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A CAPACITATED HETEROGENEOUS VEHICLE ROUTING PROBLEM FOR PHARMACEUTICAL PRODUCTS DELIVERY

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ABSTRACT

This paper describes an optimal way for retail pharmacies to deliver medical products for customers. Heterogeneous vehicle routing problem (HVRP) is one of the options for the optimal solution of the problem. This is a well-established question of combinatorial optimisation, in which a sequence in cars with varying capabilities departs from a central warehouse to satisfy a variety of customers with specific locations. The study sets out a model for the optimal transportation of medicinal products by a private company based in Medan City, Indonesia. The HVRP has time slots, delivery and allocation of fleets over a short period of time. The objective is to minimize the overall cost of transport moving across the planning horizon. The method is formulated as a linear mixed integer system, and an appropriate response requires a feasible search approach.

Keywords: Modelling, Logistic, Pharmaceutical products, Distribution, Direct search

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INTRODUCTION

In distribution system it is necessary to find the best strategy to deliver finished good products for customers. In operations research realm, a model called vehicle routing problem usually to be used to meet the term best strategy in delivering products. The problem of vehicle routing is to invent an optimal route for a set of vehicles to handle customers' need. The research on problems for deciding route has become more intensive. This is as a consequence of their financial applications and the optimization theoretical interest. The use of optimization techniques can lead to a reduction in transport costs and also time deliveries [1].

Due to the expanding global population, demand for drugs increased, so pharmaceutical distribution is one of the fastest growing sectors and has become much more important. Like any company distributing a product, pharmaceutical societies offer product delivery services to ensure efficient delivery to pharmacies and improve their competitiveness. But the pharmaceuticals distribution is not the same as the general product distribution system since pharmacies do not have a large warehouse for storing large amount of drugs, and the demand for pharmaceutical products is usually high. This fact will force each pharmacy to face several unexpected orders while the working day plan is in progress.

There are several types of VRPs in the literature which are classified based on different constraints. Two of the noted variants include: VRP (CVRP), vehicles are limited to a minimum capacity; VRP with time windows (VRPTW), each other client is handled within a specified time frame; multiple VRP (MDVRP) depots; in this model, products can be shipped to the customer from a collection of distribution centers; VRP with pick-up and delivery (VRPPD), items not only need to be transported, just as well must be collected at a number of customers and returned to the storage [2].

Various types of transport are used by a medical company for the supply of customers. There are distinctive capabilities for each vehicle class. The VRP type for the mixed vehicle fleet is the Heterogenous VRP (HVRP) which was first proposed by Golden et al. [3]. In reality, this generalization is relevant, as many types of cars meet the majority of consumer demand [4], [5]. The objective of the HVRP is to define the structure of the fleet and an effective routing strategy to reduce overall costs.

Due to the combination nature of the problem, heuristics is the most common approach to HVRP resolution. Onut et al. [6] implements GAMS software to address the HVRPTW model. Dondo and Cerda [7] recommended a 3-phase multi-depot, cluster-based optimization HVRPTW algorithm, while Paraskevopoulos et al. [8] presented a two-phase alternative framework focusing on hybridized tabu search assimilated to a new meta-heuristic reactive search neighborhood with excellent results. Jiang et al. [9] used a different approach to Tabu Search. They also created a tabu search for Lau et al. [10] M-VRPTW. Braysy et al. [11] introduced the HVRPTW deterministic annealing metaheuristic and Braysy et al. [12] formed a local meta-heuristic search for large-scale HVRPTW resolution. Amador-Fontalvo et al. [13] has developed a novel metaheuristic based on the behavior of the bacteria towards light stimulation. The Adaptive Memory Programming Approach for HVRPTW by Repoussis and Tarantilis [14] has produced excellent results in most of the performance measurements tested. Subramanian et al. [15] indicated the challenge of a hybrid algorithm. Their algorithm is a Heuristic and Set Partitioning formulation focused on Iterated Local Search (ILS). The HVRP Genetic Algorithm was created by Kang Kang and Lee [16] with soft time windows. Afshar-Nadjati and Afshar-Nadjati [17] suggested a coherent heuristic algorithm for the HVRPTW problem. The HVRPTW problem can be overcome by integrating heuristic algorithms, including sweep algorithm, insert, swap, and 2-opt move, modified elite ant system (EAS) and column generation (CG) [18]. Campelo et al. [19] uses metaheuristics to overcome the consistent pharmaceutical path of the VRP. Bouziyane et al. [20] proposes a multi-purpose VRP intervention model for the distribution of medicinal products.

