Scenario analysis of Brazilian soybean exports via discrete event simulation applied to soybean transportation: The case of Mato Grosso State

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1. Introduction

In recent years, few countries have grown as much as Brazil in international agribusiness trade. The country is now a world leader in the production and export of various agricultural products. Since 2013, Brazil has been the largest soybean exporter (CONAB, 2014). In 2015, Brazil exported 54.32 million metric tons (MT) of soybeans, an amount 19.1% higher than the 45.6 million metric tons exported in the previous year, corresponding to 40.2% of the soybeans exported worldwide (ALICEWEB, 2017; ANEC, 2015). In 2016, Brazil is expected to export 55.3 million metric tons of soybeans, reinforcing its position as the world leader in soybean exports (ABOVE, 2016).

Soy is the leading agribusiness commodity in Brazil (Dall’agnol, Roessing, Lazzarotto, Hirakuri, & Oliveira, 2007; Hirakuri, 2013). Soy and soy derivative exports account for approximately 11% of the total value of Brazilian exports (ABOVE, 2016). The growth in this sector has had a significant impact on the business environment in Brazil. The force of the soy supply chain creates a situation in which Brazil can act as a geopolitical and geo economic player, with the capacity to influence global commodities markets (Hirakuri & Lazzarotto, 2014).

In terms of production costs, Brazil has comparative advantages pertaining to soy production in relation to its international competitors, these advantages being territorial, climatic, and technological in nature (Lopes, Lima, & Ferreira, 2016; Salin, 2016). However, these advantages are reduced when products enter the inefficient logistics flow found in Brazil (Dubke & Pizzolato, 2011; Friend & Lima, 2011). Transportation and storage inefficiencies represent the main problems for agribusiness, which significantly affect Brazil’s international competitiveness (Branco & Caixeta-Filho, 2011; Enomoto & Lima, 2007; Fioroni et al., 2015; Kussano & Batalha, 2012).

Since soy is a commodity priced in the international market, it is not possible to control its sale price, with the only controls available being operational and management costs. Furthermore, Brazilian soybean plantations are located in the inland portions of the country which creates bigger challenges for product distribution logistics country (Fioroni et al., 2015; Lopes et al., 2016). The state of Mato Grosso is no exception to the rule. Located in the Midwest, Mato Grosso is the largest producer and exporter of Brazilian soybeans, representing approximately 30% of national production, and has no seaports within a 900 km radius (Lopes et al., 2016). Currently, the main destinations for soybeans from this state are the ports of Santos, in the state of São Paulo, and Paranaguá, in Paraná (ALICEWEB, 2017). These ports are also the main destinations for Brazilian soybeans and, despite having better infrastructure among national ports, they are saturated in terms of productivity and cannot keep up with the growth of export. Organizations involved with soybean logistics have been developed and gradually implemented in order to make use of other ports around the country. However, public and private investments are necessary to improve these logistics.

The development of transportation axes and infrastructure involve...
great investments. A complex and wide-ranging system such as the one studied herein needs investigation which will support decision-making and minimize the risk of investments and economic, social and environmental impacts. Integrated management of producers and exporters could generate solutions for eliminating these gaps. Currently, private companies, producers and soybean exporters carry out individual logistical management and joint ventures, which autonomously maintain the infrastructure for soybean harvest logistics, with minimal participation from the public sector.

Thus, the construction of a computational model enables a more strategic vision. Starting in the producing regions (in this case, the micro-regions of Mato Grosso), it makes possible the implementation of integrated actions to directly transportation investments.

In the search for effective alternatives to improve the efficiency of this logistics system, Discrete Event Simulation (DES) presents itself as a viable alternative. Recent studies in grain logistics research have generally used static or optimization models; the inter-relations among the variables are not modeled in these cases and the dynamic nature of changes over time in the system is not contemplated. DES has been used increasingly as an auxiliary tool for decision-making, because, through the modeling, analysis, and design of systems, it can show the impact of the parameter changes on system performance, allowing for system analysis as a whole, and not merely in parts (Sargent, 2013). This analysis is accompanied over time and as simultaneous events occur in a random manner, thus differentiating itself from static models which do not possess these characteristics of DES.

The objective of this work is to use discrete event simulation to analyze the behavior of the export system for Brazilian soybeans originating in the micro-regions of the state of Mato Grosso. The main characteristic of the model is the allocation of the soybeans which enter the system, for each discrete event, on the route which incurs the lowest cost and at a destination which has capacity to receive the grain. The model, despite not being an optimization model, seeks the best route for each arrival interval at each origin, along with the best global configuration.

