FREIGHT DISTRIBUTION LOGISTIC

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Abstract

The paper presents the development of a simulation model that aims to accurately reproduce the operation of a real freight distribution system. The model development and the simulation program are entirely original. The results of the simulation model, graphically presented in the paper, draw the attention upon their role in correlating the dimensioning of the system resources, and selecting the operating technologies.

Further development of the simulation model to include the transient states of the system lead to the conception of a computerised decision support system to manage the real time operation of the trucks in the fleet. This decision support system (DSS) allows the human operator, depending on various scenarios, to decide upon the dispatching solution that ensures the rational use of resources based on the imposed restrictions. It is designed as a DSS with directive role.

Keywords: Freight distribution; Simulation; Decision support system; GPS/GIS
Topic area: B3 Logistics, Freight and Fleet Management

1. Introduction

Transport integrates space and time. Transport ensures the link between activities developing in different spatial and temporal locations. Regardless of the type of transfer it achieves – persons, freight, information – transport belongs to the service domain. Transport takes place within and for the production process (the case of internal technological transport) or outside the production process, as a continuation into the traffic domain (the case of external commercial transport, private or public, individual or collective). In both cases, due to its tasks, the transport system has multiple direct and inverse links with the socio-economic environment. Therefore, the system approach to transport is gaining popularity in the detriment of the sectional approach; this is the case of the freight distribution logistic searching for solutions to save the resources involved both downstream and upstream of the production process, in order to ensure the competitiveness of the products.

Even though transport is involved, either as internal or external transport, in different stages of the sugar industry, this research focuses mainly on the transport of the sugar cane from the producers to the mill, accounting for about one third of the total manufacturing costs.

The principal research objective was to develop a model which provides a good approximation of the real complex system.

2. The Australian sugar industry

2.1. Operation

Australia is a world leader in mechanised harvesting and the efficient transport of cane from the field to the mill. Largely, as a result of this, the Australian sugar industry has been able to expand significantly over the past few decades while remaining internationally competitive. Maintaining this position, however, requires continual development and ongoing improvement. (SRDC, 1999)

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)

Sugar cane must be milled as soon as possible, and within 16 hours of harvesting, to minimise deterioration. For this reason it is important that the cane farms are in close proximity to the sugar mills they supply.

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 kilometres of narrow-gauge cane railways. This railway network forms the third largest rail transport system in Australia.

In Australia approximately 95% of the record cane crop is transported to sugar mills using railways. Six mills use road transport systems exclusively, and several use a combination of road and rail transport. The use of the road system offers some advantages in terms of spatial coverage and flexibility, but the road-based cane transport systems are more complex than those based on rail.

Cane transport is undertaken by the supplier and the factory together. As a rule, the supplier is responsible for loading the cane into a factory-supplied container (bin) and moving the container to a specified delivery point near to (or in) his 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. Thus there is a mutually dependent relationship between the growers and millers. Therefore it is essential that the harvesting-transport-crushing system is viewed like an integrated system when addressing any directions for either system or component changes.

2.2. Cane transport costs

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

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 look at determining the optimal size of the truck fleet, and also the optimal organisation of running the haulage system, i.e. especially select the optimal dispatching strategy that ensures maximal utilisation of the trucks.

3. Methodology

In the initial phase, both an analytical and simulation strategic model was created to reproduce the operation of the system with aggregated data.

The success of the model to represent the real system was conditioned by the repetition in successive iterations of the system-model-system-model cycle. This method was adopted in the development of both the analytical and simulation model.

The implicit dependency between the decision variables, and between these and the sub systems' technologies lead to the idea that the analytical model developed is not capable of achieving an optimum for the set criteria. However, the analytical model has its role in understanding the correlation between the operational parameters of the sub systems and the value of the resources involved, and in validating the simulation model developed.

The need for a more accurate representation of the real system, beyond the limits of the analytical model, lead to the development of a computer simulation model, StraSim, written in a general purpose simulation language for greater flexibility.

StraSim can be used to support both strategic and tactical decisions. The model, based on different scenarios is giving quantitative measures for the operation of the system in order to support the decision making process.

In a second phase, after the sensitivity of the system operation to different variations of the parameters has been tested, a detailed operational model was developed to be used as a computerised decision support system (DSS) for the management of the sugar cane harvesting-transport-processing system, based on real time information.

This system is essentially different to the one in use at the moment, where the role of the computer and communication systems is limited to the display of information about the state of the system, and the decision taken by the human operator based on his experience and routine.

In order to develop the computerised operational management system the correlations between the different activities within the system have been studied and the scenarios in which the operator in charge has to operatively decide upon the dispatching of the trucks were identified.

The operational management cases predicted are possible as a result of the communication systems between the farms and the traffic operator as well as between this last one and the truck drivers. The Global Positioning System (GPS) enables the tracking of the trucks fleet, the estimation of their arrival to the destinations time (ETA), the real time updating of the bins inventory, and harvesting situation. The human operator assisted by the computer for the complex analysis of alternative scenarios improves the quality of the dispatching decisions.

It is possible that by improving the algorithm for this combinatorial problem, the role of computer to evolve from directive to active, meaning that the dispatching decisions could be solely taken by the computer, the validation of the human operator being unnecessary.

4. Interactive simulation model

4.1. Model development

An analytical model was initially developed in order to acquire a better understanding of the behaviour of the system. The limitations of the analytical model drew the attention upon simulation as being an effective tool for detailed analysis. The results obtained from the analytical model were used to design, debug and verify the simulation model.

Simulation studies can contribute much 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.

When defining the trucks dispatching strategy two essential requirements have to be considered:

• avoid harvesting interruptions due to the temporary lack of empty bins at the farms;

• maintain sugar cane quality by ensuring its transport to the mill within a certain time interval (the critical cut to crush delay).

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, but it is unlikely to be achieved even with a sound operative management system in place. This 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 $\Delta n'_e$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 is probably 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 harvesting interruptions due to the temporary lack of empty bins on the pad.

