Plowing the streets of Pittsburgh; an integrated solution approach

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Each year, many northern cities face significant expenditures pertaining to winter road maintenance. Snow plowing constitutes a significant part of these costs. Over the last decade, a staggering number of publications targeting snow plowing and winter gritting have appeared; an excellent overview can be found in the survey series [1, 2, 3, 4]. Some authors treat the snow plowing problem from an academic perspective, thereby focusing mainly on its mathematical properties and its relations to the well-studied Chinese Postman Problem. Others focus on the operational and practical aspects of the problem. In this work, we study the problem from a dynamic vehicle routing perspective, and present an integrated adaptive approach to snow plow route optimization and management. Our goal is a route planning system that issues optimized turn-by-turn instructions to the vehicles as they execute routes, and dynamically revises these plans as unexpected events force changes.

We focus specifically on the snow plow routing problem faced by the City of Pittsburgh, Pennsylvania. This problem asks to determine a set of routes for a heterogeneous fleet of vehicles. Each vehicle simultaneously removes snow from the streets and spreads a mixture of salt and chemicals for deicing purposes. A vehicle has a limited capacity of both salt and fuel. Consequently, these resources have to be periodically replenished at one of the available depots. Roads are partitioned into disjoint priority classes; roads with a high priority must be cleared before lower priority roads. Highways, emergency routes, and main traffic arteries typically belong to high priority classes, while residential and service roads are of low priority. The goal is to compute a schedule for each available vehicle, specifying the exact route the vehicle should drive, subject to the resource and road priority constraints. Two objectives are considered: minimizing the makespan of the schedule, and a hierarchical objective which minimizes the weighted completion times of the roads in each of the priority classes.

Although many related works deal with variations on our problem, it is often impossible or unclear whether their solution methods can be adapted to our problem setting. Often, these works do not consider replenishable resources; instead they assume that the vehicles have sufficient resources to complete their entire schedule. Another factor that inhibits direct application of existing solution approaches to our problem setting comes from potential scalability issues. For instance, recently, [5] presented a solution approach for a related plowing problem and demonstrated its performance on real-world data from the City of Dieppe, New Brunswick, Canada. With a population of roughly 24,000 inhabitants, 462 intersection and 1,234 road segments, the city of Dieppe is less than one fifth the size of downtown Pittsburgh.

In this presentation, we discuss an offline version of the optimization problem, presenting a procedure for generating static routes in advance of execution, and examining its performance on various problem instances. Routes are being generated through both exact approaches (Mixed Integer Programming and Constraint Programming (CP)) as well as heuristic procedures. A constructive heuristic is used to generate an initial feasible solution fast, after which a Late Acceptance (LA) heuristic is used to improve the solution. Experiments reveal that the heuristics are capable of consistently finding solutions of good quality. The approach based on a CP model is capable of finding high-quality solutions for smaller instances, but struggles with large instances. These results motivate combination of the LA heuristic and the CP approach in a Large Neighborhood search. First, the LA heuristic is used to find a good solution, after which the CP approach can be used to optimize small area's in an iterative fashion.
The approaches presented can be easily modified to deal with an online version of the problem where actual traffic conditions, as well as unexpected events reported by the truck drivers must be taken into account. Blocked roads, emergency requests and traffic congestion may all necessitate recomputing part of the schedule. Finally, we discuss the broader applicability of the work to other city services, such as garbage collection, street surveillance and maintenance, street cleaning, sewage inspection, etc.

References

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