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An Adaptive Genetic Algorithm to Optimize Two-echelon Automotive Spare Parts Inventory

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Abstract: This study considers multiple product suppliers, multiple regional distribution centers and multiple automotive 4S stores and implement the reorder point, order quantity (R, Q) inventory policy with the background of automobile companies based on a two-echelon non-repairable automotive service parts inventory system that consists of single center warehouse. A mathematical model with the objective of minimizing the total annual inventory investment subject to constraints on the average annual order frequency, expected number of backorders and budget is formulated. An adaptive genetic algorithm is used to solve the problem and a numerical example was given to show that the algorithm is effective.

Key words: Two-echelon inventory; the adaptive genetic algorithm; spare parts

INTRODUCTION

After-sales service of Automobile products is an important part of the automotive company services. After-sales service requires a wide range of spare parts which need costs more and more to be purchased and stored, then it takes a lot liquidity to store and it is difficult to respond quickly to the customer varied demand which is stored too little. Therefore, effective management of service parts inventory is to do an important guarantee of after-sales service. At present, the study on automotive spare parts inventory are mainly concentrated in the classification, demand forecasting, inventory control strategies, but less for multi-echelon inventory of spare parts.

Caglar *et al*. (2004) and Axsater (2005) investigated a two-echelon, multi-item spare parts inventory system and presented a mathematical model with the objective of minimizing the inventory cost subject to constraint on response time. The model focus on high-cost, low demand repairable service parts. Al-Rifai and Rossetti (2007) investigated a two-echelon inventory system for non-repairable items and presented the model the objective of minimizing the total annual inventory subject to constraint on average annual order frequency and expected number of backorder. They developed an iterative heuristic optimization algorithm to solve the model. Wang *et al*. (2007) formulate a mathematical model on multi-echelon inventory system and An optimal solution based on simulation was proposed to the model. Han *et al*. (2007) investigated the newsboy model of spare parts. They calculate the optimal storage of spare parts, but the requirements are assumed the uniform distribution which does not match with the actual demand. Haji *et al*. (2009) considered a two-echelon inventory system consisting of one warehouse and multiple retailers. Each retailer which applies a new policy constantly places an order for one unit of product to the central warehouse in a pre-determined time interval. The most important advantage of this policy is that the warehouse is facing a uniform and deterministic demand originated by each retailer. Pasandideh *et al*. (2001) improve the model which is formulated by Al-Rifai and Rossetti (2007). The objective function of the model is minimizing the total annual inventory. Central warehouse and retailers respective budget constraints are added. An improved genetic algorithm is used to solve the problem.

Through the present study, the inventory optimization model is built, inventory costs are reduced and corporate profits is increased for the characteristics of spare parts. But it also has some limitation, Firstly, there is no specific consideration of the complexity of multiple regional distribution centers and multiple automotive 4S stores, it is difficult to applications in the field of professional automotive spare parts. Secondly, an iterative heuristic optimization algorithm is used to solve the problem in Al-Rifai and Rossetti (2007). This algorithm has more complex steps and it is difficult to use in the actual situation. The genetic algorithm tends to produce premature convergence, poor stability, easy to be trapped into a local optimum and slow convergent speed in Pasandideh *et al*. (2001).

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In this study, According to the characteristics of spare parts and considering multiple product suppliers, multiple regional distribution centers and multiple automotive 4S stores, a mathematical model with the objective of minimizing the total annual inventory investment subject to constraints on the average annual order frequency, expected number of backorders and budget is formulated. Adaptive genetic algorithm has better global search ability and steadiness and can be avoided falling in local optimum in Kan (2012). An adaptive genetic algorithm is used to solve the optimal order quantity and order point of 4S stores and regional distribution centers.

TWO-ECHELON INVENTORY OPTIMIZATION MODEL OF AUTOMOTIVE SERVICE PARTS

Physics model: A two-echelon inventory system consisting of one product supplier, one warehouse and multiple retailers are investigated in Al-Rifai and Rossetti (2007) and Pasandideh *et al.* (2001).

