



# Improvement of the supply chain for the sugar cane exportation process employing discrete events simulation techniques

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**ABSTRACT.** Current paper proposes a reduction on all logistic costs involved in the sugar cane exportation process for an important medium-size cargo harbor in South America. The strategy consisted in studying and improving the efficiency of the logistics transportation flow of merchandise between the sugar cane mills and the cargo ports by employing discrete events simulation as a methodology and the ProModel software as a simulation platform. The simulated scenarios show 89% reductions in additional costs for inventory management; 50% of the resources used for loading the containers; and an 11.4% increment in the efficiency of operations. In addition, the new planning strategy was also evaluated with either a positive or negative variation of the demand. It should be underscored that the improved scenarios (out of those simulated) do not involve investments in facilities or in machinery purchasing.

**Keywords:** simulation, sea port, logistics, transport.

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**RESUMO.** O objetivo desse trabalho é encontrar uma redução de todos os custos logísticos envolvidos no processo de exportação do açúcar de cana de um importante porto de carga de porte médio na América do Sul. A estratégia consistiu em estudar e melhorar a eficiência do fluxo logístico de transporte de mercadorias entre os engenhos de cana de açúcar e os portos de carga, utilizando como metodologia a simulação de eventos discretos e o software ProModel como plataforma de simulação. Os cenários simulados, levam-nos a obter reduções de 89% nos custos na gestão de estoques e 50% dos recursos utilizados para carregar os contêineres, também permitiu obter um incremento de 11,4% na eficiência das operações. Além disso, foi possível avaliar uma nova estratégia de planejamento com variação positiva ou negativa da demanda. É importante destacar que os cenários melhorados (daqueles simulados) não envolvem investimento em instalações nem na compra de equipamentos.

**Palavras-chave:** simulação, porto marítimo, logística, transporte.

## Introduction

In today's highly competitive companies it is imperative to face the challenge of reducing loading duration, stocks and costs to improve the process in a global environment. Depending on the complexity of the process and the type of solution adopted, each company has its own decision-making process. Discrete event simulation has become an important method and provides companies with several advantages like personnel training, better visualization and understanding of the industrial productive processes.

Banks et al. (2005) state that a simulation model is a mathematical model studied by using the simulation itself, this lets you design the system in a computational model in order to perform tests and experiments besides to understand the behavior of the system, applying different strategies of operation.

Law and Kelton (2000) complement the previous description stating that discrete event simulation consists of creating a model that evolves over time where the simulation variables change at specific points in time. In most systems, the no implementation of simulation experiments may be economically unviable or simply impossible to be executed.

Current article provides an alternative for researching. In fact, it involves the simulation of scenarios conducting to the planning of logistics operations for the sugar exportation process in a port with great strategic importance in Colombia. The research is delimited to the supply chain of container exportation and focuses on finding an alternative that reduces loading time, improves delivery duration and conducts to the reduction of stocks.

The planning of brand sugar production by the mills and ship assignments is common to most large sugar exporting countries, though the specific complexities within the supply chain are different in different countries (HIGGINS et al., 2006). The literature abounds with papers that investigate logistical activities at the port and shipping. Models for scheduling activities at the port primarily focus on the handling of containers from trucks to ships (GAMBARDELLA et al, 2001; HARTMANN, 2004; KOZAN, 2000). Models for shipping berth planning address the schedule of activities that a ship undertakes once in port (BROWN et al., 1994), berthing positions within large ports (PART; KIM, 2002) and chain integration with sugar production employing heuristic methods to reduce costs of sugar production and obtain a better management of logistics for ship berthing (HIGGINS et al., 2004, 2006; SELLITO et al., 2009).

### Production of sugar cane in Colombia

The sugar cane industry in Colombia is concentrated in the southwestern region of the country called the Cauca Valley. This geographical area shares its characteristics only with two other places, namely, Hawaii and the plains of northern Peru, characterized by the highly relevant differences related to thermal amplitude between day and night, essential conditions to get the best concentration of sucrose in sugar cane plants.

This privileged condition guarantees sugar production throughout the year, which doesn't occur in the rest of the world, where the harvest of sugar cane only lasts 4 to 6 months on an average. Consequently, fixed costs and the cost of capital are about half and up to a third of those for other sugar cane production areas in the world. Although production costs are lower, the logistic ones are very high, affecting seriously the revenues of the companies and their competitiveness on the international markets.

During the analyzed period (one month), 93,750 tons of sugar were exported: 33.4% in containers, 26.57% in bulk and the remaining 33.4% in sacks. To load the referred 33.4%, (31,350 tons of sugar), 1,183 containers were used.

