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Algorithm for Supply Chain Management: to Suite the Present Industrial Need

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Abstract

In this paper the effort has been made to compare the mean and variance of both order interval and order quantity produced by the two rules using basic EOQ algorithm and the EOQ algorithm with planned shortage. Algorithm was run and five replications were run for each experimental cell. It is found that LUC lot sizing rule produces higher amount of average order quantity in comparison to SM lot sizing rule in both the algorithms. It is found that the SM lot sizing rule produces a series of orders with more stable interval between orders in both the algorithm as compared to LUC lot sizing rule. The LUC lot sizing rule produces a series of more stable intervals using Basic EOQ algorithm as compared to planned shortage algorithm. For small values of basic order cycles the SM lot sizing rule produces variable amount of average order quantity using basic EOQ algorithm where as planned shortage algorithm produces constant average order quantity. Both the algorithm show different sensitivity to cost values.

Keywords: Lot sizing, Planned shortage model, Supply chain management, Bullwhip effect.

Introduction

The most important reasons of supply chain shortage is the amplification of order variability from downstream to an upstream chain (Bullwhip effect). This effect is experienced in both inventory levels and replenishment orders. As a result companies face shortages or bloated inventory levels, replenishment orders, run-away transportation and warehousing costs and major production costs. The order variability is not merely due to uncertainty of demand from the end customers but very often due to some other processes performed by each channel of the supply chain (Lee etal., 1997; Holweg, 2001). Rational processes like demand forecasting, order batching, forward buying, forecasting techniques, centralizing information, (s, S) ordering policy and lot sizing techniques etc are causes of order variability. Various workers have tried to quantify the bullwhip effect in supply chain .Experimental results of Metters (1997) investigations show the impact of bullwhip effect on supply chain profitability. According to Fransoo and Wouters (2000), bullwhip effect in a supply chain channel may be measured by the relative value of the coefficient of variation of orders created and the coefficient of variation of demand orders received by the channel. A relative value greater than one in a supply chain channel means that order variability is amplified in the channel. Quantitative algorithms are developed by Chen etal. (1998) to measure the impact of forecasting techniques and information centralization policy on bullwhip effect. He showed that the exponential smoothing technique causes higher bullwhip effect compared to the moving average. Kelle and Milne (1999) showed that the variance of orders relative to the variance of demand received by a supply chain channel is roughly proportional to the orders between the successive periods.

Many previous research workers examined the performance of lot sizing rules (e.g., DeBodt et al, 1982; DeBodt and Van Wassenhove, 1983; Wemmerlove, 1982, 1989). The above studies discussed the performance of lot sizing rules from the cost perspective only. Wemmerlove (1986) evaluated lot sizing rules comprehensively. Pujawan (2003) showed by analytical and simulation algorithms that order variability can also be affected by the lot sizing techniques applied by a supply chain channel in determining the quantity of orders to be placed to its upstream channel. He discussed the two lot sizing rules, the Silver Meals and the Least Unit Cost on the variability of orders created by a supply chain channel receiving demand with stochastic variability from its down stream channel. Pujawan (2003) presented the analysis using basic EOQ algorithm. The basic EOQ algorithm satisfies the common desire of managers to avoid shortage as much as possible. The unplanned shortage can still occur if the demand rate and deliveries do not stay on schedule. There are situations where permitting limited planned shortage makes sense from a managerial perspective. The most important requirement is that the customers are willing to accept the delay in filling their orders if need be. The EOQ algorithm with planned shortage addresses this kind of situation. When a shortage occurs, the affected customer will wait for the product to become available again. Their backorders are filled immediately when the order quantity arrives to replenish inventory.