According to the characteristics of automotive spare parts and the actual situation of the automotive company, a two-echelon inventory physics model consisting of multiple product suppliers, multiple warehouses and multiple 4S stores is built. Figure 1 provides a pictorial representation of the system. A specific description of the problem as follows.

This study assumes that an automobile manufacturing enterprise has s suppliers which its capacity of supply is unlimited and the enterprise has n different regional distribution centers which provide service parts to m same 4S stores. The demand for service parts of 4S stores obey Poisson distribution and the demand of the regional distribution centers is determined according to the demand of the 4S stores, so the demand of each regional distribution center is the sum of the 4S stores' orders (Svoronos and Zipkin, 1988)?

The assumptions of the model:

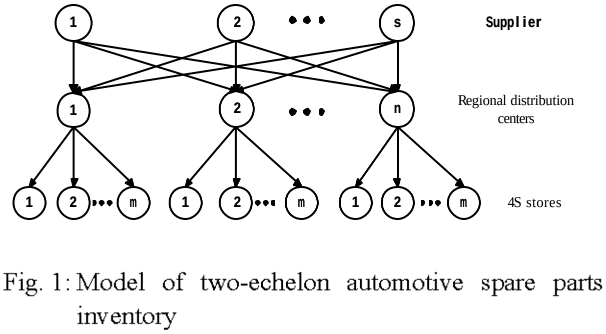

Fig. 1: Model of two-echelon automotive spare parts inventory

- The ordering lead time of the regional distribution centers and automotive 4S stores is fixed
- The capabilities of suppliers is unlimited
- The inventory strategy of the regional distribution centers and automotive 4S stores is (Q, R) ordering policy. It means that as soon as the stock level declines to the reorder point R, an order of batch size Q is placed
- Shortages are allowed at the regional distribution centers and automotive 4S stores
- Average annual ordering frequency at the regional distribution centers and automotive 4S stores are limited
- Expected number of backorder at the regional distribution centers and automotive 4S stores are limited
- The regional distribution centers budget and automotive 4S stores budget are limited

Construction of mathematic model: Symbol definitions:

h = No. of inventory items
m = No. of automotive 4S stores which is serviced by regional distribution center
n = Number of regional distribution centers
k = An index for the items where k = 1,…..., h
i = An index for the a utomotive 4S stores where i = 1,…..., m
j = An index for regional distribution centers where i = 1,…,n
C_k = Unit cost of the item (yuan)
λ_{ijk} = Demand rate of the kth item at the ith automotive 4S stores which are serviced by the jth regional distribution center (unit year^{-1})
λ_{jk} = Demand rate of the kth item at the jth regional distribution center (in units of Q_{ijk})
N_{ijk} = Average ordering frequency the kth item at the ith automotive 4S stores which are serviced by the jth regional distribution center (orders year^{-1})
N_{ij} = Target order frequency at the ith automotive 4S stores which are serviced by the jth regional distribution center (orders year^{-1})
N_{jk} = Average ordering frequency the kth item at the jth regional distribution center (orders year^{-1})
N_j = Target order frequency at the jth regional distribution center (orders year^{-}1)
I_{jk} = On-hand inventory at the jth regional distribution center for item k (in units of Q_{ijk})
I_{ijk} = On-hand inventory at the ith automotive 4S stores which are serviced by the jth regional distribution center for item k

Q_{ijk} = Batch size of the ith automotive 4S stores which are serviced by the jth regional distribution center for item k (random variable)

Q_{jk} = Batch size of the jth regional distribution center for item k (random variable)

R_{ijk} = Reorder point of the ith automotive 4S stores which are serviced by the jth regional distribution center for item k (random variable)

R_{jk} = Reorder point of the jth regional distribution center for item k (random variable)

L_{ijk} = Lead time at the ith automotive 4S stores which are serviced by the jth regional distribution center for item k (years)

L_{jk} = Lead time at the jth regional distribution center for item k (years)

