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Research Article

Location Model and Optimization of Seaborne Petroleum Logistics Distribution Center Based on Genetic Algorithm

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Abstract: The network of Chinese Waterborne Petroleum Logistics (CWPL) is so complex that reasonably disposing and choosing Chinese Waterborne Petroleum Logistics Distribution Center (CWPLDC) take on the important theory value and the practical significance. In the study, the network construct of CWPL distribution is provided and the corresponding mathematical model for locating CWPLDC is established, which is a nonlinear mixed interger model. In view of the nonlinerar programming characteristic of model, the genetic algorithm as the solution strategy is put forward here, the strategies of hybrid coding, constraint elimination , fitness function and genetic operator are given followed the algorithm. The result indicates that this model is effective and reliable. This method could also be applicable for other types of large-scale logistics distribution center optimization.

Keywords: Distribution center, genetic algorithm, locating, optimization, waterborne petroleum logistics

INTRODUCTION

Logistics Distribution Center is the node in the multi-stage supply chain, the effectiveness of whose operation directly relates to that of the entire supply chain operation. With rapid developing of Chinese economy, the demand for petroleum is growing quickly. At present China has already become the second biggest petroleum consuming country in the world, only next to US. At the same time, Chinese crude oil output actually did stagger in recent years, which causing the massive import of petroleum. The related statistical data demonstrates that Chinese import of crude oil has reached as high as 239.3million tons, the net import of the crude oil and the refined oil has achieved 253.6 million tons (Tian, 2011). The petroleum as one of the largest water-transported materials has the huge logistics network, the various materials, the complex transportation and other characteristic. With the notion of logistics more and more popular, requests us to study, plan and construct Chinese international and domestic waterborne petroleum logistics and distribution transportation network system according to the idea of system engineering. The distribution function of CWPL mainly depends on all kinds of the large-scale petroleum seaports. The seaport as an extremely important node in the international logistics network, acts an important role in Chinese Waterborne Petroleum Logistics Distribution System (CWPLDS). Therefore, it has the important strategic sense to research CWPLDS reasonable layout problem in order to speed up construction of the port petroleum logistic distribution system.

STRUCTURE OF CWPLDC AND SHIP TYPE OPTIMIZATION

About general logistics location questions, both domestic and foreign scholars have done much research (Liu *et al*., 2000; Melkote and Daskin, 2001; Mesa and Boffey, 1996; Huangy, 1997; Cooper, 1963; Sa, 1969), but few concerns the research of the petroleum logistics system. CWPLDS consists of the foreign trade import and export petroleum logistics distribution system and the domestic trade transport petroleum logistics distribution system. Considering the different characteristic of the crude oil and the refined oil and the conveyance means. This study mainly deals with the crude oil distribution system as the sample to realize the optimization and unify the domestic trade and the foreign trade to research. With the continuous development of Chinese economy will cause Chinese petroleum supply and demand gap more and more obvious. Depending upon the import in a large degree will be a long-term tendency. In addition, China still has the crude oils export quantity of near 7 million tons per year in order to satisfy the export quantity demand in the inter-governmental long-term contracts. More than 90% of Chinese petroleum import and export quantity was shipped by sea, mostly from the Middle East, the West Africa and other long-distance sea routes. The broad sea routes coverage and congestion of the seaports constitutes the complex international waterborne petroleum logistics network. Moreover,

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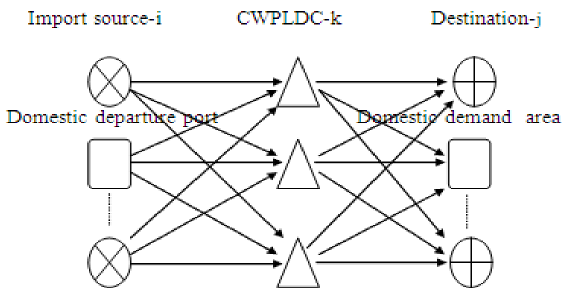

