SHORT COMMUNICATION

# CAPCONN, AN INTEGRATED SUPPLY CHAIN MODEL FRAMEWORK: DEVELOPMENT AND DEMONSTRATION

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## Abstract

Sugarcane supply chain stakeholders can benefit substantially where operations are successfully orchestrated. Computer models have been used to improve supply chains, especially in forestry, and are expected to play an increasingly important role in future planning and management. Management of sugar supply chains has previously focused on generating competitive individual supply chain components. Inter-component optimisation generally disregards many important intra-component interactions, hence efficiency improvements may be significantly limited. Integrated supply chain modelling provides a suitable approach for supply chain management and planning. The aim of this paper is to demonstrate an integrated sugar supply chain model framework stretching from field to mill back-end. The research involved two primary objectives. Firstly, to develop an integrated sugar supply chain analytical framework, named CAPCONN, and secondly, to demonstrate CAPCONN during a mechanisation case study.

*Keywords:* supply chain, CAPCONN, integrated model, mechanisation

## Introduction

Supply chains describe the physical flow of resources between enterprises. Harvesting and transport comprise a significant portion of total production cost, and sugar milling is a capital-intensive operation. Management of the sugar supply chain has previously focused on generating competitive individual supply chain components (Gaucher *et al*, 2004). Therefore, industry stakeholders need to find new ways to meet the challenges of rapid change in sugar industry operations. Inter-component optimisation of processes does not consider all intra-component interactions, and efficiency improvements may hence remain limited (Gigler *et al*, 2002).

Integrated modelling is a well recognised management and planning support approach for supply chain improvements (Gaucher *et al*, 2004; Rönnqvist, 2003). In agriculture, integrated supply chain models have been used most widely for the harvest and transport sectors, especially in timber (e.g. Rönnqvist, 2003). This short communication aims to report on (i) the development of an integrated sugar supply chain model framework, *viz* CAPCONN, and (ii) demonstrating CAPCONN within a mechanisation context.

## Methods

CAPCONN stands for Capacity Constricted Conveyance and represents a mathematical model and visualisation methodology used to analyse the physical flow of a commodity within a supply chain. In this study, CAPCONN was configured to represent one week's supply of sugarcane from field to mill back-end. This can be replicated to represent a full milling season. Different supply lines can be represented by different cohorts that converge at the mill. The model holistically quantifies the supply chain's capacity and capital utilisation, product transfer efficiency and fixed and variable cost components. The framework also includes the effects of harvest to crush delay (HTCD) using a cane deterioration model. Figure 1 illustrates the visualisation component of CAPCONN, which provides the user with an easy to use, though powerful diagnostic framework. Ideally, several supply lines (cohorts) need to be modelled to represent the diversity of a single mill area.

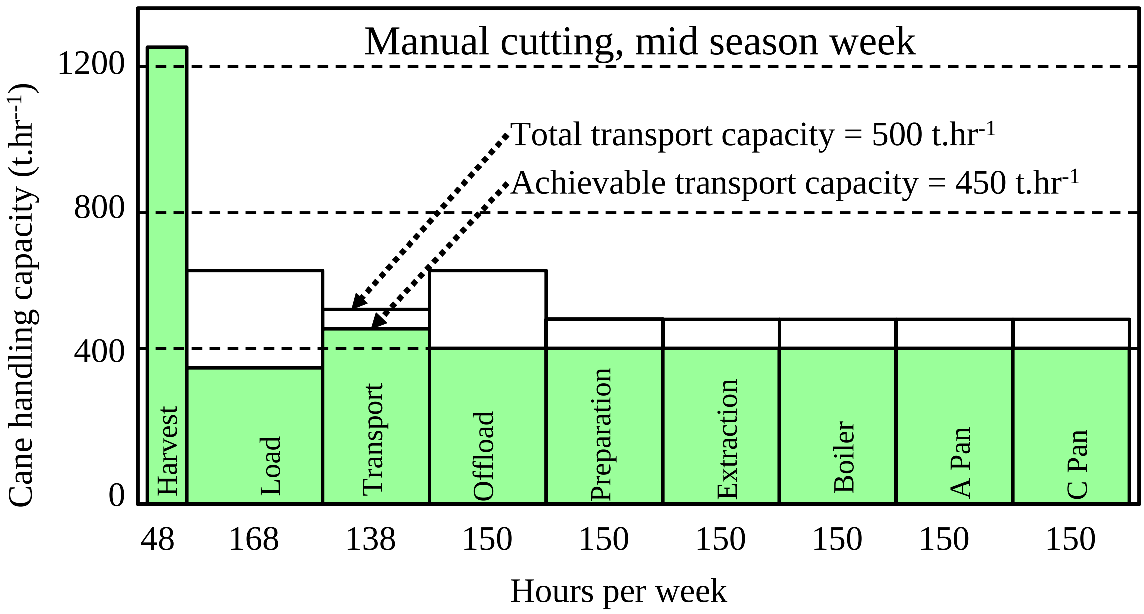


**Figure 1. The CAPCONN visualisation technique where each supply chain component is represented by a surface of capacity x duration (t/h x h/wk = t/wk). All highlighted areas have the same surface and depict the achievable weekly production.**

