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Economic Lot Scheduling of Time Varying Demand with Stockout in a Jute Industry

Subrata Talapatra [α], Ghazi Abu Taher [σ] & Mehedi Islam [ρ]

Abstract- The economic lot scheduling problem (ELSP) creates challenge between lot sizing and sequencing. The ELSP's primary goal is to minimize the total setup and holding expenditures of different products on a single machine. ELSP is a mathematical model. It deals with a company's planning what to manufacture, when to manufacture and how much to manufacture. This paper deals with the Economic Lot Scheduling (ELS) of a Jute industry for time varying demand with Stock out. This model will help to understand the total production time and allocate individual time against each product. This also increases the cycle time for a given aggregate inventory. In reality, demands and capacities are varying with time. An aggregate plan is expected to give time varying capacities since the plan is to meet fluctuating demand. It is therefore necessary to model the more realistic situation where the demand and capacity vary each day. This model will provide a production schedule of a set of items in a single machine to minimizing the long run average holding and set up cost under the assumptions of time varying demand and production rates, allowing material stock out.

Keywords: economic lot scheduling problem (ELSP); inventory; time varying demand; multi-product; lot-sizing and scheduling; sequence-dependent setups.

I. Introduction

The Economic Lot Scheduling Problem (ELSP) is assumed that the production facility in the in-control state producing items of high quality. It finds the problem of production sequence, production times and idle time of several products. It will minimize the inventory and setup cost also. In this model, the items are produced and consumed simultaneously for a portion of the cycle time. The rate of consumption of items is varying throughout the month. The cost of production per unit is same irrespective of production lot size. Here stockout is permitted. It is assumed that the stockout will be satisfied from the units produced at a later date with a penalty. The items are not produced between the period, while the inventory consumes and the next cycle begins. Then another item might be produced. There must be a setup time between the two items. The total cycle length is T.

A particular product is produced at a rate of P, the demand of that product is D. Then, inventory will built up at a rate of P-D. Because the product consumes while production. The built up inventory will consume at a certain number of period, then cycles begins again. The operation of this model is shown in Fig.1.

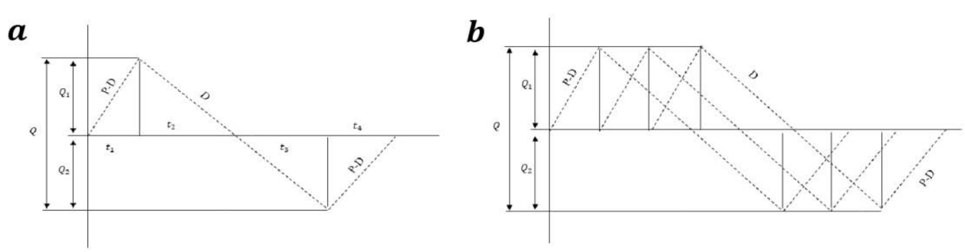

Fig.1 : (a) Manufacturing model of inventory,(b) Total cycle time for a particular facility

In the economic lot scheduling problem, it is not assumed that changeover times is sequence dependent. So, when the changeover times are sequence independent, then the economic lot scheduling problem essentially tries to minimize the total cost which is the sum of the ordering cost and carrying cost (Srinivasan, G., Quantitative Models in Operations and Supply Chain Management, sbn: 978-81-203-3981-1) .

a) Nomenclature

C_0	Cost / set up
C_c	Carrying cost / unit / period
C_s	Shortage cost / unit / period

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II. Development of Disaggregation Method with Stockout

Three products are produced such as sacking, Hessian, CBC (Carpet Baking Clothe). The daily demand and the inventory of these products remain constant. The demand and inventory of the products are summarized form the last three years data as shown in Table 1.

Table 1 : Day to day demand and inventory data of Khalishpur Jute Mill

	Sacking	CBC	Hessian	
Inventory (tons/day)	10	4	7	
Demand (tons/day), D_1	18	6	11	P_1 = 35 tons/day
D_2	20	7	10	P_2 = 37 tons/day
D_3	16	9	8	P_3 = 33 tons/day
r = Inventory/Demand	0.555	0.666	0.636	

The capacity in each of the 3 days are 35, 37, 33 tons/day, respectively. Allocation time have to find for making the products.

