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Optimization of Chemical Logistics Siting based on Improved ACO

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This paper aims to study the optimization of chemical logistics site selection through the improved ant colony optimization algorithm. Specifically, by integrating a number of domestic and foreign literatures, this paper built an improved ant colony optimization model to assign customers of different sizes, calculated the operating costs of the chemical logistics distribution center through relevant financial indicators, and then presented an optimization plan for chemical logistics site selection. Results have shown that the optimization of chemical logistics site selection based on the improved ant colony optimization can shorten the delivery time. It is concluded that the improved ant colony optimization model can provide sound solutions for site selection of large-scale chemical logistics with a complex logistics chain, and thus can be highly promoted and widely applied.

1. Introduction

Since most chemical products are flammable and explosive, they must be taken care during the transportation to ensure both the efficiency and safety of chemical product transportation. For the two considerations, optimization of chemical logistics site selection is the first step in establishing and improving the chemical logistics chain. In the process of chemical logistics site selection, safety is a key consideration. The chemical logistics collection and distribution center should be far away from residential houses and densely populated areas. However, this consideration may increase the transportation costs for enterprises. The cost factor will also affect the logistics site selection. Taking into account the cost, companies will often choose the lowest-end route, which will increase the risk borne by the residents along the transportation route. The logistics transit station plays an important role in the modern logistics system. All the contents of the basic logistics operation links can be reflected in the logistics transit station.

Based on this, this paper established an improved ant colony algorithm model to allocate customers of different sizes, calculated the operating costs of the chemical logistics distribution center through relevant financial indicators, proposed an optimization plan for chemical logistics site selection, and studied the optimization of chemical logistics site selection to determine the number, scale, and location of chemical logistics transit stations, which is designed to help chemical companies choose a safe and low-cost logistics distribution center, improve the logistics efficiency of chemical companies, and enhance the corporate customer experience.

2. Literature review

The earliest site selection problem was proposed by Weber in 1909. The problem he considered was to determine the location of a warehouse so that the total transportation distance between the warehouse and the customers was the shortest. After a long process of research, especially in the last 30 years, the theory of site selection has been developing rapidly, and the wide application of electronic computers has provided a powerful means for the feasibility analysis of different schemes. In conclusion, these logistics center site selection methods can be divided into three categories: applying the continuous model site selection, applying the discrete model site selection, and applying the Delphy expert consultation method. The first method considers that the location of the logistics center can be taken anywhere in the plane, and the representative

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method is the center of gravity method. The second method holds that the alternative location of the logistics center is a limited number of places, and the most appropriate address can only be selected from a limited number of feasible points according to the intended target. The idea of the third method is to express the judgment made by experts based on experience in numerical form. After comprehensive analysis, the site selection decision is made. It is difficult to consider all the factors in the research on site selection of the first two methods, such as terrain, environment, traffic, labor, urban land and so on, and even if they want to consider these factors fully, it is difficult to quantify the constraints in the formation of the model.

Rao considered the mutual feedback mechanism between the planning scheme of logistics center and the traffic condition of urban road, used the queuing theory and nonlinear programming technology to establish a double layer programming model for the site selection of the public logistics park, and adopted the genetic algorithm to get the solution (Rao et al., 2015). Zhang and others put the fixed cost of logistics center into objective function on the basis of Baumol - Wolfe model, and listed capacity restriction and number limit into constraint conditions. A mixed integer programming model was established, and a heuristic algorithm was designed (Zhang et al., 2017). The logistics center site selection model and its optimization methods have been developing in depth, and it is more and more closely connected with the reality. However, their service objects are mainly enterprises. By seeking the optimization methods adapted to them, the best solutions are obtained.

