Supply Chain Simulation

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INTRODUCTION

The goal of simulation is to evaluate existing supply chain configurations, as well as to aid in design of the new supply chains. In other words, it helps resolve different supply chain management (SCM) problems which can be grouped into the following categories:

- Infrastructure configuration that implies defining of the manufacturers, distribution centers, wholesalers, retailers and their locations (nodes).
- Defining strategy related to processes at the nodes. For example, for ordering process – which policy will be used (depending on the demand characteristics models can be deterministic or stochastic), for reception process (i.e. devices for checking quantities, RFID or bar code readers for identification, inspection methods, etc.), or distribution process (successive or group delivery, instant or postponed order fulfillment, etc.)
- Coordination between processes and activities with the purpose of their alignment and fulfillment of performance goals on global supply chain level.
- Information integration so that processes can exchange all necessary information.
- Supply chain validation through performance measurement which involves defining metrics at different supply chain levels.

There are different supply chain modeling methods and types of simulation. In this article, methodology and software solution based on the discrete-event simulation are presented. The background section gives definitions and explanations of key terms and concepts, as well as literature review with main contributions related to supply chain simulation. The main section of the article describes original supply chain modeling approach which enables flexible modeling of any supply chain configuration. It also describes the main components of the software solution such as model database, process library, knowledge base, and execution engine.

The main contributions and benefits of the presented simulation solution are presented. Finally, the main future research directions and opportunities are examined.

BACKGROUND

Simulation can be defined as the process of designing an abstract model of a real system (or subsystem) and conducting experiments with this model for the purpose of either understanding system behavior or evaluating various strategies within the limits imposed by a set of criteria for the operating of the system (Shannon, 1975).

By examining well designed simulation models, organizations can reinforce their decisions regarding supply chain processes. They can study and analyze effects of different supply chain initiatives and improvement programs through sensitivity analysis (such as what-if or goal seek) before investing huge amount of money or disrupting their operations.

Computer simulation and simulation models can be used to model intricate supply networks close to real systems, execute those models, and observe system behavior.

The main advantages of the supply network computer simulation are (Stefanovic et al., 2009):

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- The simulation is relatively clear and flexible.
- It can be used for analysis of the complex real systems such as supply networks.
- With the simulation, it is possible to include real-world influences, for example uncertainty factor in demand or lead time.
- ''Time compression" is possible. Effects of a certain business policy over a long period of time (months, years), can be obtained in a short time.
- The simulation enables ''what-if" analysis. Managers can test the results of different decisions.
- The simulation does not interrupt real systems. For example, experimenting with different supply network configurations can be done without disruptions and significant investment.
- With the simulation, the effects of the individual components, parameters and variables can be studied at the global level.

The main disadvantages of the supply network computer simulation can be summarized as:

- Quality simulation models can be expensive and time consuming to develop and validate.
- This is ''modify-try" approach. Typically, it does not generate optimal solutions.
- It is necessary to model and define all relevant data in order to produce valid results which can be very difficult in complex supply network scenarios.

Simulation models can be classified into several categories and based on more than a few ways. Kleijnen (2005) classifies simulation models into four types:

- **Spreadsheet Simulation:** Used in corporate modeling usually by mangers;
- **System Dynamics (SD):** Organizations are viewed as systems with six types of flows: materials, goods, personnel, money, orders, and information;
- **Discrete-Event Dynamic Systems (DEDS) Simulation:** Incorporates uncertainties and is usually part of the ERP systems;
- **Business Games:** Interactive simulation where managers operate within the simulated 'world'.

When it comes to a supply chain simulation, one of the first efforts dealing with the supply chain dynamics was undertaken by Forrester (1958) who created a simple but representative simulation model of a production distribution supply chain developed using the Dynamo simulation language. Afterwards, a number of papers have been published that deals with different aspect of supply chain modeling and simulation.

Some of them are purely mathematical models using the linear or mixed integer programming (Ettl et al., 2000), which are not fully applicable in a complex and volatile business environment. Other authors proposed a hybrid approach combining analytics and simulation methods for solving production–distribution problems in supply networks (Lee & Kim, 2000).

Tunali et al. (2011) applied a hybrid model which combines mathematical modeling and simulation in a produce-to-order manufacturing company. First, a mathematical model is used to generate production and distribution plans while minimizing costs. Based on these plans, optimal scheduling decisions are made. Finally, the dynamic and stochastic simulation is used to assess these decisions.

Li et al. (2012) used stochastic network mathematical model for analyzing the ordering dynamics and for identifying the key links in ordering networks. Based on these models and using simulation, effect of different ordering policies on economic performance of multi-stage supply chain are evaluated. The goal is to produce a decision support system for designing effective strategies to improve supply chain performance.

Nikolopolou and Ierapetritou (2012) proposed an agent-based hybrid simulation optimization approach that addresses the problem to the operational/tactical level of the supply chain management. The main criterion is cost minimization. One of the constraints of this approach is that it does not take into account stochastic nature of supply chains.

Shukla et al. (2010), introduced a hybrid approach that incorporates simulation to a comprehensive supply chain network, Taguchi method to quickly determine a robust area und optimize qualitative factors, regression