Information Sciences 264 (2014) 302–316

Contents lists available at ScienceDirect

Information Sciences

journal homepage: www.elsevier.com/locate/ins

# Scheduling a log transport system using simulated annealing

Karunakaran Haridass [a], Jorge Valenzuela [a], Ahmet D. Yucekaya [b,*], Tim McDonald [c]

[a] *Department of Industrial & Systems Engineering, 3304 Shelby Center, Auburn University, Auburn, AL 36849-5347, USA*
[b] *Department of Industrial Engineering, College of Engineering, Cibali Campus, Kadir Has University, Istanbul, Turkey*
[c] *Department of Biosystems Engineering, Auburn University, 224 Tom E. Corley Building, Auburn, AL 36849-5347, USA*

A R T I C L E  I N F O

*Article history:*
Received 23 November 2012
Received in revised form 29 October 2013
Accepted 8 December 2013
Available online 12 December 2013

*Keywords:*
Log transport
Simulated annealing
Deterministic simulation
Vehicle routing

A B S T R A C T

The log truck scheduling problem under capacity constraints and time window constraints is an NP-hard problem that involves the design of best possible routes for a set of trucks serving multiple loggers and mills. The objective is to minimize the total unloaded miles traveled by the trucks. In this paper, a simulated annealing – a meta-heuristic optimization method – that interacts with a deterministic simulation model of the log transport system, in which the precedence and temporal relations among activities are explicitly accounted for, is proposed. The results obtained by solving a small size problem consisting of four trucks, two mills, three loggers, and four truck trips showed that the best solution could be found in less than two minutes. In addition, the solution method is tested using data provided by a log delivery trucking firm located in Mississippi. The firm operates sixty-eight trucks to deliver loads from twenty-two logging operations to thirteen mill destinations. The routes assigned by a supervisory person are used as a benchmark to compare the manual generated solution to the solution obtained using the proposed method.



## 1. Introduction

The log truck scheduling problem has been discussed widely in the literatures of transportation and routing management. In forestry, nearly 40% of the costs are involved in road planning and in transportation operations and management. Monetary savings can be realized if some improvement is made to the existing logistics system. In the southern US, trees are harvested using what is termed a 'Tree-length' approach. From there, the tree-length logs are transported to consuming mills and further processed into lumber or paper. The wood products industry in southern US is facing increasing pressure from cheaper wood imports. The need to reduce transportation costs has been felt very acutely among loggers and mill owners. The logging capacity has always been in excess of demand and it is essential for the logger owner to reduce costs in order to survive in business. Usually, a logging company owns a group of trucks and operates them between a single logging site and a set of consuming mills to satisfy the demand. This dedicated trucking capacity is felt to be necessary in order to ensure logs are delivered as quickly as possible, but there is an inherent inefficiency with this approach. Depending on distance to mills and status of unloading facilities, trucking capacity can be either in short supply or severely underutilized. Trucks often spend a great deal of time simply waiting for loading or unloading.

All the upstream and downstream operations depend on the timely pick-up and delivery of wood by the trucks. The inter arrival time of trucks should be as uniform as possible with less variance to ensure smooth inventory level at the pick-up and delivery points. If trucks do not reach the pickup point at the right time, the inventory level at the logger reaches maximum

* Corresponding author. Fax: +90 2125334327.
*E-mail addresses:* valenjo@auburn.edu (J. Valenzuela), ahmety@khas.edu.tr (A.D. Yucekaya), mcdontp@auburn.edu (T. McDonald).

