A TABU SEARCH APPROACH FOR MILK COLLECTION IN WESTERN NORWAY USING TRUCKS AND TRAILERS

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1 Introduction

Milk collection is a problem which is well known in rural areas all around the world. This paper considers a real world problem for a Norwegian dairy company collecting raw milk from farmers. Chao (2002) and Scheuerer (2006) describe the *Truck and Trailer Routing Problem* (TTRP) as a variant of the traditional *Vehicle Routing Problem* (VRP). In this problem customers are divided into *vehicle customers* who can be reached with a complete vehicle with a trailer, and *truck customers* who only can be reached by a single truck. Most Norwegian farms are however small and inaccessible for a large truck with a trailer, and thus our problem can be classified as a special type of the TTRP where all customers are defined as truck-customers. The company uses a fleet of heterogeneous trucks with tanks for the milk, and a truck can either drive the route by itself or carry a trailer with an additional tank. The routes are then designed in a way that allows the trailer to be parked at a parking place while the truck is visiting the farms and collecting the milk. The possible parking places are prearranged mostly at large parking lots or petrol stations. When the tank on the truck is full, the truck will return to the parked trailer. It can then fill the milk over from the truck tank to the trailer tank and start on a new subtour from the same spot, or it can drive the trailer to a new parking place, fill the milk over and start a subtour from there.
Figure 1 shows a graph which represents a solution to the milk collection problem with the constraints mentioned. The circle marks the depot, while the squares are the parking places which are used as roots for the subtours that visits the suppliers marked with triangles. This type of solutions, with the trailer serving as a mobile depot for the truck, was first described by Vahrenkamp (1989) for the milk collection in Western Germany.

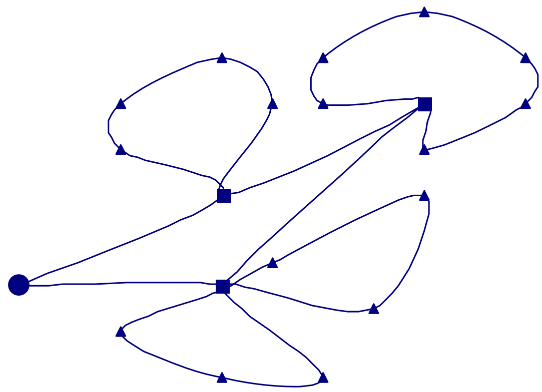

Figure 1. *The structure of solutions for milk collection used by the company*

The outline of this extended abstract is organized as follows. Section 2 provides the definitions of our real-world problem. In Section 3, we present the tabu search heuristic and shows how the algorithm is adjusted to fit our problem. Section 4 shows the computational results which are to be reported.

2 Problem definition

Our real-world problem could best be described as a TTRP where all customers (suppliers) are defined as truck-customers. However, in contrast to the earlier described TTRP, it is also a multi depot problem in that milk from a supplier can have a choice of different dairies for processing.
Since the milk does not need to be collected each day, the same vehicle can drive different tours for different days. This periodicity is solved in the model by multiplying the number of vehicles available with the frequency of the visits. If a vehicle is driving the same tour every third day, this is planned as three different tours in the model and the amount to be collected is adjusted according to the number of production days. The model is described according to today's practice where no suppliers can be visited by a complete vehicle with a trailer. Every tour is attached to one dairy plant and will not deliver milk to other plants, even if such tours are possible to construct.
Some limitations from the real world situation are used in this model partly because not all information is known and also to reduce the problem to be solvable within the limited time available for this project. Further research on this case should try to implement these matters. At first, the dimension of time is not considered, and then neither is the cost of the tours in money.

The tours are compared by a total distance cost which is similar to the distance driven but since the distance table do not specify ferries and toll roads, these matters have to be considered otherwise to reduce passing of these bottlenecks to a minimum. In the model, we have estimated the cost of using a ferry similar to driving 50 kilometres and passing a toll road similar to driving 25 kilometres and in the objective function these values are added to the driving cost when the tour passes one of these bottlenecks.
The model of the problem presented in this paper could be described by the definitions below.

