PLANNING AND MANAGING TRANSPORT RESOURCES - THE CASE OF A ROAD TRANSPORT CANE DELIVERY SYSTEM

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Abstract: Computer simulation can be used as a means of experimentation and evaluation of both truck allocation and dispatching problems especially when analytical methods are not suitable. The development of the model resulted from a need to gain an understanding of the impact of changes in transport resources on performance indicators of the system. The paper describes the operation and characteristics of the model and presents an example of an actual application. This particular model translates a complex harvesting-transport-processing situation into a user oriented interactive digital model using the programming capabilities of Microsoft Visual FoxPro.

keywords: transport resources, road transport system, simulation model, GIS/GPS

1. INTRODUCTION

Sugar cane is one of the bulkiest of crops, requiring the transport of large quantities of cane to the mills within hours of harvesting. Efficient transport is essential to minimise cane deterioration after harvesting and to maintain a uniform flow of cane through the mills. Cane deterioration can be broadly defined as any change which occurs in the sugar cane constitution from the time that it is harvested to the time that is crushed at the mill. (Willis, 1972)

Mill owners have made a substantial capital investment in cane railway networks and rolling stock. To ensure the prompt delivery of cane to the mills, Australian mills (23 mills) own and operate a network of 4,190 kilometers of narrow-gauge cane railways. This railway network forms the third largest rail transport system in Australia. However, the labour and maintenance costs associated with the operation of this transport system are high.

Few mills in Australia transport their cane by road (excluding the transport from the fields to the delivery points), and other use a combined road/rail transport.

2. OBJECTIVES OF THE STUDY

Transporting cane from the field to the mill is an expensive process. Both capital and operating costs are large. Cane transport is the largest cost unit in the manufacturing of raw sugar accounting for about one third of the total manufacturing costs. In order to maintain its international competitiveness the Australian sugar industry has to look at ways of reducing these costs.

Although a lot of research has been done into monitoring, managing and planning the cane railway transport operation, not the same attention has been given to the road transport system. The paper analyses the case of a road transport cane delivery system.

The use of the road system offers some advantages in terms of spatial coverage, but the road-based cane transport systems are more complex than those based on rail.

The sugar mills contract out the cane transport operation to commercial road transport companies. The contract cost is dependent on the number of trucks required, therefore is great financial incentive to minimise the fleet.

In order to achieve such an objective one has to:

- determine the optimal truck fleet size
- determine the optimal organisation of running the haulage system, i.e. especially select the optimal dispatching strategy in order to ensure maximal utilisation of the transport resources.

3. THE HARVESTING-TRANSPORT-PROCESSING SYSTEM

There is a mutually dependent relationship between the growers and millers. Therefore it is essential that the harvesting-transport-processing (crushing) system is viewed like an integrated system when addressing any directions.

The cane harvesting-transport-crushing system is very complex, comprising an integrated chain of activities that stretch from the grower through to transport and mill processing. This combination of a complex logistic network generates an extremely large number of alternative scenarios to be evaluated.

With the advent of continuous crushing and the accompanying rostered harvesting, the task of managing cane transport operations has become even more complicated. (Pinkney and Camilleri, 1996)

In Australia cane transport is undertaken by the supplier and the factory together. The supplier is responsible for loading the cane into a factory-supplied container and moving the container to a specified delivery point near to (or in) the field. From this point the factory is responsible for the transport of the cane to the factory and for weighing the cane and recording its delivery before it is crushed. The factory is also responsible for the supply of empty containers to the delivery point.

When considering optimising the operation of this system some specific optimisation criteria need to be established:

A. from the mill's point of view:

- uninterrupted crushing at the forecasted capacity during the whole harvesting season, providing the technical resources are in good working condition;
- limit the effects of accidental stops by modifying the harvesting rate;
- use a minimum number of trucks to haul the full/empty bins;
- use a minium number of bins.

B. from the farm's point of view:

- assure a harvesting rate according to the resources involved (machines, people);
- avoid the daily significant variations of the resources requirement;
- avoid harvesting interruptions due to the lack of empty bins on the pad;
- minimise cut to crush time (under the critical value).

