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Optimization and Simulation of Express's Vehicle Routing in Commercial District Based on Ant Colony Algorithm

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Abstract: Nowadays, the quantity of express packages is very large and the requirement of timeliness is also increasing in commercial district, so to optimize the vehicle routing for express's delivery in commercial district is the key point to improve the express enterprises' service level and competitiveness and it is the purpose of the study. Service node, the last operation in express network, is mainly to collect and deliver the express packages. In this study, the mode of mobile warehouse milk-run delivery is put forward by considering the key factors that impact the express company's competitiveness and the optimal path is found with ant colony algorithm. This paper's innovation is that a new and unique mode of network node's operation for express enterprises in downtown delivery is put forward and provides a method of path planning, then the proposed delivery model and algorithm are proven by simulating and analyzing at the SF's network node (E-World node) of Zhongguancun branch with the result that the cost of express delivery reduced and the efficiency of delivery improved, thereby the service level and competitive ability of express enterprise get improved greatly.

Key words: Vehicle routing problem (VRP), express, commercial district, ant colony algorithm (ACA)

INTRODUCTION

With the continuous development of e-commerce, the express industry is highly specialized and socialized at a rapid speed, the network node which is the last operation in express network, is mainly for the collection and delivery of the express, the delivery link plays a pivotal role in the express industry (Yang and Zhang, 2013). Research of express delivery has begun to take shape but how to optimize the delivery vehicle routing for the commercial district which with large amount of receipt and timeliness demanding, has become the limiting factor of expanding and increasing the profit of express enterprise. Therefore, optimize the delivery model and plan delivery path scientifically in the commercial district will be the key point to reduce the delivery cost and to improve the delivery efficiency. The domestic and foreign scholars have conducted in-depth research on the vehicle routing problem. Dantzig (1959) proposed the VRP problem and gives an algorithm but did not consider the problem of saving path. Subsequently, Rao *et al.* (1968) introduced the column generation method for the VRP. With the development of mathematical programming and network analysis in 1970s-1980s, the accurate mathematical programming method is put forward to solve VRP problems. In 1990s, genetic algorithm, tabu search, ant colony optimization algorithm of intelligent optimization algorithm were used for solving the problem. In the domestic, the main research methods are accurate algorithm, heuristic algorithm and some other algorithms (Guo and Li, 1994; Li and Guo, 2001; Zhang Li and Guo, 2008). The results show that the ant colony algorithm has strong universality and robustness and it has infiltrated into the electric power, construction, transportation and other fields of practical applications, it is a heuristic optimization method and suitable for solving VRP (Dorigo, 1992; Wei, 2007).

In this study, the characteristics and present situation of express delivery in commercial district are analyzed and find the important factors that affect competitiveness of commercial district's express, through the research of mobile warehouse delivery model and the milk-run distribution, a new delivery model is put forward, then construct the model of express delivery path planning in commercial district with the optimization theory and applied the ant colony algorithm to the choose of express route in commercial district. Finally, applying theory to practice, take the SF's network node of Zhongguancun for example, to optimize network operation and achieve the goal of improve the efficiency of the delivery.

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ANALLYSIS OF THE COMMERCIAL DISTRICT EXPRESS NETWORK

Commercial district refers to the concentrated regions of internal citywide or district-level commercial nodes, usually take large wholesale centers and comprehensive stores as the core, composed by dozens or even hundreds of professional or commercial enterprise. The characteristics of the commercial district is more stores, large scale and full range of products .

Commercial express delivery characteristics:

- High customer density with short distance. In commercial district, many clients are in the same office building and the couriers back and forth between each customer to collect and deliver the packages with shorter operate time
- Traffic congestion and impact the timeliness. The highly concentrated commercial facilities caused the traffic congestion and extended the delivery time of couriers
- High warehousing costs. Land price in the commercial zone is high, so the cost of leasing or building fixed warehouse is very high

The mode of network delivery:

