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Modeling of Integrated Management System of Sugar Cane: taking advantage of Sugarcane Agriculture Residues

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Abstract This paper presents the results of a phase of a research project which modeled the activities involved in the supply chain of sugar cane under the scheme and principles of the IDEF0 methodology, in order to visualize the elements involved in the generation and disposal of agricultural residues of sugarcane. The integration of the stages of field management, harvest and factory, looked into the operation of a reference sugar mill that currently does not consider agriculture residue sugarcane collection as an alternative system of business enterprise to diversify the product portfolio.

Keywords: modeling, supply chain, Sugarcane Agriculture Residues, IDEF0.

1.1 Introduction

Several countries have vast extensions of land used to grow sugar cane. In Colombia, the Cauca Valley region is known for being the first sugar cane producer, generating between 50 and 150 t/ha of residual biomass (leaves, hearts, sprouts and strains) for institutions engaged in research of bio-fuels is considered a raw material for bio-ethanol production. This is one reason why it's a priority designing a logistics system for collecting sugarcane agriculture residues (SAR) adjusted to local conditions and contribute to lower the high costs associated with their use.

This paper presents the stages that make up the supply chain of sugar cane using IDEF0, in its current state and future, in order to visualize the provision of SAR as an opportunity for product diversification through its collection in enterprise system, in this case the sugar mill.

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The paper is organized in five sections. First section provides an introduction to the problem, second part shows the IDEF0 methodology, and characterize the processes involved in the generation and production of sugar cane, the third section develops the model of sugar cane management from the perspective of IDEF0, fourth is the proposed SAR recovery by leveraging existing resources in the system. Finally, the conclusions are presented.

1.2 IDEF0 Methodology

For the representation of the activities involved in managing of sugar cane methodology was used Integration Definition for Function Modeling, commonly known as IDEF0, whose purpose is to provide simple and formal modeling techniques. Create, analyze and evaluate various systems, through the representation of hierarchically ordered diagrams, represented by boxes and arrows linking model elements in a clear and precise way Kim, 2002.

The elements used to establish the interactions between processes, are called ICOM. Figure 1 shows the proposed systemic approach of IDEF0 based on the inputs which are defined as those elements that activate the system, and are transformed by the process, in order to produce the outputs, controls, principles that regulate the way in which processes are active to produce the outputs, the mechanisms, defined as the resources the process needs and uses, generally consumed during the same transformation, and outputs, which are the result of the transformation and the articulation of the other three elements.

1.2.1 Characterization of Processes

For the model development we began with the characterization of the processes that are involved in the sugar production, based on information obtained during field visits to sugar mill test and the relevant literature of the topics (e.i., Viveros, 1995; Torres, 2006; Nova, 2010; Amu, 2010; Amu, 2011). This research provided the basis for mapping the integral production system of sugar through the IDEF0 methodology.

Through a holistic view, we identified the starting point of the generation and disposal of SAR as a raw material usable in the context of product diversification and environmental responsibility of the sugar mills. To build the model we identified four stages:

1. *Processes classification*: In this phase the activities of sugar cane were characterized, are grouped in three essential sub-processes (field, harvest and production) according to the affinity of its objectives.

2. *Description and classification ICOM items*: During the development of the characterization of the processes involved in sugar production, 106 elements were identified between variables, initial conditions, restrictions, data and parameters, which through brainstorming and a dynamic configuration in association with reference sugar mill managers were grouped in only 47 considered the most important: 19 inputs, 16 outputs, 9 control and 3 mechanisms, used in modeling.
3. *Modeling*: When you have classified the processes and ICOM elements, the sequence structure and relevance of each of these, software BPW in ®-Beta was used. The IDEF0 model of the macro-process Integrated Management Sugar Cane - A_0 in its current state is represented in Figure 1.
4. *Validation*: Finally, model was evaluated and approved by experts of reference sugar mill.