In this study we have examined the effect of lot sizing rules on order variability in EOQ algorithm with planned shortage. Pujawan (2003) method of simulation is used to compare the variability of orders in basic EOQ algorithm (algorithm-1) and the EOQ algorithm with planned shortage (algorithm-2) using Silver-Meal and Least Unit Cost lot sizing rules. The cost structure of the firm is assumed in such a way that the natural order cycle (TBO) is an integer according to the logic of basic EOQ algorithm. The demand variation is assumed to be normally distributed. The demand variability with mean μ =200 and standard deviation σ =20 and 40 per week respectively are considered for this study. It is assumed that the lead time is zero and the firm deals with single item. The assumption that the cost structure lead to integer TBOs has been taken by other research workers also (e.g., Sridharn, 1995; Zhao et al., 1995; Mettersand Vagas, 1999). The algorithm with integer TBOs are simple but they may not present the over all properties of lot sizing rules under practical operating conditions where the cost structures do not lead to integer TBOs. Therefore, we have conducted the experiments to observe the effects of non integer TBOs on the variability of orders created by the lot sizing rules. The experiment is also conducted to examine the sensitivity of algorithm-2 with planned shortage (p). Under the situation of uncertain demand, different policies may be applied to improve the performance of the lot sizing rules. This includes the safety stock policy. Safety stock policy is normally applied where there is uncertainty in demand during the lead time. In this study the lead time is assumed to be zero, hence the safety stock is not required. Pujawan (2003) has shown that when the lead time is zero adding extra quantity to an order is beneficial in terms of reducing order variability. Hence the term extra quantity is used instead of safety stock in this paper.

Methodology

The problem of buying presented by single method system in firm ordering items from the supplier to satisfy end customer's demand is considered in this study. The demand from the end customers is assumed to follow a normal distribution with a mean of μ and standard deviation of σ . The buying firm is assumed to obtain exact information of the demand for the current period at the beginning of each period. The demand for the succeeding periods is estimated at the constant level of μ . Having obtained information on demand for the current period and the on hand inventory, the buyer has to decide whether or not to place an order at the beginning of that period. If the demand in that period is greater than the available inventory at the beginning of the period, the firm is assumed to place an order. The order quantity is determined based on the lot sizing rule being applied. Two popular lot sizing techniques, the Silver-Meal and the Least Unit Cost are used and compared. The detailed description of lot sizing rules and computation procedure is given in Appendix.

Table 1 (a) and (b) to come about here

Results and Discussion

The time between consecutive replenishment of inventory calculated by the logic of basic EOQ algorithm is referred as basic order cycle and the average order cycle is referred to the average of order cycles obtained by simulation using lot sizing rules. The basic EOQ algorithm and the planned shortage algorithm are referred as algorithm-1and algorithm-2 respectively. Table 1(a) shows the comparison of average order quantity produced by lot sizing rules. It is found that the LUC lot sizing rule produces higher values of average order quantity in comparison to SM lot sizing rule in both the algorithms. For small values of basic order cycles (TBOs), there is no change in average order quantity with SM lot sizing rule in algorithm-2. This indicates that the production companies whose cost structure leads to small basic order cycles, the SM lot sizing rule produces stable order quantities. With the increase in demand variability it is found that the average order quantity for higher values of basic order cycles (TBOs) decreases in algorithm-2. Table 1(b) illustrates the variability of average order quantity cv (q) produced by lot sizing rules. It illustrates that with the increase in demand variability the SM lot sizing rule shows the decrease in variability in the average order quantity in both the algorithms. An increase in demand variability increases the variability in average order quantity using algorithm-1 and decreases in algorithm-2.

