Chapter 6
A System Dynamics Model and Interface for the Simulation and Analysis of Milk Supply Chains

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ABSTRACT

The objective of this chapter is the development of a System Dynamics model for the study of the milk supply chain and how an extreme event can affect its behavior. A simple interface is developed that can be used to increase the ease of communication and provide an interactive approach to the decision-making process. The model contains three echelons: farmers, processors and retailers. The main results show that under normal circumstances, the behavior of the system reaches equilibrium after a few oscillations. However, these oscillations can be smoothed out if the adjustment time of the order placement is increased. Under an extreme event that reduces the demand for milk, behavior changes and the system remains in dis-equilibrium for the entire simulation. Once again, adjustment times remain the leverages that can influence and mitigate those negative effects. Finally, a more robust and collaborative decision-making process among the actors of the chain could be beneficial for all not only under normal circumstances, but also in the presence of extreme uncertainty.

INTRODUCTION

The supply chain is defined as a network of flows and processes, in which companies cooperate along the chain from the initial raw materials all the way to the delivery of the final product to the end-user (Li, Zhang, & Jiang, 2008; Ramanathan, 2013; Schimith et al., 2015). A supply chain is a highly dynamic system that is subject to supply availability and demand uncertainty. Along with supply chain comes the term of supply chain management, which focuses on planning, coordinating and integrating

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the material, information and capital flows along the chain (Li, Zhang, & Jiang, 2008; Seuring, 2013), with the objective of providing maximum customer satisfaction at the lowest cost (Chu, 2003). Hence, supply chain management incorporates both strategic and tactical objectives and the management of the chain in a sustainable manner has become an increasing concern for industries across a wide range of areas (Seuring, 2013).

The dairy supply chain shares the same structure as any other chain, it is considered especially complex and it entails many links that pass from the producer to retail and the final consumer (Shepherd & Flanders, 2008; Robinson, 2009; Simonson, 2009; Kumar & Nigmatullin, 2011). However, the dairy supply chain, being part of the vast food industry, is characterized by several attributes that make it unique and require a different strategy for the management to be successful (Ruteri, 2009). Firstly, at the supplier's/producer's side there is a great differentiation of products in an increasingly competitive market (Georgiadis, Vlachos, & Iakovou, 2005). Furthermore, the end products are considered highly perishable and fragile (Ayağ, Samanlioglu, & Büyüközkan, 2013), which furthermore are constrained by specificity in terms of deadline of consumption while there is limited storage capacity (Minegishi & Thiel, 2000). Thus, there is the need to transfer the end-products in a cost-effective way (Georgiadis, Vlachos, & Iakovou, 2005), while at the same time the supplier must consider the low value to size ratio (Ayağ, Samanlioglu, & Büyüközkan, 2013) and the appropriate packaging which must comply with the legislation (Minegishi & Thiel, 2000). Finally, there are concerns about the quality and safety of the end-products (Gereffi & Lee, 2009).

From the consumer's side, there is the demand for homogeneity of batches and a long duration of presence on the shelf (Minegishi & Thiel, 2000). Furthermore, there is a fixation with the price of milk (Ayağ, Samanlioglu, & Büyüközkan, 2013), because milk is considered one of the most important elements of nutrition, accompanied by sensitivity on place of origin (Georgiadis, Vlachos, & Iakovou, 2005) integrity of sources (Kumar & Nigmatullin, 2011) and means of production. Furthermore, seasonality and varying consumer tastes put an extra burden originating from consumers (Kumar & Nigmatullin, 2011). Finally, consumers are extremely serious when it comes to quality and safety issues (Georgiadis, Vlachos, & Iakovou, 2005; Enderwick, 2009). Hence, it seems that the dairy supply chain management is not limited to the various facets of production, but entails a wider range of management objectives (Holzworth, et al., 2014; Moore, et al., 2014).

The key level of the whole chain is, nonetheless, the farm (Andersen, Elbersen, Godeschalk, & Verhood, 2007), where profit maximization, efficiency of utilization of resources and competition due to globalization (O'Hara & Stagl, 2001); (Marletta & Biere, 2009; Castelán-Ortega, et al., 2016). However, managing even small aspects of this whole process is a complex task, and the farm manager must into account both quantitative and qualitative aspects of the operation (and the whole chain), properly evaluate the current state of the entire system and timely anticipate potential evolutions in the future with bounded knowledge (Snow & Lovatt, 2008).

Yet, there is a scarcity of research concerning the management of a farm in relation to the entire dairy supply chain; models and applications are either focused on the macroscopic view of the entire chain or are concerned only with the automation of the production process (Minegishi & Thiel, 2000). As a result, there is the need of development of decision aid tools that take into account the management of the farm, how the decisions made at that level affect the entire chain and how changes in the chain affect the management and of the farm and finally be user friendly. Moreover, there is a gap on how unexpected events (such as milk adulteration) affect the behavior of the entire chain.