The Open Vehicle Routing Problem with Multiple Products and Vehicles

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ABSTRACT

Open Vehicle Routing Problems (OVRPs) have been extensively analyzed in recent studies due to the increasing interest of production companies in them. In most industries, companies use a hired vehicle fleet for the distribution of their goods. These companies then use the transportation companies’ resources (i.e., trucks etc.), and hence, do not have to endure the additional cost of returning vehicles.

Various OVRPs with different assumptions and settings have been considered in the past. In this study, we analyze an OVRP with two different products and two different types of vehicles. A mixed integer programming model has been developed for the problem. Using the model, we were able to obtain the optimal solution for small problems (i.e., 10 cities) in a few minutes. We plan to focus on generating initial routes using some heuristic approaches to improve the performance of our model.

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INTRODUCTION

Due to the fact that the OVRP consists of Hamiltonian path, traveling salesman and best Hamiltonian path for each set of customers assigned to a vehicle for the optimal solution [1]. Therefore, it can be seen that OVRP has an NP-hard structure because of the NP-hard Hamiltonian path sub-problems.

Recently, there has been an increasing interest in OVRPs with different scenarios. Many researchers have developed various heuristic approaches to solve the OVRP. Brandao [1] improved a tabu search algorithm for OVRP to generate good solutions in a short time. He obtained better results using random tabu tenure, instead of fixed tabu tenure [1]. Zachariadis and Kiranoudis [2] developed a novel approach to produce initial solutions of OVRPs. They tested their metaheuristic on well-known OVRP instances. Their approach improved several best-known solutions reported in previous studies [2]. Ekpioğlu et al. [3] presented an extensive literature review of the Vehicle Routing Problem (VRP), classified the VRP studies according to their specifications, and built the taxonomy of the VRP literature. They found that, applied researchers have become increasingly interested in the VRP in the last decade. The VRP literature was categorized into 5 main groups that contain 106 different sub-categories by the authors. They discovered that, the number of the VRP studies including load specific vehicles and heterogeneous vehicles have been three times less than the others. We note that there have been a few VRP studies with that contain heterogeneous vehicles in the literature. In our problem of interest in this study, on the other hand, the company has to distribute two different products with two different types of vehicles, to our knowledge, constituting an OVRP that has not been considered in previous studies (VRP heterogeneous products and vehicles). A mathematical model for the solution of the problem and some preliminary results were presented.

METHODS AND MATERIALS

Specifications of logistics problem are as follows;

• Material Specifications:
  • There are two different products.
  • First product’s weight coefficient is high and volume coefficient is low, whereas the second product’s weight coefficient is low and volume coefficient is high.

• Transportation Specifications:
  • There are two different types of vehicles ➔ Truck, TIR.
  • Maximum and minimum weight and volume quantities are known for Truck and TIR.
  • Transportation costs for Truck and TIR are known for each city (no return cost).
  • Transportation costs are designated according to the target city.

• Route Specifications:
  • Routes are known beforehand.
  • Each route’s cost is known.
  • Vehicle stop–leave costs are known.
  • It’s possible to carry another city’s demand if the city is on the way to the target city, but a vehicle can stop at most two different cities.
  • Each city’s demand can be met by more than one vehicle.

• Indices:
  • i, j, k ➔ For each city
  • k ➔ For each vehicle
  • l ➔ For each material

• Decision Variables
  • \( x_{ijwl} \): The quantity of product \( t \) that is left on city \( i \).
  • \( y_{ij} \): If vehicle \( i \) leaves or stops on city \( j \) while travelling to target city \( j \) (1 if vehicle \( i \) stops on city \( j \) while travelling to target city \( j \) or 0 otherwise).

• Parameters
  • \( q_k \): Volume capacity for vehicle \( k \).
  • \( Q_k \): Weight capacity for vehicle \( k \).
  • \( p_s \): product demand for city \( i \) working on transportation cost for vehicle \( k \) while travelling to target city \( j \).
  • \( c_{ijl} \): Stop cost for vehicle \( k \) on city \( i \) before leaving or returning to target city \( j \).
  • \( A_t \): Weight coefficient for product \( t \).
  • \( H_t \): Volume coefficient for product \( t \).

METHODS AND MATERIALS (cont.)

In this study, we developed a mathematical model for the OVRP which, to our knowledge, has not been studied before. We were able to obtain the optimal solution of a sample problem, however, it was not possible to solve the real-world problem with 81 nodes in a reasonable time. Therefore, our ongoing and future research efforts include generating initial routes with some heuristic approaches to improve the performance of the mathematical model. Using metaheuristics for the solution of the problem can also be considered as a future study direction.

RESULTS

Our sample problem contains 10 cities where each city’s demand (multiplied by weight and volume coefficients) determined as 400 units. Similar calculations yielded the weight and volume capacities of trucks and TIRs as 800 units and 1200 units, respectively. MPL found the optimal solution for 5 TIRs and 3 trucks in few minutes.

CONCLUSIONS

In the figure above, trucks and TIRs are represented by 1 and T, respectively. For instance, T8BW means, 8th. TIR unloads the weight (W) and volume (V) demands of 7th. node. Other nodes can be interpreted similarly.

REFERENCES