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Modeling Vehicle Routing Problem with Pair Pickup-Delivery Operations

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ABSTRACT : *The problem of vehicle routing problem (VRP) with pair operations of pick up and delivery are well-known in real applications in logistics networks, as in planning the routes for automatic guided vehicles (AGVs) in an automatic container terminal (ACT), warehouses or in some just-in-time services. This paper will present a formulation to modeling the problem mathematically which can be used to generate optimal routes of carried vehicles in the field to reduce the incurred cost of moving goods. This selected model could be used in (semi-)automatic short-term planning systems for vehicle fleet working in ACT, or in modern warehouses which the long list of requests is parted and sorted in preprocessing orders systems.*

Key words : *Vehicle Routing Problem, Logistics Networks, Automatic Guided Vehicles, Automatic Container Terminal, Warehouse*

1. Introduction

The VRP with pair pickup and delivery operations could be seeing in many real applications logistics networks as in pure water distribution where the vehicles travel around locations, collect empty bottles and replace full ones, or in operations of container terminals, the vehicles move and carry containers between ship-side and container-yard-side at specific locations in where gantry cranes (quay cranes at ship-side and transfer cranes at container-yard-side) do operations of loading (pickup) and unloading (delivery) to the vehicle fleet.

The same operations could be seen in warehouses and factories which is objects-preparing step for the next stages operations. The reducing of the operations cost could increase the benefit for companies.

Generally, the VRP with pair pickup and delivery operations could be described as there is a vehicle fleet which each vehicles state in the field, they might state at special depot at first and one might return to there when it idles, each vehicle receives requests about pickup points and delivery points, and it should satisfy that set of transportation requests based on minimizes the value of objective functions with constrains of capacity limitation and the time windows at each locations (Toth and Vigo, 2002).

In this paper, we just consider the problem in static case where all information is known. The result will be sets of points the vehicles should visit. The next section, we present a mathematical modeling for this kind of VRP. Continue with conclusion for this short paper.

2. Mathematical Modeling

Assume that we have vehicles $k \in K$, where K is set of vehicles, be assigned to a list of pair pickup points $P_k = \{p_k^i \mid i = \overline{1, m_k}\}$ and delivery points $D_k = \{d_k^i \mid i = \overline{1, m_k}\}$ respectively,

where,

$$d_k^i = p_k^i + n$$
$$P = \bigcup_{k \in K} P_k = \{1, 2, \cdots, n\}$$
$$D = \bigcup_{k \in K} D_k = \{n+1, n+2, \cdots, 2n\}$$
$$S_k = P_k \cup D_k$$
$$S = \bigcup_{k \in K} S_k = P \cup D$$

At p_k^i, vehicle k receives q_k^i units and at d_k^i, it discharges q_k^i units. The maximum capacity of vehicle k is given by C_k. S_k is the itinerancy of vehicle k. The vehicle visits at node $u \in \{1, 2, \cdots, 2n\}$ in valid time window $[e_u, l_u]$ and serving time s_u there. The network $G_k = (V_k, E_k)$, in which $V_k = S_k \cup \{origin_k, destination_k\}$, and $E_k = \{(i,j) \mid i \in V_k, j \in V_k, i \neq j\}$. Each edge $(i,j)_k$ is associated with cost a_{ijk}, and travel time t_{ijk}.

All vehicle fleet should finish all assignment with lowest of the following cost function:

$$\min f = \sum_{k \in K} \sum_{(i,j) \in E_k} a_{ijk} x_{ijk}$$

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subject to

Decision binary variables:

$$x_{ijk} = \{0,1\} \qquad \forall k \in K\ ,\ (i,j) \in E_k$$

Each request is served exactly once and by the same vehicle:

$$\sum_{k \in K} \sum_{j \in S_i \cup \{destination_k\}} x_{ijk} = 1 \qquad \forall i \in P$$
$$\sum_{j \in S_i} x_{ijk} - \sum_{j \in S_i} x_{j,n+i,k} = 0 \qquad \forall k \in K, i \in P_k$$

Ensure that each vehicle starts from its origin and terminates its route at its destination:

$$\sum_{j \in P_k \cup \{destination_k\}} x_{origin_k,j,k} = 1 \qquad \forall k \in K$$
$$\sum_{i \in S_k \cup \{origin_k\}} x_{ijk} - \sum_{i \in S_k \cup \{destination_k\}} x_{jik} = 0 \qquad \forall k \in K, j \in S_k$$
$$\sum_{i \in D_k \cup \{origin_k\}} x_{i,destination_k,k} = 1 \qquad \forall k \in K$$

Time windows constrains:

$$x_{ijk}(T_{ik} + s_i + t_{ijk} - T_{jk}) \le 0 \qquad \forall k \in K\ ,\ (i,j) \in E_k$$
$$e_i \le T_{ik} \le l_i \qquad \forall k \in K, i \in V_k$$

Force the vehicle to visit the pickup node before the delivery node:

$$T_{ik} + t_{i,n+i,k} \le T_{n+i,k} \qquad \forall k \in K, i \in P_k$$

Loading and capacity constrains:

$$x_{ijk}(L_{ik} + q_j - L_{jk}) = 0 \qquad \forall k \in K\ ,\ (i,j) \in E_k$$
$$q_i \le L_{ik} \le C_k \qquad \forall k \in K, i \in P_k$$
$$0 \le L_{n+i,k} \le C_k - q_i \qquad \forall k \in K, n+i \in D_k$$
$$L_{origin_k,k} = 0 \qquad \forall k \in K$$

3. Conclusion

This model is useful for running on computer and it can generate exact routes solution for each vehicle. So that it can be use in full or semi automatic terminal operating system.

The intractableness of problem maybe is in the number of requests and number of serving points. When these numbers are large, there is a limit applicable. But if we use other techniques to cluster or segment the request partially, so it could be overcome that problem. This should be done in another study.

References

[1] Toth, P. and Vigo, D.(2002), "The Vehicle Routing Problem", Society for Industrial and Applied Mathematics (SIAM).