SHORT NON-REFEREED PAPER

QUANTIFYING AND MODELLING DISRUPTIONS IN THE ESTON SUGARCANE SUPPLY CHAIN

KADWA M[1], BEZUIDENHOUT CN[1] AND ORTMANN GF[2]

[1]School of Engineering, University of KwaZulu-Natal, P/Bag X01, Scottsville, 3209, South Africa
[2]School of Agricultural, Earth and Environmental Sciences, University of KwaZulu-Natal, P/Bag X01, Scottsville, 3209, South Africa
mmkadwa@hotmail.com bezuidenhoutc@ukzn.ac.za ortmann@ukzn.ac.za

Abstract

The Eston Mill, which was established in 1994, is the youngest in the KwaZulu-Natal sugar belt. As with other sugar mills, daily crush fluctuations occur because of various types of disruptions. This research involved two core objectives. First, to develop, validate and verify a model to predict and quantify the factors that influence daily crush rate fluctuations at Eston. Secondly, to estimate the trends and impacts of cutter absenteeism over a number of years. Local weather station and milling data for nine seasons were collated. Four seasons were utilised for the model development and validation, while the other five seasons were used for verification purposes. Fibre was assumed to be the limiting factor for maximum daily mill crushing capacity and was used to predict the achievable daily crush rate, before the consideration of mill disruptions. The model involved the calibration of parameters for mill maintenance and operational stops and rainfall events. The model captures approximately 64% of the variation observed in daily crush rates. Subsequent to model development, additional cane supply disruptions caused by cutter absenteeism were further investigated. Cutter absenteeism was previously estimated to cost the Eston milling area approximately R1.3 million per annum (Kadwa *et al*., 2012). A gradual increase in absenteeism is observed over the period 2007 to 2010, with a decline since.

Keywords: supply chain fluctuations, mill breakdowns, crushing inconsistencies, weekday inconsistencies, cutter absenteeism.

Introduction

Previous research conducted in the Eston sugarcane supply chain (Kadwa *et al*., 2012; Bezuidenhout *et al*., 2013; Kadwa and Bezuidenhout, 2013) found that there are inconsistencies in daily crush rates. This is due to various factors, including pay-weekend related cutter absenteeism. The costs of cutter absenteeism were conservatively estimated to be in the region of R1.3 million, on average, for five seasons analysed (Kadwa and Bezuidenhout, 2013).

Other factors, such as rainfall and mill breakdowns, also impact on crush rates. It was, therefore, proposed to expand the research and consider the impacts of these disruption factors. This was conducted based on a model that was used to optimally predict and quantify the factors that influence daily crush rate fluctuations to the Eston sugarcane supply chain. In addition, an application of the model allowed for estimation of a labour absenteeism index for each season. To the authors' knowledge, the model will be the first of its kind to predict sugarcane supply consistency at a mill scale.

This short paper focuses on the understanding of the predictive model, as well as the estimation and evaluation of the labour index for each of the five seasons (2006-2010) analysed.

Materials and Methods

Model development
Fibre loading at the mill was used as the primary daily capacity limiter, as the diffuser tends to flood when cane with high levels of fibre is processed. Fibre % cane was found to range between 13 and 19%, with maximum daily crush rates (MDCR) restricted to 7000 and 5000 tons, respectively. A crush gap was then determined by subtracting the actual daily crush rate (ADCR) from the MDCR, before considering other disruption factors.

Mill breakdowns and maintenance stops were considered as secondary disruption factors in the model. It was assumed that stops and breakdowns have a pro rata impact on daily crush rates, i.e. for each breakdown hour, a 4-5% reduction in daily achievable crush rate (DACR) would occur. This was tested by regression analysis against the actual crush rate and was found to fit the profile well.