- **Mode 1:** Couriers deliver packages back and forth between customer and service node. The Couriers take the packages from service node and then deliver them to the customers, or from the customers to the service nodes. This case, the couriers shuttle like a Pendulum between customers and service nodes frequently. The SF's network nodes of Zhongguancun branch use it before 2009
- **Mode 2:** Deliver with mobile warehouse. "Mobile warehouse" refers to the transfer station (a truck) in the area which with large and stable packages, the service node uses a truck to collect and send packages between the service node and the customers back and forth. In March 2009, The SF's network nodes of Zhongguancun branch use it after 2009. Figure 1 shows an increase trend of collection quantity of zhongguancun branch and the customers' responsiveness increased, per capita efficiency also has a rise trend (see Fig. 2). (source: The case of "SF cup" the third national contest on logistics design by university students)

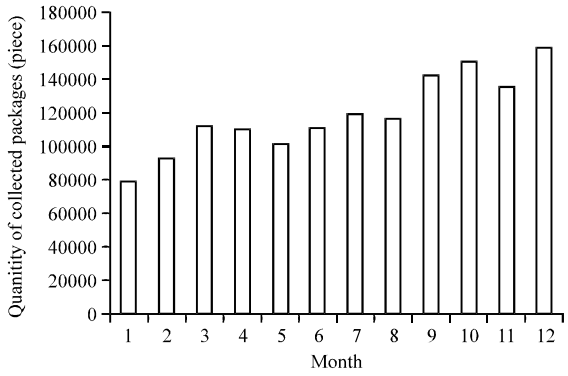

Fig. 1: Zhongguancun branch's amount of express packages in 2009

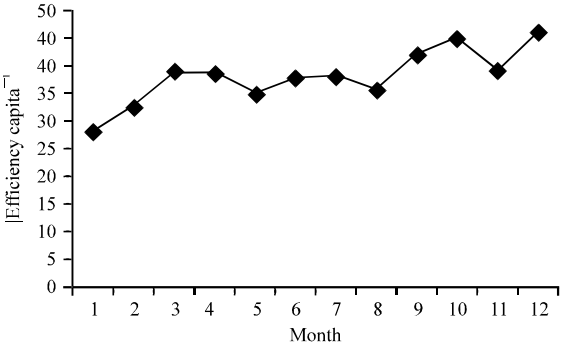

Fig. 2: Zhongguancun branch's per capita efficiency index in 2009

MODE OF EXPRESS DELIVERY IN COMMERCIAL DISTRICT AND VEHICLE ROUTING OPTIMIZATION

According to the analysis above, this study combined the "mobile warehouse" and "milk-run" and puts forward the "mobile warehouse milk-run mode", effectively reduce the warehousing cost by using the "mobile warehouse", improved the delivery timeliness and saving the cost of transportation by using the "milk-run" delivery model.

Milk-run delivery mode: Apply the Milk-run delivery model to express delivery in commercial district, that is to send express packages to a combined region (a service combination of certain number of customers) in order base on the preliminary design of path, at the same time collect the express packages which to be delivered, finally returned to the service nodes, this pattern is characterized

by multiple frequency and small batch. The milk-run delivery model can improve the vehicles' cubed out, reduce the number of empty vehicles for return and the drive distance. and also reduce the delivery cost effectively and achieve the goal of improving the efficiency of the Couriers' service.

Mobile warehouse milk-run mode: For "the mobile warehouse" can't be able to save all the couriers' delivery time which back and forth between the customers and the service nodes, optimize the mobile warehouse mode, deliver of pendulum and promote it to the entire commercial district, in another word, mobile warehouse milk-run mode of delivery is adopted in the combined regions of each service node. Van type of "mobile warehouse" acts as a transit point and it can reduce the cost of storage in commercial area, in the case of meet the delivery time, the shortest route need to be worked out, so that the fixed costs and delivery costs reduced. Combined region is a service point of "mobile warehouse" and couriers waited at the combination for the mobile warehouse to assign express packages to them, after that, the couriers only shuttle between mobile warehouse and customers instead of going back to the node, so that improved the delivery efficiency.

