SHORT NON-REFEREED PAPER

THE DEVELOPMENT OF A STRATEGIC SUGARCANE VEHICLE DISPATCH OPTIMISATION TOOL

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Abstract

In Mauritius, mill centralisation is at the heart of a sugar reform drive. Transport is a major component of the total cost of sugarcane operations. The aim of this research was to develop a transport costing model within a mathematical combinatorial solver that would create an optimal transport dispatch profile for different vehicle types within a sugar milling area. This research was motivated by a merger between two sugar milling areas. A cost equation was developed that considered cycle times, payloads and vehicle cost for different vehicles while operating in different areas. This equation was solved using the MS Excel GRG nonlinear Solver while attempting to minimise costs and concurrently ensuring that all the cane was dispatched to the mill. The dispatching plan included a mix of four different types of vehicles and both mechanical and manual harvesting were taken into consideration. The impact of different queuing times at the mill was further investigated and confirms a non-linear solution space.

Keywords: transport, optimisation, logistics, dispatch model, vehicle utilisation

Introduction

Mill centralisation is at the heart of a sugar reform drive in Mauritius. This requires important investments from milling companies to step up production capacities, while minimising the operational costs. Transport is a major cost component of total sugarcane operations (e.g. Chetthamrongchai *et al*., 2001; Salassi and Barker, 2008). This study focused on optimising the transport costs during a mill centralisation exercise at the Alteo FUEL and Deep River Beau Champ (DRBC) sugar mills in the eastern parts of Mauritius. FUEL is a sugar mill with a capacity of more than one million tons of cane and a 40-megawatt power plant. DRBC mill crushed approximately 780 tons per annum and was scheduled for decommissioning by the end of 2013. DRBC is 16 km from FUEL.

Vehicle routing is a common approach when solving transport logistics problems (e.g. Giles *et al*., 2005; Jaruthien 2010). However, often in sugarcane operations, different vehicle types service different sites. For example, tractor-trailer combinations typically serve fields close by, while larger vehicles haul cane from further afield (Turvey and Thomson, 2004). When the sugar milling areas merged, DRBC fields that were previously close by were now further away from the mill. The overall distance between fields and the mill increased and this created new demands on the transport fleet.

The aim of this research was to develop a transport costing model within a mathematical combinatorial solver that would create an optimal transport dispatch profile for different vehicle types within a sugar milling area.

Methodology

The following costing model for mill scale transport for one season was used:

$$TC = \sum_{s=1}^{3} C_s$$

where

$$C_s = \sum_{r=1}^{R}\sum_{i=1}^{I} N_i \times p_{r,i} \times \gamma_i \times \frac{\tau_{i,s}}{\left(\frac{60 \times \delta_r}{\theta_{r,i}^{\mathrm{IN}}} + \frac{60 \times \delta_r}{\theta_{r,i}^{\mathrm{OUT}}} + L_{r,i} + O_{r,i}\right)} \times c_{i,r}$$

where

TC	is the total cost (in Rupees, MUR) to transport as accumulated over three parts of the season (s), *viz.* early (C_1), mid (C_2) and late season (C_3),
N_i	is the number of vehicles in the fleet of type i,
$p_{r,i}$	is the proportion of the fleet of a specific vehicle type (i, e.g. tractor-trailer, 20 ton taxi lorry) that are dispatched to a specific region in the milling area (r),
δ_r	is the average distance (km) from region r to the mill,
$\theta_{r,i}^{\mathrm{IN}}$ and $\theta_{r,i}^{\mathrm{OUT}}$	are the average inbound and outbound speeds (km/h) for vehicle type i to and from region r, respectively,
$L_{r,i}$ and $O_{r,i}$	are the average respective loading and off-loading times in minutes,
γ_i	is the payload capacity (tons) of vehicle type i,
$\tau_{i,s}$	is the total hours that vehicle type i will be available during sub-season s,
$c_{i,r}$	is the cost per trip for vehicle type i from region r (this was calculated on a MUR/km or a MUR/h basis after the equation was appropriately adjusted).

A local nonlinear searching algorithm (GRG nonlinear in MS Excel Sover, Fylstra *et al.*, 1998) was used iteratively to find a minimum value for C_s by changing $p_{r,i} \in \Re$, while adhering to the following constraints:

$$0 \le \sum_{i=1}^{I} p_{r,i} \le 1$$

$$0 \le \sum_{r=1}^{R} p_{r,i} \le 1$$

$$\sum_{i=1}^{I} N_i \times p_{r,i} \times \gamma_i \times \frac{\tau_{i,s}}{\left(\frac{60 \times \delta_r}{\theta_{r,i}^{\mathrm{IN}}} + \frac{60 \times \delta_r}{\theta_{r,i}^{\mathrm{OUT}}} + L_{r,i} + O_{r,i}\right)} \ge \rho . T_{r,s}$$

where $T_{r,s}$ is the total tons in region r that need to be transported during sub-season s and ρ is an acceptable portion of cane that should be transported from a region to avoid consignments that are not fully loaded (e.g. $\rho = 0.998$).

