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Interfaces with Other Disciplines

Earliness–tardiness production planning for just-in-time manufacturing: A unifying approach by goal programming

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Abstract

With popularity of the just-in-time (JIT) philosophy, researchers have started to seek the integration of Manufacturing Resource Planning (MRP-II) and JIT methodologies. This paper deals with the master production planning problem for a mass manufacturing system in the JIT environment, an earliness–tardiness production planning (ETPP) problem. The objective is to determine the optimum production rate for each product so that the total penalties imposed on the early and tardy production for all production periods be minimized. A goal programming (GP) approach is proposed to formulate the ETPP problem in a more generalized form, which includes several existing models in one unifying model. Moreover, the proposed GP algorithm ensures a global optimum solution, while the existing ones did not. In addition, it also possesses the advantages over others, such as easier to comprehend, easier to solve, and easier to extend it to the problem of multiple goals.

Keywords: Goal programming; Production planning; Just-in-time (JIT); Optimization

1. Introduction

The manufacturing resource planning (MRP-II), evolved from material requirement planning (MRP) and named by Wight (1981), is a modification of master production planning for the traditional "push" manufacturing system. Unlike MRP, which is primarily a departmental planning; MRP-II is a company-

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wide resource planning, which disaggregates strategic plans into operational plans in terms of organizational resources (Sipper and Bulfin, 1997). Although this modification benefits from decreasing inventory level, reducing lead time, and improving production control; MRP-II still possesses some shortcomings intrinsic to the push system, such as relatively high work-in-process inventory and long machine/people idle time.

To alleviate these problems, a ''pull'' manufacturing system such as just-in-time (JIT) is incorporated into MRP-II. Generally speaking, JIT pursues excellence in providing customers with what they order in the right quantity at the right time. In the context of production planning, JIT seeks the production level of each product for each period with the right quantity at the right time. It implies that the levels of any early and tardy production for each planning period be minimized if the exact quantity and exact timing were not met. Thus, the primary objective of MRP-II, in JIT setting, is to minimize the total penalties caused by the earliness and tardiness for all planning periods. In this paper, the class of problems with this objective function is referred to as the earliness–tardiness production planning (ETPP) problem.

Recently, the ETPP problem has drawn a great attention. Wang (1995) addressed a multi-product multi-process ETPP problem from an aggregate-planning perspective with consideration of capacity limitations in processing stages of all periods. Li et al. (1998) proposed two efficient methods to solve the same problem. Hao et al. (1998) investigated the similar ETPP problem for one-of-a-kind production with additional considerations of manufacturing cycle time and its earliest start time. Wang and Wang (1998) revisited the earlier ETPP model concerning the due window, instead of due date, for each job order. Wang et al. (1999) extended the later problem to considering maintenance schedule for each processing facility and non-deterministic resource capacities. Ip et al. (2000) addressed the mass production problem with additional considerations of production lot size and capacity limitation.

In a related area, the JIT philosophy has been extended to the study of ETPP problems in scheduling (or sequencing jobs on machines). For example, Sidney (1977), Kanet (1981), Bagchi et al. (1987), Liman and Ramaswamy (1994), De et al. (1994), Hiraishi et al. (2002), Yoon and Ventura (2002); to name a few. However, the scheduling problems are not the subject of this paper.

This paper primarily addresses the ETPP problems dealt by Wang (1995), Li et al. (1998), Ip et al. (2000). Wang and Li et al. formulated the ETPP problem as linear programming models, while Ip et al. formulated as a discrete mathematical model and solved by a genetic algorithm. Instead of piecemeal approach, this paper proposes a unifying approach for these three problems by the use of goal programming methodology. The goal programming (GP) formulations turn out to be a linear program for the first two problems and a mixed integer program for the third problem.

The GP approach has several advantages over the existing models and algorithms: (1) easier to comprehend, (2) easier to be solved, (3) ensuring global optimality, and (4) easier to be extended.

First, unlike the existing models, the proposed GP model does not need to introduce non-linear variables (x_i and y_i) in order to transform the non-linear programming model to a linear programming model. Additionally, the relationships between the production level, the inventory level, and the demand level are expressed in a more straight-forward manner.

Second, due to the advance of computer software and hardware technology, solving a LP problem with tens of thousand constraints and continuous variables presents no problem at all. Therefore, even a large-scale ETPP problem is solvable by the GP approach in a reasonable amount of time.

Third, Ip et al. (2000) utilized genetic algorithms to solve the ETPP problem. As a result, only feasible solutions (at best, near-optimal solutions) were found. On the contrary, a global optimal solution is always guaranteed by the GP approach.

Finally, the proposed GP model provides a generalized model for all related ETPP problems. More constraints can be easily augmented to the model. Moreover, the ETTP problems with multiple goals, encountered frequently in real life, can be handled by the proposed GP approach.