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A heuristic to solve the synchronized log-truck scheduling problem

Nizar El Hachemi *, Michel Gendreau, Louis-Martin Rousseau

Interuniversity Research Centre on Enterprise Networks, Logistics and Transportation (CIRRELT), C.P. 6128, succursale centre-ville, Montreal, Canada H3C 3J7

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ABSTRACT

We present a synchronized routing and scheduling problem that arises in the forest industry, as a variation of the log-truck scheduling problem. It combines routing and scheduling of trucks with specific constraints related to the Canadian forestry context. This problem includes aspects such as pick-up and delivery, multiple products, inventory stock, multiple supply points and multiple demand points. We developed a decomposition approach to solve the weekly problem in two phases. In the first phase we use a MIP solver to solve a tactical model that determines the destinations of full truckloads from forest areas to woodmills. In the second phase, we make use of two different methods to route and schedule the daily transportation of logs: the first one consists in using a constraint-based local search approach while the second one is a hybrid approach involving a constraint programming based model and a constraint-based local search model. These approaches have been implemented using COMET2.0. The method, was tested on two industrial cases from forest companies in Canada.

1. Introduction

Forestry represents a major economic sector in Canada and account for a large proportion of its exports. Planning problems in forestry cover a wide scope of activities ranging from planting and harvesting to road building and transportation. Furthermore, in many of these activities, it is critical to pay attention to important environmental issues, such as green house gas emissions, as well as to company-specific goals, operations rules, and government restrictions.

In Quebec, transportation represents more than 30% of the cost of provisioning for wood transformation mills, i.e., approximately $15 per cubic meter of roundwood. The average distance between forest areas, where wood is collected and mills to which this wood is transported,, is around 150 km, and about 50% of the fuel required per cubic meter of collected wood is consumed by the forest trucks traveling, half of the time empty, between forest areas and mills. Transport activities between forest areas and mills should, therefore, be organized as effectively as possible. If in recent years significant attention has been devoted to transportation-related scheduling problems, mainly for economic and environmental reasons, in most Canadian forest companies, truck schedules are derived manually by an expert planner.

The main contributions of this paper are to synchronize trucks and log-loaders and to extend the log-truck scheduling problem (LTSP) to the weekly horizon, where inventories at wood mills are taken into consideration in order to allow woodmills to work in a just in time mode. Furthermore, our approach is generally applicable to problems with a need to synchronize routing and scheduling.

The paper is organized as follows. Sections 2–5 present, respectively, the previous work, the problem description and a brief description of the solution approach, the tactical model and the daily synchronized LTSP. The experimental setting is described in Section 6, where computational results are also reported. Section 7 concludes the paper.

2. Previous work

The LTSP is closely related to some routing problems encountered in other industries, in particular, so-called "pick-up and delivery problems". For general surveys of the vehicle routing problem (VRP) and pick-up and delivery with time windows (PDPTW), we refer the reader to Cordeau et al. [6], Gendreau et al. [13], Savelsbergh and Sol [33], Dumas et al. [7] and Toth and Vigo [35]. This paper considers a pick-up and delivery problem in which for each request exactly one load of wood has to be transported from its pick-up location (forest area) to its delivery location (woodmill). A truck visits only one forest area and one mill on any given trip, i.e., requests are served individually by trucks. After unloading at a mill from its previous trip, a truck is usually sent back empty to its next forest destination.

* Corresponding author.
E-mail addresses: nizar@crt.umontreal.ca (N. El Hachemi), michelg@crt.umontreal.ca (M. Gendreau), louism@crt.umontreal.ca (L.-M. Rousseau).

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Several models and methods have been developed in the literature to solve the LTSP. Among these, the heuristic-based approach of [38] has been used successfully since 1990 to produce daily plans for trucks in Chile. The application of this heuristic in Chile has led to a 32% reduction in truck fleet size, a 13% reduction in average working hours and operational costs, and a 31% increase in productive hours for one company. Linnainmaa et al. [21] propose a knowledge-based system called EPO that deals with all stages from strategic to operational planning. The input data is collected online directly from the forest areas and the main output is a weekly schedule for each truck. One main goal of EPO is the minimization of truck driving as whole. Palmgren et al. [26] have proposed more recently a pseudo-column generation based model, which is solved using a branch-and-price procedure, where each column represents one feasible route for one truck. An initial set of routes is generated at the beginning. The subproblem, which is a constrained shortest path problem, is then solved by applying a k-shortest path algorithm. The columns whose reduced costs are negative are communicated to the master problem. Flisberg et al. [12] and Andersson et al. [1] proposed a two-phase solution approach, in which the LTSP is transformed into a standard vehicle routing problem with time windows. In the first phase, flows are determined from supply points to destinations, thus yielding a number of transportation "tasks" that are combined into routes in the second phase. The dispatching procedure that continuously updates the trucks routes during the day is based on the previous work of [30,29]. Gronalt and Hirsch [14] applied a tabu search algorithm to solve a restricted variant of the LTSP in which the number of trips between each forest area and each mill is given. The same assumption is used by El Hachemi et al. [8] who develop a hybrid method combining integer programming (IP) and constraint programming (CP): the IP model generates optimal routes in term of deadheading, while CP deals with the scheduling part. For a more detailed description of optimization problems in the forest sector, we refer the reader to [28].

