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DETERMINING THE PARAMETERS OF PERIODIC OPTIONAL REPLENISHMENT MODEL WITH GENETIC ALGORITHM

İbrahim Zeki Akyurt[1], Timur Keskintürk[2] and Muhammed Vefa Arıkan[3]

Abstract - *Inventory management and its policies are key processes of supply chain management. In this paper, periodic optional replenishment model (R, s, S), and its parameters s (reorder point) and S (replenishment points) are studied. These parameters are calculated via a meta-heuristic genetic algorithm (GA). The model is applied to a raw material inventory of steal with real data of a company that produce espagnolette whose demand and lead time are random variable, where review period is constant and known. Results from computational experiments compared with the results which are calculated with simulation.*

Keywords: Genetic Algorithm, Inventory Policy, Optional Replenishment Model, (R, s, S).

INVENTORY CONTROL

Inventory control or management is one of the key proceses in supply chain management. A manufacturer company among the chain deals with purchasing raw-materials from various suppliers, holding these goods till they are inserted to the line according to the production plan and at last holding the finished goods for a certain period of time. When the manufacturer's functions in the chain is considered, the importance of the inventory management should be taken in to account. From the manufacturer's point of view, inventory can be considered as a raw-material for production, a partially finished item on the line, a finished good to be delivered and even a tool or a spare part for machines for maintenance[1]. The key variable in the problem is the outcome of the various directions of demand and supply for each product. As a result of different names given and different characteristics in each step, it is a must for the decission maker to consider the inventory control separetly in each of the production steps and develop policies. The decission maker focuses on to keep the minimum inventory on hand during the developing phase of these policies while dealing with any different inventory type. Consequently, keeping the minimum inventory on hand is the primary goal. Beside this, it is aimed to keep the inventory ordering and holding costs as low as possible. It is not enough to realize just these two conditon to design a good inventory policy. The number of items produced or purchased at the begining of each period should meet the demand of that period. Briefly, a good inventory management policy should focus on reducing the inventory related costs while redounding the customer service level. Also, low unit costs and high inventory turn over rates are sub-targets.

There are some factors effecting on the decission makers judge. These factors can be collected under four basic groups. These are demand, replenishment, lead time and cost factors.

Demand Factor: This is the key factor used for the differantiation of the inventory control models. If the demand rate is known and constant for every period than the inventory control model should be deterministic. Counterwise, if the demand rate is unknown and variable according to a known distribution thant the inventory model should be stochastic.

Replenishment Factor: In replenishment decision there are two decision criteria, quantity and time. Replenishment quantity is the amount item to be produced or purchased for each replenishment period, that can eighter be constant or variable.

Time criteria deals with the date of replenishmet whether to be done periodically or any time. For this reason the control period of the inventory is directly related with this criteria. For instance, replenishment under probabilistic demand: If the replenishment is done perodicaly, then inventory control model is based on fixed order interval model and the amount of item to be produced or puchased would change according to the needs. If the control is done continuosly, replenishment can be done anytime needed. Although the replenishment quantity is usually constant, sometimes it can also be variable because of the multi item orders.

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Lead Time Factor: Lead time is the amount of time beginning with the decision of replenishment till the point of time that the item is ready to be used. Lead time may be whether constant or variable. Like as in stochastic demand case; distribution of the lead time should be considered. Lead time is represented with L. **Cost Factor:** Cost entries are the key tools to develop optimum inventory policies.

The first cost entry is the unit cost. Although it is not usually directly considered in the inventory control model, it is important because of its role in calculation of the holding cost [2].

One another cost is the Set-Up cost (C_S) that is associated with establishing a new manufacturing procedure. Setup costs include design costs, acquisition and location of machinery, and employee hiring and training. It's also used as Order Cost which is consist of operational costs, such as; communication, documentation and sometimes agent expenses. Although set up cost is considered to be constant, some studies offers to divide in to two: constant set up costs and variable set up costs.