The model includes single- and multi-modal routes for the distribution of solid bulks in Brazil. These single and multi-modal routes include waterways and railways already in operation, as well as waterways and railways projected for future use. The projected routes are potential, or existing, alternatives, such as the waterway Tocantins-Araguaia, or the railways located in southern Brazil. The software used to build the computer model was ProModel®, where, by creating different scenarios major variables in the system were identified, and issues regarding the rationalization of resources were analyzed. This study seeks to offer guidelines for new projects, and to improve the logistical infrastructure of Brazilian soybean exports as well as the export of grains in general.

The constructed model incorporates the insertion of new routes, locations, ports and destinations. However, in a scenario which represents the real system, with the main routes for soybean transportation, the model aims for the best configurations based on lowest route cost and destination availability. Each decision alternative for soybean logistics can be adapted and inserted into the model, enabling the decision-makers to use the model for operational and economic analysis of potential transportation vectors. One additional goal of this study is the assessment of new potential projects for advancement of infrastructure and logistics for Brazilian soybeans and, generically, for grain export, aside from providing a methodology for construction and implementation of DES models for agro-industrial applications.

2. Discrete-event simulation

Simulation is defined as the importation of reality into a controlled environment where real behavior can be studied under different conditions without physical risks and high costs involved stress that simulation is an appropriate approach and widely accepted for detailed analysis of logistics networks, considering the diversity and quantity of input data (Sargent, 2013; Montevecchi, de Pinho, Leal, & Marins, 2007; Tako & Robinson, 2012; Oliveira, Lima, & Montevecchi, 2016).

In the case of soybean export in Brazil, the decision makers need to choose from the many already existing routes for product distribution. This decision requires that many criteria be considered and combined, and that costs and constraints of the logistics system’s capacity be associated with impacts on the system as a whole. Among the studies focused on logistics analysis for commodities, one can see that the models used work mainly with algebraic simulation and mathematical modeling, expressing system relationships in mathematical functions, seeking exact or excellent results. In general, models for planning agro-industrial supply chain in general are still lagging behind compared to manufacturing supply chains (Galal & El-Kilany, 2016). Chwif and Medina (2006) emphasize that in most cases, these models are static and do not have analytical solutions for complex systems, and require simplified hypotheses. Hillier and Lieberman (2010) affirm that simulation is usually used when the real system is too complex to be adequately analyzed by a mathematical model. This study presents a unique and experimental model, using Discrete Event Simulation emulating, via logical relationships, the operation of systems that change their states at discrete points in time, giving information that helps to make decisions related to the problem of Brazilian soybean distribution.

3. Simulation project

In this study the simulation methodology used was that presented by Montevecchi et al. (2007), which has three principal steps: Conception (conceptual model), Implementation (computational model), and Analysis (operational model). These steps will be detailed in the following sections.

3.1. Conception phase

The first step in the modeling process for simulation is the creation of an abstract or conceptual model (Law & Kelton, 2000). The conceptual model was developed using the IDEF-SIM technique presented by Silva, Salgado, Mello, Oliveira, and Leal (2014) and Montevecchi et al. (2010). The choice to use this technique is justified in that its logical application is similar to the logic used in discrete event simulation (Montevechi et al., 2010). Due to the complexity and number of existing networks, the conceptual model developed using IDEF-SIM (Fig. 1) is a standard model and presents the construction logic of all origin-destination networks considered in the model.

In addition to the representation in IDEF-SIM, an example representation of the model from only one origin point, the micro-region of Alto Teles Pires and its possible routes for the 12 considered ports, is also presented in Fig. 2. This representation, starting at only one origin point (the micro-region Alto Teles Pires), behaves identically for all other origins, using the main highways to arrive at the ports and terminals, along with utilization of the railways and waterways.

Upon leaving Brazilian, soy then heads to the international ports, in this model, Shanghai and Hamburg. Similarly, all micro-regions reach the ports in similar ways, with the distances of roads to exporting ports or multimodal shipping points being the key variables. This section will also define the origin points, destinations, shipping points, exporting and importing ports, the resources used on the routes, costs, and validation of the conceptual model.

3.1.1. Origins (i), arrivals, and entity considered

Twenty-two origin locations were chosen from the state of Mato Grosso. The chosen entity for analysis was “soy”, and each unit represented 1 ton of soy that arrives to the micro-regions and then runs the course of the system. In order to construct an arrival process, the available databases from SIDRA (2016) were consulted, which refers to
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