Optimization of dangerous goods recovery path base on improved ant colony algorithm

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Abstract—The objective of this paper is to find a reasonable path to recovery of dangerous goods,reduce the possible loss in the process of transportation . The research on the route of dangerous goods recycling exiting usually use the traditional vehicle routing ploblem (Vehicle Routing Problem, VRP)model, this greatly increases the dangerous goods transport vehicles in the storage time, the recovery of risks in the process of cost increases to a certain extent, so use the complete third party logistics outsourcing （3PL） way of handing to deal with dangerous goods transportation problem , then build a new multi-objective optimization model, use the inverse selection operation of ant colony algorithm （ACO-nso） to solve the model, get the Pareto optimal solution sets. An example is given to demonstrate the effectiveness of the proposed model and algorithm.

Keywords- dangerous goods recycling ; Risk in transit; 3PL; ACO-nso;; Pareto optimum

I. INTRODUCTION

Since the end of the last century, China's economy has maintained its rapid growth momentum. With the rapid increase in its production capacity, dangerous goods are no exception. Therefore, the quantity recovered is also relatively increasing. However, due to its own characteristics, more attention should be paid to the recovery process in comparison with other articles. If an accident occurs, it will be devastating for both human life and property. According to statistics, in the case of accidents involving hazardous chemicals, transportation accidents account for nearly a third, and the annual incidence of accidents is higher than the previous year [1] .

Since the 1980s, scholars at home and abroad have made researches on the reverse logistics and the recovery of dangerous goods. For example, [2] studied the problem of reverse logistics under the impossible path. Liu Yanqiu et al [3] proposed a multi-level logistics distribution network with capacity constraints. Tung-Lai Hu et al. [4] studied a multi-stage and multi-type hazardous waste reverse logistics system. Jiuh-Biing Sheu [5] established the discrete-time linear analysis model with the goal of minimizing the total recycling operation cost and considering the risk factor. Jiuh-Biing Sheu [6] mainly optimized the process of waste recycling, adding operational risk factors to the optimization model.

Most studies now include the few mentioned above considering the time factor. For example, Shuai-bin et al. [7] studied the problem of site selection and routing of recycling centers, mainly considering the compatibility of waste and the loading capacity of recycling centers, There is no mention of the time factor. Zhao Jiahong et al. [8] focused their research on waste types and diversified transport types, adding the fairness factor in the transport of dangerous goods. Samanlioglu [9] built a weighted Taylor equation and considered three factors, total transportation cost, fixed cost and total transportation risk, so as to minimize the target and not involve the time cost. GAO Hong [10] and other genetic algorithms to solve the multi-objective path optimization model, and then come to Pareto optimal solution set. Finally, by comparing the cost value and the dangerous value in the Pareto solution set, a suitable route for the recovery is selected. This document considers the time. However, due to the traditional vehicle route transportation method, the essence of this approach is a post-arrival service (Last Come First Served, LCFS) service strategy will lead to the first recovery of dangerous goods in the vehicle for the longest, which greatly increased the risk of recovery. Based on this, this paper will use third-party logistics outsourcing way to optimize the recovery path of dangerous goods to avoid the first recovered dangerous goods stored in transit for too long, while effectively reducing the recovery costs, and then add to the traditional risk assessment of dangerous goods The total amount of transportation and the distance of transportation make the risk assessment more accurate. Finally, the optimal solution is obtained by the ant colony algorithm which is suitable for inverse selection of reverse logistics.

II. HAZARDOUS GOODS RECYCLING OPTIMIZATION MODEL

A. Problem Description

There are a number of recycle bins around a treatment center, each of which has a different number of recycle needs and, in the end, needs to be sent to a treatment center. In the process of recycling, after the recovery car arrives at the recycle bin, it analyzes the number of dangerous goods in the current recycle bin and adjacent logistics nodes and the information of the risk value of the route, and transports the dangerous goods to other recycle bins by transit or warehousing collection and transportation mode, Or be shipped directly to the processing center to minimize the total transport costs and the total transport risk, provided all constraints are established [11].