With respect to numerical experiments, [24] presents a case study with on average nine trucks and 35 transport tasks per day, while [25] have solved two case studies for Sweden: one with six trucks and 39 transport tasks, and one with 28 trucks and approximately 85 transport tasks. Gronalt and Hirsch [14] solved random problems with 30 transport tasks and 10 trucks, [8] deal with daily problems having up to 18 trucks and 70 transport tasks. Finally, [12,1] have solved substantially larger instances ranging from 188 transport tasks to about 2500 full truck loads with 15–110 trucks.

Synchronizing vehicles with other tasks arise in many real-world applications. The synchronization constraints occur in the well-known dial-a-ride problem (see [32]), in which some disabled persons require assistance in order to prepare for transportation. This assistance can vary from dressing to providing a wheelchair and is not usually required at all time or by all customers. More details concerning the homecare staff scheduling are given by [9,10]. There are many other applications in which vehicles must be synchronized, like the urban mass transit systems, which combines vehicle and crew scheduling problems and where drivers are allowed to change bus in so-called relief points. As described in [15,11], the synchronized arrival of bus to the relief points is implicitly guaranteed, since it is defined by a timetable. In the airline industry, synchronization constraints have been introduced by [19]. In fact, the classical fleet assignment problem studied by [16] states that, given a fixed flight timetable, there is a need to decide which aircraft to use for each flight on a daily basis. However, Ioachim et al. [19] studied the case, where the timetable is not fixed and departure times of flights are given on a daily basis for an entire week, such that each flight has a time window on either its departure or its arrival. To obtain a more robust schedule, synchronization constraints are introduced to guarantee that every flight will have the same departure time on each day. In the forest industry, harvesting operations are performed by harvesters and forwarders. The coordination between them specifies that forwarding can only be done once harvesting has been performed (see [20]). In the same context, and related to the LTSP, there is a need to synchronize trucks that do not have an onboard crane with forest loaders. For more details about the importance of synchronization constraints in the real-world situations, we refer the reader to [4].

3. Problem description and general solution approach

It must be noted that the problem as considered in this paper differs in several ways from LTSPs addressed by other authors. These differences stem from specific characteristics of Canadian forestry operations. In Canada, cut areas and log volumes are generally quite large. It is, therefore, customary when dealing with higher value products, such as hard wood, to assemble full truckloads prior to transportation by merging similar logs that are going to the same destination. While quantities are generally expressed in cubic meters, these can be easily converted into truckloads. In several variants of the LTSP, each truck must begin and end its route at its given home base, which often corresponds to the truck operator's home or yard. In our application, the bases of all trucks are mills and we are allowed to reallocate trucks among mills to obtain more efficient solutions. Driver changes are normally performed at mill when a route exceeds the maximum allowed driving time for a driver. In this paper, issues related to driving time, rests or changeovers are not taken into account. Demands at woodmills are given on a daily basis, whereas routes and schedules of trucks are determined on a weekly basis. Since the stock of products at woodmills is constrained, this requires integrating transportation schedules over several days.

We assume that at each mill and each forest location, there is a single log-loader that ensures the loading and unloading of all trucks. When a truck arrives at a location, if the loader is busy, the truck has to wait until the loader becomes available. These waiting times can severely delay trucks and thus increase the cost of transportation; they should, therefore, be avoided as much as possible. In some variants of the LTSP studied in the literature, loaders work a fixed shift during the day, and it is assumed that they support harvesting between truck loading operations. In our application, loaders cannot effectively support harvesting operations between successive trucks as forest sites are too large, it is thus critical to maximize their usage.

The solution approach that we have implemented is based on a decomposition of the overall weekly problem into a "tactical problem", in which the destination of each full truckload of wood is determined, and a series of seven "daily problems", in which we determine deadhead trips and schedule trucks and forest loaders.

The proposed approach takes into account the cost of loaded travel in the tactical phase; once loaded trips have been determined, empty driven distance and waiting times in forest areas and at woodmills are minimized, which leads to a reduction of green house gas emissions, since these are directly proportional to fuel consumption.

4. The tactical problem

The tactical problem is addressed using a MIP model. As mentioned before, the purpose of the tactical model is to determine to which woodmill each load should be transported.