Characteristics of the mobile warehouse milk run delivery mode:

- Have less storage cost for it and needn't to lease land area for the storage of express packages
- Have less time cost for the shortest path the mobile warehouses run at the case of meeting the requirement of the timeliness and the avoidance of couriers' shuttling between customers and the service nodes frequently, so that it can improve the delivery efficiency
- Give full play to different vehicles' advantages of speed and service cost. "Mobile warehouses" run in the main roads of commercial district and couriers drive common electric cars or modified tricycles in the combined region to reduce the delivery cost and improve the delivery efficiency

Routing optimization of mobile warehouse milk-run vehicle: In commercial district the length of delivery vehicle routing of network operation directly determines the delivery cost and the delivery efficiency, so the vehicle routing optimization of mobile warehouse milk-run delivery model in commercial district's service node is an effective measures to enhance the competitiveness of express company.

Objective: Time and cost are two important indexs for commercial express delivery problem, here are two objectives for the vehicle routing optimization of mobile warehouse milk-run delivery model. First, on the premise of accomplishing delivery task, work out the route as little as possible. Second, in the case of meet the delivery time, choose the route as shortest as possible to reduce the delivery cost.

Constraint: First, the scope of problem description: The service node of network is divided into m regions and there are n express packages, adopt the road transportation.

Second, the vehicle factor: in the process of delivery, the total weight of packages shall not exceed the maximum load of the car. Each vehicle departs from the network node, along the way through all the combined region and finally returns to the starting point.

Third, timeliness requirements: as far as possible to ensure the packages collected in operating time can be shipped to the network node and be processed, also ensure the packages can be delivered to the customers in time.

Establish the mathematical model: According to the characteristics of express delivery, the path planning problem for the commercial network is described as following: Using undirected graph G = (V, E) represent the commercial network of express company, The vertex set $V = \{v_1, v_{2...}v_N\}$, Vertex v_i means the combined region in the delivery network. Undirected edge collection E = $\{E_{ij}, i, (1, 2...N), j, (1, 2...N)\}$, E_{ij} means the road between region i and j. (if there is a direct path between the region i and j, then the path length between i and j is $|E_{ij}|$, otherwise (0).

Variable definition: C_i is the amount of express packages sent to the region v_i; R_i is the amount of express packages collected the region v_i; M_i is the load of vehicles after completing loading and unloading packages when reach the region vi. (If the M_i' is the load of vehicle arrived in region vi, then $M_i = M_i'+R_i-C_i$, $M_i\$0$, $M_i'\$0$). Max Capacity is the biggest load of transport vehicles used in commercial network Q' is a collection of vehicle routes S_1, S_2, …, S_i, S_i is the ith route.

The objective functions are as follows:

$$\text{Min}|Q,|\text{Min}\sum_{\substack{|Q|\\ S_i\in Q'\\ E_{mn}\in S_i}}|E_{mn}|$$

The constraints are as follows:

$$Q' = (S_1, S_2, \ldots, S_i) \quad (1)$$

$$\sum_{v_j \in S} C_{v_j} \leq \text{Max capacity} \quad (2)$$

$$\sum_{v_j \in S_i} R_{v_j} \leq \text{Max capacity} \quad (3)$$

$$M_i \leq \text{Max capacity} \quad (4)$$

Objective function means "the least path" and "the shortest route", Constraint (1) means Q' is a collection of vehicle routes S_1, S_2, …, S_i, Constraint (2) means the amount of express packages sent to the all the region v_i in route S_i shall not exceed the maximum load of the vehicle, Constraint (3) means the amount of express packages collected in all the region v_i in route S_i shall not exceed the maximum load of the vehicle, Constraint (4) means when v_j, S_i vehicles left a regional v_j the weight of packages shall not exceed the maximum load.

Use the Ant colony algorithm to solve problem: Assuming that the combined region in commercial district as a transfer station, replace vehicles with artificial ants, when input all the combined region in the network node, then the shortest path through all the regions can be calculated. The mobile warehouse milk-run delivery meet the following conditions: All the vehicles depart from one point, through all the point of combined regions and finally go back to the start point, each point's demand shall be met at the fastest efficiency; Each combined region can only be accessed once, each vehicle can only service one route.

