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Abstract

The technician routing and scheduling problem consists in routing and scheduling a crew of technicians in order to attend a set of service requests, subject to skill, tool, and spare part constraints. In this study we propose a formal definition of the problem and present a constructive heuristic and a large neighborhood search optimization algorithm.

1 Introduction

The present work deals with the Technician Routing and Scheduling Problem (TRSP), in which a limited crew of technicians serves a set of requests. The TRSP can be seen as an extension of the Vehicle Routing Problem with Time Windows (VRPTW), where technicians play the role of vehicles and requests are made by clients. In the TRSP, each technician has a set of skills, tools, and spare parts, while requests require a subset of each. The problem is then to design a set of tours such that each request is visited exactly once, within its time window, by a technicians with the required skills, tools, and spare parts. The TRSP naturally arises in a wide range of applications, including telecoms, public utilities, and maintenance operations.

The TRSP is related to the multiple Traveling Salesman Problem with Time Windows (mTSPTW). At one end, if each technician has the required skills, tools, and spare parts to serve all requests, then the TRSP reduces to the mTSPTW. In contrast, if each request can be served by exactly one technician, the TRSP can be decomposed in independent TSPTWs (one per technician). The TRSP falls between the two problems, where both routing and assignment decisions are made, considering tools, spare parts, and return trips to the central depot.

The novelty of this problem is twofold. First, it introduces interesting compatibility constraints between technicians and requests. While skills are intrinsic attributes, technicians may carry different tools and spare parts over the planning horizon. Technicians usually start their tour from their home with an initial set of tools and spare parts that allows them to serve an initial set of requests. They also have the opportunity to replenish their tools and spare parts at a central depot at any time to service more requests. Tools can be seen as renewable resources, while spare parts are non renewable and consumed once the technician serves a customer. Second, the TRSP differs from most routing problems (including the classical VRP) in its objective, as the workload balance among technicians is at least as important as the minimization of the traveled distance.

In this work we focus on a slightly restricted version of the TRSP, where requests require one skill and have hard time windows. We also assume that while tools and spare parts are available in unlimited quantities at the central depot, technicians are indeed limited. The objective is to balance the workload, while meeting a maximum shift length.

2 Literature review

Despite its numerous applications, technician routing problems have received limited attention and relatively few research has been conducted on closely related problems.

Borenstein et al. [1] studied the technician workforce scheduling problem faced by British Telecom considering dynamic requests and skill constraints. To reduce its complexity they group requests into clusters and heuristically assign technicians to areas considering multiple objectives. They propose a rule based system that assigns and schedules requests to technicians depending on metrics such as their priority.

Xu and Chiu [7] studied a variant of the TRSP in which the objective is to maximize a weighted sum of job priorities and the technicians' idle time. Tang et al. [6] also considered job priorities and formulated the TRSP as a multi-period maximum collection problem, in which time-dependent rewards are granted for the completion of a request.

Finally, Bredström and Rönnqvist [2] studied an interesting variant of the VRPTW in which some clients must be visited simultaneously by two or more vehicles. Although they do not explicitly consider skills, the proposed model accounts for compatibility constraints between vehicles and requests.

To the best of our knowledge, no author has considered tools or spare parts. In the following section we will describe an approach to tackle this problem.

3 Proposed approach

The proposed approach couples two components, namely, a constructive heuristic with an Adaptive Large Neighborhood Search (ALNS) procedure.

The constructive heuristic is a parallelized greedy algorithm that constructs a tour for each technician by iteratively inserting requests. This is achieved by evaluating the cost of inserting all requests in all tours, and then solving an assignment problem to decide which request will be inserted in each tour. A direct consequence is that at each iteration the algorithm inserts at most one request in each tour. The procedure only considers feasible insertions, possibly inserting a trip to the depot to satisfy tool and spare part constraints. If no further requests can be inserted, the algorithm backtracks and reverts the first assignments, storing removed requests in a temporary pool to prevent cycling. Then it attempts the insertion of unserved requests. If successful, the procedure is resumed with the whole set of unserved requests; if not, additional requests are removed. The algorithm stops when a feasible solution is found or after a predefined number of iterations. If no feasible solution can be found, then the solution servicing the largest number of requests is used.

The ALNS algorithm [4] works by successively *destroying* and *repairing* a current solution. At each iteration, the algorithm selects destroy and repair procedure with a roulette wheel that reflects their past performance. Destroy methods remove a subset of 10% to 40% of the requests from the current solution, while repair procedures reinsert them using heuristics that are known to perform well on the problem at hand. The resulting new solution is accepted as current solution according to a simulated annealing criterion. The algorithm stops after a fixed number of iterations.

We developed three destroy procedures for the ALNS: the first, *random destroy*, consists in randomly removing requests, allowing diversification of the search; the second, *related destroy*, selects requests that are related in terms of required skills, time windows, and location, the goal being to exchange similar requests among technicians; finally, *critical destroy*, attempts to removes requests that are costly in the current solution. In all three cases, the goal is to reverse assignment decisions that were taken previously and overconstrain the technician tours (e.g., by forcing the visit of requests in distant areas or with conflicting time windows). In addition, destroy procedures evaluate the removal of unnecessary trips to the central depot.

On the other hand, we use two repair procedures. The first one, *best insertion*, is an intuitive greedy heuristic that iteratively inserts the request with the lowest insertion cost. The second procedure, *regret*, estimates the cost of not inserting a request in its best tour, in order to avoid postponing difficult insertions, as it can occur with best insertion.

In addition, we propose a Variable Neighborhood Descent (VND) [3] that optimizes each tour independently, without considering exchanges of requests between technicians. Two neighborhoods are used: *shift*, which moves a request within the tour, and *2-opt*; which reverses a subtour. At this stage, preventive trips to the central depot that were previously planned to ensure tour feasibility can be moved within the tour, provided that tool and spare parts constraints are satisfied. This cluster-first, route-second approach is justified by the strong compatibility constraints between requests and technicians that limit the possible intertour optimization, and by the fact that the destroy-repair process addresses this issue. The VND is used as a post-optimization procedure in both the constructive and optimization phases.

To assess the performance of the proposed approach we adapted the instances of Solomon [5] adding skills, tools, and spare parts information. Preliminary results show that a basic version of the ALNS is able to improve the initial solution total working time by 5% and the standard deviation of tour length by 7%. In addition, work currently underway involves testing the algorithm's adaptability to problems faced by maintenance companies.

4 Conclusions

We described the TRSP, a routing problem with both challenging features and numerous applications. As a first step towards the dynamic version, this work proposes a metaheuristic approach that tackles the static version of the problem, in which all information is known beforehand. Future work will focus on the development of online algorithms able to cope with both planned (e.g., preventive maintenance) and dynamic requests (e.g., corrective maintenance), that may emerge during the day, as well as unexpected delays such as longer service times.

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