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ScienceDirect
Simulation Modelling Practice and Theory 15 (2007) 113–136
SIMULATION MODELLING PRACTICE AND THEORY
www.elsevier.com/locate/simpat

Toward a methodological framework for agent-based modelling and simulation of supply chains in a mass customization context

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Available online 28 November 2006

Abstract

In a dynamic customer-centric supply chain context, classic forecasting models turn out to have a limited applicability. In order to estimate the key performance indices of these Supply Chains and to facilitate their management, it is necessary to use more elaborate tools such as a simulation. However building simulation of customer-centric supply chains is no trivial matter. It requires the elaboration of a representative model and the execution of this model according to a set of hypotheses associated to scenarios. Due to their properties, Multi-Agent Systems seem particularly well suited for the modelling and the simulation of Supply Chains and more especially in a mass customization context. In this paper we propose an agent modelling framework for the modelling and simulation of such Supply Chains to facilitate their management. We show how this framework can be applied to a case of customer-centric Supply Chain from the golf club industry and we present an experiment plan associated.

Keywords: Supply chain; Multi-agent system; Mass customization; Methodological framework; Agent-based simulation

1. Introduction

The combination of globalization and digitalization has tremendous economic impacts and radically transforms the environment in which companies operate. The internationalization and digitalization of the markets offer companies the possibility to diversify their supply, production and distribution networks. Facing a plethoric supply, customers become more and more demanding and volatile. This induces an ever more competitive environment. Companies try to respond as precisely as possible to customer needs with highly focused products, each aiming at specific highly differentiated customer class or being personalized for a single customer.

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1569-190X/$ - see front matter
doi:10.1016/j.simpat.2006.09.014

In the aim to deal with these evolutions, companies have realized more cooperation with their suppliers and customers. This leads to the emergence of new types of organization such as the Extended Enterprise, the Virtual Enterprise and the Supply Chain. Integration of companies in these organizations provides a critical mean for value creation. It allows reducing costs, raising productivity, maximizing profits and bringing out flexibility, speed and reactivity abilities. These goals imply analysis and adaptation of existing and upcoming manufacturing and logistic systems, in terms of operations, processes, interactions and flow coordination.

Experimentations that support such analyses can hardly be realized on real systems. It then becomes necessary to decision makers to have available modelling approaches and simulation tools adapted to the nature of the considered organization.

In the aim to aid and instruct them in decision making processes, such as designing and managing organizational structures, the main objective of our works is to propose methodological elements for the design of socio-technical systems simulations. These kinds of systems are characterized by interactions between actors that necessitate decision making of different complexity. We are more particularly interested in physical system behaviour in reaction to decisions taken by the decisional system, decisions which rely themselves on the actual state of the physical system. The privileged application area of our works is the Supply Chain Management in a context of mass customization, in the aim to adequately representing systems operating in a highly dynamic environment.

The following section exposes our general research problematic: supply chain management and performance evaluation through modelling and simulation. After reminding the interest of the agent approach for Supply Chain modelling, Section 3 introduces and compares the major works developed in this research area. Section 4 presents the approach and the models of the methodological framework we propose for agent-based modelling and simulation of Supply Chains. A case study is proposed to illustrate the implementation of this methodological framework. Section 5 details the conceptual model, its realization process, and its illustration on the case study. In Section 6 we put emphasis on the operational model. Section 7 is dedicated to the description of the simulation environment and presents some first simulations results concerning the customer demand. At last, we conclude on perspectives associated to our research work.

2. Research context

2.1. Introduction

In the global competitive context, companies have to face numerous decisional problems related to the integration and the management of their organizations in an enterprise network. These problems, based on companies' relationships with their environment, encompass the analysis, the design and the improvement of industrial and logistic systems. The complexity of these systems and the multiple kinds of points of view to grasp, require adapted methods, models and tools, in the aim to describe, study and improve their design and management. Such a descriptive approach provides engineers and managers with analysis tools enabling the comprehension, control and improvement of their company behaviour, and subsequently of the overall networked organization. The models allow representing the physical and logical components of the industrial and logistic systems (resources, products, etc.). However, the erratic nature of the behaviour of these systems cannot be easily studied with static modelling tools. The recourse to dynamic analysis tools, for performance evaluation of industrial and logistics systems, relies on experimentation. Simulation belongs to this experimental path, and furthers the resolution of problems related to distributed decision making.

2.2. Supply chain modelling

Modelling the network organization consists in describing its functioning, in order to improve its performance and its competitive position. The models, methods and tools developed in the area of enterprise modelling are widely used for representation of manufacturing networks. This area, focused on production systems, had stretched over the limits of the company in order to grasp its organizational and operational evolutions.