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An advanced supply chain management tool based on modeling and simulation

Francesco Longo *, Giovanni Mirabelli [1]

Mechanical Department, University of Calabria, Via P. Bucci, Cubo 44C, 87036 Rende (CS), Italy

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Abstract

The paper presents an advanced modeling approach and a simulation model for supporting supply chain management. The first objective is to develop a flexible, time-efficient and parametric supply chain simulator starting from a discrete event simulation package. To this end we propose and advanced modeling approach. The second objective is to provide a decision making tool for supply chain management. The simulator is a decision making tool capable of analyzing different supply chain scenarios by using an approach based on multiple performance measures and user-defined set of input parameters. Our simulator capabilities as decision making tool are strongly amplified if Design of Experiment (DOE) and Analysis of Variance (ANOVA) are respectively used for experiments planning and simulation results analysis. With regard to supply chain decision making process, we propose an application example for a better understanding of tool potentials. The application example considers a specific supply chain scenario and analyzes the effects of inventory control policies, lead times, customers' demand intensity and variability, on three different supply chain performance measures.

Keywords: Modeling; simulation; Decision making tool; Supply chain management

1. Introduction

A supply chain is made up by multiple actors, multiple flows of items, information and finances. Each network node has its own customers' and suppliers' management strategies, demand arrival process and demand forecast methods, inventory control policies and items mixture. The Modeling and Simulation (M&S) based approach for studying supply chain has to be: (i) flexible and parametric for evaluating different scenarios; (ii) time efficient even in correspondence of high number of supply chain stages and high numbers of items; and (iii) repetitive in its architecture for easily changing the number of supply chain stages.

A supply chain simulator that aims to reach such features should pay attention to the modeling approach. Let us consider the traditional modeling approach proposed by two commercial discrete event simulation packages, Em-Plant (by Tecnomatix Technologies) and Anylogic (by Xj-Technologies). Both of them propose

* Corresponding author. Tel.: +39 0984 494891; fax: +39 0984 494673.
E-mail addresses: f.longo@unical.it (F. Longo), g.mirabelli@unical.it (G. Mirabelli).
[1] Tel.: +39 0984 494891; fax: +39 0984 494673.

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a typical object oriented modeling approach. Each discrete event simulation model (developed by using these software) is made up by system state variables, entities and attributes, lists processing, activities and delays. Let us focus on entity, it can be dynamic (it moves through the system) or it can be static (it serves other entities, generally called resources) and it may have attributes for recording specific information (Banks, 1998). Typically, in a whole supply chain simulation model there is a high number of dynamic entities (consider for instance flows of items and information) and, in comparison with the previous ones, a small number of resources (stores, plants, warehouses). Even if the simulation model is being used to analyze a single network node the number of dynamic entities is usually greater than the number of static entities. Consider a production plant, the number of work pieces is greater than the number of machines; similarly in a maritime terminal the number of containers is remarkable greater than the number of berth and yard resources.

Each single dynamic entity corresponds to an object flowing in the simulation model. As soon as the number of dynamic entities becomes high, the time required for a simulation run becomes unacceptable. In addition, the library objects that should be used for modeling static entities very often fall short of recreating the real system with satisfactory accuracy. In other words, the traditional modeling approach (proposed both by eM-Plant and by Anylogic as well as by a number of discrete event simulation packages), in terms of library objects and dynamic entities, is characterized by two problems: (i) difficulties in modeling complex scenarios; (ii) too many entities cause computational heavy models. The first objective of this paper is to propose an advanced modeling approach for developing a flexible, time-efficient and parametric supply chain simulator starting from the discrete event simulation package, eM-Plant.

The second objective is to show that such simulator capabilities as decision making tool for supporting supply chain management. After the description of the simulator architecture, we propose an application example for testing tool potentials on a three stages supply chain consisting of stores, distribution centers (DCs) and plants. The application example allows to understand how the the supply chain manager can use the simulator as decision making tool by considering the impact of critical parameters on multiple performance measures.

The simulator translates the supply chain conceptual model that recreates a complex and high stochastic environment of a real supply chain. For each type of product, market demand to stores is assumed to be Poisson and the arrival process is independent of the other products. The required quantity is assumed to be triangular with different levels of intensity and variability. The inventory level for each item can be controlled with four different policies and suppliers' selection is made according to forecasts on variable lead times and quantities provided by suppliers. The same priority index is assigned to each network node for performing items distribution. The unsatisfied demand is recorded at each level of the supply chain. Multiple measures are used for monitoring supply chain performances: fill rates, on hand inventory, inventory costs.

The conceptual model has been translated in a flexible, parametric and time efficient simulation model that gives the possibility to supply chain manager to analyze different supply chain scenarios by changing a number of input parameters (inventory policies, lead times, demand forecast methods, demand intensity, etc.) and observing the effects of such changes on multiple performance measures. Thanks to these capabilities, the simulator can be used as decision making tool.

In addition, the capabilities of the simulator as decision making tool are strongly amplified if Design of Experiment (DOE) and Analysis of Variance (ANOVA) are respectively used for correctly setting parameters levels, number of simulation runs and replications and for evaluating analytical model to be used for supporting the decision process.

Before getting into details of the study let us give a brief overview of each section of the paper. Section 2 presents an accurate literature overview for understanding the contribution of this paper, Section 3 describes the supply chain conceptual model, Section 4 gives specific details on the modeling approach and simulator architecture, Section 5 proposes the application example (describing the supply chain scenario and proposing the simulation results), Section 6 analyzes simulation results. At last, the conclusions report a summary and research activities still on going on the same project.

2. Literature overview

Lee, Cho, Kim, and Kim (2002) underline the need to use Modeling and Simulation for analyzing and designing the whole supply chain. Existing analytical methods are not able to handle all the dynamically