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

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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

operations management, organizational behavior, project management, market uncertainties research, supply chain management and pricing strategies (Al-Kadeem et al., 2017; Gholizad, Ahmadi, Hassannayebi, Memarpour, & Shakibayifar, 2017; Gafi & Javadian, 2018).

Suryani et al. (2010) developed an SD model to predict the future cement demand in Indonesia and verify the need for a capacity expansion based on optimistic and pessimistic projections. According to the authors, their work can be considered a pilot study and there are several areas that still require further research. Two areas highlighted by the authors are the field of manufacturing strategy, which establishes a relation between S&OP and long-term planning in a production planning and control system, and the field of performance and income management, when businesses need to expand their capacity to meet a growing demand.

Domingos et al. (2015b) compiled several works that apply system dynamics in areas related to S&OP. The vast majority do not use the accounting process and only the work of Vlachos, Georgiadis and Iakovou (2007) (as cited in Domingos et al., 2015b) took into account the cost and billing, and Crespo et al. (2004) (as cited in Domingos et al., 2015b) did consider the financial process. In other words, when it comes to integrating the fields of cost, accounting, financial and billing with the S&OP process, there are few studies available in the literature.

Therefore, the SD model proposed by Domingos et al. (2015a) to simulate the S&OP process integrated in with the financial field can be regarded as innovative and, therefore, will be used in this research. It should be emphasized that Domingos et al. (2015a) have not applied the model developed in a company using real data. The authors used only hypothetical data. In this study, the model proposed by the authors was adapted and applied using real data from a Brazilian lime industry.

METHODOLOGY

The first step of this research consisted in the understanding of the causal loop diagram proposed by Domingos et al. (2015a), to understand the business rules, as well as the reinforcement and balance feedback. Based on this, the model proposed by the authors was adapted and has become the flow model of System Dynamics, which allows a greater detail of the relationship between the process variables and its computational implementation. The SD model was then implemented using real data from a lime industry and was simulated for different scenarios. The analysis of the simulated scenarios was conducted based on a comparison of different performance indicators, to identify the factors that affect the performance of the company in study.

Casual Loop Diagram for the S&OP Process

It can be observed in Figure 1 the causal diagram for the amplified S&OP process developed by Domingos et al. (2015a). The variables considered in the model were distributed in seven macroprocesses: supplies, production, capacity, sales forecast, absorption costing, billing/economic analysis and cash flow. The cause and effect relationships between the variables of these seven macroprocesses can be seen in Figure 1.

In Figure 1, each arrow depicts a relationship of cause and effect between two variables. The positive relations imply that the variables increase or decrease in a direct correlation. For example, an increase in “billing” consequently increases “bills to receive”. On the other hand, the negative relationships establish an inverse relationship. For example, when “sales” are increased, the “finished product stock” is decreased.

The causal loop diagram presented in Figure 1 is basically comprised of two types of feedback loops: positive (reinforcement loop) and negative (balance loop). In a reinforcement loop, the system status will continue to increase or decrease over time, and in the balance loop, the system has a tendency to stabilize (Hsieh, 2018).

Through the causal diagram, it is also possible, in a more strategic way, to understand the relationships between the seven macroprocesses. In this way, an increase in the sales plan (sales

Figure 1. Causal loop diagram (Source: Domingos et al., 2015a)

forecast macroprocess) causes an increase in the production plan (production macroprocess) and in the supplies acquisition supplies (supplies macroprocess) - positive relation. On the other hand, this increase in the production plan (production macroprocess) causes an increase in the planned capacity per work center (capacity macroprocess) - positive relation - which can limit production according to the increase in restriction of the available capacity of the work centers - negative relation.

The variation in the production and supplies acquisition also impacts the absorption costing macroprocess as an increase in production orders and supplies increases the variable production costs and, consequently, the total cost of production - positive relation. An increase in these costs, along with the labor costs, the taxes of sales and the administrative, financial and commercial expenses (billing and economic analysis macroprocess) have a positive impact, in turn, on the bills to pay (cash flow macroprocess). On the other hand, an increase in the labor costs and the net price of raw material (absorption costing macroprocess), increases the financial restriction of the company (cash flow macroprocess), reducing, therefore, the purchase list (supplies macroprocess) and the capacity adjustment (capacity macroprocess) - negative relation. The finished product stock (production macroprocess) also has an inverse relationship with the average unit cost of finished product (absorption costing macroprocess).

The bills to receive variable of the cash flow macroprocess is also influenced by the variable billing of the billing and economic analysis macroprocess since an increase in sales (sales forecast macroprocess), causes an increase in billing (billing and economic analysis macroprocess) which generates, consequently, an increase in bills to receive (cash flow macroprocess) - positive relation.

