

A SIMULATION STUDY ON CANE TRANSPORT SYSTEM IMPROVEMENTS IN THE SEZELA MILL AREA

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Abstract

Approximately 2.2 million tons of sugarcane is carted over a tons weighted average distance of 30 km in the Sezela mill area per annum. This costs more than R58 million per season. The Sezela cane transport system is comprised of approximately 120 independently managed vehicles owned by a wide range of hauliers and individual growers. This study investigated the potential savings that may occur as a result of a central fleet control system with integrated vehicle scheduling. A scheduling software package named ASICAM, which resulted in significant savings in the timber industry, was assessed within the Sezela region. Results suggested that the number of trucks in the fleet could immediately be cut back by at least 60%, provided that a central office controls vehicle movements and that all hauliers serve all growers in an equitable fashion. In addition, an investigation towards increasing payloads by reducing trailer tare mass showed further reductions in the number of trucks required. These adjustments will impact favourably on transport rates, queue times and uniform mill deliveries. Further research, however, is needed before the system can be implemented. This includes formulating scheduling and payment protocols and managing extreme supply/delivery periods, such as during run-away fires, frost and wet conditions.

Keywords: fleet size, truck scheduling, ASICAM, Sezela, payload

Introduction

Approximately 2.2 million tons of sugarcane is carted over a ton weighted average distance of 30 km in the Sezela mill area per annum. Based on information from Unitrans Freight (personal communication¹), Hellberg Transport Management (personal communication²) and the Sezela LIMS data (personal communication³; Walford, 2002) the cost of the present transport system is approximately R58 million, which includes both fixed and running costs. Currently 120 independently managed vehicles serve the mill supply area. Many of these vehicles are owned by growers and a large number of different contract agreements between growers and hauliers exist. Hauliers therefore serve certain growers only. Cane deliveries at the mill are managed through a Daily Rateable Delivery (DRD) protocol, allowing every grower an equitable amount of deliveries per day. However, deliveries are not scheduled within the day and queuing at the weighbridge is often problematic with long delays, especially at mid-morning, as a result of the uniform onset times of driver shifts.

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Two recent studies have researched transport and other related supply chain issues in the Sezela mill supply area. Barnes (1998) conducted an in-depth simulation study of supply chain components in an attempt to address harvest to crush delays at Sezela. In this study the supply chain was conceptually represented and several 'what if?' scenarios were simulated to identify potential bottlenecks. During a comparison with a mill in Mauritius, Gaucher *et al.* (2003) proposed an integrated modelling and optimisation approach disaggregating weekly information into daily logistics and operational practices. While both these studies acknowledged the importance of the vehicle fleet and its optimal utilisation, they did not attempt to optimise the system through transport scheduling techniques.

Transport scheduling is a well researched field. Not only have many academics enjoyed the theoretical challenges of vehicle routing and scheduling problems (e.g. Savelsbergh and Sol, 1995; Mitrovic-Minic, 1998; Bodin *et al.*, 1983), but several industries such as waste collection (Tung and Pinnoi, 2000), postal and courier services (Redmer *et al.*, 2003) and public transport systems (Stein, 1978) have made practical use of these theories. Weintraub *et al.* (1996) and Rönnqvist (2003) implemented practical transportation scheduling solutions to the Chilean and Swedish forestry industries, respectively. However, with the exception of work on scheduling rail delivery systems in Australia (e.g. Higgins, 1998), far fewer references could be found to computerised road transport scheduling systems in sugarcane (e.g. Dines *et al.* 1999; Raicu and Taylor, 2000).

The aim of this study is to assess the potential benefits to the Sezela mill supply area through the introduction of a computerised central control transport scheduling system. Specific objectives are to (1) configure the mill supply area to be simulated within a computerised vehicle scheduling system, (2) assess the financial benefits of this system and (3) investigate the additional benefits under increased payload assumptions.

