ISSN : 1978-774X

PERFORMANCE COMPARISON OF HEURISTIC LOT-SIZING MODELS

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ABSTRACT

Managing inventory in many firms is one of the critical issues nowadays. With the changing patterns of demand that varies over time and with so many inventory techniques, inventory managers find it hard to choose which techniques are applicable for their needs. This study was conducted to address some of those issues by comparing the performance of the widely used lot-sizing models. Different variations of demand ranging from low, medium to high has been simulated and performance of its lot sizing models has been measured and compared.

***Keywords**: Inventory, Inventory Managers, Lot-Sizing Models, Optimal Total Cost.*

1. INTRODUCTION

For the past few decades, customer demands had evolved from just a simple individual demand to a more generalized demand especially for consumer products. Numerous time dependent or seasonal demands arise as market needs evolve, thus, making the lot sizing problem more important for many industries. This phenomenon has also resulted in the innovation in demand forecasting and inventory handling or lot sizing procedures. Many inventory procedures have been formulized in order to optimize total cost while meeting the specific demand from their customers at exact time. Ordering or Production Methods like EOQ and EPQ has been integrated to efficient demand forecasting methods in order to satisfy customer demands.

As this area of research becomes more and more important, many researchers had formulated new methods in optimizing the total cost while meeting customers' demands. Economic Order Quantity (EOQ), as one of the oldest and classical ordering and production scheduling models (Wikipedia, 2013b). EOQ is widely use in many industries to minimize a firms total inventory costs and ordering costs. But EOQ constant demand assumption is not applicable for time varying demands or products with seasonal demand.

To solve the lot sizing problem for time varying demands, many dynamic lot-sizing models has been developed over the past few decades. One of the most well known lot sizing models is the Wagner and Whiten Algorithm developed by Harvey M. Wagner and Thomson M. Whiten (Wikipedia, 2013a). But then, due the its complexity managers and other practitioners find it difficult to use such method and thus resulting in the development of heuristic procedures like Lot for lot ordering (LFL), Periodic Order Quantity (POQ), Silver-Meal Algorithm (SMA), Part Period Algorithm (PPA) and Incremental Part Period Algorithm (Incremental PPA). Many firms were able to gain their competitive advantages and as well as sustain their businesses by utilizing the best optimal solutions in terms of demand management. But, as the number of research and optimal lot sizing solution models developed grows for this area, the task of choosing the right lot sizing procedures becomes more important.

Each of the heuristic inventory management procedures mentioned has undergone extensive simulation process in order to prove its effectiveness and accuracy before it was considered and accepted as a significant contribution to the knowledge of Inventory Management, but each of these procedures surely may outperform the other in terms of their result when use in the real world. Also, user friendly procedures may also contribute in the firms' selection of particular method.

From the above mentioned heuristic or dynamic lot sizing procedures, this paper aims to analyse the complexity and effectiveness of each lot sizing techniques and choose the most optimal solution in an environment where demand changes drastically. Assumptions of this research are illustrated in the latter part of the paper.

Based on the mentioned objectives, the paper is organized as follows: Section 2. Literature Review, Section 3.Methodology, Section 4. Result Analysis, and Section 5. Conclusion

1.1 Assumptions

- Demand is known and occurs at the beginning of each period
- Orders or production batches arrive at the beginning of each period
- Unit cost of each item is fixed with no possible quantity discounts
- Product shortage or stock out are not allowed
- Items are removed from the inventory at the beginning of each period and Inventory carrying cost is applied to the remaining inventory
- Lead times and other inventory related cost are known and fixed
- Lead time is zero
- Remaining Inventory of Period T is zero
- Starting inventory is Zero

1.2 Available information with their respective Notations

R - Demand in each period
C - Ordering cost per unit
U - Unit cost
H - Holding cost as a fraction of unit cost

2. LITERATURE REVIEW

Many recent researchers and inventory managers had used the heuristic procedures or dynamic lot sizing models in solving different inventory problems. As the number of companies utilizing the idea of Just-In-Time production and ordering, the usage of lot-for-lot ordering procedures which is known as the most simple lot sizing models grows and gained popularity in MRP applications (Alwan, et al. 2008).The mentioned authors used the lot-for-lot ordering in MRP systems and measure its performance considering the possible impact of forecasting when there is notable variability and autocorrelation in the underlying demand process.

Gaafar (2006) used his own modified version of Silver Meal Algorithm (developed by Silver and H.C Meal) (MSM) in one of his research to measure its performance in terms of solving lot sizing problems compared to other algorithm methods like genetic algorithms. In his paper entitled “Applying genetic algorithms to dynamic lot sizing with batch ordering”, he mentioned that many practitioners prefers other algorithms that are simpler, even though they may generate suboptimal solutions because of the reasons that complex algorithms are often too difficult to understand by inventory managers. From the above mentioned lot sizing algorithm solutions, Wagner and Whiten algorithm are not widely used even though it gives the optimum solution (Gaafar, 2006). On the other hand, Part- Period Algorithm (PPA) is the most commonly used lot-sizing procedures in practice and it has also been tested in simulation experiments (Wemmerlöv, 1983). It’s a policy that combines the assumptions of the Wagner and Whiten paradigm with the mechanics of EOQ (Innomet, 2013).