System Dynamics Model for the S&OP Process

The SD model developed by Domingos et al. (2015a) for the amplified S&OP process used 216 elements subdivided into variables of the type stock, flow and auxiliaries. To make the model consider

n families of finished products with their respective n raw materials and production resources, several variables were considered as matrices. The complete mathematical formulation of the model is available in Santos (2017). The model's deployment targets discrete manufacturing companies and those that Make-to-Stock (MTS). The seven macroprocesses and the adaptations made in this work are found below.

The sales forecast input variable is exogenous, since the model does not have the intention to carry out forecasting methods and is depicted by the average value of a probabilistic distribution defined in the auxiliary variable "SalesPlan". We also used a simple exponential smoothing method, connecting the stock variable "Demand" and the variable flow "InputSalesForecast" with the purpose of generating the initial stock plan (Figure 2).

As shown in Figure 2, the data relating to sales forecast and inventory plan are linked to the production macroprocess, which constitutes an initial inventory and sales plan. The input variable "sales forecast", since it is crucial for the S&OP process, will assume different values to analyze its effect on performance indicators selected from the generation of scenarios.

The company analyzed in this study had no sales forecast method. To do that, we used the forecast package of the R® software to generate the input data of sales forecast based on a time series. Historical data relating to sales of the period from January 2013 to April 2017 were used, with the exception of the product C, which is new in the market, having been launched in January 2015.

The production macroprocess directly encompasses the production, supplies, capacity, cash flow and sales forecast macroprocesses. The production plan is constituted by the bill of materials of product families. In this macroprocess, the volume of raw material is interconnected to supply and cash flow. Once it is missing, it becomes necessary to request the volume to be bought. It is crucial to identify the available capacity of the centers of restricted work to define the volumes of production orders and release the raw material for the Work in Process (WIP) which encompasses, in addition to raw material, the hours of labor required. The production orders are only completed after the production cycle, which is calculated using a probability distribution for each family of products. After this process, the finished product is sent to the stock and made available for sales, as illustrated in Figure 3.

The "Supplies" macroprocess (Figure 3) has, as an input data of the "Production" macroprocess, a bill of material to meet the production plan. Based on this, the required calculation of raw material to be purchased is made. It takes into consideration the stock levels of raw material available, purchase

Figure 2. Sales forecast model (Source: Domingos et al., 2015a)

Figure 3. “Production” and “Supplies” model (Source: Domingos et al., 2015a)

amount during the acquisition process and the coverage of raw material stock. After calculating the amount of raw materials to be purchased, the monthly purchase price per unit for the planning period is obtained.

Also regarding this macroprocess, the amount available in the “box” variable is considered a restriction. The purchase requisitions are confirmed only if there is a limit of cash available for purchase. Solely the approved purchases are transferred to the purchasing portfolio, in which they wait until the pre-established period of supply of raw material is fulfilled. The stock inputs in values of acquisition costs and quantity occur simultaneously in the model.

The “Capacity” macroprocess analyzes the capacity of each restricted work center. The main input data is the volume of finished product defined in the production plan. Based on this information, the total number of hours worked is calculated, taken into consideration the productivity and the default time for the production of a unit of each product family. This way, the total number of hours planned per restricted work center is obtained, as well as the percentage of capacity allocation for each product or family of products (Figure 4). The hour adjustment is done by comparing the planned hours and the hours of standard capacity defined by the restricted center. If the adjustment is positive, it will be necessary to increase overtime hours to ensure that the production plan is carried out. Nevertheless, some restrictions should be analyzed, such as: the impact of the additional cost of overtime hours in cash flow, the volume of overtime hours and the delay required to carry out this adjustment.

In the “Absorption Costing” macroprocess, the costs are appropriated according to the absorption costing, which is an accepted and widely used method by the accounting sector, mostly providing reports intended to reach the public outside the company. All fixed, variable, direct and indirect costs are appropriate to the products.

In this macroprocess, unlike Domingos et al. (2015a), another indicator was calculated: the accounting breakeven point. Also known as a cost-volume-profit diagram, the breakeven point represents the level at which the sales volume covers the costs. In other words, after hitting the breakeven point, the company starts to get profits and, if it stays below, it represents a warning situation, as the company is unable to cover its own costs with sales (Crepaldi, 2010).

This indicator becomes relevant to the extent that provides the cost-volume-profit relation by integrating the macroprocesses of sales, costing and economic analysis, thereby granting support for

Figure 4. “Capacity” model (Source: Domingos et al., 2015a)

decision-making. The area “a” of Figure 5 corresponds to the calculation of the indicator “Accounting Breakeven Point”.

This macroprocess also encompasses the cost-type variables, such as costs with production general expenditures (WIP GGP), raw material (WIP MP), labor force (WIP MO), fixed asset intended for the production (Immobilized Cost), expenditure with fixed asset (Immobilized Expenses), cost of raw material stock (RMInventoryCost) and cost of finished product stock (CostProductStock). It is worth noting that the costs of finished product and raw material stocks are updated based on the mobile average cost in accordance with the inputs by purchase acquisition and production costs for the period (Figure 5).

