MAGI: A SIMULATION TOOL TO ADDRESS CANE SUPPLY CHAIN MANAGEMENT

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Abstract

The management of cane supply from growers' fields to the mill involves many stakeholders and many tasks to be carried out along the chain, the successful combination of which impacts on the efficiency and profitability of the mill area. A simulation tool called MAGI has been developed to assist millers and growers in designing and assessing new ways of organising supply management. The issues addressed by MAGI include the restructuring of mill areas (industrial and agricultural capacities, chain structure), changing delivery allocation rules and season duration, and dividing the mill area according to variations in cane quality. MAGI simulates the mill supply over the season on a weekly basis. It takes into account agricultural and industrial capacities, cane production by homogeneous units at the mill area level, and some mill operating variables such as length of milling season and mill opening and closing dates. Each production unit is characterised by its cane area, cane yield, harvest-transport capacity and sucrose curve obtained from the mill database. Scenarios of supply are compared according to weekly and total sugar production over a season. The impacts of unforeseen events such as delivery failures or mill breakdowns on sugar production can also be assessed. Currently based on the Réunion situation, MAGI will be improved to take into account a wider range of sugar production environments, particularly in South Africa.

Keywords: sugarcane, mill supply, supply chain management, simulation tool, sugar production

Introduction

Sugar production at the mill area level involves three main components: (i) producing the cane, (ii) supplying it to the mill, including harvesting and transporting it from the fields to the mill, and (iii) processing the cane into sugar. Efficient management of the mill supply is a critical issue for the entire chain because it involves high costs, and the quantity and quality of the cane delivered impacts on total sugar produced.

Managing the mill supply involves many stakeholders, and there are many tasks to be performed along the chain, both in regulating cane deliveries during the harvest season and in optimising sugar production. The many variables that have to be taken into account at the grower, haulier and miller levels include harvest, transport and mill capacities, rules governing delivery allocations, and variability in cane quality over time and in different areas. These variables are linked, meaning that any change made to one part of the chain will impact on all other parts, as well as on total sugar produced. These links and impacts explain why supply management is often an area of conflict between stakeholders along the chain.

Assessing alternative organisational structures provides an attractive way of improving the efficiency of the existing chain. Modelling and simulation can prove useful in achieving this objective, considering the complexity of the system to be studied. Most of the research work that has been conducted in this field has focused on the logistics of mill supply, either to reduce burn-to-crash delays (Barnes *et al.*, 2000) or to optimise harvest schedules and equipment (Higgins et al., 1998; Arjona et al., 2001). These studies concentrate on interactions between components along the chain, without providing some form of decision support tool with which to address them (Muchow *et al*., 2000).

A collaborative project between two French research institutions (CIRAD[1] and INRA[2]) has explored an alternative way of modelling and simulating the mill supply process (Gaucher *et al.,* 1998)). This research was done initially at mills in La Réunion and Mauritius, and was recently extended to the South African sugar industry. The approach aims at providing a quantified assessment of new supply organisation modes to the various stakeholders involved in mill supply management. The decision support process is based on the comparison of scenarios simulated using a specifically developed tool called MAGI. This paper describes the objectives, conceptual background, operation and future developments of this software. The general approach and its utilisation with actual cases are presented in other papers at this Congress (Gaucher *et al.*, 2003; Guilleman *et al.*, 2003; Lejars *et al.*, 2003).

Objectives and Issues Addressed by MAGI

MAGI aims mainly at supporting discussion between grower and miller representatives to investigate changes in mill supply organisation. A simulation tool allowing the comparison of a wide range of scenarios was preferred to an optimisation approach, as the complexity of supply organisation makes it difficult to find optimal solutions. This position affects the decision support perspective. The optimisation approach provides the 'one best way' solution for stakeholders, whereas the simulation approach provides information that enhances and facilitates the negotiation process between stakeholders (Hatchuel and Molet, 1986; de Geus, 1992).

MAGI simulates the planning and operation of a mill supply chain on a weekly basis, and considers the whole season and the various components of supply management from fields to factory processing. The simulated scenarios are compared over a season to assess their impact on total sugar production at the mill area level. No cost-benefit analysis is carried out in the current version of MAGI, as the simulation characteristics and results can easily be captured in a spreadsheet program for calculation of these economic indicators.

