A DESIGN EXPERIMENT TO EVALUATE THE EFFECT OF DEMAND PATTERN INTO THE LOT SIZING PERFORMANCE

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ABSTRACT

Lot sizing technique became standard subjects in MRP. Much research focused on lot sizing techniques as the used of MRP systems has grown. Therefore many lot sizing technique are available. This paper surveys the performance of some heuristic lot sizing techniques at different demand pattern using a design experiment. Computational result on a data set consisting of 80 randomly generated problems are provided. The result show that the effect of demand pattern is statistically significant to the lot sizing techniques performance . Lot for Lot algorithm is the worst among other technique for all type of demand pattern and Silver Meals is the best techniques in any type of demand pattern but the Part Period Balance and Least unit cost perform better on a specific demand pattern.

Keywords: *Lot sizing, MRP, Demand Pattern, Design Of Experiment*

1. INTRODUCTION

Material requirement planning (MRP) systems are widely used by companies to manage resources in a manufacturing environment especially for manufacturing who uses ERP system. The economic lot-sizing problem is the core problem in MRP

Much research focused on the lot sizing techniques as the used of MRP systems has grown. Therefore many lot sizing technique are available. Wagner Within algorithm is an algorithm that results an optimal solution. Unfortunately as Silver and Peterson, (19), algorithm Wagner Within is computationally inefficient and not easy understood by practicians and therefore is often not implemented . For this reason many heuristic algorithm have been developed. Different mathematical models are designed to assist decision making at all level of plant design and control. Most of the proposed algorithm was more simply than WW. Each technique use different assumption and different algorithm resulting different total cost consequences.. This reason questioning which one these techniques performs well. The best lot sizing technique will not guaranty the best for different condition. The demand pattern, the proportion of carrying cost and set ups may cause the decision of best use of lot sizing technique.

Lot sizing technique became standard subjects in MRP. In such enviroment, the demand typically varies over the time in some pattern. For this reason, We will consider the affect demand pattern on the lot size performance using an experimental design

Previous research on the performance of lot sizing were focused on the mechanics of MRP processing . Another research has done to investigate the factor affecting the decision , but most of them is done for a specific condition so that the result cannot be generalized.

The detail of the various lot sizing heuristic are described in section 2, the design of the experiment and the performance measure are presented in section 3, Summary of computational result of the experiment is offered in section 4, analysing the performance of the lot sizing technique will be discussed in section 5 and the summary and conclusion is drawn at the end of this paper

2. LOT SIZING TECHNIQUES

Lot sizing determine when an order should be placed for all item and how many items should be ordered. In many manufacturing environment, the demand typically varies over time and therefore the classical economic order quantity models does not generally perform well. Various approaches have been developed to handle varying demand rate. A dynamic programming based optimization procedure was presented by Wagner and Within (13) for lot sizing problem. The inefficient computational of Wagner Within algorithm lead to grow many heuristics lot sizing techniques. Instead of Wagner Within algorithm, from Baker(1), Berry (2), Karmakar (5), Orlicky (9), and Silver and Peterson, (10), the commonly lot sizing techniques are proposed. There are lot for Lot, Silver Meal, Part Period Balancing, Least Total Cost, Least Unit Cost, Economic Order Quantity, period Order Quantity (Tersine (13)), and Groff algorithm (Nydick,(8)). Most of all the heuristics use a single pass to determine how many demand periods should be included in the first lot that certain decision rules is satisfied. This process continues for the entire planning horizon. Each techniques offers a different decision rule. The simplest dynamic lot-sizing rule is known as lot-for-lot, states that the amount to be produced in a period is equal to that period's requirements. Silver-Meal is another heuristic method used to determine lot sizes in MRP systems. Let C(T) be the average holding and set-up cost per period if the current order spans T periods. Let $(r_1,\dots,r_n)$ be the requirements over the n-period horizon, S is set up cost, and h is carrying cost/unit/period. Note the following: $C(1) = S$; $C(2) = (S + hr_2)/2$; in general $C(j) = (S + hr_2 + 2hr_3 + \dots + (j-1) hr_j)/2$. When $C(j) > C(j-1)$, we stop, set $y_1 = r_1 + r_2 + \dots + r_{j-1}$, and begin the process starting at period j. Least Unit Cost is a heuristic similar to the Silver-Meal method, except that instead of dividing the cost over j periods by the number of periods, j, we divide it by the total number of units demanded through period j, $r_1 + r_2 + \dots +$

r_j. The part period balancing is a policy that combines the assumptions of the Wagner-Whitin paradigm with the mechanics of the EOQ . One of the properties of the EOQ solution to the lot-sizing problem is that it sets the average inventory-carrying cost equal to the setup cost. The idea of PPB is to balance (i.e. set equal) the inventory-carrying cost and setup cost over that period and seeks to make the carrying cost as close to the setup cost as possible. It sets the order horizon equal to the number of periods that most closely matches the total holding cost with the setup cost.