Methods

Problem solving techniques

Rönnqvist (2003) notes that an Agricultural Haulage Scheduling Problem (AHSP) has many similarities with the standard Pickup and Delivery Problem with Time Windows (PDPTW) (Mitrovic-Minic, 1998). One major difference between these generic problems is that in the PDPTW a task is completely accomplished after the corresponding node has been visited once. This is typically not the case in the AHSP, since customers may need to be visited several times before the supply has been transported to the mill (Palmgren, 2001).

An important issue in routing and scheduling involves the practical aspects of solving the aforementioned problems. Due to the intrinsic complexity of these problems, the use of mathematical-program-based models and algorithms is needed (Solomon and Desrosiers, 1988). In this study a heuristic was used to solve the problem. Heuristic solution techniques (or approximation algorithms) have been developed to explore only those parts of the search space where satisfactorily results could be expected (Wren, 1998; Haksever *et al.*, 2000). This significantly reduces computation time, but runs the risk of missing out on more optimal solutions.

The ASICAM vehicle scheduling software (Cossens, 1992; Weintraub *et al.*, 1996) was used to demonstrate the benefits of vehicle scheduling at Sezela. ASICAM originates from the Chilean forestry industry, but has since been used successfully to increase vehicle utilisation in New Zealand (Cossens, 1992), Sweden and South Africa (personal communication⁴).

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ASICAM follows a multi-tier problem solving heuristic. The system assesses the supply and demand and will attempt to evenly distribute consignments over a 24-hour period. At the same time ASICAM will attempt to service all supply zones equitably, and will also give vehicles equitable shares to service long and short distance zones. The system also attempts to minimise queue times at the weighbridge, keeps track of the remaining stock on the supply zones and allows for driver shift changes. For simplicity purposes in this study, the system was configured to allow all growers to be serviced by all vehicles and all vehicles were housed at a single depot situated approximately ten minutes from the mill. It was assumed that a central control room scheduled all vehicles.

Model configuration

ASICAM was used to schedule the cane supply of week number 22 in the 2003 harvesting season (21-27 July) for the Sezela mill supply area. This week was statistically the most average and normal week in 2003 (LIMS data courtesy of Alan Simpson, Illovo). It did not experience excessively wet conditions or mill breakdowns, and also did not include large quantities of fire cane. Tuesday of week 22 (*viz.* 22 July 2003) was selected for an independent, more detailed analysis. This date was well representative of a normal week day. Mondays, Fridays, Saturdays and Sundays normally have different logistical arrangements as a result of labour and mill maintenance issues, and may therefore be less representative.

The system was configured to schedule regular cane suppliers. These excluded small and medium scale growers, as well as diverted cane. Regular suppliers constituted approximately 80% of the mill's weekly demand. The mill crush rate was assumed at 450 t/h, therefore allowing 360 t/h to be received from regular suppliers, and hence being scheduled by ASICAM. A proportion of spiller time was reserved to serve the additional 20% irregular suppliers. The regular suppliers were subdivided into three segments due to a zone number limitation within ASICAM, with each segment being serviced by its own spiller. The subdivision was done equitably by allowing each spiller to service relatively large and small, as well as closely and remotely located growers. Physical spilling was assumed to take 13 minutes (personal communication⁵). The three segments (spillers) were scheduled independently using ASICAM.

For simplicity purposes, a uniform vehicle fleet was assumed with respect to both vehicles and trailers. This comprised a gross combination mass of 56 t, with a 25 t tare mass (median tare mass of trucks in Sezela) with 31 t payloads. The vehicles have 350 kW motors and were assumed fitted with sophisticated braking systems, allowing higher downhill speeds. Typical inbound and outbound speeds, as well as time spent changing driver shifts, on weighbridge activities, millyard travel and cleaning cane trailers were obtained from local hauliers and mill operators. These are summarised in Table 1.

The above-mentioned ASICAM configuration was executed and an economic analysis was performed to estimate and compare the cost of the improved system with the current system (*cf.* next section for further details).