D_{ijk} = Lead time demand at the ith automotive 4S stores which are serviced by the jth regional distribution center item k

D_{jk} = Lead time demand at the jth regional distribution center for item k

B_{ij} = Target number of backorder at the ith automotive 4S stores which are serviced by the jth regional distribution center

B_j = Target number of backorder at the jth regional distribution center

$MaxC_{ij}$ = Available budget of the ith automotive 4S stores which are serviced by the jth regional distribution center for all items

$MaxC_j$ = Available budget of the jth regional distribution center for all items

The mathematical model of the two-echelon non-repairable automotive service parts inventory cost is building by above symbols. The objective of minimizing the total annual inventory cost contains the automotive 4S stores and the regional distribution centers ordering cost and subject to constraints on the average annual order frequency, expected number of backorders and budget is formulated.

First of all, item k's order frequency at the ith automotive 4S stores which are serviced by the jth regional distribution center is:

$$N_{ijk} = \frac{\lambda_{ijk}}{Q_{ijk}} \tag{1}$$

Demand rate of the kth item at the jth regional distribution center using Eq. 1 is:

$$\lambda_{jk} = mN_{ijk} = \frac{m\lambda_{ijk}}{Q_{ijk}} \tag{2}$$

The demand for service parts of 4S stores obey Poisson distribution, so lead time demand mean and variance of the 4S stores which are serviced by the jth regional distribution center is:

$$E[D_{ijk}] = V[D_{ijk}] = \lambda_{ijk} L_{ijk} \tag{3}$$

The lead time demand mean and variance of the jth regional distribution center is:

$$E[D_{jk}] = \frac{m\lambda_{ijk} L_{ijk}}{Q_{ijk}} \tag{4}$$

$$V[D_{jk}] = \frac{m\lambda_{ijk} L_{jk}}{Q_{ik}{}^2} + \frac{m}{Q_{ik}{}^2} \sum_{p=1}^{Q_{ik}-1} \frac{1-\exp(-\alpha_p \lambda_{ijk} L_{jk}) \cos(\beta_p \lambda_{ijk} L_{jk})}{\alpha_p} \tag{5}$$

where, $\alpha_p = 1-\cos(2\pi p / Q_{ijk})$, $\beta_p = \sin(2\pi p / Q_{ijk})$.

Expected number of backorders at the 4S stores and the regional distribution center is (Hopp and Spearman, 2001):

$$E[B_k(R_k, Q_k)] = \frac{1}{Q_k}[\beta(R_k) - \beta(R_k + Q_k)] \tag{6}$$

Where:

$$\beta(x) = \frac{\sigma^2}{2}((z^2+1)[1-\Phi(z)] - z\phi(z))$$

$$z = \frac{x-\theta}{\sigma}$$

$\Phi(x)$ and $\phi(x)$ are the pdf and cdf of the standard normal distribution function; θ and σ are the mean and standard deviation of the demand during replenishment lead time, respectively.

Under an (Q, R) policy, item *k*'s expected On-hand inventory is:

$$E[I_k(R_k, Q_k)] = E[B_k(R_k, Q_k)] + R_k + \frac{Q_k+1}{2} - E(D_k) \tag{7}$$

Item k's expected On-hand inventory at the jth regional distribution center using Eq. 3, 6 and 7 is:

$$E[I_{jk}(R_{jk}, Q_{jk})] = E[B_{jk}(R_{jk}, Q_{jk})] + R_{jk} + \frac{Q_{jk}+1}{2} - E(D_{jk}) \tag{8}$$

Item k's expected On-hand inventory at the ith automotive 4S stores which are serviced by the jth regional distribution center using Eq. 4, 6 and 7 is:

$$E[I_{ijk}(R_{ijk},Q_{ijk})]=E[B_{ijk}(R_{ijk},Q_{ijk})]+R_{ijk}+\frac{Q_{ijk}+1}{2}-E(D_{ijk}) \quad (9)$$