The paper will supply medicinal products to clients across the city of Medan, Indonesia from a medical supply company. The customer's requirements differ in terms of volume and time of arrival. The client will then plan the date of the shipment and the type of vehicle to be chosen. The expected delivery time should be recognized. This drug industry requires a broad scope of operation; the organization divides the entire region into many parts, ensuring that the preparation of the

CHVRPTW sub-sector is also included. We solve the problem by using a mixed integer programming method. A feasible heuristic neighborhood search is proposed in order to find a fully workable solution to the current problem model solution.

PROBLEM FORMULATION

For pharmaceutical distribution issues, the CHVRPTW framework working method is represented with the following description. Define $G = (V, E)$ as a directed graph, with $V = \{0,1,\cdots,n\}$ is the node and $E = \{(i,j): \in V, i \neq j\}$ is the set of vehicle travelling. The cost of c_{ij} shall be determined for each route $(i,j) \in E$. Depot node, service center, i.e. a node 0 $(i = 0)$, the place in which all vehicle used is located. The Client Vertex Collection is described by V_c. In the T day Preparation Period, each Client $i \in V_c$ has a defined $d_i \geq 0$ day demand. There is a fleet of K vehicles positioned at the distribution centre, each with capacity Q_k. At the centre (depot) of distribution, we impose a limited time to serve all customers which is given by $[a_0, b_0]$. Initially, the equipment used for production is housed in a medical storage facility. Per $i \in V_c$ consumer needs the service period s_i, the time window $[e_i, u_i]$ and exactly one vehicle of the same form. In fact, a fixed maintenance charge f_k is incurred for any vehicle k on the roads. Each travelling must arrive and end at the central node and needs to be followed by time limits for the period that ensures that the vehicle is unable to start customer service i before e_i and after u_i. But the vehicle may arrive and wait for e_i service.

In this study, the medical firm is quite notorious. It is got several clients. Indeed, the time for shipments is so limited. A short period of time for distribution is set out in the developed plan. With time constraints, the issue can be called CHVRPTW.

The binary variables

$$x_{ijk} = \begin{cases} 1 & \text{if } k \in K \text{ set of vehicles to deliver for } (i,j) \in V; \\ 0 & \text{otherwise} \end{cases}$$

l_k^i Time starts to deliver for vehicle $k \in K$ at customer i (non-negative continuous variables)

MODEL FORMULATION

The mathematical model of CHVRPTW with restricted time for medical distribution problem can be expressed with the following description.

In this particular CHVRPTW problem the decision maker of the medical company plans to utilize the accessible vehicle competently, in such a way to reduce the entire travelling cost, expressed as Equation (1).

$$\text{Minimize} \sum_{(i,j)\in V} \sum_{k\in K} c_{ij} x_{ij}^k \qquad (1)$$

Subject to several requirements

$$\sum_{j\in V} x_{ij}^k = K, \qquad \forall k \in K, i = 0 \qquad (2)$$

Constraint set (2) is to guarantee that the number of trip from depot $i = 0$ at most K arcs.

$$\sum_{j\in V} x_{ij}^k = 1, \qquad \forall k \in K, i = 0 \qquad (3)$$

The constraint set (3) guarantees that for each vehicle, there is directly one outgoing arc from the depot is picked.

$$\sum_{j\in V} x_{ji}^k = 1, \qquad \forall k \in K, i = 0 \qquad (4)$$

Similarly, the constraint (4) ensures that for each vehicle, there is exactly one arc entering into the node with respect to depot $(i = 0)$.

$$\sum_{k\in K} \sum_{j=0, j\neq i, j\in V} x_{ij}^k = 1, \qquad \forall i \in V \qquad (5)$$

The constraint set (5) makes sure that from each node i only one arc for each vehicle emanates from it.

$$\sum_{k\in K} \sum_{i=0, i\neq j, i\in V} x_{ij}^k = 1, \quad \forall j \in V \qquad (6)$$

The constraint set (6) ensures that for each node j, only one arc for each vehicle enters into it.

$$\sum_{j>i,(i,j)\forall V} x_{ij}^k = 1, \quad \forall i \in V, \forall k \in K \qquad (7)$$

The constraints Eq. (7) is to make sure that one and only one vehicle regardless their type comes back and leaves from each customer and the central depot.

$$\sum_{(i,j)\in V, i<j} x_{ij}^k - \sum_{(i,j)\in V, j<i} x_{ij}^k = 0, \quad \forall k \in K \qquad (8)$$