Given that the model required some customised features to fit the actual system operations, a general programming language was therefore the most suitable choice for model implementation. 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)

The main characteristics of the system that set this simulation model apart from other similar problems can be summarised as follows (Pinkney 1987):

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

The simulation model developed in this research (StraSim) 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
- uses a database for empty and full bins at each farm
- allows resource changes (number of farms, number of 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 the 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.

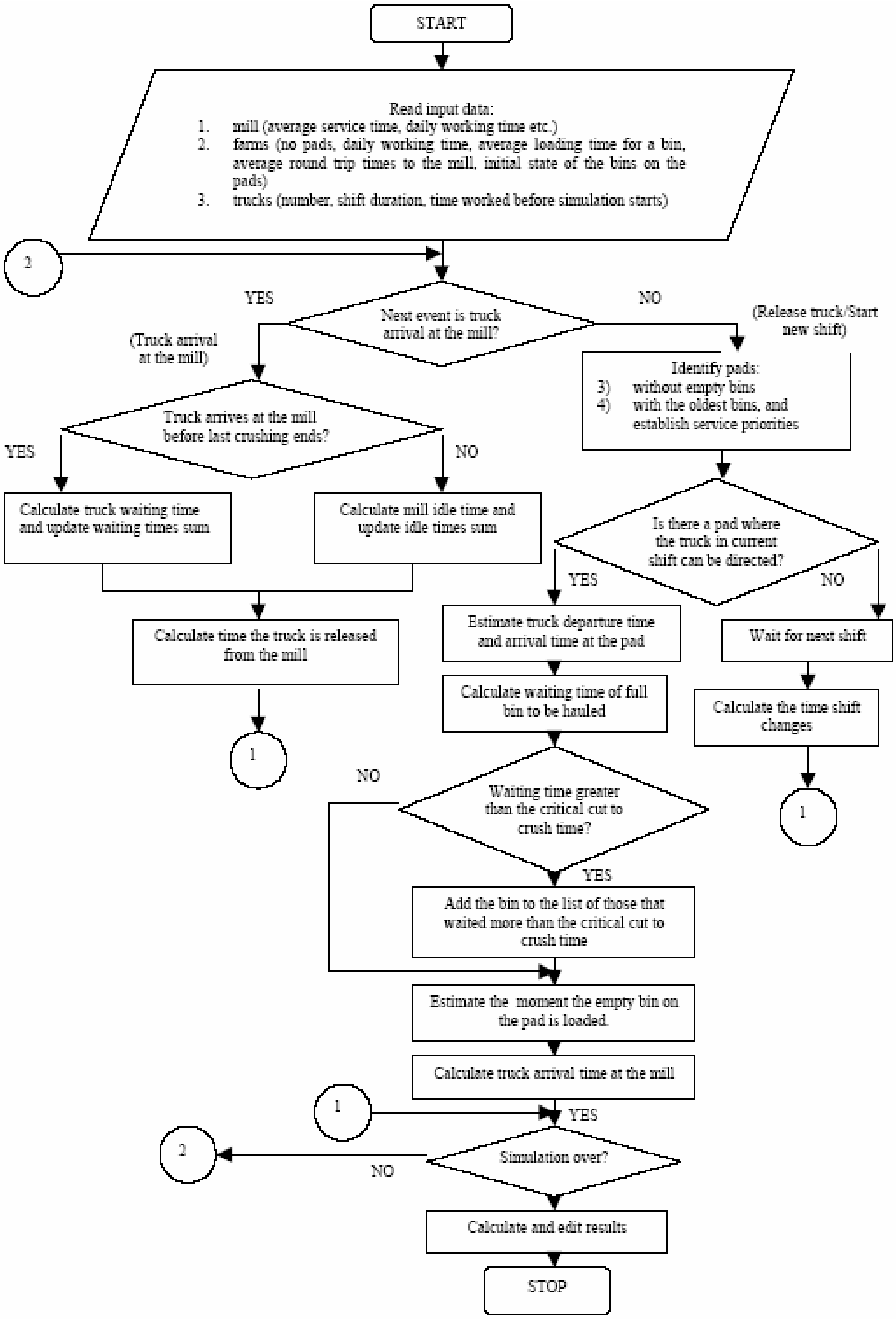

Figure 1 - Flowchart of dispatching strategy

The basic input variables of the system are:

- 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;

- mill inputs: number of available trucks, service time (crushing rate), critical cut to crush time;
- truck inputs: truck record number, length of shift for each truck driver (daily working time), time worked before simulation starts. Figure 2 shows examples.

