Pulp and Paper Business Logistics

DATA 604 Final Project

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Abstract

A simulation model was developed in Simio of a hypothetical forestry operation based on a simulation challenge issued by Simio, LLC. Experiments were carried out to assess the financial costs, wood production, logistical efficiency, and mill output. Our approach revealed a strong level of seasonality in the inventory levels of mills as well as poor inventory control creating production losses. The results of our experiments produced a total cost over two years of approximately $83 million.

Keywords: Simio, Simulation, Modeling, Forestry, Logistics, Transportation, Optimization

Introduction and Background

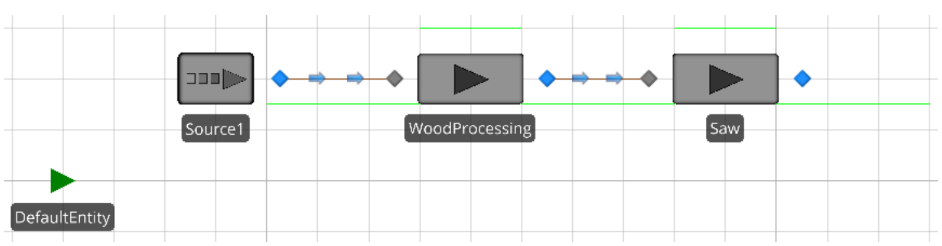
In recent years, the issues of logging and deforestation have become ones of particular importance in the global arena [Crome et al., 1996; Hansen et al., 2013; Wells et al., 2007]. As such, methods for optimizing logging methods that reduce ecological impact are under active research and are highly sought after [Huth et al., 2001, Hyyti?inen et al., 2004;]. In this project, the data of interest contains information about the logging industry of a few hypothetical paper mills; it was obtained from a data challenge hosted by Simio LLC for the March 2017 Student Competition. The system to be simulated focused on wood, which is debarked, chipped, and digested into pulp that is ultimately used to make paper. This process involves large machinery such as a digester, trucks, wood mills, and weigh scales. While machinery like the digester is designed to run 24/7, the wood acquisition process operates only during daylight hours. 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. This project sought to identify the transportation costs, mill inventory, and wood harvested, to allow for optimization and minimizing of stock-outs and penalties.

Methods

This project was completed using Simio Student Edition, version 9.147, by Simio LLC. A logging operation was simulated using primarily objects from the Standard Library. The area of logging was determined by using a 100 mile by 100 mile grid, with 3 mills and no availble trees in the areas of the grid adjacent to the mills. A ModelEntity object was created, with each entity representing a single 10-ton bundle of wood. A Source object was set up to randomly generate the appropriate number of loads each day, divided equally throughout the twelve daylight hours of the logging work schedule. Additional source objects were created for each mill to produce the initial inventory levels provided. A Vehicle object was created to carry model entities through certain servers, such as the WeighStation(In/Out) and WoodOffloading areas.

Modeling

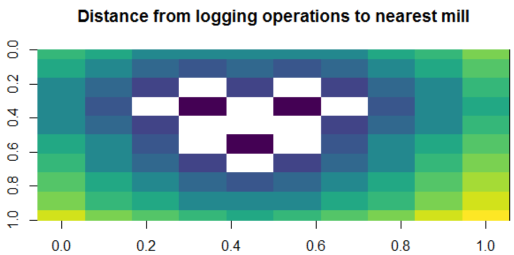
In order to model a logging operation, a hierarchical model `Logger` is created within the project. This model incorporates 3 items: a source and 2 servers (`WoodProcessing` and `Saw`). All items within the submodel are set to be not externally visible, then the output node `Output@Saw` is bound to the external node `Output_Source`. This can now be inserted into the main model to allow for the inclusion of the logging process without the need for too many objects in the model facility.



An instance of this model is added to the main model, renamed `Logger2`, and its symbol set to be that of a source.

Processes

The area of interest is divided into 100 10-mile-by-10-mile counties, each having one logging operation with the exception of those counties adjacent to the counties containing mills. Assuming a distribution of mills similar to that in the project description, an R script was created to calculate the distance from each county to the nearest mill. The distribution of these distances (rounded to the nearest hundredth of a mile) proves to be discrete with only 16 values.



Distance	Probability	Distance	Probability
14.14	0.08	41.23	0.07
20	0.08	42.43	0.05
22.36	0.13	44.72	0.07
28.28	0.07	50	0.07
30	0.06	53.85	0.01
31.62	0.13	56.57	0.02
36.06	0.12	58.31	0.01
40	0.02	64.03	0.01

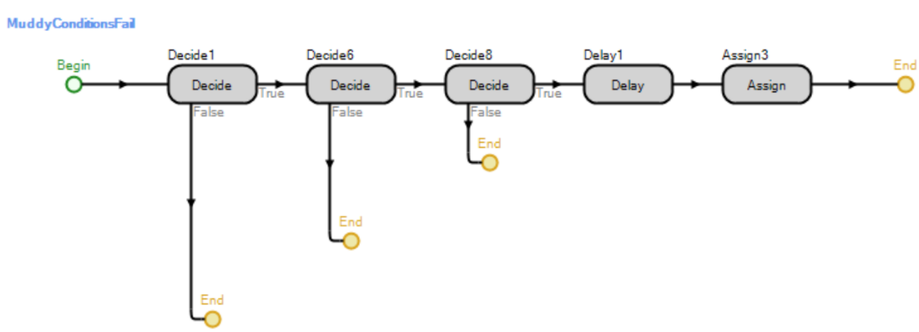
This distribution is used to assign the distance from logger to mill for each entity generated via an *Assign* step on the created `DistanceToMill` entity state variable – this is used to determine the transportation cost for each rider. This same distribution is also used to determine the time to travel the path from the logger to the routing station (in this case, it is divided by the speed of the trucks, assumed to be 50 ± 5 mph).

