16 bins
 collection at 8:49 by run 9 of 33 bins, bins left 0, crush at 3:59
 collection at 11:54 by run 10 of 15 bins, bins left 0, crush at 6:25
 delivery at 0:47 by run 1 of 32 bins

grower Airdale

siding capacity total 56 bins maximum at siding 39 bins

| | morning | | | | afternoon | | | |
|----------------------------|---------|--------|-----------|------|-----------|---|--------|--------|
| daily allotments requested | 70 | tonnes | requested | 0 | tonnes | | | |
| actual | 70 | tonnes | 70 | bins | actual | 0 | tonnes | 0 bins |

harvesting rate 22 tonnes/h 22.0 bins/h 0 tonnes/h 0.0 bins/h

| | | |
|------------------|------|------|
| harvest start | 6: 0 | 0: 0 |
| harvest end | 9:12 | 0: 0 |
| av. age at crush | 4:29 | |

collection at 7:41 by run 3 of 36 bins, bins left 0, crush at 1:48
 delivery at 7:48 by run 15 of 31 bins
 collection at 12:49 by run 10 of 34 bins, bins left 0, crush at 7:21
 delivery at 1:25 by run 1 of 39 bins

grower RowsBranch

siding capacity total 59 bins maximum at siding 45 bins

| | morning | | | | afternoon | | | |
|----------------------------|---------|--------|-----------|------|-----------|---|--------|--------|
| daily allotments requested | 74 | tonnes | requested | 0 | tonnes | | | |
| actual | 74 | tonnes | 74 | bins | actual | 0 | tonnes | 0 bins |

harvesting rate 22 tonnes/h 22.0 bins/h 0 tonnes/h 0.0 bins/h

| | | |
|------------------|-------|------|
| harvest start | 12: 0 | 0: 0 |
| harvest end | 15:23 | 0: 0 |
| av. age at crush | 8:54 | |

Table 6.5 Details of Grower Activities .. (continues)

delivery at 8:57 by run 4 of 45 bins
 collection at 13:53 by run 17 of 41 bins, bins left 0, crush at 4:23
 delivery at 14: 4 by run 11 of 29 bins
 collection at 2: 2 by run 1 of 33 bins, bins left 0, crush at 14:31

grower RowsExt

siding capacity total 43 bins maximum at siding 28 bins

| | morning | | afternoon | |
|----------------------------|-----------|---------|--------------------|--------|
| daily allotments requested | 54 tonnes | 54 bins | requested 0 tonnes | 0 bins |
| actual | 54 tonnes | 54 bins | actual 0 tonnes | 0 bins |

harvesting rate 20 tonnes/h 20.0 bins/h 0 tonnes/h 0.0
 bins/h

| | | |
|------------------|-------|------|
| harvest start | 13: 0 | 0: 0 |
| harvest end | 15:43 | 0: 0 |
| av. age at crush | 9:28 | |

delivery at 14:16 by run 11 of 29 bins
 collection at 14:21 by run 11 of 26 bins, bins left 0, crush at 4:27
 collection at 1:45 by run 1 of 28 bins, bins left 0, crush at 14: 8
 delivery at 7:36 by run 9 of 25 bins

grower DAddonas

siding capacity total 70 bins maximum at siding 50 bins

| | morning | | afternoon | |
|----------------------------|-----------|---------|--------------------|--------|
| daily allotments requested | 88 tonnes | 88 bins | requested 0 tonnes | 0 bins |
| actual | 88 tonnes | 88 bins | actual 0 tonnes | 0 bins |

harvesting rate 16 tonnes/h 16.0 bins/h 0 tonnes/h 0.0
 bins/h

| | | |
|------------------|-------|------|
| harvest start | 8: 0 | 0: 0 |
| harvest end | 13:31 | 0: 0 |
| av. age at crush | 9:52 | |

collection at 10:39 by run 4 of 38 bins, bins left 4, crush at 4:16
 delivery at 11: 8 by run 16 of 44 bins
 collection at 21: 4 by run 14 of 50 bins, bins left 0, crush at 14: 8
 delivery at 6:53 by run 3 of 44 bins

