Dynamic Evaluation of Production Policies: Improving the Coordination of an Ethanol Supply Chain

M. A. Rendón-Sagardi[1], C. Sánchez-Ramírez*[1], G. Cortés-Robles[1], G. Alor-Hernández[1] and L. A. Moncayo-Martínez[2]

[1]Division of Research and Postgraduate Studies
Instituto Tecnológico de Orizaba
Av. Oriente 9, 852. Col Emiliano Zapata C.P. 94320
Orizaba, Veracruz, Mexico
[2] Department of Industrial and Operations Engineering
Instituto Tecnológico Autónomo de México (ITAM), Río
Hondo No. 1, Col. Progreso Tizapán, C.P. 01080
Mexico City, Mexico
*csanchez@itorizaba.edu.mx

ABSTRACT
This paper uses System Dynamics modeling and process simulation to explore coordination in two logistic processes (procurement and production) of the supply chain of an ethanol plant. In that sense, three production scenarios are evaluated to identify: a) stock movement according to current inventory policies, and b) the critical variables affecting the coordination for these two processes. Since the main goal in the company is to meet customer demand, this research incorporates sales forecasting, and four performance indicators to evaluate the state of the processes: 1) average percentage of demand satisfaction, 2) maximum amount of ethanol in excess, 3) available ethanol at the end of the year, and 4) inventory costs. To model the case study, the change in production yield and specific constraints for the chain are considered. The simulation results show that System Dynamics modeling can be used to observe the effects of policies on inventory, and meeting the demand in a real system. It also can define the coordination for a supply chain and give information to improve it. The developed model uses STELLA® software to simulate the logistic processes and execute the evaluation employing the performance indicators.

Keywords: supply chain, system dynamics, procurement, production, ethanol plant.

RESUMEN
Haciendo uso del modelado en Dinámica de Sistemas y simulación, se explora la coordinación de dos procesos logísticos (aprovisionamiento y producción) de la cadena de suministro de una alcoholera. En este sentido, la evaluación de tres escenarios de producción permite identificar: a) el movimiento del inventario de acuerdo a las políticas actuales de inventario, y b) las variables críticas que afectan la coordinación de estos dos procesos. Dado que el objetivo principal de la empresa es satisfacer la demanda del cliente, se incorpora un pronóstico de ventas, y cuatro indicadores de desempeño para evaluar el estado de los procesos: 1) el porcentaje promedio de la satisfacción de la demanda, 2) la cantidad máxima de etanol en exceso, 3) el etanol a disponer al finalizar el año, y 4) los costos de inventario. Para modelar el caso de estudio, se considera el cambio en el rendimiento de producción y las restricciones particulares de la cadena. Los resultados de la simulación muestran que la Dinámica de Sistemas puede utilizarse para observar los efectos de las políticas sobre el inventario, y la satisfacción de la demanda en un sistema real, igualmente, permite definir la coordinación para una cadena de suministro y proporcionar información para mejorarla. El modelo creado utiliza el software STELLA® para simular los procesos logísticos y para realizar la evaluación utilizando los indicadores de desempeño.

1. Introduction

Any company that wishes to control the associated risk to corporative reputation and is willing to protect its value, starts ensuring an effective management of its supply chain [1], including all related activities to information, material, and funds flows from the stage of suppliers to the delivery of finished goods to end-users.

However, in order to administrate a supply chain and achieve the aim of maximizing the overall generated value [2], the decision makers need to consider the risk at every stage of the chain, especially when different actors make decisions only based on their own benefit [3]. All these logistic processes define the relationship among risk, cost, and supply chain surplus of a company [4] [5].

In this paper, a case study regarding an ethanol plant shows a supply chain with two independent suppliers (one for each of the two main raw materials: molasses and grain sorghum). The plant only supplies one product (ethanol), and counts with a demand driven production system. Hence, using System Dynamics modelling, the supply chain is simulated in order to assess the effects of three production plans to meet the forecasted demand, and understand the kind of impact on inventory policies and the suppliers responsiveness.

The structure of this paper is as follows: a brief literature review is provided in Section 2; and the case study is addressed in Section 3. The model to evaluate the production plans is introduced in Section 4; simulation results and analysis are provided in Section 5. Finally, Section 6 discusses practical and derived managerial insights from the simulation and statistical results.

2. Literature review

This section describes the main concepts of System Dynamics modeling, and presents several related works concerning the application of this approach to design supply chains.

2.1 System Dynamics

System Dynamics (SD) is a method to enhance learning in complex systems. It deals with feedback loops, variables, levels, and delays that affect the system's behavior over time [6].

Since SD approach is intended to avoid policy resistance and finding high leverage policies [7], a causal loop diagram (CLD) is an important tool to represent the feedback structure of a system, shows the involved elements in reality, and let us know and understand its behavior.

Even the best conceptual model can only be tested and improved by relying on the learning feedback provided through the real world. However this feedback is very slow and often rendered ineffectively by dynamic complexity, time delays, defensive reactions, and costs of experimentation, among others. Under this complexity and constraints, simulation is a practical way to test a model. Additionally, when experimentation in real systems is not possible, simulation becomes the only way to discover how a complex system works. In this sense, Cedillo-Campos and Sánchez-Ramírez [8] suggested four phases to develop System Dynamics models: conceptualization, formulation, evaluation, and implementation.

2.2 System Dynamics and Supply Chain

System Dynamics is useful to observe a set of interacting elements where each of them has a performance based on a common goal. This approach has been extensively studied to understand and examine the behavior of supply chains. Discrete event simulation is also a widely used tool; nevertheless, according to Tako et al., it has no clear advantage over SD [9].

For the first issue, Nam et al. [10] suggested a knowledge-management method to improve organizational performance. Potter and Lalwani [11] aimed at quantifying the impact of demand amplification on transport performance. Springer and Kim [12] used three distinct supply chain volatility metrics to compare the ability of two alternative pipeline inventory management policies in order to respond to a demand shock. Huang et al. [13] contributed to the literature by providing a better understanding of the impacts of supply disruptions on the system performance, and shedding insights into the value of a backup supply. Maheut et al. [14] evaluated transport policies at an automotive industry without affecting the supply chain performance.

For the second issue, Shin and Lee [15] used QFD and SD approach to simulate and evaluate key policies related to the improvement of key indicators. Li et al. [16] used SD to simulate the management process of the power grid-engineering project. Bouloiza et al. [17] used SD to