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Multiperiodic VRP models and hybrid solution techniques for closed loops-reverse logistics

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More and more manufacturers are confronted with the problem of "Reverse Logistics" which, as defined by the *"American Reverse Logistics Executive Council"* [Rogers and Tibben-Lembke, 1999], is: *"The process of planning, implementing, and controlling the efficient, cost effective flow of raw materials, in-process inventory, finished goods, and related information from the point of consumption to the point of origin for the purpose of recapturing value or of proper disposal"*. Companies have different reasons to design a reverse logistic system: legislation, commercial advantage, environmental issues, etc... In recent years, a significant amount of work has been focused on the design and optimization of logistic systems with reverse flows [Bostel et al., 2005].

In this paper, we consider generic problems for the multiperiodic planning and optimization of both routing activities and inventory management policies in a two level distribution network composed of a central warehouse and *n* retail stores. Distributed products sold by the stores are transported on returnable pallets. Two types of reverse flows have to be considered: for the return of unloaded pallets from the stores to the warehouses and for the return of products brought back to the stores by consumers or unsold. In order to satisfy the customer demands at the stores and replenish the inventories as well as balance the availability of pallets, pick up and delivery tours are organized over the planning period between the central warehouse and the stores using a homogeneous fleet of vehicles. Store servicing must meet time windows and they may be visited by several vehicles during one day. The purpose of the planning and optimization of the system is to determine the days of visits to each store as well as the quantities delivered or picked-up of the products and pallets. The aim of this problem is to satisfy the customer demands at the stores while minimizing the routing and storage costs. In order to determine the best management policies, we consider two cases: "just in time" delivery where the procurement to the stores must coincide with their customers demands on the same day, or "inventory" where we allow the possibility of delivering the products to the stores in advance in order to better optimize the shipments and inventories.

In order to solve these problems, we have developed both heuristic solution techniques and a column generation approach. As a basis for our heuristic solution techniques, we use the GRASP (Greedy Randomized Adaptive Search Procedure) metaheuristic [1989]. In a first phase we have adapted the classical construction method "Best Insertion", with greedy, random and adaptative features. In a second phase, we use two versions: one using a classical local search and one using a hybrid local search, and compare them. For the classical local search we use different known methods [Laporte and Semet, 2001]), in specific sequences for the “just in time case” and for the “inventory case”. For the hybrid local search, we adapted the Large Neighbourhood Search (LNS) method originally proposed by Shaw [1998]. This technique explores the neighbourhood of the solution by selecting a number of visits to be removed from the routing plan and reinserting them later. To find the best possible insertion for the nodes removed and determine a good planning on the new routes, we use the Limited Discrepancy Search (LDS) proposed by Harvey and Ginsberg [1995]. For all these methods, we combine improvement methods on each route separately (intra-route) and on several routes simultaneously (inter-route).

As a solution procedure based on exact methods, we consider a set partitioning formulation of the problems. Starting feasible solutions are generated using the previously described heuristics. A column generation procedure [Desaulniers et al., 2004] has been developed in order to solve the restricted Master problems. Several solution techniques for the resource constraint shortest path subproblems have been implemented and compared, using dynamic programming, tabu search, and constraint programming [Rousseau et al, 2002]. In order to find feasible solutions to the global problems, we restrict ourselves to a branch and bound procedure.

A set of 1848 instances has been generated based on the classical Solomon's testbed [1987] for the VRPTW with 25 sites. The results obtained by the GRASP approach depend on the resolution approach and the instances. With the column generation approach, we have limited the tests to 204 instances with 5 or 6 sites. Using the branch and bound procedure, we could obtain integer solutions for all cases of the "just in time" policy, but only for 25% of the cases of the "inventory" policy. The obtained results will be presented and compared, showing the relevancy of our models for the comparison of different logistics policies as well as for the performance evaluation of the different solution methods, depending on the characteristics of the instances.

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