Inventory cost of non-repairable automotive service parts using Eq. 8-9 is:

$$\min TC=\sum_{j=1}^{n}\sum_{k=1}^{h}C_kQ_{ijk}E[I_{jk}(R_{jk},Q_{jk})]+\sum_{j=1}^{n}(m\sum_{k=1}^{h}C_kE[I_{ijk}(R_{ijk},Q_{ijk})]) \quad (10)$$

Subject to:

$$\frac{1}{h}\sum_{k=1}^{h}\frac{\lambda_{jk}}{Q_{jk}}\le N_j \quad (11)$$

$$\frac{1}{h}\sum_{k=1}^{h}\frac{\lambda_{ijk}}{Q_{ijk}}\le N_{ij} \quad (12)$$

$$\sum_{k=1}^{h}E[B_{jk}(R_{jk},Q_{jk})]\le B_j \quad (13)$$

$$\sum_{k=1}^{h}E[B_{ijk}(R_{ijk},Q_{ijk})]\le B_{ij} \quad (14)$$

$$\sum_{k=1}^{h}C_kQ_{jk}Q_{ijk}\le MaxC_j \quad (15)$$

$$m\sum_{k=1}^{h}C_kQ_{ijk}\le MaxC_{ij} \quad (16)$$

Constraint 11 assures that average order frequencies at the regional distribution centers are not greater than the target order frequencies using Eq. 2. Constraint 12 assures that average order frequencies at the automotive 4S stores which are serviced by the jth regional distribution center are not greater than the target order frequencies. Constraint 13 assures that expected number of backorders at the regional distribution centers is not greater than the target number of backorder using Eq. 6. Constraint 14 assures that expected number of backorders at the automotive 4S stores which are serviced by the jth regional distribution center is not greater than the target number of backorder using Eq.6. Constraint 15 assures that total purchase at the regional distribution centers is not greater than the available budget. Constraint 16 assures that total purchase at the automotive 4S stores which are serviced by the jth regional distribution center is not greater than the available budget.

SOLUTION OF THE MODEL

This study establishes the mathematical model of two-echelon non-repairable automotive service parts inventory which its objective is minimizing the inventory cost. We solve the optimal order quantity and order point of the regional distribution centers and 4S stores in the model using the adaptive genetic algorithm. When we solve the model, the design of the chromosome coding, the initial population, the crossover operator and the mutation operator are included.

Adaptive genetic algorithm:

Step 1: **Preparation:** Decision variable and restrictive conditions are confirmed.

Reorder quantity and reorder point variable of the regional distribution centers as follows:

$$Q_{jk}=\begin{pmatrix}Q_{11} & Q_{12}\cdots & Q_{1k}\\ Q_{21} & Q_{22}\cdots & Q_{2k}\\ Q_{31} & Q_{32}\cdots & Q_{3k}\end{pmatrix}$$

$$R_{jk}=\begin{pmatrix}R_{11} & R_{12}\cdots & R_{1k}\\ R_{21} & R_{22}\cdots & R_{2k}\\ R_{31} & R_{32}\cdots & R_{3k}\end{pmatrix}$$

Reorder quantity and reorder point variable of the automotive 4S stores as follows:

$$Q_{ijk}=\begin{pmatrix}Q_{i11} & Q_{i12}\cdots & Q_{i1k}\\ Q_{i21} & Q_{i22}\cdots & Q_{i2k}\\ Q_{i31} & Q_{i32}\cdots & Q_{i3k}\end{pmatrix}$$

$$R_{ijk}=\begin{pmatrix}R_{i11} & R_{i12}\cdots & R_{i1k}\\ R_{i21} & R_{i22}\cdots & R_{i2k}\\ R_{i31} & R_{i32}\cdots & R_{i3k}\end{pmatrix}$$

Constraint conditions have been given in Eq. 11-16. Population is produced by binary coding.

Initialization parameters: Population size is denoted by NIND, the max number of generations is denoted by MAXGEN and the generation gap is denoted by GGAP.

