City Freight Intelligent Scheduling Model Based on Genetic Algorithm

Shao Sai
School of Traffic and Transportation
Beijing Jiaotong University
Beijing, China
shaosai1218@126.com

Huang Ailing[*]
School of Traffic and Transportation
Beijing Jiaotong University
Beijing, China
alhuang@bjtu.edu.cn

Liu Haijun
Beijing Xinzhongyuan New Energy Logistics Co. Ltd
Beijing, China
13910121305@qq.com

***Abstract*—In this paper, many similar freight demand in urban area are firstly collaborated and mixed in terms of freight classification rules. And then, with the consideration of vehicle utilization and customer logistics cost, the paper proposes a city freight intelligent scheduling model which simultaneously solve two problems of freight load and path optimization. Each customer requires the freights to be picked up and delivered by the same vehicle within a given time window. At last, the model is solved by Genetic Algorithm. A study case is introduced to show the results. The results provide a set of distribution scheme including load plan, pickup plan and delivery plan.**

Keywords- City freight intelligent scheduling; Freight load; Path optimization; Genetic algorithm

I. INTRODUCTION

With development of logistics, the object of freight scheduling with high service quality, low logistics cost and economical source is recently paid attention. Freight scheduling is similar to vehicle routing problem with backhauls (VRPB) in which each customer has simultaneous pick-up and delivery demand to be satisfied, and each vehicle must complete pick-up before starting delivery. Comparing to a pure delivery or pick-up problem which ignores the simultaneous presence of deliveries and pick-ups, VRPB is more suitable for such situations occurring frequently in school buses, express delivery, grocery freight distribution and so on. VRPB has been paid much attention and solved by many approximation algorithms because VRPB is NP-hard. [1] applied an approximation algorithm to solve VRPB. [2] proposed a exact algorithm combining integer linear programming model with Lagrangian lower bound to settle VRPB in computational test with 100 customers. In [3], the situation that all customers are just served exactly once is not restricted. Moreover, an insertion-type heuristic is present for VRPB. In addition, time windows are sometimes possibly added in VRPB to become VRP with Time Windows and Backhauls (VRPTWB). [4] solved VRPTWB based on Multi-attribute label matching algorithms. [5] respectively considered VRPTWB with and without customer precedence, and use a guided local search to continually improve initial solution. The recent decade papers increasingly paid attention to used different heuristic algorithms such as tabu algorithm [6] and genetic algorithm [7] in addressing VRPB.

Different from the previous research, the paper focuses on city freight intelligent scheduling integrating freight load and path optimization. In order to reduce logistics cost, we firstly match and collaborate similar freight demand where the features both satisfy all freight classification rules shown as follows. And then a city freight intelligent scheduling model is proposed to perform common distribution. The model considers vehicle utilization and customer logistics cost to minimize the total cost. Freight load problem and path optimization problem are simultaneously addressed. Our goal is to shorten distribution time, reduce customer logistics cost and improve resource utilization.

II. PROBLEM DESCRIPTION

There are some features such as freight weight, freight volume, pick-up node, delivery node and delivery time for each freight demand.

A. Freight Classification Rules

1) Distribution area

If the distance between two customers is too far, their freight demand will be not matched together to avoid wasting too much transport time in transit. The paper sets the same distribution area that the distance of the pick-up nodes (or delivery nodes) of any two customers must be within 20km.

2) Distribution time

The distribution time focuses on delivery time only. Similar to the distribution area, the minimum difference for the delivery time of any two customers are required within 4 hours. For example, the delivery time of customer A and B is respectively 10:00 - 12:00 and 16:10 - 17:20. The minimum difference for the delivery time of customer A and B is 4 hours and 10 minutes. The rule is not satisfied so that the freights from customer A and B cannot be mixed.

3) Freight types and vehicle requirements

For the similar freight demand which can be mixed, the freight types and vehicle requirements also need to maintain consistency. Depending on the freight types (such

DOI reference number:10.18293/SEKE2016-065

as general type, refrigeration, vegetable, ultra bulky freight and so on) and the requirements the customers propose, the freights are classified and the corresponding vehicle types are chosen. The appropriate relationship between vehicle types and freights is found out under the optimal object.

B. Scheduling and Distribution

All freight demand at current time are classified under the freight classification rules. As long as satisfying both freight classification rules, the freight demand can be mixed and applied in the city freight intelligent scheduling model to get distribution plans including load plan, pick-up plan and delivery plan. Otherwise, the freight demand can be just separately loaded. Under the condition, each vehicle visit only one customer. So we just solve the freight load model to get load plan. In the end, the used vehicles implement the results. The procedure of scheduling is shown in Figure 1.

