Multi-graph model for the Inventory Routing Problem with Energy Consideration

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1 Introduction

Our study focuses on the integration of energy aspect into the Inventory Routing Problem (IRP). Based on our previous work [3], we present the IRP to minimize the total energy consumption. In this model, the real road network is represented by a multi-graph, which contains both the travel time and the energy information. In addition, the inventory is monitored in continuous time.

2 Problem presentation

Under the Vendor Managed Inventory (VMI) conception, the Inventory Routing Problem (IRP) is a combination of vehicle routing and inventory management. In the IRP, the vendor monitors the inventory level of the customers during a long period of time and takes the central decision on when to deliver to a customer, how much to deliver and how to route the vehicle among the customers. This problem has been studied for more than thirty years, and has regained a lot of attention as the subject of the 2016 Roadef Challenge. Existing models on the IRP are mainly divided into two categories: one with continuous time, constant demand rate and infinite time horizon, typically the case of the Cyclic Inventory Routing Problem (CIRP) [1]; the other one with discrete time, variable demand rate for each time period and finite time horizon [2]. Our study focuses on the case with continuous time, variable demands and finite time horizon, which is not in these two categories but is closer to the reality according to the example of 2016 Roadef Challenge.

Nowadays, faced with the sustainability constraints, the incorporation of energy consumption into the IRP becomes very important both economically and ecologically. However, most of the studies in the literature treat inventory management and energy consumption separately and lack a system view for the sustainable routing. In our previous work [3], the mass flow serves as a link between the energy consumption and the inventory management and gives us a linear mathematical mixed integer formulation. To better understand the compromise between energy consumption and transportation and inventory cost on the real road network, here we propose a new model based on a multi-graph. On the multi-graph, both energy and travel time information are conserved. Since the energy consumption is dependent on the distance, vehicle speed and total number of stops (see [3] for energy computation), the travel time of an arc is closely related to the energy. On the other hand, for the inventory management, if the demand is deterministic and the arrival time of each demand is fixed, the travel time among the customers also have an influence on the quantity that can be delivered. That is the motivation to use multi-graph modelling.

In the following, we present the the multi-graph modelling of this problem.

3 Multi-graph model

The real road network is represented by graph $\mathcal{G} = (\mathcal{V}, \mathcal{A})$. In this graph, $\mathcal{V} = V \bigcup V'$ is the set of vertices with $V = \mathcal{C} \bigcup \{0\}$ the set of customers ($\mathcal{C}$) and the depot (0), and V' the set of intermediate points. N denote the number of customers. Each arc $(i, j) \in \mathcal{A}$ represents a link between two points $i,\ j \in \mathcal{V}$ on the road network and is characterised by $\mathcal{R}$ attributes ($\mathcal{R} \geq 1$). In the following, we consider 2 attributes: the travelling time and the energy consumption. The graph $\mathcal{G}$ can be incomplete and it is simple.

For each $(i, j) \in V \times V$, let $\mathcal{P}_{i,j}$ be the set of Pareto optimal paths from customer i to j considering the $\mathcal{R}$ attributes in $\mathcal{G}$. The multi-graph $G = (V, A)$ is introduced as follows. For each $(i, j) \in V \times V$ and road path $p \in \mathcal{P}_{i,j}$, there is an arc $(i, j)^p \in \mathcal{A}$. Each arc $(i, j)^p$ is associated with a fixed travelling time, denoted by $\tau^p_{i,j}$, and an energy consumption, denoted by $c^p_{i,j}$, which is a fixed value per arc per unit of product.

Based on the multi-graph $G = (V, A)$ over time horizon H, the inventory routing problem with energy consumption is defined as follows.

Each customer has a minimum and a maximum inventory level and an initial inventory level at the beginning. He consumes the product gradually during the time horizon considered. The time and quantity of each customer demand is given. The vendor (or transporter) monitors the inventory level of each customer and makes sure that it never goes below (or beyond) the minimum (or maximum) inventory level by making deliveries to the customers. There is a total set of K vehicles used for the delivery. Here we consider a set of homogeneous vehicles and each vehicle has a limited capacity Q and a curb weight W. At the beginning of the time horizon, the vehicles are all at the depot with full load. Vehicles can make several tours during the time horizon and they are replenished at the depot automatically each time they return to the depot.

We would like to decide the time and quantity of each delivery to each customer and the routes of the vehicle among the customers to perform the deliveries, so that the inventory level of each customer always stays inside the limits. The objective is to minimize the total energy consumption in the routing while respecting the capacity constraints of customers and vehicles.

4 Conclusions and perspectives

The multi-graph model can help us better understand the compromise between energy consumption and transportation and inventory cost. The implementation and solution of this model is still under study.

References

[1] El Houssaine Aghezzaf, Birger Raa, and Hendrik Van Landeghem. Modeling inventory routing problems in supply chains of high consumption products. *European Journal of Operational Research*, 169(3):1048–1063, 2006.

[2] C. Archetti, L. Bertazzi, G. Laporte, and M. G. Speranza. A Branch-and-Cut Algorithm for a Vendor-Managed Inventory-Routing Problem. *Transportation Science*, 41(3):382–391, 2007.

[3] Yun He, Cyril Briand, and Nicolas Jozefowiez. A mass-flow based milp formulation for the inventory routing with explicit energy consumption. In *Proceedings of 5th the International Conference on Operations Research and Enterprise Systems*, pages 242–251, 2016.