B. Variable Description and Conditional Assumptions

Variables are described as follows: n for the number of recycle bins; c_{ij} for unit transportation costs; d_{ij} for the

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distance; x_{ij} for 0 ~ 1 variable, x_{ij} take a representative of the vehicle departure from the recycle bin to the recycle bin, otherwise take 0. R_{ij} For the vehicle transport section, the risk is mainly divided into two parts: the personnel risk R_{mij} and the environmental risk R_{eij} ; $R_{1\max}$ the maximum value of the path and personnel risk; $R_{2\max}$ the maximum value of the path and the environmental risk; ω_1 the proportion of the personnel risk in the transportation risk; ω_2 The proportion of risk; T_{ij} the number of people in the affected area; $P(A)_{ij}$ the rate of transportation accidents; L_j the quantity of dangerous goods issued by the node; and y_{il}^0 the indication of whether the nodes in the process of recycling dangerous goods at the recycling station are transhipped. Which means the transport distance from the node to the node of transportation is the transportation distance from the node to the node; l_{ij} the length of the link; λ the radius of the area affected by the dangerous goods; ρ_{ij} the density of affected persons for the road section; S_{ij} the area affected; ε_{ij} the area of the affected environment relative to the standard diffusion area For the self recovery w_j ; W_j for other need to transit nodes through the node as the transit node of the total amount of recovery; Q_j Recycling station maximum load capacity; for the vehicle at the recovery amount; E_k for each vehicle capacity; e_{ijl}^0 that recycling At the process of recovering dangerous goods from the station to the processing center, the path is assumed to be transshipped.

The model is based on the following assumptions:

a) The dangerous goods in the model are all compatible.

b) The speed at which the vehicle travels on each path is fixed.

c) Assume that all dangerous goods are transported on the road between network nodes.

d) The safety grade of dangerous goods recovery path meets the requirements of dangerous goods transportation.

C. Model establishment

The establishment of an optimal model for the recovery of dangerous goods:

$$\min F = \sum_{i=0}^{n}\sum_{j=0}^{n} c_{ij} d_{ij} x_{ij} \quad (1)$$

$$\min Z = \sum_{0}^{n}\sum_{0}^{n} R_{ij} \quad (2)$$

$$R_{ij} = \omega_1\left(\frac{R_{mij}}{R_{1\max}}\right) + \omega_2\left(\frac{R_{eij}}{R_{2\max}}\right) \quad (3)$$

$$R_{mij} = T_{ij} P(A)_{ij} L_j \sum_{l=1}^{n} y_{il}^0 D_l^i \quad (4)$$

$$T_{ij} = 2 l_{ij} \lambda \rho_{ij} \quad (5)$$

$$R_{eij} = S_{ij} \varepsilon_{ij} P(A)_{ij} L_j \sum_{i=1}^{n} y_{ij}^0 D_l^i \quad (6)$$

$$L_j = W_j + w_j, W_j = \sum_{l=1}^{n} w_l y_{jl}^0 \quad (7)$$

$$D_l^0 = \sum_i \sum_j e_{ijl}^0 l_{ij} \quad (8)$$

$$D_l^k = D_l^0 - D_k^0 \quad (9)$$

$$L_j \le Q_j, \forall j = 1,2,...,n \quad (10)$$

$$\sum_{i=1}^{n} x_{ij} \ge \sum_{l=0}^{n} x_{jl} = 1, \forall j = 1,2,...,n \quad (11)$$