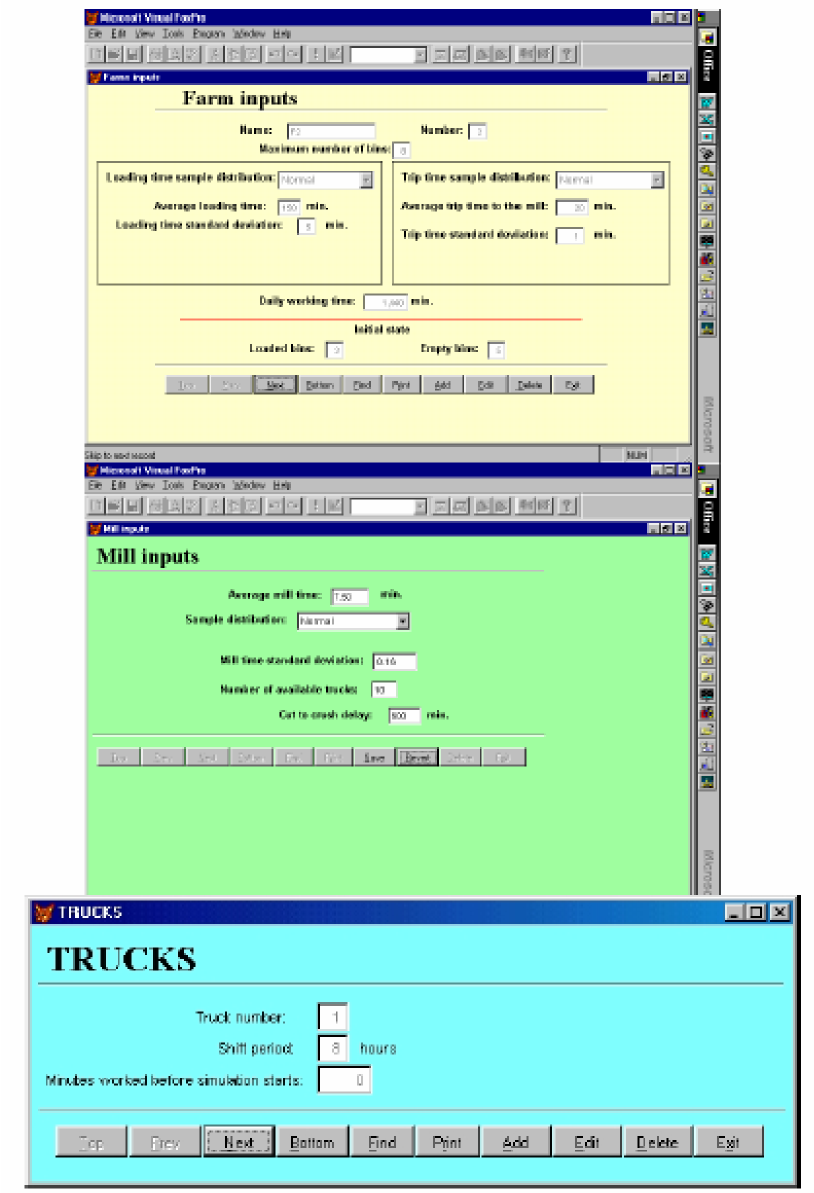

Figure 2 – Simulation screens input data

GPS allows the capture of positional and time data for each truck within the fleet which can then be integrated into a GIS using a typical multilayer GIS software such as Mapinfo – see Figure 3 for an example GIS plot of vehicle locations. The yellow circles in the figure represent the locations of the trucks, while the red flags the position of the pads.

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)

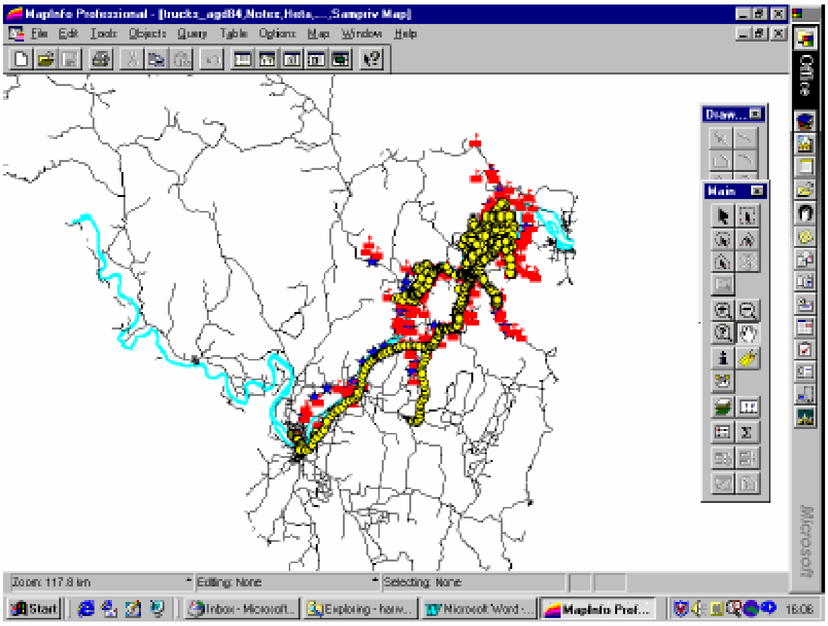

Figure 3 - Local road network and vehicle locations, Harwood Mill, NSW

The main output variables of the model are as follows:

- number of bins hauled to the mill;
- 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.

The model establishes the dependency between the number of trucks in the active fleet, the performing parameters of the mill, and the harvesting parameters.

4.2. Model application

An application of the proposed simulation model is presented hereafter. The model was used to simulate a day of the harvesting season operation at Harwood Mill, New South Wales.

A graphical representation of the results of the simulation is shown in Figure 4.

The examination of these results lead 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. DSS for the operational management of cane transport

The simulation model presented before takes into account the most frequent scenario, namely the usage cycle for the truck which appears to be the most rational for the steady operation state of the system, but this is not the only one found in actual operation. Even if the other operational cycles do not occur as frequent they cannot be omitted from the preoccupations of optimisation of the system. Thus, a computerised decision support system for the operational management of the sugar cane transport has been developed to deal with the transient state of the system.

The harvesting-transport-processing system of the sugar cane comprises important material and human resources - harvesters, bins, haul-out vehicles, trucks, loading-unloading equipment, weighing platforms, processing (milling) equipment, drivers, operators, field-inspectors - whose activities have to be precisely correlated.

The operational management of such a complex system supposes that the operator, based on his own experience with the system, adopts those dispatching decisions that would respond to the operational requirements of the system, and ensures the rational use of the resources. Because of the high dynamics of the system the human operator is forced to take decisions about the future activities of the system in a short time. When deciding on the destination of a truck available at the mill after unloading, the human operator has to take into account both the conditions of uninterrupted harvesting at all the farms, and haulage of the cane to the mill within the critical cut to crush delay in order to avoid its deterioration.

The proposed computer system was designed to assist the operator in a directive role. (Savas, 1965, Turban, 1995) The computer informs the operator of the scenario for which he/she has to take a decision, presents the operator with alternative dispatching solutions, and evaluates their respective consequences. The human operator, based on the constraints included in the algorithm, and possibly on some external reasons will be able to accept the solution, select a different one, or add supplementary constraints to the program. This system is essentially different to those currently in use, where the role of the computer and communication systems is limited to the display of information about the state of the system, and the decision is taken by the human operator based on personal experience and routine.