What is optimum for the mill may not be optimum for the farm, and vice-versa, therefore measures to improve the entire system must be investigated:

C. for the entire process (criteria gathering):

- harvesting-transport-crushing at minimum costs (minium of resources required) under conditions that maintain the quality of the sugar cane harvested (maintaining the international competitiveness of the Australian sugar industry).

Based on these specifications two systems models have been developed: (1) an analytical model (Raicu, 2000), and (2) an interactive simulation model to facilitate investigations of the optimal use of harvesting, transport and crushing resources. The paper presents just the simulation model.

4. SIMULATION MODEL

4.1 Characteristics of the system

Simulation studies can contribute a lot towards solving the problems associated with the operation of a complex system, such as the cane harvesting-transport-crushing system. In order to obtain reliable and meaningful results from simulation studies, under these circumstances, one has to take into account the conditions, restrictions and requirements of the real operation in its very complexity and details:

- empty bins dispatching is not random
- avoid lack of empty bins at the farms
- conform to the critical cut to crush time
- harvesting is a stochastic process
- harvesting and transport daily durations are different

Another characteristic of the problem is that mills control the harvesting process by controlling the supply of empty bins to the farms.

The main characteristics of the system that set this simulation model apart from other similar problems can be summarized as follows:

- two commodities (full bins, empty bins)
- perishable product
- demand pattern is a decision variable
- most of the elements are stochastic

Computer simulation of the system operation under given technological conditions seems to be the most appropriate alternative in order to ensure the correlation between the number of available bins and the size of the active truck fleet.

The case of constant harvesting and arrival rates of the trucks with empty bins represents an ideal situation for the operation of the system, and is hard to believe it can be achieved even with a sound operative management system in place. That is the reason why for the actual values of λ_e(average arrival rate of the trucks with empty bins)and μ(average bin loading rate), the Δn_e value of the empty bins stock has to be checked, in order to avoid the stockout, with consequences for the harvesting flow during $\Omega_{h/day}$(daily harvesting period). Computer simulation, treating λ_e and μ as discrete random variables can be the most convenient way to check on and eliminate the stockout, for a certain initial stock value. The operations management system has to attempt avoiding the harvesting interruptions due to the temporary lack of empty bins on the pad.

4.2 Programming language

Model implementation required the choice of a suitable computer programming language. Two broad choices were possible: (1) the use of special purpose simulation languages, or (2) the use of a general programming language.

All of the standard simulation software considered, including those specialised in transport and transfer of flows, were not completely suitable for the problem. (Imagine That, Inc.), (InterDynamics Pty Ltd.), (Banks and Carson, 1984). They all contain predefined functions that cannot deal with the dispatching of the trucks after unloading according to the dynamic evolution of the situation at the farms. The dispatching rule needs to be defined by the analyst and consists of the priority given to the avoidance of empty bins stockout at the farms with consequences for the harvesting process, and to the bins older than the critical cut to crush time.

Thus special-purpose simulation languages are not flexible and versatile enough for the problem, and programming languages for discrete-event systems simulation do not have the facilities in order to decide the destination of the trucks after unloading.

On the other hand general programming languages are flexible, allow data base management (empty and full bins inventory), and outputs are non-standard.

Given that the model required some customised features to fit the actual system operations, a general programming language was therefore the most suitable choice. Thus the interactive simulation model was built using the programming capabilities of Microsoft Visual FoxPro software for Windows, which is an object-oriented environment for database construction and application development. (Raicu and Taylor, 2000a)

4.3 Model development

The simulation model developed has the following properties:

- describes the system well at an appropriate level of detail
- utilises the available data from the harvesting-transport-crushing system
- deals with random events - exponential, Erlang, normal or uniform distributions
- uses a database for empty and full bins at each farm
- allows resource changes (no farms, no trucks)
- simulation time is 30 days in order to diminish the effects of the initial state of the system
- allows changes of harvesting and transport operation time
- outputs represent significant performance indicators for farms and mill

The most common and economic operational cycle - the truck brings an empty bin to the pad, loads a full bin off the same pad, and hauls it to the mill - is used to simulate the process. The trucks operate continuously for 24 hours/day, while the harvesting is completed during the daylight time (say 14 hours/day).

The algorithm at the base of this simulation model is shown diagrammatically in Figure 1.