The vehicles which are responsible to transport the similar freights demand start to depart from the depot and one by one visit nodes in the same distribution area to pick up, and then successively arrive at delivery nodes. After unloading the freights, these vehicles finally come back to the depot. Moreover, during mid-tour these vehicles are not allowed to return to the depot. A simple example of common distribution is shown in Figure 2.

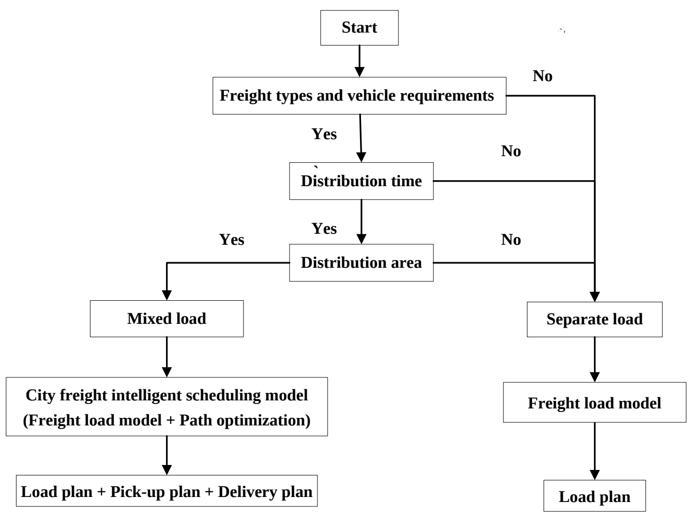

Figure 1. The procedure of scheduling.

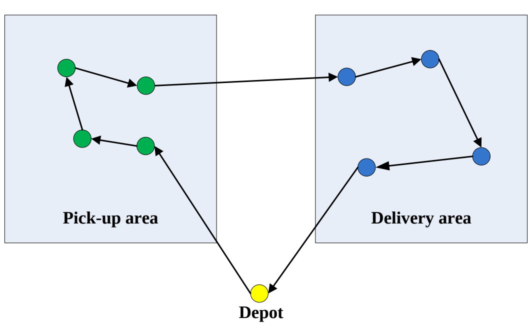

Figure 2. A simple example of common distribution.

III. City Freight Intelligent Scheduling Model

The paper develops a city freight intelligent scheduling model to simultaneously optimize load plan, pick-up plan and delivery plan for the similar freight demand. Therefore, the problem is also divided into two parts: How the freights are loaded; How and when the used vehicles visit pick-up nodes or delivery nodes. The two sub-models are introduced in detail.

As three important constraints in freight transport problem, load constraint, volume constraint and hard time window are also considered in the model. In general, the customers prefer to take over freights punctually. Therefore, hard time window just acts on delivery time in the model. In other words, there is no any requirement for pick-up time. Moreover, load constraint and volume constraint are strict during distribution.

A. Model definition

There is an directed and complete graph $G=(V,E)$. Where, node set $V=\{v_1,v_2,\ldots,v_n\}$ is the combination of start depot S, pick-up node set O, delivery node set D and end depot set S'. $V=S\cup O\cup D\cup S'$. $S=\{0\}$ and $S'=\{0'\}$. The locations of the node 0 and $0'$ are same. The set $E=\{(v_i,v_j)\mid v_i,v_j\in V, i<j\}$ represents the links connecting two nodes in V. The variables in two models are defined as follows.

kk: the number of the used vehicles and the decision variable in the freight load model.

K: the used vehicle set.

w_i: freight weight of customer i (kg).

vol_i: freight volume of customer i (m^3)

l_k: the number of customers served by vehicle k.

L: the number of all customers.

W: vehicle load capacity (kg).

VOL: container load volume (m^3).

Z: total cost (yuan).

Z_1: travel cost (yuan).

Z_2: penalty cost (yuan).

c_t: per-unit travel cost (yuan).

c_l: per-unit late arrival penalty cost (yuan).

c_e: per-unit early arrival penalty cost (yuan).

t_k^0: departure time of vehicle k from depot, decision variable .

$t_k^{0'}$: arrival time of vehicle k coming back to depot .

t_i^e : the earliest time of vehicle k visiting node i.

t_i^l : the latest time of vehicle k visiting node i.

$s_{k,i}$: pick-up node of customer i visited by vehicle k.

$e_{k,i}$: delivery node of customer i visited by vehicle k.

t_{ij} : travel time from node i to j.

t_i : arrival time at node i.

R_k : the set of pick-up nodes visited by vehicle k and the decision variable in the path optimization model.

$R_k^{'}$: the set of delivery nodes visited by vehicle k and the decision variable in the path optimization model.