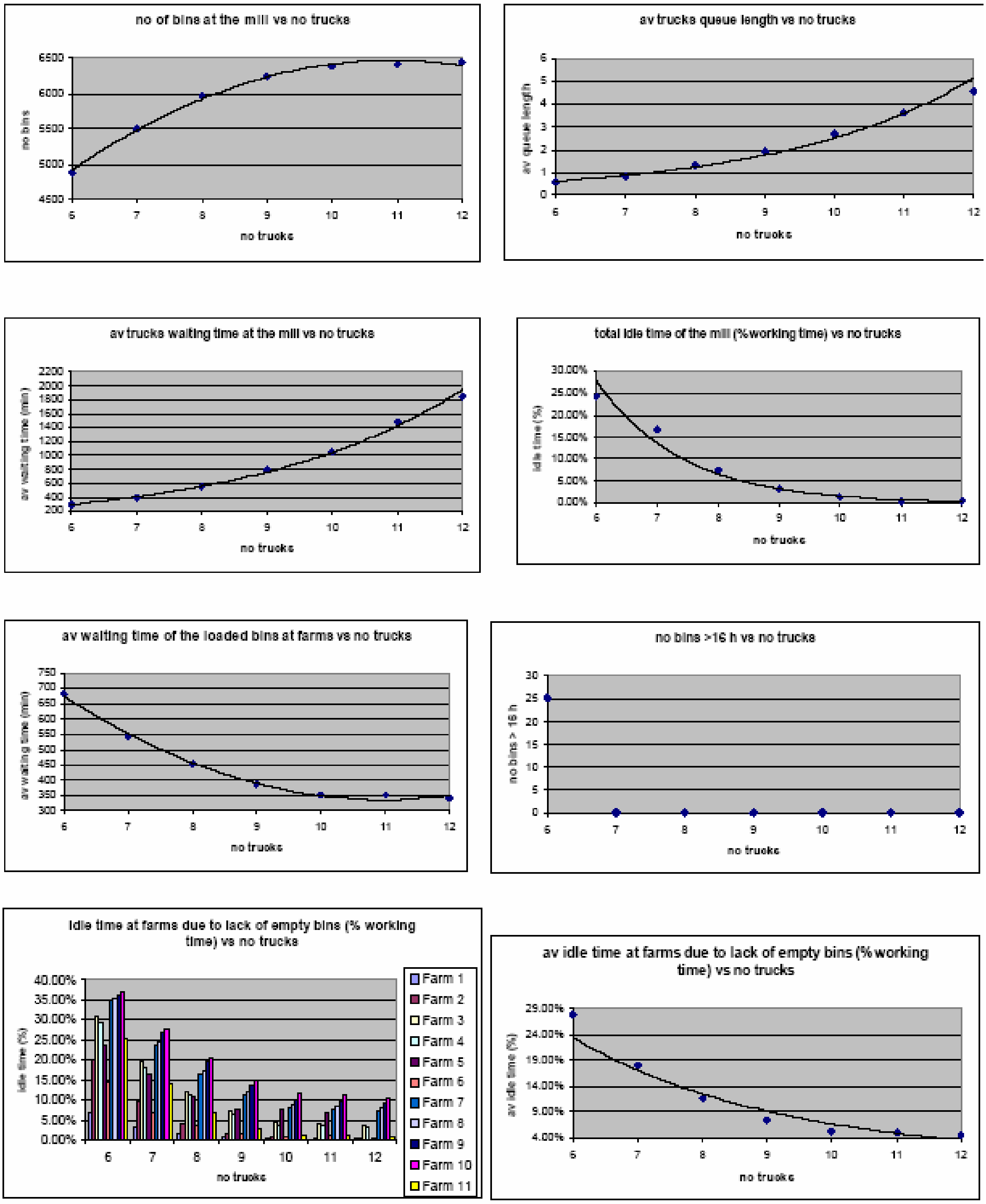

Figure 4 – Results of simulation

In order to develop the computerised operational management system the correlations between the different activities within the system have been studied. The scenarios in which the supervising operator has to decide upon the dispatching of the trucks were identified, and the algorithms corresponding to these cases are presented. Based on the conditions mentioned before (avoid the stock out of empty bins at the farms and conform to the cut to crush critical delay) four scenarios resulted, which lead to certain types of cycle for the available truck. The existing links between the different types of cycle indicated the necessity of examination of some successive decisional sequences, preference given, based on arguments that resulted from the analysis, to the completion of different types of combined cycles.

Further research on these issues will lead to increased performance of the operational management. A detailed analysis, backed up by analytical relations and graphical representations was performed in order to identify the opportunities for combined cycles of different types.

It is possible that by improving the algorithm for this combinatorial problem, the role of computer will evolve from directive to active, meaning that the dispatching decisions could be solely taken by the computer, the validation of the human operator being unnecessary.

5.1. Trucks operation

The operational cycle proposed for the truck (empty bin trip - full bin trip), though appearing to be the most rational for the stationary operation state is not the only one found in the actual operation, when more than one pad is involved. Figure 5 gives a simplified representation of some other cycle types for the truck.

Type "h" (harvesting) cycle is the one mentioned above, and the most common and economic cycle. The truck brings an empty bin to the pad, loads a full bin off the pad and hauls it to the mill. It is possible that during the harvesting season - steady state - to also encounter the type "h_d" (defective harvesting) cycle when the truck arriving to the P_i pad does not find any full bin to haul to the mill, M. In this case, the truck runs empty to the closest pad P_j which has a full bin, and hauls it to the mill.

The cycles in Figure 1b correspond to the initiation, i, and termination, t of harvesting. In the type "i" cycle case, pad P_i and neither of the pads around has full bins, so the rational usage of the truck supposes its movement without any load (empty or full bin) to M in order to assign other empty bins to the pads/farms which start harvesting.

Type "t_e" cycle corresponds to the termination of harvesting at farm/pad P_i, and because of a wrong harvesting estimation there are empty bins left which have to be hauled to M (none of the pads around needs empty bins).

Type "t_i' " cycle is also specific to the termination of harvesting at farm/pad P_i. The truck comes without any load to P_i in order to load and haul a full bin to M.

Type "t_i''" cycle can occur when the truck is moving without any load from M to pad P_i, loads an empty bin off it (P_i terminated harvesting or has got empty bins in excess), and transfers it to pad P_j, which is still in need of empty bins; then, the truck loads a full bin off P_j, and hauls it to M.