The sixth macroprocess, “Billing and Economic Analysis” (Figure 6), is related to the macroprocesses of production, capacity, sales and costs. The stock variables of expenditure with a fixed asset, cost with raw material stock and costs of production stock described in the macroprocess absorption costing are interconnected in this process. There are also the stock variables of in-process billing and accounts receivable. The variable in-process billing arises from the macroprocess sales through auxiliary variables.

In the model developed by Domingos et al. (2015a), the type of taxation used in the simulation was the “PresumedProfit”, with pre-fixed taxes and with determined characteristics for specific types of businesses by option or by the imposition of Brazil’s tax office. In this study, this macroprocess was adapted to the tributary system “Simples Nacional” (Figure 6(a)), used in Brazil by micro and small businesses whose annual revenue is R\$ 4.8 million at most, being chosen by the company researched.

Due to the adaptation of the tax system, it was also necessary to have changes in other variables of this macroprocess, such as: in the Markup indicator (Figure 6(b)), all taxes of the sole tax rate of “Simples Nacional” were taken into account and, in the indicator Earnings Before Interest, Taxes, Depreciation and Amortization (EBITDA), taxes on sales of the “Simples Nacional” were extracted to calculate the earnings before interest, taxes, depreciation and amortization. Thus, taxes on income - income tax (IR) and Social Contribution on Net Income (CSLL) - were separated and excluded from the single tax rate of “Simples Nacional” and for EBITDA calculation purposes only the taxes on sales were deducted from the gross billing. As Frezatti and Aguiar (2007) suggest, EBITDA is an indicator of the organization’s income statement in which interest, financial expenses, IR and CSLL (taxes on income), depreciation and amortization are excluded in order to get a similar value of the operating cash flow.

Figure 5. “Absorption Costing” model adapted (Source: Adaptaded from Domingos et al., 2015a)

Figure 6. “Billing and Economic Analysis” model adapted (Domingos et al., 2015a)

The last macroprocess described is the “cash flow” (Figure 7). The objective of this macroprocess is to depict the projections of payments and receipts on a monthly basis, from the variable “billing” obtained by the revenue generated in the sales plan. The macroprocesses of costs and supplies also provide information of payments to be made by the purchasing of raw materials and the payment of salaries, expenditures, overheads and taxes. Therefore, the balances of accounts payable and receivable are simulated using the average time of receipt and payments of cash inflows and outflows.

The equations of the original SD model are available at Domingos et al. (2015a) and the model adapted at Santos (2017).

Figure 7. “Cash Flow” model adapted (Domingos et al., 2015a)

Case Study Description

The industry researched is found among the seven largest lime producers which deserve to be emphasized in the southeastern region of Brazil (Consultoria, 2009). This fact is mainly related to the proximity to the source of abundantly available raw material (deposits of limestone) in the region. Besides, the industry is located between outflow roads that target several regions of the country.

Currently the industry produces and sells five types of products in five different regions. The products are targeted for civil construction, soil correction and recovery, asphaltic plants, metallurgy and sugar plants.

On the other hand, it should be mentioned that the bargaining power of suppliers is considered high in this sector. The harvesting period of sugarcane forces the suppliers to prioritize the sale of raw material for the sugarcane plants. Consequently, the purchase prices of raw material rise, impacting the direct costs of production of lime industries in the region. In contrast, consumers also have bargaining power on the product, hence they do not absorb the increase in the selling price to cover this rise in costs. Therefore, the industry researched must manage its resources efficiently and effectively to ensure their economic and financial sustainability.

Scenarios

The scenarios developed to simulate the expanded S&OP system of the company researched were divided into micro and macroenvironments. The objective of the different scenarios simulation is to assist the company with the crucial making decision processes (Bhushan, 2017). In the microenvironment scenario, only the internal perspective of the company was considered, such as the sales forecast based on the time series generated from the forecast package of R® software, the coverage of the raw material stock and stock plan of finished product provided by the company.

In this way, to create the microenvironment scenarios, it was used, akin to Domingos et al. (2015a), the variation of three factors: sales forecast, stock plan of finished product and coverage of the raw material stock. These three factors were combined in the microenvironment scenario with two levels, forming eight scenario combinations.

In this scenario, it was considered:

- In sales forecast, the following were generated from the company's historical data "Sales forecast 0- A_0 " and "Sales forecast 1- A_1 ", in the R® software through a time series. The A_0 level corresponds to the point forecast and the A_1 level to the upper limit of the forecast (Ho95);
- In the stock plan of finished product, the "Stock Plan 0 - B_0 " represents the current level of the company's storage. In turn, the B_1 corresponds to a 20% reduction of the stock of finished product;
- Finally, the factor coverage of raw material stock was characterized by the factor C_0 and C_1 . The first factor corresponds to the company's current stock for 5 months, according to the model's validation. In turn, the second factor (C_1) was represented by a 4-month level.

