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ARTICLE

Optimal just-in-time buffer inventory for preventive maintenance with imperfect quality items

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Abstract This paper deals with a just-in-time manufacturing environment which produces perfect quality items with defective items (a percentage of whole products) irrespective of the nature of the preventive maintenance. Since preventive maintenance is an essential part of production structure, performing of regular preventive maintenance results in a shutdown of the production unit for a period of time to enhance the condition of the production unit at an acceptable level. During the shutdown period just-in-time buffers for both the perfect and imperfect quality items are needed to continue the normal operation. The period of preventive maintenance depends on the nature and condition of the production unit which is random in nature. The percentage of imperfect quality item is also random. The optimal just-in-time buffer is determined to minimize the system running cost by considering the holding cost of perfect and imperfect quality items and shortage cost of perfect and imperfect quality items. A numerical example is presented to illustrate the development of the model and sensitivity of the model is analyzed.

1. Introduction

After the introduction of just-in-time production system in the literature of classical inventory, it has been widely accepted due to considerable reduction in material inventories. This reduction led some people to adopt the wrong notation that inventory should be totally eliminated. But, some inventories are required to operate the production system efficiently in the case of preventive maintenance. Maintenance is an integral part of business operations that spans the whole spectrum of activities from acquisition to retirement of production unit and its equipment. Moreover,

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effective and efficient maintenance affects asset optimization by providing equipment reliability and aims to improve service to customers whilst reducing crises of production. Maintenance contributes to the profitability of the process mainly by keeping the system functioning and capable of fulfilling production needs for longer period of time by providing higher system availability. It is also well known that effective maintenance strategy efficiently controls capacity of utilization. Olorunniwo and Izuchkwu's (1987) noted that preventive maintenance has been entirely based on one of the two extreme assumptions: the production unit is enhanced to either a good-as-new or bad-as-old condition after maintenance. According to British Standard Institute (1974), maintenance is nothing but the combination of action taken to restore an item to retain it in an acceptable condition. However, one of the basic problems for people working with polymer, cotton, leather industries, etc. is that it is quite impossible to produce 100% perfect quality items. Due to some uncontrollable factors of the production unit, some items are imperfect or not to the standard maintained by the manufacturing unit. This behavior inspired many researchers to work on imperfect quality items in details. Cheng (1991) formulated an economic order quantity model with demand dependent unit production cost and imperfect production process. Zhang and Gerchak (1990) proposed a joint lot sizing and inspection policy under an EOQ (economic order quantity) model where a random proportion of units is defective and the defective units cannot be used and they must be replaced by non-defective ones. Schwaller (1988) presented a procedure that extended EOQ models by adding the assumptions that defective items of a known proportion were present in incoming lots and that fixed and variable inspection costs were incurred in finding and removing the items. Cardenas-Barron (2009) investigated an EPQ (economic production quantity) model with reworking process at a single stage production system applying planned backorders. Cardenas-Barron, Smith, and Goyal (2010) determined the optimal ordering policies for a buyer who operated an inventory policy with planned backorders while the supplier offered a temporary fixed-percentage discount. Cardenas-Barron, Sarkar, and Trevino-Garza (2013) investigated both the optimal replenishment lot size and the optimal number of shipments jointly. Sarkar, Cardenas-Barron, Sarkar, and Singgih (2014) revisited the EPQ (economic production quantity) model with rework process at a single-stage manufacturing system with planned backorders. Sarkar and Saren (2016) studied a deterioration production system for an imperfect production system with inspection errors and warranty cost in which the in-control state shifted randomly from the out-of-control. The effect of imperfect quality items on optimal order quantity and total running cost of the system is noted in the works of Rosenblatt and Lee (1986), Chakravarty and Shtub (1987), Urban (1992), Anily (1995), Salameh and Jaber (2000), Sana (2010a, 2010b, 2012), DasRoy, Sana, and Chaudhuri (2012), etc.

In this literature, plenty of articles are available under the basic assumption that, after preventive maintenance, the production system begins with the in-control state which is shifted to the out-of-control state and later produces non-conforming items. Due to imperfect repair during preventive maintenance, the system fails to operate and performing minimal repair and the production can be started again within minimum span of time. Groenvelt, Pmtelon, and Seidmann (1992a) and Groenvelt, Pmtelon, and Seidmann (1992b) focused the problem of determining the economic lot size for an unreliable manufacturing facility and showed a trade off to exist between the overall investment to increase the maintenance level that results saving in safety stock and repair cost. Van Der Duyn Schouten and Vanneste (1997) proposed a preventive maintenance policy which was based on the information about the age of the installation and the inventory buffer. Balasubramanian (1987) proposed an approach for preventive maintenance scheduling in the light of production plan. To cope with these situations, several strategies were proposed those were found in the articles of Rosenblatt and Lee (1986), Porteus (1986), Hariga and Ben-Daya (1998), Lee and Rosenblatt (1989), Cardenas-Barron (2000), Goyal and Cardenas-Barron (2002), Panda (2007), etc.

The proposed model considers that the regular preventive maintenance improves the condition of the production unit to an acceptable level that prevents sudden failure and maintains the quality of the original as new as one. During the preventive maintenance, a just-in-time buffer inventory is needed to maintain the normal operation. Since the production unit produces both of perfect and imperfect quality items, there is a market for imperfect quality items then just-in-time buffer inventory is needed for imperfect quality items also to maintain the normal operation. As the system produces imperfect quality items in a random percentage due to some uncontrollable factors of production after preventive maintenance, not for imperfect repair during preventive maintenance, we consider the buffer inventory of the perfect quality products to minimize the total system running cost. Mainly, we discuss the effects of imperfect quality items on the buffer inventory of perfect quality and hence on the system running cost. The rest of the paper is organized as follows. In the next section, the assumptions and notations for the development of the model are proposed. The mathematical model is developed in Section 3. Sections 4 and 5 provide the numerical illustration and concluding remarks, respectively.

2. Assumptions and notations

The following assumptions and notations are used to develop the model:

- D_1 and D_2 are the consumption rate of perfect and imperfect quality items per unit time, respectively.
- Number of defective items is in percentage p which is assumed to be a random variable having probability density function $f_1(p)$. The term p' is the maximum percentage of imperfect quality items.
- Screening time to differentiate perfect and imperfect quality items is negligible. Screening cost is also negligible.
- System running time T is large in comparison to the preventive maintenance time t so that, during any time