

Research Article

Transportation Path Optimization of Modern Logistics Distribution considering Hybrid Tabu Search Algorithm

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Received 29 July 2021; Accepted 16 August 2021; Published 7 September 2021

Academic Editor: Zhendong Mu

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The optimization of transportation path for distribution vehicles, which is about the mixed tabu search method, can not only reduce the cost but also improve the optimization of the vehicle transportation path. This algorithm first studies the current situation of the logistics distribution vehicle transportation path and then uses the hybrid tabu search method to calculate the vehicle transportation path. According to the real case analysis, it can be proved that the hybrid tabu search calculation method can improve the efficiency, the proposed modern logistics distribution vehicle transportation path is also the best method, and the transportation cost is greatly reduced.

1. Introduction

The continuous development of the global economy has driven the rapid progress of the logistics industry. Due to the increase of oil price, the cost of logistics and transportation has exceeded the budget, and there are contradictions and defects between goods distribution-related services and intercity transportation [1–3]. Therefore, the current logistics distribution vehicle transportation path optimization is an important work of the entire logistics industry. The logistics distribution vehicle transportation path optimization problem is related to the logistics transportation cost, efficiency, and distribution speed. Therefore, it is an important work of the logistics research industry to choose which path optimization to quickly deliver goods to users. Optimization of transportation path for distribution vehicles, OTPDV, can use the least number of vehicles, the smallest number of vehicles to complete the distribution work, and can achieve the goal of the lowest cost and the shortest time [4–6].

In this paper, we study the transportation path of logistics distribution vehicles and establish a digital model of distribution vehicle transportation. The digital model uses

the hybrid tabu search calculation method to find the best transportation path of distribution vehicles. Taking the actual case analysis, it can be proved that the hybrid tabu search method can find OTPDV method the fastest and is the best calculation method.

2. Hybrid Tabu Search Algorithm

The hybrid tabu search algorithm is represented by a ternary array composed of zeros $(r_1, r_2, r_3) r_1 < r_2 < r_3$; its subordinate function is

$$\mu(x) = \begin{cases} \frac{x - r_1}{r_2 - r_1}, & \text{if } r_1 \leq x \leq r_2, \\ \frac{x - r_3}{r_2 - r_3}, & \text{if } r_2 \leq x \leq r_3, \\ 0, & \text{other.} \end{cases} \quad (1)$$

If hybrid tabu search $\alpha = (a_1, a_2, a_3)$, $\beta = (b_1, b_2, b_3)$. According to the extension principle of addition and multiplication of mixed tabu search numbers, there are two

aspects:

$$\mu_{\bar{\alpha}+\bar{\beta}}(z) = \sup \left\{ \min \left\{ \mu_{\bar{\alpha}}(x), \mu_{\bar{\beta}}(y) \mid z = x + y \right\} \right\} = \begin{cases} \frac{z - (a_1 + b_1)}{(a_2 + b_2) - (a_1 + b_1)}, & a_1 + b_1 \leq z \leq a_2 + b_2, \\ \frac{z - (a_3 + b_3)}{(a_2 + b_2) - (a_3 + b_3)}, & a_2 + b_2 \leq z \leq a_3 + b_3, \\ 0, & \text{other.} \end{cases} \quad (2)$$

That is, the sum of hybrid tabu search is still hybrid tabu search, and there is a difference,

$$\bar{\alpha} + \bar{\beta} = (a_1 + b_1, a_2 + b_2, a_3 + b_3), \quad (3)$$

and, from $\mu_{\lambda\bar{\alpha}}(z) = \sup \{ \mu_{\bar{\alpha}}(x) \mid z = \lambda x \}$, obtain

$$\lambda\bar{\alpha} = \begin{cases} (\lambda a_1, \lambda a_2, \lambda a_3), & \lambda \geq 0, \\ (\lambda a_4, \lambda a_3, \lambda a_2), & \lambda < 0. \end{cases} \quad (4)$$

