Research on the unfull-load vehicle logistics transportation scheduling problem based on genetic algorithm

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Abstract. Collaborative logistics transportation is the development trend of modern logistics mode, while in the collaborative transportation process is not fully loaded vehicle, this problem is a NP-hard problem. Based on the related constraints logistics transportation and logistics based on the established model, distribution of profit driven, designs the distribution task allocation algorithm based on genetic algorithm, an example is given to show the results of solving the model can increase the logistics distribution profit goal, thus verified the model's correctness and rationality.

Keywords: Collaborative Transportation; Genetic Algorithm; unfull-load.

1. Introduction

Collaborative logistics transportation is through the sharing of logistics information and transportation resources from logistics enterprises, which makes the logistics enterprises to share the transport task. So as to improve the objective of the utilization of logistics resources, reducing logistics costs, improving logistics efficiency and service level. Essentially, collaborative logistics transportation belongs to the multi-depot pick and delivery problem (MDPDP) [1]. But in the actual transport process, the more transport vehicle cooperative problem is non-fully loaded vehicle cooperative problem, so the study of this problem has strongly practical significance and theory value.

At home and abroad, optimal scheduling problem of logistics vehicles is attributed to VSP or VRP. It was first proposed in 1959 by Danting and Ramser and received extensive attention subsequently. Until now, it is still hot research problem in operations research and combinatorial optimization field [2-4]. The problem is defined as: for a set of loading and unloading points, organize appropriate travel way, to make vehicles pass through them orderly. To achieve a certain goal like the shortest distance, the least cost, use less time and vehicle as far as possible in satisfying certain constraints conditions such as the inventory, shipments, shipping time, mileage limit, time limit. Vehicle scheduling problem is a NP-hard problem, it is difficult to get the global optimal solution or satisfactory solution. At present, it is mostly using the heuristic algorithm to solve this problem. But most of the researches will focus on vehicle routing at least, less time consuming and so on. For example, Desrosiers [5] studied the problem from two yards to the multi-point transport under full load. Savelsbergh [6] established the PDP model and algorithm for non-full load conditions. Currie[7] solved multi depot full transportation problem using greedy algorithm. Liu Ran[1] got the optimal solution for the multi depot full transportation problem through the two phase heuristic algorithm. Frizzell P W[8] studied the velopark with time window constraints of non-loaded vehicle scheduling problem. But the research on the collaborative logistics between business and why logistics business would cooperate with each other forwardly from the angle of logistics business profit is a few. And between different logistics providers are mostly multi Depot, the process of transportation are mostly non full load. So it has current significance that this paper focuses on the study of the multi depot vehicle scheduling problem with non-full load of collaborative logistics.

In this paper, from the angle of logistics business profit, we established mathematical model in order to meet the task of transportation logistics business profit maximization, and used genetic algorithm to solve the problem of heavy transport task allocation. Finally, we proved the correctness and rationality of the model by an example.

2. Problem description and mathematical model

Collaborative transportation problem is that to complete a number of logistics transport tasks through the sharing of information and resources between multiple logistics business. The vehicle departure of every logistics company may be different, the shipment points may be different, transportation lines may have intersection, and delivery place may have more than one transportation after the arrival of the first distribution locations has become a full load in the transport vehicle. So for the logistics vehicles which need long distance transportation and multi unloading, it is the focus of this paper that how to make the logistics business to realize collaborative transportation. Therefore this paper's target for the problem is to make all logistics business get the greatest benefit under ensuring the timely delivery of goods.

Auto parts distribution, for example. There are multiple parts center need to transport goods to multiple locations of customers through a number of logistics business.

For this problem, we make the following settings:

The transport task is determined by the accessories Center, and it would not change after being assigned to logistics business.

Logistics have the ability to complete a delivery task that parts center issued.

Transport vehicles can carry more goods of different places, and in the process of transportation, they would be non-full load in transit in a certain period of time.

Only in the case that logistics have good prospects of gain, they and other logistics business will go with the collaborative transportation.

This paper only study on one way loading transport, the farthest point which vehicle arrives at is the last of its transport customer.

