Two-Phase Decision Support Methodology for Design and Planning an Outcome-Driven Supply Chain

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ABSTRACT
Nowadays, Supply Chain success and competitiveness heavily depend on the integration of its components and adaptability to deal with a changing environment. This article suggests the integration of design and management of a Supply Chain from an outcome-driven perspective. We propose a two-phase decision-making support methodology: first suppliers are pre-screened by solving a multi criteria sorting problem, and then a design and management plan is generated by solving a Mixed Integer Linear Programming Model. Experimentally we showed that the proposed methodology can efficiently solve to optimality the most popular benchmark instances published in previous paper moreover our model also includes problem characteristics that have not been addressed together in previous published papers.

Keywords: Supply chain design; supply chain planning; Mixed Linear Integer Programming; multi-criteria sorting problem; outcome-driven.

RESUMEN
Actualmente, el éxito y competitividad de las cadenas de suministro depende en gran medida de la integración de sus componentes y la capacidad de adaptación a los cambios que se presenten. En este artículo se propone la integración del diseño y planeación de la cadena de suministro desde una perspectiva dirigida a resultados. Se propone una metodología de apoyo a la decisión de dos fases: en la primera fase de preselección los proveedores son pre-seleccionados resolviendo un problema de ordenamiento y en la segunda fase de diseño y planeación un modelo lineal entero mixto es resuelto. Experimentalmente se muestra que la metodología propuesta puede resolver de manera óptima instancias publicadas en artículos previos, por otra parte nuestro modelo incluye características que no han tratado en conjunto en los trabajos publicados anteriormente.

1. Introduction

A Supply Chain (SC) is a network of suppliers, manufacturing plants, warehouses, and distribution channels organized to acquire raw materials, convert them into finished products, and distribute these goods to customers [1]. Supply Chains are generally complex and are characterized by numerous activities spread over multiple functions and organizations. From a functional perspective a SC typically includes the following functions [2]: logistics, inventory, purchasing and procurement, production planning, intra and inter-organizational relationships and performance measures. Therefore, coordination between members of the SC is essential for achieving highest efficiency [2,3]. Specifically, an efficient coordination of logistics activities is very important for the SC [1,4], but is not enough for the success of modern supply chains [5,6].

Coordination in a SC involves decisions at a strategic, tactical and operational level in the organization such as selecting location and capacity of plants and warehouses (strategic decisions); selection of suppliers, products range and production as well as distribution channels and transportation modes (tactical decisions) and finally, selection of flows of raw materials, semi-finished and finished products in the network (operational decisions) [1].

As stated by Melnyk et al. [5] benefits offered by a traditional SC (reduced costs, faster delivery and

improved quality) are not enough to compete today. Moreover, they assure that, while traditional SC was strategically decoupled and price-driven, the modern supply chain should be strategically coupled and value-driven. In other words, SC should be designed and managed to be outcome-driven. A recent review [6] shows that the vast majority of published papers follow a demand-driven perspective, or delivery-driven perspective. However, there are only a few papers that try to address design and planning problems in a SC from an integrated perspective [6,7]. Many relevant tactical/operational decisions in Supply Chain Management (SCM) such as procurement, routing and choice of transportation modes, are far from being integrated with location decisions, and in the few papers including these aspects, the structure of the supply chain network is considerably simplified (e.g., a single product and a single location layer are usually assumed) [7]. The integration of supplier selection (sourcing) and other SC drivers is even scarcer in the related scientific publications [6,7,8,9]. In most recent publications, where suppliers selection is integrated with SC design and/or planning, only supplier costs are taken into consideration. However, Ho et al. [10] assert that the traditional single criterion approach based on lowest cost is not supportive and robust enough in contemporary supply management.

In this paper we address the problem of integrating design and management in a SC from an outcome-driven perspective. We propose a two-phase decision support methodology: First, suppliers are pre-screened by solving a multi-criteria sorting problem and then, optimizing an integrated mixed integer linear programming model (MILM) for designing and planning SC, targeting costs, responsiveness, security, sustainability, resilience and innovation as outcomes. This model, for designing and planning a deterministic, single-period, multi-commodity SC, includes location decisions for plants and warehouses, suppliers selection, decisions about which products should be produced in each open plant, and the amount that should be produced, selection of transportation modes and channels; as well as other typical decisions found in the revised literature. Overall cost is to be minimized (fixed costs for opening plants/warehouses, transportation costs, production costs, suppliers' costs of raw materials).

Numerical experiment conducted with available benchmark instances from the revised literature [11] shows that the proposed model is both flexible and extremely efficient. Exact solutions were achieved in reasonable CPU time even for large instances.

The main scientific contributions of this paper are: a mathematical model that integrates design and planning of a three echelon, multi commodity supply chain which is both flexible and efficient, and a decision support methodology for helping the Decision Maker to carry out the process of design and planning from an outcome-driven perspective.

The paper is organized as follows. In the next section the problem is formulated and a mathematical model is presented; then, in section 3, the proposed decision support methodology is introduced. In section 4 numerical results are presented and discussed, and finally, the paper concludes with a few general remarks and future research directions (section 5).

2. Problem statement

The problem we are tackling in this paper consists in an integrated design and planning of a SC from an outcome-driven perspective. Basic outcomes to take into consideration are:

• Cost: to reduce product costs, to ensure timely and reliable delivery and to maintain quality.

• Responsiveness: to quickly respond to changes in demand (volume, mix, location) and at a reasonable cost.

• Security: to ensure that supplies coming through the supply chain are protected from disruption because of external threats. To protect product integrity and consistency.

• Sustainability: To provide products through a supply chain that ensures controlled and minimal resource impact, both today and in the future.

• Resilience: To develop a system capable of identifying, monitoring and reducing supply chain