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A flow-based three-dimensional collaborative decision-making model for supply-chain networks

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ABSTRACT

The inter-organizational collaboration of supply-chain networks is an important modern business model. This model involves the collaboration of different organizations and decentralized decision making to improve the overall performance of a supply-chain network. The current research on collaborative decision making lacks a clear and effective decision system, which leads to a series of problems, such as unclear decision positioning, vague decision processes and poor operability of decision solutions. To solve these problems, this paper studies the principles of inter-organizational collaboration and proposes a novel perspective for collaborative decision making based on material, information and time flows. A flow-based three-dimensional collaborative decision-making model for supply-chain networks is creatively advanced in this paper. The model is an efficient methodological tool for collaboration management in the following ways: (i) it clarifies both the domain and the space of collaborative decision making; (ii) it sets up mapping relationships of decision spaces in different decision domains and elaborates their formal descriptions systematically; (iii) it solves the issues related to the association and integration of inter-organizational collaboration in several decision domains; and (iv) it allows all members in all organizations to be involved in the decision making of a supply-chain network. A case is studied to elaborate and verify the efficiency of the collaborative decision-making model. Compared with previous collaborative decision-making research, this paper provides a more efficient solution for collaborative decision making. The outlined model has clearer decision-making positioning and a stronger actual operability, and it provides an effective methodological reference for operating the inter-organizational collaborative decision making of a supply-chain network.

1. Introduction

In the course of economic globalization, supply-chain networks are widely recognized as one of the most important modes of business cooperation and competition. Such networks are characterized by complex structural relationships [2,6], partial information sharing [7,20,21], and decentralized individual decision making [11,12]. The high operational performance of supply-chain networks cannot be realized without inter-organizational collaboration. Collaboration has played a significant role in improving and maintaining the performance of supply-chain networks, and it has become an inevitable choice for all organizations in a network. It requires that all organizations cross their boundaries to carry out collaborative decision making through such activities as planning, production, inventory and delivery to strengthen the competitiveness of the network [5]. Because organizations are selfish, completely centralized decision making cannot be reached for decentralized supply-chain networks. Therefore, collaborative decision making is much more difficult than centralized decision making, and it is characterized by lower precision, accuracy, and performance.

Supply-chain network collaborative decision making is a significant research topic in the field of operation management. A volume of literature has focused on issues related to this topic, such as centralized collaborative decision making and decentralized collaborative decision making.

Research on centralized collaborative decision making primarily makes use of operational research, control theory and game theory to identify the most optimal or satisfying decision solutions. Zhang et al. [24] proposed a modified multi-criterion optimization genetic algorithm for order distribution in a collaborative supply chain. The algorithm adopted a framework of a central coordination system. Che and Chiang [4] designed a collaborative supply chain plan using the analytic hierarchy process and a genetic algorithm with cycle-time estimation. Alemany et al. [1] developed an application that supports the integrated modeling and execution of the collaborative planning decision-making process in supply chains.

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The chains are comprised of several decisional centers that make decisions based on mathematical programming models under temporal and spatial integration. Zhang and Lu [25] proposed a fuzzy bi-level decision-making model for a general logistics-planning problem and developed a fuzzy number-based *K*th-best approach to find an optimal solution for the proposed fuzzy bi-level decision problem. Zhang et al. [27] applied the bi-level programming and swarm technique to address strategic bidding optimization in electricity markets. Bhattacharya et al. [3] proposed a collaborative decision-making approach using a fuzzy analytic network process (ANP)-based balanced scorecard to measure green supply-chain performance. Zhang et al. [26] proposed an integrated solution framework combining a scatter evolutionary algorithm, fuzzy programming and stochastic chance-constrained programming for the collaborative production planning of supply chains under price and demand uncertainty. Lu et al. [12] proposed a hybrid solution integrated Lagrangian relaxation and immunity-inspired coordination scheme to collaborative decision making in a decentralized supply chain. Zamarripa et al. [23] used the mathematical programming and game theory optimization-based tool for supply-chain planning in cooperative/competitive environments. Yan and Li [22] conducted a game analysis on the collaborative operation behavior in a logistics service-supply chain. Focusing primarily on complete information sharing, these studies attempt to exploit the optimization of supply-chain network collaboration by means of centralized decision making. Centralized decision making is separated from the actual operation features of supply-chain networks and limits the practical application of decision-making solutions.

