The Home Care Crew Scheduling Problem

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Abstract The Home Care Crew Scheduling Problem (HCCSP) of this paper has its origin in the Danish healthcare system. The home care service was introduced in 1958 and since then, there has been a constant increase in the number of services offered. The primary purpose is to give senior and disabled citizens the opportunity to stay in their own home for as long as possible. The problem of scheduling the services for the citizens as handled by the municipalities in Denmark can basically be decomposed into two interesting optimization problems. The first long-term planning problem fixes visit on days and assigns the visit a time window in accordance with the quality standarts of the municipality. The second short daily problem assigns theses visits for a given day to a given home carer therebye building the daily routes for a group of home carers. So in this problem, denoted the HCCSP, home carers should be assigned tasks in a way that maximizes the service level, possibly even at a reduced cost.

Keywords crew scheduling · vehicle routing · column generation · set partitioning

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The methodology presented in this paper is built on the literature of the vehicle routing problem with time windows (VRPTW). Column generation has proven an invaluable tool in optimization of vehicle routing problems. The main differences to regular vehicle routing problems are a limited number of home carers with individual shifts, temporal dependencies between visits, and the presence of a number of soft constraints. These exceptions must naturally be dealt with explicitly in the model.

When a citizen applies for home care service, a preadmission assessment is initiated. The result of the assessment is a list of granted services. The services may include cleaning and laundry assistance and support for other everyday tasks. They may also include assistance with respect to more personal needs, e.g. getting out of bed, bathing, dressing, preparing food, and dosing medicine. As a consequence of the variety of services offered, people with many different competences are employed as home carers.

Given a list of services for each of the implicated citizens, a long term plan is prepared. In the long term plan, each service is assigned to specific time windows, which are repeated as frequently as the preadmission assessment prescribes. The citizens are informed of the long term plan, and hence they know approximately when they can expect visits from home carers. From the long term plan, a specific schedule is created on a daily basis. In the daily problem, home carers are assigned to visits. A route is built for each home carer, respecting the competence requirements and time window of each visit and working hours of the home carer. In the following, we restrict ourselves to look at the daily scheduling problem only. The problem is a crew scheduling problem with strong ties to vehicle routing with time windows. However, we have a number of complicating issues that differentiates the problem from a traditional vehicle routing problem. One complication is the multi-criteria nature of the objective function. It is, naturally, important to minimize the overall operation cost. However, the operation cost is not very flexible in the daily scheduling problem. It is more important to maximize the level of service that we are able to provide. The service level depends on a number of different factors. Usually, it is very hard to fit all visits into the schedule in their designated time windows. Hence, some visits may have to be rescheduled or cancelled. In our solutions, a visit is either scheduled within the given restrictions or marked as uncovered. The manual planner will deal with uncovered visits appropriately. The main priority is to leave as few visits uncovered as possible. Also, all visits are associated with a priority and it is important to only reschedule and cancel less significant visits. Also, it is important to service each citizen from a small subgroup of the whole workforce, as this establishes confidence with the citizen. Another complication compared to traditional vehicle routing, is that we have shared visits. These are visits requiring the presence of more than one home carer, and consequently each visit must be included in the route of several home carers, where the interconnected visits must be synchronized.

HCCSP as described above is decomposed and modelled as a set partitioning problem (SPP) with side constraints. An elementary shortest path problem with time windows (ESPPTW) is used for column generation. The SPP is denoted the master problem, and the ESPPTW correspondingly is the subproblem. This approach has presented superior results on VRPTW and the similarities to HCCSP are strong enough to suggest the same approach here.

The model is solved in a Branch-and-Price framework. As the number of feasible routes is exponential in the number of visits, it is impossible to include all routes a priori. Instead, the most promising routes (columns) are generated dynamically in an iterative process. The master problem is LP-relaxed and the columns are generated based on a dual solution to the LP-relaxation.

The method is tested on authentic test instances from two Danish municipalities. The results are compared to the current practice, which is based partly on an automated heuristic and partly on manual planning. We measure three quality parameters: Uncovered visits, constraint adjustments, and total travel time. The uncovered visits are visits, where a home carer has not been assigned in the schedule. In practice, this may imply that the visit is cancelled or that a substitute is called in and assigned to those uncovered visits. Another way of dealing with an uncovered visit is to adjust the original constraints, so that we are able to fit the visit into the schedule anyway. Possible options are to: reduce the duration of the visit, extend the time window of the visit or extend the work shift of one of the home carers. This is done a lot in practice. However, any of these adjustments will naturally decrease the overall quality of the schedule. In the presented solution method, we have chosen to keep all the original constraints intact, and let the constraint adjustment be a manual post-processing task. This decision is also supported by the fact that it is hard to put a quantitative penalty on all possible adjustments before solving. The number of constraint adjustments in our solution will hence always be equal to 0.

The results clearly indicate that we are able to enhance the service level. There is a significant decrease in the number of uncovered visits and a truly dramatic decrease in the number of necessary constraint adjustments.