ASICAM: A Truck Scheduling System

Rafael Epstein
Andres Weintraub
Jaime Catalan

Department of Industrial Engineering
University of Chile
República 701 - Santiago
Chile
Fono :56-2-9784046

e-mail : repstein@dii.uchile.cl
Abstract

The Chilean forestry sector is composed of private firms that combine large timber-land holdings of mostly pine and eucalyptus plantations with sawmills and pulp plants. To compete in the world market, the Chilean forest companies and the University of Chile have developed a truck scheduling system to optimize transportation and logistics. This system, called ASICAM, has improved transport operations by 10% to 35%, with significant savings. The system has been implemented in the main Chilean forest companies, as well as in the major Brazilian forest firms. Also, the system has been implemented in Argentina, Uruguay, Venezuela and South Africa. This application has received two important recognitions. It received the 1998 Franz Edelman Award, given every year by the Institute for Operations Research and Management Science of the U.S.A. (INFORMS) to the best application of the year. Also, Mondi Forest won the 1996 South Africa Logistics Award based on the improvements for implementing this system.
Introduction

An important problem in forestry operations is deciding how to transport timber each day from different stands (origins or sources), with known supplies, to destinations, such as pulp mills, sawmills, sorting yards, and ports, to meet their daily demands. The timber products transported are characterized basically by the length and diameter of each log. The products available are usually stocks remaining from the previous day plus production throughout the day. Trucks transport loads of logs from origins to destinations. At origins and destinations cranes load and unload the trucks. Although the firms typically subcontract trucks and cranes, they usually organize their schedules. The basic decisions a log transport manager makes each day are: (1) the origins from which to transport product to satisfy each demand; (2) what trucks and cranes are needed at origins and destinations to satisfy all demands; and (3) the work schedule for each truck and crane.

Besides satisfying demands for products, forestry firms must consider (1) the characteristics of trucks and cranes, basically described by time and costs involved in trips and in loading and unloading; (2) the arrival time of trucks at destinations, which determines the number of cranes needed for unloading and coordination of deliveries of logs with downstream operations; (3) the income levels of trucks drivers and (4) the starting and ending points of each trucks daily route.

The basic objective is to satisfy the demand for different products at each destination, while minimizing transportation costs within technical, policy, and labor constraints. A typical forestry firm operates with approximately 10 to 90 origins, five to 30 destinations, and between 50 and 300 trucks. Depending on the distance involved, each truck can make from one to four trips per day. Since transportation costs account for about 40 percent of operating costs, it is important to define and control truck schedules efficiently.

The traditional log transport systems used in the Chilean forest industry were inefficient and poorly organized. Essentially truck drivers had no well-defined schedules. This led to failures to meet demand, long waiting times in queues, friction among drivers, long working days, low utilization of equipment, and poor coordination with downstream operations, such as the conveyor belt at the mill. The first effort to organize transportation was a magnetic board. The managers realized that this approach, which only allowed defining rigid trip cycles with schedules that had to be kept for many days with no capacity to respond to variations in production, could not handle the expansion in volume the Chilean forest industry faced in the 90s.

Methodology

The Chilean forest companies and the University of Chile joined efforts to develop a computational system, called ASICAM, to improve the decision on truck scheduling. The first version of the system was implemented in Bosques Arauco and very soon on the other companies. ASICAM had a dramatic impact on forest transportation. A main reason for the success of the project was the close collaboration between academics and managers to have
a clear understanding of the problem and objectives. This success showed the potential of operations research tools for forest management.

This managerial system ASICAM, is based on two notions: a centralized administrative system that schedules and controls all trips; and a simulation model for generating such decisions. The administrative overhaul was essential to centralize and coordinate decisions and to schedule trips efficiently. Determining efficient truck schedules is a complex combinatorial problem, which could clearly not be solved well with a manual approach using a magnetic board. We based the computational system on a simulation model driven by heuristic rules that assign trips to trucks. The system, which is run daily, takes the following as its main inputs: supply of timber products at origins or sources, demands at destinations, truck fleet and crane equipment characteristics, costs and times for the different trips, loading and unloading; plus an additional set of relevant constraints. As outputs, the system yields requirements for trucks and cranes, a schedule for each, and basic statistics to evaluate performance.