For the macroenvironment, the lime's duodecennial plan, developed by Consultoria (2009), was the basis. The plan consisted in the forecast of lime consumption for the period ranging from 2010 to 2030 in Brazil. The plan considered three scenarios based on the projection of the Brazilian economy for the aforementioned period. It should be noted that the authors used, as an economic indicator, the country's GDP (Gross Domestic Product). According to the plan, the fragile scenario portrays the period of stability and retrocession, whereas the vigorous scenario can be characterized by stability and reforms and, finally, the innovative scenario suggests stability, reform and innovation.

From these scenarios, Consultoria (2009) developed the projection of GDP for the period 2010-2015, 2015-2020 and 2020-2030, as stated in Table 1.

According to the scenarios outlined, a forecasting model of lime demand was adjusted (Consultoria, 2009). The adjusted model, and made available in the plan, was the auto-regressive distributed lag model in which the future behavior of consumption of lime (Cal) depends on the historical data of production of lime (C) and GDP, according to the following expression:

$$\ln \text{CAL} = 0.76949 * \ln C + 0.811311 * \ln \text{GDP} + 0.066831 * \ln \text{Cal}(-1) \quad (1)$$

To estimate the values of sales forecast based on GDP in the period ranging from 2015 to 2020, for the macroenvironment scenarios, the library dynlm of the R® software was used, applying the loop for to the estimated equation (Equation 1).

In addition to the sales forecast of the three aforementioned macroenvironment scenarios, we used the auto-regressive distributed lag model to analyze the variation in the price of acquisition of lime regarding the GDP's behavior. According to the model, the lime's cost increased by 11.55% in relation to the validation model whose arithmetic average was R\$ 94.80/ton and started to be considered R\$ 105.75/ton for the simulations of macroenvironment scenarios.

This analysis allowed to identify how the price may influence the company's internal structure, since the processing industry is subject to price fluctuations during the harvesting period. On the other

Table 1. Scenarios for the future of Brazilian economy

Economic Indicators	Scenario 1	Scenario 2	Scenario 3
	Fragile	Vigorous	Innovative
	Instability and Reverse	Stability and Reform	Stability, Reform and Innovation
GDP (%)	2.3	4.6	6.9
2010 to 2015 period	2.8	4.0	5.0
2015 to 2020 period	2.5	4.5	6.5
2020 to 2030 period	2.0	5.0	8.0

Source: Consultoria (2009)

hand, it was not possible to forecast changes in prices of products since the market is very sensitive to changes and, according to the managers' report, it does not absorb, becoming a factor of internal structure to be worked by the company to try to minimize the impact of rising costs.

In this way, 12 combinations were obtained from three levels of sales forecast and two levels of the stock plan of finished product and coverage of raw material stock. The values of three levels of sales forecast were obtained employing an auto-regressive distributed lag modeling relation to the GDP, characterized by three scenarios: fragile (A_1), vigorous (A_2) and innovative (A_3).

It should be noted that since the study that was the basis to estimate this works' sales forecast was carried out in 2009, the projections made in this paper have not considered the events occurred in 2018, such as the truck drivers' crisis in Brazil and the current exchange rate changes due to speculation in the presidential elections. These uncertain events can affect GDP projections and, consequently, demand and forecast sales. Therefore, it is recommended to regularly update the sales forecasts used in the model and perform new simulations in order to obtain accurate results in relation to the context of the analyzed period.

All the input data of the simulated model regarding the company researched and the different scenarios are available in Santos (2017).

RESULTS AND DISCUSSION

The adapted model was implemented and simulated using the IThink® software. The method of integration chosen was the Euler method, since it is the only method among those available (Euler, Runge-Kutta 2nd and 4th order) in the software used, which allows the use of Cycle-Time, the implementation mode of the developed model. The time-step (dt) used was 0.125 month. This was the time-step that represented the simulated system the best during the period analyzed.

Model Validation

To validate the model adapted to the reality of the company researched, first historical data was collected in the period ranging from January to December 2016. The use of this period is justified by accounting records provided by the company.

With the intent of checking how close the results obtained with the simulated model were to the results of the actual system, a measure of percentage relative error (PRE) was used. Then, the measurement error was defined by:

$$PRE = \left[\frac{Xr - Xs}{Xr} \right] \times 100\% \quad (2)$$

in which Xr are the real values or quantities and Xs are the simulated values or quantities, obtained through the proposed model.

As well as Domingos et al. (2015a), to obtain more reliable results, 10 replications for each scenario were conducted, since some model's variables are stochastic and, therefore, were modeled using probability distributions. In these 10 replications, the initial state of the system remained the same, only changing the seeds of random number generators in each simulation. The performance indicators of total net profit, the percentage of contribution margin, the percentage of total net margin, the sales plan's completion percentage, the percentage of use of restricted capacity, the total production and accounting breakeven point were calculated as the average of these 10 replications.

