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The Research on Vehicle Routing Plan for Road Mainline LTL Logistics

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Abstract

The current highway trunk freight information platform for the shipper mainly provides the "information integration" function, and does not provide path planning functions for the carrier of road freight LTL transport.In combination with the actual road mainline freight transport network, vehicles are often distributed in several multi-car yards. Each yard has a variety of vehicle types. And there is a one-to-one correspondence between pick-up points and delivery points in the freight transport network.Therefore, based on the above background, a mathematical model for vehicle route planning with the minimum total transport cost as the objective function is established.Then the corresponding genetic algorithm is designed to solve the model.Finally, the validity and feasibility of the model and algorithms are verified with case studies.

Keywords

Multiple car parks;Multiple vehicle types;Genetic algorithm.

1. Introduction

With the increasing popularity of the Internet and the promotion of mobile smart devices, more and more Internet companies are entering the road trunk distribution industry.This has facilitated the integration of the Internet and the mainline road freight transport industry and improved the level of information technology in freight distribution.However, the information platform only provides the integration of freight information resources, which on the one hand is not conducive to the overall reduction of logistics and distribution costs, and on the other hand does not improve the core competitiveness of the information platform, which is conducive to the sustainable development of the information platform.

Numerous scholars have done a lot of research on road mainline LTL logistics transport.Dai[1] et al. solved the problem of coordinated transport between multiple carriers and shippers using Lagrangian relaxation methods.Xin[2] et al. studied how co-distribution between multiple small and medium-sized carriers can improve distribution efficiency and reduce transport costs when the capacity of carriers is limited.Li[3] divided the vehicle and cargo matching indicator system into hard matching indicators and soft matching indicators, and established a post-trade reputation evaluation model and a multi-objective matching ranking model for vehicle and cargo supply and demand.Huang[4] addresses the shortcomings in the Dang Freight App product and improves the design of the order management module, driver task module and message pushing module in the platform so as to improve the user experience.Guo[5] established a multi-indicator linguistic evaluation system for both the vehicle source side and the cargo source side, and used the fuzzy group decision method with the highest overall mutual satisfaction between the vehicle source side and the cargo source side to establish a link between the right vehicle and the matching cargo source.Wang[6] addresses the shortcomings

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of current freight delivery platforms and provides a number of references for the optimization of information platforms.Bing[7] developed a trunk road vehicle path planning model with distribution cost minization as the objective function, and solved the model using an improved particle swarm algorithm.Li[8] and Tong[9] et al. constructed a vehicle routing plan model for LTL freight of single-vehicle type and designed the corresponding heuristic algorithm to solve the model.

From the above literature, it can be seen that the increasing popularity of Internet information has promoted many scholars to conduct detailed research on the development and design of logistics information platforms and distribution models.With the gradual maturity and development of logistics information platforms, scholars have gradually launched extensive research on the issue of vehicle routing plan for highway mainline LTL logistics.However, there is still relatively little research on this issue.In this context, this paper establishes a vehicle routing plan model for multiple vehicle types in multiple yards based on highway mainline LTL logistics.Finally, the validity and feasibility of the model and algorithms are verified with case studies.

2. Problem Description

The trunk road transport problem studied in this paper can be described as follows: a distribution network consists of a number of pairs of pick-up points and their corresponding delivery points, as well as a number of depots. After the vehicle departs from the yard, it picks up the goods at each pick-up point in turn, and then delivers the goods from the pick-up points to the corresponding delivery points in turn. Alternatively the vehicle delivery process can be described as collecting goods first and then delivering them. The specific process is shown in Figure 1. A vehicle of vehicle type I from yard A picks up the goods at pick-up point 1 and pick-up point 4, then delivers the goods to the corresponding delivery point 7, then picks up the goods at pick-up point 6, and finally delivers the goods at delivery point 12 and delivery point 10, where the vehicle stays at the last delivery point at the end of the service; a vehicle of vehicle type II from yard A picks up the goods at pick-up point 2, then unloads the goods at delivery point 8; a vehicle of vehicle type III from yard B picks up the goods at pick-up point 3 and pick-up point 5, then unloads the goods at delivery point 11 and delivery point 9. A vehicle of vehicle type III from yard B picks up at pick-up point 3 and pick-up point 5 and then unloads at delivery point 11 and delivery point 9. Where the vehicle stops at the last delivery point after completing the delivery.