In view of the shortcomings of centralized collaborative decision making, research on decentralized decision making has been conducted to improve the application value of decision solutions. These studies usually adopt the advantages of multi-agent systems in decentralized decision making. Hernández et al. [8] proposed a novel supply chain agent-based modeling methodology that supports a collaborative planning process within a collaborative planning environment. Hernández et al. [10] presented a novel collaborative planning model in multi-level supply chains that considers a multi-agent system modeling approach to carry out iterative negotiation processes, which support the decision making process from a decentralized perspective. Hernández et al. [9] used a multi-agent system to support the collaborative decision-making process in an automotive supply chain. Lin and Long [13], Long et al. [17,18], Long [14–16], and Long and Zhang [19] studied a series of multi-agent-based modeling and simulation methodologies and tools to support the collaborative decision-making process in decentralized supply chains with partial information sharing. Decentralized decision making based on incomplete information sharing has obvious advantages, but it does not consider the influences of cross-organization. The perspective of inter-organizational collaborative decision making must be employed in modern supply-chain network operation systems. Furthermore, the above-mentioned studies lack a clear and effective decision system, which leads to a series of problems, such as unclear decision positioning, vague decision-making processes and poor operability of decision solutions.

In a word, the current methods, models and technologies for collaborative decision making are less efficient, precise, and accurate in coping with inter-organizational supply-chain networks, and the decision solutions have less operability. Therefore, it is of great necessity to study a more effective inter-organizational collaborative decision-making model to improve its performance.

To solve the above-mentioned problems, this paper studies the principles of the inter-organizational collaborative operation of supply-chain networks and proposes a novel perspective of flow-based inter-organizational collaborative decision making. Then, a flow-based three-dimensional collaborative decision-making model for supply-chain networks is set up, and a systematical formal description of the model is provided. Finally, a case is studied to elaborate and verify the application of the model. The proposed model ascribes great importance to the context of inter-organizational collaboration, creatively puts forward a flow-based decision-making perspective, and improves the decision making and operability of decision-making solutions. The model defines both the domain and the space for decision making, clarifies the unified and standard process, reduces the difficulty of decision making, and improves the precision and accuracy of decision solutions. Additionally, the model provides an effective decision-making tool to allow all members in all organizations to participate in the decision-making process where their passions are motivated.

The rest of this paper is organized as follows: Section 2 exploits the flows in the inter-organizational collaboration of a supply-chain network. Section 3 elaborates the perspective of flow-based inter-organizational collaborative decision making. Section 4 puts forth a flow-based three-dimensional collaborative decision-making model for supply-chain network and provides a formal description of the model. Section 5 provides a case study on the application and verification of the model, and Section 6 presents conclusions and further study.

2. Supply-chain network flows

Complete/partial information sharing inside and outside organizations drives the inter-organizational collaboration of a supply-chain network. The collection of these information-sharing activities can be described as an information flow, as shown in Fig. 1. Outside the organization, throughout the supply-chain network—from the terminal customers to the upstream organizations—information flow drives all organizations to complete horizontal collaboration. Inside the organization, from the top strategic level to the bottom operational level, information flow drives all levels to complete vertical collaboration. Information flow is the key to guaranteeing the success of the inter-organizational collaboration of a supply-chain network. In a supply-chain network, activities such as purchasing, production, storage, sales and transportation are accompanied by another important flow—material flow. Driven by information flow, material flow moves step by step from upstream suppliers to downstream ones and finally to the terminal customers. It depicts both the property and space conversions from raw materials to the final products in the network structure. When space conversion occurs in information flow and material flow, time changes throughout the process. After a period of operation time, a specific track is left. As shown in Fig. 1, the track is described as a time axis, called time flow. Information, material and time flows should be considered together as a whole. The essence of inter-organizational collaboration is the collaboration among information, material and time flows. The success of the inter-organizational collaboration lies in the performance of collaboration among the three flows.

3. Flow-based collaborative decision making

Collaborative decision making is in pursuit of decentralized decision making, with the interests of each organization as its center. Simultaneously, it can achieve a performance similar to that of centralized decision making; that is to say, organization individuality should be maintained simultaneously with inter-organizational collaboration to the greatest degree. Material, information and time flows are the key objects and tools for inter-organizational collaboration for a supply-chain network. Correspondingly, collaborative decision making for a supply-chain network is doomed to rely on the three flows, which can cross organizational boundaries to promote their coordination. Hence, collaborative decision