MAGI allows a wide range of issues involving growers, contractors and millers along the chain, to be addressed:

- Making investment decisions that match industrial, transport and harvest capacities to maximise the total profit of the mill area. Stakeholders have to find a trade-off between capacity investments along the chain and the season length, according to the average sucrose curve during the season.
- Restructuring mill areas to take into account cane production trends, mill closure or relocation of delivery zones. Any of these structural changes will impact on the capacity to transfer a given amount of cane from one point to another.
- Changing the rules that govern cane flow management to benefit from cane quality variability within the supply area, while ensuring a regular supply of cane to the mill.

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For example, rules governing delivery allocations may switch from a rateable delivery allocation valid throughout the season, to a variable allocation for shorter harvest windows (see Guilleman *et al*., 2003 for an application in the South African industry).

The strategic issues that interest both millers and growers have to be pinpointed before using MAGI in a given mill area. The current organisation is then described and its characteristics are captured on the software, based on the available data set. The following stage consists of selecting alternative choices, simulating them and discussing their impact not only on sugar production, but on the various stages and components of the supply chain. The process can be repeated as many times as the stakeholders find necessary.

Conceptual Background of MAGI

MAGI is the computing transcription of the conceptual strategic model reported in Gaucher *et al*. (2003). It is based on two main components: modelling the mill area structure and simulating cane flows from production units to the mill.

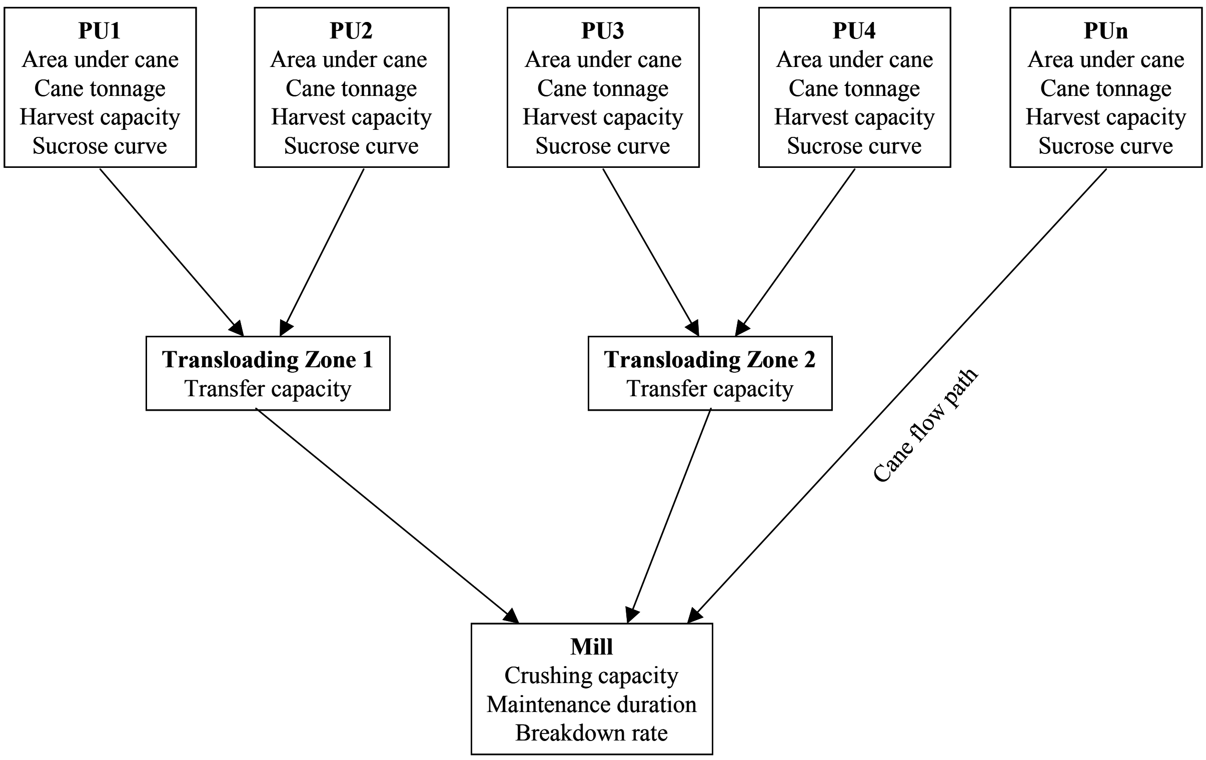

Figure 1. Schematic representation of mill supply area structure (adapted from Lejars *et al*., 2002).