grower Hingley

siding capacity total 49 bins maximum at siding 46 bins

| | morning | | afternoon | |
|----------------------------|-----------|---------|--------------------|--------|
| daily allotments requested | 62 tonnes | 62 bins | requested 0 tonnes | 0 bins |
| actual | 62 tonnes | 62 bins | actual 0 tonnes | 0 bins |

harvesting rate 12 tonnes/h 12.1 bins/h 0 tonnes/h 0.0
 bins/h

| | | |
|------------------|-------|------|
| harvest start | 6:45 | 0: 0 |
| harvest end | 11:55 | 0: 0 |
| av. age at crush | 7:39 | |

Table 6.5 Details of Grower Activities .. (continues)

| | | | |
|----------------------------|---------------|-------------------|----------------|
| collection at 10:25 by run | 4 of 42 bins, | bins left 2, | crush at 4:58 |
| delivery at 10:57 by run | 16 of 16 bins | | |
| collection at 19:40 by run | 7 of 20 bins, | bins left 0, | crush at 13:18 |
| delivery at 20:53 by run | 14 of 46 bins | | |
| grower Andreassens | | | |
| siding capacity total | 80 bins | maximum at siding | 80 bins |
| | morning | | afternoon |
| daily allotments requested | 100 tonnes | requested | 0 tonnes |
| actual | 100 tonnes | actual | 0 tonnes |
| | 100 bins | | 0 bins |
| harvesting rate | 20 tonnes/h | 20.0 bins/h | 0 tonnes/h |
| | | | 0.0 bins/h |
| harvest start | 9: 0 | | 0: 0 |
| harvest end | 14: 1 | | 0: 0 |
| av. age at crush | 10:41 | | |
| delivery at 9:56 by run | 4 of 80 bins | | |
| collection at 10: 1 by run | 4 of 20 bins, | bins left 0, | crush at 3:57 |
| delivery at 18:51 by run | 7 of 20 bins | | |
| collection at 18:56 by run | 7 of 80 bins, | bins left 0, | crush at 12:22 |

