Hybrid SD/DES Simulation for Supply Chain Analysis

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INTRODUCTION

According to Shapiro (2007), simulation models permit the study of the dynamic behaviour of a supply chain. Simulation models can describe how all parts of the supply chain will operate over time in respect to a set of parameters and policies defined by managers/analysts. Understanding the dynamics of the supply chain in a safe computer environment is the main value of computer simulation models.

According to Akkermans and Dellaert (2005), there are two distinct approaches to computer simulation for supply chain analysis: Discrete Event Simulation (DES) and System Dynamics (SD). Both approaches have been used extensively, as reported in the literature (Jahangirian, Eldabi, Nasser, Stergioulas, & Young, 2010; Tako & Robinson, 2012). Simulation models in both DES and SD are built to understand how systems behave over time: DES is considered to be more appropriate for modelling problems at the operational/tactical level, whilst SD is more suited for modelling problems at strategic level (Tako & Robinson, 2012). However, a number of authors have suggested the use of a hybrid SD/DES simulation for supply chain analysis (Reiner, 2005; Pereira, 2009; Venkateswaran & Son, 2005; Rabelo, Helal, Jones, & Hyeunk-Sik, 2005; and Lee, Cho, Kim, & Kim, 2002). A hybrid SD/DES simulation approach analyses both discrete and continuous aspects of a supply chain simultaneously (Pereira, 2009). Moreover it allows the analysis of both strategic (long-term) and tactical (short-term) aspects simultaneously (Venkateswaran & Son, 2005).

BACKGROUND

Complexity of the supply chain is one of the difficulties associated to supply chain analysis. A supply chain consists of a series of linked activities that intersect departmental and organizational boundaries. When combined with elements of dynamic complexity (Sterman, 2000), such as feedback, time delays, nonlinearity, accumulation and dispersal of resources (stock and flows), the analysis becomes even more difficult. The existence of these elements compels the use of a systemic and dynamic approach to tackle such complexity (Fowler, 1998). System dynamics (SD) can be used in supply chain analysis to generate insight into dynamic behaviour and causal relationships (Towill, 1996; Akkermans & Dellaert, 2005). In SD modelling, a supply chain is represented as a series of stocks and flows where state changes occur continuously over time; individual entities are not specifically modelled, models are generally deterministic and variables usually represent average values (Tako & Robinson, 2012). Although SD is well suited to model complex systems, it has limitations in providing a detailed representation of a supply chain with discrete changes such as high variability, stochastic uncertainties and discrete disturbances (Pereira, 2009). Failure to grasp the impact of uncertainties is considered to be a major pitfall in understanding supply chains (Tannock, Cao, Farr, & Byrne, 2007).

Another simulation approach widely used for supply chain analysis is Discrete Event Simulation (DES). DES simulation models are usually built upon process maps or flow chart diagrams (Sweetser, 1999). The popularity of DES is due to

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its ability to mimic the dynamics of a real system over time (Moon & Phatak, 2005). DES models systems perform as a network of queues and activities where changes occur at discrete points of time, entities of a system are represented individually; models are generally stochastic in nature where randomness is represented through the use of statistical distributions (Tako & Robinson, 2012). DES is better suited to analyse specific, well-defined sequential systems or processes such as production lines, and is often used to model particular processes, not entire systems (Sweetser, 1999). Nevertheless, two main drawbacks when using DES in supply chain analysis are (1) difficulties in modelling the interaction between supply chain partners and (2) the complexity found when constructing more detailed models (Lee et al., 2002). In addition, DES cannot capture qualitative relations such as those between supply chain partners, and requires a long and arduous data gathering (Banks, Buckley, Jain, & Lendermann, 2002). Furthermore, DES evaluations are applied for specific values (Rabelo et al., 2005); thus it cannot determine the region where the supply chain may stabilise, this is particularly important in supply chain systems with non-linear, time-delay and cause-effect relations (Pereira, 2009).

Additionally, it needs to be considered that supply chains are neither completely discrete nor continuous (Lee et al., 2002). To exemplify this, Lee et al. (2002) refer to information flows and inventory levels as continuous, and transportation as discrete. Thus, for an exhaustive supply chain analysis via simulation, it is necessary to consider simultaneously both discrete and continuous aspects. This is in line with An and Jeng's (2005) view that DES and SD are complementary in the analysis of business processes, such as those present in the supply chain. According to An and Jeng (2005), understanding the sequencing and synchronization of activities through a DES approach is not enough; SD can provide an insight on the hidden factors affecting performance. SD can be applied to understand the supply chain structure and interaction between partners (Vlachos, Georgiadis, & Iakovou, 2007); whilst DES can be used to represent uncertainties, individual events and disturbances (Kleijnen, 2003). Thus, hybrid DES/SD simulation could provide more insight and accurate analysis of a supply chain.

MAIN FOCUS

Two different approaches can be distinguished on how to conduct a hybrid SD/DES simulation: one is to use multiple simulation models and the other is to represent continuous and discrete components of a supply chain in one model. Both approaches are the focus of current research in this field.

Multiple SD/DES Simulation

Jahangirian et al. (2010) report that SD/DES simulation has often been conducted upon a combination of multiple simulation models, where SD is used to model a system at a higher level while DES is used for the lower level. Rabelo et al. (2005) conducted a study where SD simulation captured long-term effects of management decisions, and DES provided detailed analysis on shorter term decisions and actions. In another study, Rabelo, Hamidreza, Shaalan, and Helal (2007) used SD to build an overall model of an enterprise system, whereas DES was used to model the manufacturing function and the operational level tasks. In this study Rabelo et al. (2007) modelled a production/assembly supply chain system with service components added. SD was used to model the extended enterprise system, whereas DES was used to model the manufacturing and service sub-systems. The SD model consisted of three major units based on a generic value chain system model developed by Rabelo and Speller (2005). The three major business units are:

Business Unit 1: Representing the manufacturing section.
Business Unit 2: Representing the service section.
Business Unit 3: Representing customer requests, acquisitions and relationship management.