Expression for maintaining vehicles movement is necessarily in order to keep the continuity of each vehicle trip at each time period. This expression is expressed in (8).

$$\sum_{i\in V} d_i \sum_{j=0, j\neq i} x_{ij}^k \leq Q_k, \qquad \forall k \in K \qquad (9)$$

Constraint (9) guarantees that the vehicle capacity will not be exceeded.

$$l_i^k + s_i + t_{ij} - M_{ij}\left(1 - x_{ij}^k\right) \leq l_j^k, \quad \forall i \in V, \forall j \in V, \forall k \in K \qquad (10)$$

Equation (10) sets a minimum time for beginning the service of customer j in a determined route and also guarantees that there will be no sub tours. The constant M_{ij} is a large enough number,

$$e_i \leq l_j^k \leq u_i, \qquad \forall i \in V, \forall k \in K \qquad (11)$$

Constraint (11) guarantees that all customers will be served within their time windows.

$$x_{ij}^k \in \{0,1\}, \qquad \forall (i,j) \in V, \forall k \in K \qquad (12)$$

Constraints (12) state that x_{ij} are binary variables.

$$l_j^k \geq 0, \qquad \forall i \in V, \forall k \in K \qquad (13)$$

Constraints (13) that l_i^k are continuous variables.

THE ALGORITHM

We presume that an integer variable with a non-integer value is necessary for a continuous solution.

$$x_{i'} = x_{i'} + f_{i'}, \qquad 0 < f_{i'} < 1$$

Level 1.

1. Determine a row which has the smallest integer infeasibility, to minimize the deterioration of the target function
2. Perform pricing calculation using $v_{i*}^T = e_{i*}^T B^{-1}$
3. Solve $\sigma_{ij} = v_{i*}^T \alpha_j$

   Where non basic j related to $\min_j \left\{ \left| \dfrac{d_j}{\alpha_{ij}} \right| \right\}$

This Step is to determine the maximum movement of nonbasic variables.

4. Calculate $B\alpha_{j^*} = \alpha_{j^*}$ for α_{j^*}

5. Perform ratio test.

6. Replace basis variables accordingly

7. If no more row with integer infeasibility go to Level 2, or back to 1

Level 2.

1. Do fractional movement for integer infeasible superbasics

2. Do localized search for integer feasible superbasics.

AN ILLUSTRATION

We present an example of the model described in Section 3 to solve medical distribution from a medical company located in Medan city of Indonesia. There are four consumers to be delivered, using two vehicles. The model is presented as follows.

The decision is to get the travelling costs minimum.

Minimize $100x_{011} + 100x_{021} + 100x_{031} + 100x_{041} + 150x_{012} + 150x_{022} + 150x_{032} + 150x_{042} + 50x_{121} + 70x_{131} + 50x_{141} + 50x_{211} + 60x_{231} + 70x_{241} + 70x_{311} + 60x_{321} + 50x_{341} + 50x_{411} + 70x_{421} + 50x_{431} + 80x_{122} + 50x_{132} + 70x_{142} + 80x_{212} + 90x_{232} + 80x_{242} + 50x_{312} + 90x_{322} + 70x_{342} + 70x_{412} + 80x_{422} + 70x_{432}$

Subject to

Constraint (2)

$$x_{011} + x_{021} + x_{031} + x_{041} \le 2$$
$$x_{012} + x_{022} + x_{032} + x_{042} \le 2$$

Constraint (3)

$$x_{011} + x_{021} + x_{031} + x_{041} = 1$$
$$x_{012} + x_{022} + x_{032} + x_{042} = 1$$

Constraint (4)

$$x_{101} + x_{201} + x_{301} + x_{401} = 1$$
$$x_{102} + x_{202} + x_{302} + x_{402} = 1$$

Constraint (5)

$$x_{121} + x_{131} + x_{141} + x_{122} + x_{132} + x_{142} = 1$$
$$x_{211} + x_{231} + x_{241} + x_{212} + x_{232} + x_{242} = 1$$
$$x_{311} + x_{321} + x_{341} + x_{312} + x_{322} + x_{342} = 1$$
$$x_{411} + x_{421} + x_{431} + x_{412} + x_{422} + x_{432} = 1$$

Constraint (6)

$$x_{011} + x_{211} + x_{311} + x_{411} - x_{101} - x_{121} - x_{131} - x_{141} = 0$$
$$x_{021} + x_{121} + x_{321} + x_{421} - x_{201} - x_{211} - x_{231} - x_{241} = 0$$
$$x_{031} + x_{131} + x_{231} + x_{431} - x_{301} - x_{311} - x_{321} - x_{341} = 0$$
$$x_{041} + x_{141} + x_{241} + x_{341} - x_{401} - x_{411} - x_{421} - x_{431} = 0$$