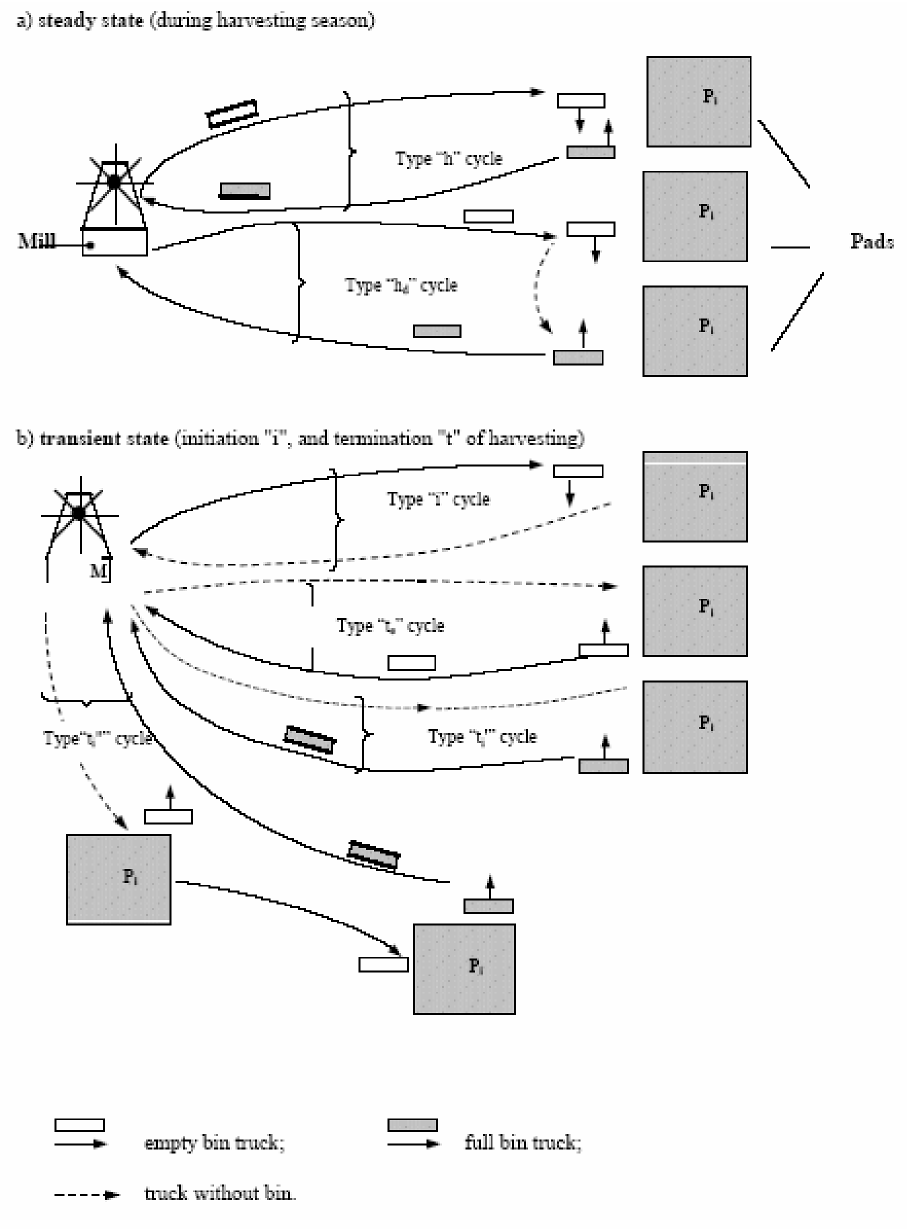

Figure 5 – Types of operational cycles for trucks

5.2. Development of the computerised DSS

The analysis detailed hereafter constitutes the basis for the development of the computerised decision support system for the operational management of the transportation of sugar cane.

The main cases identified in the operation of the system are as follows:

Case I (SO & OB) – stockout and old bin scenario

Case II (SO & $\overline{\text{OB}}$) - stockout and no old bin scenario

Case III ($\overline{\text{SO}}$ & OB) - no stockout and old bin scenario

Case IV ($\overline{\text{SO}}$ & $\overline{\text{OB}}$) - no stockout and no old bin scenario

All the types of cycle for the truck referred to in the following analysis have been previously defined.

Two of these scenarios are presented in detail hereafter.

Case I (SO & OB) – stockout and old bin scenario

Figure 6 shows the dispatching algorithm corresponding to the "stockout and old bin" scenario. The description of blocks 1° to 17° in the flowchart is as follows:

1° SO - ***stockout***, means lack of empty bin on the pad for loading the cane, in which case harvesting would cease. Direct (with priority) the truck with empty bin to that pad.

OB - ***old bin***, means bin loaded with cane, waiting on the pad to be hauled to the mill; the waiting time on the pad is about to equal the critical cut to crush delay.

2° P_i is the pad with imminent stockout (SO), so it has to be supplied with an empty bin; P_j is the pad where an old bin exists (OB), and has to be hauled to the mill with priority

3° Check if the pad P_i with imminent stockout coincides with the one that holds the old bin, P_j.

4° Check if there is a pad with an extra empty bin (harvesting is over at that pad or it is estimated that for the quantity of cane left to be harvested the pad has got too many empty bins)

5° If the two pads coincide ($P_i = P_j$) and there is no extra empty bin on another pad, without any other verification, select the type "h" cycle for pad $P_i = P_j$

6° From the pads with extra empty bin select P_k pad, for which $L(M\text{-}P_k)+\underline{L}(P_k\text{-} P_j)=\min$[1].

7° After finding pad P_k with the extra empty bin for which the distance is minimum, check if at the mill (M) there is a truck available (ready to start a new trip, and without bin; maybe a truck that just starts operating)

8° If the truck to be dispatched has an empty bin loaded, then estimate the equivalent distance, $\Delta\underline{L}$, this truck could cover with the empty bin during the time spent with the unloading of the empty bin at the mill. The truck would go to P_k pad (the pad with extra empty bin), pick up the empty bin, haul it to P_j pad, completing a type "t_i''" cycle.

