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Remission of Batch Order Quantity in Single Echelon Supply Chain Using Inventory Model

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Abstract: Business organization confronts difficulties while dealing the global market. One of the challenges is prediction of optimal batch quantity of an inventory. This paper addresses the research void that has been left to suggest a solution in earlier research paper to alleviate the Whip-Lash effect. The main causes of Whip-Lash effect are order-batching, Demand forecasting updating, price fluctuation, rationing and gaming. In supply chain stages (Manufacturer, Distributor, Retailer, Customer), the prediction of order batching perplexed the distributor and retailer much higher than any other two stages. Hence, a Lagrangian function with the objective and constraints are implied to predict the optimum lot size among the variety of items namely (A-G), that limits to prescribed inventory aspired by the distributor. Finally it minimizes the inventory cost of particular supply chain stage irrespective to the importance of an item. The results confirm that the entire economic order quantity of items depends upon the sensitivity of Lambda value and it is predicted. Furthermore, a MATLAB program is drafted to solve the linear programming model, which can be extended to any number of items.

Keywords: Whip-Lash Effect, Supply chain management, order batch quantity

I. INTRODUCTION

The objective of computing the optimum order batch quantity is to produce the product in desired quantity and the quantity with least holding cost [6],[12].Essentially, there are two choices of devising the batch order quantity [1].

(a) Devising a hefty batch of product in long layoff.
(b) Devising a meager batch of a product in short layoff.

The optimal batch quantity i.e, the cost/unit product of the quantity is at minimal, lies amid large and small batch quantity.The major concerning aspect in supply chain management is the Whip-Lash effect. The causes that arousing the WLE in supply chain are order batching, demand forecast updating, rationing and gaming and price fluctuation. In this paper, the factors that matters the amplification of order quantity are deeply analyzed and eradicated to a great extent applying inventory management empirical concepts. Many researchers has studied and analyzed the behavior of demand variability and derived a primitive solution. The concept of Bull-Whip effect was initially coined by Forrester (1961), termed the phenomenon as "Demand Amplification" [5] since then many research works has been published by numerous authors. Forrester stated that the system dynamics is the primary cause of order variance and demand amplification. Towill (1996) validated the conclusions of Forrester that disintegration of all cycle times and alleviating the delays can mitigates the Bull-Whip effect [15].

Lee et al. (1997) established that the WLE is provoked by batch ordering, rationing and gaming, price amplification and Demand signal and can be minimized through effective information sharing [8]. [9] Attempted to reduce the WLE to some extent using Linear Programming formulation and simplified the complex relations using MATLAB and LINGO software.

A system of control framework was introduced to analyze the behavior of smoothing parameters [10], using Minitab and Excel spread-sheet. In which, three factors including (α, β, γ) are considered at various supply stages of a firm and the demand for such item are forecasted using winters model and the optimum smoothing parameters are estimated which considerably reduced the effect of order variance to a great extent.

The research gaps that led to carry-out a furthermore investigation on factors that influence the BWE. In this research, the forecasted demand data predicted using winters model over a period of one year is considered as a batch quantity for all the items ranging from A-G. Further, the optimal order quantity or EOQ of each item over a period of one year is estimated at distributor level, where the predefined quantities of all the items are enlisted in prior. The objective is to limit the average no. of inventory per year to less than or equal to the predefined value. Accordingly, Lagrangian function is introduced to solve the non-linear problem where the optimum constant value of 'λ' is determined using sensitivity analysis that limits the annual batch order quantity.

II. ORDER BATCHING AND BULL-WHIP EFFECT

Lee et al.(1997) [8] and Riddalls and Bennett (2001) [11] diagnosed that order batching is one of the primary cause of Whip-Lash effect. Order batching is the aspect of establishing orders to upstream supply chain stages in batches. The prediction of optimal batch order quantity is much difficult as it is comprised with inventory holding cost and backlog costs. In most of the supply chain stages, the fixed lot sizes moves from one stage to another. For example a distributor might place order a load of container from the manufacturer to attain for a discount and to reduce transportation costs by completely making use of fixed-cost truck or container. A manufacturer can gain significant amount of profits by making the products in batches, but it may cause to increase in inventory holding costs. However, the inventory policies may reduce the inventory to a great extent and keeps the holding cost at minimal.