Constraint (7)

$$x_{012} + x_{212} + x_{312} + x_{412} - x_{102} - x_{122} - x_{132} - x_{142} = 0$$
$$x_{022} + x_{122} + x_{322} + x_{422} - x_{202} - x_{212} - x_{232} - x_{242} = 0$$
$$x_{032} + x_{132} + x_{232} + x_{432} - x_{302} - x_{312} - x_{322} - x_{342} = 0$$
$$x_{042} + x_{142} + x_{242} + x_{342} - x_{402} - x_{412} - x_{422} - x_{432} = 0$$

Constraint (8)

$$20x_{101} + 20x_{121} + 20x_{131} + 20x_{141} + 20x_{201} + 20x_{211} + 20x_{231} + 20x_{241} + 20x_{301} + 20x_{311} + 20x_{321} + 20x_{341} + 20x_{401} + 20x_{411} + 20x_{421} + 20x_{431} \le 100$$
$$20x_{102} + 20x_{122} + 20x_{132} + 20x_{142} + 20x_{202} + 20x_{212} + 20x_{232} + 20x_{242} + 20x_{302} + 20x_{312} + 20x_{322} + 20x_{342} + 20x_{402} + 20x_{412} + 20x_{422} + 20x_{432} \le 100$$

Constraint (9)

$$l_{11} - l_{21} + 500x_{121} \le 825$$
$$l_{11} - l_{31} + 500x_{131} \le 825$$
$$l_{11} - l_{41} + 500x_{141} \le 825$$
$$l_{21} - l_{31} + 500x_{231} \le 825$$
$$l_{21} - l_{11} + 500x_{211} \le 825$$
$$l_{21} - l_{41} + 500x_{241} \le 825$$
$$l_{31} - l_{11} + 500x_{311} \le 825$$
$$l_{31} - l_{21} + 500x_{321} \le 825$$
$$l_{31} - l_{41} + 500x_{341} \le 825$$
$$l_{41} - l_{11} + 500x_{411} \le 825$$
$$l_{41} - l_{21} + 500x_{421} \le 825$$
$$l_{41} - l_{31} + 500x_{431} \le 825$$
$$l_{12} - l_{22} + 500x_{122} \le 825$$
$$l_{12} - l_{32} + 500x_{132} \le 825$$
$$l_{12} - l_{42} + 500x_{142} \le 825$$
$$l_{22} - l_{32} + 500x_{232} \le 825$$
$$l_{22} - l_{12} + 500x_{212} \le 825$$
$$l_{22} - l_{42} + 500x_{242} \le 825$$
$$l_{32} - l_{12} + 500x_{312} \le 825$$
$$l_{32} - l_{22} + 500x_{322} \le 825$$
$$l_{32} - l_{42} + 500x_{342} \le 825$$
$$l_{42} - l_{12} + 500x_{412} \le 825$$
$$l_{42} - l_{22} + 500x_{422} \le 825$$
$$l_{42} - l_{32} + 500x_{432} \le 825$$

We solved the model using the algorithm mentioned in Section 4. The results are presented as follows.

The minimum travelling cost is 500 thousands Rupiah

- Distribution process.
  - For vehicle 1.
    The medical deliverance from Depot to Consumer 4. Then from Consumer 4 back to Depot.
  - For vehicle 2.
    The medical deliverance from Depot to Consumer 2, then to Consumer 4, after that to Customer 3, then to Customer 1, from Customer 1 to Customer 3, then from Customer 3 back to Depot.
- Waiting time.
  - Vehicle 1
    Needs to wait 30 minutes then go back to Depot.
  - Vehicle 2.
    It needs to wait 10 minutes at Customer 2, then at Customer 4 stays for 10 minutes, at Customer 3 the vehicle needs to wait for 10 minutes, it waits again at Customer 1, from Customer 3 it waits for 10 minutes before go back to Depot.

CONCLUSIONS

The pharmacy business has a number of clients who have a range of product containers to accommodate. The organization also wants to produce many kinds of transport. This article will set out a model for Capacitated Heterogeneous Vehicle Routing with Time Windows Problem. This model is being developed in Medan City, Indonesia, to address the issue of a pharmaceutical distributor. The resulting model is a mixed integer linear programming issue. To solve this model, a neighborhood heuristic algorithm is used.

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