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Comparison between two policy strategies for scheduling trucks in a biomass logistic system

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Abstract

Approximately 75% of the cost to load, haul, and deliver a weekly supply of herbaceous biomass from temporary storage locations near the production fields to a bioprocessing plant (50 Mg/h average capacity, 24/7 operation) is truck cost. The management policy that a bioprocessing plant uses to schedule trucks determines the maximum number of trucks required, and thereby, the total cost for the logistic system. Three land use rates corresponding to 50%, 45%, and 40% of existing pastureland within a 3.2-km radius of chosen satellite storage locations were used to establish a production base surrounding the plant location. Total area harvested was 25,500 ha, or about 2.1% of the total land area in the 7-county region studied. Assumed average yield was 8.3 Mg/ha. Two different management policies, one based on travel time (Policy 1) and another based on the assignment of trucks to given sectors of the surrounding production base (Policy 2) were used to develop truck schedules. The logistic system was modeled as a discrete event simulation model, and the schedule was validated.

The maximum number of trucks needed for the logistic system was 32, 33 and 34 for 50%, 45% and 40% land use rates, respectively. In Policy 1, the maximum number of loads accumulated in the at-plant inventory was 384 truckloads at 50% land use rate (maximum inventory corresponds to about 3 days of plant operation). In Policy 2, the maximum number of loads accumulated in the at-plant inventory was 330 truckloads at 50% land use rate. Total number of loader and unloader operating hours for both the policies was computed, and the loader and unloader utilization rates were 83.5% and 70.8%, respectively. The delivered cost (load, haul, and unload) varied from \$14.68 (Policy 1) to \$16.14 per Mg (Policy 2) for 15% w.b. moisture content biomass.

Keywords: Logistics; Simulation; Biomass; Traveling salesman; Economic analysis

1. Introduction

A major cost factor in a logistic system is the trucks that are used to move biomass loads from distributed storage locations to a bioprocessing plant. These costs are associated with owning (truck ownership cost) and operating (fuel cost) these trucks. The fuel cost for hauling feedstock to a bioprocessing plant is fixed by the location of the plant with respect to a given set of satellite storage locations (SSLs) and cannot be reduced without changing the location of these SSLs (Ravula, 2007). The truck ownership cost, on the other hand, depends on the maximum number of trucks used on any given day during a season. Due to the specialized nature of the trucks used, and the fact that the maximum number may need to be scheduled at any time, any excess trucks not used for transporting loads on any given day cannot be reassigned for other productive purposes, and these trucks will remain idle. The capital cost for owning these idle trucks will be reflected in the higher cost of biomass delivered to the plant. This variation in truck requirement can be controlled by varying the order in which SSLs located at varying distances from the plant are emptied. Therefore, the goal of any scheduling policy is to reduce the maximum number of trucks needed to deliver the same number of loads each week. This study examines

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two different management policies for sequencing the emptying of the SSLs and calculates the effect of such policies on the at-plant inventory and maximum number of trucks needed by the system.

Mukunda et al. (2006) simulated the scheduling of trucks hauling large square bales (1 m × 1.2 m × 2.4 m) of corn stover from on-farm storage to a cellulosic ethanol plant. They used the discrete event simulation software Extend v6 (Imaginthat Inc., San Jose, CA) to model loading, transportation, weighing, sampling, and unloading of loads of large square bales over 350-days. Average time to load a truck (17.7 dry Mg) was 20 min. Travel velocity was assumed to be 48 km/h for a loaded truck and 72 km/h for an empty truck. The maximum haul distance was 80 km. In their simulation, Mukunda et al. (2006) triggered a load delivery whenever feedstock inventory at the plant dropped below a 10-day supply. Hauling was done 16 h/day, seven days a week over the 150-day season they simulated. Plant size was 378 million L/y (100 million US gal/y). Results from this study are compared to results from their study in a later section. Sokhansanj et al. (2006) used the Integrated Biomass Supply Analysis and Logistics (IBSAL) model to evaluate five scenarios for collecting, road-siding (for storage), and hauling biomass to a biorefinery. Their scenario “C2” envisions a round bale system similar to the one described in this study.