$$\sum_{i=1}^{n} q_i y_{ki} \le E_k, \forall k = 1,2,...,n \quad (12)$$

$$\sum_{i=1}^{n} e_{ijl}^0 = y_{jl}^0, \forall j,l = 1,2,...,n \quad (13)$$

$$\sum_{j=1}^{n} e_{ijl}^0 = y_{il}^0, \forall i,l = 1,2,...,n \quad (14)$$

$$y_{ij}^0 \in \{0,1\}, \forall i,j = 0,1,...,n.i \ne j \quad (15)$$

$$x_{ij} \in \{0,1\}, \forall i,j = 0,1,...,n.i \ne j \quad (16)$$

Among them, the type (1) represents the transportation cost;(2) represents the total risk value; (3) represents the risk factor value of the road segment; (4) represents the personnel risk; (5) is the number of people in the affected area; and (6) Environmental risk; (7) said the recycle bin at the issue of dangerous goods is the recycle bin itself, the amount of dangerous goods and the total amount of dangerous goods received, that all dangerous goods can be processed; (8) that the logistics node (9) represents the transport distance required to transport the dangerous goods at the recycle bin to the recycle bin; and (10) is the recycle bin load constraint, indicating that the recycle bin itself (11) indicates that each recycle bin can receive dangerous goods from more than one recycle bin but can only transport dangerous goods to one recycle bin; 12) represents the vehicle capacity constraint; Eqs. (13) and (14) are path circuit elimination constraints, which means that loops are not allowed during the recycle of dangerous goods; the type (15) and (16) for the variable constraints, that is 0-1 variable.

III. ALGORITHM DESIGN

A. Reverse selection operation ant colony algorithm

Ant colony algorithm is a heuristic algorithm, which has strong robustness and good parallelism in itself, and has great advantages in the probability selection operation of dealing with the vehicle routing problem of recovery, which is suitable for the solution of this problem Choose to use ant colony algorithm to solve. Because this paper does not use the traditional mode of transport, and thus make the dangerous goods recovery path has changed, the emergence of a branch path, but due to the traditional solution of the ant colony algorithm can not be the result of the operation of the solution to express the situation of warehousing stock transport, its The selection method is one-to-one. Therefore, this paper needs to improve the traditional ant colony algorithm coding method and probability selection operation, and then put forward the inverse selection operation ant colony algorithm to solve the problem.

B. Coding improvements

This paper will use the path string encoding, the path string is composed of two structures, the structure of the elements represent the logistics node number, so the solution can be expressed as: ($1,2,\ldots,k,\ldots,n$) → ($i_1, i_2, \ldots, i_k, \ldots, i_n$) In the Recycle Bin i_k for Recycle Bin transport k , and for $k \neq l$, i_k and i_l can be the same, so that the branch path in warehousing mode can be expressed. E.g (1,2,3,4,5,6,7,8) → (0,1,0,2,1,3,0,3) Indicating that the dangerous goods at the recycle bins 1, 3, and 7 are directly delivered to the processing center, the recycle bins 2 and 5 are transshipped and transported through the recycle bins 1, the recycle bins 3 provide the recycle bins for the recycle bins 6 and 8, and the recycle bins 4 are firstly recycled Station 2 is transported to Recycle Bin 1 and eventually shipped to the Processing Center.

C. The probability of the next node selection operation

Next, we improve the operation of probability selection of ant colony algorithm: for ants k, Let the first point in Unvisited (k) be the node i to be visited, and then calculate the transition probability of each element in the visited node set Visited (k). Assuming j∈Visited (k) is the selected node, j is added to the end of Tabu (k), and i is removed from Unvisited (k) and then added to Visited (k).

