SHORT, NON-REFEREED PAPER

A NETWORK ANALYSIS APPROACH TO IDENTIFY PROBLEMS IN INTEGRATED SUGARCANE PRODUCTION AND PROCESSING SYSTEMS

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Abstract

Generic networks can ease and speed up the process of diagnosing problems in complex systems. South Africa's sugarcane production and processing system consists of 14 mill areas. The multitude of issues that affect the system, coupled with the complex interrelationships between the issues, make it time and energy demanding to diagnose the problems in each of the mill areas. A generic network comprising the issues that negatively affect the performance of a sugarcane production and processing system and their causal relationships was developed. The network was then used as a blueprint to explore the issues that negatively affect the performance of four mill areas in South Africa, *viz*. Eston, Felixton, Komati and Umfolozi. This resulted in the production of networks for the four mill areas. Analyses of the four mill area networks revealed a set of common, shared and unique issues across the mill areas. Eight percent of the issues that affect South Africa's sugarcane production and processing system were common to the four mill areas. A majority of the common issues were related to transportation and the supply of sugarcane to the mills. Indications are that the results can potentially be used to develop a decision support tool for improving the performance of mill areas in South Africa.

Keywords: generic network, network analyses, cause-and-effect, diagnostics, sugarcane

Introduction

Generic networks can ease and speed up the process of diagnosing problems in complex systems (Bezuidenhout *et al*., 2011). Generic networks enable researchers to approach stakeholders for information with a preconfigured knowledge, and this makes it possible to streamline data collection and analyses.

The integrated sugarcane production and processing system (ISPPS) exhibits multiple issues (or problems) that interrelate in a complex way to determine the overall performance of the system. Cause-and-effect relationships are the fundamental attribute to the apparent complexity of the interrelationships between the issues. This attribute makes an ISPPS amenable to modelling using networks, where the issues can be represented by vertices (dots) and the causal relationships by arcs (arrows). When the network of an ISPPS has been developed, the problems in the system can be diagnosed using a range of network analysis approaches. However, the multitude of issues that affect ISPPS, and their complex

interrelationships, would make it time and energy demanding to develop a network for each of the 14 mill areas in South Africa. This problem can be alleviated to some extent by using a generic network that incorporates all the possible causal relationships that typically may exist in all mill areas. The generic network is then transformed into specific mill area networks by focusing on causal pathways relevant to a specific mill area.

This short paper demonstrates how a generic network for an ISPPS was developed and how it was transformed into four mill area specific networks. The paper also shows how network analyses approaches were used to diagnose the problems in the four mill areas.

Methodology

The issues that negatively affect the performance of an ISPPS (e.g. drought, pests, diseases and aged equipment) and their causal relationships were populated using information obtained from literature reviews and consultations with experts in the South African (SA) sugar industry. The issues that were covered in this study are limited to those that affect the following sectors of the SA sugar industry: (1) the production of sugarcane, (2) the harvesting of sugarcane, (3) transportation of sugarcane to mills, and (4) the processing of sugarcane into raw sugar. The production of raw sugar was chosen as the terminal point because (i) raw sugar is a stable product that is produced by all sugar mills in SA and (ii) the study focused on assessing the biophysical drivers of the system, rather than the market drivers. The issues and their causal relationships were used to develop a generic network for the SA ISPPS. The issues were represented by vertices and the causal relationships between the issues were represented by arcs. All arcs in the network were assigned a default weight of one. The Pajek network analysis software was used to produce the generic network. This package has a good capability to handle very large networks (Huisman and Van Duijn, 2005; De Nooy *et al*., 2005; Mueller *et al.*, 2007), it can perform complex network analyses (Xu *et al*., 2010), it can facilitate the reduction of a large network into several smaller networks that can further be analysed using sophisticated methods, it has powerful network visualisation tools, and it allows for the implementation of a selection of efficient network algorithms (Huisman and Van Duijn, 2005). Additionally, Pajek was chosen because of its good track record and widespread use. Mueller *et al.* (2007) compared Pajek to other network analysis software and found it to be appropriate for supply chain related research studies. There are diverse examples in the literature where Pajek was used successfully (e.g. Li and Ma, 2008; Ma *et al*., 2009; Nor *et al*., 2009; Piao *et al*., 2009, 2010; Gonzalez-Alcaide *et al*., 2010; Graeml *et al*., 2010). The generic network has 340 vertices and 643 arcs.

The generic network was used as a blueprint during the interviews that were conducted in 2010 and 2011 with representative samples of stakeholders at the Eston, Felixton, Komati and Umfolozi mill areas. The four mill areas were chosen because of their relatively diverse configurations. For example, Eston mill has a relatively narrow diffuser that is prone to flooding. Felixton mill has two independent diffuser lines that are relatively long, and hence has high incidences of inversion. Umfolozi mill is fairly old and breakdowns occur frequently. Komati mill, on the other hand, is a new and sophisticated mill. The stakeholders that were interviewed included (among others) sugarcane growers, hauliers, millers and other service providers, such as extension and grower support services personnel. The stakeholders were prompted to weigh up the strength of the causal pathways in the context of their specific mill areas. The strength and frequency of occurrence of the pathway that connects problematic issues were used as criteria to assign weights to the arcs. A scale of zero to 10 was used to weigh up the arcs, with a value of one as the default and a value of 10 representing the most severe and high occurrence of an issue. The responses of different

stakeholders were incorporated into the final network for the mill area. Each mill area network was therefore a replica of the generic network, with the exception of arc weights.