Table 1(a) Comparative study of average order quantity produced by lot sizing rules

	ALGORITHM - I				ALGOROTHM -II			
TBO	SM		LUC		SM		LUC	
	S(20)	S(40)	S(20)	S(40)	S(20)	S(40)	S(20)	S(40)
2	313.20	302-.32	400.90	414.14	313.20	302.32	313.20	302.32
3	494.55	493.21	601.96	612.44	313.20	302.32	402.81	424.23
4	706.07	711.98	805.28	815.60	494.55	493.21	596.00	577.45
5	906.49	906.24	1003.60	1012.57	706.07	711-98	714.00	705.02

Table 1(b) Comparative study of variability of average order quantity CV(Q) produced by lot sizing rules

	ALGORITHM - I				ALGORITHM -II			
TBO	SM		LUC		SM		LUC	
	S(20)	S(40)	S(20)	S(40)	S(20)	S(40)	S(20)	S(40)
2	0.280	0.262	0.078	0.117	0.280	0.262	0.28	0.261
3	0.160	0.139	0.058	0.083	0.280	0.262	0.075	0.111
4	0.108	0.105	0.049	0.066	0.160	0.139	0.062	0.102
5	0.076	0.073	0.044	0.054	0.108	0.105	0.103	0.085

In Table 2 the average order intervals produced by lot-sizing rules are shown. It is found that both the lot sizing techniques produce shorter average order cycles using algorithm-2. Hence more orders are placed during a certain time horizon if the algoritthm-2 is used in compared to algorithm-1. This indicates that the use of algorithm-2 results in producing lower average inventory levels but higher costs associated with placing orders. The use of advance information technology very much reduces the cost of placing orders. Hence buying companies may be benefited if they use algorithml-2.

It is also found that the algorithm-2 produces smaller average order cycles with the use of SM lot sizing technique as compared to LUC lot sizing technique.

Table 2 Comparison of average order interval produced by lot sizing rules

	ALGORITHM - I				ALGORITHM-II			
TBO	SM		LUC		SM		LUC	
	S(20)	S(40)	S(20)	S(40)	S(20)	S(40)	S(20)	S(40)
2	1.56	1.50	2.00	2.06	1.56	1.50	1.56	1.50
3	2.47	2.07	3.00	3.03	1.56	1.50	2.00	2.10
4	3.52	3.31	4.02	4.02	2.47	2.06	2.97	2.86
5	4.52	4.45	4.72	5.00	3.52	2.54	3.56	3.50

Table 3(a) shows the effect of adding extra quantity in the order quantity for standard deviation of demand equal to 20 (s(20)). It is found that for a given addition of extra quantity in order quantity the SM lot sizing rule produces reduced variability in average order quantity. The algorithm-2 for small basic order cycles shows no variation in average order quantity. By adding the extra quantity, higher variability in average order quantity is obtained in algorithm-2 as compared to algorithm-1. An increase in the addition of extra quantity in the order quantity, the variability in order quantity decreases in both the algorithms. For small basic order cycles an increase in extra quantity has no effect in algorithm-2.

Table 3(b) shows that using LUC lot sizing rule the variation in the average order quantity for a given addition of extra quantity in order quantity is same as in SM lot sizing rule.

Table 3(a) Variation of order quantity CV(q) with SM rule for different extra quantity(zeta) with demand variation S(20)

	ALGORITHM - I				ALGORITHM -II			
Zeta	TBO				TBO			
	2	3	4	5	2	3	4	5
0.0 S	0.280	0.160	0.108	0.076	0.280	0.280	0.160	0.102
0.5 S	0.219	0.149	0.103	0.078	0.219	0.219	0.149	0.102
1.0 S	0.179	0.132	0.094	0.072	0.179	0.179	0.132	0.103

Table 3(b) Variation of order quantity CV(q) with LUC rule for different extra quantity(zeta) with demand variation S(20)

	ALGORITHM- I				ALGORITHM-II			
	TBO				TBO			
Zeta	2	3	4	5	2	3	4	5
0.0 S	0.078	0.058	0.049	0.044	1.560	0.075	0.062	0.103
0.5 S	0.076	0.059	0.050	0.045	0.218	0.072	0.061	0.092
1.0 S	0.074	0.063	0.051	0.046	0.179	0.086	0.059	0.088

Table 4(a) shows the variation of order quantity using SM lot sizing technique for different values of extra quantity added to order quantity with standard deviation equal to 40 in customer demands(s (40)). As the value of extra quantity added increases, the variability in average order quantity decreases in both the models. The model-2 shows higher variability in average order quantity compare to algorithm-1. The same pattern is found using LUC lot sizing technique.