Holding cost (C_h) is money spent to keep and maintain a stock of goods in storage. It is represented as the price paid per unit for a unit period of time (day, week, year, ect.). The critical point in holding cost calculation is to decide the way to associate the cost with the inventory level. Because in some cases this cost is effected on maximum inventory level and in other cases it is applied over average inventory level.

Shortage or stockout cost (C_p) results when demand exceeds the supply of inventory on hand. This cost may consist in two ways and calculated differently. When a demand cannot be met then it may be backlogged and it does not dissolve till the next order it is met. Else it cannot be backlogged, so it can be met with an urgent order or it can be missed. In the first case the stockout cost consists of urgent order costs such as missed discounts or individual shipping. But in the second case of no-backlogging there is not only a loss in endorsement but also a loss in future sells because of injured customer goodwill [3]. Stockout cost represents the expected cost per unit. It can either be dependent to time or not. For instance, if being lack of inventory aborts the production line then it is dependent on time till the line becomes re-active and it is the cost of shortage per unit per unit time [4]. In this study stockout cost is going to be accepted as independent of time because the inventory entry on the case is a finished good.

Many inventory control models had been developed on the basis of the fundamental goals of inventory management, using the factors described above. When diversification is made with a demand oriented view; deterministic and stochastic inventory control models had been came out, according to the definiteness of demand.

Every inventory control model consists of policies dealing with the decision of "when to replenish" and "how many to purchase/produce". The aim of inventory management is to develop the suitable inventory control model for each item and determine the policies related. While the policies are determined, a mathematical model is structured according to the factors mentioned. By adopting all the costs to the model, an inventory control model with the minimum cost is achieved. The outcome of this model is the answers of "when to replenish" and "how many to purchase/produce". In order to determine these cost values various mathematical methods can be used.

OPTIONAL REPLENISHMENT MODEL (R, s, S)

In Stochastic (R, s, S) inventory policy inventory level is reviewed every R periods. But the decision to order is given according to a certain order point of inventory level determined previously. If the inventory level is lower than reorder point (s) an order is given to catch up the replenishment level (S), else order delays. So the order quantity is going to be calculated as in (1).

$$\begin{aligned} &Q = 0 && x_n + Q_0 > s \\ &Q = S - x_n - Q_0 && x_n + Q_0 \le s \end{aligned} \qquad (1)$$

In (1) x_n is the inventory on hand at the observation point and Q_0 is the level admired with the order given but not reached yet. The sum of this two parameter refers to inventory level. In this study, as a result of variable lead time; Q_0 only refers to the given orders expected to arrive that week.

In single item inventory systems, from the economical aspect of replenishment, order and stockout case, this method can be managed to be favorable in comparisson to other models under certain assumptions [5]. Consequently, many studies had been achieved in the last century and many are in progress.

The basis of (R, s, S) model depends on Arrow [6] and Karlin et al. [7]. But the optimization issue for finite periods is studied by Scarf [8], under specific assumptions. Scraf' s model is studied by Iglehart [9] for infinite periods under fixed demand and cost structure. Subsequent years, Veniott [10] and Porteus [11] had researches on this field. Federguen and Zheng [5] determined the calculation of the parameters with average cost per period for infinite periods, in case of discretely distributed demand for each period. Beside this there are some other heuristic methods. Robert [12], Sivazlian [13], Nador [14], Wagner [15], Ehrhardt [16]-[17] Freeland ve Porteus [18], Tijims ve Groenevelt [19], Bollapragad and Morton [20].

GENETIC ALGORITHM

Genetic Algorithm (GAs) is a population based optimization technique developed by Holland [21]-[22]. Vectors called Chromosome represents solution variables. This representation can not only be done with binary coding but with real values as well. With randomly selected values from the pre-determined value range an initial solution is generated. This group of solutions produced with the number of chromosomes (population size) is called Initial Population. Then evaluates the quality of each solution candidates according to the problem-specific fitness function. Fitness function in our model is considered as minimization of the total cost including holding cost, stockout cost and set-up cost.