Additional sets of simulations were executed during which the potential benefits of increased vehicle payloads were investigated. Higher vehicle payloads in the South African forestry industry significantly reduced the number of vehicles required (personal communication⁶). Forestry, however, has longer lead distances than sugarcane, which significantly influences

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transport efficiencies. Table 2 summarises changes to the afore-mentioned vehicle configuration that were assumed under increased payloads. A 35 t payload was based on a rigid and drawbar type configuration and this was assumed to reduce tare mass by 4 t, but increased the offloading times from 13 to 15 minutes. Secondly, a 38 t payload was based on a Brazilian system after removing all spiller chains. Offloading time, however, was assumed to increase to 16 minutes. Thirdly, a vehicle design based on the Australian Performance Based Standards (PBS, data courtesy of Andrew Crickmay of Crickmay and Associates) was assumed. This vehicle was allowed a 44 t payload and gross mass of 61.5 t, but was assumed legal, based on successful safety and performance evaluations as per PBS Australia. Offloading time was increased to 18 minutes to compensate for the mill's maximum potential crush rate of 450 t/h.

Table 1. Typical vehicle speed, millyard travel time and time taken to change shifts, weigh cane and clean trailers.

Item	Value	
	Inbound	Outbound
Typical vehicle speed:		
Coastal	52 km/h	60 km/h
Hinterland	25 km/h	40 km/h
Midlands (Highflats)	51 km/h	51 km/h
Weighbridge time (in and out), millyard travel and trailer cleaning	12.5 min	
Spilling	13 min	
Shift change	30 min	

Table 2. System properties that were changed to simulate and investigate higher vehicle payloads.

Property	31 t (Benchmark)	35 t (Rigid & Drawbar)	38 t (Brazil)	44 t (PBS)
Offload time (min)	13	15	16	18
Inbound time increase (%)	N/A	N/A	N/A	9.7
Load time (min)	50	56	1.01	1.11

Economic analyses

Economic analyses were performed after ASICAM simulations were completed. These were primarily based on the HTM Operation Cost Estimate tool (Martin Dammann, HTM) and subsequently by a large haulier, to confirm the findings. The analyses included fixed costs of instalments, driver wages, insurance, licence fees and overheads. Variable costs included fuel and lubricants, tyres and maintenance. The improved scheduled fleet cost was based on the maximum required vehicles, while the payload study was performed independently on data from Tuesday 22 July, and shows the relative improvements by increasing payload at Sezela.

Results and Discussion

The maximum fleet requirement found by scheduling week 22 in the 2003 milling season was found to be 41 vehicles. Based on this, the total cost of the scheduled transport system with

standard Interlink cane trailer configurations is estimated at approximately R43 million. This is a 26% reduction on the current transport system cost, which is estimated at R58 million, and it is believed that significant savings to the Sezela transport system can be made by using a centralised vehicle scheduler. This excludes the possible cost savings associated with no cane stops and higher milling efficiencies due to rateable cane supply.

Table 3 summarises the number of trucks, mean working hours, mean queuing times and mean vehicle performance for Tuesday 22 July 2003 achieved for different vehicle configurations under optimal scheduling conditions for three spillers at Sezela. Figure 1 depicts the total number of trucks (dotted bars) and the total cost of the transport system for the different vehicle configurations (striped bars). Higher payloads resulted in relatively small changes in fleet performance (Table 3), but allowed for annual cost savings from R39.6 million for the standard interlink scenario to 35.9 million, 35.0 million and 34.9 million for rigid and drawbar trailers, rigid and drawbar trailers without chains and a PBS vehicle design, respectively. Savings associated with higher payloads are, however, substantially lower than those associated with efficient scheduling. The authors believe that higher sugarcane payloads may not result in similar savings relative to those achieved in forestry. This is mainly due to shorter lead distances resulting in bottleneck conditions at the mill and at loading zones. Improvements to the sugarcane transport system may, therefore, be more complex and integrated, compared with forestry, with several system properties, such as loading times, queuing times, driver shift changes and contractual agreements being significantly more sensitive transport system parameters. A multi-tier research and management solution may be more appropriate and successful, as opposed to efforts where single properties (such as payload) are identified and optimised.