Step 2: **Production of initial population:** The initial population formed by random NIND individuals in the feasible region

Step 3: **Selection:** Parents are selected using roulette-wheel according to the fitness function of the individual. Selecting NIND times, copy NIND individuals

Step 4: **Crossover and mutation:** Crossover and mutation probability in the basic genetic algorithm are a fixed parameter, but adaptive genetic algorithm is to adaptively adjust the crossover and mutation probability, so that each individual fitness size can select a different crossover and mutation probability. The crossover and mutation probability, respectively, as follows:

$$p_c = \begin{cases} p_{c1} - \dfrac{(p_{c1} - p_{c2})(f' - \bar{f})}{f_{max} - \bar{f}}, f' \geq \bar{f} \\ p_{c1}, f' \geq \bar{f} \end{cases} \tag{17}$$

$$p_m = \begin{cases} p_{m1} - \dfrac{(p_{m1} - p_{m2})(f - \bar{f})}{f_{max} - \bar{f}}, f \geq \bar{f} \\ p_{m1}, f \geq \bar{f} \end{cases} \tag{18}$$

Crossover operator control parameters are denoted by P_{c1} and P_{c2}. Mutation operator control parameters are denoted by P_{m1} and P_{m2}.the maximum of the Fitness function is denoted by f_{max}. The average value of the Fitness function is denoted by $\bar{f}$. The values of the individuals fitness function is denoted by f. The larger value of the Fitness function in crossing individuals is denoted by f'.

The individual is retained if its fitness value is equal to the maximum fitness value, otherwise calculating the crossover and the mutation probability by the above formula, cross-operating and mutation-operating.

Step 5: Determine the termination condition: If it does not reach the max number of generations, go to Step 3, or output variables and function value

CASE ANALYSIS

The car company contains three regional distribution centers which service four automotive 4S stores and orders six kinds of spare parts (Table 1-3). Demand rate and lead time at the automotive 4S stores,lead time at the regional distribution centers and the price of spare parts as follows. Order frequency at each 4S stores and regional distribution centers are $N_{ij} = 12$ and $N_j = 20$, respectively. Number of backorder at each 4S stores and regional distribution centers are $B_{ij} = 4$ and $B_j = 8$. Available budget at each 4S stores and regional distribution centers are $MaxC_{ij} = 60000$ and $MaxC_j = 800000$. the optimal order quantity and reorder point of the 4S stores and regional distribution centers is solved using adaptive genetic algorithm.

Solution by adaptive genetic algorithm: Reorder quantity and reorder point variable of the regional distribution centers and 4S stores as follows:

$$Q_{jk} = \begin{pmatrix} Q_{11} & Q_{12} \cdots & Q_{16} \\ Q_{21} & Q_{22} \cdots & Q_{26} \\ Q_{31} & Q_{32} \cdots & Q_{36} \end{pmatrix} R_{jk} = \begin{pmatrix} R_{11} & R_{12} \cdots & R_{16} \\ R_{21} & R_{22} \cdots & R_{26} \\ R_{31} & R_{32} \cdots & R_{36} \end{pmatrix}$$

Table 1 Regional distribution center 1 and its serviced 4S stores

Spare parts	λ_{ijk}	L_{ijk}	L_{jk}	C_k
Tire	20	0.21	0.10	230
Condenser	14	0.10	0.08	334
Battery jar	40	0.24	0.10	300
Headlight	60	0.30	0.08	265
Bumper	30	0.50	0.05	214
Glass	15	0.56	0.08	370

Table 2: Regional distribution center 2 and its serviced 4S stores

Spare parts	λ_{ijk}	L_{ijk}	L_{jk}	C_k
Tire	28	0.26	0.10	230
Condenser	25	0.11	0.10	334
battery jar	45	0.21	0.08	300
Headlight	70	0.40	0.07	265
Bumper	35	0.48	0.05	214
Glass	25	0.50	0.08	370

