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Hybrid modeling and empirical analysis of automobile supply chain network

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Abstract: Based on the connection mechanism of nodes which automatically select upstream and downstream agents, a simulation model for dynamic evolutionary process of consumer-driven automobile supply chain is established by integrating ABM and discrete modeling in the GIS-based map. Firstly, the rationality is proved by analyzing the consistency of sales and changes in various agent parameters between the simulation model and a real automobile supply chain. Second, through complex network theory, hierarchical structures of the model and relationships of networks at different levels are analyzed to calculate various characteristic parameters such as mean distance, mean clustering coefficients, and degree distributions. By doing so, it verifies that the model is a typical scale-free network and small-world network. Finally, the motion law of this model is analyzed from the perspective of complex self-adaptive systems. The chaotic state of the simulation system is verified, which suggests that this system has typical nonlinear characteristics. This model not only macroscopically illustrates the dynamic evolution of complex networks of automobile supply chain but also microcosmically reflects the business process of each agent. Moreover, the model construction and simulation of the system by means of combining CAS theory and complex networks supplies a novel method for supply chain analysis, as well as theory bases and experience for supply chain analysis of auto companies.

Keywords: complex network, complex self-adaptive system, automobile, supply chain, hybrid modeling, empirical analysis

1. Introduction

Node enterprises in supply chains with autonomy, self-organization and self-learning ability, can properly adjust their management strategies according to changes of external environment, and therefore are a complex adaptive system (CAS) [1-3]. The agent-based model (ABM) proposed by R Axelrod [4] shows significant superiority in the modeling of CAS in supply chains. However, the majority of modeling methods based on ABM are centered on the model with one main manufacturer to conduct simulation research for microscopic problems of supply chains (e.g. inventory strategy). The built models have a fixed structure, so it is difficult to establish a dynamic supply chain model reflecting entry and exit mechanisms of node enterprises. Supply chains are not only a CAS but also a network with complexity, which shows typical features including clustering, scale-free and small-world. [5-7]. Some scholars designed macroscopic evolutionary models endowing nodes with entry and quit mechanisms in viewpoint of complex network, but nodes lack of autonomy and self-learning ability [8].

Taking automobile supply chains as research background, a specific simulation model is established to study operation process, evolutionary law and network characteristics of automobile supply chain by comprehensively considering CAS and complex network evolutionary characteristics of supply chains. The established simulation model not only microscopically reflects various main processes (plan, purchase, production and delivery) during operation process of node enterprises in supply chain but also shows dynamic evolutionary process of supply chain macroscopically. The research attempts to provide references for scientific and effective management and design of supply chain, in order to make the automobile manufacturing industry obtain sustainable competition ability.

2. Concept model

2.1 Basic ideas of model design

Automobile supply chain is a complex network where competition coexists with cooperation. It is driven by consumer agents, centered on manufacturers, and composed of suppliers, manufacturers and distributors. When secondary suppliers are considered as a category and not regarded as a layer of network, the established network is a four-layer supply chain network, as shown in Figure 1. It primarily reflects competitive relationship among associated nodes in each layer of the network while there is no relationship among non-associated nodes. Each layer of the network is connected with the next layer and by doing so, a local-world is formed. In addition, cooperation relationship is the most important relationship of different network layers in each local-world. Namely, three local-worlds are separately formed between network layers of suppliers and manufacturers, distributors and manufacturers, as well as manufacturers and suppliers, distributors,