1. The problem consists of a set of depots D, a set of parking places P, a set of suppliers S and a fleet of vehicles V.
2. Each depot $d \in D$ should have delivered a minimum daily amount ζ_d.
3. Each supplier $s \in S$ has a certain amount of daily production ρ_s.
4. A solution σ to the problem consists of M routes of vehicles $v \in V$ starting and ending at a depot d and visiting all suppliers in S.
5. The vehicles can be of different sizes. The capacity Q_v of the complete vehicle should not be exceeded on a full tour, and the capacity of the truck Q_t should not be exceeded on a subtour
6. The distance between all depots $d \in D$, parking places $p \in P$ and suppliers $s \in S$ are given in a distance table C. $c_{ij} \in C$ gives the distance between nodes i and j where $i,j \in D \cup P \cup S$. The total driving cost of a solution σ is given by the function $\gamma(\sigma)$.
7. Extra costs for ferries and toll roads when driving between depot, parking places and suppliers are calculated from a table of extra costs E. $e_{ij} \in E$ gives the extra costs between nodes i and j where $i,j \in D \cup P \cup S$. The total extra costs of a solution σ are given by the function $\varepsilon(\sigma)$.
8. A solution is defined as infeasible if the total load exceeds the vehicle capacity or the load on a subtour exceeds the truck capacity. In addition a solution is infeasible when the sum of the driving cost and the extra cost exceeds an upper limit or when the tours attached to a depot do not deliver the necessary amount ζ_d. These solutions are accepted in the search with a penalty $\beta(\sigma)$ to the calculated cost.
9. The objective function $f(\sigma)$ of a solution is to minimize the cost of all tours.
   $f(\sigma) = \gamma(\sigma) + \varepsilon(\sigma) + \beta(\sigma)$

In addition the following assumptions are used to describe the problem.

10. Every supplier is served by exactly one vehicle.

11. Milk from a supplier can be delivered to different depots, although not on the same tour.
12. No suppliers can be reached with a truck carrying a trailer.
13. When using truck with a trailer the depot should be visited only once.
14. Tours using only a truck may consist of several subtours from the depot.
15. A tour should start and end at the same depot and can not deliver milk to another depot in the same tour.
16. A trailer tour consists of a tour between possible parking places and subtours from those with the truck as shown in figure 2.
17. A trailer can be parked several times and several subtours can be driven from each parking place.
18. Parking places are separate entities and not attached to any customer.
19. A parking place is only used if it is favourable. Parking places do not have to be visited as they have no demand, and the model chooses the best parking place from the set P which may contain more parking places than needed.
20. When creating the tours, the planners will not take time windows for the visit into consideration. This is managed by the drivers of the vehicles in agreement with each farmer.
21. When planning tours where the suppliers not are visited every day, each day is treated as a separate tour and the amount to be collected are adjusted according to the frequency of the visits.
22. The model considers no extra cost for driving with a trailer compared to a single truck. Neither is the speed considered different if the trailer is attached the vehicle.
23. All ferries are treated in the same way with a constant added to the cost function. This is independent of the length of the ferry distance, the fare, the departure frequency or if the trailer is attached. This addition to the cost function is necessary to avoid superfluous ferry trips.
24. The toll roads are similarly treated as ferries with a constant added to the cost function.
25. The driving time is not considered in the model, but there is a constraint that the sum of the driving cost and extra costs of a feasible tour should not exceed an upper limit. This constraint will prevent the tours from being too long.

3 Tabu Search

Tabu search is a well-known metaheuristic which is described in Glover and Laguna (1997). A standard one-interchange neighborhood (Osman, 1993) is defined and techniques from Granular Tabu Search (Toth and Vigo, 2003) are introduced to reduce the size of the neighborhood to those neighbors most probable to lead to a better solution. A partial neighborhood examination in each iteration based on ideas from Semet and Taillard (1993) is used to reduce the computation time even more.

To exploit the advantages of tabu search in the best possible way, it is necessary with a careful calibration of the parameters used in the search. Several tests are performed to find the right number of iterations to use in the search and the length of the tabu list. To allow infeasible solutions in the search, a penalty function is introduced and a dynamic penalty factor is adjusted during the search to make it possible to oscillate between feasible and infeasible solutions. In addition a diversification strategy is included to avoid that the same move is performed to often, and the factor used for diversification is adjusted to the value that gives the best results. Creating an initial solution is an important step in the process of obtaining good solutions from a search. A clustering technique based on the strategy suggested by Fisher and Jaikumaar (1981) is used in the construction phase of initial solutions. Here every tour in the solution is constructed by containing one *seed order*, and then the other orders are assigned to the tours by solving a *Generalized Assignment Problem* (GAP).

4 Computational results

Results of a tabu search for solutions with different type of vehicles and different visiting frequency at the farmers will be reported.

Finding the optimal parking places for the subtours is an important issue of getting good solutions. The possibility of using different parking places for different subtours is clearly an advantage which affects the total driving cost, and results of a search which compares solutions were the trailer can be moved with solutions where the trailer uses the same parking place as root of all the subtours will also be presented.

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