Modelling the mill supply area

Forwarding cane from the fields to the mill is characterised by modelling the structure of the mill supply area. The physical industrial entities, i.e. the mill, transloading zones and hauliers, are described as they are, while the production area is split into several production units (PUs). A PU may be either a mill sub-estate, a large farm, an agro-climatic zone or a class of grower. Each PU is assumed to be homogeneous with regard to its cane quality and the delivery allocation rules applied by the mill. The split criteria are selected according to the issue being studied.

For example, agro-climatic zoning may be used to investigate the impact on production of supply based on cane quality, as variations in climate explain variations in quality. Each PU is then linked to the mill through a given transloading zone (Figure 1).

Each entity along the chain is characterised by a potential weekly capacity: harvesting and transport capacity for the PU, including transfer capacity from PU to transloading zones, transfer capacity from transloading zones to the mill, and processing capacity of the mill. These values are used as limits not to be exceeded when simulating a new scenario. PUs are also characterised by their total production (cane yield multiplied by cane land size under harvest in a given season) and their weekly sucrose curve.

On the mill side the weekly process capacity is calculated by multiplying maximum hourly crushing capacity with weekly work hours (taking into account maintenance time) and an average breakdown rate. Sugar losses throughout the process are characterised by a weekly efficiency rate.

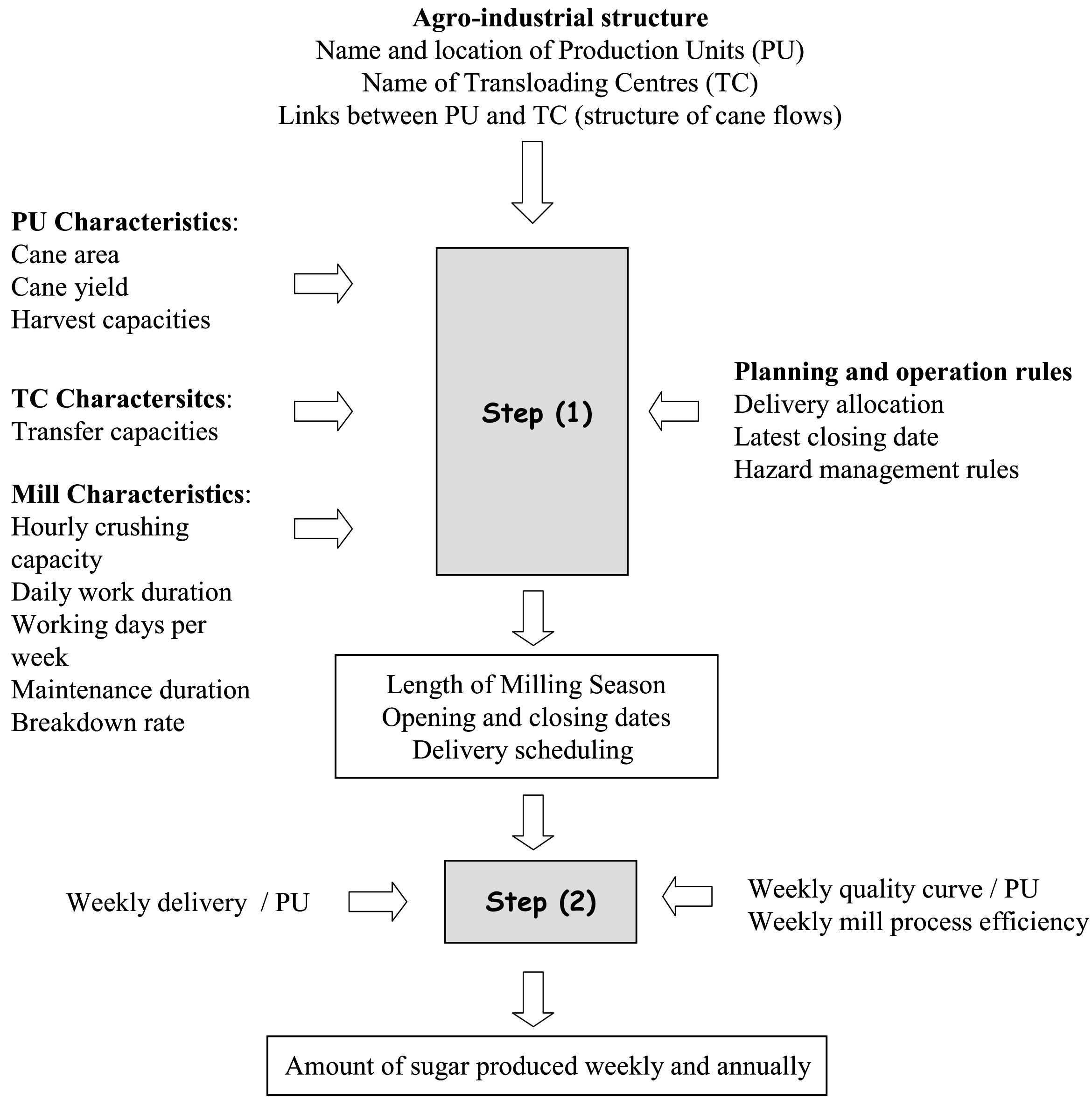

Figure 2. Conceptual framework of MAGI (adapted from Gaucher, 2002).

Simulating cane flows

MAGI mimics the way the mill is supplied with cane and the way it produces sugar during the season, by carrying out two different modelling and simulation steps (Figure 2). The first step consists of defining the rules of supply planning and operation that will be applied to the mill area structure. This includes (i) establishing the first and last crushing weeks (the length of the milling season will be calculated automatically), and (ii) the delivery allocation rules applied to each PU. This delivery plan is then simulated to provide a delivery schedule for the mill.

The second step consists of processing the mill weekly delivery into sugar and calculating the amount per week and over the season. This is done by (i) multiplying each PU delivery by its corresponding sucrose rate, (ii) adding the individual weekly sucrose production and multiplying the result by the weekly efficiency rate of the mill. Various quality indicators can be used, depending on local agreements such as the Recoverable Value (RV) in South Africa.

MAGI allows the inclusion of unforeseen events in a scenario, such as a PU not delivering or a mill breakdown during a given week. The user then has to define some adjustment rules, e.g. compensating for one PU under-delivering by allocating additional tonnage to another PU, or decreasing all PU allocations to a given ratio when the mill stops crushing. These simulations indicate the sensitivity of a given supply organisation to unforeseen events, and the relevance of the suggested adjustment rules.

