Bi-objective Fleet Size and Mix Vehicle Routing Problem for Hazardous Materials Transportation

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1 Introduction

Hazardous materials (HazMat) transportation decisions are multi-objective in nature and they include conflicting objectives given the multiple stakeholders (shippers, freight carriers, administrators, and residents or consumers) involved. However, according to [2] most of attention in hazardous materials (HazMat) transportation has been directed towards risk minimization. This work deals with determining a set of routes that minimizes simultaneously two conflicting objectives, the total expected routing risk, and the total transportation cost when a fleet of different type vehicles are used for distributing a single HazMat using a road network traversing population centers. The routing risk values are considered to vary with the type and load of the trucks and the size of the neighboring population.

The multi-objective variant of the vehicle routing problem (VRP) has not been studied in a intense way, and it is not frequent the use of a Pareto approach in multi-objective algorithm performance measures. [4] and [5] provide an overview of the research into multi-objective VRP. They established that multi-objective VRP with time windows is the most investigated variant, and the two most preferred strategies for solving it are scalar methods and multi-objective evolutionary algorithms (MOEAs). [4] present HazMat distribution as a type of multi-objective problem where a specific real-life situation is studied. [1].

2 Multi-objective neighborhood search for fleet size and mix vehicle routing in HazMat transportation

Here an adaptation of the Variable Neighborhood Search (VNS) meta-heuristic to solve bi-objective fleet size and mix vehicle routing problem (FSMVRP) for HazMat transportation is explored. Particular emphasis is placed on the dominance relation, the solution selection, the neighborhood exploration, the archiving of the Pareto optimal set approximation, and the stopping condition.

A set of efficient points generated using the path relinking technique that connects the best solution for the cost minimization problem and the best solution for the risk minimization problem is used as the initial incumbent solution. The neighborhood exploration is done simultaneously in all the objective functions, and the updating the neighborhood structure is based on the improvement of the current local Pareto-front approximation. The number of consecutive perturbations without improvement of the hypervolume indicator is established as the stopping criterion. Choosing the solution to shake have a strong impact on the quality of the Pareto front approximation [6], thus, the potential efficient solutions are ranked according to their crowding distances, and those with the greatest values are selected to be perturbed.

3 Experiments and Results

To assess the quality of the algorithm performance in finding the Pareto-front approximation when the total routing risk function and the total routing costs are minimized, the FSMVRP instances in [3] are used. The hypervolume indicator that measures the area dominated by the Pareto-optimal solutions, and Δ metric that measures the extent of spread achieved among the obtained solutions are used as quality indicators.

Instance	Number of Nodes	Avg. time (s)	Avg. hypervolume	Avg. Δ
3	20	35.8125	0.9231	0.8409
4	20	51.2322	0.8106	0.565
5	20	43.1561	0.8724	0.7595
6	20	57.0562	0.7862	1.6378

TAB. 1 – Average hypervolume indicator and Δ metric for 30 runs of the multi-objective neighborhood search algorithm for 20 nodes instances FSMVRP in HazMat transportation

For the instances of the problem variant considered the simultaneous minimization of total cost and of total risk are indeed conflicting objectives. The different Pareto-front approximations show that an important decreasing in risk can be achieved at the cost of a small increase in the total routing cost near to the best cost solution, but it is the opposite case when we are close to the best risk solution.

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