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An aggregate production planning model for two phase production systems: Solving with genetic algorithm and tabu search

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ABSTRACT

Aggregate production planning (APP) is a medium-term capacity planning to determine the quantity of production, inventory and work force levels to satisfy fluctuating demand over a planning horizon. The goal is to minimize costs and instabilities in the work force and inventory levels. This paper is concentrated on multi-period, multi-product and multi-machine systems with setup decisions. In this study, we develop a mixed integer linear programming (MILP) model for general two-phase aggregate production planning systems. Due to NP-hard class of APP, we implement a genetic algorithm and tabu search for solving this problem. The computational results show that these proposed algorithms obtain good-quality solutions for APP and could be efficient for large scale problems.

1. Introduction

Aggregate production planning is medium-term capacity planning often from 3 to 18 months ahead. It is concerned with the lowest-cost method of production planning to meet customer's requirements and to satisfy fluctuating demand over the planning horizon.

A survey of models and methodologies for APP has been represented by Nam and Ogendar (1992). Some researchers have used a hierarchical approach for production planning that called hierarchical production planning (HPP) (Ari & Axsater, 1988; Axsater, 1986; Bitran, Haas, & Hax, 1982). Also, the multi criteria decision making (MCDM) approach has been used for production planning (Masud & Hwang, 1980; Tabucanon & Majumdar, 1989).

Nowadays, meta-heuristic methods are used to solve NP-hard problems and due to NP-hard class of aggregate production planning, these approaches have been used for solving APP (Fahimnia, Luong, & Marian, 2006; Jiang, Kong, & Li, 2008). Researchers have used fuzzy approach with genetic algorithm to formulate and solve APP (Aliev, Fazlollahi, Guirimov, & Aliev, 2007; Hsu & Lin, 1999). Other methods such as hybrid algorithms (Ganesh & Punniyamoorthy, 2005; Mohan Kumar & Noorul Haq, 2005) and tabu search algorithm (Baykasogluy, 2006; Pradenas & Pe~nailillo, 2004) have been implemented to solve APP. But these presented methods are generality concentrated on the solution algorithm but not on a general model. On the other hand, the consideration of the all parameters in an APP model makes it more difficult. So researchers have not presented a comprehensive and general model to formulate real production environments. The majority of models in the APP are relevant to single product and single stage systems and they are not compatible to real production systems. In this paper a general and comprehensive aggregate production planning model is represented and is solved by meta-heuristic approaches.

This paper considers a multi-period, multi-product multi-machine and two-phase system in which involves setup costs and setup times. If a specific product is produced in a period then each required machine must be set up exactly once in that period. Since there is setup decisions in this system so we must formulate this model as a mixed integer programming (MIP) problem (Hung & Hu, 1998).

The rest of this paper is organized as follows. In Section 2, the proposed aggregate production planning model is demonstrated. In Sections 3 and 4, genetic algorithm and tabu search for solving the problem are described. In Section 5, the computational results are given and in last section we present our conclusion.

2. Aggregate production planning model

In this section, a proposed MILP for APP is presented. This model is relevant to multi-period, multi-product, multi-machine and two-phase production systems. At first phase, the individual pieces are produced by first groups of workers and machines; we call these pieces, first-phase products. At the next stage, the first-phase products and other purchased products are assembled into aggregate products by second groups of workers and machines. We call them second-phase products (Fig. 1).

There are several features which are involved in the model such as setup decisions and lead time. If a specific product is produced

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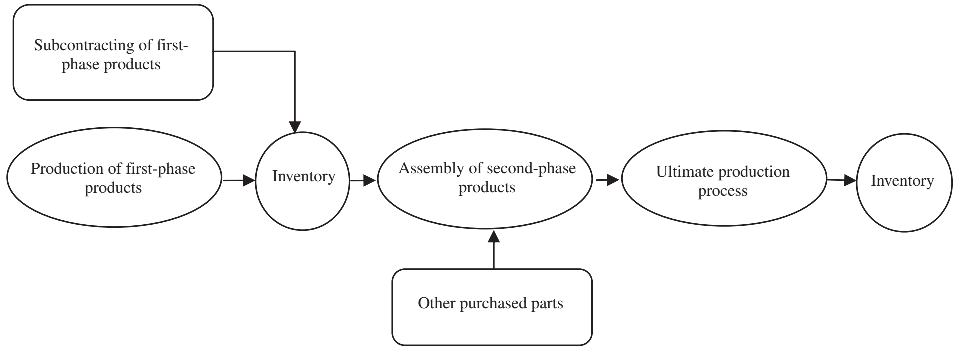