Table 6.5 Details of Grower Activities

Summary of bin usage

| time | sidings | | | mill yards | | | locomotives | | | depots | | | total | | |
|------|---------|-----|-----|------------|-----|-----|-------------|-----|-----|--------|---|---|-------|-----|-----|
| | e | f | t | e | f | t | e | f | t | e | f | t | e | f | t |
| 0800 | 348 | 73 | 421 | 211 | 8 | 219 | 39 | 36 | 75 | 0 | 0 | 0 | 598 | 117 | 715 |
| 0900 | 349 | 92 | 441 | 129 | 32 | 161 | 80 | 33 | 113 | 0 | 0 | 0 | 558 | 157 | 715 |
| 1000 | 333 | 139 | 472 | 82 | 19 | 101 | 60 | 82 | 142 | 0 | 0 | 0 | 475 | 240 | 715 |
| 1100 | 324 | 108 | 432 | 125 | 58 | 183 | 0 | 100 | 100 | 0 | 0 | 0 | 449 | 266 | 715 |
| 1200 | 274 | 161 | 435 | 151 | 14 | 165 | 0 | 115 | 115 | 0 | 0 | 0 | 425 | 290 | 715 |
| 1300 | 212 | 141 | 353 | 90 | 71 | 161 | 104 | 97 | 201 | 0 | 0 | 0 | 406 | 309 | 715 |
| 1400 | 212 | 204 | 416 | 75 | 125 | 200 | 58 | 41 | 99 | 0 | 0 | 0 | 345 | 370 | 715 |
| 1500 | 135 | 293 | 428 | 119 | 142 | 261 | 0 | 26 | 26 | 0 | 0 | 0 | 254 | 461 | 715 |
| 1600 | 116 | 413 | 529 | 17 | 125 | 142 | 44 | 0 | 44 | 0 | 0 | 0 | 177 | 538 | 715 |
| 1700 | 67 | 318 | 385 | 60 | 82 | 142 | 0 | 188 | 188 | 0 | 0 | 0 | 127 | 588 | 715 |
| 1800 | 0 | 389 | 389 | 64 | 226 | 290 | 36 | 0 | 36 | 0 | 0 | 0 | 100 | 615 | 715 |
| 1900 | 36 | 234 | 270 | 107 | 183 | 290 | 0 | 155 | 155 | 0 | 0 | 0 | 143 | 572 | 715 |
| 2000 | 36 | 214 | 250 | 104 | 215 | 319 | 46 | 100 | 146 | 0 | 0 | 0 | 186 | 529 | 715 |
| 2100 | 82 | 214 | 296 | 148 | 171 | 319 | 0 | 100 | 100 | 0 | 0 | 0 | 230 | 485 | 715 |
| 2200 | 82 | 164 | 246 | 191 | 228 | 419 | 0 | 50 | 50 | 0 | 0 | 0 | 273 | 442 | 715 |
| 2300 | 82 | 78 | 160 | 234 | 235 | 469 | 0 | 86 | 86 | 0 | 0 | 0 | 316 | 399 | 715 |
| 0000 | 82 | 64 | 146 | 151 | 291 | 442 | 127 | 0 | 127 | 0 | 0 | 0 | 360 | 355 | 715 |
| 0100 | 114 | 64 | 178 | 194 | 248 | 442 | 95 | 0 | 95 | 0 | 0 | 0 | 403 | 312 | 715 |
| 0200 | 209 | 36 | 245 | 237 | 205 | 442 | 0 | 28 | 28 | 0 | 0 | 0 | 446 | 269 | 715 |
| 0300 | 209 | 3 | 212 | 281 | 222 | 503 | 0 | 0 | 0 | 0 | 0 | 0 | 490 | 225 | 715 |
| 0400 | 273 | 3 | 276 | 207 | 179 | 386 | 53 | 0 | 53 | 0 | 0 | 0 | 533 | 182 | 715 |
| 0500 | 326 | 0 | 326 | 250 | 136 | 386 | 0 | 3 | 3 | 0 | 0 | 0 | 576 | 139 | 715 |
| 0600 | 348 | 0 | 348 | 228 | 95 | 323 | 44 | 0 | 44 | 0 | 0 | 0 | 620 | 95 | 715 |
| 0700 | 345 | 47 | 392 | 207 | 52 | 259 | 64 | 0 | 64 | 0 | 0 | 0 | 616 | 99 | 715 |

average number of full bins = 335

Table 6.6 Bin Usage Summary

7 Techniques to Avoid Model Limitations

It is possible to represent track configuration, operational parameters and grower details in such a way that some of the scheduling system's restrictions can be side-stepped. Some techniques for avoiding the various restrictions are discussed below and these techniques may suggest other possible ways around particular problems. However, these 'tricks' will often have side-effects, chiefly through forcing the scheduling system ignore quite valid operations for the railway.

7.1 Multiple Growers for a Period Using the Same Siding

The scheduling system does not permit two or more growers harvesting in the same period to be allocated to the same siding. There are two methods around this restriction.

The first method is to combine the allotments and harvesting rates for the growers and to specify these for a single grower for that siding. This is simply done, but has some undesirable consequences.

- It does not accurately cater for the situation where the harvesting rates for the growers differ significantly.
- Only one harvesting start time per period can be specified for all the growers using the one siding.

The second method is to create 'dummy' sidings which are at zero distance from the 'real' siding, and allocate one grower to each of these. The correct allotments and harvesting rates and different start times for each may be then specified. The consequences are that the solution time (and charges for computer use) will rise somewhat, and that extra locomotive time will be used to shunt the dummy sidings.

7.2 Non-Uniform Running Speeds

If the speeds for a section of track differ significantly from the uniform speeds in the input data, some compensation can be made by giving an adjusted length for the section, rather than the actual length. This will yield a running time closer to the actual time than if the actual length and the uniform speeds were used.

