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Production planning of a multi-site manufacturing system by hybrid modelling: A case study from the automotive industry

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Abstract

The paper deals with lot sizing and scheduling problem (LSSP) of a multi-site manufacturing system with capacity constraints and uncertain multi-product and multi-period demand. LSSP is solved by an hybrid model resulting from the integration of a mixed-integer linear programming model and a simulation model.

The hybrid modelling approach is adopted to test a local as well as a global production strategy in solving the LSSP concerned.

The model proposed is applied to a supply chain of a multi-site manufacturing system of braking equipments for the automotive industry. Solutions obtained by the hybrid model under the local or the global production strategy are compared with an actual reference production plan. The approach could help decision making in adopting a cooperative, rather than competitive, production strategy.

Keywords: Production Planning; Hybrid modelling; Supply chain management

1. Introduction

Integration and synchronism of information and material flows of manufacturing sites belonging to a supply chain (SC) are characteristics strongly required by modern industrial organizations.

Automotive industrial groups are introducing structural changes in their manufacturing systems in order to guarantee optimal trade-off between customer satisfaction and production costs (Haag and Vroom, 1996; Proff, 2000). Outsourcing is a common solution to this problem. According to such a strategic perspective, main contractors involve suppliers from development and engineering phases of new products. Automotive manufacturers became more and more dependent on suppliers. An analysis of vulnerability in the supply chain of a mid-size European car manufacturer (Svensson, 2000) revealed that disturbances appearing at the subcontractors level propagate downstream and upstream in the supply chain. As a consequence, a more in depth level of integration and cooperation among car manufacturers and subcontractors are recommended to avoid or reduce supply chain vulnerability. Several manufacturers integrate successfully their internal process to external suppliers and customers in a single SC (Frolich and Westbrook, 2001).

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Customer–suppliers relationships need to be continuously updated; strategic knowledge and information tend to be shared among manufacturers in a larger measure than in the past inducing more in depth industrial relationships.

Three levels of supply chain integration in formulating scheduling policies are defined in Wei and Krajewsky (2000). A "myopic" policy occurs when the top tier member only considers its internal flexibility costs. An "intermediate" policy considers flexibility costs of members nearest to the top tier of the supply chain. Finally, "total" policy considers flexibility costs extended to all members of a supply chain.

A further complexity factor occurs when suppliers are involved into different SCs. According to such a point of view, an integrated approach to supply chain management (SCM) requires a co-operative, rather than competitive, approach among legally independent but economically and strategically dependent subjects of a SC (Christopher and Towill, 2000). Main goal of SCM consists in establishing optimal combination of competition and cooperation considered as a basic feature of inter-firm networks (Pfohl and Buse, 2000).

Stochastic variability in product demand as well as in manufacturing and transportation times are being increasingly considered as a major source of uncertainty (Shobrys and White, 2000).

In this paper, after reviewing supply chain models available in the literature (Section 2), the authors introduce (Section 3) an industrial case concerning the supply chain of multi-site manufacturing system producing braking equipment components for the automotive industry. The hybrid model proposed, consisting of an analytical and a simulation model, is described in Section 4. The paper focuses on investigating the way demand stochastic variability can differently affect technical and economic performances of the whole production system, in case of both local and global optimization strategy. Results are finally provided in Section 5.

2. Supply chain modelling

SCM usually deals with strategic and operational problems. At the strategic level SCM goals mainly consist in solving resource allocation problems. At the operational level main goals pursued are optimization of lot sizes, inventories, and service levels.

Recent studies in the scientific literature deal with the application of new methodologies, e.g. artificial intelligence, expert systems and neural networks, in SCM (Fulkerson, 1997; Fox et al., 2000; Wu, 2001). A recent classification of SC models is given in Sabri and Beamon (2000). The authors classify deterministic and stochastic models. The former mainly consist of analytical models for mathematical programming (Cohen and Lee, 1988; Thomas and Griffin, 1996). The latter, e.g. fuzzy and simulation models, seek to capture uncertainty of supply chain environment by considering stochastic variability of supply chain variables (Lee and Billington, 1992; Petrovic et al., 1998).

Currently, some research is focused on integrating different modelling methodologies in order to join advantages offered by each of them in facing with complex problems. Analytical models search for solutions evaluating optimal values of decision variables according to a given technical–economic objective. However, solutions provided are generally limited in their fields of application because of preliminary restricting hypotheses. On the other hand, simulation models, which explicitly consider randomness of exogenous and endogenous production variables, are more capable in capturing actual system behavior but reveal as not adequate in solving optimization problems.

Bose and Pekny (2000) propose an integrated architecture composed of forecasting and optimization models both interfaced with a simulation model to manage uncertainty and dynamics of SCs.

Integration of analytical and simulation models leads to hybrid models (HMs); a first taxonomy of HMs is in Shanthikumar and Sargent (1983). HMs represent a challenging option to capture best capabilities of both analytical and simulation models. Recent studies concerning capability of hybrid models in solving efficiently production planning and control problems are in Ozdamar and Birbil (1998), Byrne and Bakir (1999), Mummolo et al. (1999) and Benedettini et al. (2001).