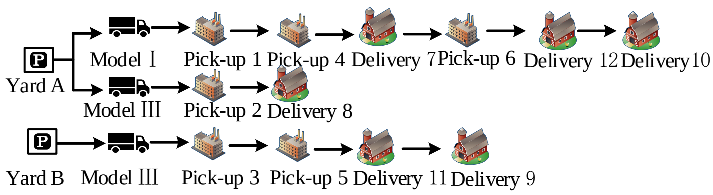

Fig.1 Schematic diagram of the vehicle delivery process

3. Modeling

3.1. Assumptions of model

(1)Each supplier has a one-to-one corresponding receiver, and the amount of goods transported between each supplier and receiver shall not exceed the rated load of any vehicle.

(2)No less than 1 pair of pickup and delivery points per vehicle service.

(3)Each supplier and recipient can only be served by one vehicle.

(4)The types of vehicles in the car park are not identical.

3.2. Description of symbols

The symbol $B_1=\{1,2,\ldots,n\}$ represents the set of shippers.The symbol $B_2=\{n+1,n+2,\ldots,2n\}$ represents the collection of receivers corresponding to the sender.The symbol $O=\{2n+1,2n+2,\ldots,2n+r\}$ represents the set of vehicle starting positions.The symbol $K=\{2n+1,2n+2,\ldots,2n+r\}$ represents the set of vehicle numbers.The symbol $B=B_1\cup B_2$ represents the set of sender and receiver nodes.The symbol $U=B\cup O$ denotes the set representing all nodes.The symbol P_k represents the calling cost of vehicle k;The symbol Z_k represents the driving cost per unit distance of vehicle k.The symbol Q_k represents the rated load of vehicle k.The symbol Q_{ki} represents the load of vehicle k when it reaches node i.The symbol T_{ki} represents the time when vehicle k arrives at node i.The symbol ST_i represents the loading or unloading time of the vehicle at node i.The symbol d_{ij} represents the distance between nodes.The symbol LT_i represents the latest arrival time accepted by nodes.The symbol β represents the penalty cost per unit time for the vehicle to arrive late.The symbol x_{ijk} is 1 when the vehicle goes from node to node, otherwise the symbol x_{ijk} is 0;

3.3. Building the model

$$Z=\sum_{k\in K}\sum_{j\in G_1}\sum_{i\in K}x_{ijk}\cdot P_k+\sum_{k\in K}\sum_{i\in U}\sum_{j\in U}Z_k\cdot x_{ijk}\cdot d_{ij}+\sum_{k\in K}\sum_{i\in B}\beta\cdot\max(T_{ki}-LT_i,0) \quad (1)$$

$$Q_{ik}\le Q_k \quad \forall k\in K, i\in B_1 \quad (2)$$

$$\sum_{i\in B_1\cup O}x_{ijk}=\sum_{l\in B}x_{l(j+n)k} \quad \forall k\in K, j\in B_1 \quad (3)$$

$$T_{kj}=\sum_{k\in K}\sum_{i\in U}x_{ijk}(d_{ij}/V+ST_i+T_{ki}) \;\; \forall j\in B \quad (4)$$

$$T_{ki}<T_{k(i+n)} \; i\in B_1 \quad (5)$$

$$\sum_{k\in K}\sum_{i\in B\cup O}\mathrm{x}_{ijk}=1\,\forall j\in B_1 \quad (6)$$

$$\sum_{k\in K}\sum_{i\in B}\mathrm{x}_{ijk}=1\,\forall j\in B_2 \quad (7)$$

$$\mathrm{x}_{ijk}, y_{ik}\in\{0,1\} \quad \forall i,j\in O, k\in K \quad (8)$$

The equation (1) represents the objective function of the model, and the total delivery cost includes the vehicle calling cost, the vehicle running cost and the time penalty cost. The equation (2) indicates that when the vehicle reaches any node, the weight of the cargo carried is less than the rated load of the vehicle. The equation (3) indicates that the same vehicle delivers the supplier's goods to the corresponding receiver. The equation (4) represents the time when vehicle k arrives at any pickup or delivery node. The equation (5) means that the vehicle visits the pickup point before visiting the delivery point. The equations (6)-(7) indicate that each node must be visited and can only be visited once. The equation (8) indicates that the decision variables are 0, 1 variables.

4. Algorithm Design

4.1. Coding

There are n pickup points in the distribution network, n corresponding delivery points and r vehicles of different types.In the individual, the pickup point number is $1,2,\ldots n$, the delivery point number is $n+1,n+2,\ldots 2n$, and the vehicle serial number is $2n+1,2n+2,\ldots 2n+r$. The population of individuals is N.

