Simio March 2017 Student Competition

Pulp and Paper Business Logistics

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Forward Thinking

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Problem Overview

An American group of pulp and paper manufacturers is increasingly aware of inefficiencies in obtaining wood as a raw material. Because they operate independently, very often logging trucks drive past one mill to deliver to a competitor mill, adding potentially avoidable transportation cost into the system. They are aware of a European consortium that controls wood deliveries to minimize logistics cost.

They want to evaluate the creation of a new consortium to manage wood deliveries to their mills. The objective would be to minimize logistics cost. Each mill involved has independent demand and maximum inventory, and some have offsite "drop yards" for additional inventory. Wood is cut from in the region by small owner-operator logging companies. Each independent logging operation has its own cutting and delivery capacity that varies seasonally.

The consortium would like a representation of the present system as well as the proposed system so they can evaluate the potential required investment, best operational parameters, and expected savings.

Background and Context

The major raw material input for paper is wood. Wood is debarked, chipped, and digested into pulp that is ultimately used to make large rolls of paper. The digester is a huge and expensive piece of equipment designed for high volumes. It is also the rate limiting step of the manufacturing process. Accordingly, the digester must be run continuously 24/7.

In the old days, paper manufacturers owned land and harvested trees exclusively from their own territory with their own equipment. During this era, logistics coordination was easy because all the pieces belonged to the paper mill. Wood cutting and delivery could be scheduled, or at least planned in rough terms. Over time however, financial pressure from declining demand for printed paper forced paper manufacturers to divest their land and logging assets and contract raw material procurement. While this transition made room on the balance sheet, it also decentralized the logistics process and created chaos. Today, paper mills have no control over logging operations. They simply offer a price for wood by the ton and contract loggers work on their own schedule to deliver as much as they can.

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Paper Mill Information

There are three paper manufacturers in the region: Koala Paper, Bright, and PaperTech. Though they make a variety of printed paper products, the raw material input is the same: hardwood. Koala and Bright have fairly old equipment, both for wood handling and processing. Their daily consumption is limited to 4,000 tons of wood per day on average. PaperTech has newer, more efficient equipment and they average 5,000 tons per day.

Each mill has a maximum capacity of inventory that is limited by the available real estate to stack logs of wood. The older operations have considerably more space, though they don't necessarily want to fill it because holding inventory costs money. Determining the optimal inventory to keep on hand is part of the modeling task. Assume that each mill starts January 1 with 60,000 tons of inventory at Koala and Bright and 55,000 tons at PaperTech.

Demand and inventory data are listed in the following table:

Manufacturer	Daily Consumption of wood (tons)	Inventory capacity (tons)
Koala Paper	Random.Normal(4000,200)	100,000
Bright	Random.Normal(4000,100)	120,000
PaperTech	Random.Triangular(4500,5000,5500)	60,000

The optimal inventory quantity should minimize inventory holding cost with no stock outs. If the digester ever stops, it requires a major setup operation that would shut the mill down for days. This would be a disaster for a mill. Of course, if inventory ever gets low, the mill panics and increases the price they are willing to pay dramatically until inventory is restored. The net result is that a stock out is avoided but procurement costs increase. However, if the stock out does occur at any of the mills, then the digester cannot be restarted unless the inventory at hand is at least equal to 1,000 tons. If inventory levels drop below 20,000 tons at any mill, increase their priority for deliveries and assume a one-time $1M penalty. With the increased costs, some loggers would be willing to supply on Sundays.

To calculate inventory holding cost, assume that each company has a 6% weighted average cost of capital (WACC), and the price of wood is fixed at $50/ton throughout the entire year. Modelers can experiment with allowing the optimal quantity of inventory at each mill and let the safety stock fluctuate with seasons.

The model must incorporate the delivery and offloading process to the mill. Delivery trucks arrive at a single gate with a scale house. The scale house capacity is 1 truck at a time in each direction. The truck pulls up to the scale house, and the driver gets out of the truck and goes inside to give information about the delivery. Simultaneously, the weight of the truck is measured to calculate the total price. This is usually a quick 2 minute process, but occasionally the paperwork needs to be corrected and it can take as much as 7 minutes. In this region, the department of transportation limits the amount of wood on any truck to 35 tons. The weight on any individual truck varies with tree diameter, stacking pattern, and moisture content. Assume it varies between 25-35 tons with an average of 30. After the weight is measured, the scale house operator directs the driver to a drop point in the yard

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where there is space to stack the wood. The total area to store wood is about the size of 4 football fields. Speed limit around this area is 10 mph due to safety concerns. Offloading wood is performed by crawlers with a claw attachment. This takes around 10 minutes per truck, plus or minus 2 minutes. Crawlers take a lot of abuse and require maintenance every operating 250 hours. Maintenance is typically 1 day, but sometimes part delays stretch it as long as 5 days. Assume each mill has 6 crawlers. After offloading, the truck goes back to the scale house to be re-measured. The difference between entry weight and exit weight is how the mill determines the actual amount delivered. This is also quick, and does not have much variability. Process times for these steps are as follows:

Operation	Average process time
Weigh-in	2-7 minutes
Travel	Determined by speed limit of 10mph
Offload	10 minutes
Weigh-out	1 minute
Crawler maintenance	1-5 days (98% are completed within 1 day)

The mill is open to receive 24/7. Arrival rates vary throughout the day but this is determined by the work schedule of the loggers (details below). As a sanity check, the line of trucks waiting to get into the mill usually piles up in the morning as everyone makes their first delivery. Sometimes there can be 20 trucks or more waiting to cross the scale house.

Logger Operation Information

The consortium is less interested in the specifics of the logging operations. The focus is really on the logistics and transportation. However, there are a few key considerations to capture.