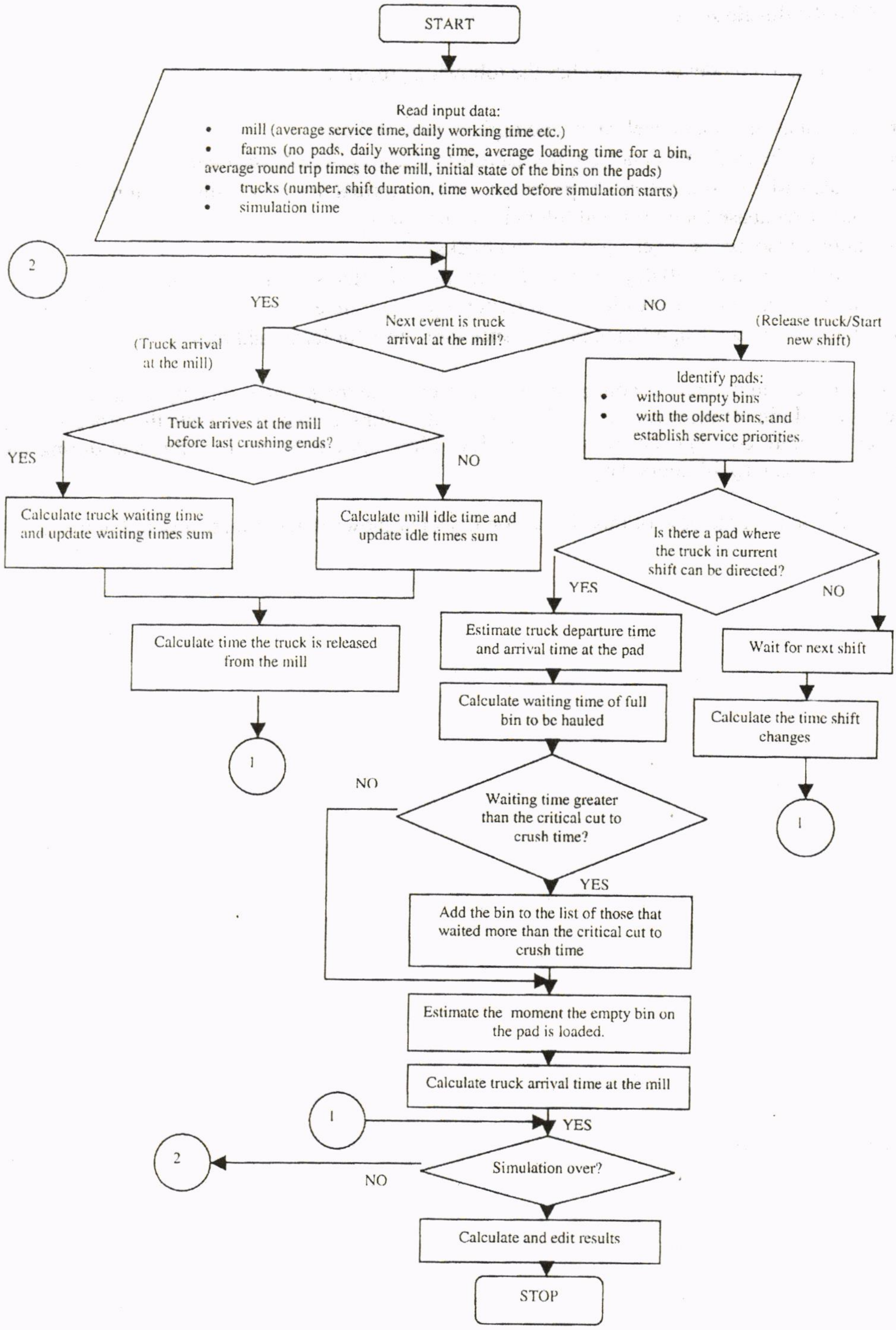

Fig.1 - Flowchart of dispatching strategy

Basic input variables

The basic input variables of the system:

- farm inputs: number of pads, maximum number of bins that can be stocked on each pad, loading time of a bin(harvesting rate), round trip time (truck cycle duration)- collected using Global Positioning System (GPS) receivers in each truck and from daily working hours;
- mill inputs: number of available trucks, service time (crushing rate), critical cut to crush time. Figure 2 shows examples.

