A stochastic inventory routing problem for infectious medical waste collection

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1 Problem description

In the south-east region of France, the disposal of medical waste accumulated by patients in self treatment, is commonly organized as follows. At pharmacies, patients receive empty boxes which are dedicated to the safe storage of their medical waste. Full boxes are brought back by the patients to any of the pharmacies, where they are stored. When a certain limit on the number of boxes at a pharmacy is reached, the pharmacist makes a call to the local authority, which organizes the pick-up of the waste material. The pharmacy is then visited on the one or two following days.

With this organization, collection routes can hardly be optimized, as no anticipation on the saturation of pharmacies is allowed. In this paper, we envisage an improvement of the planning process, permitted by the integration of a Radio Frequency Identification (RFID) technology. Being equipped with RFID tags, boxes can automatically be registered when deposited at a pharmacy. The exact number of boxes at pharmacies can then be accessed at any time by the collector. It is then able to organize collection tours by taking into account actual numbers of boxes in pharmacies, estimated arrivals of boxes in the future (computed from past data) and distances between pharmacies.

We limit the study of this paper to the case where a single planning is computed, at the beginning of a predifined period and for the whole period. The main advantage of this scheme is to define the schedule of the driver(s) in advance. Collection tasks can then be integrated smoothly in their plannings. We formulate the problem as a Stochastic Collector Managed Inventory Routing Problem (SCMIRP). Two decisions have to be made: (1) when to visit each pharmacy, (2) how to route the vehicle to minimize costs [3]. Note that the dynamic situation, where routes are reoptimized daily with updated inventory levels, can be adressed with a simple extension of this work.

In the following, we assume that full boxes of infectious medical waste arrive at pharmacies according to a Poisson distribution. One vehicle is located at the local authority site (depot), where it starts and ends each of its tours, which is at most one tour per day. We consider a planning period of several weeks. The inventory level at the end of the time horizon can be different from the starting level.

The total cost is composed of transportation costs, fixed vehicle costs associated with tours, and inventory costs. Inventory costs are composed of two components, determined by the difference

between the number of boxes picked up by the vehicle at a pharmacy and minimal/maximal levels (representing inconvience for the pharmacist and excess of inventory, respectively).

2 Solution approaches and experiments

Due to the complexity of the SCMIRP, an exact solution method cannot be envisaged for realistic problem instances. Therefore, we propose two heuristic methods. The first solution approach is a sampling method, where a fixed sample of random scenarios are optimized as realizations of the stochastic problem. The second solution approach is based on a tabu search (TS) algorithm with an original local search operator.

In the sampling method, a solution is obtained by solving a large integer program where the objective function averages the solution cost of every scenario [1].

The second approach is based on a TS algorithm [2], encompassing a so-called collection pattern based operator. A collection pattern is defined as a set of visit dates for a pharmacy. The best collection pattern is determined for each pharmacy by solving a shortest path problem on the following structure. Each node of the graph represents a day. Additionally, a fictitious start node and a fictitious end node complete the graph. Visiting a node means that the corresponding pharmacy p is visited at time instant (day) t. The distance (cost) for the shortest path problem is composed of the routing cost, which incurs when the corresponding node in the graph is visited, and the average inventory cost, associated with the length of a traversed arc (number of days between two visits). Differential in routing costs are estimated *a priori* with the Lin-Kernighan heuristic. The best solution out of the neighborhood replaces the current solution by changing the collection pattern for a pharmacy p, leading to the best improvement, and by updating the vehicle routes.

Results will be presented, evaluating and comparing the two approaches on real-world instances from the region of Provence-Alpes-Côte d'Azur, where a pilot study for improving the treatment of infectious medical waste with RFID technologies is currently conducted. Comparisons with the actual organization, without RFID, will also be presented.

Acknowledgments

The present research work was partly financed by the French Environment and Energy Management Agency (Ademe). The authors gratefully acknowledge the support of this institution.

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