Fig. 1: Chinese waterborne petroleum logistics distribution system network

Chinese land oil resources mainly distributed in northeast, south china and northwest areas, but the petroleum chemical industries are mostly located in the eastern seaboard. Chinese crude oil is shipped by the pipeline from the oil field, 40% of which needs to be shipped by the waterway to the petrochemical plant located in the seaboard or along the river. Therefore the domestic productive forces layout and the oil resources distribution imbalanced have also caused the long-term historical pattern that the oil is transported from the north to the south, thus set up the domestic seaboard waterborne petroleum logistics. The oil network combined with foreign trade and domestic trade are intricate as shown in Fig. 1.

CWPLDS is composed of complex shipping line network, whose transport distance is very large. It is firstly necessary to optimize the vessel type for each line network and calculate the transport operating data of all kinds of vessel types. In the past we had already did much work in this area. The literature (Xie *et al*., 2001) introduces a set of optimization method for the oil tanker's main key factors and set up the mathematical models. The Request Freight Rate (RFR) is used as the index to collect the statistics and compare the actual ship data of 173 crude oil tankers, built in 1990s and whose capacity are above 30,000 tons. The calculated result shows that the RFR of SUEZMAX, AFRAMAX is far higher than that of VLCC under the same line of the Middle East-China (pass through the Malacca channel, transport distance is about 6000n mile). In other words, the unit transportation cost difference between the big ship and the small ship was extremely large. The West Africa-China lines belong to the long-distance lines (transport distance is above 10000 n miles). With the increase of the export petroleum quantity in West Africa Area, the harbor construction also was developed continuously. The situation of limiting VLCC business transport was improved, therefore both of VLCC and SUEZMAX business transport are workable here. The Southeast Asia-China lines belong to the short distance lines (line mileage is about 2000 n mile), Generally AFRAMAX and PANAMAX oil tanker should be used to transport the crude oil. For the domestic petroleum transport along sea, mostly PANAMAX and HANDY are used to transport crude oil.

CWPLDC LOCATION MODEL

Basic assumption:

- For the study emphasis on the waterborne petroleum logistics, we will not concern the influence of other transportation ways such as the pipeline, land transportation etc.
- The supply source which is composed of the aboard import source and inland petroleum amount to m, Candidate place of distribution centre amount to p, The domestic petroleum demand and the overseas destination amount to n.
- The freight of the supply source and the demand source to the petroleum logistics center depends on the length of route course and ship type choice, which is partition function.
- Unit handling cost for the petroleum is a concave function of petroleum flux, that is V^{θ}_{k}, $\theta \in (0,1)$
- There is no restriction for the throughput capacity of CPLDC.

Mathematical models:
Objective function:

$$\min F = \sum_{i=1}^{m}\sum_{k=1}^{p} C_{ik} X_{ik} + \sum_{k=1}^{p}\sum_{j=1}^{n} C_{kj} Y_{kj} + \sum_{k=1}^{p} W_k F_k + \sum_{k=1}^{p} W_k C_k V_k^{\theta} \quad (1)$$

In the formula above: X_{ik}-oil quantity of supply source i to distribution center k; C_{ik}-unit oil freight of supply source i to distribution center k; C_{kj}-unit oil freight of distribution center k to demand place j; Y_{kj}-oil quantity of distribution center k to demand place j; F_k-fundamental investment of distribution center k ; W_k-decision variable of alternative distribution center is selected or not; C_k-the handling cost of distribution k to deal with unit oil; V_k-the flux of distribution center.