Batching refers to concatenation of items for transportation, purchasing and manufacturing processes and namely called as lot-sizing. It is a process that is time bounded production, which is normally unmatched with actual demand. As a result, the accumulation of excessive inventory arises. Batch order quantity is also relevant to economic batch quantity, where it is economically beneficial to the supply chain stages to produce in large batches, since it can minimizes the facility setups and reforms manufacturing efficiency. Organizations usually chooses to order in batch to make it more economical. The consequences of large batch sizes can result to large variances in inventory levels.

Holland and Sodhi (2004) [7] perceived two echelon supply chain model, for which the retailer is intended to place order in integer multiples of batch size. The manufacturer and retailer pursue a order-up-to level and periodic review replenishment policy. Reproduction was compiled for various batch sizes and analysis is performed to measure the influence BWE of batch size in each supply chain stages. They established that the BWE among supply stages reciprocal to the product of the batch size. Hejazi and Himolla (2006) [6] contended that batching or lot sizing decisions of an upstream may also result order batching at the low stream of the supply chain. The simple supply chain in business environment is shown in Fig.1.

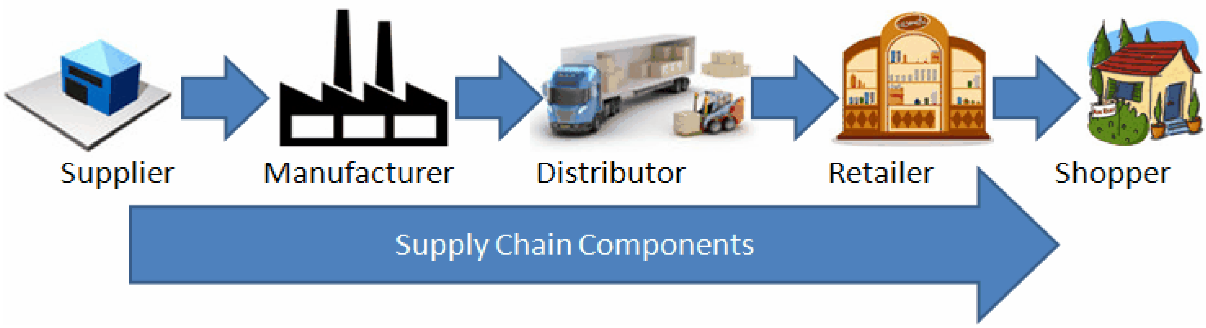

Fig.1. Supply chain in Business Scenario

III. ASSUMPTIONS

1. Twelve months data is considered for computation
2. Equal weightage is given to all the items irrespective of its Importance
3. All the Inventory Items possess equal demand
4. The replenishment is instantaneous
5. No back orders are allowed

IV. STEPS INVOLVED IN ORDER BATCH QUANTITY

The mass maintenance of varieties of items in storage location may increase the holding cost of inventory for distributor. On the other hand Bull-Whip effect affects the production flow instantaneously, if the variety of items is procured in meager batches. So, the intensity of impact for both the conditions under procurement is deeply analyzed and paralyzed the factors which contribute to high total inventory cost for distributor. The supply chain echelons trade seven varieties of items, namely (A, B, C, D, E, F & G) and the forecast demand data over 12 months are depicted in the Table 1.

TABLE 1
Demand forecast of Inventory Items

Items → / Months ↓	A	B	C	D	E	F	G
Jan	2223	2489	1781	2159	1527	1997	2091
Feb	2467	1480	2094	2898	2348	1845	2089
Mar	2421	1533	1742	1490	1636	1896	1951
Apr	2055	1556	2477	1897	1636	1971	2548
May	1468	2512	1785	1474	2046	1896	2034
Jun	1945	2520	1719	1537	1691	1845	2176
Jul	2410	1689	1694	1887	1801	1795	2194
Aug	1342	1982	1733	1506	1968	1764	1799
Sep	1842	1511	1771	2031	1691	1946	2176
Oct	1690	1745	2650	1552	1746	2178	2107
Nov	1500	1444	1704	1892	2145	2712	1985
Dec	1405	1400	1742	2399	2415	2143	2020
Total	**22768**	**21861**	**22892**	**22722**	**22650**	**23988**	**23270**

The total inventory of each item for 12 months are enumerated and used as a source of demand data for next twelve months. Furthermore, the EOQ of all the items are added together and considered as the maximum limit, taking the seasonality factor into the account. The details of setup and holding cost are shown in Table 2.