If $\bar{\alpha}_i = (a_{i1}, a_{i2}, a_{i3})$, $i = 1, 2, \dots, m$, is a hybrid tabu search, we obtain $\bar{\alpha}_i$'s nonnegative linear combination and mixed tabu search programming based on fuzzy logic

$$\sum_{i=1}^m \lambda_i \bar{\alpha}_i, \quad \lambda_i \geq 0, \quad (5)$$

which is still hybrid tabu search, and

$$\sum_{i=1}^m \lambda_i \bar{\alpha}_i = \left(\sum_{i=1}^m \lambda_i a_{i1}, \sum_{i=1}^m \lambda_i a_{i3} \right). \quad (6)$$

Hybrid tabu search is a kind of stochastic programming, in which the constraint conditions include random parameters, and chance represents the probability of the constraint conditions [7–9]. In the hybrid tabu search environment, the hybrid tabu search constrained programming is understood by taking opportunity as the possibility of the constraint. Random hybrid tabu search and hybrid tabu search control plan provide a powerful tool to solve optimization problems with random parameters and mixed tabu search parameters. This model is in general form:

$$\begin{cases} \max_x f(x, \xi, \eta), \\ s.t. g_j(x, \xi, \eta) \leq 0, \quad j = 1, 2, \dots, m. \end{cases} \quad (7)$$

Among them, x is the decision vector, ξ is a random vector parameter, η is a hybrid tabu search vector parameter, $f(x, \xi, \eta)$ is the objective function, and $g_j(x, \xi, \eta)$ is a constraint function, due to the appearance of hybrid tabu search parameter η and random parameter ξ . As a result, the symbols max and constraints in model (1) are lacking of clear meaning. In order to solve this problem, the mixed tabu search and random elements in the model are considered as the coexistence of mixed tabu search and random chance.

3. Design of Hybrid Tabu Search Algorithm for Distribution Vehicle Routing Optimization

3.1. Determination of the Number of Hybrid Tabu Search. Let n be customers in total, then the number of ants in the hybrid tabu search is m ; then, there are

$$m = \sum_{i=1}^n b_i(t), \quad (8)$$

where $b_i(t)$ is the number of ants in customer i .

3.2. Hybrid Tabu Search Path Transfer Rule. In the process of OTPDV problem solving, the transition probability of ant K from customer I to customer J needs to consider the length of transportation path and pheromone concentration of the following customer points [10–12]. J is the accessible customer; O is the modern logistics distribution center. The calculation formula of the probability of selecting ant K to transfer from client I to client J is as follows:

$$P_{ij}^k(t) = \begin{cases} a \times \frac{\tau_{ij}(t)^\alpha \times \eta_{ij}(t)^\beta}{\sum_{h \in Q} (\tau_{ij}(t)^\alpha \times \eta_{ij}(t)^\beta)} + \frac{(b/|t_{ij} - e_h| + |t_{ij} + l_h|)}{\sum_{h \in Q} (1/|t_{it} - e_h| + |t_{ih} + l_h|)}, & \text{if } j \in Q, \\ 0, \text{ or.} \end{cases} \quad (9)$$

In the formula, a and b are weighting factors, and t_{ij} is the time from client i to client j . α indicates the information transmission factor. β indicates the factors of looking forward to departure. $\eta_{ij}(t)$ identifies the initiation information value related to the transportation path (i, j) as defined below.

$$\eta_{ij}(t) = \frac{1}{d_{ij}}, \quad (10)$$

where d_{ij} is the distance between customer i and customer j .

3.3. Pheromone Update Rules. In the hybrid tabu search algorithm, in order to make full use of the best solution of the cycle and the best solution found so far, each cycle will update the pheromone of each ant. The rules of pheromone update are as follows:

$$\begin{aligned} \tau_{ij}(t+n) &= (1-\rho) \times \tau_{ij}(t) + \Delta\tau_{ij}(t), \\ \Delta\tau_{ij}(t) &= \sum_{k=1}^m \Delta\tau_{ij}^k(t). \end{aligned} \quad (11)$$