For example, if the actual length is 10 km, the actual speed is 20 km/h, the uniform speed given is 15 km/h, then the adjusted length is $10(15/20)$ which gives 7.5 km.

The problem, of course, is that the ratio of uniform to actual speeds will probably be different for trains with empties, fulls and light engine, so that some judgement will have to be used to arrive

at a suitable adjusted length. A good practice is to use the lowest ratio, as this leaves some latitude in performing any manual revision.

A similar scheme can be followed to allow for shunting, and the like, required to move from a main line to a branch line and vice versa.

7.3 Servicing Branch Lines with Different Runs

There might be circumstances that make it impractical for a combination of branch lines to be serviced by a single run. In Figure 7.1, for example, the points at the junction might not permit a train going from siding 1 towards the mill to go to siding 2.

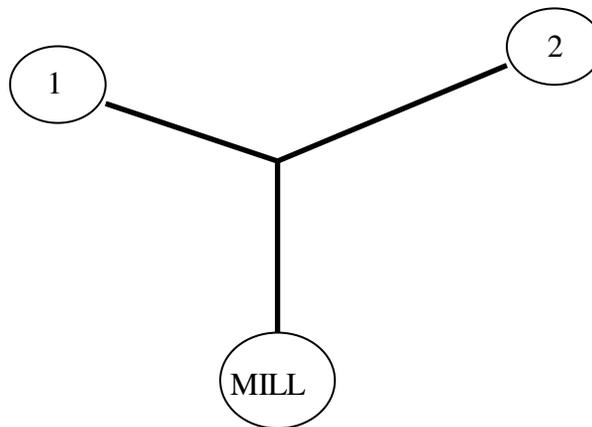


Figure 7.1 Actual Track Configuration

By modifying the network data as shown in Figure 7.2, ACRSS will keep the branch line areas separate and will not produce any locomotive runs that service both branches. As the scheduling system does not allow a run to pass through the mill, sidings 1 and 2 will never appear in the same run.

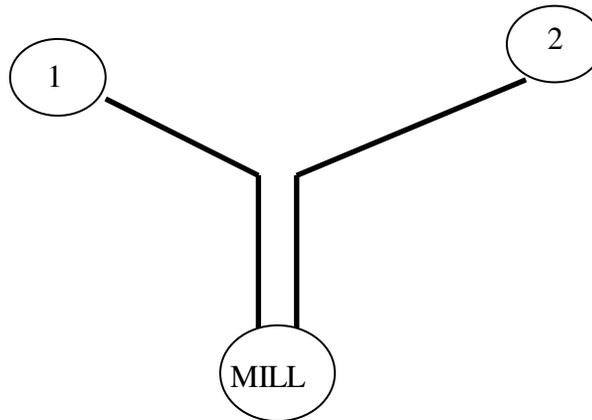


FIGURE 7.2 MODIFIED TRACK CONFIGURATION

However, this will apply to all runs. Even if the points at the junction can, in fact, allow a locomotive by itself to move from one branch to the other, runs will not be generated where empties are delivered to one branch and the locomotive then moves to the other branch to collect fulls.

7.4 Load Restrictions

In many mill networks, there are either isolated track sections (e.g. hills) where loads are limited, or larger, extensive areas of the network where loads are limited. The first type of load restriction can be handled by (artificially) stretching the track section where the load restriction occurs. This increases the locomotive running time, compensating for the increased time taken to split the load and haul it across the section in multiple trips. The second type of load restriction can be handled by incorporating depots into the system. With a depot, the area of the network where the load restrictions occur is modelled as a separate network with its own set of load restrictions.

7.4.1 Extended distance method to Model load Restrictions

To carry the whole full bin capacity of the locomotive on the restricted track sections, the locomotive may need to make several trips over the load-restricted section of track. These extra trips increase the time for the locomotive run. This can be incorporated into ACRSS by

extending the length of the restricted section of track. A distance factor (DF_i) can be calculated and used to multiply the exact length of section i to allow for the extra locomotive time. Appendix B details how the distance factor can be calculated.

The extended distances are incorporated into the network before the ACRSS program is run.