Relationships between different supply chain variables were obtained from the literature, consultation and, where necessary, theoretical assumptions. Specific inputs with regard to capacities, working time, rate of work and efficiency are required for each supply chain component (e.g. Harvest: number of cane cutters, daily cane cutter rate, cost per cutter per day). A mathematical procedure then constricts the weekly throughput in each supply chain component. Constriction is regulated by the single component (such as Preparation) that can not handle higher throughputs as a result of cane quality (e.g. high fibre contents). Other supply chain components such as Transport will thus have a limited throughput even when their capacities are under-utilised. The overall efficiency and cost implication as a result of constriction is calculated and summarised. Ideally, CAPCONN is simulated for each week in the milling season, which will effectively indicate different constrictors (bottlenecks) during different times of the year.

*Case study*

CAPCONN was applied in the Komati mill area, where an exercise was carried out to compare a burnt manual harvesting system with a green cane mechanical harvesting system.

Three weeks (early, mid and late) within the milling season were simulated. Cane quality for each week was adjusted according to historic records. A weekly crush of 60 000 tons was assumed. The manual system had 1429 harvesters, a relatively long HTCD (45 hours) and low amounts of sand (1.3%). The mechanical harvesting system had 12 chopper harvesters and a short HTCD (3 hours), with fast deterioration of billets and high sand contents (6.5%). The existing truck fleet was reduced by 25 trucks as it was significantly under-utilised in the mechanical harvesting scenario. A trash removal system was installed at the mill prior to preparation. Analyses include cost comparisons, efficiency comparisons and throughput comparisons.

## Results and Discussion

Table 1 summarises the results of the Komati case study. Figure 1 illustrates the manual harvesting scenario. The supply chain is generally under-utilised as a result of the limited area under cane. Transport, off-loading and preparation requirements are significantly lower in the mechanised system. Higher sand contents in billeted cane, however, increased demands on the extraction and boiler processes. The mill back-end was reasonably similar in both cases. Marginally more sugar could be produced from manually harvested cane. On average, the cost of producing sugar was 20% higher under mechanical harvesting. It should also be noted that the influences of (i) soil compaction over a prolonged period, (ii) trash during extraction and (iii) field inaccessibility by chopper harvesters under wet conditions were probably underestimated in this study. It may also be interesting to compare a green cane manual harvesting scenario against the above-mentioned mechanical harvesting system.

**Table 1. Summaries from CAPCONN of three weeks in the Komati milling season under a manual burnt cane and a mechanical green cane harvesting strategy, respectively.**

| Parameter | Manual burnt cane harvesting | | | Mechanical green cane harvesting | | |
|---|---|---|---|---|---|---|
| | Early season | Mid season | Late season | Early season | Mid season | Late season |
| | **Capacity utilisation (%)** | | | | | |
| Harvest | 100 | 100 | 100 | 100 | 100 | 100 |
| Load | 54 | 54 | 54 | N/A | N/A | N/A |
| Transport | 86 | 86 | 86 | 88 | 88 | 88 |
| Offloading | 61 | 61 | 61 | 51 | 51 | 51 |
| Preparation | 65 | 65 | 65 | 54 | 54 | 54 |
| Extraction | 74 | 63 | 74 | 81 | 71 | 73 |
| Boiler | 17 | 17 | 17 | 87 | 87 | 86 |
| A Pan | 61 | 89 | 68 | 60 | 87 | 67 |
| C Pan | 85 | 80 | 88 | 83 | 79 | 86 |
| | **Costs (R/week)** | | | | | |
| Total cost (fixed + variable + stock) | 4,629,005 | 4,630,226 | 4,631,491 | 5,522,993 | 5,524,540 | 5,525,497 |
| Average | 4,630,241 (100%) | | | 5,524,343 (119%) | | |
| | **Efficiency** | | | | | |
| Estimated diffuser E (%) | 98.62 | 98.76 | 98.62 | 98.21 | 98.34 | 98.21 |
| Estimated sugar recovery (%) | 87.96 | 87.97 | 87.96 | 87.97 | 87.97 | 87.96 |
| Estimated sugar recovery (t/h) | 37.83 | 55.22 | 42.07 | 37.32 | 54.25 | 41.60 |

## Conclusion

Although not yet developed to its full potential, the CAPCONN model provides a suitable diagnostic framework to analyse and investigate sugarcane supply chains. Bottlenecks are highlighted and the model facilitates capacity manipulation for efficiency improvements under different harvesting methods. The system requires more development, but could already be used to caution against an overall mechanisation strategy in a mill area. Conservative production costs are estimated to be 20% higher under a mechanical harvesting system than a manual system. A relatively large number of technical inputs are required to run the model.


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