An automated decision support tool for prisoner transportation in The Netherlands

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Abstract
DV & O is responsible for prisoner transportation in The Netherlands. The organization needs to solve a vehicle routing problem with time windows [2], where prisoners have to be picked up and delivered while respecting capacity and safety constraints. A daily demand of about 700 prisoner transportations yields a very complex combinatorial problem, solved by three full time planners. A new heuristic approach, developed in cooperation with Conundra, will be demonstrated. The heuristic enables computing a routing solution for the prisoner transportation problem in less than 100 seconds with a potential to a significant cost reduction.

1 The prisoner transportation problem

Prisoners have to be transported between different locations in The Netherlands with a heterogeneous fleet of trucks. The prisoners’ criminal records determines security measures during transportation. The fleet is spread over multiple depots. Trucks are divided in compartments and have different levels of security. A truck must be escorted by employees (guards), with specific skills and based at different depots.

Each prisoner transport has several constraints. A pickup and delivery location is given with corresponding time windows that should always be respected. The service times determine the time needed to (dis)embark a prisoner from the vehicle. The prisoner has to be transported with one of the allowed truck types and must be supervised by a minimum number of employees with the requested skills. The prisoner allocation in a truck should respect the allowed combinations of specific prisoners in one truck or compartment. Furthermore, a transportation request can consist of two trips. The first trip (visit trip) brings the prisoner from the prison to another location (e.g. court house or a hospital). The second trip returns the prisoner to the base location. The return trip can only start after a given residential time has passed. Both trips can be either strongly coupled, i.e. in such a way that the vehicle has to wait and execute the return trip as well, or loosely coupled, i.e. when the return trip can be executed by an other vehicle. Each route should start and end in the same depot where the truck was originally located and the total execution time of the route is limited.

The objective of the prisoner transportation problem is to minimize the total transportation cost. The total cost consists of the employee costs per hour and differs according the skills of the employee. Each truck in the solution generates a fixed cost aswell as an operational cost proportional to its distance travelled. Both fixed and operational costs are truck dependent.
2 Methodology

The heuristic integrated in the decision support tool first generates an initial solution followed by improvement attempts in a ruin-and-recreate manner. A constructive heuristic, namely a ‘best fit’, has been developed, which serves as a subroutine in this approach.

The best fit searches for an existing route where the pickup and delivery services can feasibly be inserted at minimal additional cost. If no such route exists, the prisoner will be transported in a newly created route. An efficient data structure is used to speed up the search process where all possible insert moves are examined. This data structure generates feasibility time windows based on the given time windows of the pickup and deliveries currently included in the route.

After an initial solution is obtained, the heuristic attempts to improve this solution during a ruin-and-recreate step. In each iteration a route is removed from the solution whose visits are reassigned to the remaining routes with the same best fit heuristic. Only new solutions with a lower cost are accepted (greedy). If a certain number of generations does not yield a lower cost solution, then the whole process is repeated with a new initial solution.

Because of particular constraints on prisoner combinations (e.g. prisoner A cannot sit together with prisoner B), a feasible prisoner allocation in the truck compartments must exist as well. Packing prisoners into vehicles, which is a hard problem itself, is solved with a particular heuristic based on well performing graph coloring algorithms [1].

3 Demonstration

The decision support tool is written in the Java programming language and will be demonstrated on a modern pc. The tool is platform independent and can thus run on windows, linux and mac. During the demonstration, the tool will be launched three times, showing 1) all transporation requests for 1 day and their locations, 2) the current solution generated by manual planners, and 3) the very cost efficient solution produced by the new heuristics. The estimated demonstration time is about 10 minutes.

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References