The next crush rate disruption factor was rainfall. Average rainfall (across six different homogenous climatic zones in Eston) for each day was calculated and related to additional crush rate reductions. It should be noted that rainfall usually causes increased levels of fibre in cane. It is, therefore, likely that some of the impacts of rainfall may already have been considered by the primary daily capacity limiter.

Model calibration and verification
Four milling seasons (2004, 2005, 2011, 2012) were utilised to calibrate, refine and validate the model, while five other seasons (2006-2010) were reserved for verification purposes. The Microsoft Excel Solver add-in optimisation technique was used for calibration. This was conducted by changing the coefficients to allow the model data to optimally fit the actual data on a 1:1 line. The R statistic was used to estimate the fit of the model.

Model residual and estimation of cutter absenteeism
After the model was developed, calibrated and verified, a residual remained between the estimated modelled daily crush rates and the actual. Residual values were analysed to optimally estimate the impacts of cutter absenteeism over five seasons. Only residuals associated with pay-weekends were inspected. Pay-days were assumed to occur on the first Saturday of each month (Kadwa *et al*. 2012). During the week after pay, crush rates were analysed to detect systematic residual deviations assumingly caused by cutter absenteeism. Therefore, only eight or nine weeks were analysed for each season.

Results and Discussion

Figure 1 illustrates the comparison between the actual and the modelled daily crush rates for the 2007 season. The model accuracy is moderate, with an overall R^2 of 64%. Fibre % cane and mill breakdowns collectively capture 59% of the variation in daily crush rates. Rainfall explains 6% of the daily crush rate variation. It is estimated that for every 5 mm of rain, a crush rate is reduced by approximately 1000 tons, spread over four days, with 49% of the impacts experienced on the first day after a rainfall event. About 36% of the overall variation in daily crush rates is unexplained. This could be due to various factors, including cutter absenteeism.

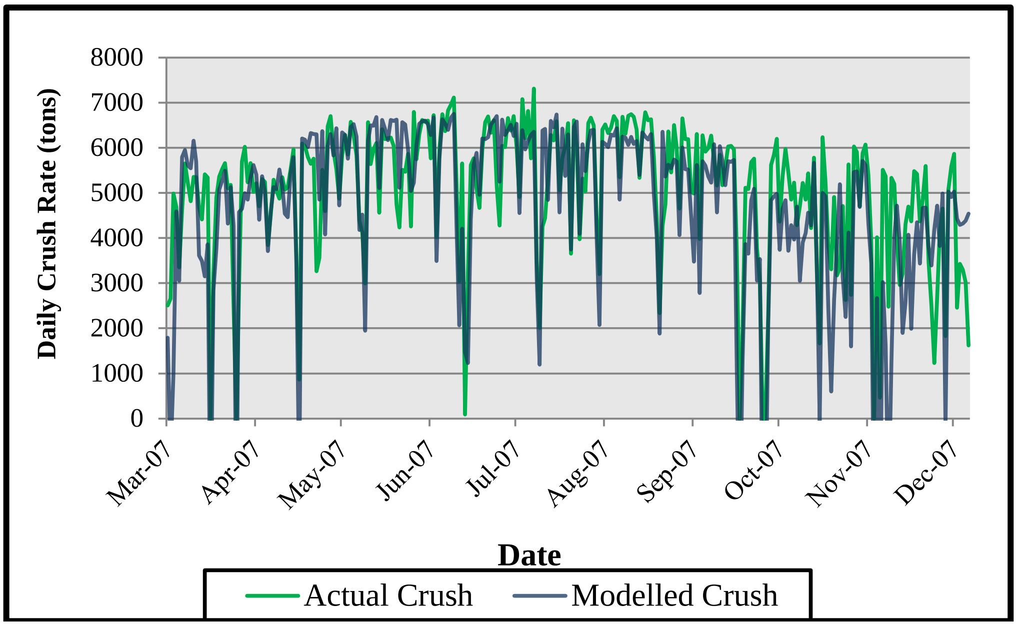

Figure 1. Comparison between actual and modelled daily crush rates, 2007 milling season, Eston Mill.