In a few days, ρ , the pheromone volatility coefficient, is a random number between $[0, 1]$. $1-\rho$ represents the residual factor of pheromone. $\Delta\tau_{ij}(t)$ represents the transport path in this cycle. The increment of the information element on (i, j) : its initial value is $\Delta\tau_{ij}(0) = 0$. It means that the k th ant stays on the transport path in this cycle. $\Delta\tau_{ij}^k(t)$ (i, j) the total amount of the above pheromones:

$$\Delta\tau_{ij}^k = \begin{cases} \frac{Q}{L_k}, \text{ ant } k \in (i, j), \\ 0, \text{ or.} \end{cases} \quad (12)$$

Here, Q is the concentration of information elements, which is a constant and affects the convergence speed of the algorithm. L_k is the length of the transport path taken by the k th ant in this cycle.

4. The Realization of Vehicle Distribution and Transportation Path Algorithm

If the hybrid tabu search algorithm is used to solve the optimization problem of vehicle transportation path, artificial ants are used to provide services instead of vehicles. The key point of serving a guest is to exceed the loading capacity of the car and the maximum distance. The vehicle will continue to serve other guests. There is a service at all the guests. At this time, the artificial ants representing the car completed a parade. Remember a cycle after all the ants have marched [13–15]. After a cycle, according to the quality of each ant cycle, the increase of pheromone is calculated, and the pheromone is updated at the same time. After cycling for many times, some ants choose the same transportation path or find the best transportation path. The specific steps are as follows:

- (1) Initialize parameters, read the client data to be served, and generate global initial solution.

- (2) Please only put M ants in the distribution center of modern logistics. The initial time $t=0$ and the number of repetitions $NC=0$ were used to establish the mixed tabu search tabu list.
- (3) For each ant i , it searches the node that does not walk from the node list and selects the next client node j from these nodes according to the transmission probability formula.
- (4) Calculate transportation route (i, j) , total cargo volume q , if $q=t > Q$. Here, Q is the maximum capacity of the vehicle, so go to step 5. Otherwise, node j will join the executable point group A and move forward to step 6.
- (5) The waiting time of customer demand point j is calculated, and the path length and cost from node i to node j are added to the tabu list when the request of time window is satisfied. At the same time, skip to step 3. Otherwise, node j joins the new executable point group A and advances to the next step 6.
- (6) Count the number of vehicles and judge the executable point group A. if a is empty, skip to step 7. Otherwise, the node not retrieved from a will be obtained, the node with the shortest start time will be selected as the starting point, and the next node will be found in step 3.
- (7) Update the pheromone and pheromone increment of the line part of the transport path that each ant passes through.
- (8) Search for the shortest transport path length and shortest transportation path of K ants. At the beginning of the cycle, after all ants' tour, the pheromones of the edges searched by K ants are updated. Otherwise, we will update the best transportation route for this cycle.
- (9) Compared with the global optimal solution, if the optimal solution in this iteration is better than the global optimal solution, it will replace the global optimal solution and update the global optimal transportation route table.
- (10) If the number of iterations reaches the maximum or the global optimal solution is found, the program ends. Otherwise, clear the tabu list and skip step 2.

The specific flow of the algorithm is shown in Figure 1.

Before planning the global path of logistics vehicles, we need to complete the modeling of logistics storage environment to improve the logistics storage status of logistics vehicles. In this section, the mixed tabu search algorithm is selected for logistics storage environment modeling. Hybrid tabu search divides the environment where logistics vehicles are placed into area and volume and divides it into several two-dimensional or three-dimensional grids with the same shape. Other elements in the logistics environment are described abstractly by using the small grid as the unit, so as to build a logistics environment that logistics vehicles can easily understand. The length of the logistics system is described by m , and the width by N ; with a certain angle of the