7.4.2 Using a depot to Model Load Restrictions

At some mills, depot-like facilities are used for the temporary storage of both empty and full bins. Depot-like facilities are utilised where either cane areas are geographically separated from the main mill area or there are significant regions of load restrictions in the depot area and the loads hauled to and from the mill vary significantly from the loads hauled in the depot area.

With ACRSS depots, the locomotive can start at the mill, take empty bins to the depot, deliver empty bins & collect full bins in the depot region, and finally return to the mill with the full bins. Alternatively, the locomotive may start and end its operations at the depot, with a different, mill based locomotive transferring empties and fulls from the depot to the mill.

Depot subsystems are incorporated into ACRSS program in two stages. Firstly, the depot and its sidings are considered as a separate system, with the depot replacing the mill, and a separate schedule is developed for this subsystem. In this step ACRSS generates a suitable set of locomotive runs to service the sidings in the depot area and also generates a list of arrivals and departures from the depot. This list of depot activities is used in the second step to produce an overall schedule. In the second step, depot subsystems are included in the network as single points of supply and the supply of the bins and the empty bins requirements at these depots are calculated from the list of the depot activities.

The incorporation of depots into ACRSS is detailed in Chapter 5 of this manual.

Appendix A

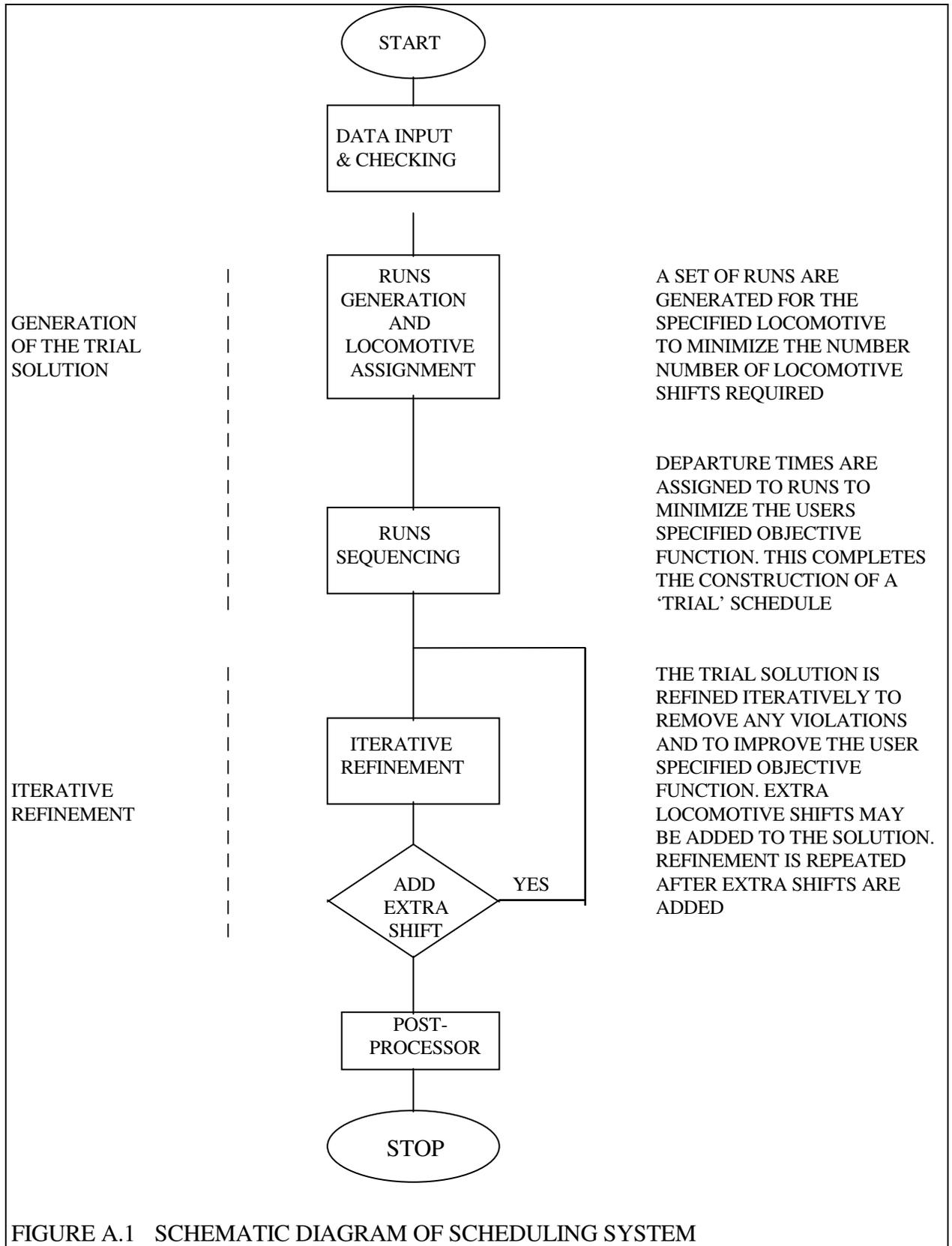
Overview of ACRSS Algorithm

This appendix outlines how ACRSS designs a schedule.

A schematic diagram of the system is shown in Figure A.1. The solution technique differs from that used in manual design. The change to a different method was necessary for the system to perform well for mills with widely different track configurations, rolling stock and harvest patterns.

A.1 Data Input and Checking

The first part of the ACRSS system inputs and checks the user's data. The data required is specified in Section 4 of this document. If the data input and checking routines do not find errors in the input data, they produce files that are used by the remainder of the ACRSS system to produce schedules. If errors are detected, a message is produced detailing the error and the preprocessor programs will proceed as best they can but will not generate the files for the other programs.



A.2 Runs Generation

The system begins by developing a set of runs making all the required deliveries and collections and allocating those runs to locomotives. The objective at this stage is to minimize the number of locomotive shifts and hence the number of locomotives. Where more than one type of locomotive is present, the system will use locomotives in the order in which they were specified on input. At this stage of the solution, the starting times of the runs that have been developed are not considered. The technique is basically to construct runs one at a time for each locomotive. Program Phase1 performs this function.