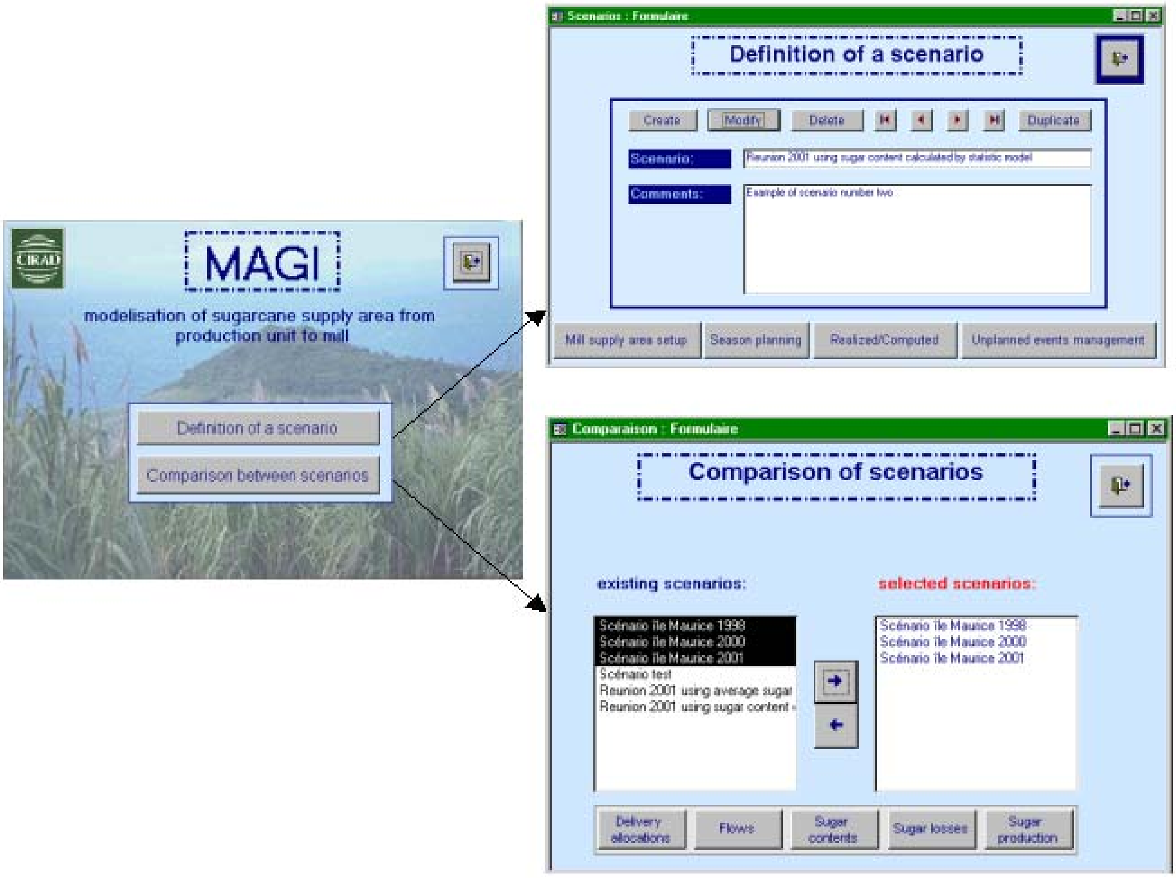

Figure 3. General structure of MAGI.

Current Version of MAGI

General description

An initial application was developed as a Microsoft Excel® spreadsheet, based on the above conceptual background and the Réunion case. The spreadsheet program was easy and quick to develop for the first simulation experiment with the local millers, but various constraints and limitations had to be dealt with before it could be applied to other users and cases. For example, it was difficult to model modifications that would alter the relationship between cells within the program. It was thus decided to re-program the application with Microsoft Access®, as this database format appeared better suited to the objectives. The version described here is entirely programmed with Access®, calculations included.

MAGI is structured into two modules (Figure 3). The first allows the characterisation and simulation of a scenario with a given supply organisation, and the second allows comparison of the results of different scenarios. Each screen is designed in a user-friendly way to facilitate its manipulation by a diverse range of potential users (researchers, consultants, mill supply managers). The user has simply to follow the various sub-modules and capture the data characterising the simulated scenario in the pre-programmed spaces. The process does not require any specific computer literacy.

Creating a scenario

A scenario is created using the module named *Definition of a scenario*. The user will generally start with the current context of the mill supply organisation in order to validate the simulation of this benchmark scenario by comparing its result with actual sugar production tonnage in a given year.