Lack of planning for the dispatching of the product from the sugar mills to the maritime port generated a cost overrun of US\$ 8,190 month<sup>-1</sup> and a resource utilization of 30.81%.

Under the same circumstances of demand, current study demonstrated that it was possible to reduce fines up to US\$ 822 month<sup>-1</sup> and increase the resource utilization to 60.85%.

### The Maritime Port

Cargo sea ports are fundamental in Colombia's business development since more than 90% of exports currently occur by sea port facilities.

Colombia has nine important sea ports, comprising seven on the Caribbean coast: Guajira, Santa Marta, Cienaga, Barranquilla, Cartagena, Golfo de Morroquillo, Urabá and St. Andrew; and two on the Pacific coast: Buenaventura and Tumaco.

Cartagena, Barranquilla and Santa Marta are the main cargo ports on the Caribbean's coast. The port of Buenaventura on the Pacific coast has been established as the country's main multipurpose port and is actually the epicenter of most imports and exports of non-traditional products.

In 2010, 9.02 million tons of different products were transported from the port of Buenaventura. Table 1 shows that 1,178 ships were docked.

**Table 1.** Tons transported through the port of Buenaventura in 2010.

Type of Cargo	Exported Tons	Imported Tons	Total Tons
General Cargo	60,212	686,422	746,633
Solid bulk	53,659	2,855,151	2,908,810
Liquid bulk	-	324,870	324,870
Coal in bulk	619,871	-	619,871
Container 20LI	638,774	1,661,165	2,299,939
Container 40LI	488,005	1,631,609	2,119,614
Total	1,860,521	7,159,217	9,019,737

The operations of the maritime port of Buenaventura may be comparable to some small ports in Brazil such as Tup Ussiminas, São Paulo State, Porto de Salvador, Bahia State, Porto de Belém, Pará State or Porto de Fortaleza, Ceará State and others, which exported an average of 3 millions of tons in 2009. However, these ports transport the amount of tons corresponding to the 9.7% of the total tonnage transported through Brazilian ports, as shown in Table 2.

**Table 2.** Tons transported through the Brazilian ports in 2009.

Millions of Tons	Quantity of Ports	% Total of Ports	Total Tons	% Total Tons
75-90	3	6	247,217,674	33.7
30-50	6	12	232,632,344	31.7
10-20	8	16	116,242,879	15.9
5-10	10	20	71,094,321	9.7
0-5	24	47	65,743,923	9.0
Total	51	100%	732,931,141	100

### Restrictions and definition of the problem

The logistic process includes the following activities: 1. Products loading at the 12 sugar mills of the region. 2. Freight (via roads). 3. Cargo admission to the port of Buenaventura. 4. Quality control. 5. Weight-in. 6. Unload. 7. Storage. 8. Loading the ships (containers, sacks and bulk).

The above system is fraught with multiple restrictions of a social, political and environmental nature, which together affect its performance and involve high logistic costs due to excess of inventory, poor use of resources and delivery failures. These restrictions may be summarized as follows:

- The travel time of trucks from the sugar mills to the port of Buenaventura may take between 5 and 24 hours. Variations are mainly due to transit restrictions related to cargo type, hours, vehicles, highly curvy roads and behavioral factors, with difficulties to have a good control on truck drivers. The latter factor will not be dealt with in current study and only travel time will be analyzed as a system constraint. An average speed of 24 km h<sup>-1</sup> was considered for simulation purpose.

- The sugar is exported mainly in three forms: bulk, sacks and containers. In the case of sugar in bulk, approximately 40% of the total time available is lost since the operation is interrupted by rain or foul weather. The port of Buenaventura has a relative humidity of 51%.

- At the period of current study, the loading operation of containers for the United States and Canada had to be undertaken in a protected area with cameras and in the presence of anti-narcotics police officers. They only had three available anti-narcotics agents who could only monitor up to two containers simultaneously. Nowadays the conditions are different since the company has a warrant allowing it to operate by itself.

- The company owns three warehouses at the port of Buenaventura. One is only used for sugar in bulk and has a storage capacity of 40,000 tons; the other two warehouses with a capacity of 20,000 tons each are areas of free storage where sacks can be stored.

- Contracts between the company under study and the shipping companies on failure in the estimated load times feature rewards and punishments paid by both parties in the following scenarios: when the loading is done in less time than estimated, the shipping company pays the company under analysis a sort of 'reward'; on the other hand, when the product is not ready for loading, the company pays the shipping company a sort of 'penalty'.