9° This block has to select between the type "h" and "t_i''" cycle. The selection is based on the comparison between distances (it is also possible to compare travel times or costs). The length of the type "h" trip L( ) is $\underline{L}(M\text{-}P_j)+\overline{L}(P_j\text{-}M)$, the sum of the trip length from the mill M, to pad P_j with empty bin, including the unloading of the empty bin $\underline{L}(M\text{-}P_j)$, and the trip length from pad P_j to the mill M, with full bin loaded from P_j, $\overline{L}(P_j\text{-}M)$. The length L( ) of the type "t_i''" trip is the sum of the empty truck trip length from the mill to the pad P_k, where it picks up an empty bin, $L(M\text{-}P_k)$, and the empty bin truck trip length from P_k to P_j, where it leaves the empty bin, $\underline{L}(P_k\text{-}P_j)$, and the full bin truck trip length from P_j to the mill, $\overline{L}(P_j\text{-}M)$ at which adds up the equivalent distance $\Delta\underline{L}$ calculated at (7). In the case of a type "t_i''" trip the problem of hauling to the mill the extra empty bin from pad P_k is solved, too. In the case of a type "h" trip in order to haul the extra empty bin from pad P_k to the mill a type "t_e" trip appears, with the length $L(M\text{-}P_k)+L(P_k\text{-}M)$.

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[1] $\underline{L}$( ) or $\Delta\underline{L}$, , $\overline{L}$( ), L( )are the length of the trips corresponding to empty bin truck, full bin truck, and truck without bin. This way the results of the calculations can be expressed in the same type of units after conversion.

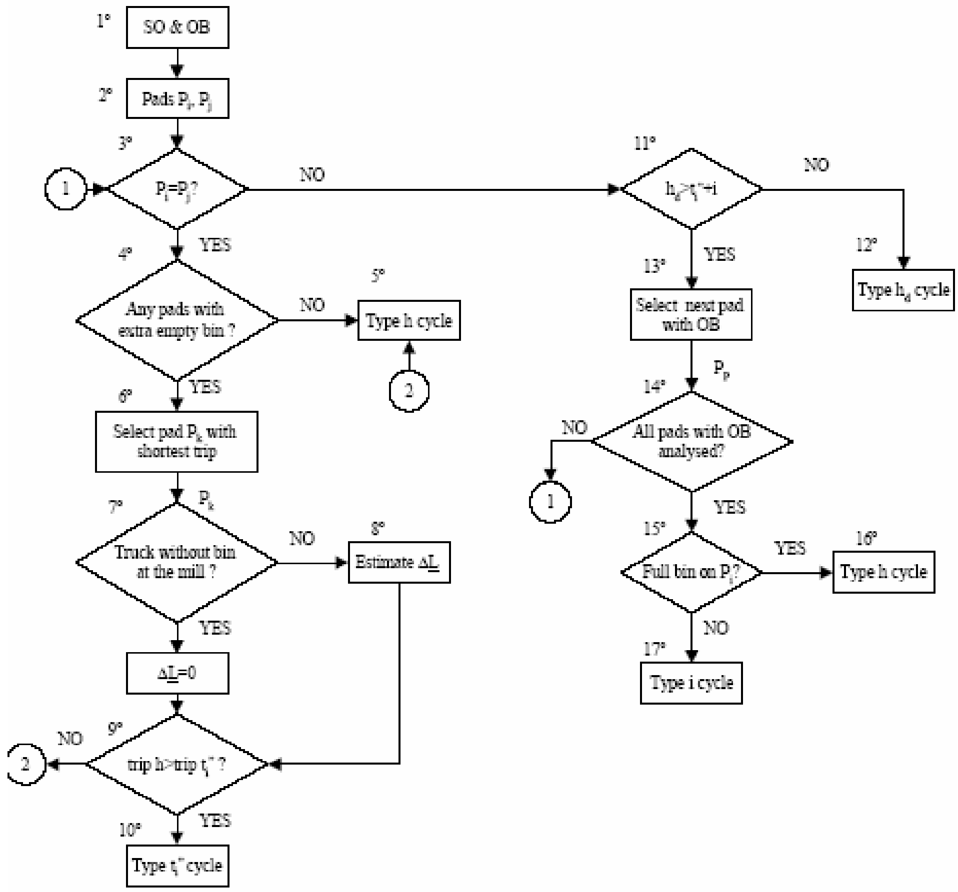

Figure 6 – Dispatching algorithm for the "stockout & old bin" scenario

The length of the trip in the case of type"h" and type "t_e" trip is then:

$\underline{L}(M-P_j)+\bar{L}(P_j-M)+L(M-P_k)+\underline{L}(P_k-M)$,

and in the case of the type "t_i''" trip is:

$L(M-P_k)+\underline{L}(P_k-P_j)+\bar{L}(P_j-M)+\Delta\underline{L}$

Comparing the length of the two trips, after excluding the identical segments, results that if:

$\underline{L}(M-P_j)+\underline{L}(P_k-M)>\underline{L}(P_k-P_j))+\Delta\underline{L}$,

then the type"t_i''" trip is selected, and if not the type"h" trip (the type "t_e" trip is left to be completed without priority by another truck, as outlined in a following flowchart).

10° By completing a type "t_i''" trip a type "t_e" trip is eliminated. The stockout, SO, avoidance, and haulage of the old bin, OB to the mill are simultaneously accomplished.

11° If the pad P_i, with the imminent stockout SO, does not coincide with pad P_j, with old bin OB, then priority is given to the problem of ensuring uninterrupted harvesting - avoid SO at P_i, which could be accomplished with a type"h_d" trip. This would solve the pick up of OB from P_j, too.

