An Inventory Pick-up and Delivery Problem in the Reverse Logistics Context: Optimization using a GRASP and hybrid approach

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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 [7]), 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"*. In a logistics network, many different elements can be returned to their point of origin (warehouse, plant, etc.): products having reached their end of life, products to be repaired, packaging, spare parts, etc… Manufacturers have different reasons to design a reverse logistics system: evolution of the legislation, commercial advantage, environmental issues, etc... In recent years, a significant amount of work has been focused on the design and optimization of logistics systems with reverse flows (see the recent survey by Bostel et al. [1]).

In this paper, we consider the multiperiodic planning and optimization of both transport activities and inventory management in a two level distribution network composed of a central warehouse and *n* retail stores. For our purpose, distributed items sold by the stores can be assimilated to a single product family logistic unit ("products") transported over returnable pallets. Two types of reverse flows have to be considered: the return of unloaded pallets from the stores to the warehouses and the return of items 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 system is to determine the days of visits of each store over the planning horizon as well as the quantities of products and pallets delivered or picked-up. The aim of this problem is to satisfy the customer demands of the stores while minimizing the routing and storage costs without violating the vehicle capacities, the store time windows, and storage capacities. In order to determine the best 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 "advance delivery" where we allow the possibility of delivering the products to the stores in advance in order to better optimize the shipments and inventories. Because of its combinatorial complexity, we have decided to solve this problem by using a method calling for either classical local search or hybrid methods (combining constraint programming and operations research techniques). Constraint programming (from artificial intelligence) and mixed integer programming (from operations research) are two complementary techniques for solving combinatorial optimization problems. Recent works for really hard real-life problems involve hybrid techniques that efficiently combine the advantages of both methods (see [9], [8] and [2]).

As a basis for our solution technique, we use the GRASP (Greedy Randomized Adaptive Search Procedure) metaheuristic [3]. In the first phase of GRASP, we use the classical construction method "Best Insertion". We start with empty tours, all the un-routed nodes are estimated, we place the best candidates according to the best insertion criterion (greedy part of the method) into a restricted list (typically of size 3 or 5) and choose randomly one of them to be planned (random part of the GRASP). All the nodes that have not been routed are estimated again (adaptive side of the method) and we restart the procedure until all the nodes are inserted into the planned tours.

For the second phase of GRASP, we develop two versions: one using a classical local search and one using a hybrid local search, and compare them.

The classical local search uses different known methods. We combine improvement methods on each route separately (intra-route) and on several routes simultaneously (inter-route). For the intra-route improvements we use different methods: 2-exchange of nodes, Or-Opt and 2-opt (see [6]). For the inter-route improvement we use: String Exchange, String Relocation (see [6]). In addition, we develop a local search which tests if a solution with an advanced demand is better (in spite of the storage cost) than without advanced demand. These methods have already been used successfully for our problem using classical construction and improvement techniques (see [4]).

The hybrid local search method uses a Large Neighbourhood Search (LNS) based on another local search. LNS was originally proposed by Shaw in 1998 [9]. 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 removed nodes and determine a good planning on the new routes, we use constraint programming techniques. The branching technique used is the Limited Discrepancy Search proposed by Harvey and Ginsberg [5]. With this method we seek improvements between routes (removed nodes and replanification) and within routes (planning removed nodes and optimising the route).

In order to validate our method, a set of instances were generated based on the classical Solomon's testbed [10] for the VRPTW with 25 sites. Our preliminary results depend on the resolution approach and the instances. In addition, the hybrid method must be improved by testing various values for the parameters. A comparative analysis of several variants of the proposed GRASP approach will be presented and discussed. In the future research we will work on the improvement of the hybrid approach.

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