- Lack of planning in the transport of the product from the sugar mills. In many cases since the sugar is dispatched from the sugar mills several days before ETA (Estimated Time of Arrival), there is an increase in storage days and sometimes the company has to rent an additional warehouse. Although the

product is available for the immediate loading of the ships and thus assets are obtained, in the long run excessive storage costs do not compensate the losses.

- Low utilization of the cargo's resources of the producing companies. Capacity allows the loading of 16 trucks day<sup>-1</sup> with 32 tons each; however, in the current scenario, only between 8 and 10 trucks with 32 tons each loaded per day.

The need for companies to compete within a faster, globalized and demanding market and at the same time to comply with the principles of quality, service and delivery time at minimum costs requires the development of a new management model to reduce the aggregated costs and improve the response time of supply chain.

## Material and methods

The simulation model was developed with ProModel V 4.0 on Windows XP Operating System.

ProModel software has high flexibility and ability to interact with the system. It is one of the most advanced softwares for discrete event simulation to evaluate, plan and design production, storage, logistics and other operational and strategic situations, and thus generate considerable money savings to improve the planning and control systems.

The technique of Discrete Event Simulation makes possible the development of virtual scenarios which emulates the behavior of virtually any type of process.

The model includes the logistical process from 12 sugar mills to the maritime port of Buenaventura, Colombia, taking into consideration each of the system's segments and constraints.

The simulation model and the scenarios for improvement are analyzed from two perspectives:

1. Loading operations in containers.
2. Sacks and bulk.

It is important to underscore that current paper only analyzes the operations of loading containers.

## Operations of loading containers

The input data for simulation software refer to a month considered representative and characteristic. The simulation is based on two routes: northern and southern.

Southern route: for this particular month, 11 cargo ships, distributed along the month, were loaded with 696 containers.

Northern route: 15 cargo ships were loaded, also distributed along the month, with 487 containers.

## Analyzed indicators

- Value of awards and penalties.
- % Compliance Cut Off (Cut Off: the date and time in which the entire load must be physically

within the port, ready, properly documented and approved for shipment).

- % Northern Route penalized containers.
- % Southern Route penalized containers.
- Maximum inventory of pallets.
- Average inventory of pallets.
- Maximum number of loaded containers per day.
- Average quantity of loaded containers per day.
- % Utilization of resources per day.

#### Input data and assumptions

All time intervals in each stage of the supply chain, namely, travel time, weighing time, quality control, inspection and loading of containers, were analyzed separately for the northern and southern routes.

- The Information and Statistical Analyses were performed by StatFit, a tool provided by ProModel. Information was collected from the physical documents where the company keeps the control records of its operations.

- Penalties for non-compliance are calculated by the staying time of the ships after the fifth day of berth at the port; moreover, containers must be completely loaded two days before ETA.

- Current cargo capacity has an average of 56 containers per day for the southern route and 48 for the northern one.

- Capacity of container: 12 pallets per container.

- Number of teams of operators for loading containers: Northern route: 6 teams working from 8:00 to 18:00; Southern Route: 9 teams, one of which works from 8:00 to 18:00 and the other eight from 18:00 to 8:00.

- Each loading team is composed of six people who carry the sacks to the pallets; the pallets are then lifted and loaded onto the containers.

#### Results and discussion

Since the process started when the trucks were loaded at the mills, the scenarios were designed by defining the optimal time to start loading the truck so that the cargo was ready at the port of Buenaventura by the arrival time of the ships.

The definition of the scenarios was based on three alternatives: 1. Improved scenarios defined by the company. 2. Internal Benchmarking. 3. Trial and error.

Twelve main scenarios were simulated by varying the date of dispatch from the mills, as follow:

1 - Dispatch 7 days before the northern route and ETA to 5 days before ETA to south route.

2 - Dispatch 6 days before ETA for the north and south routes.

3 - Dispatch 5 days before ETA for the north and south routes.

4 - Dispatch 4 days before ETA for the north and south routes.

5 - Dispatch 3 days before ETA for the north and south routes.

6 - Dispatch 2 days before ETA for the north and south routes.

7 - Date of dispatch for each route calculated by the formulas: Northern route:  $\text{Cut Off} - (\# \text{ Containers}/48) - 1$ ; Southern route:  $\text{Cut Off} - (\# \text{ Containers} / 56) - 1$ .

8 - Dispatch 7 days before ETA for the north and south routes.

9 - Dispatch 7 days before ETA for both northern and southern routes, maximum load capacity and dispatch (16 trucks day<sup>-1</sup>).

10 - Dispatch 6 days before ETA for both northern and southern routes; maximum load capacity and dispatch (16 trucks day<sup>-1</sup>).