Firstly, place m vehicles on m combined regions randomly, Ant k depart from the current vertex s, according to the strategy of path selection, select a route satisfy the constraint conditions from the collection of the route associated with vertex s. and then depart from the other region I connected the route, select a route satisfy the constraint conditions from the collection of the route associated with vertex s and then depart from the other region i connected the route, of the road I set out, choose another road from the collection of the route associated with vertex i. So on, until the search to the vertices and the ant k get a s-t-s solution. After the ants choose a path, pheromone on the way get updated immediately. Repeat the above steps for the rest ants until the m ants complete the search, then get a combination of m solutions. Adjust the ant pheromone intensity constantly according to the ants' experience, make the ants' migration path optimized and eventually get the optimum solution or approximate solutions (Chen, 2011; Sun *et al*., 2008).

SIMULATION ANALYSIS OF SF'S NETWORK NODE OF ZHONGGUANCUN BRANCH

The background of the case of SF's network nodes of Zhongguancun branch

Zhongguancun commercial zone gathered a number of high-tech enterprises and merchants, there are six nodes of SF's network of Zhongguancun branch and they are named: Kemao node, E-World node, Zhongguancun node, Zhichun node, Peking University node and Weigongcun node.

Each node has 5-10 combined regions, a total of 37 combined regions. Each combined region has 1-4 unit region(s), a total of 50 unit regions and covered the whole high-tech park. The zoning diagram is as shown in Fig. 3.

Through the analysis about the present situation of the zhongguancun branch, the problem of time waste during the delivery is prominent increasingly. Each courier of Zhongguancun E-World node shuttle between customers and combined region frequently and limit the contact time with customers and the service level. Take this node for example analysis, use the "mobile warehouse milk-run" delivery model to collect and send express packages. This node contains seven combined regions, the network node diagram as shown in Fig. 4, the selection of path before optimization as shown in Fig. 5.

The vehicle routing optimization of mobile warehouse milk-run delivery model in E-World node

There are seven combined regions in E-World node and ascertained the combined regions' coordinates by MATLAB, they are (75, 47), (303, 38), (176, 132), (66, 307), (221, 260), (351, 183), (340, 336), (282, 189). The Calculation program based on MATLAB and the initial parameter is set to m = 7, n = 2, the number of iterations is 50, $\rho = 0.4$, $\beta = 3$. Through MATLAB programming and use ant colony algorithm to select the path, the result is shown in Fig. 6 and 7.

The total length of the optimized path is 2403 meters, before the optimization the total length of the path is 2086 * 2(to and from) = 4172 meters (linear distance between