Groff algorithm develop a new single pass heuristic. The idea is to add the demand for the n^{th} period to a lot if the marginal savings ordering cost are greater than the marginal increase in storage costs. Groff 's decision algorithm will add the demand during the n^{th} period to the lot if satisfy $n(n-1)\, R_n < 2S/h$

3. EXPERIMENT DESIGN

Experiment design that is used to evaluate the effect of the demand pattern to the heuristic lot sizing performance is full factorial design. The design of the experiment is factorial design for 2 factor and each factor have four levels factor, that is demand pattern have 4 levels factor and lot size technique have 4 levels factor resulting 16 treatment combination. Planning horizon is set at 12 periods .The factors and the levels of each factors are defined as follow

Factor A: Demand pattern consists of 4 levels factor :
(1) Stationer demand pattern
(2) Increasing demand trend
(3) declining demand pattern
(4) Cyclical demand pattern.
Factor B: Lot Sizing Technique consist s of 4 algorithm :
(1) Lot For Lot Algorithm
(2) Silver Meal algorithm
(3) Part Period Balancing,
(4) Least Unit Cost .

The data set was randomly generated for each combination of demand pattern and lot sizing technique. Each treatment is replicated by 20 times. Thus 80 data are generated for all the demand pattern. For the interested reader the data sets are available

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on the author. The average demand per period for each set data was fixed at 34 unit. and the total demand for along the planning periods was 408. This was set as uniform demand pattern. The increasing demand was set with the same total demand but the pattern is linearly increasing occupying Y = 12.+ 4x and the declining demand pattern is set at equation Y = 56 – 4x. The cyclical pattern was set arbitrary around the same total demand.

Without loss of generality, the carrying cost was arbitrary set at $2/unit product/period. and the setup cost was set at $ 150/set up

The performance of a heuristic lot sizing technique can simply define as the deviation from the heuristic lot sizing and the optimal solution of Wagner Within This Algorithm solution is set as a benchmark of the heuristic lot sizing performance. Any deviation from the Wagner Within solution is called the relative bias. The greater the relative bias, the more worse the performance of the heuristic lot sizing technique. For this reason we use percentage relative bias as the variable response of the experiment to measure the performance of the experiment. The percentage of relative bias measurement (RB) is as follows:

$$\mathrm{RB} = 1/\mathrm{N} \sum_{i=1}^{n} 100[\mathrm{Hi} - \mathrm{OPTi}/\mathrm{OPTi}]$$

Where N = The number of replication
H_i= The solution value of the i^{th} heuristic lot sizing technique
OPT_i= The optimal solution value for the the i^{th} problem define by Wagner Within algorithm

There are many other performance measure that can be used to measure the lot sizing technique performance. Some of them are (1) the number of time that the heuristic solution was optimal, (2) the maximum relative bias (worst case) over all replication (3) the number of percentage of times that the heuristic, first lot equal to the optimal first lot. However, all the performance measure is resulting the same conclusion (Nydicks et all, (7)). For this reason, in this experiment we used percentage relative bias as the performance measure of the experiment

4. COMPUTATIONAL RESULT

We will compare the the commonly heuristic lot sizing technique describe in section 2. The experiment was design for 2 factor and it's levels factor as presented in the experiment layout in the appendix 1. The experiment is replicated 20 times. Each data set have four demand patterns. We provide summary result for each lot sizing technique instead of presenting individual computational result for all replication. That is we average the percentage of relative bias result for 20 data set.

The experiment is run through the following steps

1. Run the experiment for the i^{st} replication. Put the first demand generation to the experiment. Take the stationer demand pattern (SD) and the first experiment is ready to run using 4 lot sizing techniques with the following treatment.

   Treatment 1:
   Calculate the solution using Wagner Within algorithm resulting the lot size decision and the optimal value of total cost for the stationer demand pattern ($OPTSD_1$). This step should be done first so that we can compute the percentage of relative bias for all the heuristic lot sizing technique $(RB_i\ SD)_1$ where *i* is the heuristic lot sizing techniques.

   Calculate the solution of the same problem using Lot For Lot resulting the lot size and the total cost value of Lot For Lot techniques for the stationer demand pattern $(H(_{LFL}SD)_1)$. Find the Relative bias of Lot For Lot for stationer demand pattern $(RB_{LF}LSD)_1$ as the difference of total cost for Lot For Lot $(H(_{LFL}SD)_1$ from the optimal total cost of Wagner Within solution. ($OPTSD_1$).