Table 4(a) Variation of order quantity CV(q) with SM rule for different extra quantity(zeta) with demand variation S(40)

	ALGORITHM - I				ALGORITHM -II			
zeta	TBO				TBO			
	2	3	4	5	2	3	4	5
0.0 S	0.262	0.139	0.105	0.073	0.262	0.262	0.139	0.105
0.5 S	0.250	0.143	0.099	0.076	0.250	0.250	0.143	0.099
1.0 S	0.232	0.137	0.097	0.075	0.232	0.232	0.137	0.097

Table 4(b) Variation of order quantity CV(q) with LUC rule for different extra quantity(zeta) with demand variation S(40)

	ALGORITHM - I				ALGORITHM -II			
	TBO				TBO			
Zeta	2	3	4	5	2	3	4	5
0.0 S	0.117	0.083	0.066	0.054	0.261	0.111	0.102	0.085
0.5 S	0.112	0.082	0.060	0.048	0.249	0.107	0.098	0.084
1.0 S	0.110	0.082	0.060	0.048	0.231	0.104	0.091	0.084

Table 5(a) shows the variability of order intervals with addition of extra quantity with the small order variation in the customer's demands. It is found that SM lot sizing rule produces lower variability in average order interval with an increase in the addition of extra quantity. The Algorithm-2 shows that higher variability in the average order intervals in comparison to Algorithm -1.

This shows that Algorithm-1 produces more stable average order cycles in comparison to Algorithm-2. Table 5 (b) shows that the pattern of average order variability remains same with an increase in demand variability.

Table 5(a) The Variation of order quantity CV(I) under different extra quantity(zeta) with demand variation S(20)

ALGORITHM - I							ALGORITHM -II					
TBO	SM			LUC			SM			LUC		
	zeta=0	zeta=10	zeta=20	zeta=0	zeta=10	zeta=20	zeta=0	zeta=10	zeta=20	zeta=0	zeta=10	zeta=20
2	0.338	0.262	0.183	0.346	0.346	0.346	0.338	0.262	0.187	0.344	0.262	0.183
3	0.236	0.188	0.152	0.231	0.231	0.231	0.338	0.262	0.187	0.344	0.262	0.262
4	0.141	0.137	0.121	0.184	0.145	0.145	0.202	0.181	0.152	0.241	0.210	0.181
5	0,110	0.103	0.096	0.189	0.189	0.106	0.141	0.137	0.121	0.183	0.175	0.137

Table 5(b) The Variation of order quantity CV(I) under different extra quantity(zeta) with demand variation S(40)

ALGORITHM - I							ALGORITHM -II					
TBO	SM			LUC			SM			LUC		
	zeta=0	zeta=10	zeta=20	zeta=0	zeta=10	zeta=20	zeta=0	zeta=10	zeta=20	zeta=0	zeta=10	zeta=20
2	0.334	0.319	0.291	0.342	0.350	0.354	0.334	0.319	0.298	0.334	0.319	0.291
3	0.285	0.197	0.188	0.249	0.236	0.244	0.334	0.319	0.298	0.343	0.308	0.262
4	0.149	0.146	0.136	0.176	0.175	0.175	0.265	0.197	0.188	0.256	0.255	0.232
5	0.119	0.123	0.123	0.152	0.139	0.143	0.148	0.146	0.136	0.181	0.174	0.204

Sensitivity Analysis

To observe the effects of non-integer TBOs on the variability of orders created by the lot sizing rules, experiments have been conducted with 14 different cost structures leading to TBOs from 1.5 to 4.5. Figures 1(a) and (b) shows the effect of cost structure on the variability of the order quantity with SM and LUC lot sizing rules respectively.

