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Production planning: An improved hybrid approach

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Abstract

This paper proposes an extended linear programming model for the hybrid approach proposed by Byrne and Bakir (International Journal of Production Economics 59 (1999) 305) and Kim and Kim (International Journal of Production Economics 73 (2001) 165). In this new model the workload of jobs is sub-divided to introduce the unit load concept of JIT. While an optimum plan is sought, due to this unit load concept, the model takes account of the requirement of small lot sizes which is one factor of the JIT approach. The effective loading ratio (ratio of the output quantity to the input quantity) is modified by omitting the slack time for each job. This helps to ensure that correct quantity of product is produced in each period, thus minimising any excess inventory or backlogging. Omission of slack time will also improve equipment utilisation and throughput. A flexible capacity constraint is also introduced which takes into account the availability of resources based on their previous histories.

The incorporation of the unit load concept and modification of resource requirements and constraints in the proposed LP formulation are expected to help to improve the planning model by reducing the level of WIP and total flow time.

Keywords: Production planning; Hybrid approach; Simulation; Optimization

1. Introduction

Linear programming (LP) models for production planning have been well known for many years. A typical LP planning model has the objective of minimising the total cost (generally covering the production cost, inventory cost, shortages cost, etc.) over a fixed planning horizon. The usual constraints are inventory balances, production quantity, demand quantity and capacity constraints in each period of the planning horizon.

Material requirement planning (MRP) systems are widely used in production planning. Billington et al. (1983) presented mathematical programming formulations for the general MRP planning problem, together with a method to reduce the

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problem size. However, the complexity of real production systems makes it difficult for MRP systems to deal with the real characteristics of system demand. Segerstedt (1996) further developed the models of Billington et al. (1983) and identified the issue of scheduling constraints, which can lead to infeasibility of mathematical solutions. To overcome some of these difficulties the hybrid solution approach, which gives the advantages of both analytical and simulation solution procedures has been proposed and investigated by Byrne and Bakir (1999) and Kim and Kim (2001).

This paper describes an extended LP model for the hybrid approach proposed by Byrne and Bakir (1999) incorporating JIT concepts.

2. Background review

The different types of production planning models are discussed in Bakir (1996) and Byrne and Bakir (1999). It appears however that LP models and simulation models are the most widely used. For simple production scenarios LP models are effective and more nearly optimal than simulation models. However, for complex situations simulation models can be more effective. It is possible to take advantage of both approaches by using the hybrid solution approach. These approaches are discussed by Nolan and Sovereign (1972) and Hoover and Perry (1989). To take advantages of both, an integrated has been discussed by Shanthikumar and Sargent (1983).

Byrne and Bakir (1999) showed that the solution from the classical LP planning model may be infeasible for real production system due (*inter alia*) to non-linear behaviour of the workloads at the machines. The two major parts of the LP model, the workloads and capacity constraints, are the issues of concern. They proposed the adjustment of capacity constraints based on the results of the simulation runs to obtain more realistic capacity constraints.

Hung and Leachman (1996) proposed a similar approach modifying the workloads on the left-hand side of the LP model. Kim and Kim (2001) combined and extended the ideas proposed by the previous researchers by applying the loading ratio for workloads and the effective utilization at machines for capacity adjustment.

Estrada et al. (1997) explored the number of production kanbans (NPK) and the unit load size (ULS) for the introduction of Just-in-Time (JIT) techniques. Their model they used determines the combination of NPK and the ULS that results in the lowest probability of stockout (PS). Bard and Golany (1991) also presented a model for determining the optimal number of kanbans at each workstation in a manufacturing system.

Yellig and Mackulak (1997) incorporated knowledge of past machine performance into the scheduling logic by capacity hedging. The optimal capacity hedge is based on a machine's history of interrupted production or unplanned downtime.

In this paper, we apply and extend all these ideas to develop a capacity feasible production plan using the hybrid (LP/simulation) approach.

3. Proposed approach

We propose the following model by applying ideas from the previous section to develop a new formulation of the LP model.

The objective function is:

$$\text{Min} \sum_{i=1}^{N}\sum_{t=1}^{T}(c_{it}Y_{it} + h_{it}I_{it} + \pi_{it}B_{it}),$$

subject to

$$\sum_{i=1}^{N}\sum_{j=1}^{M_i} e_{ijk}a_{ijk}\alpha_i G_{it} \leqslant P_a C_{kt} c,$$

$$I_{it} - B_{it} = I_{it-1} - B_{it-1} + Y_{it} - d_{it},$$

$$X_{it} = \alpha_i G_{it},$$

$$G_{it} \leqslant \text{ULS} \leqslant \text{PC}_i,$$

where T is the time period, $1, 2, 3, \ldots, t, \ldots T$; N the number of products, $1, 2, 3, \ldots, i, \ldots N$; c_{it} the production cost of one unit for product i in time period t; Y_{it} the output quantity for product i in time period t (relationship with input quantity is: $Y_{it} = e_{ijk}X_{it}$); h_{it} the inventory carrying cost of one unit for product i in time period t; I_{it} the inventory of product i after time period t; π_{it} the backlogging cost