   Treatment 2:
   Recalculate the same problem using Silver Meal algorithm (SM) resulting the solution value of Silver Meal algorithm

$(H(_{SM}SD)_1)$ and find the Relative bias of the the Silver Meal solution $(RB_{SM}SD)_1$

Treatment 3:
Recalculate the same problem using Part Period Balancing algorithm (PPB) resulting the solution value of Part Period Balancing algorithm $(H_{PPB}SD)_1)$ and find the Relative bias of the the Part Period Balancing solution $(RB_{PPB}SD)_1$

Treatment 4:
Recalculate the same problem using Least Unit Cost algorithm (LUC) resulting the solution value of Least Unit Cost algorithm $(H_{LUC}SD)_1)$ and find the Relative bias of the the Least Unit Cost solution $(RB_{LUC}SD)_1$

2. We next experimented the above steps for the next four treatment (treatment 5-8) for different demand pattern of the first data set generation, that is for increasing demand pattern (ID). All the heuristic lot sizing techniques are applied to find the Relative bias of each heuristic lot sizing and resulting $(RB_{LFL}ID)_1$. $(RB_{SM}ID)_1$, $(RB_{PPB}ID)_1$,and $(RB_{LUC}ID)_1$.

3. Rerun the next four experiment (treatment 9-12) for declining demand pattern (DD) of the first data set generation using each heuristic lot sizing technique to find the response of the experiment $(RB_{LFL}DD)_{1.,}$ $(RB_{SM}DD)_1$,, $(RB_{PPB}DD)_1$, and $(RB_{LUC}DD)_1$

4. The last four experiment (treatment 12-16) is rerun for cyclical demand patern (CD) of the first data set generation using all heuristic lot sizing techniques to find the experiment response of $(RB_{LFL}CD)_1$. $(RB_{SM}DD)_{1,}$ $(RB_{PPB}DD)_1$, and $(RB_{LUC}DD)_1$,

All the sixteen experiments are replicated for the rest of 19 data set generation. Instead of presenting individual computational result of Relative Bias as the response variable of the experiment for all 80 data set. That is we only provide the summary result as an average percentage Relative Bias result for each demand pattern for 20 replication. The summary results is presented in Table 1.

Table 1. Average % Relative Bias

Lot Sizing	Demand pattern			
	Increasing	Declining	Stationair	Cyclical
Lot For Lot	343.43%	420.33%	363.06%	409.66%
Silver Meal	0.29%	26.11%	0%	0%
Period Balan	32.80%	38.76%	18.17%	70.33%
east Unit Cos	5.68%	26.57%	0%	45.20%

5. RESULT ANALYSIS

The experiment result is then analyse using ANOVA. The summary result of ANOVA for both factor is presented in Table 2.

Table 2. Analysis Of Variance

ource of Variance	dk	JK	KT	F	F tabel
Mean	1	2129760	2129760.11	438.475	
Factor					
A	3	4161970	1387323.21	285.622	2.6
B	3	43257	1441904583.00	2.9686	2.6
Error	316	1534873	4857.19		
Error B	316	1534873	4857.19		

The result shows that the value of F greater than the value of F table at 0.1% level of significant and it conclude that the performance of lot sizing techniques are statistically significant affecting by the demand pattern and the lot sizing techniques. Even when the variance is analyse using 0.05% level of significant, the test is still significant.

To see the performance of the lot sizing techniques at different demand pattern we can use Table 1. The result shows that Silver Meal has the lowest relative bias for all type of demand pattern while Lot for Lot has the largest relative bias for all type of demand pattern. Therefore the Lot for Lot technique is not recommended to use. Although the algorithm is quite easy, the deviation of this technique is quite big and it will result big problem when the decision is implemented. The least unit cost is a good alternative for Silver Meal while Part Period Balancing is not recommended to use except when the demand pattern is uniform. In other word, when the demand pattern is uniform, we can use any algorithm except Lot for lot. When the demand use Silver Meal or Least on Unit Cost. When the demand pattern is cyclical, only Silver Meal is recommended,

To see whether the above recommendation is still applied at any situation, the experiment is implemented for another situation. The above experiment is done at the condition where the proportion of set up cost and carrying cost is very high. The ratios of carrying cost to set up cost is 1:75. Further experiment will run at smaller proportion of set up cost and carrying cost. We arbitrary set a set up cost at $250 and carrying cost is set at $8 with proportion of 1:30. Further experiment is only rerun for the first 10 data set generation.

