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Properties of lot-sizing rules under lumpy demand

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Abstract

When a lot-sizing problem is viewed from a context of buyer–supplier relationships, an important phenomenon frequently encountered by the supplier is a so-called lumpy demand. However, there has been very little attention devoted to study the behaviour and performances of lot-sizing rules under the situation of lumpy demand. This paper presents both analytical and experimental studies of lot-sizing rules for lumpy demand situations. The analytical study is based on the assumption that constant demand occurs for every fixed number of periods. In the experimental study, both the quantity of and the time between demands are allowed to vary. The studies show that analytical results provide good insights in understanding the behaviour and performances of lot-sizing rules when more realistic situations are addressed in the experimental study. The paper also confirms that the results of lot-sizing studies under the situation of non-lumpy demand cannot be entirely generalised to the situation with lumpy demand.

Keywords: Inventory; Lumpy demand; Dynamic lot-sizing; Boundary values of ordering cost; Supply chain management

1. Introduction

In a supply chain the first-level supplier/producer receives the stochastic demands of the consumers on a continuous time basis. If the level of demand is not sufficiently stable over time so a JIT production system is appropriate, the supplier will have to produce in discontinuous lots. This means that the second tier suppliers, who provide the materials and components needed by the first level supplier, will have to deal with the phenomenon of so-called lumpy demand. The term lumpy demand is used to represent the situation where a demand for an item does not occur every period, but rather, there is a large proportion of periods having zero demand. Lumpy demand received by a supplier will arise as a result of a buyer using an inventory ordering system or a deterministic lot-sizing procedure in an ERP or MRP system which lead to a decision not to order every period. The payment terms offered by the supplier to its buyers also play a role. As Kingsman (1983,1991), Carlson and Rousseau (1989), Carlson et al. (1996), and Pujawan and Kingsman (1999) have shown, date terms payment at a fixed time in the month after delivery gives larger and less frequent orders than day terms, where payment is required a fixed time after delivery.

Most of the large amount of work on lot-sizing theories over recent decades appears to overlooked the fact that lumpy demand is an important issue in practice and that the behaviour of lot-sizing techniques under non-lumpy demand is not

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necessarily the same as that under lumpy demand. Lot-sizing rules that provide good solutions under non-lumpy demand might turn out to be unsatisfactory when they are applied in a lumpy demand situation. Experiments described by Blackburn and Millen (1985) showed that the Silver Meal lot-sizing rule, which usually performs well under non-lumpy demand turns out to be less satisfactory when demand becomes lumpier.

Some methodological issues on demand lumpiness studies are also still inconclusive. Following the work of Kainmann (1969), many studies have based their measure of the demand profile on the coefficient of variation (CV) of demand per period. Bobko and Whybark (1985) even concluded that CV is a robust measure of demand profile. Although a little modification was introduced in generating the demand pattern, Ho (1993,1995) still relied on the coefficient of variation of demand to provide the measure of demand lumpiness. On the other hand, Williams and Peters (1987) commented that the use of CV might not be a sufficient descriptor of the demand profile.

Some studies on demand lumpiness have concentrated on the issues of reorder levels (e.g., Williams, 1982; Mak and Hung, 1986) and forecasting (e.g., Croston, 1972; Bartezzaghi et al., 1999). Very few papers have been devoted to study the behaviour of lot-sizing rules such as Silver Meal, Least Unit Cost, Part Period Balancing, etc., under the situation of lumpy demand. Our observation to date reveals that the rare studies on this issue have been conducted by using simulation, for example, Ho (1993,1995). However, to obtain a better understanding on the behaviour of the system, an analytical study for some restricted assumptions is often helpful. There appears to be no paper clearly addressing the analytical properties of lot-sizing rules under the situation of lumpy demand. Given the emphasis now on co-ordination and management of the supply chain, the neglect of the effect of lumpiness in demand needs remedying. This paper describes a small part of a major research project in this area by the authors, see Pujawan (2000).

Following the approach first introduced by Croston (1972) we distinguish demand profiles on the basis of two separate characteristics, demand lumpiness and demand variability. Demand lumpiness relates to the average inter-arrival time between demands. A set of demands is considered to be lumpy if they do not occur every period. Demand variability refers to the degree of variation of the size of the demands that occur. When demand is lumpy but all positive demands occur at the same quantity, demand variability is zero. The CV of the positive demands will be used to measure demand variability.

In this paper, both analytical and experimental studies of lot-sizing rules under the situation of lumpy demand will be presented. Section 2 of the paper presents some analytical models on the behaviour of lot-sizing rules under the situation of simple lumpy demand. Section 3 discusses the results of simulation studies that allow both the inter-arrival times between demands and the demand sizes to be stochastically variable. The final section concludes the paper with some future issues.

2. Analytical models of ordering decisions of different rules under simple lumpy demand

The analyses in this section are evaluating the effect of demand lumpiness, as defined above, rather than the demand variation. Without loss of generality, it will always be assumed that the period an order has to be placed is referred to as period one. For modelling purposes, the following notation will be used:

A	ordering cost or setup cost
c	unit price of the item
h	inventory holding cost represented as a fraction of unit price of the items in inventory at the end of a period
p	periods between demands
d_k	demand in period $k = \begin{cases} pd & \text{in periods } k = 1, p+1, 2p+1, 3p+1, \ldots, \\ 0 & \text{otherwise,} \end{cases}$
n	the order of demand in the future periods to be considered in one order