Every customer can load and unload goods, here we do not consider the time delay of loading and unloading.

We set that after vehicles complete the transport task assigned initially, they would return without goods.

We assume that the distance between distribution centers is far away, and we don't consider the allocation between distribution center.Based on the above described, we make the following definitions:

There are n (1,2,3...) parts center and $T=\{T_1,T_2,...,T_m\}, m\geq 1$ transport task set. T_i Is the distribution of tasks set of the i parts center. At the same time task set T_i can be further decomposed into sub tasks. $Sub(T_i)=\{Sub(T_i,1),Sub(T_i,2),...,Sub(T_i,Q(T_i))\}$ Among them, $Q(T_i)$ represents that the number of tasks which T_i can be resolved.If the transport task T_i be delivered to the logistics business A to complete, and the logistics business A has the ability to complete the task, then we use sets $Cr(T)=\{Cr(T_1),Cr(T_2),...,Cr(T_m)\}$ to express. The logistics business A uses the vehicle k to accomplish a mission (T_i,q), then we use a variable quantity $x^k_{(T_i,q)}=1$ to show, or else it is 0. (T_i,q) represents the q subtask of the task sets T_i, if this mission be accomplish by logistics business A with vehicle k and logistics business B with vehicle f synergistically, we will use $\begin{cases} x^k_{(T_i,1)}=1 \\ x^f_{(T_i,2)}=1 \end{cases}$ to show that.

If after vehicle k completed the task (T_i,q) it also completed the task (T_j,p), then $y^k_{(T_i,q)(T_j,p)}=1$. We define that $d_{(T_i,q)}$ is the transport mileage the task required, $g_{(T_i,q)}$ is the sum of the weight of goods and the weight of the vehicle transport, $p_{(T_i,q)}$ is the transport price of the task and

$p_{(T_i,q)} = \alpha \times d_{(T_i,q)} \times g_{(T_i,q)}$. The α is the weight of price. It's objective to make logistics business get the most profit without affecting the traffic conditions.

The following is the mathematical model:

The Objective function:

$$\max(z) = \sum_{i=1}^{m} \sum_{q=1}^{Q(T_i)} \sum_{k=1}^{n} (p_{(T_i,q)} - \rho \times d_{(T_i,q)} \times g_{(T_i,q)}) \tag{1}$$

The constraint conditions:

$$\sum_{i=1}^{m} \sum_{k=1}^{V} x_{(T_i,q)}^{k} \geq \left[\frac{\sum_{i=1}^{m} g_{(T_i,q)}}{W} \right] + 1 \tag{2}$$

$$\begin{cases} x_{(T_i,q)}^{k} = 1 & p_{(T_i,q)} > \rho \times d_{(T_i,q)} \times g_{(T_i,q)}) \\ x_{(T_i,q)}^{k} = 0 & p_{(T_i,q)} \leq \rho \times d_{(T_i,q)} \times g_{(T_i,q)}) \end{cases} \tag{3}$$

$$W_k \geq \sum_{i \in m} g_{(T_i)} \tag{4}$$

$$\begin{cases} x_{(T_i,q)}^{k} \geq (\sum y_{(T_i,q)(T_j,p)}^{k} + \sum y_{(T_j,p)(T_i,q)}^{k})/2 \\ x_{(T_i,q)}^{k} - 0.5 \geq \sum y_{(T_i,q)(T_j,p)}^{k} + \sum y_{(T_j,p)(T_i,q)}^{k} \end{cases} \tag{5}$$

$$\sum_{j=1}^{m} x_{(T_i,q)}^{j} = Q(T_i) \quad q \in [1, Q(T_i)] \tag{6}$$

In the above model, formula (1) show that all logistics business get the maximum profits by completing tasks, ρ is the parameter to control losses, it's value is 0.005; formula (2) show that each task must be accomplish. Symbol [] represents the maximum integer value in the values in brackets. W is the vehicle load, V is the total number of vehicle required; formula (3) show that only when the task profit is more than the loss, there will be some logistics company vehicles to bear the transportation task; formula (4) limits that the total weight of each car's transport task can't exceed the vehicle payload. In the distribution of the actual process, there are many actually happened or constraints to consider; formula (5) ensures that the completed tasks of each car is sequenced, and is sequentially complete. Formula (6) ensures that a car only take part in once in a task's subtasks, $Q(T_i)$ is the number of sub tasks decomposed from the task.