The ant colony algorithm (ACA) was proposed by M.Dorigo and other Italy scholars in 1991, to solve the TSP problem based on the similarity between the process of searching food by ant colony and the TSP problem. In 1996, Gambdarella and Dorigo put forward the "ant colony system" to improve the performance of ant colony algorithm. ACA is a "natural" algorithm generated being inspired by the behavior of natural organisms. It comes from the study of the behavior of the ant colony. The colony's indirect asynchronous connection with "pheromone" is the biggest characteristic of ACA. Ants will leave some chemical materials (called "information") in the places they pass by in the action (or path looking for food or looking for the way to return to the nest). The materials can be felt by the ants in the same ant colony, and act as a signal to affect the action of ant. In a certain period of time, the shorter path will be accessed by more ants, and the information it accumulates will be more, and thus more likely it will be selected by the other ants next time. The process will continue until all the ants take the shortest path. Tian and so on proposed a new ant colony algorithm. The selection strategy adopted multiple pheromone weights, and pheromone updating combined local pheromone updating and global pheromone updating (Tian et al., 2016).

Among them, the global pheromone updating uses two best solutions. In addition, an external set is set up to store the Pareto solution, and the improved algorithm is applied to the dual target TSP (traveling scheduling problem). Finally, a simulation experiment is carried out and the results show that the new method is more effective than NSGA-II and SPEA2. Holzinger and so on, aiming at the premature convergence of ant colony algorithm, put forward a parallel multi-group ant colony algorithm. The algorithm generated a variety of groups with heuristic information when initializing the ant colony. Many groups used multi-kernel system parallel processing methods to solve the shortest path independently (Holzinger et al., 2016). In the process of getting the solution, each group can share the path information. When a population solves the shortest path, it generates the whole population global shortest path, thus ensuring the population diversity, the algorithm solution rate and the global search equilibrium. Ant colony algorithm has been successfully applied in some fields. The most successful application is the application of combinatorial optimization problem, whose typical representative is TSP, QAP (Quadratic Assignment Problem), job-shop (job vehicle scheduling problem) and other classical combinatorial optimization problems. Zhao and so on used ant colony algorithm for the first time to solve the problem of vehicle routing optimization. A special ant colony transfer strategy was designed for the problem, and the 2-opt method was used to optimize the path (Zhao et al., 2018). Liu applied the idea of ant colony algorithm, developed the ACO (An Colony optimization) algorithm to solve the vehicle routing optimization problem with capacity constraints, and carried out the experimental simulation of several typical types of VRP, so as to verify the validity of the algorithm (Liu et al., 2016). An improved ant colony algorithm for solving VRP problems was proposed by Zhao and so on. The algorithm accelerated the convergence efficiency by introducing heuristic factors and parameters adaptively, and improved the global search capability (Zhao et al., 2016).

Cao pointed out the superiority of ant colony algorithm in solving large nonlinear system optimization problems. According to the characteristics of the logistics vehicle scheduling system, the basic ant colony algorithm was improved properly and the algorithm framework was given. Through comparison, the proposed improved ant colony algorithm was proved to be correct and effective (Cao, 2016).

To sum up, it can be found that the emergence of ant colony algorithm provides a new idea for combinatorial optimization problems, and is a potential algorithm for solving NP-Hard problems, such as combinatorial optimization problems. In terms of the problem of logistics location optimization, we can solve the different types of VRP problems by adjusting the basic ant colony algorithm, and a large number of experiments have proved that the solution results are good.

3. Methods

The development of modern logistics has accelerated the circulation of commodities and better adapted the logistics system to the characteristics of customer needs. Logistics transfer stations have gradually shifted from the transition-oriented to distribution-oriented model. Therefore, this paper used the location selection of multiple distribution-oriented transfer stations as the research object. The logistics operation costs as the basis for the site selection include the distribution and transportation costs (including the transportation cost from the transfer station to the distribution unit and that from the distribution center to the transfer station) and the construction cost of the transfer station. The number of distribution units should be determined before the site selection of the transfer station, and the number of selected species points should be set to determine the number of distribution units. Set that there is a linear relationship between the selection of the number of species points and the distance from each point to the customer point. Therefore, the mathematical model for selecting the number of species points is:

$$\min\left(\sum_{i}\sum_{j}a_{ij}y_{ij}\right)$$

In the formula, a_{ij} is the cost of transportation from customer point j to species point i (ie, the distance between point j and point i). The decision variable y_{ij}: Customer point j is set in the partition of species point i with a value of 1, otherwise of 0.

