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Determining the adaptive decision zone of discrete lot sizing model with changes of total cost

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ABSTRACT

The Economic Order Quantity (EOQ) zone is beneficial for giving some latitude in picking the lot sizes in a *continuous* time inventory problem, but it is not suitable for a *discrete* time inventory problem, the discrete lot sizing (DLS) problem. In this paper, a novel enumeration method is proposed and coded as a user-friendly computerized scheduling system to "visualize" the complex DLS problems by projecting the entire feasible solutions on a two dimension space, where setup frequency and total cost are placed on the horizontal and the vertical axis respectively. First, the zone around the optimal solution in the DLS problem is demonstrated always smooth and this phenomenon is defined as DLS zone in which giving a small penalty cost from the optimal solution brings several alternative solutions for picking the lot sizes. Second, even if the penalty costs are changed, the computerized scheduling system is able to determine the adaptive decision zone and find the included alternative solutions. The flexibility in picking the lot sizes for discrete time inventory problems is significantly enhanced since decision makers are enabled to choose a preferable solution from the DLS zone.

1. Introduction

From the perspective of the continuous time scale, constant demand rate, and infinite planning horizon, Harris (1913) introduced the Economic Order Quantity (EOQ) model. The total cost curve of EOQ model is available to reflect the total costs corresponding to various order quantities and it is usually a shape of bowl (Solomon, 1959). Most importantly, a region around the lowest point (Q^*) on the total cost curve is relative flat and this phenomenon is the well-known "EOQ zone", displayed in Fig. 1 (Stevenson, 2002). From practical standpoint, the EOQ zone gives some latitude in picking the lot sizes because the change in total cost among Q^* and a number of order quantities included in the "zone" is not too much. Therefore, the EOQ zone is an *adaptive decision zone* in which there are several alternative solutions for decision making. From academic standpoint, Solomon (1959) was motivated by the EOQ zone to introduce the mathematical approach for defining the *economic lot size range*. Decision makers could set an acceptable penalty cost in advance and they would produce anywhere within a range of quantities relatively. However, the EOQ zone is only beneficial for giving some latitude in picking the lot sizes in a *continuous* time inventory problem but not suitable for a *discrete* time inventory problem, the material requirement planning (MRP) problem.

MRP is an approach used in production scheduling to determine the required parts and materials for end items (Fakhrzad & Khademi Zare, 2009). MRP system was introduced in the 1950s in US and it had received widespread acceptance in enterprises (Sum, Png, & Yang, 1993). Newman and Sridharan (1992) undertook a comprehensive survey of US companies including machine tools, defense electronics, medical equipment, automobile, plastics, computers, components, and furniture. Their survey results indicated that MRP was the most widely used system for production planning and control (56% of the companies reported using a MRP system).

From the perspective of discrete time scale, dynamic demand, and finite planning horizon, Wagner and Whitin (1958) firstly introduced a standard forward dynamic programming formulation to conduct the discrete lot sizing (DLS) problem in MRP system. Wagner and Whitin's model could be adopted to get the optimal production plan (PP) in a single-stage environment. Then, in a multi-stage environment, Zangwill (1969) proposed a backward recursive algorithm to find the optimal PP set (PPS) for the DLS problem with a serial production structure (each stage has at most one direct predecessor and one immediate successor). By virtue of the optimal PP or PPS (in terms of a single- or multi-stage version), decision makers are enabled to determine how many quantities have to be produced in which periods at the operation stage.

Since solving the DLS problems is particularly formidable (Bahl, Ritzman, & Gupta, 1987), developing the quantitative approaches

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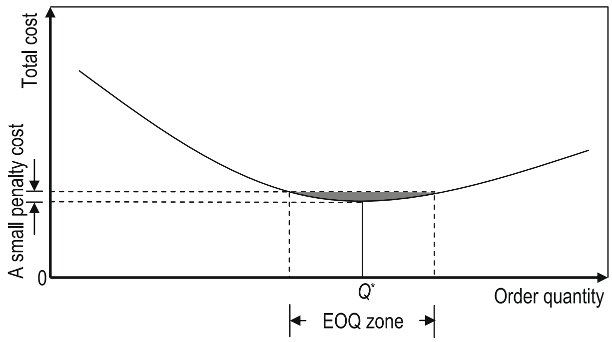

Fig. 1. An adaptive decision zone (EOQ zone) in a continuous time inventory problem.

for finding an optimal or suboptimal solution efficiently was always a main stream in the past literature. As only one solution can be provided to decision makers, it is the "stationary strategy" for decision making. In practice, however, decision makers desire to know more than an optimal or suboptimal solution, but the flexibility in picking the lot sizes for the DLS problems was given relatively little attention.