Most logging operations are small owner-operator type businesses. For context (this does not need to be included in the model), there are 4 machines in the operation. First a tree is cut down or "felled" by a feller-buncher. The feller-buncher lays trees down into bunches. A grapple skidder grabs bunches of felled trees and drags them to a de-limber. The de-limber knocks the branches off, leaving just the trunk of the tree. Finally, a saw cuts the tree into nearly identical lengths to be stacked on the truck. The important part of the operation to keep in mind is that a logging operation typically cuts and delivers about 60,000 tons per year.

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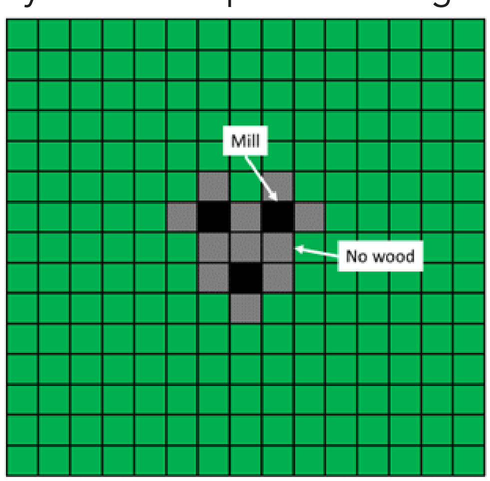
Daily production is limited by ground conditions. Soft ground makes it hard for the equipment to move around. On a good day, when the ground is frozen, a logging operation can cut 6-8 truckloads of wood (30 tons per load). On an average dry day, 5-7 loads. If the ground is soft, 3-5 loads. Finally, if there is a heavy rain, operations are halted. This is an environmental restriction because the logging equipment would leave deep, permanent ruts in the earth in poor (wet) conditions. Assume the mills are in the Midwest and follow the seasonal pattern below:

Ground condition	Loads per day	Months
Frozen	6-8	Jan-March
Soft	3-5	April-May
Dry	5-7	All others
Muddy (operations halted)	0	5% chance each day April-May

Because wood delivery is contracted, actual data for number of logging operations in the region and delivery trucks per operation is unknown. For the baseline model, assume that there are around 100 operations, with 4-6 trucks each. Full trucks travel at an average of 45 mph; empty trucks travel at an average 55 mph. For transportation cost, assume $0.12 per ton per mile. In other words, a 30-ton truckload that travels 100 miles would add $360 (=$0.12 x 30 x 100). Note that this cost is scaled to the 1-way trip distance between the logging site and the mill. You can assume that the cost of the empty truck's return trip is included in this figure (i.e., return trips are "free"). Logging is dangerous when it is dark out, so logging operations are typically limited to daylight hours, 5-6 days per week. Loggers use the 7th day for equipment maintenance. Therefore, you can assume that there are no equipment failures during the work week. The loggers are at their own discretion to choose which day to take off.

Logging is a highly regional market. Mostly, logging occurs within 100 miles of the mill. One way to approach the model is to consider the region as a square that is 100mi on each side. The region is broken into counties (smaller squares), each 10mi x 10mi. For the model, place mills near the center of the region, but in separate counties. Assume that any regions adjoining the mills have zero wood to be harvested, as they have developed into towns and no longer contain timber. Each available county has its own independent logging operation. Because loggers are territorial, only allow 1 logging operation per county. An example diagram illustrating only the central part of the region is below:



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The state forestry service is very concerned about the health of the surrounding timberlands and the natural beauty of the environment. It takes hardwood trees about 40 years to re-grow after being cut down. The government has mandated that growth-drain ratio be maintained at least at a value of 1. This means that the rate of wood growth must exceed the rate of harvesting. The team will have to research how much wood could be available in each county and set appropriate limits for the total amount that can be harvested in a given year.

In the baseline (as-is) model the loggers have little information regarding supply and demand at each mill, so just randomly assign deliveries from a logging site to a mill and run the simulation for 2 years.

For the improved model with a consortium managing deliveries, decide how you would assign deliveries to each mill. One potential option is to divide the region into territories and assign territories to a mill based on distance. The consortium will alleviate any territorial squabbling amongst the loggers, so multiple logging operations could possibly be assigned to work inside the same county. However, the same restrictions apply on maximum consumption per county.

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Questions for the Baseline Model

1. What is the total transportation cost for the system?
2. What is the average inventory at each of the mills?
3. What is the total inventory holding cost?
4. How much was spent on penalties for low inventory?
5. How many days are lost due to weather conditions?
6. Did any stock outs occur? If so, how many?
7. What is the maximum amount of wood cut in any county?
8. What is the average amount of wood cut by each logging operation?
9. What is the average waiting time at each scale house for incoming trucks?
10. How many crawler repairs occurred for the year?
11. How many days' production is lost due to stock out at each mill?

Questions for the Improved Model

1. What is the total transportation cost for the system?
2. How many trucks are needed to sustain operations?
3. What is the average inventory at each of the mills?
4. What is the total inventory holding cost?
5. How much was spent on penalties for low inventory?
6. How many days are lost due to weather conditions?
7. Did any stock outs occur? If so, how many?
8. What is the maximum amount of wood cut in any county?
9. What is the average amount of wood cut by each logging operation?
10. What is the average waiting time at each scale house for incoming trucks?
11. How many crawler repairs occurred for the year?
12. What is the total cost improvement for the system, including inventory and transportation?
13. What other improvements to the system can you recommend?
14. Like any model, this represents an approximation of the system. What are the potential problems with modeling the system as described?
15. How many days' production is lost due to stock out at each mill?

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