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An optimal batch size for a JIT manufacturing system

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Abstract

This paper addresses the problem of a manufacturing system that procures raw materials from suppliers in a lot and processes them to convert to finished products. It proposes an ordering policy for raw materials to meet the requirements of a production facility. In turn, this facility must deliver finished products demanded by outside buyers at fixed interval points in time. In this paper, first we estimate production batch sizes for a JIT delivery system and then we incorporate a JIT raw material supply system. A simple algorithm is developed to compute the batch sizes for both manufacturing and raw material purchasing policies. Computational experiences of the problem are also briefly discussed. © 2002 Elsevier Science Ltd. All rights reserved.

Keywords: Inventory control; Materials procurement; JIT; Periodic delivery; Optimum order quantity

1. Introduction

A desirable condition in long-term purchase agreements in a just-in-time (JIT) manufacturing environment is the frequent delivery of small quantities of items by suppliers/vendors so as to minimize inventory holding costs for the buyer. Consider a manufacturing system that procures raw materials from outside suppliers and processes them to convert into finished products for retailers/customers. The manufacturer must deliver the products in small quantities to minimize the retailer's holding cost, and accept the supply of small quantities of raw materials to minimize his own holding costs. In the traditional JIT environment, the supplier of raw materials is dedicated to the manufacturing firm, and normally is located close by. The manufacturing lot size is dependent on the retailer's sales volume (/market demand), unit product cost, set-up cost, inventory holding cost and transportation cost. The raw material purchasing lot size is dependent on raw material requirement in the manufacturing system, unit raw material cost, ordering cost and inventory holding cost. Therefore, the optimal raw material purchasing

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Nomenclature

D_p	demand rate of a product p, units per year
P	production rate, units per year (here $P > D_p$)
Q_p	production lot size
H_p	annual inventory holding cost, \$/unit/year
A_p	set-up cost for a product p (\$/set-up)
f_r	amount/quantity of raw material r required in producing one unit of a product
D_r	demand of raw material r for the product p in a year, $D_r = f_r D_p$
Q_r	ordering quantity of raw material r
A_r	ordering cost of a raw material r
H_r	annual inventory holding cost for raw material r
PR_r	price of raw material r
Q_r^*	optimum ordering quantity of raw material r
x	shipment quantity to customer at a regular interval (units/shipment)
L	time between successive shipments $= x/D_p$
T	cycle time measured in year $= Q_p/D_p$
m	number of shipments during the cycle time $= T/L$
n	number of shipments during production uptime
T_1	production uptime in a cycle
T_2	production downtime in a cycle $= T - T_1$
$\mathrm{IP}_{\mathrm{avg}}$	average finished goods inventory

quantity may not be equal to the raw material requirement for an optimal manufacturing batch size. To operate the JIT manufacturing system optimally, it is necessary to optimize the activities of both raw material purchasing and production lot sizing simultaneously, taking all the operating parameters into consideration. Unfortunately, until recently, most JIT studies in the literature have been descriptive (Aderohunmu, Mobolurin, & Bryson, 1995; Chapman & Carter, 1990), and most of the analytical studies do not take all the costs for both sub-systems into consideration (Ansari & Hechel, 1987; Ansari & Modarress, 1987; O'Neal, 1989). Therefore, the overall result may not be optimal.

A larger manufacturing batch size reduces the set-up cost component to the overall unit product cost. The products produced in one batch (/one manufacturing cycle) are delivered to the retailer in m small lots (ie m retailer cycles per one manufacturing cycle) at fixed time intervals. So the inventory forms a saw tooth pattern during the production uptime and a staircase pattern during production downtime in each manufacturing cycle. Likewise, the manufacturer receives n small lots of raw material, at regular intervals, during the production uptime of each manufacturing cycle. The raw materials are consumed at a given rate during the production uptime only. It is assumed that the production rate is greater than the demand rate. So the accumulated inventory during production uptime is used for making delivery during production downtime until the inventory is exhausted (see Fig. 1). Production is then resumed and the cycle repeated.

Sarker, Karim and Azad (1993, 1995a) and Sarker, Karim and Haque (1995b) developed a model operating under continuous supply at a constant rate. In their paper, they considered two cases. In case I, the ordering quantity of raw material is assumed to be equal to the raw material required for one batch of the production system. The raw material, which is replenished at the beginning of a production cycle, will

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