Node i is the first node in the set of unvisited nodes of ant k, and J (i) represents all accessible set of nodes. If the node is an uncorrectable point, the decision of defining this point is -i and i Into the set of visited nodes; if, then the transfer probability from node i to j is p_{ij}^k :

$$p_{ij}^k = \begin{cases} \dfrac{\tau(i,j)^\alpha \eta(i,j)^\beta U(i,j)^\gamma R(i,j)^\lambda}{\sum\limits_{j \in J(i)} \tau(i,j)^\alpha \eta(i,j)^\beta U(i,j)^\gamma R(i,j)^\lambda}, j \in J \\ 0, j \notin J \end{cases} \tag{13}$$

$$U(i,j) = \left(\frac{d_{i0}^k}{d_{ij}}\right)^2 \tag{14}$$

Equation (13) shows the transition probability of ant k from node i to j. Wherein the path strength of the path is denoted as $\tau(i,j)$, and the initial value of the path is 1. After the ant completes several cycles, the trajectory intensity becomes $\tau_{t+1}(i,j) = \rho\tau_t(i,j) + \Delta\tau_t(i,j)$, representing the pheromone volatility coefficient, The pheromone added in the tth cycle; is the visibility of the path; then the weight expressed α , the weight β , the weight γ , the risk factor $R(i,j)$; the weight λ of the representation $R(i,j)$; and the expression (14) $U(i,j)$ Distance (i,j) saving ratio. Which d_{i0}^k represents the k-th ant from the node i directly transported to the processing center distance, d_{ij} said the node i to node j distance.

IV. SIMULATION EXPERIMENT AND COMPARATIVE ANALYSIS

There is a processing center, 10 recycle bins and processing center coordinates (45,90). All the recycle bins should be sent back to the processing center. The information of the 10 recycle bins is shown in Table 1. α , β , γ , λ , ω_1 , ω_2 , ε_{ij} respectively 1,5,2,3,0.6,0.4,0.5, Affected area area, the impact of access to personnel density and transport accident rate omitted here, calculated by the formula in Table 2, as the risk factors between the various sections of the recycle bin.

Num	0	1	2	3	4	5
	45,90	50,155	59,52	55,137	40,28	52,20
	0	20	20	30	10	20
Num	6	7	8	9	10	
	65,110	20,109	35,135	32,20	24,60	
	10	10	40	20	20	

Tab.1 Recycle bin information

	0	1	2	3	4	5
0	0	0.025	0.071	0.151	0.195	0.312
1	0.025	0	0.049	0.091	0.131	0.259
2	0.071	0.049	0	0.053	0.092	0.143
3	0.151	0.091	0.053	0	0.023	0.111
4	0.195	0.131	0.092	0.023	0	0.041
5	0.312	0.259	0.143	0.111	0.041	0
6	0.041	0.391	0.275	0.221	0.116	0.092
7	0.046	0.459	0.307	0.283	0.167	0.018

8	0.059	0.592	0.396	0.037	0.275	0.262
9	0.076	0.081	0.052	0.555	0.043	0.378
10	0.085	0.094	0.629	0.622	0.523	0.043

	6	7	8	9	10
0	0.041	0.046	0.059	0.076	0.085
1	0.391	0.459	0.592	0.081	0.094
2	0.275	0.307	0.396	0.052	0.629
3	0.221	0.283	0.037	0.555	0.622
4	0.116	0.167	0.275	0.043	0.523
5	0.092	0.018	0.262	0.378	0.043
6	0	0.029	0.074	0.144	0.016
7	0.029	0	0.016	0.055	0.116
8	0.074	0.016	0	0.114	0.187
9	0.144	0.055	0.114	0	0.039
10	0.016	0.116	0.187	0.039	0

Tab.2 Risk value of each recycle bin

The new Pareto optimal solution is obtained by the inverse selection operation of ant colony algorithm, which is compared with the Pareto optimal solution obtained by the traditional transportation method. As shown in Figure 1, similar to point A and point B The point in the square is the Pareto optimal solution obtained by the traditional method of transportation. Point A in the traditional solution corresponds to point C in the new solution, and point D corresponds to point D in the same way. It can be seen that the traditional solutions are located below the new solution, which means that the transportation cost and total risk of point A are obviously higher than that of point C, and the same point B is higher than point D. This is the result you want, proving the validity of adopting this model.