The type"h_d" trip will be recommended if its length $\underline{L}(M\text{-}P_i)+L(P_i\text{-}P_j)+\overline{L}(P_j\text{-}M)$ is not greater than the sum of the length of type"i" and "t_i''" trips, which separately satisfy the requirements of pad P_i, respective P_j, so $\underline{L}(M\text{-}P_i)+L(P_i\text{-}M)+L(M\text{-}P_j)+\overline{L}(P_j\text{-}M)$. After excluding the identical segments, if the following relation $L(P_i\text{-}P_j) > L(P_i\text{-}M)+L(M\text{-}P_j)$ is not satisfied, then the type"h_d" trip is preferred.

12° Completing the type"h_d" trip solves simultaneously the SO at P_i and the OB at P_j.

13° Select the pad with the next OB in order to firstly complete type"h" trips which will solve simultaneously the SO and OB problem, without any dead-runs of the truck. Suppose the next old bin is located on pad P_p.

14° Check if all the pads with old bins have been analysed. Set a range of oldness between $T_{critical}$ and $T_{critical}$ -θ, where $T_{critical}$ is the critical cut to crush delay, and θ, a random time, but not greater than the maximum time of the type"h" cycle.

15° If all the pads with OB in the preset range have been analysed, and no type"h", "h_d" or "t_i''" cycles have been identified, then try a type "h" trip to pad P_i which needs an empty bin to avoid harvesting interruption. For this check if there is a full bin on pad P_i.

16° Except for the initiation of harvesting case, there is at least one full bin at P_i to induct the SO state analysed. Thus, the type "h" cycle at P_i is possible.

17° At the beginning of harvesting at pad P_i the only possible cycles are the type "h_d" and "i" ones. Because there are no P_j pads with OB on this link of the flowchart, means a type "i" cycle is completed.

Case II (SO & $\overline{\text{O}}$B) - stockout and no old bin scenario

Figure 7 shows the dispatching algorithm corresponding to the "stockout and no old bin" scenario. The description of blocks 1° to 15° in the flowchart is as follows:

1° SO - lack of empty bin to be filled with cane on the pad

OB - no old bin means no bin older than the critical cut to crush time that has to be hauled with priority to the mill.

2° P_i is the pad with imminent SO, so needs empty bin.

3° Check if the P_i pad, which needs an empty bin has at least one full bin.

4° Check if there are any other pads with full bins (if P_i has not a full bin)

5° If neither P_i pad, nor others have full bins (harvesting initiation case mainly) then provide empty bin to P_i pad, type "i" cycle.

6° Check if there are pads with empty bin, and they do not need it.

7° If there are not any pads with extra empty bin, then provide empty bin at P_i pad and pick up full bin, with type "h" cycle.

8° From the pads with extra empty bin select the P_k pad, with the corresponding shortest trip $L(M\text{-}P_k)+\underline{L}(P_k\text{-}P_j)$.

9°&10° Do the functions of blocks 7&8, case I (SO&OB).

11° Do the functions of block 9, case I, in order to select between type "h" and "t_i''" trip.

12° See block 10, case I.

13° If there are pads with full bins, select out of them the pad P_j, with shortest trip, after the delivery of the empty bin to P_i.

14° Compare the length of the type "h_d" cycle

$\underline{L}(M\text{-}P_i)+L(P_i\text{-}P_j)+\ \overline{L}(P_j\text{-}M)$

in order to avoid SO at P_i and pick up full bin from P_j, with the type "i" cycle for the service of pad P_i and type"t_i'" cycle for the service of pad P_j, so

$\underline{L}(M\text{-}P_i)+L(P_i\text{-}M)+L(M\text{-}P_j)+\ \overline{L}(P_j\text{-}M)$

After eliminating the identical terms results that if

$L(P_i\text{-}P_j)>L(P_i\text{-}M)+L(M\text{-}P_j)$,

then the type "i" cycle has to be selected (the completion of type "t_i'" cycle for pad P_j is delayed for a next sequence)

15° The type "h_d" cycle is completed, which solves both the lack of empty bin problem at P_i and the haulage of the full bin from P_j to the mill M.

Note: In the above description in order to avoid redundancy the information explained in detail for case I was not repeated.

