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Extended model for a hybrid production planning approach

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Abstract

The traditional production planning model based upon the famous linear programming formulation has been well known in the literature. However, the capacity constraints in such a model may not correctly represent the actual situations of the shop floor, as pointed out by Byrne and Bakir (International Journal of Production Economics 59 (1999) 305–311). A hybrid approach was proposed by them, applying simulation and a linear programming model iteratively, to find the capacity-feasible production plan. This paper proposes an extended linear programming model for a similar hybrid approach. At each simulation run, the actual workload of the jobs and the utilization of the resources are identified. The information is then passed to the linear programming model for calculating the optimal production plan with minimum total costs. Through the case study, it is shown that the proposed approach finds the better solution in a less number of iterations compared to the approach by Byrne and Bakir. © 2001 Elsevier Science B.V. All rights reserved.

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1. Introduction

The classical linear programming (LP) models for planning production have been around for many years. A typical formulation of the LP planning model has the objective of minimizing the total production-related costs, such as variable production costs, inventory costs, and shortage costs, over the fixed planning horizon (see, for example, [1, 2]). The usual constraints employed are: (1) inventory balance equations for making the inventory and/or shortages balanced with those from the previous period, production quantity, and the demand quantity, (2) capacity constraints which ensure the total workload for each resource (labor, machine, etc.) not exceed the capacity in each period. A formal description of the classical LP formulation is given in the next section.

Even though the classical LP model does consider the limited availability of the resources through the capacity constraints, it is known that such capacity constraints may not correctly represent the complex behavior of the resource consumption in a real production system. Byrne and Bakir [3] recently showed that the solution from the classical LP planning model may be infeasible for the real production system, due to the non-linear behavior of the workloads at the machines. The reason for the infeasibility of the LP solution is that the classical capacity constraints assume the

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workloads from the decision variables (i.e., the production quantities) to be linear in each period. The total workload in a period is defined as the sum of the processing time multiplied to the production quantity for each product type at the machine. The capacity constraint says the workload should be less than the capacity of the machine in that period.

There are two 'unrealistic' parts in the classical capacity constraints. First, in the real production system, the workload of the production quantity at a machine as calculated above seldom occurs in the same period as the production quantity is out. For example, let us assume 100 units of a product type are to be produced in period 5. To produce the type, we assume 3 machines are used, and each machine handles one processing step for total of 3 steps. At each machine, 1 hour of unit processing time is required. In the classical capacity constraints, the workload of (1 hour $\times$ 100 units) will occur at each machine, and it must not exceed the machine work hours in period 5. However, in the real production system, the workload on a machine may not entirely occur in period 5. Instead, the workload may be divided into two periods, say 5 and 6, so that the last machine (machine 3) may finish 100th unit by the end of period 6. Thus, to correctly describe the actual workload at each machine, it is necessary to figure out how much of the total workload will occur in each period. This task is not an easy one due to the fact that the profile of the workload depends upon the production plan, operation rules, and the system configuration.

The second unrealistic part in the classical capacity constraint is the right-hand side (i.e., the available amounts of the resources) of the constraint. It is assumed that the full working hours of the machines can be utilized by the production output in the corresponding period. However, even in a deterministic system without failures of the machines or yield loss, it is not possible to achieve it. For example, buffer limits or the operational sequence of the jobs may create some idle times for a machine even if the machine is available. One may adjust the capacity by multiplying the average utilization to the full capacity, but it does not exactly count the 'feasible' amount of the resource capacity. The actual amount of the capacity to be allocated to the requirements for each machine in a period is hard to estimate a priori. It also depends upon the product mix, operating rules, and the system configuration.

To overcome such shortcomings of the classical capacity constraints, Byrne and Bakir [3] proposed a hybrid approach using a simulation model to support the LP planning model. The proposed approach is based on imposing 'adjusted capacities' derived from the simulation model results, which is recursive in structure as follows:

Step 1: Solve LP model and find the optimal production plan.
Step 2: Using the current plan, run the simulation model.
Step 3: If the current plan is found feasible through the simulation, terminate the iteration. The current plan is the final solution. Otherwise, continue.
Step 4: Calculate the adjusted capacities for the LP capacity constraints based on the simulation results. Use the new capacities for the capacity constraints of the LP model.
Step 5: Go to step 1.

In step 4, the proposed adjustment is made through the following formulation:

(Adjusted capacity of a machine for period t) = (Full capacity of a machine for period t) $\times$ (Fraction of the full capacity of the machine actually consumed in period t during the simulation run).

Thus, in each iteration of the procedure, the simulation results are reflected to the right-hand sides of the capacity constraints by multiplying the utilization fractions. The iteration terminates if the current LP plan is identical to the previous one, i.e., the plan is feasible to the capacities of the resources.

The approach by Byrne and Bakir [3] solved the second part of the shortcomings mentioned above. However, the assumption that the workloads by the production quantity in a period occur in the same period still needs to be generalized. To solve this part, Hung and Leachman [4] proposed a similar approach to Byrne and Bakir [3] in which the LP model is revised by the results from the simulation runs iteratively. Hung and Leachman's [4]