In this way, the annual PRE of the performance indicators of total production, gross revenue and net revenue was on average 5.6%. It was not possible to validate the indicator "capacity of the restricted center", since the company did not have statistical control of the process. It was not possible to validate the indicator "sale's plan attendance percentage", given that the company had no sales

forecast to oppose “forecast” and “demand”. Since historical data and sales forecast were used in the validation, the percentage of 94.09% of the sale’s plan attendance of the historical sales was obtained.

Having in mind these results, the PER of three performance indicators being less than 6% and percentage of sale’s plan attendance being greater than 90%, it can be assumed that the proposed model accurately depicts the reality of the company researched in this study.

Analysis of the Results of the Microenvironment Scenarios

Table 2 displays the results of the performance indicators obtained through the simulation of each of the scenarios of the microenvironment.

Based on the results shown in Table 2, when considering the average point of forecasted sales generated in the R® software, scenarios $A_0B_0C_0$, $A_0B_0C_1$, $A_0B_1C_0$ and $A_0B_1C_1$, the total simulated production stayed around 6% below the actual total production for the previous year (2016), which was of 7,540.98 kg. Keeping the current levels of input data of the validation model, except the update of the values of costs and prices for the year 2017, and values of sales forecast, in the scenario AoBoCo the percentage of sales plan’s attendance was better than the one of the validation model, being 97.29%.

On the other hand, it should be emphasized that, in every simulated scenario, the accounting breakeven point was higher. In the period of the validation model, the monthly average breakeven point was R\$ 55,818.30. In turn, in the period ranging from May/2017 to April/2018, the average breakeven point was R\$ 89,939.10 for the first scenario $A_0B_0C_0$, for instance. This increase of 61.12% in the “accounting breakeven point” can be mainly characterized by adjusting the cost of raw material without mirroring such increase in the products selling price.

Another important point that should be highlighted is related to the stock coverage of finished product (factor C). According to information provided by the company, it would be necessary to invest about R\$40,000 in the expansion of its storage area, since it is not possible to store the products in outdoor environments, since they are influenced by storms.

In the simulations, it was found that by keeping the current stock level of finished products (C) or reducing it in 20% (C_1), the company will be able to attend on average 95% of its sales plan for the first four simulated scenarios. Therefore, it is not yet necessary to invest in the expansion of the stockage area, since with a PPC (production planning and control), the latter will be able to address their consumers.

Table 2. Performance indicators obtained from microenvironmental

	Total Net Profit (R\$)	Net Profit Margin (%)	Contribution Margin Rate (%)	Use of Restricted Capacity (%)	Sales Plan Attendance (%)	Total Production (1,000)	Break-Even Point (R\$)
$A_0B_0C_0$	148,983.47	15.64	39.64	16.65	97.27	7,123.26	89,939.10
$A_0B_0C_1$	150,380.12	15.78	39.76	16.65	97.29	7,117.45	89,430.25
$A_0B_1C_0$	149,616.36	15.87	39.68	16.49	96.08	7,026.90	89,148.42
$A_0B_1C_1$	151,759.58	16.11	39.87	16.49	95.91	7,023.76	88,437.22
$A_1B_0C_0$	445,061.51	21.04	39.31	41.01	93.95	14,013.60	79,099.01
$A_1B_0C_1$	440,597.33	20.98	39.30	41.10	93.29	13,901.82	79,284.57
$A_1B_1C_0$	442,286.43	21.12	39.37	40.51	93.13	13,868.52	78,801.85
$A_1B_1C_1$	434,685.42	21.17	39.47	40.62	91.36	13,597.25	78,719.50

Total net profit (R\$) = TotalNetProfit

Contribution margin percentage (%) = Contribution Margin Perc

Use of restricted capacity (%) = PercUtil_PlanCpRest [6]

Sales plan attendance (%) = SalesPlanAttendance%

Concerning financial indicators (net profit, percentage of net margin), the scenarios $A_1B_0C_0$, $A_1B_0C_1$, $A_1B_1C_0$, $A_1B_1C_1$, in which the upper limit of sales forecast was taken into account, presented more favorable results regarding the remaining scenarios, as expected. Since these indicators are regarded as crucial for businesses, these scenarios may be considered target scenarios for the company to get good results.

On the other hand, when considering the percentage of sales plan's attendance, it is observed that the scenarios characterized by the sales forecast A_1 , despite producing a quantity greater than the scenarios with sales forecast A_0 , shows a reduction in the value of this indicator of around 93%. This fact can be characterized by the absence of cash in hand for the purchase of raw material or even the lack of it.

Finally, it should be noted that, as the coverage of raw materials stock is reduced and the finished product inventory is at 20%, the "accounting breakeven point" consequently decreases (scenarios B_1C_1). In turn, based on the indicator usage percentage of the center of restricted capacity, it is possible to state that this center is oversized since, even in scenarios with higher sales forecast (A_1), a maximum 41.1% of its total capacity available was actually used.