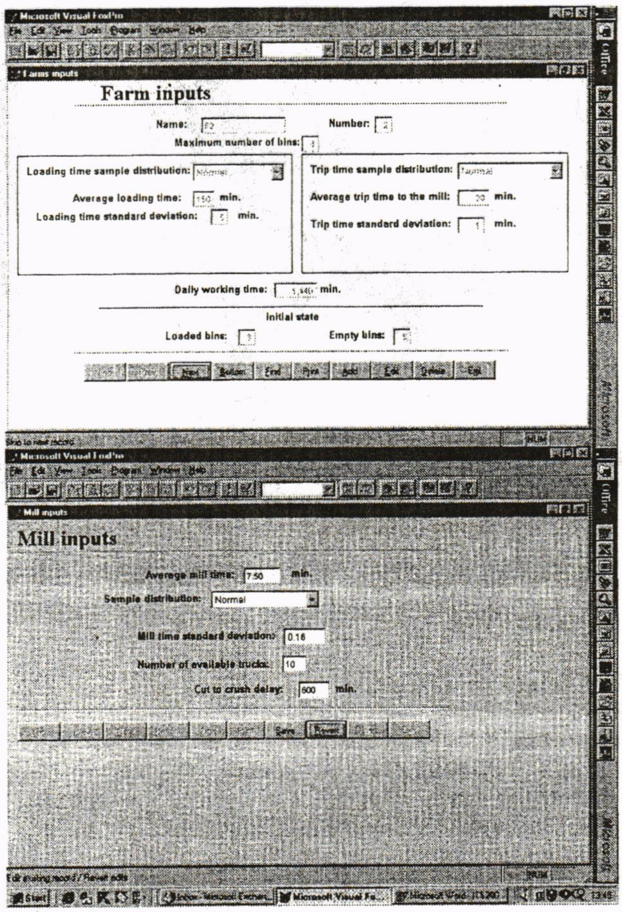

Fig.2 - Simulation screens-input data

GPS allows the capture of positional and time data for each truck within the fleet which can then be GIS integrated using a typical multilayer GIS software such as Mapinfo - see Figure 3 for an example GIS plot of vehicle locations.

Due to the continuous tracking by GPS any deviation from the correct route can be acknowledged and the appropriate message sent to the operator to change course. This facility can also be used as a part of an incident detection system. Events frequently occur that disrupt the planned schedule. Examples are cuts to the mill's cane requirements and the resulting changes to the harvesters' allotments, or the inability of a harvester to supply the required amount of cane. Providing the traffic officers with this real time information enables them to more effectively reschedule the operation. (Raicu and Taylor, 2000b)

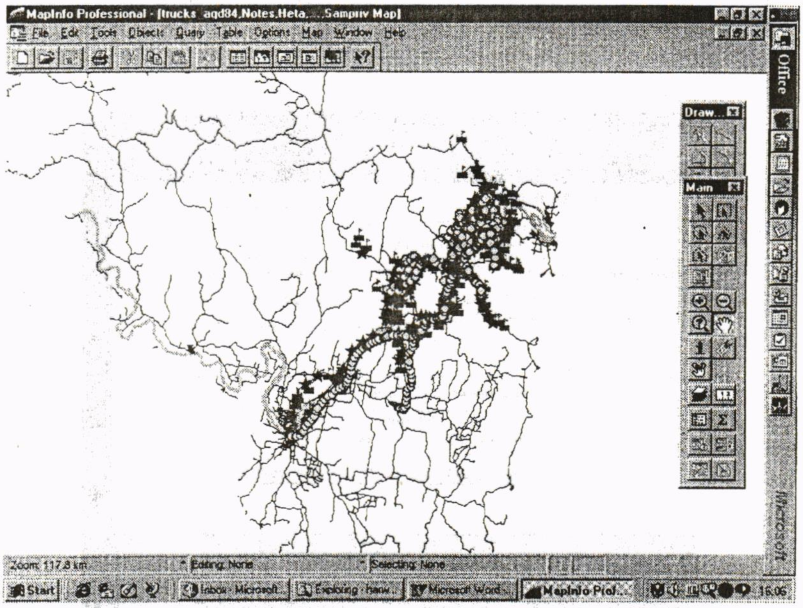

Fig.3 - Local road network and vehicle locations, Harwood Mill, NSW

Main output variables

- average trucks waiting time at the mill;
- average trucks queue length;
- total idle time of the mill;
- average waiting time of the loaded bins on the pads;
- number of bins that waited more than the cut to crush critical time after loading;
- idle times at farms due to lack of empty bins. [Figure 4]