A.3 Runs Scheduling

The next step of the solution is to determine the times at which runs should be made. Once run start times are known, all other variables (such as the zero hour, carryovers, harvest start times for 'floating' growers, and the number of bins at sidings) can be determined. The output from the runs scheduling stage is thus a 'complete' schedule. It is not necessarily a schedule meeting all the requirements of the model, as the system does not require (at this stage) that all collections can feasibly be made given an earliest start time for a grower and his harvesting rate or that the growers' siding capacities will not be exceeded.

The technique used in this program is simply to consider all the sequences in which each locomotive can make its runs. As the runtime for each run has been determined by the runs generation program and as the runs scheduling program assumes runs are made immediately after the previous run, the start times for runs can be easily computed for a given sequence of runs.

The objective for this step is minimization of harvest start and siding capacity violations, weighted cane age, average cane age, zero hour, and bin fleet size (or some of these) in the order of priority the user specifies. Program Phase2 performs this function.

A.4 Iterative Refinement

The refinement program searches for and implements changes to the schedule which will improve it. Typical changes considered are creation of new collections and deliveries, swapping runs between locomotives and resequencing runs for locomotives. These changes are made one at a time and continue until no further improvements can be found.

The refinement phase modifies the schedule as produced by the runs scheduling phase to remove any harvest start or siding capacity violations. Whilst any violations are present, the refinement phase will not utilize the available free time to reduce cane age, zero hour or bin fleet size.

The removal of violations should be made the prime objective of this phase and the other objectives are minimization of weighted age, average age, zero hour, bin fleet size and total yard

size (or only some of these) in an order of priority specified by the user. Note this program's objective function need not be the same as for the runs sequencing program.

This program is also able to introduce extra locomotive shifts, if shifts are available with the existing number of locomotives or if extra locomotives have been declared as available. The user nominates the order in which shifts are to be added. Program Phase4 performs this function.