11 - Dispatch 7 days before ETA for the northern route and 5 days before ETA for the southern route; maximum load capacity at the sugar productions facilities (16 trucks day<sup>-1</sup>).

12 - Dispatching date for each route calculated by the equations: Northern route:  $\text{Cut Off} - (\text{Quantity of containers } (\#) / 48) - 1$ ; Southern route:  $\text{Cut Off} - (\text{Quantity of containers } (\#) / 56) - 1$ , with a maximum loading capacity and dispatch (16 trucks day<sup>-1</sup>).

Within the context of these scenarios, simulation demonstrated that Scenario 12 would provide the best performance for the defined indicators, reduce the additional non-budgeted costs for storage and decrease penalties. In this scenario, the operations were scheduled and took into account that the starting date of the loading process must be established some days before the Cut Off and the efficiency in loading containers as well, which was 56 containers for the southern and 48 for the northern route.

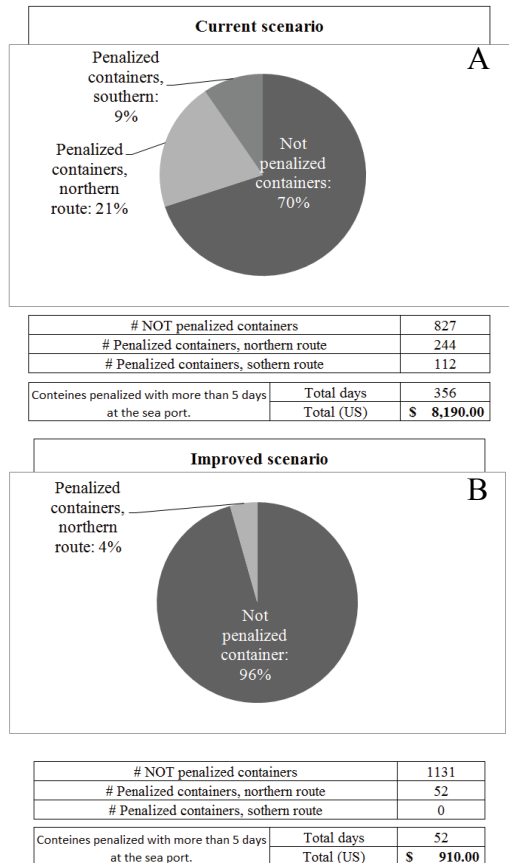
Starting of the loading process (Northern route) =  $(\text{Cut Off} - (\# \text{ Containers}/48) - 1) \text{ days [1]}$

Starting of the loading process (Southern route) =  $(\text{Cut Off} - (\# \text{ Containers}/56) - 1) \text{ days [2]}$

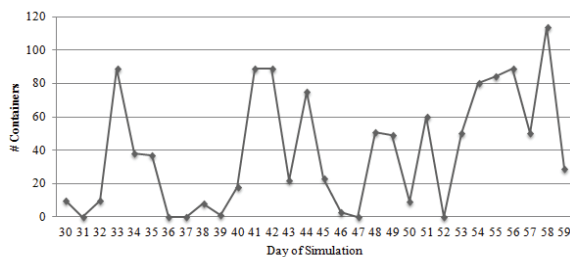
With this improvement, the cost overrun for storage was reduced by 88.89% (penalties) and a 99.75% fulfillment was obtained for the cut off dates. Within a total of 1,183 containers loaded during the month, the number of penalized containers had a reduction of 85.4%; that is, it went down from 30 to 4%, with costs decrease

US\$ 7,280 month<sup>-1</sup> and US\$ 87,360 year<sup>-1</sup>, under the current conditions of demand. Figure 1A and B show the monthly results that could be obtained with the new scheduling.

Improvement allowed increase of efficiency of the loading process for the containers, as Figures 2 and 3 show.

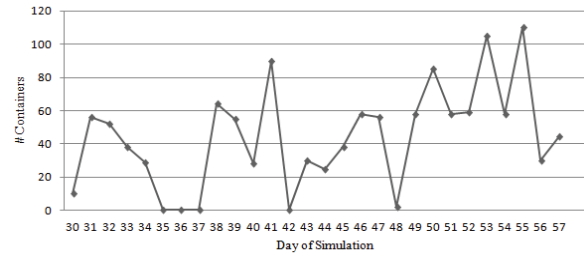


**Figure 1.** (A) Storage costs of the current situation, (B) storage costs of the improved scenario.



**Figure 2.** Number of containers loaded per day (current scenario).

Whereas in current situation, the number of loaded containers per day was 39, the average number in the improved scenario increased to 44, a 4.9% improvement in the efficiency of the loading operations. A decrease in penalties and a better utilization of resources might also be observed.