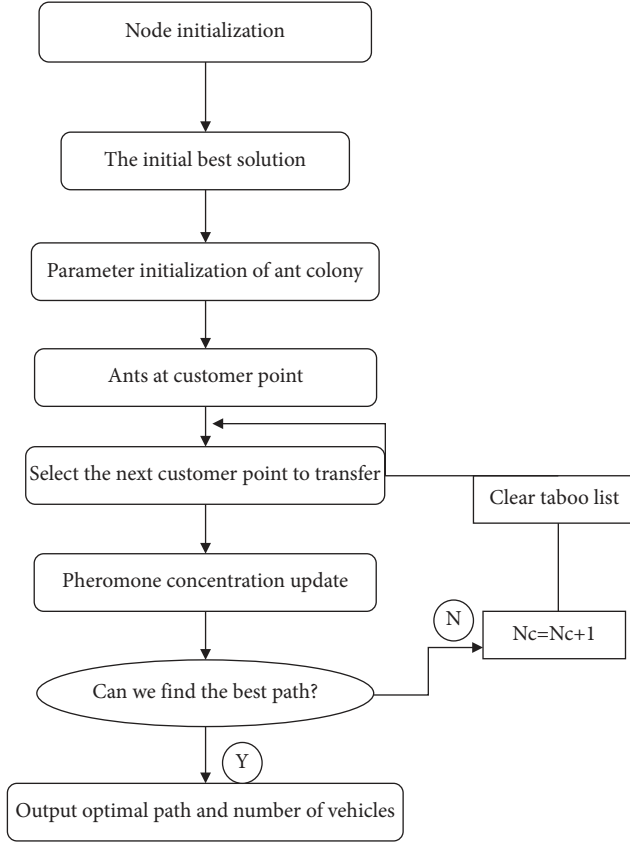


FIGURE 1: Flow chart of vehicle transportation route optimization.

logistics as the origin, set the grid coordinates of the upper left corner as $(0, 0)$ to build a rectangular coordinate system. Suppose the cargo boundary is a , when the size block of 3D reconstruction technology a is regarded as a cell grid and the grid of logistics environment is changed to several small grids; the number of each grid can be described as follows: the number of $\text{ceil}(n/a)$ grids in different columns is described by $\text{cell}(m/a)$, where ceil means upward sorting. Among them, ceil means upward sorting.

Two-dimensional and one-dimensional space structures are used in the storage environment after gridding.

In the process of path planning, according to the requirements of the planning algorithm, the mapping relationship is as follows:

$$\text{bianhao} = (x - 1) \times \text{ceil}(m/a) + y. \quad (13)$$

A local schematic of the simulated logistics environment will be described with reference to Figure 2.

The route planning problem is divided into two parts according to whether the initial point of the logistics vehicle has an exit or not. One of them is that the initial point of logistics vehicles at the time of export is considered as a typical TSP problem. The other is that if the initial point is not at the exit, the end point of the initial point is considered to be an invariant TSP problem, namely, OTPDV problem. The mathematical model of typical TSP problem can be expressed by formula (2) and calculating the best path $P = \{u_1, u_2, \dots, u_k\}$.

$$\min Z(P_\alpha) = \sum_{i=1}^{k-1} d(u_{\alpha_i}, u_{\alpha_{i+1}}) + d(u_{\alpha_1}, u_k). \quad (14)$$

In the formula, $d(u_{\alpha_i}, u_{\alpha_{i+1}})$ is used to describe the Manhattan distance between two points, which is a recombined set of the order of K path points.

If the potential field ant colony algorithm is used to solve the typical TSP problem, all the path points are considered as group individuals and can be the adaptive function selection formula (2). For TSP and OPTPDV, the potential energy field ant colony algorithm can only obtain the best access order of global path points. Instead of path, it cannot meet the requirements of mobile wheeled logistics vehicle volume selection path plan. It is necessary to obtain the accurate global planning path by 3D reconstruction.

In the grid environment, in the process of planning the global path of logistics vehicles through 3D reconstruction technology, set the OPEN table and CLOSE table; during initialization, the initial point is appended to the OPEN table. The current CLOSE table is empty, initial point:

$$f(s) = h(s), \quad (15)$$

where $f(s)$ is the initial point evaluation function. $h(s)$ is used to describe the estimated interval between the initial node and the end point.