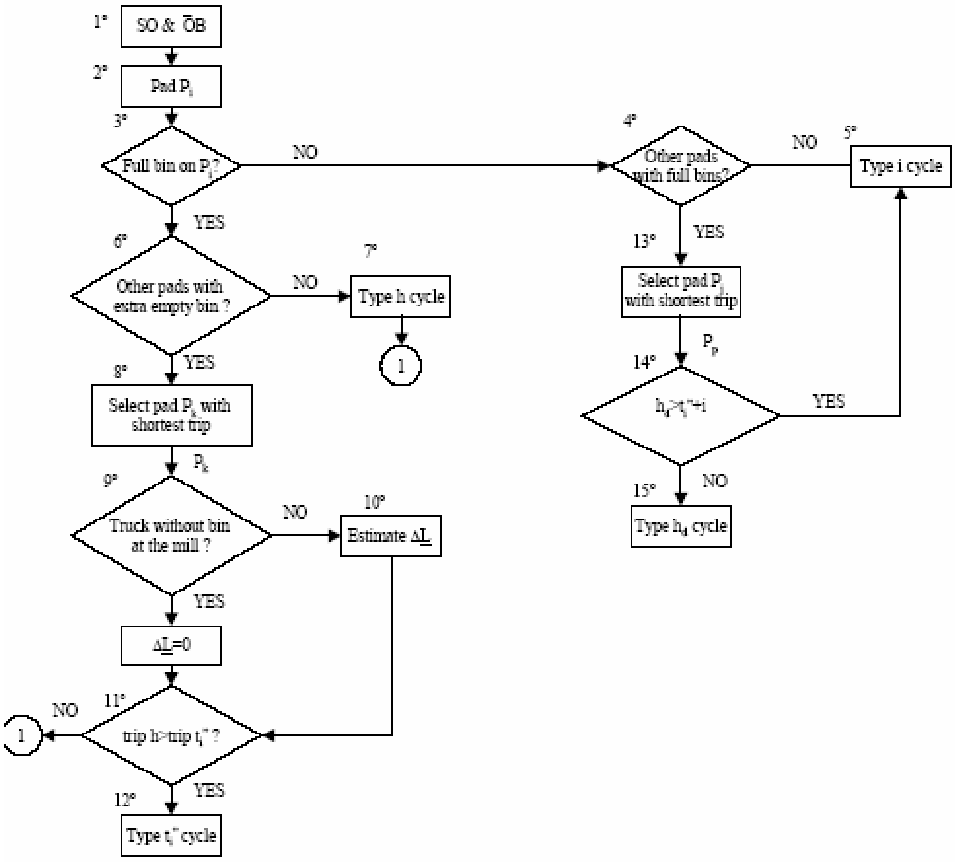

Figure 7 – Dispatching algorithm for the "stockout & no old bin" scenario

5.3. Model implementation

Within the computer program written in Visual Fox Pro, the events time-advance (loading of a bin, processing the load of a bin, truck arrival with a full/empty bin at the mill, etc) is ensured using an artificial sample (Monte Carlo method). Thus, an accelerated simulation (as to time) of the real system is performed in order to demonstrate the utility of the operational management system.

5.4. Model application

An example of application of the proposed computerised DSS is presented hereafter. The same day of the harvesting season at Harwood Mill, NSW was chosen to run the operational simulation as for the StraSim model application.

The best understanding of the operational model and its output is achieved by running the application on computer, and following the decisional process in real time. It is just few examples of screenshots showing the dispatching solutions proposed by the computer program for certain initial conditions are presented here.

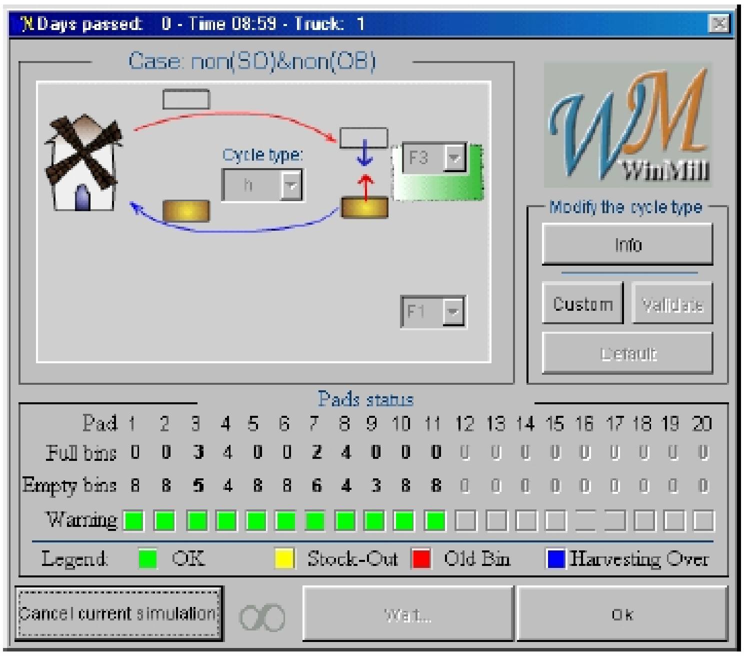

Figure 8– Dispatching solution for truck no 1 at 08:59

It is easily apparent that the bin inventory at the pads changes from one sequence to the other.

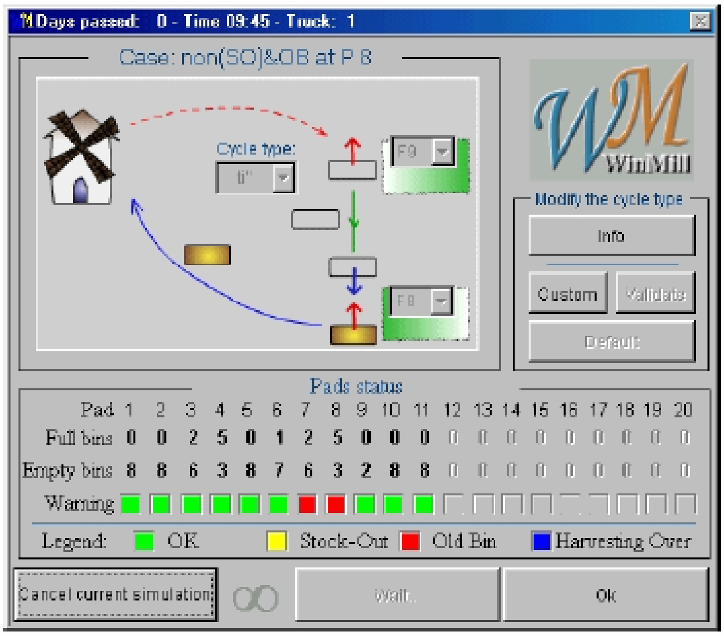

Figure 9 – Dispatching solution for truck no 1 at 09:45

In this sequence "old bin" warnings are displayed at two of the pads (the red squares at pad number 7 and 8). The dispatching decision of truck 1 chosen by the computer in this case is meant to alleviate the problem by hauling an empty bin from pad 9 to pad 8, and an old bin from pad 8 to the mill – a type "$t_i^{''}$" cycle.

Dispatching solutions, like the examples presented above, are provided in real time for the entire truck fleet in operation at the mill.

6. Conclusions

The models developed as part of this research project provide the cane traffic inspectors with a method for optimising the resources of the harvesting-transport-processing system over large horizons 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.

StraSim provides a good approximation of a real complex system, whose operation is affected by many random elements (loading of the bin time, full/empty bin truck travel time, mill service time, etc).

In these conditions, simulation proved 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.

StraSim can be used to support both strategic and tactical decisions. The model, based on different scenarios is giving quantitative measures for the operation of the system in order to support the decision making process. StraSim also served as a basis for the development of a computerised decision support system for the operational management of the sugar cane road transport.

A similar approach can be applied to solve other important transport problems. The road transport of containers between the terminals of different transport modes (rail, port) and the beneficiaries that can be served only by road is a similar problem. A solution as the one presented herein would optimise the use of resources (vehicles, fuel, people, containers) and diminish pollution and congestion on the main urban road arteries (mainly by eliminating the dead-runs).

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