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***Key words**: Hub location-routing problem, less than truckload shipments, integer programming*

1 Introduction

In many logistic systems for less than truckload (LTL) shipments, transportation of goods from one origin to its destination is made through collection tours to a hub and delivery tours from the same or another hub, while the goods are shipped between two hubs using Full Truckload (FTL) shipments. Therefore, managers need to determine the location of the hubs, the allocation of non-hub nodes, and the optimal collection and delivery routes within the network. This problem, known as the *hub location-routing problem* (HLRP), is related to both the hub location problem (HLP) and the location-routing problem (LRP). The HLP involves the location of hub facilities concentrating flows in order to take advantage of economies of scale and through which flows are to be routed from origins to destinations. For an extensive review on the HLP, ones can refer to Alumur and Kara [1] or Campbell and O'Kelly [2]. The goals of the LRP are to determine the locations of the depots, the allocation of customers to depots, and to design the distribution (or collection) routes. Nagy and Salhi [7] presented a survey on issues, models and methods for the LRPs. In their classification, they pointed out a particular case of the LRP where inter-facilities routes are considered and both pick-up and delivery routes must be determined: the many-to-many location routing problem (MMLRP) that is similar to the HLRP. Different from the LRP which only considers one type of routes, the HLRP considers both collection and distribution routes. Hence, the objective of the HLRP is to minimize the total costs including hub costs, inter-hub transportation costs, and collection/distribution routing costs. Based on the literatures review, the aims of this paper are to analyze the state of the art, propose some generic mathematical models for the HLRP and implement some tests using a MIP solver.

2 A state of the art for Hub Location-Routing Problem

In contrast to the HLP and the LRP which have been the subject of many works, only very few works directly address the HLRP. Liu *et al.* [6] introduced a heuristic algorithm to determine the delivery mode for each supplier-customer pair and to perform vehicle routing in a hub-and-spoke system with only one hub. Therefore, it can be treated as 1-HLRP with direct shipment. In addition, some researchers focused on the partitioning-hub location-routing problem (PHLRP). Gourdin *et al.* [5] firstly introduced and compared three integer programming (IP) models. Catanzaro *et al.* [3] explored possible valid inequalities to strengthen the IP model and introduced a branch-and-cut algorithm to solve the PHLRP that contains 20 vertices. Ta *et al.* [8] presented a binary integer linear programming model and a new method based on difference of convex functions algorithms to solve larger problems with up to 25 vertices. The hub location-routing problem has been also implemented for the application of postal service network. Wasner *et al*. [9] developed a generalized and complex two-layer HLRP model of an Austrian parcel delivery service. This model divided the network into two interrelated design phases: line haul design and pickup/delivery design. Çetiner *et al.* [4] developed a two-stage method that includes locating and routing for an uncapacitated/length limited HLRP for the Turkish postal delivery system. Unlike the above particular cases of the HLRP, our research focus on developing and applying generic models for the hub location-routing problem.

3 Mathematical models and Computational experiments

In order to address and solve the HLRP with a generic approach, this paper proposes mathematical models based on the following assumptions: each spoke is allocated to one hub; each vehicle route begins and ends at the same hub; vehicles are capacitated; and collection/delivery routes are distinguished. Based on different hypothesis for the hubs, we develop mixed integer programming models of fixed cost HLRP and p-HLRP with capacitated/uncapacitated single allocations. In these models, there are three main decision variables: flow variables, hub location variables and routing variables. Computational results obtained using CPLEX 12.1 will be presented on several test cases. Further research will consist in developing a metaheuristic procedure for solving the generic HLRP.

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