Table 2
Costs and EOQ of Demand Inventory Items

Items → / Months ↓		A	B	C	D	E	F	G
Setup cost		325	300	700	225	500	230	410
Holding Cost		0.03	0.04	0.07	0.02	0.06	0.02	0.05
Demand	Previous Demand	22768	21861	22892	22722	22650	23988	23270
	EOQ	22210.5	18108.4	21397.1	22610.7	19429.35	23488.8	19535.3

The optimal order quantities under the restriction of no. of units can be determined
I = Total Average no of items.
q_i= Economic batch order quantity for item i.

Step -1:
Calibrate the optimal batch order quantity for each item using the expression below.

$$q_i = \sqrt{\frac{2 * C_{oi} * R_i}{C_{hi}}} \qquad \text{-------------------------------- eq. (1)}$$

Where i= no. of items, (i= A, B, C, D, E, F & G)
Calculate total Average of all the items using

$$\sum_{i=A}^{G}\left(\frac{q_i}{2}\right) \qquad \text{----------------------- eq. (2)}$$

If $\sum_{i=A}^{G}\left(\frac{q_i}{2}\right)$ □ I, ---------------------- eq. (3)

If eq.(3) satisfies, then terminate the iteration, otherwise go to step-2.
Where 'I' is the restricted inventory quantity for the period of one year. The restricted inventory quantity for distributor is 71,250 units. This results in least minimum inventory cost for the particular echelon.

Step -2:
Formulate lagrangian function with the objective function and a constraint

$$L_e = \sum_{i=A}^{G}\left(\frac{C_{hi}q_i}{2}\right) + \frac{C_{oi}R_i}{q_i} + \lambda\sum_{i=A}^{G}\left(\frac{q_i}{2} - 2I\right) \text{----------------------------eq. (4)}$$

Differentiating eq.(4) w.r.t q_i and equate it to '0'.

$\frac{\partial\lambda}{\partial q_i} = 0$; for i= A, B, C, D, E, F & G

$$\sum_{i=A}^{G}\left(\frac{C_{hi}}{2}\right) - \left(\frac{C_{oi}R_i}{q_i^2}\right) + \lambda = 0$$

$\frac{C_{hi}}{2} = \frac{C_{oi}R_i}{q_i^2} - \lambda$

Further Simplification, the expression is $q_i = \sqrt{\frac{2*C_{oi}*R_i}{C_{hi}+2\lambda}}$ ---------------------------- eq. (5)

Step -3:
Enumerate'λ' using hit & trial method, which limits the Average EOQ of all the items to predefined inventory quantity.

Step -4:
If $\sum_{i=A}^{G}\left(\frac{q_i}{2}\right)$ □ I,
Declare the optimal batch order quantities of all items q_i, for i=A, B, C, D, E, F, G.
Followed by the mathematical formulation, the search for optimal λ value that results in minimization of inventory level is predicted after the execution of MATLAB program. Sensitivity analysis is performed at various levels of λ value and its corresponding inventory is shown in the Table 3

Table 3
Sensitivity analysis for the various levels of λ value

A □ / **Items □**	**0.001**	**0.005**	**0.01**	**0.02**	**0.03**	**0.04**	**0.05**	**0.06**
QA	21505.23	19234.86	17204.18	14540.19	12823.24	11599.05	10669.52	9932.841
QB	17672.01	16196.66	14785.46	12804.58	11452.77	10454.9	9679.35	9059.211
QC	21097.91	20015.24	18870.55	16680.25	15343.6	14617.06	13730.34	12987.6
QD	21558.4	18461.58	15988.19	13054.31	11305.36	10111.82	9230.79	8546.05
QE	19113.41	17988.52	16826.31	15049.91	13738.63	12719.5	11898	11217.54
QF	22395.69	19178.52	16609.09	13561.27	11744.4	10504.51	9589.26	8877.93
QG	19155.93	17833.28	16510.34	16680.25	15343.6	12115.27	112778.7	10597.5
SUM	142498.6	128908.7	116794.1	102370.8	91751.6	82122.12	177576	71218.67
Avg. Demand of Items	**71249.29**	64454.33	58397.06	51185.38	45875.8	41061.06	88787.99	35609.34

