

A template based adaptive large neighborhood search for the consistent vehicle routing problem

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1 Introduction

The consistent vehicle routing problem (ConVRP), as defined in [1], is an extension of the periodic vehicle routing problem. This problem category involves the construction of routes over a given time period, e.g several days, such that customer demands are met. However, a simple delivery is nowadays not enough for companies to differentiate themselves in a competitive environment. For this reason, many companies started to focus on customer satisfaction to increase customer loyalty and to obtain a competitive advantage. From the customers' point of view, an important criterion for a high quality service is consistency. So, the ConVRP, besides considering the traditional constraints, also accounts for this additional requirement of service consistency. This is modeled in two ways. First, in order to form a stronger relationship between the supplier and the customer, a customer can only be assigned to one driver. Second, to enable the customers to prepare themselves for a delivery, they have to be serviced at about the same time of the day. Customers to be serviced are situated at regionally different locations where they demand a predetermined number of services during the planning horizon. The demand pattern for each customer is characterized by the amount of goods delivered on a given day and the time needed for this service. A delivery can be required on several days, however, customers are visited only once a day if service is demanded. Visits are performed by a homogeneous fleet of vehicles. This fleet is located at a single depot, which is left at time 0. The number of vehicles is not restricted but their maximum capacity is. Due to the tour length restriction, the vehicles must return to the depot before the maximum tour length is exceeded. Even though the fleet is homogeneous, the drivers are not. The first consistency requirement therefore dictates that a customer is serviced by the same driver over the whole planning horizon. The second consistency requirement bounds the difference between the earliest and the latest arrival time over multiple days for all customers to a given value. Vehicle idling to decrease the arrival time difference is not allowed.

The objective is to create a routing plan for each day in the planning horizon such that the aggregated travel time is minimal and the constraints are satisfied.

2 Solution method

For tackling the described problem, a template based adaptive large neighborhood search (TALNS) [2, 3] framework is developed. Template based in our context refers to the fact that the routing plans for several days are derived from a single set of template routes [1]. To make the best use of such a template, it has to include all customers for which consistency requirements have to be considered. Those are all customers that require service on two or more days. The actual daily routes are then derived by resolving the template: customers that

do not demand service on that particular day are removed, customers that only demand service on that particular day are inserted.

Given an initial solution, different template sets are generated and resolved repeatedly during the TALNS phase in the hope of finding a minimal cost assignment. This procedure relies on the basic idea of iteratively removing customers from the template routes to reinsert them at positions where they might fit better. In other words, the template is repeatedly destroyed and repaired. Based on this approach, the main feature of the TALNS is that it integrates several problem-specific destruction and repair sub-heuristics. In every iteration there is a sub-heuristic pair selected according to its performance in previous iterations and used to obtain an altered template. The consideration of the past performance of the sub-heuristic pairs enables the TALNS to adjust itself to different problem instances and different search stages.

By the time the actual routes are obtained and all customers are assigned, a local search is performed to correct the potential inefficiency resulting from the deletion of excessive customers.

In an alternative ConVRP model, we relax the constraint for the vehicle departure times to be zero. Given this modification, solutions that are infeasible because of time consistency violations can be repaired by delaying the vehicles' departure times. To shift the departure times, we developed a heuristic and an exact approach, which are called during the TALNS every time a solution is produced that violates only the time consistency.

3 Results

The algorithm is implemented in C++ and is tested on the benchmark instances developed for the ConVRP by Groër et al. [1] and on two modified sets derived from the benchmark set. To test the performance of the developed algorithm, the results are compared to those obtained by the template based record-to-record travel algorithm (ConRTR) [1] and a tabu search algorithm (TTS) [4] that is also template based. The proposed TALNS generates results that are, on average 5.68% better than those achieved by the ConRTR and 0.76% better than those of the TTS. These comparisons clearly indicate that the TALNS is a competitive solution method for the ConVRP. Further experiments are performed to investigate the effect of different maximum arrival time difference constraints, L . The results show that the TALNS can produce robust solutions even with decreasing maximum arrival time differences. However, when this constraint gets too tight, it is no longer possible to obtain reasonable solutions. Experiments show that a 60% decrease in L can cause the average total travel times to increase by more than 186%. The possibility to shift the vehicles' arrival times, on the other hand, enables the generation of solutions that are almost independent of the maximum allowed arrival time difference. A 60% decrease in L leads to an increase of 1.19% in the average total travel time with the integrated exact shifting approach and of 5.97% with the heuristic shifting approach.

References

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