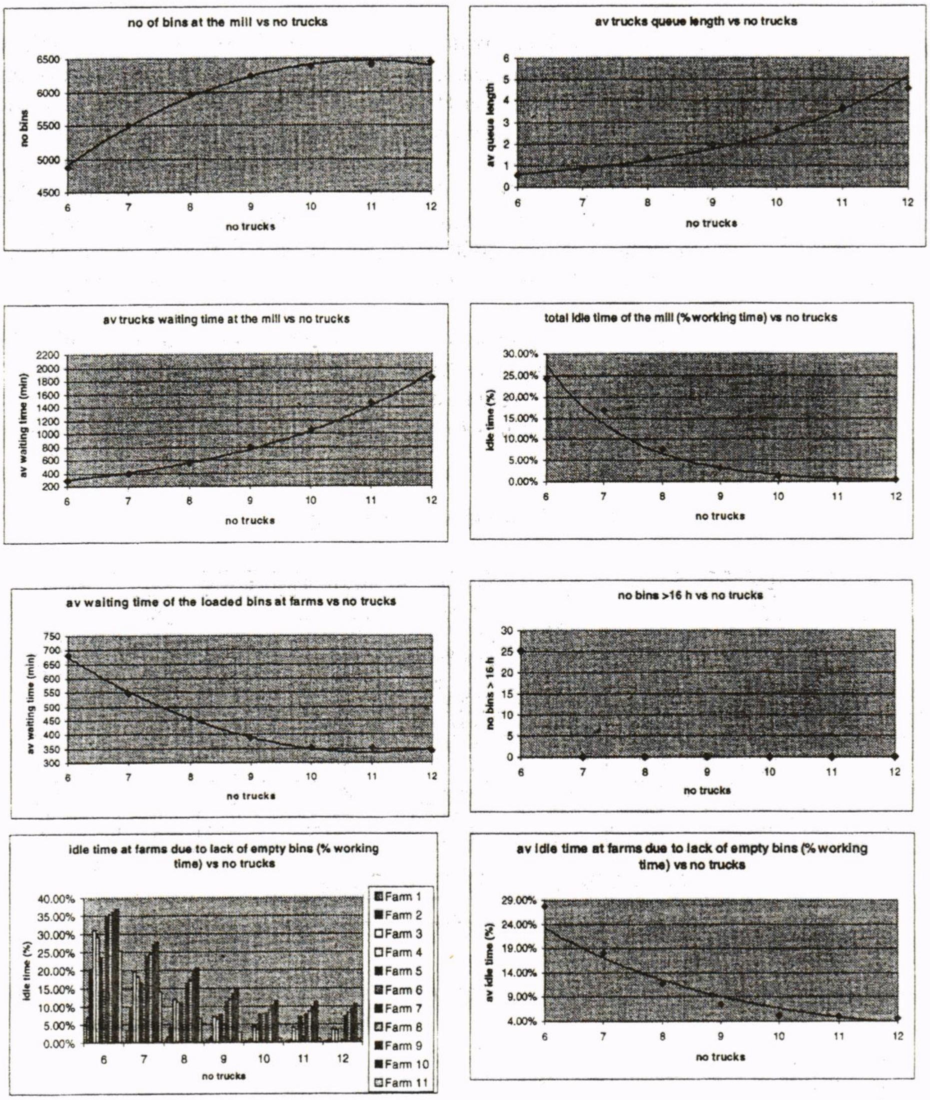

Fig 4 - Results of simulation

4.4 Case study

By 1975, the three mills in the New South Wales Sugar Milling Co-operative had converted from rail and river transport to 100% road using the multi-lift system. In 1989 a new cane weighbridge was constructed and automated at Harwood Mill. By 1992, an effort was made to complete the automation of cane receivals by allocating truck trips automatically, particularly on the afternoon and night shifts. To assist in determining arrival times, GPS receivers were fitted to each of the trucks in the Harwood fleet in 1994. Harwood Mill operates at rates of 200-220 tones cane per hour, using 10 trucks with the average trip distance of 27 km. With an area of over 6000 ha to harvest, the mill uses four harvesting groups operating eight harvesters to harvest 900,000 tones of cane. (Dines *et al.*, 1999)