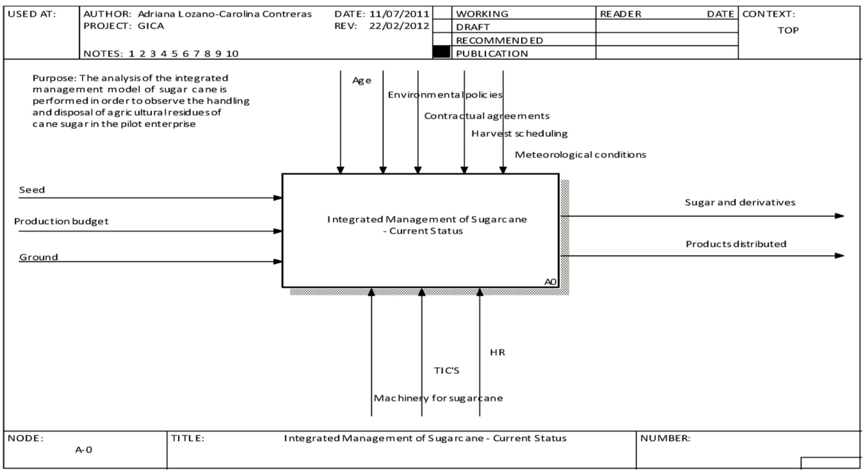

Fig. 1.1 Integrated management of sugarcane

1.3. Integrated Management Model of Sugarcane

The processes involved in the supply chain of sugar cane are grouped into three stages of management, because in each of these, operations are where you should plan, organize, manage and control all types of resources, looking for the efficiency of operations. Classification stages were performed according to the affinity of its objectives:

Field Management: sub-processes are controlled growing conditions and generation of high quality sugar cane. *Harvest Management*: activities take place to comply with supply of sugar cane to the sugar mills, and, *Production Management*: carried out activities and operations for generating of sugar and derivatives.

This proposal has been called "Integrated Management of Sugar Cane - GICA" (for its acronym in Spanish) which integrates the stages of field management, harvest and production, providing a new way to identify and recognize the processes composes.

1.3.1 GICA Processes

In Figure 2, the sequence of sub-processes is structured what makes the GICA macro process, where it's shown the disaggregation of A_0 model in its first hierarchical level A_1. From close observation focused on the interaction between harvest management and production management appears SAR as product that combines these two stages. 80% of his material is burned in field and 20% are admitted to production management as strange material.

To go further in functionality of harvest management process, which produces among others SAR, was a second hierarchical level analysis of depth A_2, see Figure 3, here are four sequential steps: i) *pre-harvest and maturation*, where is planned and defined harvest type to be developed (mechanical or manual) as well as harvest scheduling sub-area for harvest sugar cane; ii) *Cut*, performance operation of previous programming. The products coming out of this stage are chopped cane (mechanical) or long (manual) and SAR, that are buried or burned to ensure good germination of the strain and weed control, wasting the potential to generate new products; iii) *Lift*, operation where cane cutters organized in packages to increase the efficiency collection of lifters machine at cane wagons; and iv) *Cane transportation*, laden wagons move to chaining operation, which are clustered and hooked 3 or 4 wagons to a sugarcane train to move to the cane patios in the reference sugar mill.

1.4. Proposal for SAR Recovery

In order to facilitate the process of collecting SAR proposes to modify the stage of harvest management based on a technological alternative collection SAR, that makes it economically feasible and meets two elements of assessment.

On the one hand, to options of collection selected by importance level according to the literature reviewed (Marchi, 2005; Azevedo, 1996; Ripoli, 2010; Michelazzo, 2008) these are: baling, integral harvest, waste chopper and harvest machine adapted; and on the other hand, at four critical variables of GICA system identified as: land conditions, SAR density, foreign material and SAR disposed, obtained through a matrix of causality vs. dependence (see Figure 4, quadrant III) from the valuation of causality between elements (Table 1).

For the selection of critical variables, it performs the division of the quadrants based on the data in Table 1 and the calculation of mathematical expectation. The elements are located in the corresponding area. The quadrants are divided in I: Input variables (high mobility and low dependency), II: Link variables (high mobility and high dependency), III: Outcomes measure (Low mobility and high dependency) and IV: minor problems (low mobility and low dependency). The variables used to define the collection system are contained in quadrant III, because to solve these elements reduces the impact of the other quadrants.

