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Economic order quantity for growing items

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ABSTRACT

Economic order/production quantity (EOQ/EPQ) models have generally been presented for manufacturing products. Incorporating some important features of a specific category of products, different EOQ/EPQ models have been proposed in literature. This study proposes a new class of inventory models, i.e. a model for a specific type of inventory items: growing items. Poultry and livestock are good examples of growing inventory items. We begin by proposing a general mathematical model, which can be used for different types of growing items, followed by a particular mathematical model for a specific type of poultry. We calculate the optimal order quantity of the growing items at the start of a growing cycle, the optimal length of the growing cycle and the optimal total profit. Numerical examples are provided, for a type of poultry, to illustrate the model. A sensitivity analysis is presented to study the effect of the main parameters of the model in terms of its decision variables and objective function. The results of the sensitivity analysis suggest that production costs are the most crucial parameter.

1. Introduction

The first economic order quantity (EOQ) model was formulated by Harris (1913). The basic traditional EOQ model is used to determine the optimal order quantity, with the aim of minimizing overall costs, including holding and ordering costs, such that demand is met. Many variants of the EOQ model have been proposed in recent decades. Economic production quantity (EPQ) is one of the initial extensions of EOQ, where the basic assumption is that two organizations – a buyer and a producer – are involved in the problem and the order is placed from buyer to the producer. In EPQ, on the other hand, it is assumed that the buyer and producer are the same organization. As a consequence, in EOQ the order quantity is assumed to be received at once, while, in EPQ, items are assumed to be received gradually over time. Traditional EOQ/EPQ models can be applied to most products. However, because of their inability to incorporate specific features of some product categories, particular models have been proposed for some specific types of products. For example, there is a research stream on EOQ/EPQ models for perishable products such as food, vegetables, milk (Nahmias, 1982; Padmanabhan and Vrat, 1995; Dye and Ouyang, 2005; Chung and Liao, 2006). While, in traditional models, it is implicitly assumed that inventory items can be stored for an infinite amount of time, for perishable products, this assumption needs to be relaxed, which is why separate models have been proposed. Imperfect products, like electronic products, are another type of product that has received increasing attention in the last decade (see, for example, Salameh and Jaber, 2000; Cárdenas-Barrón, 2000; Goyal and Cárdenas-Barrón, 2002; Rezaei, 2005; Wee et al., 2007; Rezaei and Salimi, 2012). For imperfect items, the implicit assumption is that not all the received (produced) items are of perfect quality. Other examples of specific products are repairable products, such as military products (Mabini et al., 1992; Richter, 1996), and reusable products (Koh et al., 2002; Choi et al., 2007), such as soft drink bottles. What all the models that have been developed in the literature have in common is that the inventory items remain unchanged during storage time (like many manufacturing products: computers, cars), or even shrink (like perishable products: vegetables, fruits). We can, however, also think of *growing* items, such as poultry, and livestock. The weight of the inventory level of a regular item is usually unchanged when it is not consumed (during time period t_1 in Fig. 1). For example, a supermarket stores one hundred shampoos on the shelf. Without ordering extra shampoos, the weight of the inventory level decreases if one or more shampoos are sold (during t_2), and otherwise remains unchanged (during t_1). For growing items, however, the weight of the inventory level increases over time period t_1 (Fig. 2). For example, at the beginning of a growing cycle, a company buys a hundred chicks, with an overall weight of 400 g, and after a few days the weight of the inventory level may increase to 1200 g, without ordering extra chicks. Figs. 1 and 2 show the behavior of regular items and growing items, respectively, over time.

A literature review reveals that no systematic research has been devoted to these kinds of items in the area of inventory management. Due to the importance of these items, we argue that

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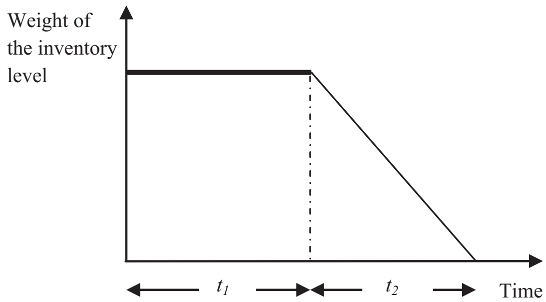

Fig. 1. Behavior of regular items over time.

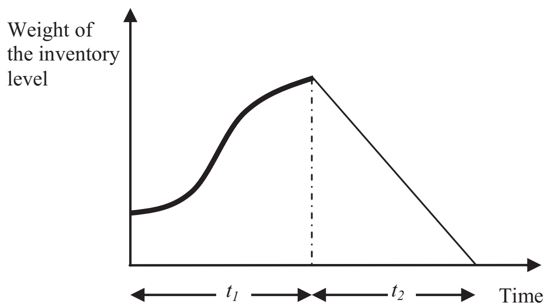

Fig. 2. Behavior of growing items over time.

more attention should be paid to the development of specific EOQ/EPQ models for these items. In this paper, we develop a general model for these items, which can be extended for different growing items. However, to make the model more specific, we extend our general model for a specific type of poultry.

