Int. J. Production Economics 135 (2012) 451–457

Contents lists available at SciVerse ScienceDirect

Int. J. Production Economics

journal homepage: www.elsevier.com/locate/ijpe

A model for supply management of agile manufacturing supply chains ☆

Nicola Costantino [a], Mariagrazia Dotoli [b], Marco Falagario [c,*], Maria Pia Fanti [b], Agostino Marcello Mangini [b]

[a] Dipartimento di Ingegneria Meccanica e Gestionale, Politecnico di Bari, Italy
[b] Dipartimento di Elettrotecnica ed Elettronica, Politecnico di Bari, Italy
[c] Dipartimento di Ingegneria Meccanica e Gestionale, Politecnico di Bari, Via Japigia 182, 70126 Bari, Italy

ARTICLE INFO

Article history:
Received 17 December 2009
Accepted 24 August 2011
Available online 3 September 2011

Keywords:
Agile manufacturing
Supply chain
Strategic design
Sourcing strategy
Supply planning
Performance optimization
Integer linear programming

ABSTRACT

This paper addresses the configuration problem of Manufacturing Supply Chains (MSC) with reference to the supply planning issue. Assuming that the manufacturing system is composed of different stages, we present a technique for the strategic management of the chain addressing supply planning and allowing the improvement of the MSC agility in terms of ability in reconfiguration to meet performance. More in detail, we enhance a previous design method by some of the authors that employs digraph modeling and integer linear programming to optimally design the MSC. The original approach avoids supply chain disruption and stock out and, at the same time, can manage spare parts distribution. In order to take into account the level of demands and maximum production capacities with single/multiple sourcing, in this new formulation we introduce supplier capacity constraints. A case study is presented describing the optimal MSC configuration of an Italian manufacturing firm. The obtained results show that the design method provides managers with key answers to issues related to the supply chain strategic configuration and agility, e.g., choosing the right location for distributors and retailers for enhanced MSC flexibility and performance.

1. Introduction

1.1. Problem statement

The ever-growing global market requirements for enterprise competitiveness produced as an outcome the increased importance of strategic choices in the Manufacturing Supply Chain (MSC), e.g. decisions regarding inventory control policies, just-in-time solutions, information flows management and partner selection. In this context, agile manufacturing has been introduced as a concept to satisfy the demand for low-volume and high-variety products. By integrating computer systems, hardware and information flows, automated manufacturing systems provide agile manufactures with flexibility and reconfigurability. Flexibility is a manufacturing system's ability to adjust to customers' preferences and reconfigurability is the ability to meet the changing demand by reconfiguring the system structure (Zhou and Zurawski, 1995; Gosling et al., 2010). Moreover, agility refers to the capability that embraces organizational structures, information systems and, in particular, minds sets (Christopher, 2000). Agile manufacturing requires embedding production flexibility into (re)configuration and control of manufacturing systems (Yang et al., 2003; Dotoli et al., 2006).

A common and accepted issue to achieve agility in a manufacturing system is manufacturing products in geographically different sites connected through communication networks. An agile MSC may be defined as a network of different companies, possessing complementary skills and integrated with streamlined material, information and financial flow, focusing on flexibility and performance. Here we consider a set of MSC partners including suppliers, manufacturers, distributors, retailers and final customers. All these actors are taken into account in order to generalize the network structure that can however be simpler in principle. Clearly, successful MSC operation calls for efficient supply chain design and management. This contribution addresses the problem of optimizing the logistic flow in the MSC network, starting from the suppliers till the final customers, while considering alternative supply strategies and focusing on network agility and performance.

1.2. Literature review

A guideline for supply chain management is proposed by Chopra and Meindl (2001) and is based on the three levels of the decision hierarchy: strategic, tactical and operational ones. Strategic level

☆ This work was supported by Fondazione Cassa di Risparmio di Puglia, Bari, Italy.

* Corresponding author. Tel.: +39 080 5963312; fax: +39 080 5963411.
E-mail addresses: costantino@poliba.it (N. Costantino), dotoli@deemail.poliba.it (M. Dotoli), m.falagario@poliba.it (M. Falagario), fanti@deemail.poliba.it (M.P. Fanti), mangini@deemail.poliba.it (A.M. Mangini).

0925-5273/$ - see front matter © 2011 Elsevier B.V. All rights reserved.
doi:10.1016/j.ijpe.2011.08.021

planning involves MSC design, which determines the location, size and optimal number of partners to be used in the network. It considers time horizons of a few years and requires approximate and aggregate data. Tactical level planning basically refers to supply planning, which primarily includes the optimization of the flow of goods and services through a given supply chain network. Finally, operational level planning is short-range planning, involving production scheduling at all plants on an hour-to-hour basis.