The genetic algorithm is used to select the species point in large-scale customer points and then the number of distribution units is set. The specific operation is as follows:

Step 1: Genetic manipulations are performed to generate an initial population. Each chromosome in the population is coded with 0-1. When the gene position in the chromosome is 1, the position is selected as the species point. And set that each chromosome of the initial population randomly generated contains n species points;

Step 2: Allocate customer points to species points in the nearest principle and apply the above mathematical model to calculate the fitness value;

Step 3: The combination of optimal selection and roulette selection results in new populations;

Step 4: Perform cross-operation on the population with the crossover probability of 1, check whether the constraints are met, and test whether the offspring individuals are better than the parent individuals. If they are superior, substitute them; otherwise, do not replace them and create new populations.

Step 5: Perform a mutation operation on the population with the mutation probability of Pm, check whether the constraints are met, and test whether the offspring individuals are better than the parent individuals. If they are superior, substitute them. Otherwise, do not replace them and create new populations.

Step 6: Satisfy the termination rule to end. Otherwise, go to step 2.

Through the above operations, the number of species points is determined, and the number of customer points corresponding to the number of species points is determined based on the number of species points, and then the number of distribution units is determined. The distribution unit division diagram is shown in Figure 1.

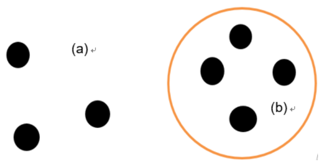

Figure 1: Distribution Unit Distribution Diagram ((a)Distribution unit before delineation; (b)After the distribution unit is demarcated)

The method of calculating the practical value of funds is the simple interest method and the compound interest method. In the engineering economic analysis, the compound interest method is usually used. The so-called compound interest method, that is, the value added (interest) of the principal in each period, can be added to the principal at the end of the period for more value added in the next period, featuring “interest on interest”. The use of compound interest method to calculate the equal amount of capital once paid can also be referred to as the current value annuity method, that is, the current investment is converted to the annual cost. The calculation process is as follows: Set the annual rate of appreciation of funds or interest rate as r0 and the existing funds as P which is the current value of capital, and the value of funds after n years becomes F, which is called the future value of funds. There are:

$$F = P(1 + r_0)^n$$

In consideration of the time value of funds, the values of income or expenditures that occur at different times cannot be directly added or subtracted. They can only be converted to the same point of time for analysis through capital equivalent calculations. Therefore, the item costs are converted into equal annual values for calculation.

For the establishment of the multiple transit station siting model, the assumptions are as follows:

(1) The site selection of the transit station is to select a certain number of locations (g) from a limited number of locations (m), and to establish a transit station with reasonable planning to deliver goods for n distribution units. Make sure that the selected point for a transit station costs the lowest (including construction costs and operating costs) in the premise of meeting the distribution requirements, in order to facilitate the calculation of the coordinates of the location of the fetching and distribution units to calculate the distance between the two areas.

(2) The flow of goods is two-way, that is, the distribution center and the transit station have both input and output.

(3) The demand features certainty, that is, the demand for goods is known and relatively stable within a certain period of time.

(4) There are multiple transit stations. Carts are responsible for distribution in the distribution center. For the distribution unit, the distribution center and the transit station are respectively responsible for the distribution through the trolley.

(5) Distribution of large models and mini-vehicles. After the vehicle completes the transportation task, it will return to the departure place and the distance will be calculated based on twice the single trip.

(6) If there are multiple objectives, the total cost of meeting the objective function is minimum, and the vehicle speed is assumed to be a constant v.

(7) The land area of the transit station is proportional to the distribution volume, and the construction cost of the transit station varies with different locations.