The value of r represents the demand that can be met with the existing inventory. The production of jproduct has to be started before r_j hours. The products are sorted according to increasing value of r. The order is found as Sacking- Hessian- CBC. The products will be produced in the said order. The process flow also depends upon the value of r. The maximum value of r is 0.666, from which the cycle time is counted considering the demand constant.

It is assumed that, the reasonable upper limit of the cycle time is $(r+\frac{1}{r}) = 2.166$. Therefore, capacity for 2.166 days,the equivalent daily demands are 18, 6 and 10 tons/day for the three products respectively and equivalent daily capacity is 35 tons/day.

For Sacking, $\frac{Demand\ \ for\ 2.1\ days}{2.1} = \frac{18+20+0.1\times16}{2.1} = 18$ tons/day

For CBC, $\frac{Demand\ \ for\ 2.1\ days}{2.1} = \frac{6+7+0.1\times9}{2.1} = 6$ tons/day

For Hessian, $\frac{Demand\ \ for\ 2.1\ days}{2.1} = \frac{11+10+0.1\times8}{2.1} = 10$ tons/day

Now, using the demand of each product to construct a manufacturing model with shortages (Panneerselvam, R., Production and operations management, 2nd edition, Chapter-9, Page-214),

For Sacking,

D = 18 tons/day, P = 25 tons/day, C_0 = 0.25, C_c = 0.10, C_s = 0.50

Economic Batch Quantity (EBQ),

$$Q = \sqrt{\frac{2C_0}{C_c}\times\frac{PD}{P-D}\times\frac{C_c+C_s}{C_s}} = \sqrt{\frac{2\times0.25}{0.10}\times\frac{(25\times18)}{(25-18)}\times\frac{(0.10+0.50)}{0.50}} = 19.639\text{tons/day}$$

Maximum inventory, $Q_1 = \sqrt{\frac{2C_0}{C_c}\times\frac{D(P-D)}{P}\times\frac{C_s}{C_c+C_s}} = \sqrt{\frac{2\times0.25}{0.10}\times\frac{18(25-18)}{25}\times\frac{0.50}{(0.10+0.50)}} = 4.5825$ tons/day

Maximum stockout, $Q_2 = \sqrt{\frac{2C_0C_c}{C_s(C_c+C_s)}\times\frac{D(P-D)}{P}} = \sqrt{\frac{2\times0.25\times0.10}{0.50(0.10+0.50)}\times\frac{18(25-18)}{25}} = 0.9165$ tons/day

Cycle time, $t = \frac{Q}{D} = \frac{19.639}{18} = 1.091$

Production and consumption times,

$$t_1 = \frac{Q_1}{P-D} = \frac{4.5825}{(25-18)} = 0.654, t_2 = \frac{Q_1}{D} = \frac{4.5425}{18} = 0.2545, t_3 = \frac{Q_2}{D} = \frac{0.9165}{18} = 0.0509,\ t_4 = \frac{Q_2}{P-D} = \frac{0.9165}{(25-18)} = 0.1309$$

$$t' = t_1 + t_2 + t_3 = 0.6546 + 0.2545 + 0.0509 = 0.96$$

$$t = t_1 + t_2 + t_3 + t_4 = 0.6546 + 0.2545 + 0.0509 + 0.1309 = 1.091$$

Similarly for CBC,

D = 6 tons/day, P = 10 tons/day, C_0 = 0.25, C_c = 0.10, C_s = 0.50

Q =9.4868, Q_1 = 3.1622, Q_2 = 0.6324, t=1.5811, t_1=0.7905, t_2=0.5270, t_3=0.1054, t_4=0.1581, t' =1.4229

For Hessian,

D = 10 tons/day, P = 15 tons/day, C_0 = 0.25, C_c = 0.10, C_s = 0.50,Q =13.4164, Q_1 =3.7267, Q_2 = 0.7453, t=1.3416

t_1= 0.745, t_2=0.3726, t_3=0.0745, t_4=0.1490, t'=1.1924

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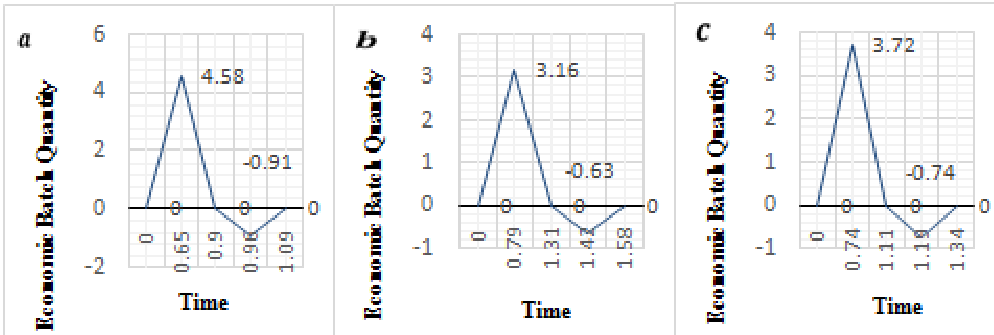