The rest of the paper is organized as follows. In the next section, a mathematical modeling of the problem is presented. In Section 3, a numerical example is used to illustrate the model. A sensitivity analysis is presented in Section 4. Finally, the conclusion and suggestions for future research are provided in Section 5.

2. Mathematical modeling

In this section, we first introduce the notations, and then develop the model.

2.1. Notations

y	number of ordered items
w_t	weight of unit item at time t
p	purchasing price per weight unit
s	selling price per weight unit
c_f	feeding cost per unit item
h	annual holding cost per weight unit
K	set-up cost per growing cycle
Q_t	total weight of inventory at time t
d	annual demand rate
A	asymptotic weight
k	growth rate
n	shape parameter of the growth function
b	integration constant of the growth function

A general mathematical model is presented, which can be used for different growing items. We consider a situation where a company buys newborn animals (e.g. poultry and livestock), raises them, and then slaughters and sells them to the market. The company wants to determine the optimal quantity of newborn animals (e.g. one-day chicks) to be purchased, and the optimal day to slaughter them, in order to meet demand. With these two decision variables and the company's annual demand, we are able to calculate the optimal number of times the facilities should be set up to start a new cycle of newborn animals. The optimal values of these decision variables are the values at which the total profit of the company is maximized. The total profit function is as follows:

$$Total\ profit = total\ revenue – total\ costs$$

The total revenue is the sum of total sales of the slaughtered animals. The total costs are made up of the total purchasing costs of newborn animals, the total costs of production, which mainly consists of feeding costs, the total cost of holding slaughtered animals during the sales period and, finally, the total cost associated with setting up the facilities for a new growing cycle. Consequently, the total profit function would look as follows:

$$Total\ profit = total\ revenue – (total\ purchasing\ cost + total\ production\ cost + total\ holding\ cost + total\ setup\ cost)$$

Let y be the number of newborn animals the company orders from the supplier at each growing cycle, and w_0 and w_1 the initial weight (the weight of newborn animals) and the final weight (the weight of slaughtered animals), respectively. Considering the selling price s and purchasing price p, the total revenue would be syw_1, while the total purchasing costs would be pyw_0. As the newborn animals grow, their production (feeding) costs vary over time. If we assume a general function for production (feeding) costs $f(t)$, the total feeding costs would be $c_f y \int_0^{t_1} f(t)\,dt$, where c_f is the feeding cost per unit and t_1 is the length of the growing cycle at the end of which the animals are slaughtered. As mentioned before, the holding costs are associated with the slaughtered animals, which means that company pays the holding cost for period t_2. Considering h as the annual holding costs per weight unit, and $(yw_1/2)$ as the average weight of the inventory during storage period, the total holding costs would be $(ht_2(yw_1/2))$. Finally, considering set-up costs K, the total profit function per cycle would be as follows:

$$\mathrm{TP} = syw_1 - pyw_0 - c_f y \int_0^{t_1} f(t)\,dt - ht_2 \frac{yw_1}{2} - K \quad (1)$$

The behavior of the inventory system is depicted in Fig. 3. At the beginning of the growing cycle, the level of inventory is obtained by multiplying the number of received newborn animals y by their initial weight w_0 as $Q_0 = yw_0$. At the end of the growing cycle t_1 (slaughter date), the animal weight reaches w_1 and the total weight of the inventory goes up to $Q_1 = yw_1$. The slaughtered animals are then gradually sold at demand rate d. At the end of period t_2, the inventory of this cycle ends at the slaughter date of the next growing cycle.

To arrive at the total profit function per unit time, TP is divided by $t_2 = (yw_1/d)$, which means that, for the total profit function per

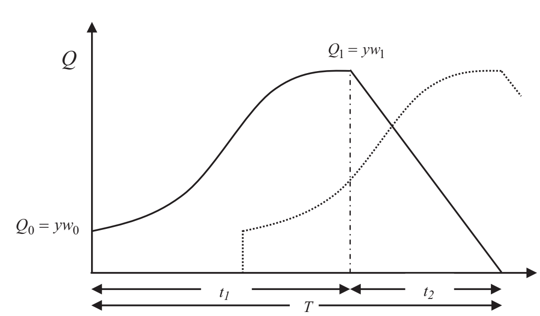

Fig. 3. Behavior of inventory system over time.