New solution candidates are created by selecting relatively fit members of the population and recombining them through various operators: selection, crossover, mutation [23].

Selection: The purpose of parent selection in GA is to offer additional reproductive chances to those population members that are the fittest. One commonly used technique, the roulette-wheel-selection, is used for this proposed GA.

Crossover: The crossover is the most important operator for solution space search. It is the procedure of creating new chromosomes (individuals) with randomly selected genes from parent chromosomes. When the crossover operation is applied opposite sides of the pre-determined crossing point are switched across this point. There are various versions of crossover. In this paper, one-point crossover is used.

Mutation: Mutation plays secondary role in the operation of GA. "In artificial genetic systems the mutation operator protects against such an irrecoverable loss" [22]. The genes selected with a low probability (mutation rate) are switched randomly. In the study real-value coding is used. Depending on this a different mutation method is implemented, rather than conventional ones. The variable set for the mutation application is increased or decreased, with a step value 1 to 5.

The steps of GA are as follows:

Step 1. Generation of initial population
Step 2. Evaluation of each individual
Step 3. Selection
Step 4. Crossover
Step 5. Mutation
Step 6. If stopping criteria is not met return to Step 2
Step 7. Select the best individual as a final solution.

CALCULATION OF (R, s, S) INVENTORY CONTROL PARAMETERS USING GENETIC ALGORITHM

In application of the GA to the (R,s,S) model real-value coding is used. Chromosomes are consist of genes representing s and S. Data used in the case is gathered from the paper of Akyurt and Önder [24]. In the study involved, an "A type" inventory of refined steel in an espagnolette manufacturer was examined. And the re-order and replenishment points of this raw material were calculated via simulation. Demand fits to Beta (80, 118, 1,13, 1,07) and the lead time fits to uniform distribution between 1 to 4 weeks. Ordering cost is calculated as in (2).

$$C_s(Q)=\begin{cases}100+1*(Q), & Q>0\\ 0 & , Q\ 0\end{cases} \quad (2)$$

Holding cost is assumed to be 15% of the unit cost. Weekly holding cost is going to be calculated as in (3).

$$c=750\ pb$$

$$Ch=\frac{x_n+Q_0}{2}.(750*0,15)/52 \qquad x_n+Q_0>0 \quad (3)$$

$$Ch=0 \qquad x_n+Q_0\le 0$$

Stockout cost occurs in case of urgent orders when the order cannot be backlogged for a certain period of time. Stockout cost is calculated as in (4):

$$C_p=300 \quad D_n>x_n+Q_0 \quad (4)$$

Weekly average inventory cost is going to be as given in (5).

$$TC=[100+(Q)]+\left[\frac{x_n+Q_0}{2}.(750*0,15)/52\right]$$

or (5)

$$TC=[100+(Q)]+\left[\frac{x_n+Q_0}{2}.(750*0,15)/52\right]+300 \qquad D_n>x_n+Q_0$$

GA parameters used in calculation (R,s,S) model with genetic algorithm is given in Table 1:

TABLE 1
Parameters used in GA algorithm for (R,s,S) Model.

GA parameters	Value used in (R,s,S) model
Iteration	5000
Population size	20, 50, 100
Crossover rate	% 100
Mutation Rate	%1, % 10, %20

GA was run for 100 times and the averages of the results are presented in Table 2 and Table 3. Consistency of the results gathered for various production alternatives under beta distributed demand (between 80 and 118) and uniform distributed lead times was analyzed after 100 runs. The codes were generated with MATLAB 7.0 and the algorithm was run with an Intel(R) Core(TM)2 Duo CPU T6570, 3.0 GB Ram configured PC.