0020-0255/$ - see front matter © 2013 Elsevier Inc. All rights reserved.
http://dx.doi.org/10.1016/j.ins.2013.12.005

**Nomenclature**

| | |
|---|---|
| $T$ | number of trucks |
| $M$ | number of mills |
| $L$ | number of loggers |
| $N$ | number of trips |
| $I$ | denotes truck $i$ ($i = 1, \ldots, T$) |
| $m$ | denotes mill $m$ ($m = 1, \ldots, M$) |
| $l$ | denotes logger $l$ ($l = 1, \ldots, L$) |
| $j$ | denotes trip $j$ ($j = 1, \ldots, N$) |
| $L_{ilmj}$ | equal to one when truck '$i$' goes from the logger '$l$' to mill '$m$' during trip '$j$' |
| $U_{ilmj}$ | equal to one when truck '$i$' goes from the mill '$m$' to logger '$l$' during trip '$j$' |
| $D_{lm}$ | distance between logger '$l$' and mill '$m$' |
| $S_{lm}$ | load requirement between logger '$l$' and mill '$m$' |

and the logging process gets blocked due to the unavailability of stocking space. Similarly, at the location of mills, there should be sufficient logs available to keep expensive cranes and other Woodyard equipment working at peak capacity.

Ideally, the role of a log transport manager would be to form a demand matrix of loads to be delivered based on data provided by mills and loggers. A distance matrix containing the shortest path between any two locations would then be used to create an efficient transport schedule that met demand for all loads and that minimized the total distance traveled. Unfortunately, this type of system does not exist in practice, resulting in a large percentage of unloaded miles and wasted fuel for loggers, and highly variable utilization of woodyard equipment at consuming mills. An optimization system that effectively allocated and scheduled loads to be delivered would result in greater transport efficiency in wood procurement and lower overall costs for the forest products industry.

The truck routing problem is a complex combinatorial problem and few approaches to solve the problem have been proposed in literature. There are many heuristic approaches like tabu search, column generation, branch and bound heuristics to solve the general vehicle routing problem where the destinations are visited only once as in Audy et al. [1], Benjamin and Beasley [3], Drexl [9], El Hachemi et al. [10,11]. But in the case of the log truck scheduling problem multiple visits to a single mill or logger are required to meet the demand. Since this involves repeated visits to the customer sites, it cannot be easily solved using existing heuristic approaches.

The majority of work done previously discusses solving the vehicle-routing problem where the destinations are visited only once rather than a log-truck scheduling problem. A solution methodology is needed to solve the log-truck scheduling problem which is a special case of vehicle-routing problem where multiple visits to a single mill or logger are required to meet the demand. Gerdessen [13] has made an attempt to solve the vehicle-routing problem with trailers. The problem is solved in two phases. Construction heuristics are first used to obtain a feasible solution and then improvement heuristics are used to obtain an improved solution from the initial solution.

Heuristics and metaheuristic algorithms are common in literature. In [25] simulated annealing and immune system is combined to solve the optimization problems that are taken from the literature. In Yildiz [26,27] Particle Swarm Optimization is used to solve the design problems. In Yildiz and Durgun [28] and Yildiz [29] Cuckoo search is used to solve the design problems and parameter selection problems. In Yildiz [30], a comparison analysis for the population-based optimization algorithms is given. Chao [7] models a truck and trailer routing problem and uses the tabu search heuristic to solve the problem. The customers are assigned to the trucks by relaxing the integrality constraint and obtaining a linear initial solution. The three types of routes namely pure vehicle route, pure truck route and complete vehicle route are constructed in the next step using the cheapest insertion heuristic. Sumichrast and Markham [21] have compared the solutions obtained by a heuristic algorithm with that of a lower bound integer programming solution from a commercial solver. The problem size used in the paper was small in terms of demand met for the day and in the number of trucks used to meet the demand.

Thangiah et al. [22] have developed a heuristic algorithm for the vehicle routing problem with backhauls and time windows. In this paper, the earliest and latest times were defined which indicate the lower bound and upper bound at the customer's site. The loading time, unloading time and waiting time were exclusively accounted for when calculating the total route time of the trucks. Czech and Czarnas [8] have used parallel simulated annealing algorithm to solve a vehicle routing problem with time window without any backhauling. The objective function minimized the number of vehicles used as well as the total distance traveled. The truck could only serve customers whose total demand is less than the total capacity of the truck in one trip.

Audy et al. [1] propose a literature review that includes planning methods and decision support systems for vehicle routing of forest products. They summarize many related vehicle routing literature that are focused on forest transportation. Rix et al. [18] propose a column-generation method to solve the multi-period log-truck scheduling problem. The objective is to