3. Algorithm design

Collaborative transportation problem can be viewed as the coordination between logistics enterprises or between distribution center, and the Collaborative Vehicle Routing Problem related to it. While the heuristic algorithm has been used by many scholars to solute this problem in VRP NP-hard and have obtained good results. Therefore this paper uses the genetic algorithm to solve the CVRP problem.

3.1. Chromosome code

In the genetic algorithm, the solution can be expressed by a string, so there are a lot of ways to code, such as binary code, the natural number coding and so on. Here we constructed the following chromosome coding to solve the corresponding problem we need to. Suppose that there are M client corresponds to N transport task T_N , these transportation task will be carried by K vehicles C_K . We define that the chromosome matrix is $((sub(T_i,q),...,sub(T_j,p))_{C_1},...,(sub(T_x,q),...,sub(T_y,q))_{C_K})$ .Among them

$i, j, x, y \in [1, N], p, q \in [1, M], M$ represents the number some task can be decomposed. The gene $(sub(T_i, q),..., sub(T_j, p))_{C_K}$ in chromosome indicates that the task vehicle C_K completed is $(sub(T_i, q),..., sub(T_j, p))$.

3.2. Setting the initial chromosome

Here according to the rules of TSP distance from the nearest neighbor heuristic method: Starting from an arbitrary starting point, select the nearest point from it in the unvisited task node as the subsequent node, until this vehicle is full and be replaced or all the nodes are visited over, so then compose the initial solution. This is also the main way that the general manufacturing factory distributes transport tasks for their carrier.

3.3. Fitness function

To solve the constraints mentioned above we use the way of punishment: for example, a solution violates some constraint, give a certain punishment depending on its degree, so some infeasible solutions may also enter the group in order to ensure the diversity of chromosomes. After a certain number of iterations, the infeasible solution accounted for less proportion in the population, so that the solution approaches the optimal solution.

Here according to the principle of making the profit of the logistics business be the maximum, we get the fitness function as follows:

$\max(z) = \sum_{i=1}^{m} \sum_{q=1}^{Q(T_i)} \sum_{k=1}^{n} (p_{(T_i,q)} - \rho \times d_{(T_i,q)} \times g_{(T_i,q)}) - \sum_{i=1}^{4} F_i \times w_i$ Among them, the Fi is the penalty function the constraints formed, being corresponding to the various constraints above, which is the weight of each penalty function, it gets a positive generally. The penalty function is as follows:

$$F_1 = \left\lceil \frac{\sum_{i=1}^{m} g_{(T_i,q)}}{W} \right\rceil - \sum_{i=1}^{m} \sum_{k=1}^{V} x^k_{(T_i,q)} + 1$$

$$F_2 = \sum_{i \in m} g_{(T_i)} - W_k$$

$$F_3 = \sum y^k_{(T_i,q)(T_j,p)} + \sum y^k_{(T_j,p)(T_i,q)}) / 2 - x^k_{(T_i,q)}$$

$$F_4 = \sum y^k_{(T_i,q)(T_j,p)} + \sum y^k_{(T_j,p)(T_i,q)} - (x^k_{(T_i,q)} - 0.5)$$

3.4. Setting the initial chromosome

The chromosome will be decomposed according to the customer point the task passed. For example, the vehicle k of logistics business A bore three tasks (T1,T2,T3), that means logistics business A need to transport for three customers (a,b,c) from factory 0, and the sequence is (0-a-b-c). So we can make the task be divided to subtasks (T1,T(2,1), T(2,2),T(3,1),T(3,2),T(3,3)) according to the driving route, the route corresponding to the task is ((0-a),(0-a),(a-b),(0-a),(a-b),(b-c)). The crossover operation of chromosome will be mainly on the divided subtasks.

