Available online at www.sciencedirect.com
ScienceDirect
Computers & Industrial Engineering 54 (2008) 95–109
computers & industrial engineering
www.elsevier.com/locate/dsw

Coordinating a two-level supply chain with production interruptions to restore process quality

Ahmed M.A. El Saadany, Mohamad Y. Jaber *

Department of Mechanical and Industrial Engineering, Ryerson University, Toronto, ON, Canada M5B 2K3

Received 23 August 2006; received in revised form 20 June 2007; accepted 20 June 2007
Available online 23 June 2007

Abstract

The classical inventory model, known as the lot size problem (LSP), assumes items produced and stocked to be of perfect quality. In reality, production processes are not defect free. Such imperfect processes generate defects that are reworked, and in some cases scrapped. The move by practitioners towards smaller lot sizes; e.g., just-in-time (JIT), as a mean of improving process and product quality prompted researchers to modify the LSP to represent reality more faithfully. The studies conducted by these researchers confirmed the observed benefits of smaller lot sizes. The inventory models developed in these studies assume that defects increase as the lot size increases, and that adjusting the process within a production cycle is not possible. Contrary to this assumption, in a JIT environment workers are authorized to stop production if a quality or production problem arises. This practice encouraged Khouja [Khouja, M. (2005). The use of minor setups within production cycles to improve product quality and yield. *International Transactions in Operations Research*, *12*(4), 403–416] to reformulate some inventory models which take into account the negative relationship between lot size and quality and the possibility of performing minor setups. This requires stopping the process during a production cycle. This paper investigates the work of Khouja in a centralized decision model where players in a two-level (manufacturer–retailer) supply chain coordinate their orders to minimize their local costs and that of the chain. Mathematical models are developed with numerical results discussed.

Keywords: Quality and inventory; Process improvement; Supply chain coordination

1. Introduction

The simplistic assumptions of the lot size problem, also known as the economic order/manufacture quantity (EOQ/EMQ) model, which make its mathematics easy to use and understand is probably why the lot size problem has been widely used and accepted by researchers and practitioners alike. Among the assumptions of the lot size problem is that items produced and stocked are of perfect quality.

Production processes are not defect free, and result in items that require reworking (e.g., Agnihothri & Kenett, 1995; Buzacott, 1999). Rework occurs when a product or a service does not meet the internal or

* Corresponding author. Tel.: +1 416 979 5000x7623; fax: +1 416 979 5265.
E-mail address: mjaber@ryerson.ca (M.Y. Jaber).

0360-8352/$ - see front matter © 2007 Elsevier Ltd. All rights reserved.
doi:10.1016/j.cie.2007.06.037

external quality requirements, and could be defined as doing something at least one extra time due to non-conformance to these requirements (e.g., Bohn & Terwiesch, 1999; Love, Li, & Mandal, 1999). This additional effort adds cost and not value to the product, which the just-in-time (JIT) philosophy considers as waste to be eliminated. The JIT also advocates that inventory is a blanket that covers problems is production and quality (Waters, 2003). To uncover these problems inventory levels must be reduced. This led many manufacturers to move towards smaller lot sizes to improve process and product quality; i.e., to reduce reworks.

Porteus (1986) and Rosenblatt and Lee (1986) were probably the first to independently investigate the negative relationship between lot size and quality. Although these models approach the deterioration of the process differently, they result in similar conclusions (Urban, 1998). The works of Porteus (1986) and Rosenblatt and Lee (1986) assume that once the production process goes out-of-control it is never interrupted and continues in that state until the entire lot is produced. Defective items generated are reworked once production ceases. Khouja (2005) corrected this assumption by allowing for adjustments to the process within a production cycle. The assumption of Khouja (2005) is corroborated by a common practice in JIT manufacturing environments where line workers have the authority to stop the line if a quality or production problem arises (Inman & Brandon, 1992). Khouja (2005) reformulated some inventory models which take into account the negative relationship between lot size and quality and the possibility of performing minor setups. Performing minor setups requires stopping the process during a production cycle. His results showed that interrupting the production process to bring it back in control reduces reworks. The models developed by Khouja (2005) have not been investigated in a supply chain context.

Supply chain management emerged in the late 1990s and the beginning of this millennium as a source for sustainable competitive advantage for companies (Dell & Fedman, 1999). It involves functions such as production, purchasing, materials management, warehousing and inventory control, distribution, shipping, and transport logistics. To attain sustainable competitiveness in these functions, effective coordination among the players representing these functions in the supply chain is required. The effectiveness of coordination in supply chains could be measured in two ways: reduction in total supply chain costs and enhanced coordination services provided to the end customer, and to all players in the supply chain (Pagel, 1999). Coordination schemes in supply chains are based either on centralized or decentralized decision-making processes. In the case of a centralized decision-making process, there is a single decision-maker whose main objective is to minimize (maximize) the total supply chain cost (profit). Whereas in the case of a decentralized decision-making process, there are multiple decision-makers in a supply chain, where each decision-maker tends to optimize his/her own performance leading to an inefficient system. This paper assumes a centralized decision-making process as a scheme for coordination in the supply chain model to be investigated herein. The case of no coordination among the players in a supply chain may be viewed as a decentralized decision-making process, where a retailer orders according its EOQ from its supplier (the manufacturer), who in its turn determines its economic order quantity and orders it from its supplier (the manufacturer's supplier). In this paper, the case of no coordination will be used as the base case for comparison of results.

The work of Goyal and Gupta (1989) is the earliest review of literature on the interaction between a buyer and a vendor (a two-level supply chain). Their survey showed that coordination could be achieved by integrating lot-sizing models. Coordination in a supply chain is not possible without incentives schemes, with quantity discounts being the most common one (e.g., Moses & Seshadri, 2000; Munson & Rosenblatt, 2001). Readers may refer to the work of Dolan (1987) for review of quantity discounts.

Limited are those works that investigated an integrated inventory problem for imperfect production process; i.e., processes generating defective items. Goyal, Huang, and Chen (2003) developed a simple approach for determining an optimal integrated vendor–buyer inventory policy for an item with imperfect quality. In their model, Goyal et al. (2003) assumed that defective (or poor quality) items are not reworked but rather sold at a discounted price. A similar problem to that of Goyal et al. (2003) was investigated by Comeaux and Sarker (2005). Khouja (2003) is believed to be the first to formulate and solve a two-stage (manufacturer–retailer) supply chain inventory model in which the quality of the output deteriorates with increased lot sizes. He investigated his model independently for the assumptions of Porteus (1986) and Rosenblatt and Lee (1986). Khouja (2003) assumed no incentives scheme for coordination. Siajadi, Ibrahim, Lochert, and Chan (2005) presented an integrated inventory system where a manufacturer consumes and purchases raw materials from a supplier in order to produce a specific finished item. They assumed that these defective