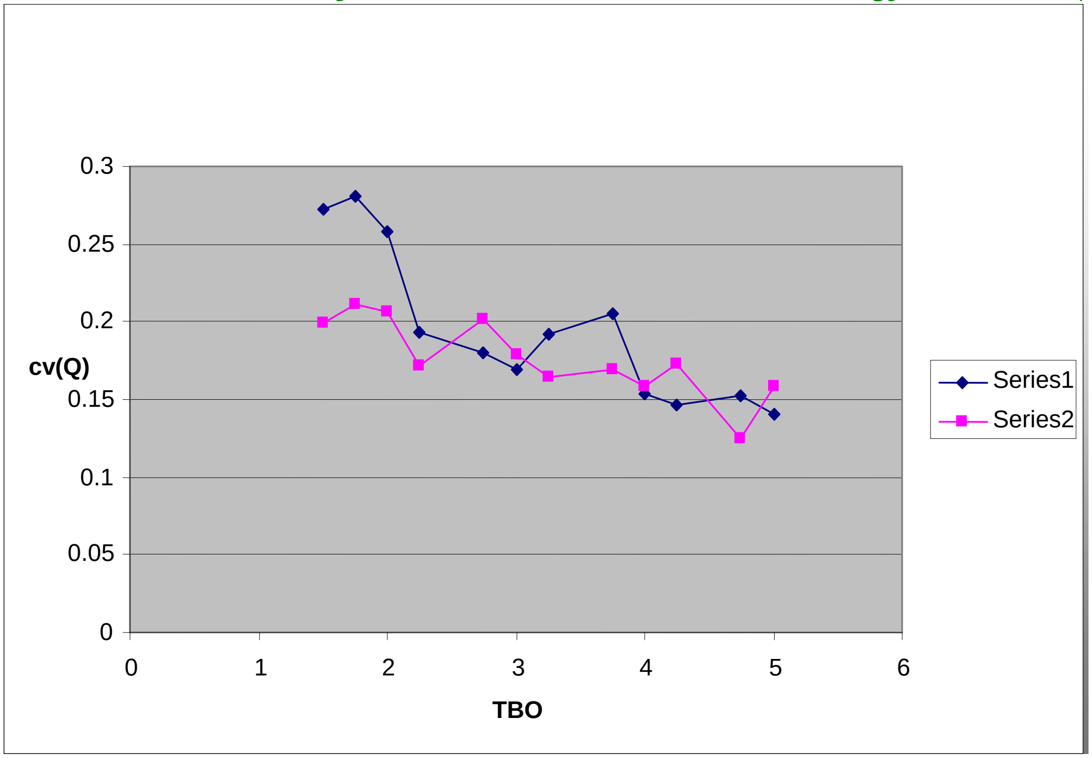


Figure 1(a). The figure depicts the effect of cost structure on variability of orders quantity created by Silver-Meal lot sizing rule