This paper focuses on the strategic problem of supply planning for agile MSC. Significant literature deals with the issue of MSC partner selection and network design, which is recognized as the most significant topic of strategic logistic planning (Jang et al., 2002). In particular, Wu et al. (1999) formulate partner selection as an integer programming problem to choose one and only one candidate for each task of the production process. However, the constraint to select only one candidate for each task is restrictive and affects the flexibility of the resulting network structure. Moreover, Jang et al. (2002) propose an optimized supply network design module and a planning scheme of production and distribution activities that are modeled as three decomposed mathematical formulation. However, the complete procedure appears complex and needs a genetic algorithm procedure to generate the final integrated production distribution plan. On the other hand, Viswanadham and Gaonkar (2003) study and analyze a multi-tier MSC by using a multi-integer programming model, which takes into account capacities and costs. However, information necessary to describe and characterize the MSC can be so complex and large that the definition of constraints appears critical. To face such a complexity, Talluri and Baker (2002) consider a three-phase approach to design an MSC. Nevertheless, the network design procedure does not consider the transportation connections among the stages in the network design and the routing of material is analyzed in the third phase only. In addition, Luo et al. (2001) present an approach to describe and optimize an MSC network incorporating e-commerce. The MSC structure is modeled by a digraph where nodes are stage partners and edges are links. Assigning different costs to the material links, Luo et al. (2001) obtain the performance indices and the optimal flow material network by a fuzzy multi-objective optimization approach. However, the proposed method cannot address the production capacity constraints. Later on, Ambrosino and Scutellà (2005) presented a technique for MSC design analyzing concurrently strategic, tactical and operational issues. Such a simultaneous treatment of different MSC management levels leads, however, to an increased complexity, which in turns results in obtaining the practical solution of the problem only by way of a relaxation procedure. Moreover, Franca et al. (2010) proposed a stochastic method for optimal MSC configuration. However, the model parameters number and complexity to determine make the technique impractical. In addition, we point out that other authors propose MSC optimization techniques that are essentially manufacturer-centered and do not take into account the overall MSC network: for instance, Zanjirani Farahani and Elahipanah (2008) present a genetic algorithm to optimize the cost and service level of a MSC distribution network; similarly, Nagurney (2010) proposes a technique, based on variational inequalities to choose optimal production capacities and flows, that does not consider in detail the supplier stakeholders in the network; conversely, Wu and Barnes (2010) propose an optimization method based on Dempster-Shafer theory that does not consider the MSC distribution stage. Finally, other approaches to MSC strategic design and optimization—see for instance the work by Tsiakis and Papageorgiou (2008) and the cited paper by Nagurney (2010)—determine the minimum-cost MSC configuration and do not take into account additional crucial factors for service level such as, for instance, quality and transportation time.

1.3. Proposed approach

In this paper we propose a generic model for use by MSC managers to determine alternative and efficient chain configurations that are optimal with respect to one or more supply planning criteria. The presented model is an extension of the framework proposed by some of the authors in (Dotoli et al., 2006) and has a particular focus on the supply planning and agility issues. Starting from the approach by Dotoli et al. (2006), using digraph modeling to describe an MSC and employing multi-objective optimization to obtain the optimal flow material network, the MSC structure is modeled by a digraph where nodes are partners and edges are links, considering at the same time material and information connections. The paper extends the previous MSC framework in order to model the production capacity of each supplier, so that both the single and multiple sourcing strategies may be taken into account in the supply chain operation while assuring agility in terms of flexibility and performance (see also Costantino and Pellegrino, 2010). We formulate a multi-criteria objective problem to optimize the MSC configuration and an Integer Linear Programming (ILP) problem is solved providing a set of possible alternative solutions to the decision maker. The methodology allows optimizing the supply chain network selecting the edges of the digraph, e.g., introducing particular links or imposing one or more partners in the network. The optimization model is applied under structural constraints to a case study, i.e., an Italian manufacturing firm with a focus on the advantages of the resulting supply chain configuration in terms of flexibility and agility. The MSC design is performed considering several attributes, i.e. costs, quality and transportation time. The model solution proposes different optimal MSC structures, enabling the supply chain manager to choose the best solution in the procurement process, including the single/multiple sourcing options and allowing the improvement of the MSC flexibility and performance.

The proposed model exhibits several advantages compared to the contributions in the related literature. First, by a hierarchical approach to decisions, we focus on the MSC strategic configuration and, disregarding the time variable, avoid the complexity of the related literature that analyzes simultaneously also tactical and operative issues and often results in obtaining the practical solution of the formulated problem by way of a relaxation procedure. Second, since we address a strategic problem, we consider aggregate and deterministic product flows, demand and performance; the resulting model is modular and allows a systematic and straightforward ILP formulation. On the one hand, disregarding the system variations in time, by aggregated values for the strategic horizon (about 1–3 years), the model can be successfully applied to MSC that exhibit a stable market during such a time horizon. Moreover, avoiding a stochastic MSC model leads to a strategic design that is much simpler and straightforward than other available models in the literature, whose parameters complexity and number often make them impractical. Third, we remark that, differently from previously cited approaches to MSC strategic design, we do not only determine the minimum-cost configuration but can take into consideration also service level factors, i.e., quality and delivery lead time. Indeed, the formulated multi-criteria objective problem considers both production and distribution aspects, and imposes production capacity constraints that are often neglected in the related literature.

As a result of the discussed advantages, our formulation appears more flexible and suited than other approaches to improving the MSC structure while satisfying the different design requirements of the supply planning problem. Moreover, the presented model may be used as a starting point for developing a decision support tool by MSC managers and decision makers allowing the improvement of the MSC flexibility and performance. We leave this as a subject for future research.