Fig. 2 : Inventory model with stockout for (a) Sacking, (b) CBC and (c) Hessian

LP (Linear Programming) formulation is,

Objective function: maximize T

The constraints are,

Subject to

$$t_j \leq r_j \text{ -- (1)}$$

$$(t_{He} - t_{Sa})35 + 1.091 \times 35 \geq T \times 18[\text{ production time for Sacking}] \text{ --------- (2)}$$

$$(t_{CBC} - t_{He})\ 35 + 1.5811 \times 35 \geq T \times 10[\text{ production time for Hessian}] \text{ ----- (3)}$$

$$(t_{Sa} + T - t_{CBC})\ 35 + 1.3416 \times 35 \geq T \times 7[\text{ production time for CBC}] \text{ ------- (4)}$$

$$t_{Sa} \leq 0.555[\text{ production time limit for Sacking}] \text{ ------------- (5)}$$

$$t_{CBC} \leq 0.666[\text{ production time limit for CBC}] \text{----------------- (6)}$$

$$t_{He} \leq 0.636[\text{ production time limit for Hessian}] \text{------------- (7)}$$

$$t_{Sa}\,, t_{CBC},\ t_{He}\,, T \geq 0$$

Where,

$$t_{Sa} = \text{Production start time for sacking}$$
$$t_{He} = \text{Production start time for Hessian}$$
$$t_{CBC} = \text{Production start time for CBC}$$
$$T = \text{Total cycle time}$$

Here TORA software is used for solving the problem.The optimal solution is given by,

$X_1 = t_{Sa} = 0 \leq 0.555$, $X_2 = t_{CBC} = 0.0143 \leq 0.666$, $X_3 = t_{He} =$ 0.636 $\leq$ 0.636, $X_4 = T = 3.3581$

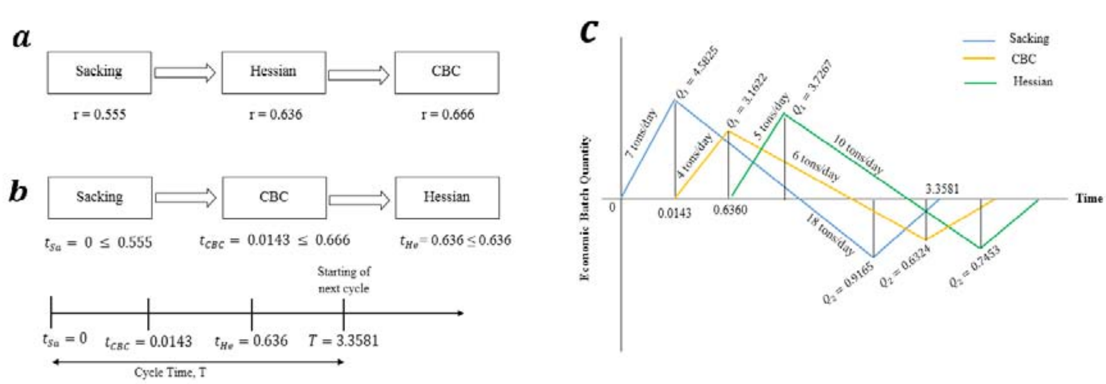

Fig. 3 : Sequence of production according to (a) value of r, (b) stockout of product, (c) EBQ of each product

This becomes the first cycle and this is implemented for $T = 3.3581$ days. The inventories of the three products at the end of 3.3581 days aresummarized in the table 2.

Table 2 : Day to day demand and inventory data of Khalishpur Jute Mill

	Sacking	CBC	Hessian	
Inventory (tons/day)	-50	6	65	
Demand (tons/day), D_2	20	7	10	P_2 = 37 tons/day

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D_3	16	9	8	P_3 = 33 tons/day
D_4	18	6	11	P_4 = 35 tons/day
r	-2.5	0.857	6.5	

The maximum value of r is 6.65, from which the cycle time is counted, that is 1 day. Again, it is assumed that, the upper limit of the cycle time is$(1 + \frac{1}{r}) = 6.65$. Therefore, capacity for 6.65 days, the equivalent daily demands of the three products are found 7, 3 and 5 tons/day respectively and equivalent daily capacity is 35 tons/day.