Statistical analysis of one day of the 1999 season data collected from Harwood Mill, New South Wales showed that in most of the cases truck trip times were described by normal or Erlang distributions, while loading times were best described by uniform distributions.
Table 1 indicates some of the observed results for Harwood Mill. This data was used as input data for the simulation.

Table 1 - Harwood Mill data analysis

Pads 6/08/99	Av.trip time	Std.dev.	c.v.	distrib	Av. loading time	Std. dev.	c.v.	distrib
36	26.9	4.9	0.18	normal	43	0	0	uniform
37	25.7	5.9	0.23	normal	75.25	64.5	0.86	negative exp.
52	16.7	6.4	0.38	Erlang(k=7)	47.5	19	0.4	Erlang(k=6)
53	21.7	21.4	0.98	negative exp.	38	6.36	0.17	normal
126	48	4.2	0.09	normal	40	0	0	uniform
147	36.4	7.1	0.19	normal	34	0	0	uniform
148	38.9	3.5	0.09	normal	56.67	39.26	0.69	Erlang(k=2)
176	43.9	7.4	0.17	normal	35	0	0	uniform
200	41.2	3.4	0.08	normal	34	0	0	uniform
222	74.5	6.2	0.08	normal	35	0	0	uniform
223	77.8	14.4	0.19	normal	34	0	0	uniform

Av.mill time	Std.dev.	c.v.	distrib
7.2	3.05	0.42	Erlang (k=6)

The results presented in Figure 4 were obtained after a series of simulations using the above data.

The examination of these results leads to some interesting findings:

- performance indicators as the average idle time at farms due to lack of empty bins, the average waiting time of the loaded bins at the farms, the total idle time of the mill, the number of bins hauled to the mill, and the number of bins older than the critical cut to crush time improve as the number of trucks increases;
- performance indicators as the average trucks queue length (or the average trucks waiting time at the mill) deteriorates as the number of trucks increases.

Thus, for a fleet of 11÷12 trucks all the performance indicators are very well behaved except for the average trucks queue length in the mill yard that reaches maximum values;for a fleet of 7 trucks, the queue length in the mill yard drops to a minimum, and there are no bins older than the critical cut to crush time in the system, but all the other performance indicators deteriorate. Therefore when looking for an optimum in terms of fleet size the two contrary effects have to be balanced.

The simulation model determines the number of trucks required in order to ensure uninterrupted crushing at the mill, uninterrupted harvesting (avoiding a lack of empty bins on the pad) and comply with the critical cut to crush time interval.

Designed as an interactive model, the simulation allows changes of the transport, harvesting and crushing resources characteristics.

For long term planning the simulation model could be used in a number of what if scenarios to evaluate different combinations of harvesting and transport, i.e. to determine the effects of increasing or decreasing resources, and giving indicators as to what is the optimal fleet size for various conditions.

5. CONCLUSIONS

The simulation model developed is not Harwood Mill specific; it can be used for planning purposes at any of the sugar cane mills using road transport system exclusively. Being designed as an interactive model it allows changes of the resources characteristics.

Simulation proves to be a useful tool for predicting the performance of the transport cane delivery system in various scenarios. It is relatively easy to also identify areas where optimisation is needed such as the number of trucks in the active fleet as a function of the operation and slack costs related to transport, harvesting and crushing. The difficulties of combining the optimisation criteria can be eased by adopting some harmonization levels for the use of transport, harvesting and crushing resources. (Raicu, 2000)

The simulation model will provide the cane traffic inspectors with a method for optimising the resources of the harvesting-transport-processing system over large horizons (entire harvesting season) while at the same time planning the day to day operation. This will lead to productivity gains in the mill cane supply operations by minimising operating expenses and the maximum utilization of capital.

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