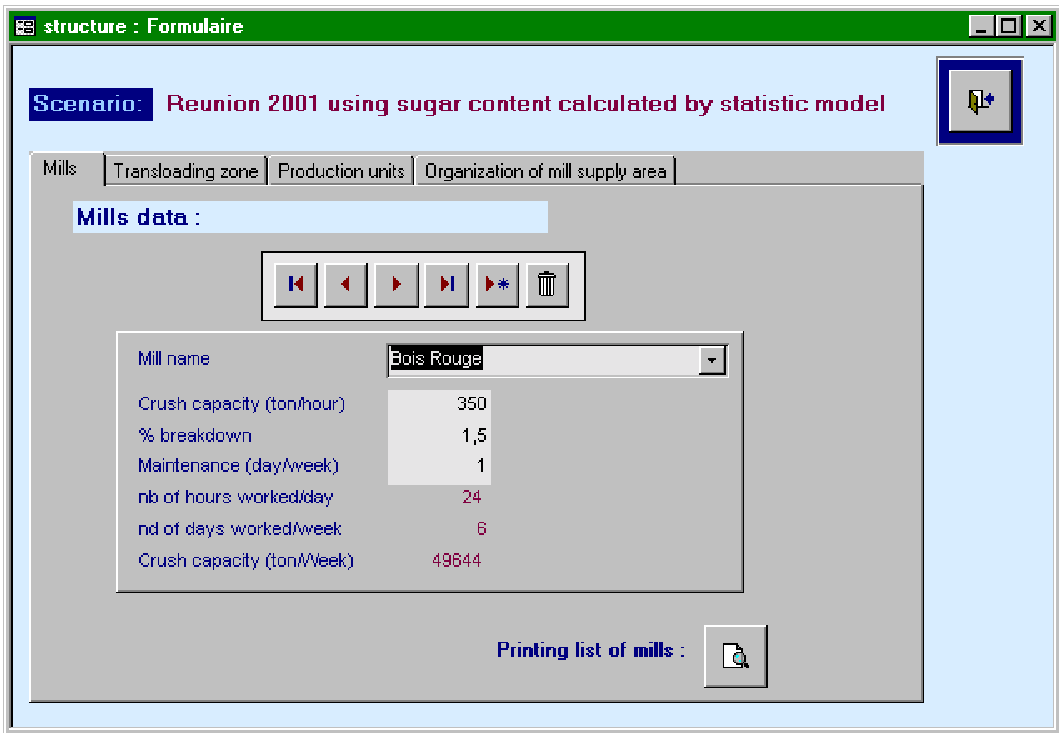

Figure 4. 'Mill supply area set-up' sub-module (mill data screen).

A scenario is described using four sub-modules: *Mill supply area set-up*, *Season planning*, *Realised/Computed* and *Unplanned events management*. The *Mill supply area set-up* sub-module is itself divided into four sections (Figure 4).

Mill, Translouding Zones and *Production Units* are used to create all the existing elements required to model cane flows. Each element is described by its name and its particular characteristics. For example, the mill weekly crushing capacity is calculated automatically from the hourly crushing capacity, the weekly maintenance time and the breakdown rate. The paths followed by the cane flows between these components are then captured with the *last section, Organisation of mill supply area* (Figure 5). Here the user selects the elements that are linked by browsing a menuscroll.

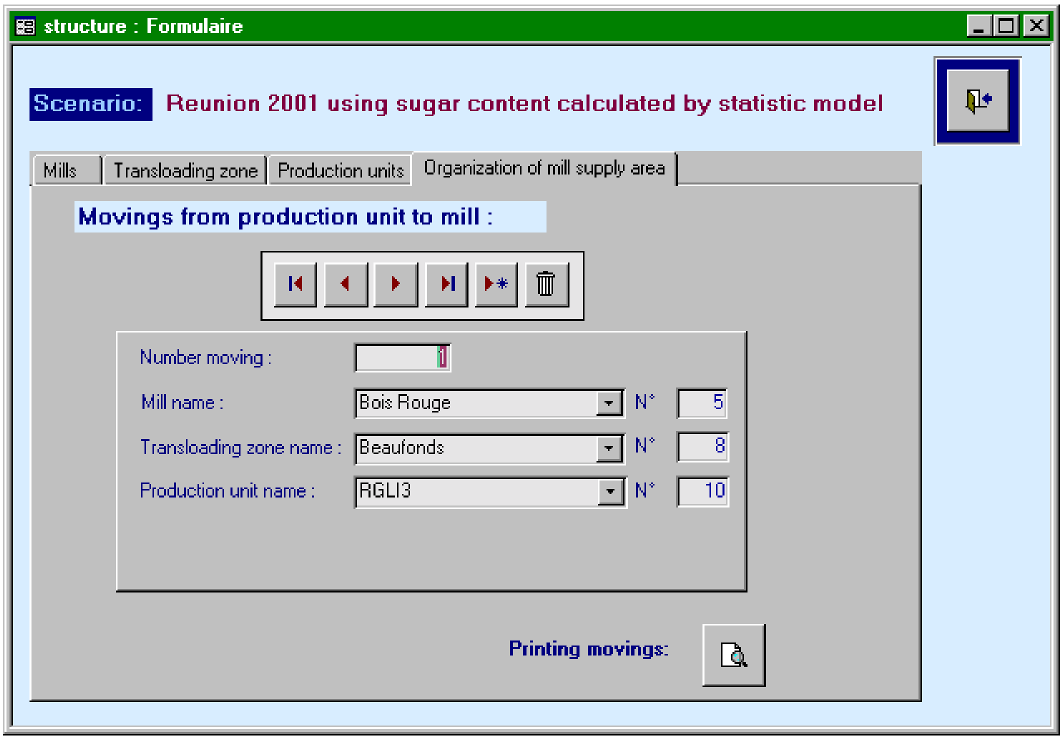

Figure 5. 'Organisation of mill supply area' screen.

When the structure of the mill supply area has been defined, the user has to capture the details of the season planning so that the program can calculate (i) the season duration and its starting date, (ii) the cane flows between each component of the mill supply area, and (iii) sugar production per week, per production unit and for the entire season. The sub-module *Season planning* is divided into nine sections. Six concern the characteristics of various components such as season dates and duration, delivery allocation rules, weekly harvest and transfer capacities, PU sucrose curves and mill sugar losses. The other three concern the simulation results of cane flows between transloading zones and the mill, sugar production at the PU level and sugar production at the mill.