A.5 Post Processor

Finally, a report on the schedule generated is produced, in a form designed to be easily understood by a scheduling officer. The reports can be produced as a text file or can be exported back to TOTools as a ledger. This provides a familiar environment for the user to examine the schedules produced and also provides a platform from which the schedules can be exported to SRI's Animated display program, ACTSS.

A.6 Incorporating a Depot

Two steps are involved in incorporating a depot into a system. Firstly, the depot and the sidings serviced from it are regarded as a separate system, with the depot replacing the usual mill and a schedule is developed for this subsystem in the manner outlined previously. For this step, a depot resembles a mill in most aspects. However, the requirement of continuous crushing is relaxed and cane is "crushed" on arrival at the depot. For depot subsystems, interim weighted and average cane ages are calculated from the time the cane arrives at the depot and these interim ages can be considered in the objective function. Bin fleet size can also be included in the objective function, but for depot subsystems, the zero hour and the yard (depot) size are not considered.

The schedule produced in this first step not only generates a suitable set of locomotive runs to service the sidings in the depot area, but it also generates a list of arrivals and departures from the depot. This list of activities is used in the second step to produce an overall schedule. For this second step, a depot subsystem is included in the network as a single point of supply and the supply of full bins and the empty bin requirements at the depot are calculated from the list of depot activities. The interim ages of the parcels of cane arriving at the depot are used to calculate the cane ages for the complete system. For this second step, a depot resembles a grower siding in many aspects with depot violations occurring if there is insufficient cane at the depot to satisfy the collection requirements.

Appendix B

Extended distance factor

Distance factor DF_i is to be determined where ruling grade loads (RGL) are less than 100% in some sections of the routes. The value of DF_i will depend on the distance of the restricted track section i , full bin locomotive speed, empty bin locomotive speed, shunting time of empty and full locomotives of both the ends of the restricted section i , maximum siding capacity (MSC) and allotment (ALT) of bins of all sidings beyond RGL restricted sections to the tail of those routes have to be considered.

The following definitions are necessary to calculate DF_i .

i = RGL restricted section, $1 \leq i \leq I$

where, I = total number of restricted section in the network

S_i = siding set for section i ,

RGL_i = ruling grade load (% of bin) of section i ,

d_i = one way distance of section i in km,

Se_i = empty bin locomotive speed on section i in km/h for the fasted locomotive type,

Sf_i = full bin locomotive speed on section i in km/h for the fasted locomotive type,

ST_i = total shunting time of empty bin delivery and full bin collection in one round-trip on section i in hours,

MLC = maximum locomotive capacity (bins)

$$\begin{aligned} \text{Speed factor for section } i, f_i &= \frac{\frac{d_i}{Se_i} + \frac{d_i}{Sf_i} + ST_i}{\frac{d_i}{Se_i} + \frac{d_i}{Sf_i}} \\ &= \frac{d_i(Se_i + Sf_i) + ST_i * Se_i * Sf_i}{d_i(Se_i + Sf_i)} \end{aligned}$$

MSC_{ij} = maximum siding capacity (bins) of siding j in set S_i ,

ALT_{ij} = allotment (bins) of siding j in set S_i ,

where, j = siding index $1 \leq j \leq J$ and

J = total number of sidings in set S_i

The calculation of number of round-trips required for the restricted section i (RT_i) is as follows.

Maximum load carrying on section i ($Load_i$) is

$$Load_i = \min \left[\left\{ \sum_{\substack{J \in S_i \\ (j=1) \in S_i}} \min(MSC_{ij}, ALT_{ij}) \right\}, MLC \right] \quad \text{for all } i \quad (1)$$

Now the number of round-trips required for restricted section i is

$$RT_i = \text{trunc}\{(Load_i - 1) / RGL_i\} + 1 \quad (2)$$

The distance factor, DF_i is defined as

$$DF_i = RT_i \cdot f_i \quad (3)$$

Extended distance of track section i (Ed_i) in km is

$$Ed_i = d_i (DF_i - 1) \quad (4)$$