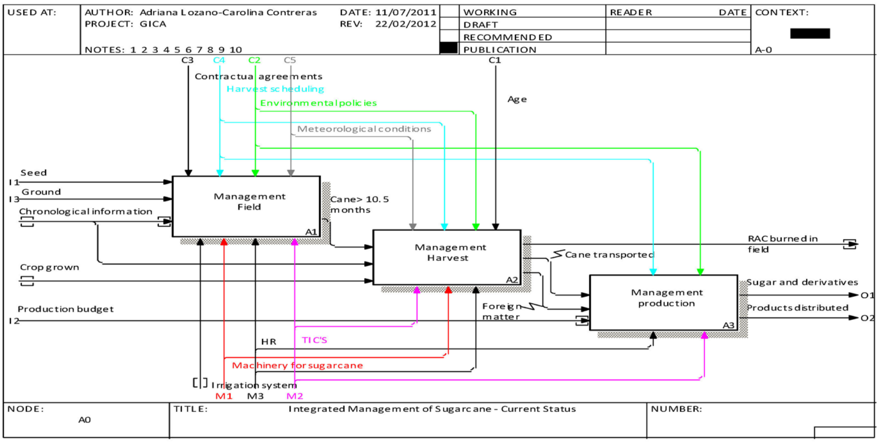

Fig. 1.2 GICA Disaggregation (A_1)

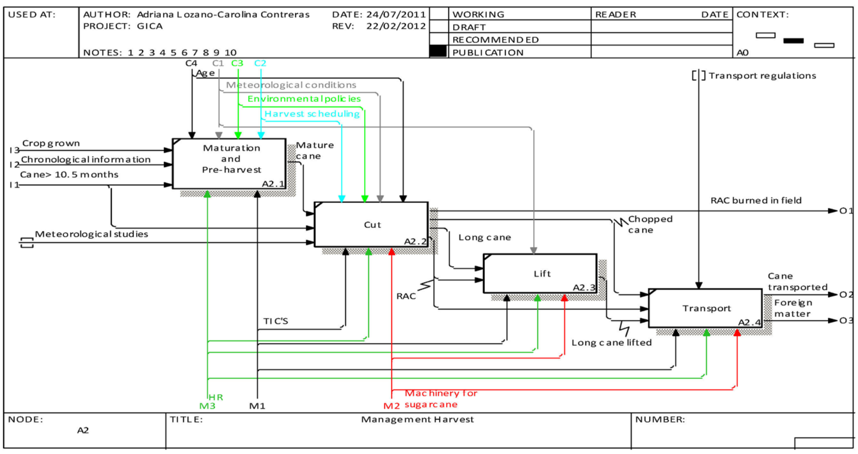

Fig. 1.3 Disaggregation harvest management. Current status (A_2)

The positive impact on land conditions with integral harvest machine because it allows a controlled leave in the field for 50% of waste to contribute to the contribution of organic matter, as suggested by Scala, 2007. In the case of the baler and chopper this percentage is very low, whereas with harvest machine adapted its percentage tends to zero. Ripoli, 2010, indicates that the system of integrated harvest yields a low percentage of foreign matter from the SAR compared with other systems, in addition to the effective performance of harvest machine and its effect on the charge density, which varies from 466 to 333 kg/m3.

Table 1.1 Valuation of causality between elements

CAUSALITY \ DEPENDENCY	SS	TC	SC	SL	SDD	W	SD	EA	SM	EP	ST	GC	CA	T. Sum	% P
◆ Size sub-area harvest cane (SS)		4	2	5	3	0	0	4	1	0	0	0	0	19	10,6
◆ Type of cut (TC)	0		0	5	5	0	4	3	2	0	3	4	0	26	14,4
◆ State of cane(SC)	0	0		5	5	0	3	5	3	0	4	3	0	28	15,6
◆ SAR in land (SL)	0	0	0		5	0	0	4	0	0	3	5	0	17	9,4
◆ SAR disposed (SDD)	0	0	0	4		0	0	0	0	0	0	4	0	8	4,4
◇ Weather (W)	0	5	4	0	0		3	3	4	0	4	3	4	30	16,7
◆ SAR density (SD)	0	0	0	0	3	0		0	0	0	0	0	0	3	1,7
◆ Efficiency of alternative (EA)	0	0	0	3	5	0	5		5	0	0	0	0	18	10,0
◆ Strange material (SM)	0	0	0	0	0	0	0	1		0	0	0	0	1	0,6
◆ Environmental policies (EP)	0	1	5	0	0	0	0	0	0		0	0	0	6	3,3
◆ SAR tenure in land (ST)	0	0	0	0	0	0	4	2	5	0		5	0	16	8,9
◇ Growing conditions (GC)	0	0	0	0	0	0	0	0	0	0	0		0	0	0,0
◆ Contractual agreements (CA)	0	4	4	0	0	0	0	0	0	0	0	0		8	4,4
Total sum	0	14	15	22	26	0	19	22	20	0	14	24	4	180	
Participation Rate (%)	0,0	7,8	8,3	12,2	14,4	0,0	10,6	12,2	11,1	0,0	7,8	13,3	2,2		