The *Season data* section is at present based on the Réunion situation. The user captures the last week of the season and the number of extra weeks required to carry over loads of cane not delivered in time during the season because of various unplanned events. The last week of planned deliveries is then calculated using the following formula:

Last week of planned deliveries = Last week of delivery – Carry over weeks.

The program then automatically calculates the season length by dividing the total tonnage by the weekly crushing capacity of the mill, and the starting week of the season with the following formula:

Starting week = Last week of planned deliveries – Season length + 1 week.

Alternatively, the user can capture the length of the milling season directly, without defining extra delivery weeks.

The *Delivery allocation* section allows the user to define the rules used to allocate weekly deliveries to each PU throughout the entire season. In the current version these data are captured manually, so that all types of allocation distribution can be simulated. The third sub-module, called *Realized/Computed,* aims at validating simulations by comparing their results with an actual situation. The user captures actual deliveries, sucrose curves per PU, sucrose losses and sugar production for a given year, and MAGI provides a cross-analysis between real and computed values for each variable and each season week.

The fourth sub-module, called *Unplanned events management,* aims at assessing the impact on sugar production of hazards such as partial or non-delivery by a PU in a given week, or total/partial breakdowns at the mill or transloading zone (Figure 6). Pre-programmed management rules are used to adjust the delivery schedule to these events.

For example, three alternatives are available in the PU case:

- Adjustment within the transloading zone: the non-delivered allocated tonnage is transferred to the PU(s) which has experienced the most delays in its delivery schedule and with respect to its harvest capacity during the given week(s).
- Adjustment from one transloading zone to another: the non-delivered allocated tonnage is transferred to PU(s) belonging to another transloading zone. The mill takes this option if PUs from the initial transloading zone cannot absorb the extra tonnage to be delivered.
- Delivery carry-over: the non-delivered allocated tonnage is carried over at the end of the season, during the extra weeks planned for this purpose.

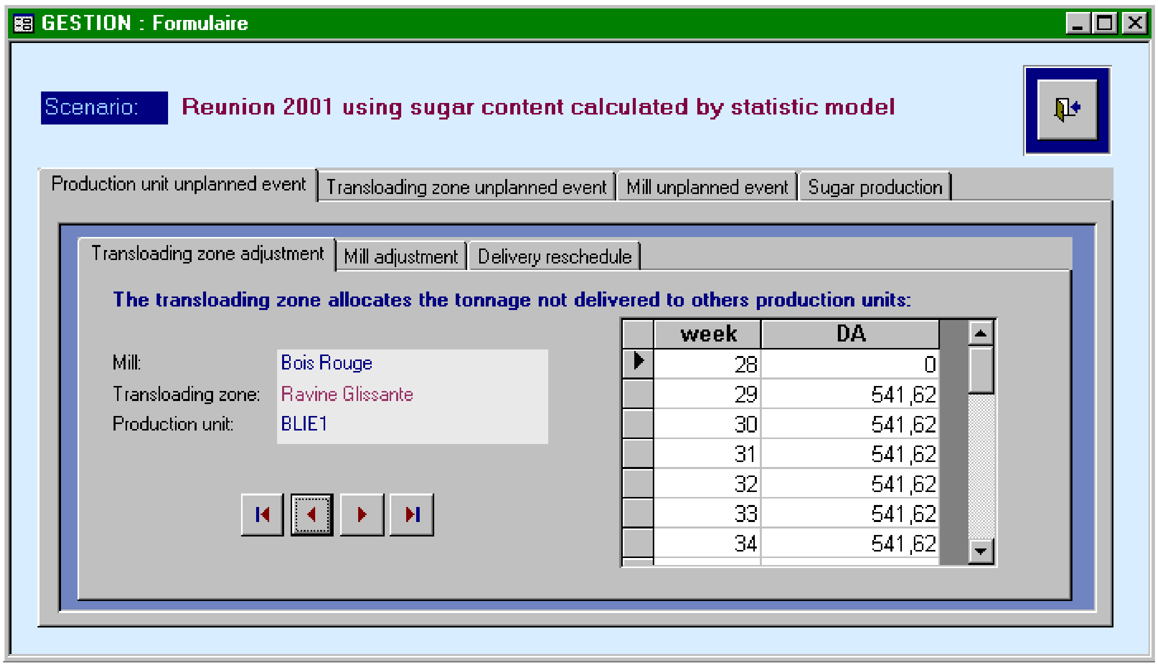

Figure 6. 'Unplanned events management' screen, showing non-delivery by production unit in the 28th week of the season.