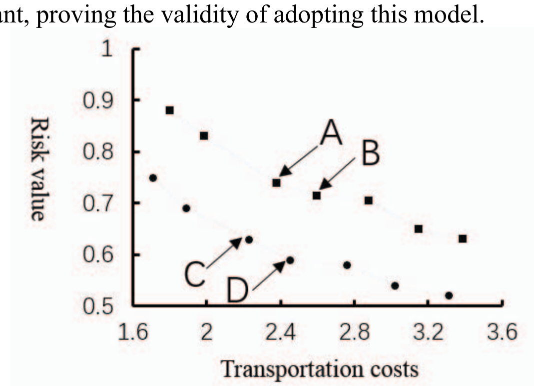

Fig.1 Multi-objective optimization results

Next, compare the recovery path with the transportation cost and risk value, the recovery path of point A is shown in Figure 2, the path is: 0-8-3-4-0,0-1-2-9-7-0,0- 6-5-10. The transportation cost of point A is 2.38×10^4 , the risk value is 0.7389.

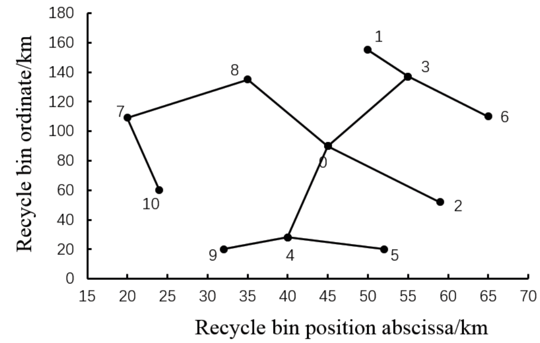

Fig.2 Recycling paths for point A

Point C recovery path shown in Figure 3, is divided into four: the first 1 and 6 have been transferred to 3 after 3, the second is 8-0, the third is 7-10-0, the fourth After 2 to 5 and then together to 4 and 9 together to transport to 0. The cost of transportation at this point is 2.21×10^4 , with a risk of 0.6368.

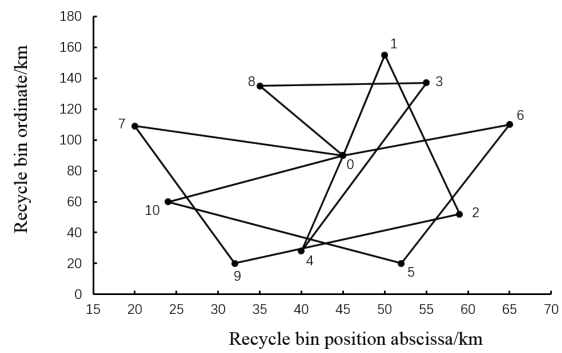

Fig.3 Recycling paths for point C

Then find the D point of the recovery path, divided into four: the first 1 and 6 have been transferred to 3 after 3, the second is 2-0, the third is 10-7-8-0, the fourth Transfer to 0 with 4 and 5 together. The cost of transportation at this point is 2.45×10^4 , with a risk value of 0.5987.

After comparison, the cost of transportation is reduced by 7.14% and the value of risk is reduced by 13.81% compared with that of point A. The efficiency of this model is also proved to be better. The validity of this model is also proved. From point D to point C Compared with the transportation cost increased by 14.93% and the risk value decreased by 5.98%, the decision-maker could choose the reasonable path of recovery of dangerous goods according to the preference of different cost and risk value.