(Baciarello, et al. 2013) uses the PPA together with the other best known lot sizing algorithms and elaborated each procedure with a unique modeling approach and have then been exhaustively tested on several different scenarios. From literature reviews literatures, we have noticed that many research papers used Wagner and Whiten and Silver Meal Algorithm as their basis of comparison in terms effectiveness and efficiency. Silver Meal Algorithm also known as Least Period Cost (LPC) is widely regarded as one of the most well known and effective methods(Johnny C. Ho, 2008).

ISSN : 1978-774X

Table 1.Lot Sizing Rules

Methods	Definition/Functions
Wagner and Whiten Algorithm (WWA)	Provides the optimal Solution by the use of dynamic algorithm
Part-Period Algorithm(PPA)	Includes a future demand requirement as long as the additional (or Incremental) carrying cost created by its inclusion is less than the cost of placing a separate order for that period's requirement
Period Order Quantity(POQ)	Uses the EOQ to determine the reorder time cycle and then orders what is actually forecasted for that time cycle
Lot-for-Lot(LFL)	uses a traditional MRP way of ordering exactly what is needed in every period (Optimal if set-up costs are zero)
Silver Meal Algorithm(SMA)	Selects the order quantity so as to minimize the cost per time unit over the time periods that the orders lasts

This paper focuses on heuristic lot sizing procedures and Wagner and Whiten Algorithms.

2.1 Lot Sizing rules

Each of the lot sizing techniques utilizes unique ideas in solving lot sizing problems. Definitions or Functions are illustrated on Table 1.

3. METHODOLOGY

All heuristic lot sizing techniques which includes Silver Meal Algorithm (SMA), lot-for-lot ordering (LFL), Periodic Order Quantity (POQ), Part Period Algorithm (PPA) and Incremental PPA have been tested comprehensively with different scenarios or variation of demand within a specified time frame. Holding cost per unit as a fraction of the remaining inventory is constant during the whole testing period. The minimum total cost is obtained by each lot sizing models. Bench marking with Wagner and Whiten Algorithm has been conducted in terms of total cost percentage savings for each item.

3.1 Data Simulation

A set of data's has been generated using simulation software creates a unique sequence of numbers for each data. Maximum level of demand for each period is 100 and variations have been set into three categories. Table 2 shows Low Demand Variation (greater than or equal to 10 but less than 100),
Table 3 shows Medium Demand Variation (greater than or equal to 30 but less than 100), and Table 4 shows High Demand Variation greater than or equal to 50 but less than 100). See below illustration.

Demand Variation

- $\geqq$10 - $<$100 (Low)
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- $\geqq$ 30 - $<$100 (Medium)
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- $\geqq$50 - $<$100 (High)

ISSN : 1978-774X

Table 2.Low Demand Variation

Period	Item 1	Item 2	Item 3	Item 4	Item 5
1	75	76	76	76	76
2	92	55	85	56	90
3	61	90	80	55	92
4	51	95	76	58	57
5	87	73	89	81	52
6	53	80	89	88	62
7	95	70	58	77	64
8	75	100	76	68	89
9	81	75	64	60	79
10	90	78	52	70	77
11	79	89	52	65	95
12	93	54	77	100	53
Mean	77.67	77.92	72.83	71.17	73.83
Std.Dev.	15.39	14.30	13.27	13.84	15.79
CoV.	19.81%	18.35%	18.21%	19.45%	21.38%

Table 3.Medium Demand Variation

Period	Item 1	Item 2	Item 3	Item 4	Item 5
1	65	66	66	66	66
2	89	37	79	38	86
3	45	86	72	37	88
4	31	93	66	41	39
5	82	62	85	73	33
6	34	71	84	82	47
7	93	58	41	67	49
8	64	99	67	55	84
9	73	64	49	43	71
10	85	69	32	58	68
11	70	84	33	51	92
12	90	35	67	99	34
Mean	68.42	68.67	61.75	59.17	63.08
Std. Dev.	21.618	19.947	18.67	19.126	21.956
CoV.	31.60%	29.05%	30.23%	32.32%	34.81%

Table 4.High Demand Variation

Period	Item 1	Item 2	Item 3	Item 4	Item 5
1	55	56	56	56	56
2	86	18	73	20	82
3	30	81	64	19	85
4	11	91	56	23	22
5	76	50	80	65	14
6	16	63	80	77	31
7	90	46	24	58	34
8	54	99	57	42	80
9	65	54	34	27	62
10	81	60	12	46	58
11	62	79	13	37	90
12	87	17	58	99	15
Mean	59.4167	59.5	50.583	47.417	52.417
Std. Dev.	27.5102	25.675	24.217	24.759	28.356
CoV	46.30%	43.15%	47.87%	52.22%	54.10%