The result oh the further experiment is slightly difference, The rank of the performance of lot sizing techniques are almost the same except for the Lot for Lot performance. Silver Meal still the best follows by Least Unit Cost and Part period balancing but in this case, the Lot For Lot technique is now can be used as long as the demand pattern is uniform. These result proves that the proportion of set up cost and carrying cost affects the performance of the lot size techniques.

6. CONCLUSION

The experiment concluded that the effect of the lot sizing techniques and the demand pattern into the performance are statistically significant. The Silver Meal is the best algorithm to define the lot size follows by Least Unit Cost. The lot for lot performance is very poor when the proportion of set up cost to carrying cost is very high while this algorithm is still work well in the case the proportion os carrying cost and set up cost is small.

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Appendix 1 Experiment Layout

Ex	Treatment Combination		Replication						Average relative bias
	Level A	Level B	1	2	....	......	19	20	
1	A_1	B_1	$RB_{LFL}SD_1$	$RB_{LFL}SD_2$			$RB_{LFL}SD_{19}$	$RB_{LFL}SD_{20}$	$RB_{LFL}SD$
2	A_1	B_2	$RB_{SM}SD_1$	$RB_{SM}SD_2$			$RB_{SM}SD_{19}$	$RB_{SM}SD_{20}$	$RB_{SM}SD$
3	A_1	B_3	$RB_{PPB}SD_1$	$RB_{PPB}SD_2$			$RB_{PPB}SD_{19}$	$RB_{PPB}SD_{20}$	$RB_{PPB}SD$
4	A_1	B_4	$RB_{LUC}SD_1$	$RB_{LUC}SD_2$			$RB_{LUC}SD_{19}$	$RB_{LUC}SD_{20}$	$RB_{LUC}SD$
5	A_2	B_1	$RB_{LF}LID_1$	$RB_{LF}LID_2$			$RB_{LF}LID_{19}$	$RB_{LF}LID_{20}$	$RB_{LF}LID$
6	A_2	B_2	$RB_{SM}ID_1$	$RB_{SM}ID_2$			$RB_{SM}ID_{19}$	$RB_{SM}ID_{20}$	$RB_{SM}ID$
7	A_2	B_3	$RB_{PPB}ID_1$	$RB_{PPB}ID_{12}$			$RB_{PPB}ID_{19}$	$RB_{PPB}ID_{20}$	$RB_{PPB}ID$
8	A_2	B_4	$RB_{LUC}ID_1$	$RB_{LUC}ID_2$			$RB_{LUC}ID_{19}$	$RB_{LUC}ID_{20}$	$RB_{LUC}ID$
9	A_3	B_1	$RB_{LFL}DD_1$	$RB_{LFL}DD_2$			$RB_{LFL}DD_{19}$	$RB_{LFL}DD_{20}$	$RB_{LFL}DD$
10	A_3	B_2	$RB_{SM}DD_1$	$RB_{SM}DD_2$			$RB_{SM}DD_{19}$	$RB_{SM}DD_{20}$	$RB_{SM}DD$
11	A_3	B_3	$RB_{PPB}DD_1$	$RB_{PPB}DD_2$			$RB_{PPB}DD_{19}$	$RB_{PPB}DD_{20}$	$RB_{PPB}DD$
12	A_3	B_4	$RB_{LUC}DD_1$	$RB_{LUC}DD_2$			$RB_{LUC}DD_{19}$	$RB_{LUC}DD_{20}$	$RB_{LUC}DD$
13	A_4	B_1	$RB_{LFL}CD_1$	$RB_{LFL}CD_2$			$RB_{LFL}CD_{19}$	$RB_{LFL}CD_{20}$	$RB_{LFL}CD$
14	A_4	B_2	$RB_{SM}CD_1$	$RB_{SM}CD_2$			$RB_{SM}CD_{19}$	$RB_{SM}CD_{20}$	$RB_{SM}CD$
15	A_4	B_3	$RB_{\mathbf{PP}}BCD_1$	$RB_{\mathbf{PP}}BCD_2$			$RB_{\mathbf{PPB}}CD_1$	$RB_{\mathbf{PPB}}CD_{20}$	$RB_{\mathbf{PPB}}CD$
16	A_4	B_4	$RB_{\mathbf{LUC}}CD_1$	$RB_{\mathbf{LUC}}CD_2$			$RB_{\mathbf{LUC}}CD_{19}$	$RB_{\mathbf{LUC}}CD_{20}$	$RB_{\mathbf{LUC}}CD$

Note that the abreviation used in the layout are RB for Relative bias follows with the abreviation ot the lot sizing techniques and its replication