Fig. 1. The two phase production system.

in a period then each required machine must be set up exactly once in that period. The assumptions of the model are as follows:

- Setup times and setup costs are considered.
- Setup times are independent on jobs sequence.
- Machines are available at all times.
- All programming parameters have deterministic value and there is no randomness.

2.1. Model variables

P_{k1t}: Regular time production of first-phase product k in period t (units).
O_{k1t}: Over time production of first-phase product k in period t (units).
C_{k1t}: Subcontracting volume of first-phase product k in period t (units).
I_{k1t}: The inventory of first-phase product k in period t (units).
P_{i2t}: Regular time production of second-phase product i in period t (units).
O_{i2t}: Over time production of second-phase product i in period t (units).
C_{i2t}: Subcontracting volume of second-phase product i in period t (units).
B_{i2t}: Backorder level of second-phase product i in period t (units).
I_{i2t}: The inventory of second-phase product i in period t (units).
H'_t: The number of first group workers hired in period t (man-days).
L'_t: The number of first group workers laid off in period t (man-days).
W'_t: First workforce level in period t (man-days).
H_t: The number of second group workers hired in period t (man-days).
L_t: The number of second group workers laid off in period t (man-days).
W_t: Second workforce level in period t (man-days).
C_{k10}: Subcontracting volume of first-phase product k in the beginning of planning horizon (units).
y_{k1t}: The setup decision variable of first-phase product k in period t, a binary integer variable.
y_{i2t}: The setup decision variable of second-phase product i in period t, a binary integer variable.

2.2. Model parameters

D_{i2t}: Forecasted demand of product i in period t (units).
p_{k1t}: Regular time production cost of first-phase product k in period t ($/units).
o_{k1t}: Over time production cost of first-phase product k in period t ($/units).
c_{k1t}: Subcontracting cost of first-phase product k in period t ($/units).
h_{k1t}: Inventory cost of first-phase product k in period t ($/units).
p_{i2t}: Regular time production cost of second-phase product i in period t ($/units).
o_{i2t}: Over time production cost of second-phase product i in period t ($/units).
c_{i2t}: Subcontracting cost of second-phase product i in period t ($/units).
b_{i2t}: Backorder cost of second-phase product i in period t ($/units).
h_{i2t}: Inventory cost of second-phase product i ($/units).
a_{i2j}: Hours of machine j per unit of second-phase product i (machine-days/unit).
a_{k1l}: Hours of machine l per unit of first-phase product i (machine-days/unit).
u_{i2j}: The setup time for second-phase product i on machine j (hours).
u_{k1l}: The setup time for first-phase product i on machine l (hours).
r_{i2jt}: The setup cost of second-phase product i on machine j in period t ($/machine-hours).
r_{k1lt}: The setup cost of first-phase product i on machine l in period t ($/machine-hours).
R_{jt}: The regular time capacity of machine j in period t (machine-hours).
R'_{lt}: The regular time capacity of machine l in period t (machine-hours).
hr_t: Cost to hire one worker in period t for second group labor ($/man-days).
l_t: Cost to layoff one worker of second group in period t ($/man-days).
hr'_t: Cost to hire one worker in period t for first group labor ($/man-days).
l'_t: Cost to layoff one worker of first group in period t ($/man-days).
w_t: The first group labor cost in period t ($/man-days).
w'_t: The second group labor cost in period t ($/man-days).
I_{i20}: The initial inventory level of second-phase product i in period t (units).
I'_{k10}: The initial inventory level of first-phase product i in period t (units).
w_0: The initial first group workforce level (man-days).
w'_0: The initial first group workforce level (man-days).
B_{i20}: The initial first group workforce level (man-days).
f_i: The number of unit of first-phase product k required per unit of first-phase product i.