Network analyses approaches were used to identify the issues that were (a) common to all four mill areas, (b) shared by some mill areas and (c) unique to a particular mill area.

Results and Discussion

The number of issues that were reported by stakeholders to negatively affect the performance of the Eston, Felixton, Komati and Umfolozi mill areas were 109, 82, 68 and 119, respectively. Twenty seven issues (eight percent) were common to all four milling areas. Figure 1 provides a theme network depicting the issues that were common to all four mill areas. The issues that are directly related are connected by an edge (line). The common issues can be grouped into five thematic areas, *viz*. (1) agronomics, (2) harvesting, (3) transport and cane supply, (4) cane quality and (5) milling.

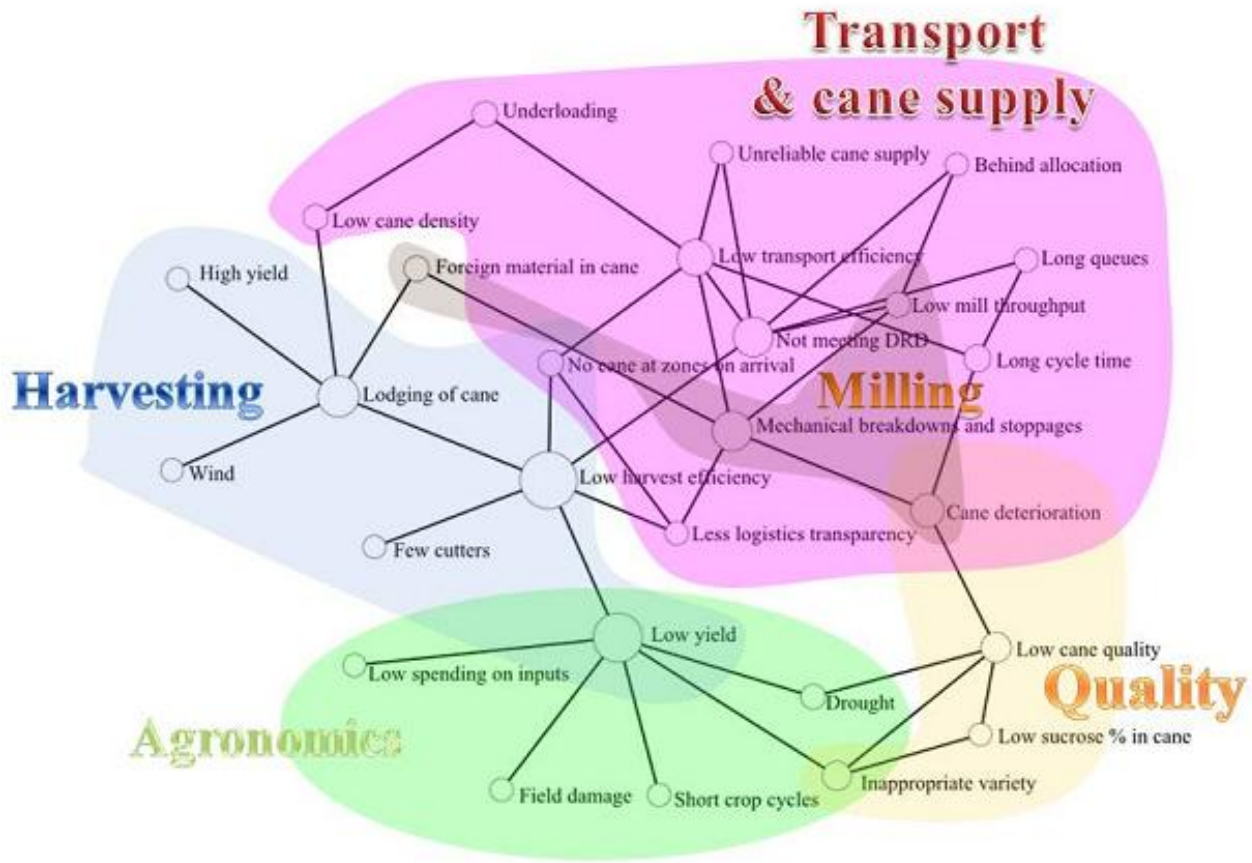

Figure 1. Theme network of common issues across four mill areas in the South African sugar industry.

It is evident from Figure 1 that most of the issues that are common to the four mill areas fall under a transport and cane supply theme, whereas cane quality and milling issues are the least common among the four mill areas. The respective central issues under the five thematic areas are low yield, low harvesting efficiency, not meeting daily rateable delivery (DRD), low cane quality, and mechanical breakdowns and stoppages at the mills. Some issues were unique to a specific mill area. Eston, Felixton, Komati and Umfolozi mill areas had 42, 15, 4 and 45 unique issues, respectively. The remainder of the issues at each mill area are shared by

at least one other mill area. These results can be used to develop a decision support tool for improving the performance of mill areas. Interventions targeting common issues would result in solving the problems that affect the entire SA sugar industry, while those targeting unique issues would be aimed at improving the performance of individual mill areas.

Conclusions

Network analysis approaches appear to be valuable for diagnosing problems in mill areas. Analysis of cause-and-effect pathways appears to be valuable for identifying key issues within and across mill areas. South Africa's sugarcane mill areas differ substantially; however, there are some issues that are common to all the mill areas.

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