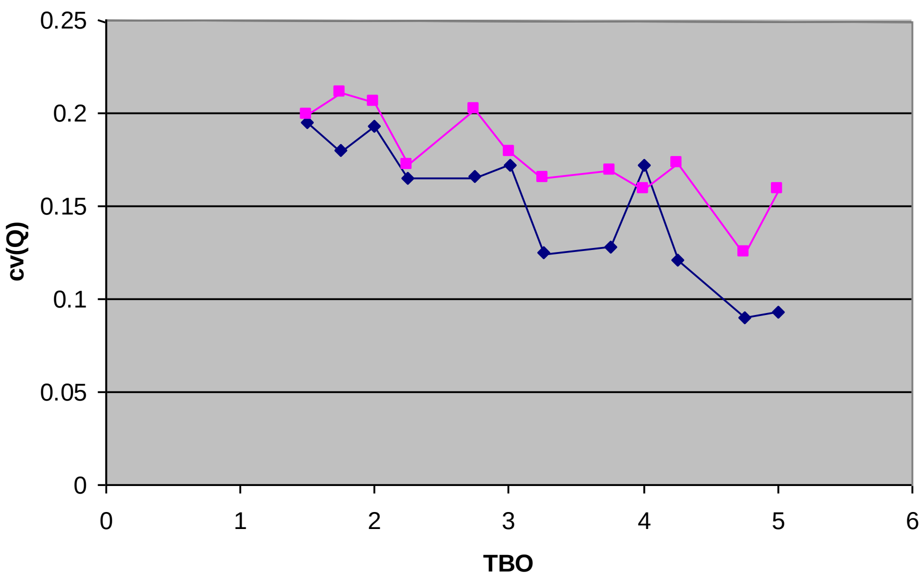


Figure 1(b). The figure depicts the effect of cost structure on variability of orders quantity created by Least Unit Cost lot sizing rule

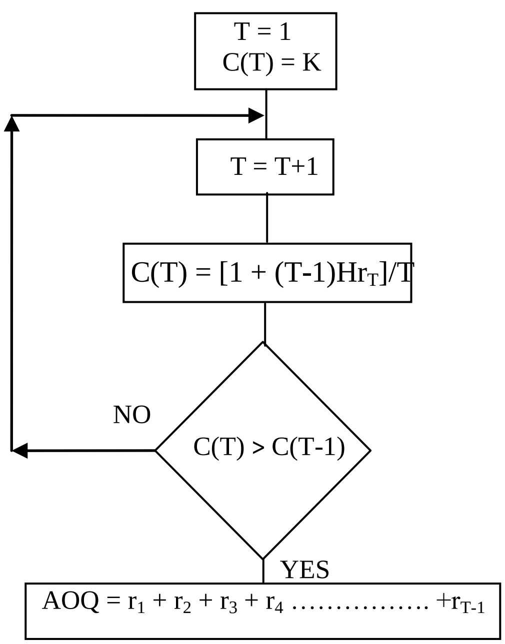
The Figures show that the two models have significantly different sensitivity with respect to cost structures. The SM lot sizing rule is insensitive to the cost structure near the integer basic order cycles. The LUC lot sizing rule is sensitive to cost structure in the neighborhood of the integer basic order cycles. Also Figure 1(b) shows the effect of planned shortage (p) on the order quantity produced by lot sizing rules. With SM lot sizing rule the average order quantity remain constant for lower values of p (p<0.75). There is sharp increase in the value of average order quantity between p=0.75 and p=1. The average order quantity is again constant for p >1. The LUC lot sizing rule behaves differently. The average order quantity for lower values of basic order cycle (TBO=2) is constant for p <1 and then there is a gradual increase for p >1. For large values of basic order cycle (TBO=5) the LUC rule shows the gradual increase in average order quantity with an increase in planned shortage (p).

Conclusion

A important achievement of this paper is that a purchasing company may be benefited if it uses the planned shortage algorithm instead of basic EOQ algorithm. It is also found that for the small values of basic order cycles the planned shortage algorithm is more stable in producing average order quantity as compared to basic EOQ algorithm. The LUC lot sizing rule produces higher values of average order quantity in compare to SM lot sizing rule in both the algorithms. For small values of basic order cycles the SM lot sizing rule produces variable amount of average order quantity but with the planned shortage algorithm the average order quantity remains constant. In case of higher demand variation also the addition of extra quantity in order quantity reduces the variability in order quantity but higher variability is found in planned shortage model in comparison to basic EOQ algorithm. The addition of extra quantity in order quantity reduces the variability in average order cycle in both the algorithms but planned shortage model shows higher variability in comparison to basic EOQ algorithm. Both the algorithms show different sensitivity to cost structure. In planned shortage algorithm, a sharp increase in average quantity is found for planned shortage values between 0.75-1.0.