During the simulations of scenarios in this study, the behavior of the gross income of the last 12 months was observed. As expected, the increase in sales plan resulted in an increase in the rate base of "Simples Nacional". Therefore, in the scenarios that used the sales plan 1 (A_1), the annual gross revenues for the months of March and April of 2018 reached a value exceeding R\$ 4 million at one point. This means that, for those months, the gross revenue of the company would be above 3.6 million, which is the limit allowed for the use of the tax system "Simples Nacional" in the year 2017 (Casa Civil, 2017). However, this fact still does not require a change in the company's tax system since, in the year of 2018, the new cap and the basis of calculation started to be used.

In the meantime, this fact draws the company's attention to outline a tax planning for the next year, since its position in the system "Simples Nacional" may no longer be suitable or it can even be barred by extrapolating the limit imposed by the law if its gross revenue increases.

Analysis of the Results of the Macroenvironment Scenarios

The nation's political-economic suggests that the company head quartered here have to be more careful, since the stagnation and crisis period in the country, which emerged after the World Cup in 2014, became even more obvious with the impeachment of the president, corruption scandals, among other factors.

The scenario goes through labor and social security restructuring and successive tax increases to restrict the budget imbalance and the public deficit (Brazilian Embassy in Washington, 2017). These actions cause a chain reaction, particularly in companies, something that fosters uncertainties and the constant need for planning.

Therefore, the macroenvironment analysis is in line with these issues, since it considers periods of restructuring, innovation or stabilization to the specific sector of the company researched. On the other hand, one cannot say with a strictness that these results will be ideal.

The goal is to guide the company examined and give a quantitative basis to help in its decision-making, as well as to identify some factors that can strongly influence its results. Table 3 shows the results obtained through simulations of 12 scenarios generated from the variations of sales forecast, coverage of raw material stock and stock of finished product.

According to Table 3, a little sensitivity can be noticed about the scenarios by changing the three factors with the two levels (current and reduced). However, in a comparative analysis between the first scenario $A_1B_0C_0$ of the macro environment, in which the only changes were the input data of sales forecast (fragile scenario) and the microenvironment scenario $A_0B_0C_0$, the net profit of the macro environment scenario had an increase of 72.44%, being equal to R\$ 148,983.47 ($A_0B_0C_0$ scenario - microenvironment) and R\$ 256,910.15 ($A_1B_0C_0$ scenario - macroenvironment).

Table 3. Performance indicators obtained from macroenvironmental

	Total Net Profit (R\$)	Net Profit Margin (%)	Contribution Margin Rate (%)	Use of Restricted Capacity (%)	Sales Plan Attendance (%)	Total Production (1,000)	Break-Even Point (R\$)
A ₁ B ₀ C ₀	256,910.15	17.25	39.12	28.52	96.47	10,151.79	90,524.94
A ₁ B ₀ C ₁	255,378.97	17.19	39.09	28.50	96.31	10,131.51	90,740.19
A ₁ B ₁ C ₀	244,129.10	16.71	39.16	28.11	95.20	10,031.90	90,116.75
A ₁ B ₁ C ₁	254,004.94	17.31	39.09	28.14	94.99	10,002.03	90,567.34
A ₂ B ₀ C ₀	256,035.64	17.18	39.04	28.52	96.49	10,165.87	90,767.70
A ₂ B ₀ C ₁	256,996.60	17.23	39.09	28.52	96.56	10,143.25	90,747.18
A ₂ B ₁ C ₀	252,663.98	17.20	39.10	28.10	95.29	10,010.12	90,363.18
A ₂ B ₁ C ₁	252,855.94	17.23	39.11	28.12	95.16	10,002.44	90,561.12
A ₃ B ₀ C ₀	271,439.54	16.92	39.17	30.63	95.78	10,981.39	91,758.93
A ₃ B ₀ C ₁	275,094.00	17.14	39.32	30.66	95.64	10,956.66	91,307.29
A ₃ B ₁ C ₀	271,276.27	17.10	39.26	30.20	94.58	10,840.40	91,482.73
A ₃ B ₁ C ₁	270,146.54	17.05	39.23	30.22	94.46	10,831.14	91,648.23

Total net profit (R\$) = TotalNetProfit

Contribution margin percentage (%) = Contribution Margin Perc

Use of restricted capacity (%) = PercUtil_PlanCpRest [6]

Sales plan attendance (%) = SalesPlanAttendance%

Even though the scenarios depicted above indicate an increase in the total production concerning the scenarios A₀ of the microenvironment, and concerning the validation scenario and, consequently, increased financial performance indicators, it is worth noting that caution becomes necessary. To broaden the horizon of analysis, information from different sources and experts on the current economic-political scenario of the country, as well as growth projections, have been searched.

Starting with the leading representatives of the country's financial institutions, the president of Itaú BBA, and also responsible for the operations of ItaúUnibanco, Eduardo Vassimon believes that no radical changes will happen in 2018. "We still have uncertainties about the fiscal environment, which is the main issue today. Recent facts show that there is no (political) climate to raise taxes, for instance" (Scaramuzzo, 2017).