Table 3: Regional distribution center 3 and its serviced 4S stores

Spare parts	λ_{ijk}	L_{ijk}	L_{jk}	C_k
Tire	18	0.20	0.10	230
Condenser	20	0.14	0.09	334
Battery jar	38	0.25	0.09	300
Headlight	55	0.40	0.07	265
Bumper	30	0.45	0.06	214
Glass	18	0.48	0.07	370

$$Q_{ijk} = \begin{pmatrix} Q_{i11} & Q_{i12} \cdots & Q_{i16} \\ Q_{i21} & Q_{i22} \cdots & Q_{i26} \\ Q_{i31} & Q_{i32} \cdots & Q_{i36} \end{pmatrix} R_{ijk} = \begin{pmatrix} R_{i11} & R_{i12} \cdots & R_{i16} \\ R_{i21} & R_{i22} \cdots & R_{i26} \\ R_{i31} & R_{i32} \cdots & R_{i36} \end{pmatrix}$$

Constraint conditions have been given in Eq. 11-16. Parameters are initialized. Population size is10, the max number of generations is 200 and the generation gap is 0.3. Selecting 10 times and copying 10 individuals according to the fitness function of the individual. Crossover operator control parameter $P_{c1}$is 0.9 and P_{c2} is 0.6. Mutation operator control parameter P_{m1} is 0.03 and P_{m2} is 0.001. The crossover and the mutation probability are calculated using Eq. 17-18. If the max number of generations does not reach 200, go to step 3, or output variables and function value.

Calculation results: Reorder quantity and reorder point values of the regional distribution centers as follows:

$$Q_{jk} = \begin{pmatrix} 10 & 8 & 12 & 14 & 10 & 11 \\ 18 & 12 & 16 & 15 & 12 & 13 \\ 9 & 13 & 9 & 9 & 13 & 11 \end{pmatrix} R_{jk} = \begin{pmatrix} 2 & 4 & 5 & 2 & 1 & 2 \\ 3 & 5 & 2 & 4 & 2 & 2 \\ 1 & 1 & 2 & 2 & 3 & 1 \end{pmatrix}$$

Reorder quantity and reorder point values of the automotive 4S stores as follows:

$$Q_{ijk} = \begin{pmatrix} 10 & 5 & 10 & 8 & 10 & 14 \\ 11 & 9 & 8 & 6 & 6 & 10 \\ 10 & 6 & 8 & 6 & 9 & 10 \end{pmatrix} R_{ijk} = \begin{pmatrix} 0 & 3 & 2 & 1 & 3 & 2 \\ 3 & 2 & 2 & 4 & 3 & 0 \\ 1 & 3 & 0 & 3 & 2 & 2 \end{pmatrix}$$

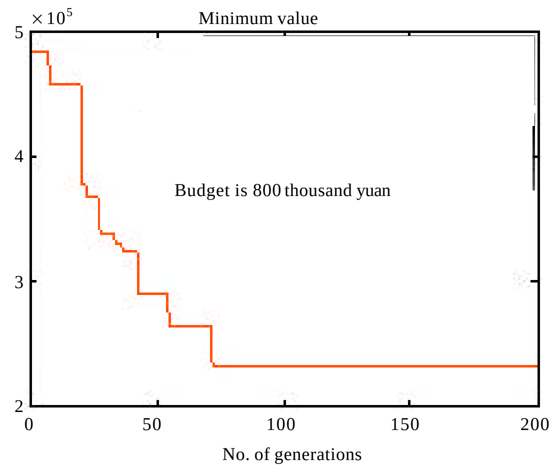

Fig. 2: Total inventory cost of regional distribution centers with 800000 budget

The total inventory cost is 2.3223×10^5. The experimental result is displayed by Fig. 2.

When the number of generations reaches 70, it searches the optimal solution.

