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A goal programming model for aggregate production planning with resource utilization constraint

Stephen C.H. Leung *, Shirley S.W. Chan

Department of Management Sciences, City University of Hong Kong, Hong Kong

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Abstract

This paper addresses the aggregate production planning problem with different operational constraints, including production capacity, workforce level, factory locations, machine utilization, storage space and other resource limitations. Three production plants in North America and one in China are considered simultaneously. A pre-emptive goal programming model is developed to maximize profit, minimize repairing cost and maximize machine utilization of the Chinese production plant hierarchically. A set of data from a surface and materials science company is used to test the effectiveness and the efficiency of the proposed model. Results illustrate the flexibility and the robustness of the proposed model by adjusting goal priorities with respect to importance of each objective and the aspiration level with respect to desired target values.

Keywords: Production management; Goal programming; Aggregate planning; Supply chain management; Utilization

1. Introduction

The company being studied is one of the largest multinational surface and materials science companies in the world. The company develops technologies to improve customers' products and processes in order to deliver significant value to its customers in a broad array of different end use markets. The company has four divisions within its business portfolio, including Environmental Technologies, Process Technologies, Appearance and Performance Technologies, and Materials Services. This study focuses on the Appearance and Performance Technologies division, and the data obtained for the study come from the Asia Pacific Region, Australia and New Zealand. Major products from this division include colour pigments, dispersions and universal colorants, as well as performance minerals. These products are raw materials for further processing, to be applied in various industries such as automotive furnishing, personal care materials, architectural materials, coatings, packaging, pharmaceutical products manufacturing and agriculture.

The company has four production plants for this division; three in North America and one in China. Composition of minerals at different locations is different due to climate and geological factors and, therefore,

* Corresponding author. Tel.: +852 2788 8650; fax: +852 2788 8560.
E-mail address: mssleung@cityu.edu.hk (S.C.H. Leung).

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products from each production plants are slightly different from those of other plants. Customers have preferences about specific plants and this has an impact on machine utilization at individual plants. Usually, some plants are over-utilized while some are under-utilized. However, such imbalances in machine utilization can be improved through differential selling prices, as well as additional technical advice or consultation. These actions serve as an incentive for customers to further refine the products during their production process. After the refining process, the same quality of end products is achieved, regardless of the location of the production plant.

Recently, the company has undertaken a system upgrade and adopted a big bang approach. All modules were implemented at the same time; all went alive at once, instead of phase-by-phase. This aggressive move has not been very successful as disorders have significantly increased after implementation, especially in order processing and product delivery. Though it is a systems integration failure, the ineffectiveness of, and chaos in, production planning is considered to be the major cause for the disorders. It is also one of the major challenges faced by the company and its sales force in its history and is likely to remain unresolved in the near future. The company has always encountered problems such as delay in production and product shortages, which usually result in loss of sales and increase in transportation cost as it has to switch from sea-freight to air-freight mode to meet committed delivery dates. The production planning problem also creates additional workload for its sales force and customer services team. The sales force always receives complaints from customers about the long lead-time or stock-outs. The team of customer service often needs to re-allocate or transfer stocks from one region to another. Therefore, the problem of multi-site aggregate production planning is addressed in this study.

Traditionally, the objective of aggregate production planning is either to maximize profit or minimize cost and is formulated to a single-objective function in linear programming. Recently, many researchers and practitioners are increasingly aware of presence of multiple objectives in real-life problems (Vincke, 1992). Decision-makers always want to develop a model that can consider real-life situations with multiple objectives. To achieve this, in this paper, a goal programming approach is taken because the company's management has indicated several targets with various priorities assigned.

The problem is an aggregate production planning (APP) problem. Baykasoglu (2001) defined APP as medium-term capacity planning over a 2–18 month planning horizon. Nam and Logendran (1992) reviewed APP models from 140 journal articles and 14 books, and categorized the models into optimal and near-optimal classifications. Masud and Hwang (1980) presented three MCDM methods, which are goal programming (GP), the step method (STEM) and sequential multiple objective problem solving (SEMOPS), for the APP problem, with objectives of maximizing of contribution to profit, minimizing of changes in workforce level, minimizing of inventory investment, and minimizing of back-orders. A set of data consisting of two products, a single production plant and eight planning periods was generated to compare the results. Baykasoglu (2001) extended Masud and Hwang's model with additional constraints, such as sub-contractor selection and set-up decisions. A tabu search algorithm was designed to solve the pre-emptive goal programming model. An object-oriented program in C++ called MOAPPS 1.0 (Multiple Objective Aggregate Production Planning Software) was developed and used to compare Masud and Hwang's model with the extended model. Integration of production planning problems with other planning problems was considered; for instance, scheduling problems (Buxey, 1993; Foote, Ravindran, & Lashine, 1998), workforce planning problems (Mazzola, Neebe, & Rump, 1998) and long set-up time problems Porkka, Vepsalainen, and Kuula (2003).

The organization of this paper is as follows. After this introduction, background of the goal programming formulation is described. A pre-emptive goal programming model is formulated to solve the production planning problem in Section 3. In Section 4, a set of data from the Hong Kong-based company is used to test the effectiveness and the efficiency of the proposed model. Our conclusions are given in the final section.

2. A goal programming approach

Most of the real-world problems are formulated into a single-objective linear programming (LP) methodology or the LP model. Researchers and practitioners are more and more aware of the presence of multiple criteria in real-life problems of management and decisions (Tamiz, Jones, & Romero, 1998; Vincke, 1992).

Goal programming (GP), which is an extension of LP, is commonly applied to deal with multi-objective problems (Rifai, 1994). Charnes and Cooper (1961) described that GP is used to derive a set of conflict objectives as close as possible. Tamiz et al. (1998) reviewed the state-of-the-art current developments in goal