The prospects are unanimous when it comes to considering the pause in the economy's recovery, with the executive whistleblowing of brothers Batista, owners of JBS, part of the food industry. A fact consubstantiated in the interview of Hans Lin, manager of Bank of America. In turn, according to Júlio Mereb, a researcher from the Brazilian Institute of Economics of Fundação Getúlio Vargas, the GDP will grow 1.8% in 2018, below the estimate of 2.5% (Gerbelli, 2017). According to the Brazilian Economics Institute (IBRE), in 2018 the industry is expected to grow by 2.4%, four percent below the forecasts. As for the Brazilian Embassy in Washington (2017), the GDP is expected to increase by 1% in 2017 and 2.5% in 2018.

This way, in accordance with the forecasts and perspectives of experts, it can be concluded that, even though the reforms mentioned above are expected to be implemented, as well as an economic recovery with a GDP growth of 2% to 2.5% in 2018, the conclusion is that the most favorable scenario depicted in the context of macroenvironment is the fragile, albeit the prospect of reforming measures (vigorous scenario). In this way, the scenario A₁B₁C₁, characterized by the sales forecast of the fragile scenario, and the reduction of coverage of raw material stock and stock plan of finished product, at the present moment, represents the way according to which the company should guide itself, since,

among the simulated fragile scenarios (A_1), this was the one that showed the best results for the financial indicators.

So, even if in the macroenvironment scenarios the performance indicators have been better regarding the indicators of the validation scenario and microenvironment scenarios (A_0), caution is suggested in decision-making, as well as constantly making new simulations, taking into account the new market forecasts, given the uncertainties of the country's political-economic scenario.

CONCLUSION

The objective of this study was to analyze the S&OP of a Brazilian small lime industry, based on system dynamics technique, to identify and understand the causal relations between its internal process and the influences on organizational management.

The model's simulations allowed an analysis of the balance between supply and demand of the company researched, considering the restrictions of the company's productive system and even generating satisfactory financial results. Also, it was possible to simulate different scenarios by providing additional information for decision-making, from the strategic to the operational level of the company. It was analyzed the impacts of the variables of the internal structure of the company (microenvironment) and the influence of external variables (macroenvironment) in the system. It was observed that the sales forecast is one of the factors that most impact the system.

Even though the simulations results of scenarios A_1 point out to growth prospects of the company, one must be careful. The uncertain environment around the Brazilian political landscape, and the possible ongoing reforms, require a greater attention from managers. This way, new simulations are recommended on a constant basis.

SD proved to be effective for the S&OP integrated with the financial management of the company researched. The model implementation in the sector of calcination brought academic and organizational gains, for one of the most profitable industries of the country, while facing changes in the micro and macro business environment.

Regarding future works, adapting the model to fit the make-to-order (MTO) concept, and attach it to other simulation techniques, such as the technique of discrete event simulation, is recommended. This would allow the company to better understand the system, not only from a strategic and tactical standpoint, but also operational. In addition, an expansion of the model is recommended in order to consider the two types of tax systems used in Brazil, "Presumed Profit" and "Simples Nacional", with the objective of generalizing the use of the model to small, medium and large companies, not restricting the use of the model to the company's revenue. By doing so, the company could compare the effect of a tax regime change due to an increase in sales, which would assist in its tax planning.