Four types of vehicles were available at the mills, namely 6, 15, 18 and 33 ton carriers (Figure 1). Estimates of transport costs were obtained from the local garage managers (Jugurnauth, 2013). Both mechanical and manual harvesting were taken into consideration and, in cases where vehicles were not adapted for either whole stick or billeted cane, the cost variable ($C_{i,r}$) was inflated to make these options not viable.

The model was used for various applications:

- The numbers of vehicles of a certain type in the fleet (N_i) were made representative of the current fleet, but were also adjusted to ascertain a future combination of vehicle types that may be optimal.
- The impact of different queuing times at the mill was investigated since the milling company was not sure what could be expected once the mills were merged. Some of these results are reported below.
- An adapted version of the model was applied at another mill on the island to assist with their annual transport budget planning.

Figure 1. Four vehicle types used for dispatch optimisation at the FUEL consolidated sugar mill, *viz.* (a) 15 ton, (b) 18 ton, (c) 6 ton and (d) 33 ton.

Results and Discussion

Figure 2 illustrates the optimal combination of vehicles out of the four categories under different average queue times assumed at the new consolidated FUEL mill. Vehicle numbers do not simply increase when utilisation decreases. Certain vehicles, such as 33 ton rigs with high fixed costs, are traded off against vehicles with cheaper operating costs (e.g. 15 ton). This demonstrates the non-linear nature of vehicle dispatch problems when the entire mill area is managed as a single entity. Vehicle utilisation is reduced by approximately 40% when queuing time is increased from zero to 60 minutes; however, because the model has the opportunity to trade-off vehicles in the fleet, the overall cost in transport increased by only 3%.

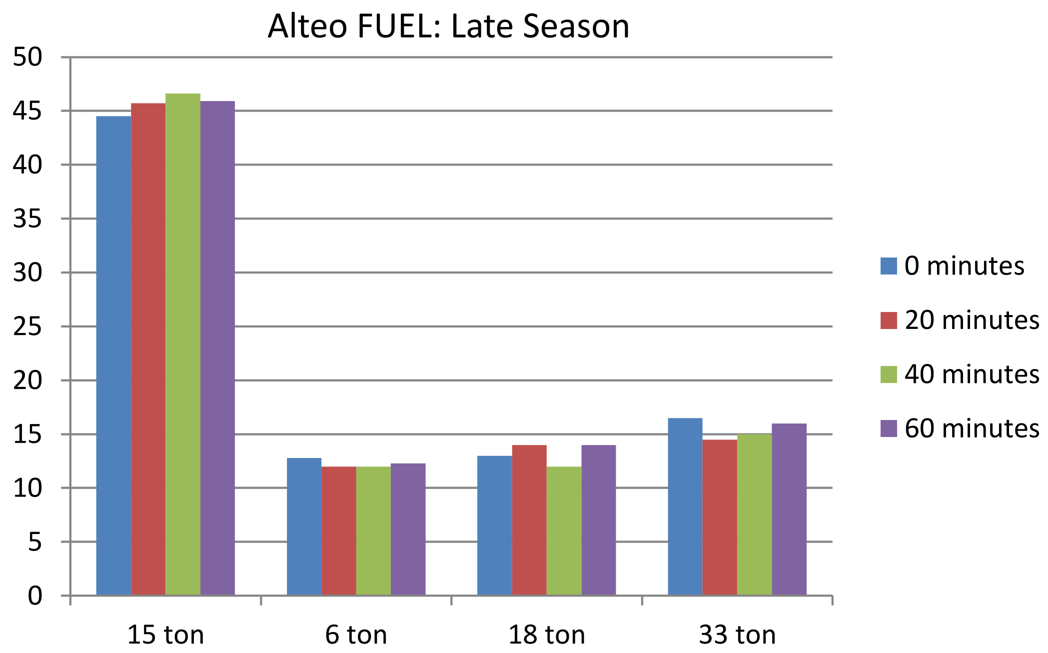

Figure 2. Optimal fleet numbers at Alteo FUEL for the late season under different average queue times at the mill.

Similar outcomes were achieved when the model was used to calculate the optimal dispatching of the current combined vehicle fleet at FUEL and DRBC. Likewise, the model was also useful at another mill when a tactical vehicle dispatching plan was drawn up with the season's annual transport budget.

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