Restricted conditions: The assignment quantity of each supply source is A_i:

$$\sum_{k=1}^{p} X_{ik} \le A_i \qquad i = 1,2,\cdots m \quad (2)$$

The assignment quantity of each requirement source is B_j:

$$\sum_{k=1}^{p} Y_{kj} \ge B_j \qquad j = 1,2,\cdots,n \quad (3)$$

$$\sum_{i=1}^{m} X_{ik} = \sum_{j=1}^{n} Y_{kj} \qquad k = 1,2\cdots, p \quad (4)$$

$$\sum_{i=1}^{m} X_{ik} - MW_k \le 0 \quad (5)$$

$$W_k = \begin{cases} 1 & k \quad is \quad selected \\ 0 & k \quad is \quad missed \end{cases}$$

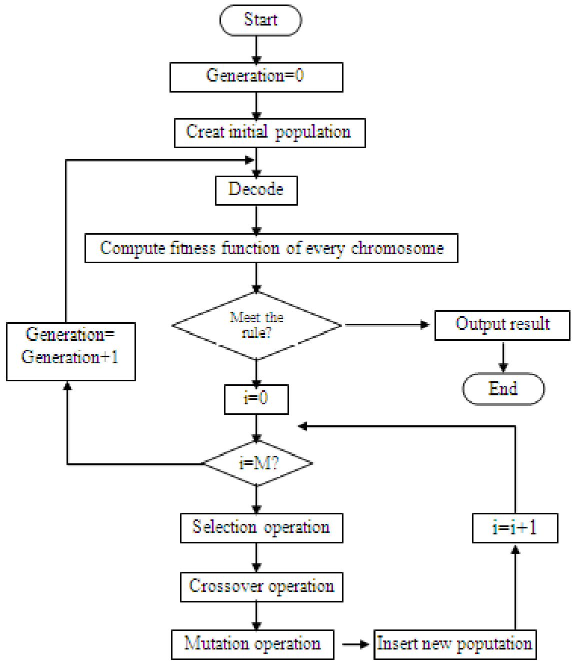

Fig. 2: Flow chart of genetic algorithm for CWPLD

$$X_{ik} \geq 0 \quad Y_{kj} \geq 0$$

In formula (1) above. $V_k = \sum_{i=1}^{m} X_{ik} = \sum_{j=1}^{n} Y_{kj}$ index θ will be among 1/3-1/2.

According to the above analysis, parameter C_{ik} and C_{kj} is determined by the different ship type, we consider that different ship will be selected as follows:

$$\begin{cases} d \geq 5000nmile, \text{ VLCC and } SUEZMAX\ ship \\ 2000nmile \leq d \leq 5000nmile, \quad AFRAMAX and\ PANAMAX \\ d \leq 2000nmile, \quad PANAMAX and\ HANDY \end{cases}$$

The model mentioned above is a nonlinear mixed integer planning model which takes on the character of NP (Nonliner Programming), with the spread of oil transportation network, It is difficult to solve by the traditional methods. This study introduces the Genetic Algorithm (GA) to solve the problem.

OPTIMIZED TACTICS OF GENETIC ALGORITHM

As a random planning algorithm, GA can reach the most probable and omnidirectional optimal solution by searching for many spots in different region of solution space (Wang and Chao, 2002; Cheng and Wang, 2004). The concrete solution strategy is shown in Fig. 2.

Hybrid coding strategy: This model has two kinds of decision variations; W_K is an integral variation of two values 0, 1, which indicates the points which will be selected as logistics distribution centers. It employs binary code. The length of code string equals the number of candidate distribution centers n. For example, there are 12 candidate distribution centers, use ID number 1~12 to describe each distribution center, so from the code string {1, 1, 0, 1, 1, 1, 0, 1, 0, 0, 1 and 1}, we know that the distribution center which ID number is 1, 2, 4, 5, 6, 8, 11 and 12 have been selected. Decision variation X_{il}, Y_{kj} denotes the quantity of petroleum from accommodate source to distribution center and Y_{kj} denotes the quantity of petroleum from distribution center to destination. X_{il}, Y_{kj} could use float coding, the length of every chromosome equals as the number of decision variation, so the length of code string will not be too long and could be decoded easily, which will improve the effect of calculation.