Again, the model gives the following values considering the stockout.

For Sacking,

D = 7 tons/day, P = 10 tons/day, C_0 = 0.25, C_c = 0.10, C_s = 0.50

$Q = 11.83,\ Q_1 = 2.95,\ Q_2 = 0.59,\ t = 1.69,\ t_1 = 0.9833, t_2 = 0.4214,\ t_3 = 0.0845,\ t_4 = 0.1966,\ t' = 1.4892$

For CBC,

D = 3 tons/day, P = 7 tons/day, C_0 = 0.25, C_c = 0.10, C_s = 0.50

$Q = 5.61,\ Q_1 = 2.67,\ Q_2 = 0.53,\ t = 1.81,\ t_1 = 0.6675,\ t_2 = 0.89,\ t_3 = 0.1766,\ t_4 = 0.1325, t' = 1.7341$

For Hessian,

D = 5 tons/day, P = 8 tons/day, C_0 = 0.25, C_c = 0.10, C_s = 0.50

$Q = 8.94, Q_1 = 2.79,\ Q_2 = 0.559, t = 1.788, t_1 = 0.93, t_2 = 0.558, t_3 = 0.1118, t_4 = 0.1863, t' = 1.599$

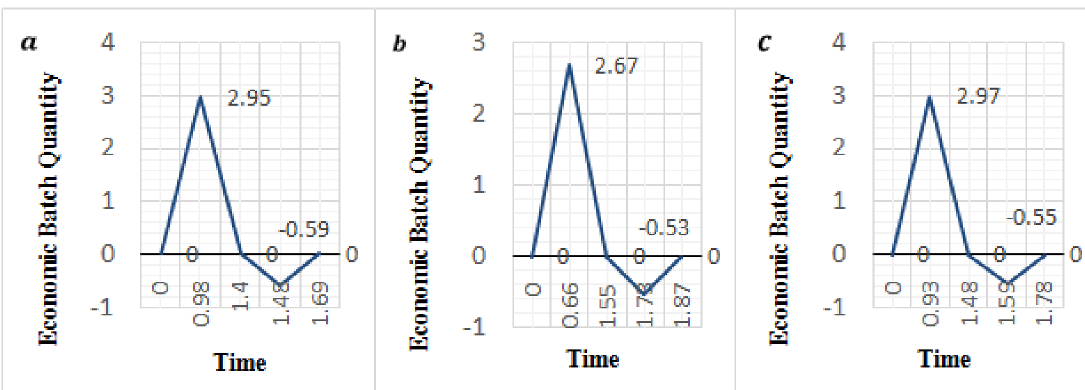

Fig. 4 : Manufacturing model of inventory with stockout for (a) Sacking, (b) CBC and (c) Hessian

LP formulation is

Objective function: maximize T

Subject to

$$t_j \leq r_j \text{ --- } (1)$$

$$(t_{CBC} - t_{Sa})35 + 1.69 \times 35 \geq T \times 7[\text{production time for Sacking}] \text{ ----------- } (2)$$

$$(t_{He} - t_{CBC})\, 35 + 1.87 \times 35 \geq T \times 3[\text{production time for CBC}] \text{ --------------- } (3)$$

$$(t_{Sa} + T - t_{He})\, 35 + 1.78 \times 35 \geq T \times 5[\text{production time for Hessian}] \text{ ------- } (4)$$

$$t_{Sa} \leq 0[\text{production time limit for Sacking}] \text{ ---------------- } (5)$$

$$t_{CBC} \leq 0.857[\text{production time limit for CBC}] \text{ -------------- } (6)$$

$$t_{He} \leq 6.5[\text{production time limit for Hessian}] \text{ ------------- } (7)$$

$$t_{Sa}, t_{CBC}, t_{He}, T \geq 0$$

TORA software is used for solving the problem. The optimal solution of our problem is given by,

$X_1 = t_{Sa} = 0 \leq 0,\quad X_2 = t_{CBC} = 0.857 \leq 0.857, X_3 = t_{He} =$ 0.0786 $\leq$ 6.5, $X_4 = T = 12.7350$

