A System Dynamics Model for Sales and Operations Planning:
An Integrated Analysis for the Lime Industry

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ABSTRACT

The use of system dynamics techniques to model the sales and operations planning (S&OP), associated with the economic and financial processes, is an innovative proposal. The objectives of this article are to model and simulate the S&OP process integrated with the financial management in a Brazilian lime processing industry, based on the system dynamics approach. Initially, the model was validated. Then, over twenty scenarios were simulated to assess the behavior of the system with its key factors variation. In the microenvironment scenarios, the company's internal perspective was the only element taken into account. In turn, regarding the macro environment scenarios, the basis was the projection of lime consumption related to the country's GDP. The results have genuinely contributed to the industry researched, since the lime processing industry is struggling with obtaining enough supply due to lime acquisition price fluctuations and, consequently, the oscillation of its production costs.

KEYWORDS

Dynamic Modeling and Simulation, Financial Management, Integrated Business, Management Process, Scenario Analysis

INTRODUCTION

The process of Sales and Operations Planning (S&OP), albeit not something new in the organizational environment, has been assuming new shapes in terms of coverage and use, allowing a holistic vision of the processes and providing support in decision-making, from the operational to the strategy levels (Domingos et al., 2015a).

S&OP has been ensuring good results to organizations in several areas, such as an improved communication between the sectors, improvement in capacity planning, good adjustments of goals, organizational learning and setting realistic plans (Ivert & Jonsson, 2010; Thomé et al., 2012).

S&OP is a complex process that provides a dynamic behavior due to fluctuations and uncertainties in its own internal procedures. In addition to the complexity related to efficiently developing and managing an S&OP, it should also be considered the need for managers to have an overview of the

activities and variables involved in the process. To understand the behavior of this type of system over time, there is a methodology named System Dynamics (Domingos et al., 2015a).

The simulation and analysis of a system through the system dynamics (SD) technique allow an improved understanding of the system's behavior as a whole and the influence of each of its parts on the whole (Sterman, 2002).

Brazil holds the 5th place in the ranking of lime production in the world, a ranking led by China. The several applications of lime, such as in steel, cellulose and paper, sugar, water treatment and soil stabilization allowed the extension of its consumption. In Brazil, the consumption is 40kg/capita/year. The Central West region of Minas Gerais, the *loco* of this research, concentrates more than 140 lime industries that supply 40% of the population, being the main source of income of the municipalities of Formiga, Córrego Fundo, Pains and Arcos (Consultoria, 2009).

Given this sector's importance, this work aimed the understanding of the causal relations between the internal processes of a lime industry, and their influences on the organizational management by the calculation of indicators of financial performance, economic, production and sales. To do so, the S&OP process, integrated with the economic and financial sectors, was modeled and simulated by means of system dynamics technique, in a small lime industry in the Center West of Minas Gerais. The basis was the model proposed by Domingos et al. (2015a), which was adapted to depict, in the financial macroprocesses, the Brazilian tax system "Simples Nacional".

LITERATURE REVIEW

Sales and Operations Planning (S&OP)

The S&OP emerged after the identification of gaps in the classic resources and materials planning (Platt & Klaes, 2010).

S&OP fosters the reduction of operational costs, while it increases the business top line (Prokopets, 2012). According to this result, information obtained through the S&OP application, according to APQC (Open Standards Benchmarking), indicate that companies that had a S&OP process decreased US$ 1.34 in costs related to demand and supply planning every US$ 1,000.00 in revenue (Spiegel, 2011).

Kralik and Fogliato (2016) compiled the main results obtained through the implementation of the S&OP in businesses related to cleaning products, a multinational of the chemical industry sector, a large scale petrochemical industry and an industrial electronics company. The main results found were: an increased accuracy of sales forecast, improvement in the level of customer service and an increase in the inventory turnover. The authors also found an improved balance of the supply chain and an alignment between the organizational strategy and the companies' functional areas.

S&OP is an effective process and, in unstable or a drift economies, it can become a "cornerstone", particularly in the introduction of new products (Atkinson, 2009). However, according to Singh (2011) and Iyengar and Gupta (2013), the majority of companies knows the concept, but could not execute it properly. The association of the S&OP with strategic objectives, financial metrics, detailed mapping of "action" and "metrics" is therefore necessary, dodging the "tribal knowledge" used by former managers in the management of the balance between supply and demand.

System Dynamics Applied to S&OP

The System Dynamics is based on the theory of control of engineering and the modern theory of nonlinear dynamical systems. Their main components are formal mathematical models and flight simulators, whose function is to connect tangible and intangible resources related to political decision-making and analysis of impacts on the behavior of the system over time (Sterman, 2002; Al-Kadeem, Backar, Eldardiry, & Haddad, 2017; Nikabadi & Hakaki, 2018; Bhushan, 2017). SD has been applied in different fields. Regarding the management field, SD has been introduced to some areas such as

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