OPEN table is empty, stop searching when there is no target location, and there is no valid path. On the contrary, when the OPEN table is empty, repeat the following steps before obtaining the target node:

- (1) Select the node with small f value in the OPEN table to add to the CLOSE table and delete the corresponding value of the OPEN table. Suppose that the node with the smallest f value of the adjacent nodes of the initial point is q , then the initial point is considered as the parent node.
- (2) Calculate all the adjacent nodes of the current point p , assuming that the adjacent nodes are used for illustration, and then calculate the $f(u_i)$, $h(u_i)$, and $g(u_i)$; here, in order to explain the interval between the selection point and the object node, $g(u_i)$ makes the following determination:
 - (1) If it is the terminal station, the point can be skipped. Take the terminal point as the starting point u_i and trace back to the initial point from the parent node to obtain the shortest route selected for the batch of logistics vehicles
 - (2) If u_i is an inaccessible point, skip the point
 - (3) If u_i is in the CLOSE table, skip the point
 - (4) If u_i is not in either of the OPEN table or the CLOSE table, it will be added to the OPEN table as the parent node of u_i
 - (5) If u_i is in the OPEN table, find out the g value of the new path and judge whether it is the smallest. If so, P is the parent node of u_i , and update F , h , and g at the same time. On the contrary, no change is made.

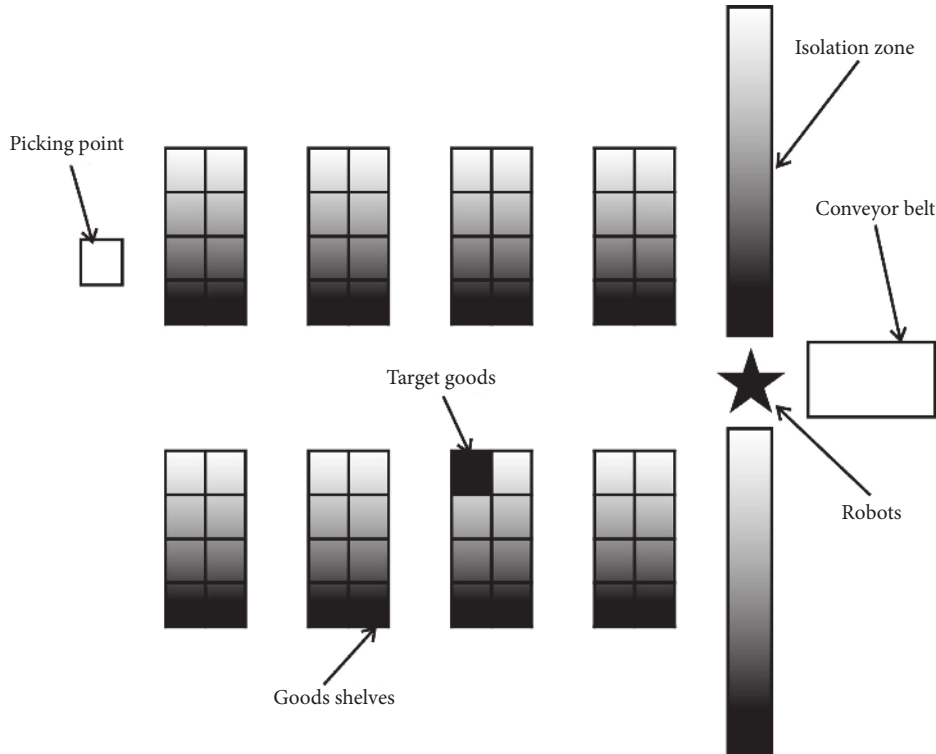


FIGURE 2: Partial schematic diagram of simulated transportation road.

- (3) The search track is saved and the parent node is used to trace back to the initial point.

5. Simulation Research

5.1. *Dataset.* Modern logistics mobile vehicles can replace people for heavy and complex work, improve people’s work efficiency to some extent, and reduce labor costs. In addition, it can continuously increase the economic benefits of different industries. During the practical application of modern logistics mobile vehicles, how to choose a reasonable and scientific path has gradually become the key technology in this field. At present, in most cases, the path planning of logistics mobile vehicles is based on traditional methods, but the path planning of logistics mobile vehicles include natural language and the path planning of logistics mobile vehicles based on artificial factory method.