2.2 Improved Ant Colony Algorithm for Regional Planning Model

When ants forage, there are many roads from the nest to the food source. At the beginning, different ants will choose different paths. In the end, almost all ants will find the same shortest route. Since the process of ants searching for the shortest path is an interactive process, all ants leave a certain amount of pheromone on their way. The other thing is that ants can also sense the presence and quantity of this hormone and select the path with the most hormones. Therefore, these hormones will change with the number of ants that pass through the path, and will also disappear in a certain functional relationship with the passage of time. Because there are more ants passing through the shortest path, the accumulation of hormones on the shortest path is faster than that on other paths. Therefore, ant colonies exchange feedback information through pheromones continuously and eventually find a shortest path from the nest to the food source. This is the basic principle of the ant colony optimization algorithm.

Combining with the actual situation of cluster analysis, the site selection of the transit station is regarded as a clustering problem. The allocation unit is taken as the distribution unit, with the distribution center and all the transit stations as candidate locations. Based on the transit station siting model with the least total cost, multiple ants are used to deliver distribution units to distribution centers and transit stations, and the distribution center is granted a greater probability of selection. After the end of the calculation, examine the number of distribution units contained in each transit station. If not empty, then retain the transit station; otherwise, the transit station is removed.

(1) Set up an ant population M so that M ants perform several searches.

(2) The distribution center and the candidate transit station are the ant nest centers, and the corresponding parameters of the ant colony algorithm are initialized.

(3) Record the pheromone increment of ant k.

4. Research results and discussion

In order to verify the validity of the algorithm, the computer programming simulation calculation was carried out. Suppose there is a logistics and distribution area with the range of (0,0) to (0,140), and 2,000 customer points are scattered. Divide it into 120 distribution units, and select 8 candidate station locations. The coordinates of the distribution center and candidate transit stations are shown in Table 1, and the coordinate of the distribution center is (65, 65).

Table 1: Coordinate Table of Distribution Center and Transit Center Location

Transit station	Abscissa	Y-axis	land price
1	35	65	1.2
2	50	25	1.8
3	15	95	1.3
4	50	110	1.6
5	65	65	-

The demand scale of distribution units (expressed by q_j) is shown in Table 2.

Table 2: Demand Tables for Distribution Units

q_j	Variable
q_1	8
q_2	9.5
q_3	11
q_4	10
q_5	12

By applying the improved ant colony algorithm, the distribution capability variable matrix is calculated as:

D=[123.9, 182, 126.4, 104.6, 124.1, 175, 108.9, 0, 246.5]

The chemical logistics site selection is shown in Figure 2:

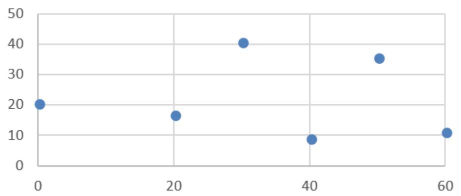

Figure 2: Multi-logistic Transit Station Location

As can be seen from Fig. 2, * is the location of the selected transit station and + is the location of the unselected transit station. The above algorithm is used to calculate 10 times, and the minimum value is selected as the total cost: Z=180640 (yuan), and the respective distribution units are defined.
The distribution relationship matrix r_{ij} of distribution units in the charge of distribution centers and distribution stations is shown in Table 3.

Table 3: Distribution Relationship Matrix

r1, j	r2, j	r3, j	r4, j	r5, j
r1, 12	r2, 5	r3, 6	r4, 3	r5, 8
r1, 26	r2, 11	r3, 53	r4, 4	r5, 9
r1, 27	r2, 13	r3, 54	r4, 7	r5, 31
r1, 30	r2, 14	r3, 55	r4, 63	r5, 32
r1, 51	r2, 15	r3, 56	r4, 65	r5, 41

In order to further verify the effectiveness of the proposed algorithm, the genetic algorithm and ant colony algorithm were used to calculate the site selection model, and the same parameter values as the improved ant colony optimization (IACO) algorithm were designed. The optimization results are compared as shown in Table 4. From Table 4, it can be seen that for the large-scale customer point planning issue, the IACO algorithm is superior to the ACO algorithm and the AG algorithm in the five random calculations in terms of the mean solved and calculation time, and solves the problem in the site location of multiple transit stations and the ownership of distribution units that exist in large-scale customer points. Especially for special industries such as the tobacco industry, salt distribution industry, etc., the IACO algorithm has a high application value for the selection of transit station sites and the ownership of customer points.