This study is based on a paradigm that emulates operation of a cotton gin. The cotton gin schedules specialized trucks (module haulers) to pick up loads of seed cotton from the side of production fields. The cotton module haulers self-load and self-unload their loads. The trucks in our system, however, need a loader at the SSL to load and an unloader at the plant to unload round bales. This additional machinery, which serves more than one truck, introduces queues for loading and unloading, since the trucks wait until the loader becomes available. All hauling costs in a cotton logistic system are paid for by the gin, and the gin has responsibility for operating the fleet of trucks. It is expected that the bioprocessing plant will own and operate, or contract, the required loaders, trucks, and unloaders. We assume that all scheduling is done by a feedstock procurement manager at the plant, so individual trucks can be dispatched to any one of several SSLs being emptied on a given day.

2. Policy strategies for scheduling

The loader in this study has an operational capacity of 15 truckloads per day, assuming no waiting time for a truck to load. With each truckload being 14.4 Mg, a bioprocessing plant designed to operate at 50 Mg/h consumes 3.5 truckloads per hour. Since the plant operates 24/7, and the transport system operates only 12 h per day and 5 days per week, the system must transport (50 week)(24 h)(7 day)/((14.4 Mg)(5 day)) = 117 loads/day to maintain 24/7 operation. With eight loaders, the system can supply 8 × 15 = 120 loads/day when all eight loaders are operational. However, each loader loses one day when it moves from an empty SSL to the next SSL on the schedule. This constraint, along with the fact that the maximum capacity of a transportation system with eight loaders is very close to 117 loads, creates a system with little “elasticity”, meaning that some weeks the system will not be able to supply the required number of loads to the plant. Therefore, this study used nine loaders to provide additional capacity.

The number of trucks needed to haul 15 loads each day from a given SSL will depend on the travel time. The trucks hauling from SSLs that are closer to the plant will complete their travel cycle faster, thus this SSL will require fewer trucks than a SSL that is at the outer boundary of the procurement region. As the loaders move from an empty SSL to the next SSL on the schedule, the travel time for the trucks also changes. This changes the total number of trucks needed for the transportation system on any particular day. This variation in number of trucks will cause some trucks to be idle during part of the season. The goal of this analysis was to minimize the maximum number of trucks while supplying the bioprocessing plant with the required amount of material each week. Ideally, all trucks will be used to their maximum capacity every day.

The importance of SSL sequencing can be illustrated with a simple example. Assume all loaders are assigned to SSLs that are at the outer edge of a plant’s procurement region. Each of these SSLs will require a larger number of trucks to operate the loader at the design capacity (15 loads per workday) than SSLs that are closer to the plant. As the season progresses, the loaders will move closer to the plant decreasing the truck cycle time, thus each truck can haul more loads per day and fewer trucks are required. Fig. 1 shows a two loader system in operation. At the initial starting point, both loaders 1 and 2 need five trucks to transport 15 loads per day from their SSLs. At the closest point to the plant, each loader needs only two trucks, leaving the remaining trucks idle. The type of loader assignment described in Fig. 1, with decreasing truck cycle time as the season progresses, is referred to as a Longest Travel Time first, or LTT, strategy.

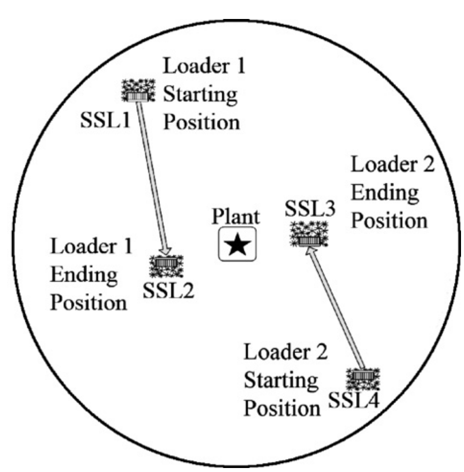

Fig. 1. Loaders 1 and 2 both following longest travel time (LTT) policy.