Comparing scenarios
From a decision support perspective, the interest of MAGI lies mainly in its capacity to make comparisons between a wide range of scenarios. These comparisons are based on PU delivery schedules, cane flows between elements along the chain, PU sucrose contents, mill sugar losses, sugar production per PU and sugar production at the mill.

The results of the scenarios are transferred to an Excel® spreadsheet that allows the user to carry out statistical analysis or to produce graphs. The final products are then used to facilitate discussion and negotiation between stakeholders involved in mill supply management.

Evolution of MAGI

This first version of MAGI was developed in 2001, based mainly on the Réunion situation where it was tested. Feedback from La Réunion and South Africa has provided a number of elements to improve the software and make it more generic and user-friendly. The improvement process started in 2002 and will continue in a three-year collaborative project between CIRAD, INRA and SASEX. At this stage it includes the following main points:

Computing tools
Because Access® is not flexible enough, a different development language will be used to perform calculations. The database structure and the user interfaces will remain in Access® in order to facilitate MAGI portability. Links with Excel® will be included to import data already captured elsewhere, such as sucrose curves, and to export simulation results for graphic presentations and statistical calculations.

Languages
MAGI is currently available in French and English. The next version will be designed in such a manner that other language versions such as Spanish and Portuguese can be easily created.

Structure of MAGI
The structure of MAGI will be changed to improve its versatility, its reliability and its general application:

- The *Mill supply area set-up* sub-module will include all the characteristics of each element along the supply chain. For example, PUs will be defined by their name, their total production, their weekly harvest capacities and their weekly sucrose curve.
- The *Season planning* module will be limited to the two sub-modules, *Season data* and *Delivery allocation*.
- A *Results* module that will include cane flows between elements along the chain and sugar production, will be created.
- The *Transloading Zone* element will be replaced by a more generic concept called *Intermediate operators*. It will refer to any stakeholder involved in cane flow management between the PUs and the mill. The user will define the number of different stakeholders involved in the process, give each a generic name and then define each unit of this type (name and cane transfer capacity).

Definition of delivery allocation rules
Pre-programmed rules will be proposed to the user to safeguard and speed up the data capturing process.

Four options will be available:

- Uniform over the season. The PU delivers the same amount of cane each week of the season. This amount is calculated by dividing the PU's total cane production with the season duration.
- Uniform for a specified number of time slots. Each time slot will be defined by a starting and ending week.
- Priority to sucrose content. Each week, PUs with cane to offer will be ranked according to sucrose content. Delivery priority will be given to those with the highest cane quality. Delivery allocations will be decided on PU harvest capacity and mill capacity.
- Manual. The user captures directly the weekly delivery allocation for each week and each PU.

Additional options may be programmed in the future, depending on new ideas and issues. All options will have to respect three constraints: PU total cane tonnage, PU' weekly harvest capacity and the mill weekly crushing capacity.

Conclusion

MAGI is a simulation tool designed for investigating strategic re-organisation of mill supply. It operates on a weekly basis at mill supply area level, and as such it is not suitable for addressing logistic issues that concern the impact of equipment choices and strategic organisation on daily management of cane flows. Logistic issues need to be addressed by generic industrial simulation platforms that will provide accurate estimates of harvest, loading and transport capacities for MAGI simulations.

MAGI is also not able to determine the impact of strategic scenarios on harvest management at the farm level, as the model considers aggregated production units, which are described with very few variables. Using MAGI in a real context shows that growers are aware of and deeply concerned by these impacts on their farm management. Specific decision support tools dedicated to work organisation at the farm level are useful for investigating such issues (Le Gal, 1997).

Originally developed for La Réunion, MAGI will be largely improved by including the South African situation. The authors aim to develop a tool that can be adapted to a wide range of situations, not only in terms of mill and organisational issues in a given country, but also between one country and another. This generic objective means that the tool will have to be tested in various environments, and as much feedback as possible will have to be obtained from these experiments. For this reason it is planned to provide free access to MAGI through the Internet, while maintaining a close link with any future user, based on an electronic device such as a product-key.

Acknowledgements

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