Table 3. The number of vehicles, mean working hours, mean effective working hours and mean queuing times of scheduled vehicles at three spillers at the Sezela mill. Vehicle types range from the current standard Interlink to a Performance Based System.

Vehicle	Number of trucks required	Average working hours per truck (h/d)	Average effective hours per truck (h/d)	Total daily queuing time (h/d)
31 ton Standard Interlink	35	21.38	19.14	1.68
35 ton Rigid and Drawbar	32	21.52	19.04	1.97
38 ton Brazilian no chains	32	20.14	16.85	2.79
44 ton Performance Based System	31	20.22	17.77	1.94

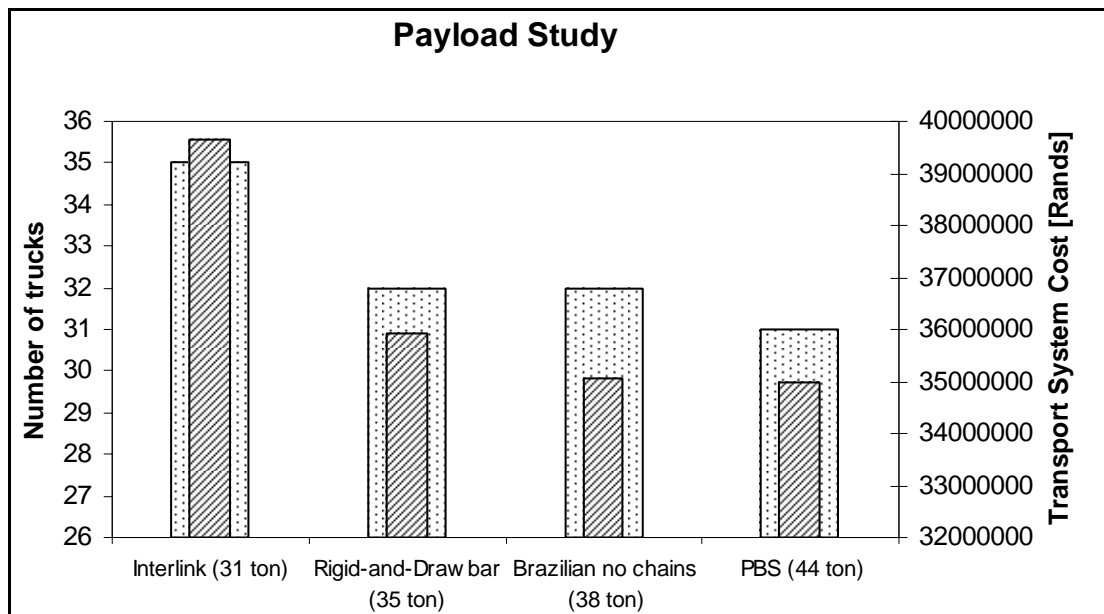


Figure 1. Vehicle fleet requirements and total transport costs of three independent spiller segments at the Sezela mill under four vehicle payload scenarios. These are (1) standard interlink, (2) rigid and drawbar, (3) spiller chains removed and (4) a Performance Based System (PBS) design.

Conclusions

A simple computer based vehicle scheduling program could manage to reduce the number of required trucks at Sezela by approximately 60%. This reduction in capital plus improvements in vehicle efficiencies resulted in a total cost saving of approximately R15 million. The ASICAM vehicle scheduling software is, however, limited and various crude and impractical assumptions of the Sezela transport system had to be made. The results of this study nevertheless suggest that significant potential improvements to the Sezela transport system could be achieved if vehicles are scheduled from a centralised control point.

Higher vehicle payloads resulted in smaller benefits, compared with the vehicle scheduling exercise and compared with similar payload work done in the forestry industry. This is attributed mainly to short lead distances resulting in bottleneck conditions at mills and loading zones. The authors believe that several system properties may need to be changed simultaneously in order to achieve a more efficient transport system at Sezela. These may include loading times, queuing times, driver shift changes and contractual agreements.

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