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Production planning with limited inventory capacity and allowed stockout

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Abstract

In production planning, there is a situation where the production quantity is limited by inventory capacity rather than production capacity. This situation often happens in petrochemical manufacturing, food processing, glass manufacturing, etc. Only a few studies can be found in literature for this situation, among which the stockout strategy is not well studied. In this paper, we consider the production-planning problem with inventory capacity as a limiting factor. We further consider the problem with the following features: (1) the stockout is allowed, (2) production and lost sale cost functions are time varying and non-increasing, and (3) inventory capacity is constant. These features have their roots in practice. In this paper, first we present a stockout model, and then we prove some properties at an optimal solution to our model. Based on these properties, we further develop an algorithm with polynomial time complexity using the network flow approach. The paper also provides a case study to further justify practicability of the stockout strategy with limited inventory and to show the effectiveness of our model and algorithm.

Keywords: Production planning; Bounded inventory; Stockout; Algorithm

1. Introduction

The intensive competition among manufacturing companies today demands that they have to make right decisions on allocation of resources and scheduling their operations. With the expansion of market size, efficiency of production is becoming a critical point of success in manufacturing companies. The normal motivation for effective production planning is to resolve the conflicting resource needs and to meet customer demands within a given period of time. Fruitful solutions have been generated over last decades for somewhat conventional problems that exclude stockout and its related issues (e.g., cost function, etc.). However, the stockout strategy in production planning, together with the limited inventory and its related issues, has not been well studied. In the following two paragraphs, we discuss the background of the limited inventory and define the stockout strategy in production planning for the lowest cost.

Generally, in production planning, two primary limiting factors are production capacity and

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inventory capacity, of which the former is more popular and well discussed. However, in many process industries such as paper manufacturing, petrochemical manufacturing, food processing, and pharmaceutical manufacturing, inventory capacity may become a limiting factor. For example, in the refinery industry, production is usually with sufficiently high capacity (due to a relative stability in both equipment and skills) and hence, customer demands for the petrochemical products are usually restricted by their sizes of oil tanks or barrels (in other words by inventory or storage capacity). There are a couple of other situations that production is not able to meet customer demands. These situations include (1) the setup and production costs are too high and/or (2) the product holding and storage costs (assuming that products need to be held in storage for a while) are too high. When meeting of customer demands is controlled under the limit of inventory capacity, we call this situation limited or bounded inventory capacity.

It is known that in production planning two primary goals are meeting customer demands and having the lowest cost. These two goals may not always be consistent. For example, an increase in the inventory level can certainly maximize the meeting of customer demands, but the holding cost may be too high, leading that the total cost is not the lowest one. Therefore, from the cost point of view, customer demands may not be satisfied. The unsatisfied demand means sale loss to a manufacturing company, and this situation in this paper is called stockout. The stockout strategy simply means to allow the stockout situation to happen.

In general, the issue in production planning in which inventory capacity is a limiting factor and there is a stockout situation has not been well addressed in literature, though this issue makes sense in practice. In this paper, we will discuss this issue. For simplicity, we name this issue production planning with limited inventory capacity and allowed stockout (PPLICS). We will further consider that demands and costs with PPLICS are time-varying (non-increasing) functions.

The remainder of this paper is organized as follows. In Section 2, we will review related work along with a further introduction to some background of PPLICS. In Section 3, a model for PPLICS will be formulated. In Section 4, some properties of the model will be presented. Based on these properties, a polynomial time complexity algorithm is proposed in Section 5. In Section 6, a case study for a real-life problem in a refinery company by using the proposed approach is presented. Finally, in Section 7 a conclusion is drawn along with a discussion of future research.

2. Related work

The capacity production-planning (CPP) problem can be described as follows. For a finite time horizon T, there are T periods from 1 to T, denoted by t ($t = 1,2,\ldots,T$). In any production period t, there is a dynamic demand. This demand must be satisfied by one or more of the following strategies: (1) production; (2) inventory; (3) backlogging; (4) outsourcing; and (5) sale loss. Note that there are limits, respectively, on production, inventory, backlogging, outsourcing, and sale loss levels. Furthermore, five kinds of costs must be taken into account: production cost (including setup cost), holding cost, backlogging cost, outsourcing cost, and sale loss cost. There are two kinds of capacity limits: (1) production capacity and (2) inventory capacity. When a production planning takes production capacity as a limiting factor, it is called *capacitated* production planning, and when a production planning takes inventory capacity as a limiting factor, it is called production planning with *limited inventory capacity* or *bounded inventory* (see also previous discussion). The objective of CPP is to determine periods and quantities supplied during these periods with the objective of minimizing the total cost aggregated from the five kinds of costs over the definite time horizon T.

In literature, the following four families of models are proposed, corresponding to the five strategies mentioned before.

- *Models without backlogging*: Each demand d_t must be entirely delivered at period t by production and/or inventory.
- *Models with backlogging*: Each demand d_t must be entirely delivered at a time period later than t at the expense of backlogging cost. In other words, each demand must be satisfied by production and/or inventory from previous periods and/or from subsequent periods.
- *Lost sale models*: There are two kinds of lost sale models, stockout models and conservation models. In *stockout models*, the demand does not have to be entirely met in all periods. Unmet demands