Heuristic column generation for railroad track inspection scheduling

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1 Introduction

The French railway infrastructure manager (RFF[1]) delegates some maintenance to the French railroad company (SNCF[2]). One of them is rails defectoscopy, the detection and survey of defects inside the rails. These actions are performed with ultrasonic propagation analysis. The more loaded the railroad tracks are, the more frequently they must be checked. With the increase in railroad traffic, the need to better schedule these inspection becomes a prevalent task.

Inspection frequencies range from 6 months to 20 years. 2/3 of the total inspections distance is due to tracks which should be visited once or twice a year. These tracks are called *primary tracks*. They form a yearly homogeneous subnetwork. The remaining inspections (*secondary tracks*) are planned each year for the next 3 years.

The problem we are solving is to visit a given set of tracks given that tracks can't be inspected all over the year and track outages can alter vehicles speed. Furthermore, vehicles speed depend on their type and circulation mode (either inspecting or not). These vehicles have limited capacity defined by the amount of water which can be brought on board. For organisational purposes, water tanks can only be refilled at the end of a shift and the objective is to minimise the total deadhead distance. We named this problem the Railroad Track Inspection Problem (RTISP).

[1] http://www.rff.fr
[2] http://recherche.sncf.fr

2 Literature review

The railroad track inspection scheduling problem (RTISP) can be seen as an arc routing problem and generalises some of them. It consists in visiting with a heterogeneous fleet a given set of arcs during valid time windows. Good introductions to arc routing problems are the book (1) and the reviews (2), (3).

The water capacity constraint can be modelled by using a capacitated arc routing problem (CARP)(4), which consists of visiting arcs with vehicles of limited capacity. The heterogeneous capacitated arc routing problem (H-CARP) generalises it by allowing different velocity and capacity characteristics for each vehicle type. A common variant is the one with time windows on arcs (CARP-TW). These time windows describe the period during which vehicles can traverse them. In the capacitated arc routing problem with intermediate facilities (CARP-IF), vehicles are allowed to refill at any time at given points. The RTISP is a generalisation of these problems with time windows defined on arcs, vehicles, but also on nodes (refill). Furthermore, two limited capacities are constraining daily circulation: shift duration and water tank size. As (5) notified, industrial vehicle routing problem are rich, models to solve them are often a generalisation of lots of academic works and input data size can be huge. The RTISP is a good illustration of this fact.

Related industrial problems have been solved in the literature. Some of them are about road weeding, winter road maintenance, waste collection or postal delivery.

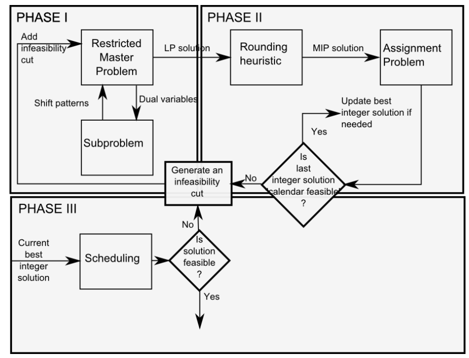
3 Model

Train unit circulation are modelled by a graph which contains arcs and edges representing either inspection tasks, deadhead traversals or complex moves in a train station. Arcs are used when the railroad track is unidirectional whereas edges are used when the railroad track has bidirectional equipment. Nodes describe communication between railroad tracks and stations.

Because refill can only be performed at the end of a shift, every shift is constrained to start and end at a refill station. Hence, every shift is a trip between two refill stations having a total distance to inspect lower than the capacity of the water tank and total trip duration lower than the duration of a work shift. Given all the feasible shift paths, the RTISP becomes the problem of selecting and scheduling them in order to satisfy all inspections with the lowest total deadhead distance.

Train unit maintenance rendezvous, region vehicle reservation and track outage minimum duration are set to one shift for organisational purposes. Inspection task duration can vary from minutes to hours. Vehicles can be geographically constrained.

4 Column generation based heuristic



The proposed algorithm is based on a mathematical decomposition which is heuristically solved in three phases. During Phase I simple tasks are aggregated into work shifts with the use of a column generation algorithm. The generated continuous solution is used as an incumbent for Phase II. In Phase II a rounding greedy heuristic is used to get an integer solution. This new integer candidate solution is tested against calendar day assignment to check if all selected shifts can be assigned a calendar day. If it is not, a cut is generated. If it is, the new candidate solution will be used to generate a constraint program for a complete feasibility test during Phase III. This last stage is about testing if scheduling the set of work shifts is feasible. If this test fails, a cut is added to the master problem. Otherwise, a solution with minimum total deadhead traversal distance is selected.

5 Conclusion

We present the railroad track inspection problem and propose a mixed integer program formulation for it. To tackle its resolution we choose to solve it by an original column and cut generation framework. The computational tests performed on real datasets (750 nodes, 1340 arcs, 752 edges, 2 vehicles), highlight the quality of the solution obtained after 4 hours of computing. The algorithm successed in scheduling the 700 tasks of year 2009. The solution have a theoretical performance ratio (inspected distance / total distance) greater than 90%. These results are currently tested against the one obtained by hand.

References

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