ELSEVIER

Int. J. Production Economics 64 (2000) 1–9

international journal of production economics

www.elsevier.com/locate/dsw

Lot-sizing problem with setup times in labor-based capacity production systems

El-Houssaine Aghezzaf*

School of Business Administration, Al Akhawayn University, P.O. Box 1821, Avenue Hassan II, 53 000 Ifrane, Morocco

Abstract

In many production systems, capacities depend not only on machine capacities, but also on the available work-force levels in each period of the planning horizon. Therefore, these capacities are given in terms of labor hours. In order to develop aggregate plans, work-force levels should be established first, and then translated into available regular-time and overtime production capacities. In this paper, we suggest an integrated approximation procedure that generates efficient aggregate plans based on staffing mixed strategies. We first develop an algorithm that produces an efficient mixed strategy-based staffing plan. The labor capacities resulting from this algorithm are then translated into available regular-time and overtime unit production capacities. These capacities are finally integrated into another algorithm to generate the final aggregate plan.

Keywords: Aggregate planning; Labor-based capacity; Setup times

1. Introduction

In almost all production systems, capacities depend not only on machine production rates, but also on the available work-force levels. Therefore, in order to develop an aggregate plan, the available work-force level, in each period of the planning horizon, should be established and then translated into regular and overtime production capacities. Work-force level variables are considered in certain aggregate planning models reported in the literature. However, in almost all these models, regular-time and overtime unit production capacities are assumed to be given, and the major concern is typically the minimization of the regular and overtime production costs, subcontracting costs, and inventory costs. In this paper, we suggest an explicit formal and integrated procedure to solve the staffing mixed strategies-based aggregate planning problems. Therefore, in our suggested model the concern is not only the minimization of the production costs, subcontracting costs, and inventory costs, but also the cost of labor. For labor-based capacity production systems, it is necessary to establish a staffing plan, and then use the resulting labor capacities to determine the available regular and overtime unit production capacities to finally generate aggregate plans.

* Tel.: 212-5-86-23-17.

E-mail address: e.aghezzaf@alakhawayn.ma (E.-H. Aghezzaf)

0925-5273/00/$ - see front matter
PII: S0925-5273(99)00029-8

Several authors have studied and developed various solution techniques for variants of aggregate planning problems. Holt et al. [1] have used linear decision rules, Taubert [2] has used the search decision rule for some simple aggregate planning models. These models are very basic in the sense that they take into consideration neither setup costs nor setup times, which are among aspects that complicate the aggregate planning problems. Other authors have tackled more complex models which take into account either setup costs or setup times, and have developed solution techniques, among others, Dixon and Silver [3], Dzelinsky and Gomory [4], Lasdon and Terjung [5], Bahl [6], Anderson and Cheah [7], Barany et al. [8], Eppen and Martin [9], Maes et al. [10], Millar and Yang [11], Aghezzaf and Artiba [12]. Here, we propose an approximation procedure to solve the staffing mixed strategies based aggregate planning problems, based on Lagrangean decomposition. The main distinguishing features of our decomposition are two: (i) unlike the usual Lagrangean relaxations which remove the complicating constraints, and hence a part of the constraint set, our Lagrangean decomposition retains all of the original set of constraints; (ii) unlike almost all Lagrangean decomposition algorithms in which subgradient procedures are used to compute Lagrangean multipliers, in our Lagrangean decomposition the Lagrangean multipliers are obtained through shadow prices corresponding to some constraints of the model.

2. Problem statement

Consider the problem of planning the production of a set of N products, $i = 1, \dots, N$, over a planning horizon of T periods. Assume that production capacities, in each period, are given in terms of available labor hours, and that backorders are not allowed. Also, assume that each worker contributes δ hours on regular time per period. In addition, let τ_i be the average production rate of product i per hour. Overtime production and subcontracting are possible options to supplement regular-time production. Overtime is limited to α percent of regular-time production in any period.

2.1. The model

To formulate the model used for aggregate planning in the labor-based capacity production systems, namely the staffing mixed strategy-based aggregate planning problem, let us first define the following parameters:

- C_t^{w} regular wage per worker per hour,
- C_t^{o} overtime wage per worker per hour,
- C_t^{hr} cost of hiring a worker,
- C_t^{l} cost of laying off a worker,
- c_{it}^{I} internal production cost of a unit of product i in period t,
- c_{it}^{E} external purchasing cost of a unit of product i in period t,
- c_{it}^{Hl} holding cost per unit per period,
- D_{it} demand for product i in period t.

Also, let us define the following variables:

- W_t workers on hand at the start of period t,
- O_t overtime equivalent worker in period t,
- H_t workers hired at the start of period t,
- L_t workers laid off at the start of period t,
- Q_{it}^{I} internal production of product i in period t,
- Q_{it}^{E} external quantity of product i supplied in period t,
- I_{it} quantity of product i in the inventory at the end of period t,
- y_{it} binary variable set to 1 if product i is produced in period t.

In addition, we let αW_t be the maximum equivalent overtime workers, and let s_i be the setup time of product i. Also, consider the following changes in the costs: $c_t^{\mathrm{w}} = \delta C_t^{\mathrm{w}}$, $c_t^{\mathrm{o}} = \delta C_t^{\mathrm{o}}$, $c_t^{\mathrm{hr}} = \delta C_t^{\mathrm{hr}}$, and $c_t^{\mathrm{l}} = \delta C_t^{\mathrm{l}}$. Now the model labeled (MILP), may be stated as follows:

Program MILP:

Minimize $Z_{IP} = Z_{IP}^{\mathrm{Labor}} + Z_{IP}^{\mathrm{Prod}}$,

where

$$Z_{IP}^{\mathrm{Labor}} = \sum_{t=1}^{T} (c_t^{\mathrm{w}} W_t + c_t^{\mathrm{o}} O_t + c_t^{\mathrm{hr}} H_t + c_t^{\mathrm{l}} L_t),$$

$$Z_{IP}^{\mathrm{Prod}} = \sum_{t=1}^{T} \sum_{i=1}^{N} (c_{it}^{\mathrm{I}} Q_{it}^{\mathrm{I}} + c_{it}^{\mathrm{E}} Q_{it}^{\mathrm{E}} + c_{it}^{\mathrm{Hl}} I_{it}),$$