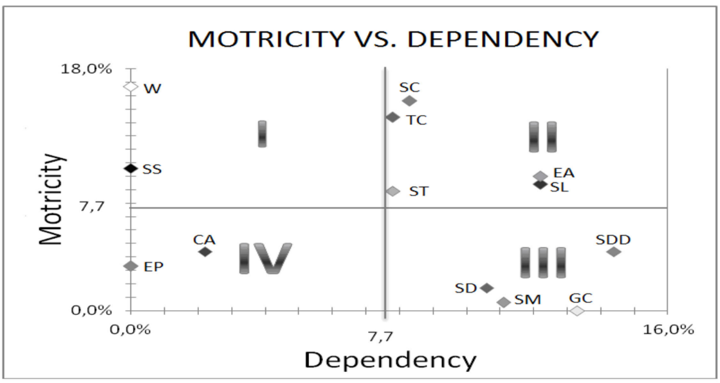

Fig. 1.4 Motricity vs dependency matrix

Michelazzo, 2008, claim that SAR transportation costs to factory with integral harvest machine have less variation in costs at different distances, which does not happen with other systems, evaluated, because it is influenced by the distances that increase its handling costs, caused by the low density or by increasing number of wagons required.

For these reasons, model of logistics system of SAR collection will be based on the integral harvest system, using a dry cleaning center for residue separation. Model of proposal of operational process of SAR collection in parallel to harvest cane, when it's carried out mechanically, is shown in Figure 5.

From analysis proposed model of harvest management can be set to reduce operations in the crop and labor by removing activities like cut the leaves of sugar cane and separate roadside or residue burning, at harvest reduces the number of machines by leveraging the current harvesting system that collects parallel cane and SAR products, also reduces land compaction, which results in better conditions for growing sugar cane.

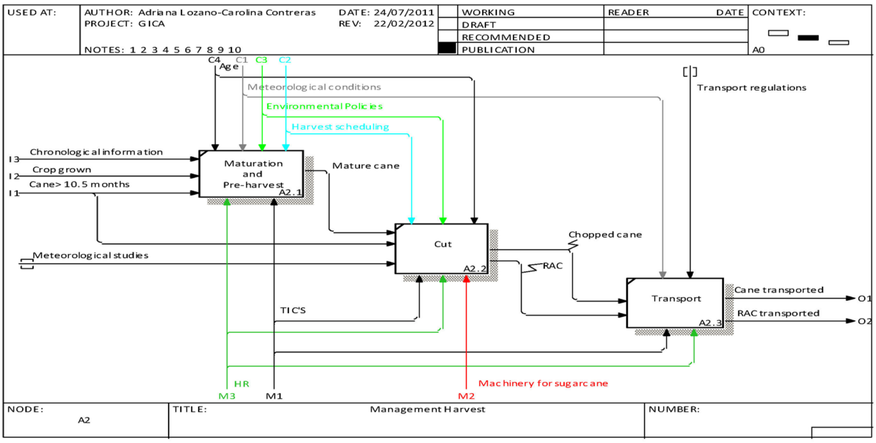

Fig. 1.5 Disaggregation harvest management. Future status (A_2)

1.5. Conclusions

Proposed methodology for current system analysis identified critical elements, selecting the technological alternatives appropriate to geographical and environmental conditions in the interest area, in this case for location of reference sugar mill. Also, modeling techniques use IDEF0 related, make visible hierarchically the set of processes and activities, consumed resources and relationship between elements that integrated management of sugar cane of a Colombian reference sugar mill.

The reference sugar mill currently considers two stages: agricultural, where the sugar cane is seen as the only usable product; and industrial, the one where products originate as sugars and derivatives. This perception is revalued to determine the SAR collection as a simultaneous operation to harvest cane, without adding complexity to the current system, or afford the current economic structure. Taking advantage of the SAR is not a fundamental feature of the business system (reference sugar mill), so it is proposed that it becomes a second product of the agricultural stage.

The emptiness expressed by the flow of materials in the supply chain reference sugar mill corresponds to the conventional structure of enterprises and their supply chains in the decades 60 and 70, where wasn't recognized the importance of the use of waste, and processes recovery were focused exclusively on the recovery of finished products and packaging. The approach presented in this paper offers a different view and current of the logistics chain for the companies of sugar industry in Colombia, including the waste recovery operations and business potential for the expansion of product portfolio, principle worked in chains supply of great food industry in the world.

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