Figure 2 illustrates the statistically optimal estimated impacts of cutter absenteeism for the first Sunday, Monday and Tuesday of each season. The cutter absenteeism rate for each season is estimated to be different. It appears that there was an increasing trend from 2007 onwards, especially on Sundays. In 2010, however, Mondays and Tuesdays had a reduction in cutter absenteeism. This confirms the problem of cutter absenteeism at Eston, as previously highlighted (Kadwa *et al*., 2012; Kadwa and Bezuidenhout, 2013). Since 2010, there has been a decreasing trend in cutter absenteeism.

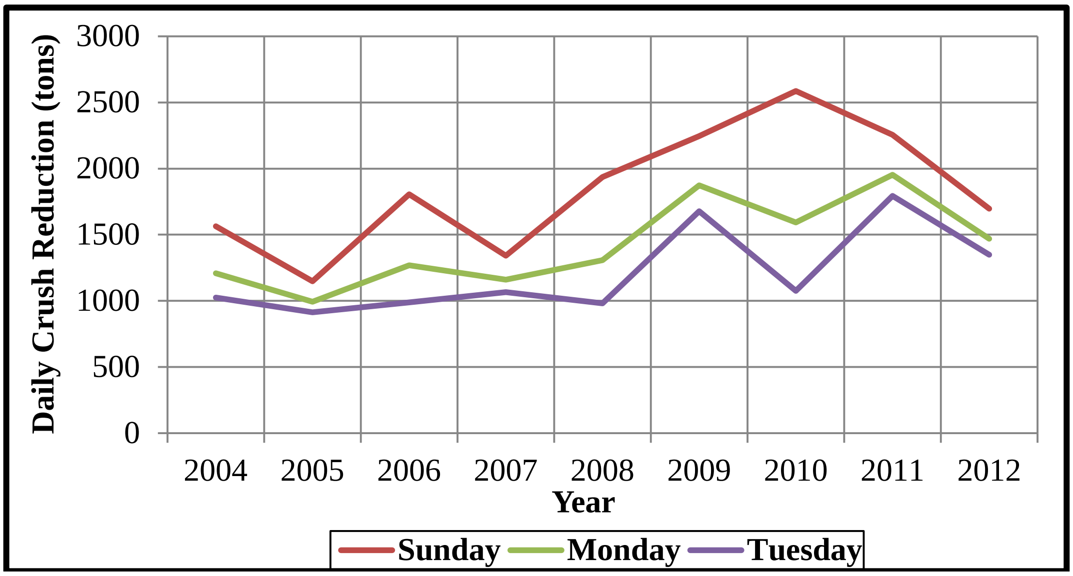

Figure 2. The estimated impact of cutter absenteeism on the first Sunday, Monday and Tuesday of each month, 2004-2012 milling seasons, Eston Mill.

The model developed can be utilized to critically evaluate different sugarcane milling areas. The model allows for the daily crush rates, mill breakdowns and rainfall events to be stochastically simulated for future seasons, with the same calibrated coefficients being used to analyse the data. In addition, the specific innovative labour absenteeism indexes for each season can be investigated in other industries and comparisons can be drawn.

REFERENCES

Bezuidenhout CN, Kadwa M and Sibomana MS (2013). Using theme and domain networking approaches to understand complex agri-industrial systems: A demonstration from the South African sugar industry. *Outlook Agr* 42(1): 9-16.

Kadwa M and Bezuidenhout CN (2013). A study of cane supply benefits associated with *ad hoc* mechanical harvesting to mitigate cutter absenteeism. *ZuckerIndustrie* 138(8): 532-538.

Kadwa M, Bezuidenhout CN and Ferrer SRD (2012). Cane supply benefits associated with the mitigation of labour absenteeism in the Eston sugarcane supply chain. *Proc S Afr Sug Technol Ass* 85: 47-49.