B. *Model formulation*

Firstly the freight load model with the minimum number of the used vehicles is developed and solved in view of volume constraint and weight constraint. And then, the number of the used vehicles is introduced into the path optimization model.

1) *Freight load model*

Minimize $Z_1 = kk$ (1)

Subject to:

$$kk \le V \tag{2}$$

$$kk = \max(\mathrm{Int}(\frac{\sum_{i=1}^{L} w_i}{W}) + 1, \mathrm{Int}(\frac{\sum_{i=1}^{L} vol_i}{VOL}) + 1) \tag{3}$$

Object (1) minimize the number of the used vehicles. Constraint (2) ensures the used vehicles are available. Constraint (3) calculates the number of the used vehicles takes in terms of freight weight and freight volumes. The decision variable kk represents load plan.

The freight load model is very simple and can be computed directly to get result.

2) *Path optimization model*

Minimize $Z_2 = \sum_{k=1}^{kk} z_k^1 + z_k^2$ (4)

$$z_k^1 = c_t(t_k^{0'} - t_k^0) \tag{5}$$

$$z_k^2 = \sum_{i=2}^{l_k - 1} \left[c_l \max\left\{0, t_{e_{k,i}} - t_{e_{k,i}}^l\right\} + c_e \max\left\{0, t_{e_{k,i}}^e - t_{e_{k,i}}\right\} \right] \tag{6}$$

Subject to:

$$R_k = \{s_{k,i} \mid s_{k,i} \in O, i = 1, 2, \cdots, l_k\} \qquad k \in K \tag{7}$$

$$R_k^{'} = \{e_{k,i} \mid e_{k,i} \in D, i = 1, 2, \cdots, l_k\} \qquad k \in K \tag{8}$$

$$\sum_{k=1}^{kk} l_k = L \tag{9}$$

$$0 \le l_k \le L \qquad k \in K \tag{10}$$

$$R_i \cap R_j = \{0\} \qquad i, j \in K \tag{11}$$

$$R_i^{'} \cap R_j^{'} = \{0\} \qquad i, j \in K \tag{12}$$

$$t_{s_{k,i+1}} = t_{s_{k,i}} + t_{s_{k,i}s_{k,i+1}} \qquad k \in K,\ i = 1, 2, \cdots, l_k \tag{13}$$

$$t_{e_{k,i+1}} = t_{e_{k,i}} + t_{e_{k,i}e_{k,i+1}} \qquad k \in K,\ i = 1, 2, \cdots, l_k \tag{14}$$

$$t_{s_{k,1}} = t_k^0 + t_{0s_{k,1}} \qquad k \in K \tag{15}$$

$$t_{e_{k,1}} = t_{s_{k,l_k}} + t_{s_{k,l_k}e_{k,1}} \qquad k \in K \tag{16}$$

$$t_k^{0'} = t_{e_{k,l_k}} + t_{e_{k,l_k}0'} \qquad k \in K \tag{17}$$

In the path optimization model, Object (4) minimizes the total cost consisted of travel cost and penalty cost. The travel cost shown in constraint (5) is proportional to the travel time. Since the vehicles early or later arrive at delivery nodes, constraint (6) gives the corresponding penalty cost. Constraint (7) and (8) express the sets of the vehicle respectively visiting pick-up nodes and delivery nodes. Where, the pick-up node and delivery node for the same customer is required to be visited by the same vehicle. The decision variables R_k and $R_k^{'}$ respresents pick-up plan and delivery plan, respectively. Constraint (9) and (10) ensure all customers can be served and restrict the number of the customers served by each vehicles. Constraint (11) and (12) require each pick node (or delivery node) is just visited by one vehicle once. Constraint (13)-(17) both express the arrival time (the sum of the arrival time at last node and the travel time between two node). Constraint (13) and (14) gives the arrival time at the pick-up node (or delivery node). The arrival time of the vehicle visiting first node respective in pick-up area and delivery area is present in Constraint (15) and (16). To the end, in constraint (17) the time of the vehicle coming back to depot is given.

The path optimization model belongs to NP-hard problem that computation time increases exponentially with the number of nodes in network. There are many methods to solve the problem. Exact algorithms are good choices for some comparatively simple networks and heuristic algorithms always achieve better performance for some complex networks. In order to effectively get effective solution, the paper applies Genetic Algorithm (GA) as the solution technology.

IV. STUDY CASE

A. *Freight data*

Assume there are totally four customers to make requests for distribution at current time. The freight demand data is shown in Table 1 and Table 2. According to the freight classification rules introduced in Section 2.1, the freights from customer 1 and 2 can be mixed and performed common distribution using the city freight intelligent scheduling model. Because the freights from customer 3 and 4 are required to be separately served, only load plans are not given in the paper.