ISSN : 1978-774X

Table 5.TC for Low Demand Variation

Total Cost						Average Cost
LFL	600	600	600	600	600	600
POQ	381.8	383	384.4	375.2	379.6	**380.8**
PPA	381.8	383	384.4	375.2	379.6	**380.8**
SM	391.6	390	390	382	374.6	385.64
WW	381.8	377.6	372.2	374.8	369	**375.08**

Table 5 shows that WW algorithm is expected as optimal while POQ and PPB provides the second best solution outperforming SM algorithm and LFL.

Table 6.TC for Medium Demand Variation

Total Cost						Average Cost
LFL	600	600	600	600	600	600
POQ	357.8	358.8	361.6	347.8	355	**356.2**
PPA	357.8	358.8	361.6	352.6	355.4	357.24
SM	371.8	358.8	366.2	341.8	343.6	**356.44**
WW	353.2	356	348.2	341.4	343.6	**348.48**

Table 6 shows that as demand variation increases, SM algorithm outperformed PPB in terms of the optimal total cost while POQ remained to be the second best solution. As expected, an increased in variation has no effect on the optimal solution provided by WW algorithm, while LFL remained to the least favourable solution as its cost remained to be constant through-out the period.

Table 7.TC for High Demand Variation

Total Cost						Average Cost
LFL	600	600	600	600	600	600
POQ	334.8	335.2	339	321.6	330.4	**332.2**
PPA	334.8	359.8	332	319	397.6	348.64
SM	337.8	335.2	330.8	310	309.8	**324.72**
WW	323	332.2	315.2	307	308.6	**317.2**

Table 7 shows that as the gap of demand between each period increases, SM algorithm becomes the second best solution among the giving lot sizing techniques. It outperforms both POQ and PPB in optimal total cost while WW remained to be the optimal solution.

4. RESULT ANALYSIS

The actual simulation has been repeated 20 times for each set of demand variation. But due to the uniformity of each result, only the first 5 sets are used. Table 2 illustrates the lowest variations of demand for each period ranging from 18%-21% while Table 4 shows the widest variations of demands for each period ranging from 43%-54%. The total cost incurred for each period has been calculated using the given lot sizing heuristic models.

4.1 Wagner and Whiten Benchmarking

Table 8 shows the % variation in total cost for each models compared to Wagner-Whiten Algorithm optimal total cost obtained in each variation of demand.

4.2 Summary of Results

This research shows that for low and medium variation of demand for each period, POQ is the best solution for solving lot sizing problems. Even though, Wagner and Whiten algorithm provides the lowest total cost among the mentioned models, its complexity is one of the main issues. It is not commonly used in inventory management. Experiment also shows that, for high variation of demands, Silver Meal algorithm is the best solution for solving lot sizing problems. It's procedures is not as complex as Wagner and Whiten algorithm, thus making it as one of the best choice for solving lot sizing problems especially for time varying or seasonal type of demand.

5. CONCLUSIONS

Each lot sizing techniques has their own advantage and disadvantage for varying demand. WW algorithm is considered to be optimal for all cases. But, due to its complexity, managers prefer to use other simpler method like POQ, PPA, LFL and SMA. In this research, LFL is a good method if the holding cost lead time is also equal to zero.

6. REFERENCES

Table 8. % Savings in Total Cost

Low Demand Variation						
% Savings						Av. Savings %
LFL	57.2%	58.9%	61.2%	60.1%	62.6%	60.0%
POQ	0.0%	1.4%	3.3%	0.1%	2.9%	**1.5%**
PPA	0.0%	1.4%	3.3%	0.1%	2.9%	**1.5%**
SM	2.6%	3.3%	4.8%	1.9%	1.5%	2.8%
Medium Demand Variation						
% Savings						Av. Savings %
LFL	69.9%	68.5%	72.3%	75.7%	74.6%	72.2%
POQ	1.3%	0.8%	3.8%	1.9%	3.3%	**2.2%**
PPA	1.3%	0.8%	3.8%	3.3%	3.4%	2.5%
SM	5.3%	0.8%	5.2%	0.1%	0.0%	**2.3%**
High Demand Variation						
% Savings						Av. Savings %
LFL	85.8%	80.6%	90.4%	95.4%	94.4%	89.2%
POQ	3.7%	0.9%	7.6%	4.8%	7.1%	**4.7%**
PPA	3.7%	8.3%	5.3%	3.9%	28.8%	9.9%
SM	4.6%	0.9%	4.9%	1.0%	0.4%	**2.4%**

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