Constraints elimination and fitness function: The study employs punish function to eliminate constraints. According to preceding model, we set:

$$U_i = A_i - \sum_{k=1}^{p} X_{ik} \qquad i = 1, 2, \cdots m \tag{6}$$

$$V_i = \sum_{k=1}^{p} Y_{kj} - B_j \qquad j = 1, 2, \cdots, n \tag{7}$$

$$W_k = MW_k - \sum_{i=1}^{m} X_{ik} \quad k = 1, 2 \cdots, p \tag{8}$$

$$S_k = \left| \sum_{i=1}^{m} X_{ik} - \sum_{j=1}^{n} Y_{kj} \right| \quad k = 1, 2 \cdots, p \tag{9}$$

Set:

$$D_q = \begin{cases} \max\{0, U_i, V_j, W_k\}(q = 1, 2 \cdots, m+n+p) \\ S_k(m+n+p+1, m+n+p+2, m+n+2p) \end{cases} \tag{10}$$

We adopt improved method to get the formula of punish function:

$$p = \begin{cases} \frac{t+1}{2\tau_0} \cdot \sum_{q=1}^{m+n+2p} D_q^2, \text{if not meet the constrain condition} \\ 0 \quad \text{if meet the constrain condition} \end{cases}$$

In the former formula, t is the genetic generation and τ_0 is initial coefficient, we set $\tau_0 = 1.5$.

In this way constraint problem change into unconstraint optimize problem: eval = F+P

F is object function and eval is evaluate function.

Since formula (1) computes the minimum, this study constructs the following fitness function for formula (1):

$$f_f = C_{max} - eval \quad (11)$$

f_f = Fitness function
C_{max} = A positive integer which is big enough

The preceding operation can ensure preferable chromosome in population always have the higher fitness value. Because the worse chromosome can hardly meet the constraint condition because of the larger punish function P.

Genetic operators:

- **Selection:** The study adoptes optimum reservation to select chromosome. First, it ensures t chromosome which has max fitness value in parents generation appears in children generation at least one time. Then complete the selection operation according to the standard roulette wheel method. In this way we could ensure the optimal chromosome will be reserved in children generation.
- **Crossover:** The study adoptes two-point crossover method, since one-point crossover operation contains less information and some important gene in bottom of the code string always be exchanged. The study use liner descending function to yielding crossover probability P_c. In first generation we set P_c = 75% and liner descend to last generation P_c is 25%. The aim of this operation is to ensure more information will contain in young generation and will be good to the algorithm convergence in upper generation.
- **Mutation:** According to the characteristic of coding, we could just apply mutation operation in X_{il}, Y_{kj}. The study adopts a liner function to yield mutation probability P_m, which equation is:

P_m = 0. 001+(0. 3−0.001) x current iterations/total iterations

In formal formula, P_m will increase according to the generation increasing. So it could accelerate convergence in upper generation.

VERIFICATION OF THE MODEL

Selected the parameter: The system analyzes our country's domestic crude oil shipping line and the import and export place according to the domestic crude oil distribution chart and the import and export crude oil chart, totally identifies 9 international and domestic supply sources, 11demand sites and 12 candidate distribution centers. The quantity of every source of the supply and demand is determined by the statistics data and prediction results. Transportation cost of different type of the ship should be identified by concrete shipping lines and the parameters.

Realizing program and optimization result: Combining with genetic algorithm of the frame of flow char above, program is designed by MATLAB language. By executing the program, the final result is chromosome = 110011110001; it shows that No 1.2.5.6.7.8.12 is the best distribution center. Because the variable is numerous, as space is limited, the value of X_{ik}. Y_{kj} is omitted:

CONCLUSION

From the results, we get that waterborne petroleum logistics distribution center is Dalian, Qingdao, Shanghai, Ningbo, Zhoushan, Guangzhou and Quanzhou by using the model and algorithms above. The result is basically consistent with our country's planning addresses of petroleum strategic reserves. It also shows this model can be used to solve the problem of CWPLDC. Meanwhile, the genetic algorithm is an overall searching arithmetic, it is simpler than traditional mathematics method and it is a good method to identify the petroleum distribution center. Finally, the model and the method can be used to allocate the distribution center and optimize network of other large scale distribution center.

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