TABLE I. FREIGHT DEMAND DATA

Customer No.	1	2	3	4
Freight type	Common	Common	Frozen	Common
Freight weight (kg)	5000	10000	8000	10000
Freight volume (m^3)	2	2	5	1
Pick-up node	X1	X2	X3	X4
Delivery node	Y1	Y2	Y3	Y4
Time window	15:00-17:00	15:30-16:00	12:00-14:00	18:00-22:00

TABLE II. THE TRAVEL TIME AND DISTANCE BETWEEN TWO NODES (MIN/KM)

Node	X1	X2	Y1	Y2
X1		8/4	72/36	80/40
X2	8/4		64/32	68/34
Y1	72/36	64/32		8/
Y2	80/40	68/34	8/4	

B. *Constant parameter determination*

Several constant parameters in the model are determined in terms of operation experience. $c_t = 1$, $c_l = 5$ and $c_e = 5$. The number of the available common vehicles is ten. The load capacity is 20000kg and load volume is $4m^3$.

C. *Results and analysis*

Firstly, load plan is obtained based on the freight load model. The result indicates 8 common vehicles are used. And then the path optimization model is solved by GA to obtain the pick-up plan and delivery plan. The routes, departure time at depot and arrival time at pick-up nodes or delivery nodes for the used vehicles are shown in Figure 3 and Table 3. The used vehicles depart from depot at 13:30 and successively visit node X1 and X2 to pick up for customer 1 and 2. And then, the used vehicles visit node Y1 and Y2 in delivery area, and finally come back to the depot.

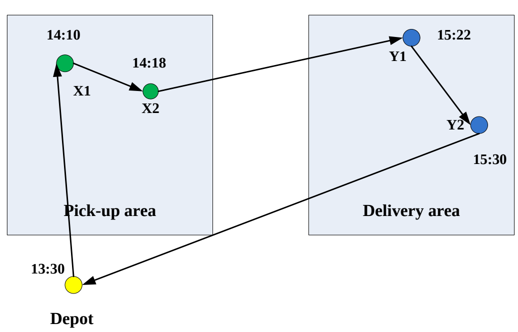

Figure 3. Pick-up plan and delivery plan

TABLE III. PICK-UP PLAN AND DELIVERY PLAN

Node order	Depot	Pick-up area		Delivery are	
		X1	**X2**	**Y1**	**Y2**
Time	13:30	14:10	14:18	15:22	15:30

I. CONCLUSION

The paper comprehensively considers vehicle utilization and customer logistics cost to develop the city freight intelligent scheduling model combining intelligent goods consolidation with capacity scheduling optimization for many similar mixed freight demand. The common distribution is implemented to pick up and deliver these freights in sequence. two problems, freight load problem and path optimization problem are addressed in the city freight intelligent scheduling model. In conclusion, the paper provides a set of operation scheme consisted of load plan, pick-up plan and delivery plan to the logistics company. The load plan can be obtained straightly by the freight load model. Because of being formulated as a mixed integer linear programming, the path optimization model is solved by GA to get pick-up plan and delivery plan.

ACKNOWLEDGMENT

This research was supported by National Science and Technology Support Program of China (Grant No. 2014BAH23F01), Beijing Municipal Institute of Science and Technology (Grant No. PXM2015_178215_000008) and enterprise fund (Grant No. T15L00210).

REFERENCES

[1] Goetschalckx, M. and Jacobs-Blecha, C., "The vehicle routing problem with backhauls," European Journal of Operational Research, vol. 42(1), pp.39-51, 1989.

[2] Toth, P. and Vigo, D., "An exact algorithm for the vehicle routing problem with backhauls," Transportation science, vol. 31(4), pp.372-385, 1997.

[3] Wade, A.C. and Salhi, S., "An investigation into a new class of vehicle routing problem with backhauls," Omega, vol. 30(6), pp.479-487, 2002.

[4] Cheung, R.K. and Hang, D.D., "Multi-attribute label matching algorithms for vehicle routing problems with time windows and backhauls," IIE transactions, vol. 35(3), pp.191-205, 2003.

[5] Zhong, Y. and Cole, M.H., 2005. A vehicle routing problem with backhauls and time windows: a guided local search solution. Transportation Research Part E: Logistics and Transportation Review, 41(2), pp.131-144.

[6] Brandao, J., 2006. A new tabu search algorithm for the vehicle routing problem with backhauls. European Journal of Operational Research, 173(2), pp.540-555.

[7] Tasan, A.S. and Gen, M., 2012. A genetic algorithm based approach to vehicle routing problem with simultaneous pick-up and deliveries. Computers & Industrial Engineering, 62(3), pp.755-761.