The major purposes of this work are to: (1) explore whether an adaptive decision zone as well as a phenomenon of EOQ zone exists in the DLS problems; (2) find the included alternative solutions when the total cost of the optimal solution is changed. The research results are available to fill the gap regarding the flexibility in decision making for the DLS problems and to bring about some interesting research directions in OR/MS.

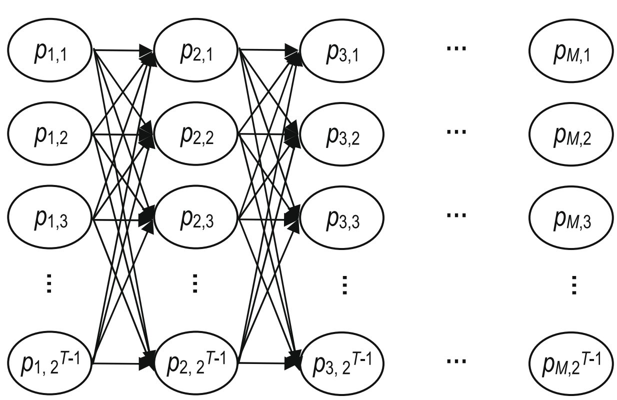

Fig. 2. The serial DLS problem represented by a network.

2. Notations and problem statement

2.1. List of notations

The following notations are adopted in this paper.

m	stage index ($m = 1, 2, \ldots, M$)
t	period index ($t = 1, 2, \ldots, T$)
$s_{m,t}$	setup cost in period t at stage m
$h_{m,t}$	unit inventory holding cost from period t to period $t+1$ at stage m
$d_{m,t}$	demands in period t at stage m
$q_{m,t}$	the produced quantities in period t at stage m
$I_{m,t}$	the inventory level at the end of period t at stage m
$c_{m,m+1}$	c unit of demands have to be yielded at stage m in order to produce one unit of demands at stage $m+1$ namely "production ratio"
$\delta_{m,t}$	Boolean variable: $\delta_{m,t} = 1$ indicating a production policy adopted in period t at stage m; otherwise, $\delta_{m,t} = 0$ meaning an inventory policy
x	row index corresponding to the Solving-Process data sheet ($x = 1, \ldots, 2^{T-1}$)
$p_{m,x}$	the xth feasible PP at stage m
$c(p_{m,x})$	total cost of $p_{m,x}$
$ops_{m,x}$	an optimal PPS represented by a set of x, meaning $\{p_{1,x}, p_{2,x}, \ldots, p_{m,x}\}$
$R_{m,x}(v,j)$	i. at the first round to implement the solution method: a set of x represents various $p_{1,x}$ which can connect with $p_{2,x}$ ii. after the first round to implement the solution method: a set of x represents various $ops_{m-1,x}$ which can connect with $p_{m,x}$, where $m = 3, 4, \ldots, M$
$c(R_{m,x}(v,j))$	i. at the first round to implement the solution method: minimal value of various $p_{1,x}$ which can connect with $p_{2,x}$ ii. after the first round to implement the solution method: minimal value of various $ops_{m-1,x}$ which can connect with $p_{m,x}$, where $m = 3, 4, \ldots, M$
$c(ops_{m,x})$	the optimal cumulative total cost of $p_{m,x}$
${}^{m}otc_f$	i. at the stage 1 in the serial DLS problem: minimal value of $c(p_{1,x})$ with f times of setup ii. from stage 2 to M in the serial DLS problem: minimal value of $c(ops_{m,x})$ with f times of setup
mtc	minimal total cost of the DLS problem

Table 1
Values of the parameters given in the illustrated example.

Operation stages		Planning periods											
		January	February	March	April	May	June	July	August	September	October	November	December
1	$s_{1,t}$	500	500	500	800	800	1000	1300	1300	1000	800	500	500
	$h_{1,t}$	1	1	1	1	1	1	1	1	1	1	1	1
2	$s_{2,t}$	350	350	350	550	550	700	900	900	700	550	350	350
	$h_{2,t}$	2	2	2	2	2	2	2	2	2	2	2	2
3	$s_{3,t}$	250	250	250	400	400	550	700	700	550	400	250	250
	$h_{3,t}$	3	3	3	3	3	3	3	3	3	3	3	3
The demand of end item	$d_{4,t}$	10	10	10	15	15	20	25	25	20	15	10	10