Results analysis: This study expands to the secondary inventory system which has more 4S stores and more regional distribution centers based on the secondary inventory system in literature Mohammad H. Al-Rifai and Rossetti (2007) and Pasandideh *et al*. (2001), solves the order quantity and order point of the regional distribution centers and 4S stores. The present order quantity is compared with the original order quantity in Table 4 and the spare parts in 4S stores are ordered from the regional distribution center, so this study only calculates the order quantity in regional distribution centers. The present order quantity reduces based on the minimum inventory cost. The present inventory cost is compared with the original inventory cost in Table 5; the total inventory cost is the sum of the costs which the company orders six kinds of spare parts and the total inventory cost decrease obviously in the contrast with original total inventory cost.

When the annual budget of the 4S stores is not changed, the initial value of the annual budget in the regional distribution center takes 600 thousand Yuan, the length of the step δ = 100000 and the value of other parameters remain unchanged, the value of the objective function decreases with the increasing of the genetic algebra by many experiments and at last the result is stable. When the annual budget of the regional distribution is 600 thousand Yuan, the cost is 322 thousand Yuan, such as Fig. 3, the value of the annual inventory cost reduces relatively with the increasing of the annual budget, such as Fig. 4, 2 and 5, when the budget is 1 million Yuan, the annual inventory cost can reduce to 192 thousand Yuan, such as Fig. 6. The curve which the inventory cost changes accordingly with the change of the annual budget in the regional distribution center is shown in Fig. 7, and the abscissa is the annual budget of the distribution center, the value is 600 thousand Yuan, 700 thousand Yuan, 800 thousand Yuan, 900 thousand Yuan, 1 million Yuan, the cost reduce fast when the value of the regional distribution center is 600 thousand Yuan between 800 thousand Yuan in the figure,