4.2. Initialization of the population

(1) Randomly select a vehicle from all vehicles in the delivery network as the current delivery vehicle. (2) A pick-up point is randomly selected from the pick-up queue set, and the pick-up point and its corresponding delivery point are added to the back of the vehicle code to form a delivery sequence of the vehicle. (3) Repeat steps (1) and (2) until the collection of pickup queues and the collection of delivery queues are empty. (4) Add the redundant vehicles in the vehicle queue to the end of the individual to ensure that the length of the individual is consistent. (5) According to the sequence of vehicle number, each individual is converted from an array structure to a linked list structure, and decomposed into chromosomal gene segments.The schematic diagram of the initialization result is shown in Figure 2.

21	1	7	4	10	6	12
22	2	8				
23	3	9	5	11		

Fig.2 Schematic diagram of initialization

4.3. Calculation of adaptation

In the genetic algorithm, the fitness function reflects the degree of the individual's pros and cons, so as to select the individual to survive the fittest. Since the mathematical model established in this paper is a minimum optimization problem, the fitness value of the individual is inversely proportional to the performance of the individual. Therefore, the fitness function of the individual is represented by the formula $fit(x_i)=1/C(x_i)$, and the variable $C(x_i)$ in the formula x_i represents the objective function of the individual.

4.4. Individual selection

Roulette selection is performed on the population composed of the current parent individuals, and N individuals are selected for crossover and mutation to obtain the next generation of individuals.

4.5. Crossover

(1) Randomly select an integer x from the vehicle number $2n+1, 2n+2, \ldots 2n+r$.(2)The chromosome segment x selected from individual A and individual B is recorded as x_A and x_B , respectively, and then the content of the chromosome gene segment is exchanged.(3)Delete the genes that are duplicated in other gene segments and chromosome gene segment x in individual A.(4)Delete the genes that are duplicated in other gene segments and chromosome gene segment x in individual B.(5) The genes deleted in individual A and individual B are denoted as sets a and b, respectively. The pickup points in set A and their corresponding delivery points are sequentially inserted into the positions of individual A that satisfy the model constraints by using the method of greedy insertion of costs[10]. (6) Similarly, the missing genes in individual B after crossover are supplemented according to the same operation[11,12].

4.6. Variation.

A single-point mutation operation is performed on the gene segment corresponding to each vehicle in the individual. A pair of pick-up points and corresponding delivery points are randomly selected from the chromosome gene segment corresponding to each vehicle, and then the pair of pick-up points and delivery points are re-randomly inserted into the chromosome gene segment that satisfies the model constraints.

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4.7. Retention of the optimal solution

In order to ensure that the optimal individual in the offspring is better than the optimal individual in the parent, the strategy of retaining the optimal solution is used. When the fitness value of the optimal individual in the offspring obtained after the genetic operation is not as good as the fitness value of the optimal individual in the parent generation, the worst individual in the offspring obtained after crossover mutation is replaced by the optimal individual in the parent generation.

4.8. Termination Strategy

When the number of iterations does not reach the specified number of iterations, the genetic operation is continued, otherwise the vehicle path planning result corresponding to the optimal individual in the last generation of the population is output.

5. Case Study

A highway distribution network consists of 15 pairs of pick-up points and corresponding delivery points, as well as 12 vehicles of 3 types of vehicles. The pickup point information is shown in Table 1, the delivery point information is shown in Table 2, and the vehicle information is shown in Table 3. In addition, the customer's time penalty cost is 5 yuan/H.Vehicles depart from the parking lot at 6:00.

The algorithm parameters are set as follows: the maximum number of iterations is 150, the population size is 50, the crossover probability is 0.9, and the mutation probability is 0.2. The iterative process of the algorithm is shown in Figure 3, and the optimal vehicle path planning is obtained as shown in Table 4.

According to the location information of pick-up point, delivery point and vehicle in Table 1, Table 2 and Table 3, the latitude and longitude coordinates of each node a in the delivery network can be obtained. Calculate the distance between any two nodes according to formulas[13] (9) and (10).In the formula, R_r represents that the radius of the earth is 6378.137km.

$$D_{ij} = 2 \cdot R_r \cdot \sqrt{\sin^2(\frac{\pi}{180} \cdot X') + \cos(\frac{\pi}{180} \cdot X_i) \cdot \cos(\frac{\pi}{180} \cdot X_j) \cdot \sin^2(\frac{\pi}{180} \cdot Y')} \tag{9}$$

$$X' = \frac{x_i - x_j}{2}, \quad Y' = \frac{y_i - y_j}{2} \tag{10}$$

Tab.1 Information of pick-up point

No.	Abscissa	Ordinate	LT_i	Quantity of supply	ST_i
1	112.821970	34.160108	7.5	7.5	2.20
2	113.454377	34.152460	8.5	8.5	2.60
3	113.072633	34.373953	9	6	1.80
4	113.376189	34.541589	10	9	3.60
5	112.810472	34.743063	11.5	3	0.90
6	113.026640	34.769636	8	8	2.90
7	113.353192	34.796200	11.5	11.5	3.50
8	112.980647	34.309094	13.5	6.5	2.30
9	112.842667	34.568227	9.5	7.5	2.00
10	113.215212	34.655692	10.5	8	1.60

