Available online at www.sciencedirect.com
ScienceDirect
Fuzzy Sets and Systems 161 (2010) 1511 – 1529
FUZZY sets and systems
www.elsevier.com/locate/fss

Fuzzy hierarchical production planning (with a case study)

S.A. Torabi[a,*], M. Ebadian[b], R. Tanha[a]

[a]Department of Industrial Engineering, College of Engineering, University of Tehran, Tehran, Iran
[b]Department of Wood Science, University of British Columbia, 2424 Main Mall, Vancouver, BC V6T-1Z4, Canada

Received 18 February 2009; received in revised form 9 August 2009; accepted 9 November 2009
Available online 14 November 2009

Abstract

Hierarchical production planning (HPP) is a well-known approach to cope with the complexity of multi-level production planning and scheduling problems in real-world industrial cases. However, negligence of some issues such as inherent uncertainty in critical input data (i.e., market demands, production capacity and unit costs) as well as possible infeasibility of these problems due to imposing the decisions made at a higher level as a hard constraint to the inferior level without allowing any deviation often result in the inefficiency of HPP approach in practice. In this regard, we incorporate the fuzzy set theory into the HPP structure to handle the uncertainty and infeasibility issues. Inspired by a real industrial case, a fuzzy HPP (FHPP) model is proposed which is composed of two decision making levels. At first, an aggregate production plan is determined by solving a fuzzy linear programming model at the product family level and then it is disaggregated through another fuzzy linear programming model at the next level to find a disaggregated production plan in final products level. The FHPP model is implemented for the real industrial case and it is compared with the previously developed crisp model. The corresponding results are discussed and some important managerial implications are provided.

Keywords: Hierarchical production planning; Fuzzy mathematical programming; Make-To-Stock systems

1. Introduction

Production planning and scheduling involves different complicated tasks dealing with a hierarchy of decision making problems in the manufacturing environments which require cooperation among multiple functional units (e.g., production, accounting and marketing) in an organization. Generally speaking, to be competitive in the today's marketplace, the firms need to cope with these issues at different strategic, tactical and operational levels. The strategic issues deal with long-term decisions such as facility layout and resource capacity planning. Regarding the tactical decisions, the firms have to make optimal decisions for example about production, inventory and overtime levels to absorb dynamic demands in a multiple period mid-term planning horizon. Finally, in a short-term planning horizon, some detailed decisions for example; scheduling and sequencing of several jobs through the different workstations are made.

To reach consistency between decisions made at different levels of production planning and obtaining feasible and consistent plans, the upper level decisions should impose constraints on the lower level ones while the latter provide required feedbacks to revise the higher level decisions. This approach which is one of the important advances in the field of production planning and scheduling is referred to hierarchical production planning (HPP). HPP partitions

* Corresponding author. Tel.: +9821 88021067; fax: +9821 88013102.
E-mail address: satorabi@ut.ac.ir (S.A. Torabi).

0165-0114/$ - see front matter
doi:10.1016/j.fss.2009.11.006

the production planning and scheduling problem into the different sub-problems at different levels of a hierarchical framework compatible with the organizational structure of company. In this approach, the outputs of a higher decision making level are considered as the inputs of the lower one. Since the decisions at each level are made with respect to the outputs of the upper one, developed plans will be more feasible while carried out in practice and also more compatible with the plans of the upper levels which would result in reaching the firm's final goals. Totally, providing these compatibility and consistency among various planning activities in the different levels of organization's hierarchy is the main advantage of the HPP approach.

In spite of this advantage, in most of the proposed HPP structures, the decisions made at the higher level are imposed to the lower level as *hard* (*crisp*) *constraints*. Moreover, due to internally and externally dynamic production environment, determining the exact value of critical data is relatively impossible. Thus, using the hard constraints as well as crisp data in all levels of the HPP model reduces the flexibility and also compatibility among the solution of different levels. As a result, the final outputs of the HPP model can be infeasible while being implemented in practice. In other words, imposing the decisions made at an upper level as the hard constraints to the lower level without allowing revising them (if necessary) reduces the flexibility and feasibility of HPP structure, and it may lead to inconsistency and infeasibility issues [1].

An appropriate approach to alleviate this deficiency is to use fuzzy set theory by introducing *imprecise/fuzzy data* along with the *soft constraints* allowing some minor deviations from the outputs of the upper level while making a decision in the lower level. Incorporating the fuzzy set theory into the HPP framework allows to cope with several issues involving: (1) the inherent ambiguousness existing in some critical parameters, say market demands, unit cost data and capacity levels, (2) the natural vagueness in soft equations applied for connecting two adjacent decision making levels, and also (3) involving the decision makers' past experiences and judgments more efficiently into the problem formulation [2]. The above characteristics of the fuzzy approach would increase the reality of the corresponding HPP models and their attractiveness for both practitioners and researchers.

It should be noted that unlike the previous studies in HPP literature, critical parameters (such as market demands and capacity levels) are imprecise (fuzzy) in nature due to incompleteness and/or unavailability of the required data over the mid-term decision horizon. In such situations, for example, the manufacturer knows its demand requirements almost certainly, but quotes it in an imprecise manner (e.g., 500 ± 10 units). Therefore, we have to estimate the problem parameters subjectively based on both the current insufficient data and the decision makers' experiences [3].

The main purpose of this paper is to improve the practicality and performance of the HPP approach when applying in real cases. In this regard, instead of using the crisp data and imposing hard constraints to provide required consistency between decisions of adjacent levels, the imprecise input parameters along with some soft constraints are introduced in the model formulation. In this manner, the resulting production plans through fuzzy HPP would be more feasible and compatible in practice.

The rest of the paper is organized as follows. The relevant literature is presented in Section 2. A brief description of case study is followed by the proposed structure of FHPP model and the corresponding fuzzy mathematical models in Section 3. In Section 4, the FHPP structure is elaborated and by applying appropriate strategies, the associated fuzzy linear programming models are converted into their equivalent auxiliary crisp ones. The proposed FHPP structure is implemented for the case study and through its comparison with the previously developed crisp model; the obtained results as well as some managerial implications are provided in Section 5. Finally, Section 6 is devoted to the concluding remarks and some future research directions.

2. Literature review

The fuzzy set theory has been considerably applied for modeling and solving the different variants of production planning and scheduling problems in an uncertain environment. Hsu and Wang [4] developed a possibilistic linear programming (PLP) model based on Lai and Hwang's [5] approach to determine appropriate strategies regarding the safety stock levels for assembly materials, regulating dealers' forecast demands and numbers of key machines in an assemble-to-order environment. Fung et al. [6] presented a fuzzy multi-product aggregate production planning (FMAPP) model to cater different scenarios under various decision-making preferences by applying integrated parametric programming and interactive methods. Wang and Liang [7] developed a fuzzy multi-objective linear programming model with piecewise linear membership function to solve multi-product APP problems in a fuzzy environment. In another research work, the authors [8] presented an interactive possibilistic linear programming model using Lai and Hwang's [5]