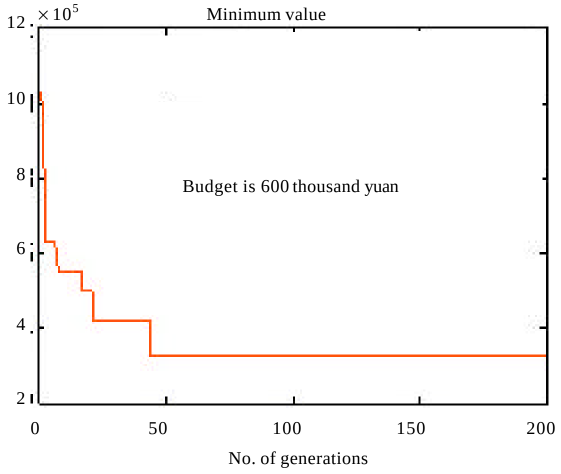

Fig. 3: Total cost of regional distribution centers with 600000 budget

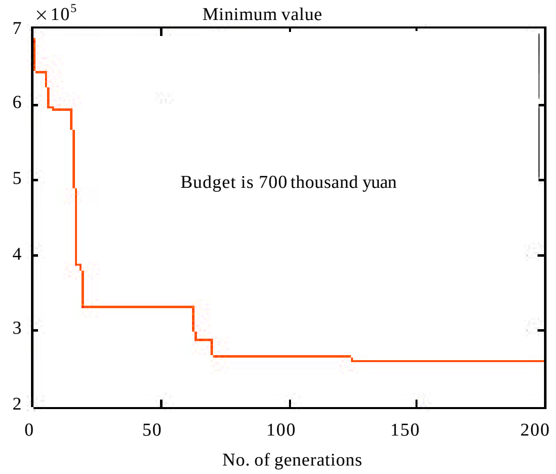

Fig. 4: Total cost of regional distribution centers with 700000 budget

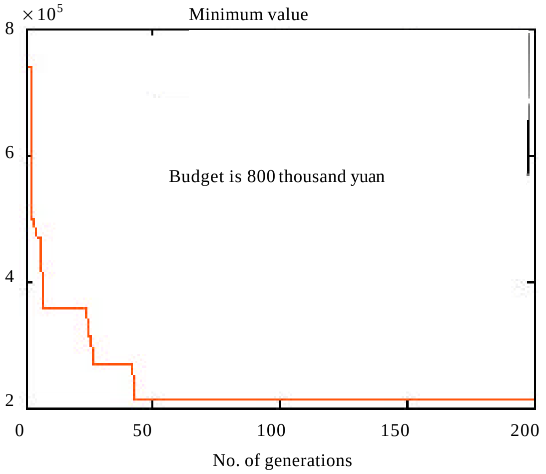

Fig. 5: Total cost of regional distribution centers with 900000 budget

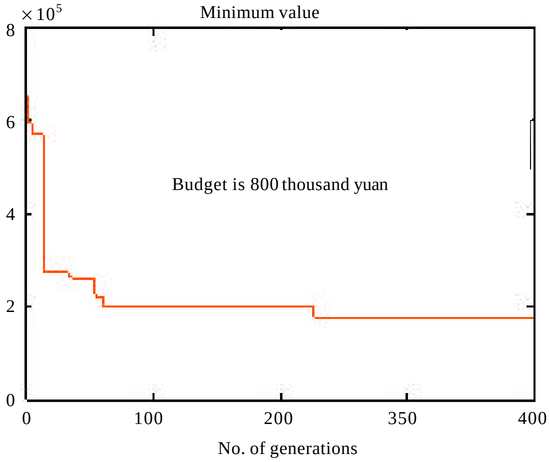

Fig. 6: Total cost of regional distribution centers with 1000000 budget

Table 4: Comparing between original order quantity and present order quantity

Spare parts	Original order quantity	Present order quantity	Reduce (%)
Tire	400	388	3.0
Condenser	250	226	9.6
Battery jar	350	320	8.5
Headlight	280	256	8.4
Bumper	300	289	3.7
Glass	400	394	1.5

Table 5: Comparing between original total inventory cost and present total inventory cost

Original total inventory cost	248000
Present total inventory cost	232230
Reduce (%)	6.36

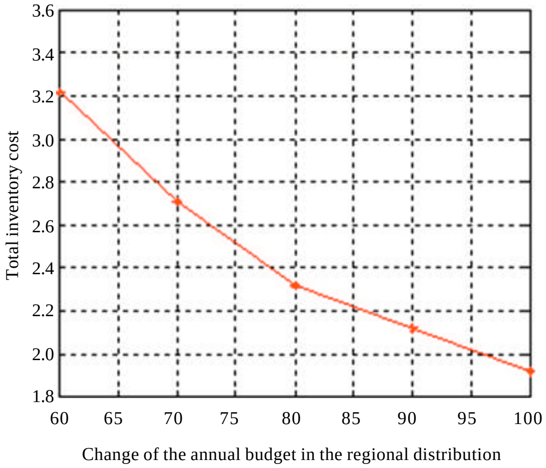

Fig. 7: Changes in inventory cost

the cost reduce slowly when the value of the regional distribution center is 800 thousand Yuan between 1 million Yuan.

CONCLUSION

This study considers multiple regional distribution centers, multiple automotive 4S stores and the characteristics that the need of the service parts is uncertainty with the background of automobile company based on a two-echelon non-repairable automotive service parts inventory system that consists of single center warehouse, a mathematical model with the objective of minimizing the total annual inventory cost of the service parts with the constraints on the annual budget, the annual order number and the expected number of backorders is formulated, the model is a two-echelon inventory with multiple regional distribution centers and multiple 4 sec stores and it is similar with the practical non-repairable automotive service parts inventory system. An adaptive genetic algorithm is used to solve the problem, the algorithm adjusts the crossover probability and mutation probability and then it solves the problem effectively. A practical number example is designed to verify the validity of the two-echelon inventory model of non-repairable automotive service parts, the number example shows that the model can reduce parts of the inventory cost and when the annual budget of the regional distribution center increases, the inventory cost reduce correspondingly, when the budget increase to 800 thousand Yuan, the speed which the inventory cost reduce slow down. This study considers that the regional distribution center service the same 4S stores, so the research direction is that the regional distribution centers serve the different 4S stores and the multiple-echelon inventory consist of the order of the supplies also is the research direction.

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