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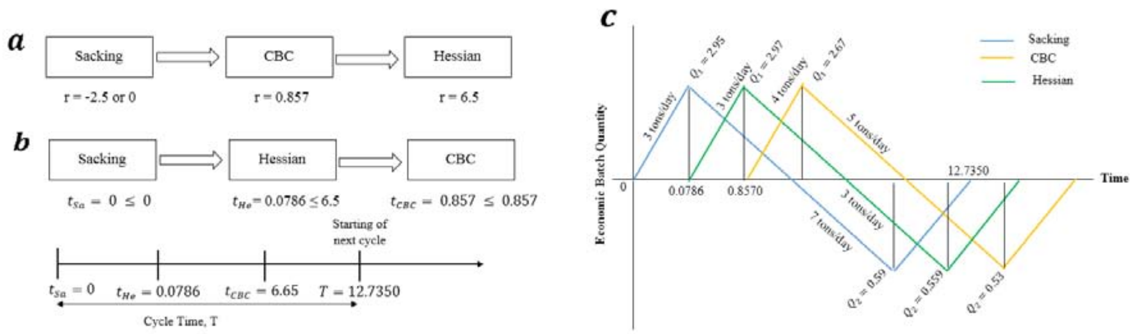

Fig. 5 : Sequence of production according to (a) value of r, (b) stockout of product, (c) EBQ of each product

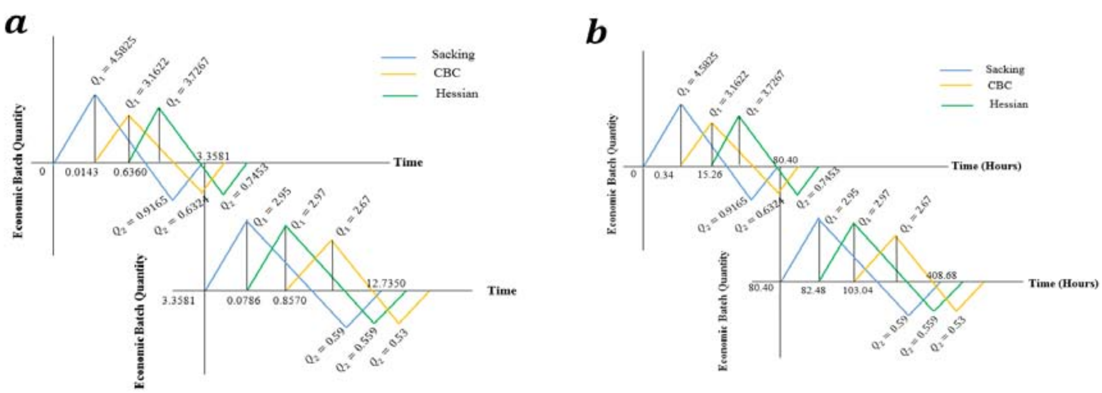

Fig. 6 : (a), (b) Sequential manufacturing model of Khalishpur Jute Mill Ltd

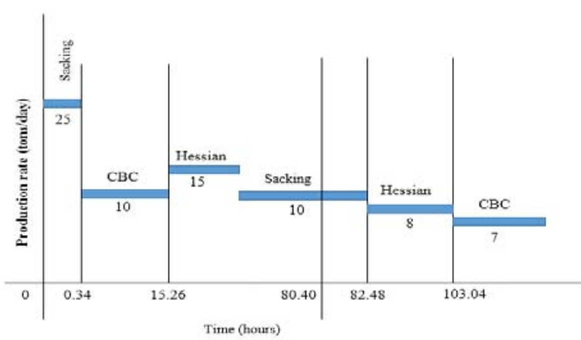

Fig. 7 : Production Schedule of Khalishpur Jute Mill Ltd

III. Result and Discussion

This paper translates the ELS of a Jute industry for time varying demand with Stock out. At the beginning of every cycle, the existing inventories are worked out. The expected inventory at the end of each cycle has been calculated. These values are used to compute r_j for finding the sequence of production. The order of production has changed in the two cycles because of the values of r_j. Again the shortage of inventory in each cycle has also changed the order of production. Therefore, it is observed that, the order of production does not depend upon the values of r_j, but depends on the values of stockout of inventories. The change of order satisfies all the constraints and factors. Finally the starting time of each product is calculated by LP. This is acceptable and the model provides flexibility in this regard.

IV. Acknowledgements

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