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11	113.017441	34.282372	12.5	3.5	1.20
12	113.353192	34.339622	12	8.5	2.00
13	113.275004	34.431140	13.5	8	1.50
14	112.888660	34.495904	14	8	1.90
15	113.495771	34.389207	11	9	2.60

Tab.2 Information of delivery point

No.	Abscissa	Ordinate	LT_i	Quantity of demand	ST_i
16	114.366481	38.082590	22	7.5	2.20
17	115.014985	38.526571	20.5	8.5	2.60
18	115.585302	38.004384	21	6	1.80
19	115.589901	38.004384	22	9	3.60
20	114.987389	38.191573	23.5	3	0.90
21	115.192059	37.946130	20	8	2.90
22	115.656591	37.756482	23.5	11.5	3.50
23	115.382931	38.098948	25.5	6.5	2.30
24	115.104672	38.115302	21.5	7.5	2.00
No.	Abscissa	Ordinate	LT_i	Quantity of demand	ST_i
25	115.396729	38.314889	22.5	8	1.60
26	114.968992	38.314889	24.5	3.5	1.20
27	114.727528	38.133469	24	8.5	2.00
28	115.031083	38.082590	25.5	8	1.50
29	115.226554	38.521152	26	8	1.90
30	115.318541	38.267764	23	9	2.60

Tab.3 Information of vehicle

No.	Yard	Abscissa	Ordinate	Load rating	Cost of per kilometer	Invocation cost
31	A	112.757867	34.42179	13	5	300
32	A	112.757867	34.42179	18	7	500
33	A	112.757867	34.42179	18	7	500
34	B	112.851606	34.592938	25	9	800
35	B	112.851606	34.592938	25	9	800
36	B	112.851606	34.592938	18	7	500
37	C	113.007983	34.428264	25	9	800
38	C	113.007983	34.428264	13	5	300
39	C	113.007983	34.428264	25	9	800

Tab.4 Best vehicle routeing plan

Route	Total cost
31→7→22	2093.56
32→1→9→5→16→20→24	2954.06
33→14→13→28→29	2912.35
35→6→10→15→21→30→25	4016.29

36→12→2→27→17	2867.67
39→8→11→3→4→26→23→18→19	4193.15

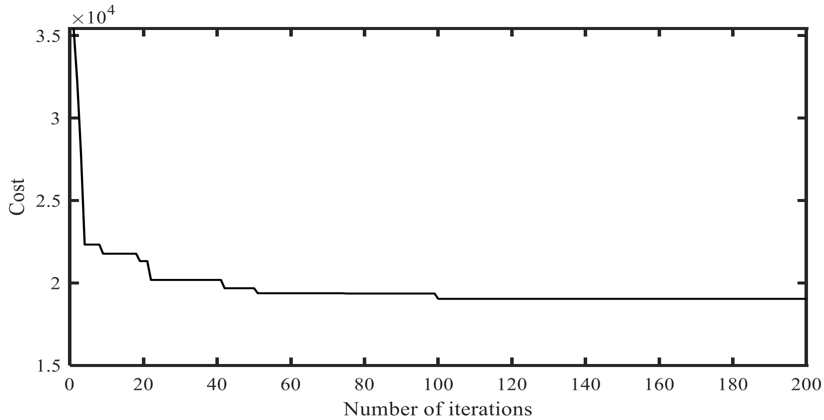

Fig.3 Schematic diagram of genetic algorithm iteration

6. Conclusion

Based on the actual background of LTL freight distribution under the information platform, this paper establishes a LTL transportation model with the goal of minimizing the transportation cost. Considering the characteristics of the correspondence between the pickup point and the delivery point, the vehicles have various types in the LTL transport model of the highway trunk line. Genetic manipulation of individuals using single-strand coding is highly destructive and may easily lead to invalid solutions. Therefore, the multi-chromosomal genetic algorithm is used to solve the model. Finally, by solving the model, the validity and feasibility of the model and the multi-chromosomal genetic algorithm are verified.

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