Appendix

Let
K – Set up cost
H – Holding cost per unit
C(T) – Average Holding and Set up cost per period, if the order spans for "T" periods.
$r_1, r_2, r_3, \ldots\ldots r_n$ – requirements for 'n' periods
(1) For period – 1:
Average cost C(T) = C(1) = K [since, there can be no holding cost during initial period, and H = 0].
(2) For period – 2:
Average cost $C(2) = (K + Hr_2)/2$
(3) For period – 3:
Average cost $C(3) = (K + Hr_2 + Hr_3)/3$
.
.
.
For "T" periods,
$C(T) = (K + Hr_2 + Hr_3 + Hr_4 \ldots\ldots\ldots\ldots + Hr_T)/T$
Optimal condition is the order quantity when C(T) > C(T-1). Therefore when C(T) > C(T-1) is reached, stop iterating and add all the requirements as below to get the Average Ordered Quantity.
Average Ordered Quantity = $r_1 + r_2 + r_3 + r_4 \ldots\ldots\ldots\ldots + r_{T-1}$



The LUC lot size rule is similar to Silver-Meal rule, except that instead of dividing the cost over 'T' periods by the number of periods 'T', we divide it by the total number of units demanded through the period 'T'. That is,

$r_1 + r_2 + r_3 + r_4$ ……………. $+r_T$

References

[1] Chen, F. et al., "The bullwhip effect: Managerial insights on the impact of forecasting and information on variability in a supply chain: Taysur, S., Ganeshan, R, Magazine, M. (Eds), "Quantitative models for supply chain management". Kluwer, pp. 418-439, 1998

[2] De BodT, M.A., Gelders, L.F. and Van Wassenhove, L.N., "Lot sizing and safety stock decisions in a MRP system with demand uncertainty", Engineering cost and production economics 6, pp. 67-75. 1982.

[3] De Bodt, M.A.and Van Wassenhov, L.N., "Cost increases due to demand uncertainty in MRP lot sizing", Decision Sciences 14, pp. 345-439, 1983.

[4] Fransoo, J.C. and Wouters, M.C.F., "Measuring the bullwhip effect in the supply chain", Supply Chain Management, 5 (2), pp.78-89, 2000

[5] Kelle, P., Milne, A., "The effect of (s, S) ordering policy on the supply chain", International journal of production economics, 1999.

[6] Metters,R.D. and Vargas, V., "A comparison of production scheduling policies on costs, service levels, and schedule changes", Production and Operations Management 8(1),pp. 76-91, 1999.

[7] Metters, R., "Quantifying the bullwhip effect in supply chains", Journal of Operation Management 15, pp.89-100, 1997.

[8] Pujawan I.N., "The effect of lot sizing rules on Order Variability", European journal of Operations Research, pp. 617-635, 2004.

[9] LaForge, R.L. and sridharan, S., "On using buffer stock to combat schedule instability" International journal of Operations and Production Management 10(7), pp.37-46, 1990.

[10] Wemmerlov, U., 1989, 'The behavior of lot sizing procedures in the presence of forecast errors'. Journal of operations management, 8(1), pp.37-47.

[11] Zhao, X., Goodle, J.C. and Lee, T.S., "Lot sizing rules and freezing the master production schedule in material requirement planning systems under demand uncertainty", Production Research, 33(8), pp.2241-2276, 1995.

Biographies

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He had been successful in managing the administrative tasks, such as, Head of Department, Dean of College of Engineering & Technology assigned to him during my tenure. Some of his projects are Design, fabrication and erection of (a) High-Tech Passenger shelter, (b) Car parking shelter, (c) Fountain, (d) Entrance gate, etc., which he has exposed to his students during its fabrication and erection to build their practical capabilities.

He did consultancy services to nearby industries and local community. He worked as a consultant Managing Director for a local industry in Ethiopia assuring community service.

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