Table 4: The optimization results

Frequency	IACO		ACO		GA	
	Solved	time	Solved	time	Solved	time
1	195660	85	210510	143	256620	95
2	188035	90	231564	125	248156	110
3	180640	76	220930	131	220578	136
4	201075	80	206838	152	236589	115
5	190658	75	215689	133	215730	152
Mean	191214	81	217106	137	235535	122

5. Conclusion

The locations of logistics transit stations and distribution stations are very critical. Under normal circumstances, chemical companies have a large number of logistics customers and the network is complex. Based on this condition, this paper constructed an improved ant colony algorithm model to allocate customers of different scales, calculated the operating costs of chemical logistics distribution centers through related financial indicators, proposed an optimization plan for chemical logistics site selection, and studied the optimization of chemical logistics site selection. The research results show that the optimization of chemical logistics site selection based on the improved ant colony optimization algorithm can shorten the distribution time, and the problem of chemical logistics site selection has been better solved. According to the results of the research, we can see that the improved ant colony optimization algorithm can provide a better solution to the large-scale chemical logistics siting optimization with a complex logistics chain, which is worthy of promotion and application.

Owing to limited knowledge of the author, this paper has the following deficiencies: First, the large increase of independent variables leads to a rapid increase in the number of ant colonies, which may make it difficult to obtain an optimal solution for the improved ant colony algorithm. This problem needs to be further solved. Secondly, the reference map for the chemical logistics site selection is static without such factors as geological conditions taken into account.

Reference

Cao J., 2016, Robot Global Path Planning Based on an Improved Ant Colony Algorithm, Journal of Computer & Communications, 04(2), 11-19, DOI: 10.2991/ic3me-15.2015.182.

Holzinger A., Plass M., Holzinger K., 2016, Towards interactive Machine Learning (iML): Applying Ant Colony Algorithms to Solve the Traveling Salesman Problem with the Human-in-the-Loop Approach, International Conference on Availability, Reliability, and Security, Springer International Publishing, 81-95, DOI: 10.1007/978-3-319-45507-5_6.

Liu M., Zhang F., Ma Y., 2016, Evacuation path optimization based on quantum ant colony algorithm, Advanced Engineering Informatics, 30(3), 259-267, DOI: 10.1016/j.aei.2016.04.005.

Rao C., Goh M., Zhao Y., Zheng J., 2015, Location selection of city logistics centers under sustainability, Transportation Research Part D, 36, 29-44, DOI: 10.1016/j.trd.2015.02.008.

Tian J., Gao M., Ge G., 2016, Wireless sensor network node optimal coverage based on improved genetic algorithm and binary ant colony algorithm, Eurasip Journal on Wireless Communications & Networking, 2016(1), 104, DOI: 10.1186/s13638-016-0605-5.

Zhang Y., Zhang Y., Li Y., Liu S., Yang, J., 2017, A study of rural logistics center location based on intuitionistic fuzzy topsis, Mathematical Problems in Engineering, 15, 1-7, DOI: 10.1155/2017/2323057.

Zhao B., Gao J., Chen K., 2018, Two-generation Pareto ant colony algorithm for multi-objective job shop scheduling problem with alternative process plans and unrelated parallel machines, Journal of Intelligent Manufacturing, 1-16, DOI: 10.1007/s10845-015-1091-z.

Zhao J., Cheng D., Hao C., 2016, An Improved Ant Colony Algorithm for Solving the Path Planning Problem of the Omnidirectional Mobile Vehicle, Mathematical Problems in Engineering, 12, DOI: 10.1155/2016/7672839.