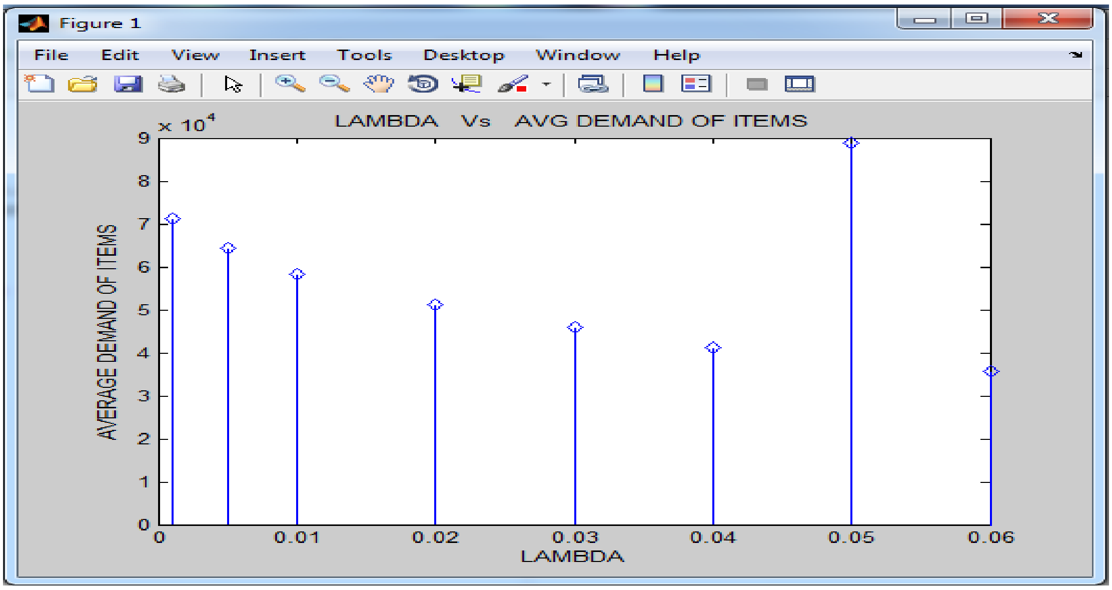

Fig. 2. Lambda Vs Avg. Demand of Inventory Items

The MATLAB result shown in Fig.2 elucidates the optimal λ value that limits to the predefined inventory quantity level.

V. CONCLUSION

In the Competitive market scenario, Whip-Lash effect has more impact on organization profits at various levels of supply chain echelons. Many researchers conducted thorough study to minimize the intensity of order amplification. Primarily, there are four factors that adversely influence the WLE. Controlling of one factor is not enough to stabilize the order amplification. Among the said factors, the batch order quantity abnormally increases the order variance for one echelon in supply chain. The mostly influenced echelon in supply chain is Distributor. This paper focuses on alleviating the total inventory cost of distributor. Initially, demand forecast data over twelve months period is calculated and the data is used as a demand for the next twelve months period. Economic order quantity for the particular items is estimated using mathematical relations and its Avg. inventory quantity for all the items are enumerated. The Avg. inventory quantity is compared to the desired quantity level. Upon the no. of iteration the result shows that the λ =0.001 will leads to equalization of aspiring inventory to the desired inventory quantity for all the items. Hence, the optimal inventory quantities of all the items for a distributor will results to the alleviation of total inventory cost to some extent, the optimal item quantities of Q_A, $Q_{B,}$ $Q_{B,}$ $Q_{D,}$ $Q_{E,}$ $Q_{F,}$ $Q_{G,}$ are 21505.23, 17672.01, 21097.91, 21558.4, 19113.41, 22395.69, 19155.93,. Furthermore, this model can be extended to ‘n’ no. of items for any organization at any echelon stages, where the order amplification is mostly influenced.

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