Given the high combinatorial complexity of the problem, we chose an approach that simulates daily operations. We tried to replicate real-time scheduling, given the volumes of products that have to be hauled from origins to destinations and the trucks available. In the simulation process, we assign trucks following specific rules. The simulation starts, for example, at 6:30 AM as the first group of trucks starts loading and later are dispatched to their destinations. As the cranes at origins become available again, new trucks enter the system. After trucks unload at destinations, they are assigned new trips. The system moves along in this manner during the day.
Between $t_0$ and $t_0 + 1$, trucks 1 and 2 arrive at destination $D_1$, and trucks 3 and 4 arrive at destination $D_2$. At $t_0$ the simulation model assigns a trip for trucks 1, 2, 3, and 4. Decisions for trucks 1 and 3 are performed while decisions for trucks 2 and 4 are released. The simulation time is increased by 15 minutes and the process is then repeated at $t_0 + 15\text{'}$. A decision consists of an unloaded trip to an origin and a loaded trip to a destination. For instance, a decision for truck 1 could be loading at origin $O_2$ and unloading at destination $D_2$.

To assign trips in a coordinated way, we chose a moving time horizon of one hour. Given a starting time $t_0$, the system evaluates all possible trips for all trucks that will become free before $t_0 + 1$ hour. Only those trips that are assigned by the simulation process during the first 15 minutes are actually fixed. Then the starting time moves to $t_0$ plus 15 minutes and the trip assignment process is repeated (Figure 1). The assignment of trips is based on evaluating every feasible option a truck has after unloading. An option is a trip to an origin to load a product and another trip to a destination for unloading. An option is feasible depending on truck frame and engine characteristics, and on policy decisions. These options are evaluated based on priorities and desirability of the trips.

To evaluate the desirability of each feasible trip, we define an index that considers the total real cost plus a congestion penalty. While by contract payment to truck owners is based on the loaded trips carried out, the firms realized that in the long run they needed to consider the real costs the trucks owners faced. So the objective was defined to minimize the real costs of transportation. Total real costs include operational costs (fuel, tires,
maintenance) and fixed costs (capital depreciation, insurance, salaries) prorated by the number of hours the truck is used. The penalty for congestion at origins is a heuristic estimate that depends on (1) the trucks that may load at the same time at a given origin, (2) the alternative trips available for those trucks, and (3) the probability of selecting a conflicting trip. The simulation process estimates the congestion effect as it analyzes possible future trips to origins to be made in addition to those already scheduled. The congestion penalty is not a real cost; it is just a device to reflect the loss of efficiency some trip assignments cause to other trucks, and it is not included in the reports.

The selection of the next trip to be assigned is based on the desirability index just described but in the context of trip priorities. Priorities are based on the models perception of urgency by the model in scheduling trips. Thus, the first priority is for trips to destinations with urgent requirements. For example, if a destination requires four truckloads per hour, and the simulation has assigned only two between 14:00 and 15:00 with few options available to provide the remaining two truckloads, those trips become first priority. The schedule programs efficient trips to minimize transportation costs and reduces queuing at origins and destinations.

Because destinations and downstream operations have limited unloading capacity, arrivals at destinations must be regular. This is not trivial as complete cycles (trip to origin, load, trip to destination, unload) can vary significantly (1.5 to five hours) depending on the locations of the origins and destinations. During the simulation, the system dynamically determines when a destination will be in critical need of supply in order to continue regular operations.

**Results and Conclusions**

The development and fine-tuning of these heuristic rules took over a year, including tests in different firms. The final algorithm turned out to be robust for all firms and situations. A detailed description of the system is given by Weintraub et al. [1996]. The system runs on a PC and takes approximately three minutes to find a solution. The operators need to have good knowledge of the transportation system but not a high level of technical preparation. Typically, the operator needs three or four runs of the system to evaluate several scenarios before choosing a solution.

The implementation of the system has provided significant benefits, both quantitative and qualitative. The quantitative improvements have been measured in terms of numbers of trucks, numbers of cranes, operational costs, and total transportation costs. As trucks productivity increases, fewer trucks are needed (Table 1). This allows a decrease in capital investments. Because the firms usually share the savings with the trucking firms, the trucks that remain in the system have improved the income for their owners. In most cases, reorganizing the administrative system was responsible for a significant fraction of the improvement. As peak arrivals at destinations flattened, the number of cranes needed for loading and unloading decreased by about 20 percent.
More efficient assignment of trips leads to shorter trips and less queuing. Eight Chilean firms have implemented ASICAM, and they report savings of 15 to percent and 35 percent of transportation costs, equivalent to total annual savings of more than 8.5 million dollars a year.