3.5. Crossover and mutation

The crossover operation in genetic algorithm is the main way to form the new individuals, which decided the local search ability of genetic algorithm. Mutation operation is the aided method for generating new individuals, which decided the local search ability of genetic algorithm. The chromosome operation which is partheno genetic algorithm this paper stains contains the inserting and exchanging of genes.

(1) Insert. It is that we make some gene of the chromosome (T_j, p) move from a current position i to the other position j. the i and j can belong to the same one gene segment and they also can belong to different gene segments, so then we can produce new chromosomes. For example, we make the task 0

of the solution $s=(\underline{T_0}-T_1-T_3-\underline{T_4}-T_5)_A(\underline{T_2}-T_6-T_7)_B$ move from position 1 to position 4 or position 6, then we get the new solution $s=(T_1-T_3-\underline{T_4}-T_0-T_5)_A(T_2-T_6-T_7)_B$ or $s=(T_1-T_3-T_4-T_5)_A(\underline{T_2}-T_0-T_6-T_7)_B$.

(2) Swap. It is that we make the gene (T_i, p) of the chromosome move from position i to position j and swap the position. The i and j can belong to the same gene segment, and also they can belong to different gene segments, so then we can get new chromosomes. For example, swap the task 4 and task 2 of the solution $s=(T_0-T_1-T_3-\underline{T_4}-T_5)_A(\underline{T_2}-T_6-T_7)_B$, we can form the new solution $s=(T_0-T_1-T_3-T_2-T_5)_A(T_4-T_6-T_7)_B$.

In the traditional genetic algorithm, more mutation probability is random generation, so it is likely to generate a lot of new infeasible solutions, which wastes the calculation time. It is likely to fall into the local optimum to use adaptive manner to adjust the probability. So this paper according to the characteristics of non-full load and collaborative transportation, it mainly considers two aspects, the transportation profit and the vehicle loading.

Transportation profit: if the transportation profit is greater than the threshold M the logistics set, then this task would not be exchanged or be moved; If the task's profit is less than the threshold but greater than 0, then it have a certain probability to be exchanged; If the task's profit is less than 0, it's that the task is not profitable, then it would be certainly exchanged. So the probability of the task moving between gene segments is:

$$f_{p(T_i,q)}=\begin{cases}0,\ p_{(T_i,q)}>M\\ 1-p_{(T_i,q)}/M, 0\le p_{(T_i,q)}\le M\\ 1,\ p_{(T_i,q)}<0\end{cases}$$

Vehicle loading: from the angle of the launching weight of vehicle, for the tasks vehicle C_K completed $(sub(T_i,q),...,sub(T_j,p))$, there is that the load weight of current vehicle is $\sum g(T_i,q)$. So the probability of this gene group's variation is:

$$f_{g(T_i,q)}=1-\frac{\sum g(T_i,q)}{g_{\max}}.$$

It is that if thisvehicle is full load, then it would not be variation, if it is non-full load, then it would be a variation.

Finally, we calculated the probability of each gene's mutation on the chromosome which is

$$f=f_{g(T_i,q)}\times f_{p(T_i,q)}$$

The detailed algorithm process is as follows, the i is the number of iterations, the j is the number of iterations which is continuous and without improvement, max(i) is the maximum number of iterations, max(j) is the maximum number of iterations which is continuous and without improvement:

Step1: Use the nearest neighbor heuristic method to construct the initial chromosomes and decompose that;

Step2: i=1, j=0, calculate the sufficiency;

Step3: According to the initial chromosome, insert and exchange the genes, forming a new chromosome;

Step4: calculate the sufficiency of new chromosome, at the same time i++;

Step5: If the sufficiency of new chromosome is larger than the old, than j=0, otherwise j++;

Step6: Make the chromosome with the currently highest degree of adaptation as the initial chromosome to step to step3 to continue to mutate;

Step7: Until i>max(i) or j>max(j), stop.