TABLE 2
GA results for various population sizes for the mutation rate of 0.2

	mean of s	mean of S	Annually mean of TC	Weekly mean of TC	mean of cpu
GA (ps:20)	17.31	116.34	16974	326.43	5.1772
GA (ps: 50)	11.7	113.98	16832	323.68	11.432
GA (ps: 100)	9.21	112.09	16692	320.99	22.902
Simulation*	10	120	17697	340.33	-

* In the study, inventory policy parameter values are varied with steps of 10.

TABLE 3

GA results for various mutation rates for the population size of 100

Mutation rate	mean of s	mean of S	Annually mean of TC	Weekly mean of TC	mean of cpu
.01	30.51	119.43	17088	328.62	23.158
.1	13.17	114.62	16809	323.24	23.483
.15	9.69	112.79	16714	321.43	23.282

Since better results had been reached when 0.2 of mutation rate and 100 of population size is used; s may be chosen approximately as 9 and S as 112. Even it is used with different parameters, GA produces similar results with similar accepable performance over time.

In Figure 1 the graph of a best result after iterations of one run over 100 is represented. Since, at the beginning GA works with randomly selected values, the results are not satisfactory. After the first iteration the rapid improvement in the result can be seen. Afterwards the slope softens and results become stable. In this case best results are observed between 1000 to 2000 iterations.

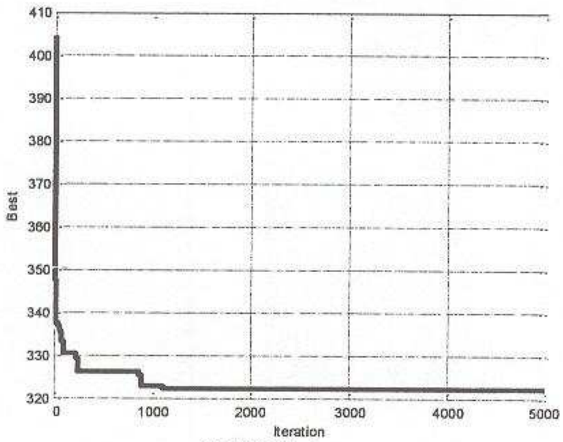

FIGURE. 1

Graph representing for the iteration best.

Figure 2 represents the average results gathered for every iteration for 100 runs when population size is 100 and mutation rate is 0,2.

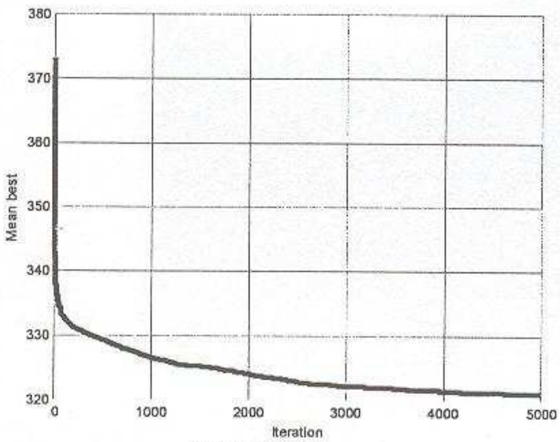

FIGURE. 2

Graph representing averages of 100 runs for the iteration best.

CONCLUSION

When the results are considered; GA can be accepted as a good alternative solution method for (R,s,S) model calculations. Especially when the GA results are compared to simulation results for determination of s and S, for demand structure under beta distribution and lead times under uniform distribution, calculation speed and effectiveness is highly attracting attention. Owing to flexibility of GA appropriate s and S values can be calculated in case of different demad structures and lead times. It can also be practised for other variables of the problem after certain modifications, such as R can be set as the variable.

Via various modifications in GA's structure and parameters the calculation time can be decreased and solution studies may be enlarged to a wider field as a result of R which has already been calculated. Besides ant colony optimization, is very popular and has succesfull applications in various fields recently, can also be applied on the solution phase of the problem.

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