**Figure 3.** Number of containers loaded per day (improved scenario).

### Planning of the dispatches with the current demand

The scheduling of dispatches at the sugar mills was done by formulas [1] and [2] for each case.

The working shifts will not change and they will remain the same as follows:

North: Monday thru Friday, 6:00 to 20:00; Saturday, 6:00 to 12:00.

South: Monday thru Friday, 2 shifts of 12 hours, Saturdays: 6:00 to 12:00.

In order to appraise the efficiency of the resource's utilization, the behavior of the two different routes was analyzed (Northern route: 6 morning shifts, Southern Route: 8 night shifts, 1 morning shift) by numerical simulation.

1 - Four teams for loading the containers for each shift (day and night); it is mandatory that the loading of the northern route is done during the day (this is a system's restriction)

2 - Four teams for loading the containers during the morning shift.

Table 3 shows the results of these simulated scenarios.

**Table 3.** Reduction of resources with current demand.

Scenario	Penalties	% Penalized containers	Average of Containers loaded per day	% Resources Utilization
Improved scenario				
Current	\$ 910,00	4.4	44	34.23
Resources				
Scenario 1: 4 Teams Shift <sup>-1</sup>	\$ 822,00	4.0	44	60.85
Scenario 2: 4 Teams Shift <sup>-1</sup> Daily <sup>-1</sup>	\$ 1,820.00	7.0	44	34.23

Simulation showed that scenario 1: 4 teams shift<sup>-1</sup> could reduce even more the penalties: US\$ 822 month<sup>-1</sup> representing additional savings per year, besides those by the first improvement of US\$ 1,000 year<sup>-1</sup>. The better use of the resources triggered a 167% increase in productivity and a reduction of downtime from 65.77 to 34.15%. Since salaries and compensations are not part of current analysis, it is not possible to calculate their cost reduction. However, a working hypothesis using the

minimum salary would lead to savings of US\$ 140,000 year<sup>-1</sup>. Total savings may reach US\$ 228,360 per year when they are coupled with penalties reduction.

#### Planning of dispatches to reduce demand by 40%

Two main scenarios were simulated for this purpose:

1 - Current teams (6 for the northern route; 9 for the southern route), with 40% reduction in demand.

2 - Four teams for loading the containers at each shift (day, night); the packaging is a priority for the Northern Route, to be done during daytime and with a reduction of 40% in demand.

Table 4 shows results obtained in the simulation of the proposed scenarios:

**Table 4.** Reduction of demand in 40%.

Scenario	Penalties	% Penalized containers	Average of Containers loaded per day	% Resources Utilization
Scenario 1: Current teams	\$ 0	0.0%	26	20.69%
Scenario 2: 4 Teams Shift <sup>-1</sup>	\$ 0	0.0%	26	36.78%

The simulated scenarios show that the new planning model is also applicable if it has a demand reduction since the latter doesn't generate penalties. It also demonstrates that the number of teams may be reduced to even less than 4 teams shift<sup>-1</sup>.

#### Planning of dispatches with a 20% increase of demand

Two main scenarios were simulated for this purpose:

1 - Current teams (6 for the northern route; 9 for the southern route) increase demand by 20%.

2 - Four teams for loading the containers for each shift, a 20% increase in demand.

Table 5 lists the results obtained in the simulation of the proposed scenarios:

**Table 5.** Increase of demand by 20%.

Scenario	Penalties	% Penalized containers	Average of Containers loaded per day	% Resources Utilization
Scenario 1: Current teams	\$ 1,137.5	5.49	53	41.23
Scenario 2: 4 teams shift <sup>-1</sup>	\$ 227.5	1.0	51	70.68

The new operation plan generates good results even with a greater demand. However, to achieve the projected objective, or rather, better alternatives having low costs, Scenario 2: 4 teams shift<sup>-1</sup> not only

reduces the penalties to US\$ 227.50 month<sup>-1</sup> but also increases the utilization of resources with 70.68%.

#### Conclusion

The golden goal was to redefine the strategy of the entire sugar supply chain, minimizing costs but aligned with the operational restrictions. Simulations provided crucial information to the high management for decision making, appraising new alternatives and understanding the impact of certain changes. New planning policies reduced penalized containers from 356 to 52; a reduction of 85.4%, with costs reduction of US\$ 7,280 month<sup>-1</sup> or US\$ 87,360 year<sup>-1</sup>. Simulated scenarios with changes in the loading working crews demonstrated that half of the resources with increased utilization (167%) resulted in US\$ 140,000 year<sup>-1</sup>; global saving of US\$ 228,360 year<sup>-1</sup>.

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