4. The results and analysis of an example

We take the distribution of auto parts as an example, suppose that there are three distribution centers (1,2,3), use three logistics providers (A,B,C) to distribute goods to seven customer sites (4,5,6,…,10), among them, the distribution 1 need to distribute to the customer point (4,5,6), the distribution 2 need to distribute to the customer point (5,6,7,8), the distribution point 3 need to distribute to the customer point (7,8,9,10). Take the common 9.6 meters long truck as an example, it weights ten tons or so, its largest load is twenty-five tons. The following table describes the weight of goods and profit which are needed to from every distribution point to every customer point:

Table 1 Weight between sites

Weight	4	5	6	7	8	9	10
1	15	8	2	-	-	-	-
2	-	6	6	5	3	-	-
3				3	4	8	2

So the initial task chromosome is $s = (4-5-6)_1(5-6-7-8)_2(7-8-9-10)_3$.

After being distributed, the task chromosome is:

$s = (T_1, T_{2,1}, T_{2,2}, T_{3,1}, T_{3,2}, T_{3,3})_1(T_4, T_{5,1}, T_{5,2}, T_{6,1}, T_{6,2}, T_{6,3}, T_{7,1}, T_{7,2}, T_{7,3}, T_{7,4})_2$

$(T_8, T_{9,1}, T_{9,2}, T_{10,1}, T_{10,2}, T_{11,1}, T_{11,2}, T_{11,3}, T_{12,1}, T_{12,2}, T_{12,3}, T_{12,4})_3$. The corresponding path is

$(1-4,1-4,4-5,1-4,4-5,5-6)_1(2-5,2-5,5-6,2-5,5-6,6-7,2-5,5-6,6-7,7-8,)_2$

$(3-7,3-7,7-6,3-7,7-8,3-7,7-8,8-9,3-7,7-8,8-9,9-10)_3$ The distance between the sites is shown in the following table:

Table 2 Distance between sites

	1	2	3	4	5	6	7	8	9	10
1	-	2000	4000	500	1000	2500	3000	3500	4000	4500
2		-	2000	1700	1200	2700	3200	3700	4200	4700
3			-	3000	2500	1000	500	1000	1500	2000
4				-	500	2000	2500	3000	3500	4000
5					-	1500	2000	2500	3000	3500
6						-	500	1000	1500	2000
7							-	500	1000	1500
8								-	500	1000
9									-	500
10										-

According to the table of distance, we calculate the transportation profit of this path, it is (1550, 2090, 2400), make that $\alpha = 3$ $\rho = 1$.

Use C# to program the verification algorithm, we suppose that the maximum number of iterations is twenty, the maximum number of iterations which is continuous and without improvement is eight. The calculation result is:

$s = (T_1, T_{2,1}, T_{2,2}, T_{3,1}, T_{3,2})_1(T_4, T_{3,3}, T_{5,1}, T_{5,2}, T_{6,1}, T_{6,2}, T_{6,3}, T_{7,1}, T_{7,2}, T_{7,3}, T_{9,1})_2$ $(T_8, T_{7,4}, T_{9,2}, T_{10,1}, T_{10,2}, T_{11,1}, T_{11,2}, T_{11,3}, T_{12,1}, T_{12,2}, T_{12,3}, T_{12,4})_3$

This solution gives the task $T_{3,2}$ of the logistics business which is responsible for the distribution center 1 to the logistics business which is responsible for the distribution center 2 to complete. Exchange the task $T_{7,4}$ of the logistics business which is responsible for the distribution center 2 with the task $T_{9,1}$ of the logistics business which is responsible for the distribution center 3. Now the transportation profit of this path is (2100, 2380, 2600). At this time the task solution with variation is better than the previous solution for every logistics company. So it is easily to reach a collaborative contract between logistic company driven by profit.

5. Summary

This paper is in the condition of that the distribution task is certain and it will return empty after completing the initial distributed task, we designed the non-fully loaded vehicle logistics collaborative model driven by the profits of distribution. By adjusting the distribution task to improve the profit of distribution, reduce the loss of logistics companies in the distribution process, in order to achieve "win-win". And we proved that the collaborative transportation can increase the profit of distribution transportation. This laid the foundation for the logistics business to establish a strategic alliance, thus unified price, share the market, to improve the level of information and management and get more profit. This paper don't consider the constraints such as the distribution of benefits of joint distribution among logistics companies and the transporting time, the vehicle loading and unloading time and the vehicle's waiting time for loading and unloading. These are the direction of next research.

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