Deterministic annealing algorithm for a time-dependent routing problem in drayage operations

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ABSTRACT

Drayage operations refer to the full truckload container transport activities that take place on a regional scale around the intermodal container terminals. They involve the transport of loaded and empty containers between these container terminals, container depots, consignees and shippers. Drayage operations are mostly performed by truck and constitute a large part of total costs of an intermodal transport. Therefore, efficient planning of these operations is an important task. Special attention should be paid to minimizing empty container movements since they are costly non-revenue generating activities.

In the past, often a sequential planning approach is proposed to plan empty container movements. First, an empty container allocation model is used to determine the optimal distribution of empty containers in the region, based on supply and demand information of consignees and shippers respectively. Next, a vehicle routing problem is solved to create efficient vehicle routes performing loaded and empty container transports. Recently, efforts to integrate both planning steps are introduced by several authors (Smilowitz 2006, Ileri 2006, Zhang et al., 2009, 2010, Braekers et al. 2012). In an integrated approach, empty container allocation decisions are not taken in advance. Instead, these decisions are taken simultaneously with vehicle routing decisions. As a result, drayage costs can be reduced (Braekers et al., 2012). Zhang et al. (2009, 2010) show that the integrated problem may be formulated as an asymmetric multiple vehicle Traveling Salesman Problem with Time Windows (*am*-TSPTW). They propose respectively a Reactive Tabu Search algorithm and a time window partitioning method to solve the problem. Braekers et al. (2012) take a similar approach and propose a two-phase deterministic annealing algorithm which outperforms the method of Zhang et al. (2009, 2010).

A simplifying assumption made in these papers mentioned above is that travel times are assumed to be constant in time. In practice, the travel time on a link will depend on the time of the day, especially in the often heavily congested areas where drayage operations take place. In this paper, the two-phase deterministic annealing algorithm of Braekers et al. (2012) is adapted to a time-dependent problem setting. The planning period is divided into several time intervals and for each interval the expected speed on a link is determined. Based on this speed information, a travel time matrix is calculated which indicates the travel time between each pair of nodes for each point in time. It is ensured that these travel times satisfy the non-passing or FIFO-principle.

The objective of the problem is to first minimize the number of vehicles needed and second the total duration of the routes. A major difference between the time-dependent and the time-independent problem is the complexity of evaluating the impact of a local search move on the secondary

objective. For the time-independent problem this impact can be evaluated relatively efficiently by storing the appropriate information of the current routes during the search. For the time-dependent problem this option is no longer valid. For example, inserting a node *i* into a route will affect the arrival times of consecutive nodes in the route. As a result, travel times in this part of the route might change. Predicting these changes without recalculating arrival times of all nodes after node *i* is not possible. Furthermore, the optimal starting time of the vehicle at the vehicle depot might change. Leaving the depot earlier or later may result in a smaller duration of the route.

The two-phase deterministic annealing algorithm that is proposed works as follows. In the first phase the number of vehicles is minimized while in the second phase the total duration of the routes is minimized. During each phase, several local search operators are used to find neighbors of the current solution. Since the effect of a move on the objective function cannot be determined efficiently, each time a feasible move is found, the move is temporarily accepted and the corresponding routes are recalculated. This means that for all nodes new arrival times are calculated and the optimal starting time of the vehicle is determined. Based on these new values and the value of the deterministic threshold, it is determined whether the move is permanently accepted or not.

Results show that this algorithm is able to find good quality solutions. However, average computation times are much higher compared to the time-independent problem. Several approaches to speed up the search are considered. First, it seems that calculating the optimal start times of the vehicles after each local search move is not necessary. Often, adapting these start times has little effect on the total duration of the routes. It is proposed to use the latest possible start time during the search and calculate the optimal start time only at the end of the search. Second, the idea is explored to immediately reject some feasible local search moves, before calculating the effect on the objective function. When carefully selecting the moves to be rejected immediately, computation time can be saved without decreasing the quality of the results. Preliminary results show that both approaches are suitable for the reduction of computation time with little effect on solution quality.

Future research will focus on the improvement of the algorithm. The local search operators currently in use may be adapted to better take the time-dependent problem information into account. New local search operators may be proposed as well. Finally, additional computational experiments are needed to investigate how the algorithm performs under different travel time conditions.

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