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<thead>
<tr>
<th>Company</th>
<th>Before ASICAM</th>
<th>After ASICAM</th>
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<tbody>
<tr>
<td>Bosques Arauco</td>
<td>156</td>
<td>120</td>
</tr>
<tr>
<td>Forestal Millalemu</td>
<td>80</td>
<td>50</td>
</tr>
<tr>
<td>Forestal Bio Bio</td>
<td>118</td>
<td>76</td>
</tr>
<tr>
<td>Forestal Río Vergara</td>
<td>120</td>
<td>80</td>
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Table 1: The number of trucks four forestry firms required for hauling similar volumes of timber decreased with the implementation of ASICAM.

The firms also achieved qualitative improvements, such as improved overall control of the system by organizing timber stocks at origins, keeping trucks and cranes in good shape, and handling disruptions that occur during the day; and smoother downstream operations by making regular deliveries at demand nodes. In addition, the system has improved quality of life of workers, reducing their workdays from 14 to 11 hours, increasing their salaries because of higher productivity. Managers of forestry firms have commented on these improvements. Claudio Rodríguez, head of the Division of Timber Supply at Forvesa (presently Mininco) noted: “We have reduced our fleet by 32 percent, but the most positive aspects, in my judgment, are the qualitative benefits concerning people.” Bosques Arauco tripled its operations in 1990; Pier Traverso, head of transportation, said in 1992 “ASICAM has been in operation for three years in Bosques Arauco with very significant benefits, which were especially evident when a new plant came into operation. We went from 120 trucks to 300 trucks in a peak month, and in spite of this expansion, there was no chaos, no disorder. In addition, the quality of work of the drivers improved as well as the control over the system, especially with respect to loading and unloading.”

Leonidas Valdivieso, head of the Department of Harvesting and Transport at Mininco said, “We have been able to optimize not only transport, reducing the number of trucks, favoring the remaining with more trips, but we have also achieved better coordination between harvesting operations and demand centers.” Mauricio Peña from Forestal Millalemu commented, “The most visible and immediate effect was the reduction in the truck fleet from...
80 to 50 trucks. Additionally, the number of internal personnel dedicated to programming and supervising transportation was reduced. Further benefits obtained have included the detection of equipment shortages, a reduction of wood stock at origins and the subsequent decrease in losses due to degradation.”

The system has proved to be extremely portable to different realities. For instance, Sawmills Arauco, a subsidiary of Holding Arauco that handles sawtimber production through eight sawmills, has used a version of ASICAM to schedule its truck fleet since 1997.

Mondi in South Africa implemented ASICAM. At that time, Mondi’s implementation of ASICAM required minor modifications to account for the fact that Mondi works around the clock. Today, almost all the companies using ASICAM operate on a continuous basis. ASICAM was one of the tools that led to Mondi Forests being awarded the 1996 South African Logistics Achievement Award. As Don Alborough, supplies and logistics manager of Mondi-Natal explains, “Over a period of years ASICAM was purchased and implemented very successfully into our Natal operations. The control over our and contractor fleet increased dramatically and Mondi saw doubling of vehicle utilization and a halving of the fleet transporting some 400,000 tons per annum. The system now forms the cornerstone of a quality initiative where it is essential that we feed the merchant mill with a consistent supply of timber with similar properties.”

ASICAM is used by all the large and medium forest firms in Chile, like Arauco and CMPC. Since 2001 ASICAM has been implemented in the leader forest companies in South America beside Chile. Aracruz, the Brazilian world largest pulp mil implemented ASICAM in 2001 increasing truck efficiency by 10%. VCP, the Brazilian giant and the largest Latin America paper producer, implemented ASICAM in 2004 with big improvement in efficiency. Also, ASICAM has been implemented in Alto Parana, the Argentinean pulp mill, FOSA, the UPM plant in Uruguay and Terranova in Venezuela. In average, every four years a new version of the system is developed and implemented incorporating new optimization advances and/or other computational based new features.

In addition to the 1996 South Africa Logistics Award won by Mondi Forest, in 1998 the Chilean forest companies and the University of Chile received the prestigious Franz Edelman Award. This prize is given every year by INFORMS (The Institute of Operations Research and Management Science of the U.S.A.) to the best application of the year. Winners of other years include companies like IBM, General Motors, American Airlines and Motorola.
References