REFERENCES

- Al-Kadeem, R., Backar, S., Eldardiry, M., & Haddad, H. (2017). Review on using system dynamics in designing work systems of project organizations: Product development process case study. *International Journal of System Dynamics Applications*, 6(2), 52–70. doi:10.4018/IJSDA.2017040103
- Atkinson, W. (2008). Now More than ever. *Supply Chain Management Review*. Retrieved from http://www.who.int/whr/2008/whr08_en.pdf
- Bhushan, S. (2017). System Dynamics Base-model of Humanitarian Supply Chain (HSCM) in Disaster Prone Eco-Communities of India: A Discussion on Simulation and Scenario Results. *International Journal of System Dynamics Applications*, 6(3), 20–37. doi:10.4018/IJSDA.2017070102
- Brazilian Embassy in Washington. (2017). *The brazilian economy towards sustainable growth (Document Series I)*. Washington, DC: Press and Public Affairs Office.
- Casa civil. (2016). Lei nº 155. Brasília: Subchefia para assuntos jurídicos. Retrieved from http://www.planalto.gov.br/ccivil_03/leis/LCP/Lcp155.htm
- Crepaldi, S. A. (2010). *Curso de contabilidade de custos*. São Paulo, Brasil: Atlas.
- Crespo, A. M., Bianchi, C., & Gupta, J. N. D. (2004). Operational and financial effectiveness of e-collaboration tools in supply chain integration. *European Journal of Operational Research*, 159(2), 348–363. doi:10.1016/j.ejor.2003.08.020
- Domingos, J. C., Politano, P. R., & Pereira, N. A. (2015a). Modelo de Dinâmica de Sistemas para o processo de S&OP ampliado. *Gestão & Produção*, 22(4), 755–788. doi:10.1590/0104-530X1702-14
- Domingos, J. C., Politano, P. R., & Pereira, N. A. (2015b). Uma revisão sobre o uso de dinâmica de sistemas em planejamento de vendas e operações. In *Proceedings of the XXII Simpósio Engenharia de Produção Política Nacional Inovação e Engenharia Produção*. Retrieved from www.researchgate.net/publication
- Frezatti, F., & Aguiar, A. B. (n.d.). EBTIDA: possíveis impactos sobre o gerenciamento das empresas. *Revista Universo Contábil*. Retrieved from <http://proxy.furb.br/ojs/index.php/universocontabil/article/view/593>
- Gafi, E. G., & Javadian, N. (2018). A system dynamics model for studying the policies of improvement of chicken industry supply chain. *International Journal of System Dynamics Applications*, 7(4), 20–37. doi:10.4018/IJSDA.2018100102
- Gerbelli, L. G. (2017, Junho 12). Crise política afetará economia em 2018. Retrieved from <http://exame.abril.com.br/economia/crise-politica-afetara-economia-em-2018-dizem-analistas>
- Gholizad, A., Almadi, L., Hassannayebi, E., Memarpour, M., & Shakibayifar, M. (2017). A system dynamics model for the analysis of the deregulation in electricity market. *International Journal of System Dynamics Applications*, 6(2), 1–30. doi:10.4018/IJSDA.2017040101
- Hsieh, Y.-H., & Chou, Y.-H. (2018). Modeling the impact of service innovation for small and medium enterprises: A system dynamics approach. *Simulation Modelling Practice and Theory*, 82, 84–102. doi:10.1016/j.simpat.2017.12.004
- Ivert, L. K., & Jonsson, P. (2010). The potential benefits of advanced planning and scheduling systems in sales and operations planning. *Industrial Management & Data Systems*, 110(5), 659–681. doi:10.1108/02635571011044713
- Iyengar, C., & Gupta, S. (2013). Building Blocks for successful S&OP. *Supply Chain Management Review*. Retrieved from <http://web.b.ebscohost.com/ehost/pdfviewer/pdfviewer>
- Kralik, L. S., & Folgliatto, F. S. (2016). Método para implementação de planejamento de vendas e operações (S&OP) aplicado em empresas do ramo automotivo. Retrieved from <http://web.a.ebscohost.com/ehost/pdfviewer/pdfviewer>
- Mendo Consultoria, J. (2009) Produtor RT22: perfil da cal. Retrieved from <http://www.mme.gov.br/documents>
- Nikabadi, M. S., & Hakaki, A. (2018). A dynamic model of effective factors on open innovation in manufacturing small and medium sized companies. *International Journal of System Dynamics Applications*, 7(1), 1–26. doi:10.4018/IJSDA.2018010101

Platt, A. A., & Klaes, L. S. (2010). Utilizando o Sistema Integrado de Gestão (ERP) no apoio ao ensino de logística e gestão da cadeia de suprimentos. *Revista de Ciências da Administração*, 12(28), 224–241.

Prokopets, B. L. (2012). Ong Advocated in the Pages. *Supply Chain Management Review*. Retrieved from <http://web.b.ebscohost.com/ehost/pdfviewer>

Santos, N. T. (2017). Análise e simulação do processo de S&OP integrado à gestão financeira de uma indústria: uma abordagem de dinâmica de sistemas. Unpublished master's thesis, Instituto de Educação Tecnológica, Belo Horizonte.

Scaramuzzo, M. (2017, Agosto 12). Bancos estão otimistas com retomada. Retrieved from <http://economia.estadao.com.br>

Singh, L. (2011). What makes a winning S&OP. *Supply Chain Management Review*. Retrieved from http://www.scmr.com/article/what_makes_a_winning_sop_program

Spiegel, B. (2011). Tallying the Benefits of S & OP. *Supply Chain Management*. Retrieved from <http://web.b.ebscohost.com/ehost>

Sterman, J. D. (2002). *Business dynamics: System thinking and modeling for a complex world*. New York: McGraw-Hill.

Suryani, E., Chou, S. Y., Hartono, R., & Chen, C. H. (2010). Demand scenario analysis and planned capacity expansion: A system dynamics framework. *Simulation Modelling Practice and Theory*, 18(6), 732–751. doi:10.1016/j.simpat.2010.01.013

Thomé, A. M. T., Scavarda, L. F., Fernandez, N. S., & Scavarda, A. J. (2012). Sales and operations planning and the firm performance. *International Journal of Productivity and Performance Management*, 61(4), 359–381. doi:10.1108/17410401211212643

Vlachos, D., Georgiadis, P., & Iakovow, E. (2007). A system dynamics model for dynamic capacity planning of remanufacturing in closed-loop supply chains. *Computers & Operations Research*, 34(2), 367–394. doi:10.1016/j.cor.2005.03.005

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