Algorithm classification	Search success rate	average cost	Average risk value	Search time
ACO-nso	37.5%	2.49	0.63	9.38

Genetic	8.5%	2.58	0.75	37.52

Tab.3 Comparison of ACO-nso algorithm and genetic algorithm simulation

scale	average value	time	Success rate	frequency
30	9.32	21.09	37.9%	11.43
50	10.23	25.19	35.8%	17.58
70	22.78	32.17	32.5%	25.44
90	30.34	47.34	21.4%	55.46
100	33.82	66.93	10.6%	83.69

Tab.4 Comparison analysis of simulation results

Through the comparison of Table 3, we can see that ACO-nso algorithm has short calculation time and high stability, and the result is more satisfied. This is because the ACO-nso algorithm guarantees the feasibility of the initial solution during the probability selection operation. However, when the genetic algorithm generates the initial solution in the path-string coding, a large number of infeasible solutions exist in the initial solution space. Which also reduces the search success rate of genetic algorithm, thereby increasing the search time can be seen from Table 4, when the scale of the problem is less than 70, the algorithm also maintained a high stability, and can find better simulation results ; When the scale of the problem continues to increase, the stability of the algorithm also decreases. This is mainly reflected in the success rate of the search, the number of iterations and the computation time increase. Therefore, the algorithm is suitable for solving medium and large-scale dangerous goods Recycle path problem.

V. CONCLUSIONS

In this paper, the problem of hazardous materials recovery route is studied. The full 3PL outsourcing is used to deal with the transport of dangerous goods. The traditional risk assessment adds the factors of transportation time and vehicle loading, and the inverse selection operation ant colony algorithm is used to solve the problem. Compared with the traditional method of transportation, the result is lower recovery cost, lower risk of recovery and higher safety of recovery. At the same time, the ant colony algorithm with reverse selection increases the search success rate and reduces the average calculation time. In further research, the risk factors of different time periods may be considered as different factors, so as to assess the risk of the dangerous goods recovery process more accurately..

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REFERENCES

[1] Shang H. Taking about the Logistics of Chemical Transport of Dangerous Goods Status and the Development of Countermeasures[J]. China Market, 2008(19):18-19.

[2] LIU Yan-qiu,WU Meng,XU Shi-da . Reverse logistics recovery routing path problem with considering unfeasible[J].Journal of Shenyang University of Technology, 2016, 38(4):416-420.

[3] LIU Yan-qiu,JIAO Ni,LI Jia. Optimization design of multi-level logistics network based on determined network[J].Journal of Shenyang University of Technology, 2016, 38(4):416-420.

[4] Hu T L, Sheu J B, Huang K H. A reverse logistics cost minimization model for the treatment of hazardous wastes[J]. Transportation Research Part E Logistics & Transportation Review, 2002, 38(6):457-473.

[5] Sheu J B. A coordinated reverse logistics system for regional management of multi-source hazardous wastes[J]. Computers & Operations Research, 2007, 34(5):1442-1462.

[6] Sheu J B. Green supply chain management, reverse logistics and nuclear power generation[J]. Transportation Research Part E Logistics & Transportation Review, 2008, 44(1):19-46.

[7] SHUAI Bin,ZHAO Jia-hong . Multi-objective 0-1 Linear Programming Model for Combined Location-Routing Problem in Hazardous Waste Logistics System[J]. Journal of Southwest Jiao Tong University, 2011, 46(2):326-332.

[8] A New Multi-objective Model for the Combined Location-routing Problem in Hazardous Waste Recycling Logistics[J]. Journal of Transportation Engineering & Information, 2011.

[9] Samanlioglu F. A multi-objective mathematical model for the industrial hazardous waste location-routing problem[J]. European Journal of Operational Research, 2013, 226(2):332–340. J61.

[10] GAO Jv-hong,ZHAO Tian-yi . Analysis of routing Optimization for Hazardous waste recycling path[J]. Chinese Journal of Safety Science, 2013, 23(11):66-71.

[11] LIU Yan-qiu,XU Shi-da,ZHANG Ying. Research on vehicle routing problem considering path feasibility and storage volume model[J]. Chinese Journal of Management Science, 2016(12):98-107.

[12] SONG Yang,XU Zhen,WANG Yan-qing . Route Optimization for Dangerous Goods Transportation Based on Ant Colony Algorithm[J]. Safety & Environmental Engineering, 2014