There are 20 delivery vehicles in the distribution center of a modern logistics company. The maximum load of each vehicle is 10 tons. At the same time, they need to serve 25 customers. The basic information of the guests is shown in Table 1.

5.2. *Simulation Platform and Parameter Setting.* The simulation platform is as follows: CPU is 2.8GMHz, memory is 2 GB, operating system is Windows 2000, VB6.0 programming language environment. Parameters of hybrid tabu search algorithm: the number of ants is $20\alpha=1, \beta=1.5, a=0.3, b=0.7$, maximum number of iterations 1000, and $\rho=0.6$.

TABLE 1: Basic information of customers.

Customer number	Coordinate	Cargo transportation volume (ton)
0	(14, 13)	—
1	(12, 9)	1.7
2	(18.1, 3.4)	1.5
3	(15.5, 16.6)	2.1
4	(19.2, 15)	2.2
5	(15.2, 11.4)	1
6	(9.6, 7.3)	2.5
...
25	(19, 7.1)	2.6

5.3. Experimental Results and Analysis

- (1) In this paper, the optimal distribution vehicle transportation path of the algorithm is proposed.

When the hybrid tabu search algorithm is used to solve the transmission path of the optimal distribution vehicle, if the algorithm is repeated 280 times, the optimal solution of the problem is found, and the length of the optimal transmission path is 164. The results are shown in Figure 3. It can be seen that the algorithm in this paper is an effective optimization method for distribution vehicles.

- (2) The results are compared with other optimization algorithms.

In order to further verify the superiority of the optimization algorithm, the genetic algorithm and simulated annealing algorithm are used for comparative experiments.

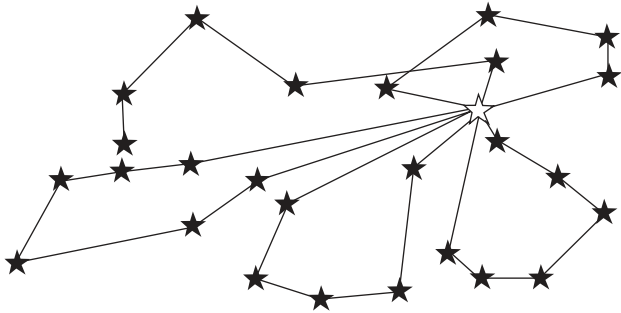


FIGURE 3: Optimal transportation path of distribution vehicles.

TABLE 2: performance comparison of various algorithms.

Algorithm	Success rate (%)	Optimization time (s)	Optimal transport path length (cm)
Genetic algorithm	64	50	180.13
Simulated annealing algorithm	77	45	170.51
Hybrid tabu search algorithm	97	20	165

Each algorithm is executed 10 times, and the average value of the calculation results is compared with the algorithm, and the results are shown in Table 2. Here, it is found that the optimal transmission path of transport vehicle based on hybrid tabu search algorithm is the shortest. Do not use too many vehicles and empty vehicles. So, cut costs. At the same time, the speed of finding the optimal solution is the fastest, and the number of success is the most, which can improve the transportation efficiency and economic benefits of modern logistics enterprises to a certain extent. The results show that the transportation path optimization algorithm based on hybrid tabu search algorithm is in line with the real-time and rapid characteristics of modern logistics enterprises, and it is an effective transportation path optimization method for modern logistics distribution vehicles.

6. Conclusions

The key to improve the current logistics economic benefits is to make a reasonable planning for the transportation path of vehicles in the current logistics transportation system. This paper studies the transportation path problem of distribution vehicles in the current logistics. In the face of the existing situation, it is more reasonable to use the hybrid tabu search method, which has the advantage of high efficiency. This calculation method not only improves the optimization efficiency but also has fast efficiency, which is applied to the current logistics distribution vehicle transportation path optimization.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

This research study was sponsored by Chongqing Vocational College of Transportation. This paper is published for the conclusion of the project Study on Layout Optimization of Energy Replenishment Facilities for Electric Vehicles, project no. CJSK201916. The authors thank the project for supporting this paper.

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