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Supply chain models for an assembly system with preprocessing of raw materials

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Abstract

In this paper, we investigate the material procurement and delivery policy in a production system where raw materials enter into the assembly line from two different flow channels. The system encompasses batch production process in which the finished product demand is approximately constant for an infinite planning horizon. Two distinct types of raw materials are passed through the assembly line before to convert them into the finished product. Of the two types of raw materials, one type requires preprocessing inside the facility before the assembly operation and other group is fed straightway in the assembly line. The conversion factors are assigned to raw materials to quantify the raw material batch size required. To analyze such a system, we formulate a nonlinear cost function to aggregate all the costs of the inventories, ordering, shipping and deliveries. An algorithm using the branch and bound concept is provided to find the best integer values of the optimal solutions. The result shows that the optimal procurement and delivery policy minimizes the expected total cost of the model. Using a test problem, the inventory requirements at each stage of production and their corresponding costs are calculated. From the analysis, it is shown that the rate and direction change of total cost is turned to positive when delivery rates per batch reaches close to the optimal value and the minimum cost is achieved at the optimal delivery rate. Also, it is shown that total incremental cost is monotonically increasing, if the finished product batch size is increased, and if, inventory cost rates are increased. We examine a set of numerical examples that reveal the insights into the procurement-delivery policy and the performance of such an assembly type inventory model.

Keywords: Inventory model; Raw materials; Nonlinear integer programming

1. Introduction

An efficient inventory model is designed to operate under a strategy that procurement of raw material and delivery of finished products will be such that the facility does not carry extra inventory but satisfy the customer demands in time. In spite of the significant researches in inventory modeling, the studies published did not consider some of the important issues such as preprocessing of raw materials inside the facility before

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final operation, conversion factors of raw materials to finished product and work-in-process inventory capacity. An assembled product may require raw materials in different quantities such as a *swivel* (*office*) *chair* needs one frame, but requires a number of wheels to operate. The number of units required for each component to produce one unit of finished product may vary (if same, then the conversion factor is one). So assigning conversion factors is important to determine the quantities of raw materials batches needed to produce one batch of finished product in one production cycle.

The body of the present work is the extension of Sarker and Parija (1996), but the raw materials considered are of two different natures and the production line design is as such that a preprocessing line feeds the assembly line. Among the raw materials, one group named *unfinished raw materials* needs preprocessing inside the facility, which is then converted into *processed raw materials* and prepared for the assembly operation. The other group directly arrives in the assembly line without requiring preprocessing as *ready raw materials*.

It is understood that manufacturers do not produce all items of a product inside the facility. They may want to produce few items inside the facility and buy the rest items from outside. For example, an air compressor manufacturer may produce compressor casing and air tanks inside the factory (from an *unfinished raw material* such as sheet metals), but may purchase some other components such as compressor motor (as *ready raw materials*) from outside suppliers. However, manufacturers may keep a variety of sizes of air compressors coupled with different power ranges of compressor motors. It is then convenient to manufacture a large variety of different sizes of compressor casing, air tanks etc. inside the facility to reduce the expenditure of acquiring such voluminous items (which also includes extra costs due to transportation and bulk storage). On the other hand, the compressor motors of different power ranges may be readily available in the market. It is now manufacturer's decision to select components to buy or manufacture depending on their expertise, availability of the raw products in market and obviously, the cost effectiveness of production.

In classical inventory model, the order placement policy and delivery policy are explored by a number of researchers. In just-in-time delivery system, Golhar and Sarker (1992) tested a generalized inventory model where uptime and cycle time are integer multiples of the shipment and the total cost is a piecewise convex function. Introducing several practical considerations such as multi-order procurement policy for raw materials, Sarker and Parija (1996) extended Golhar and Sarker's (1992) model in a single stage-manufacturing system. Gurnani et al. (1996) considered an assembly problem of two critical components where the finished product demand is stochastic. The study conducts the effect of supplier costs and the uncertainty of supply and delivery of raw materials.

Fujiwara et al. (1998) considered a Kanban-controlled, multi-stage assembly production system where raw materials acquisition times, reorder points, number of Kanbans, production lead time and demand are the variables. Numerical and iterative experiments are performed to obtain the optimal parameters performance evaluation of the system. Powell and Pyke (1998) addressed unbalanced assembly systems with limited buffer capacity. Some heuristic rules are developed to improve existing operations or to design new lines for new products. Wilhelm and Som (1998) considered performance measure of a single-product single-stage assembly system where raw materials are ordered under the material requirement planning (MRP) policy, and the inventory position process is a Markov renewal process where lead-time is a random variable. Park and Kim (1999) focused on make-to-order policy in an assembly system where delivery dates are constraints. A nonlinear mathematical model was presented to minimize the costs of the inventories. Park and Kim (2000) extend Park and Kim's (1999) model and incorporated 'branch and bound' (B&B) algorithm to find the best integer solutions. Agrawal and Cohen (2001) analyzed the cost-service performance and component stocking policies due to shortages and delayed production completion rates of finished product. Other researchers who worked in the related field are Schonberger and Schneiderjans (1984), Ramesh (1990), Rajamani (1993), De Kok and Ton (1999), Rosenblatt and Lee (1996), Sun and Atkins (1997), and Betts and Johnston (2001). An overview of the related works is shown in Table 1.

In this paper, we propose an inventory requirement problem for an assembly system where work-in-process inventory also plays an important role in total cost function. If there were no allowable work-in-process inventory in a production plant, i.e., restricted to zero, the output of the plant could be severely affected. The objective of this paper is to present a plan for materials procurement and deliveries in an inventory system for assembly production that minimizes the total cost by reducing the level of wasted materials, time and effort involved at each of the production stages. Both raw materials are procured through suppliers by a number