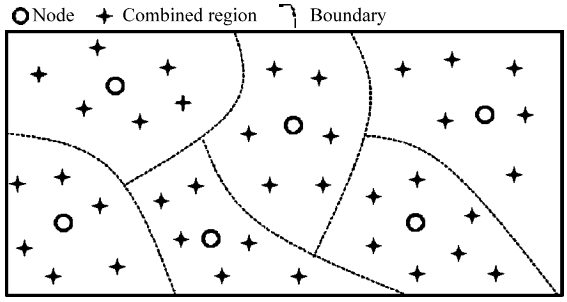

Fig. 3: Zoning diagram of zhongguancun branch

Fig. 4: Network node diagram

Fig. 5: Route choice before optimization

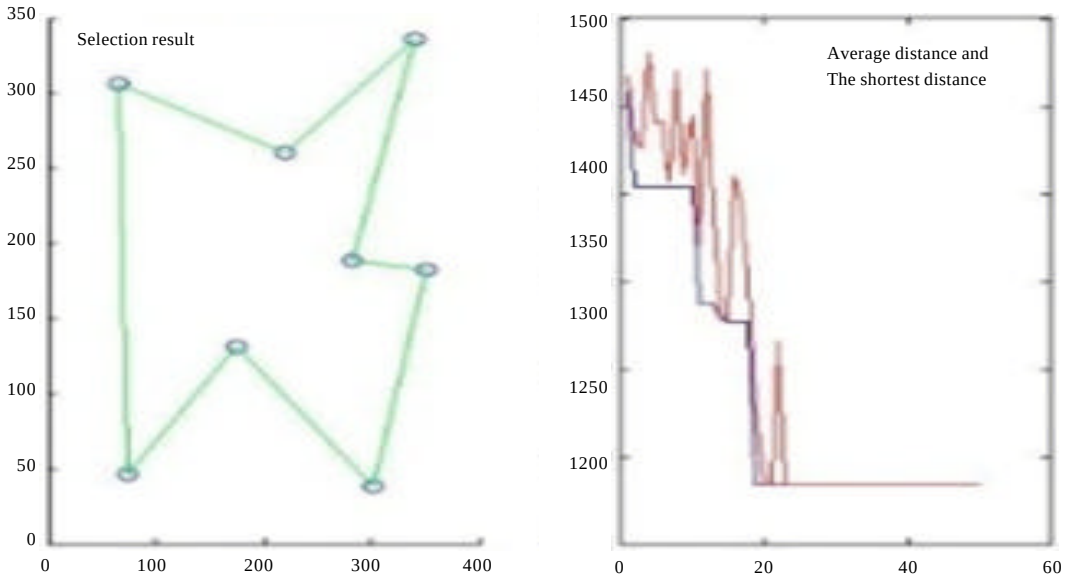

Fig. 6: Result of routing simulation

Fig. 7: Route selection after optimization

(before and after optimization), the optimized path reduces 1769 meters, a 42.4% drop in the path, the path length gets shortened and save the delivery cost and time.

CONCLUSION

This study analyzes the express industry's characteristics and status quo in commercial district first and then put forward the "mobile warehouse milk-run mode" among all the combined regions , each combined region is a service point of mobile warehouse, the couriers just only shuttle between the mobile warehouse and customers, establish the model of vehicle routing optimization based on the optimization theory, on the premise of accomplishing delivery task, work out the route as little as possible to reduce the input of vehicle and manpower. In the case of meet the delivery time, choose the route as shortest as possible to reduce the delivery cost.

In the end, the study take the zhongguancun E-World node as an example for simulation analysis by adopting the "mobile warehouse milk-run delivery model", the result shows that a 42.4% drop in the path and the time the couriers spend during the delivery time reduced, so the purposes of improving the service level and the competitiveness are reached by optimizing the route choice and controlling the delivery time. There still exist the following problems: In this paper, there are still lack of the following: first, in the optimization of delivery vehicle routing of SF, the instability of the traffic in the city is not taken into consideration due to the limitation of the model. Second, in the simulation analysis of mobile warehouse milk-run delivery mode, only take into consideration of the linear distance between combined regions in theory but there exists difference between the linear distance and the actual distance. All of these needs further research.

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REFERENCE

Chen, J.J., 2011. The research of Ant colony algorithm in the logistics distribution path optimization. Comput. Simul., 28: 268-271.

Dantzig, G.B. and J.H. Ramser, 1959. Optimum routing of delivery trucks. World Petro. Cong., 5: 19-19.

Dorigo, M., 1992. Optimization, learning and natural algorithms. Ph.D. Thesis, Department of Electronics, Politecnico di Milano, Italy.

Guo, Y.H. and J. Li, 1994. The Basic Theory: Vehicle Optimization Scheduling. Chengdu University of Science and Technology Press, China, pp: 30-80.

Li, J. and Y.H. Guo, 2001. The Basic Theory: Theories and Methods of Logistics Distribution Vehicle Scheduling. China Supplies Press, China, pp: 30-100.

Rao, M.R. and S. Zionts, 1968. Allocation of transportation units to alternative trips-A column generation scheme with out-of-kilter subproblems. Operat. Res., 12: 60-68.

Sun, J.X., G.G. Gao and L. Zhang, 2008. The research of ant colony algorithm applied in the postal planning. J. Guizhou Univ., 4: 461-465.

Wei, Z.Y., 2007. The research of ant colony algorithm in logistics transportation scheduling system. University of Nanlv.

Yang, H.X. and M.N. Zhang, 2013. The research of shortage of logistics during holiday shopping based on game theory. J. Beijing Technol. Commer. Univ., 28: 42-46.

Zhang, J.Y., J. Li and Y.H. Guo, 2008. Dynamic VRP insertion heuristic algorithm with a confused booking time. J. Southwest Jiaotong Univ., 43: 107-113.