A HEURISTIC ALGORITHM FOR THE POLLUTION-ROUTING PROBLEM

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ABSTRACT

Introduced in the late 50s, the Vehicle Routing Problem (VRP) has a large number of variants. Most of them aim to represent constraints and objectives found in real world problems in order to optimize the transportation costs. Given the growing global concern about environmental issues, VRPs started to incorporate aspects of green logistics such as pollution, alternative fuels, among others. In 2011 the Pollution-Routing Problem (PRP) was proposed in the literature, with an objective of minimizing both the operational and environmental costs, considering the customers time-window constraints. The total distance traveled, the amount of load carried per unit distance, the vehicle speeds and the duration of the routes are the main factors considered when computing the total cost. Operational costs include drivers wages, which are proportional to the route durations, whereas environmental costs consider the amount of pollution emitted, which is modeled as a non-linear function of the vehicle speeds. In many cases, operational costs and environmental costs are conflicting. In the PRP, this conflict is dependent on the vehicle speeds. Higher speeds imply on shorter routes (operational costs) but at the same time on larger amount of pollution emitted (environmental costs) and *vice-versa*. In addition, the speeds have a direct impact on customers' arrival time, i.e, in meeting their time windows. Given that the vehicle speeds are decision variables, the PRP contains a sub-problem called the Speed Optimization Problem (SOP) which consists of finding the optimal speeds of each arc that is part of a particular route. The PRP is $\mathcal{NP}$-hard since it includes the VRP with Time Windows (VRPTW) as a particular case. Therefore, the use of exact methods to solve large-scale problems is an extremely hard task. In view of this, the use of heuristic methods, which are capable of generating high quality solutions in an acceptable computing time, is usually more suitable for addressing this class of problems in practice. To solve the PRP, we propose a heuristic algorithm, called ILS-SOA, that combines Iterated Local Search (ILS) with a recursive Speed Optimization Algorithm (SOA). Unlike a previous approach from the literature, that first solves the VRPTW and then the SOP, ILS-SOA solves the SOP every time a local search is performed. The developed approach is very efficient in solving instances from the PRPLIB, ranging from 10 to 200 customers. More precisely, it was possible to improve the result of 122 out of 180 instances, and to equal the result of another 54. The improvements are more substantial for the 200-customer instances, where the average gap between the average solutions found by ILS-SOA and the best known solutions was $-1,8\%$.

KEY WORDS. Iterated Local Search, Green Logistics, Speed Optimization.

Main areas: Logistics and Transport. Metaheuristics. Combinatorial Optimization.