A separate, more complex process is used to route trucks from the logging operation to the appropriate mill. At a high level, this process performs the following steps:

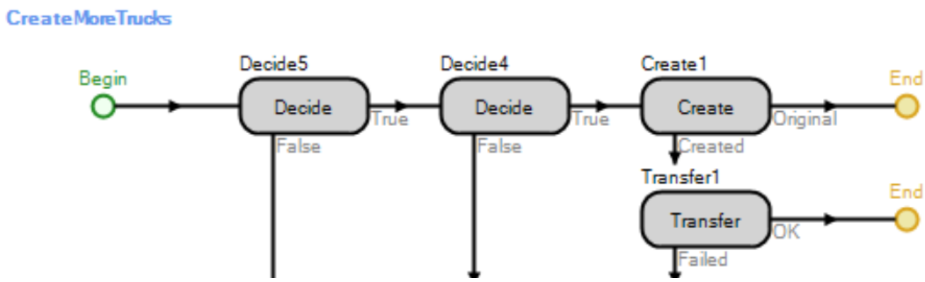
- Find the mill with the lowest inventory
- Check if sending a truck to this mill would exceed the inventory capacity
  - If not, route to the mill and increment the inventory
  - If so, loop back and find he next-lowest inventory

The full detail of this process can be viewed in the included Simio project.

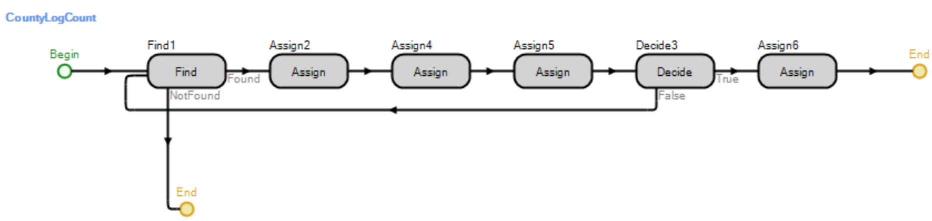
A process is used to determine and track days of logging lost due to muddy conditions. The process utilized decide steps to trigger on 5% of days in April and May at the beginning of the day; when triggered, it delays all entities by 24 hours and increments the counter for number of muddy days.



To reflect the dispatch of trucks as needed, a process is created to check if the number of trucks created is equal to or less than maximum ($83 \times 5 = 415$) and if all created trucks are currently occupied; if so, a new truck is created and tranfered to the output node of the logger:

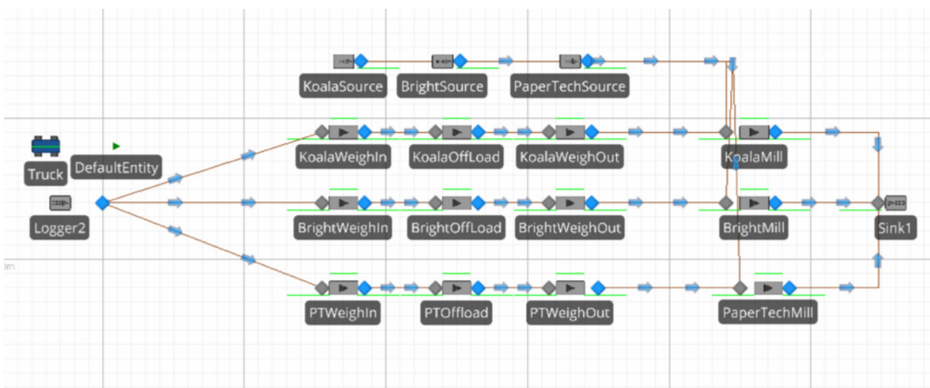


Finally, a process is created to simulate the number of logs generated in each county over the two year simulation. A real state variable `LogPerCounty` is created as an 83-item vector, and at the end of the run, each item is filled with a probabalistic estimate of the number of logs generated using the `Random.Uniform` function to allow some variance around the expected number of logs generated. This is done by utilizing *Find*, *Assign*, and *Decide* Steps to track the maximum and average amounts.



Model Facility

The model facility, as described, is depicted below:



Results

To measure the performance of the system, an experiment is run with the following responses:

- **Q1__TruckCost:** `transport_cost.Cost`
- **Q2__Inventory__Koala:** `KoalaInventory.Average`
- **Q2__Inventory__Bright:** `BrightInventory.Average`
- **Q2__Inventory__PT:** `PaperTechInventory.Average`
- **Q3__TotalHoldingCost:** `50 * 10 * 0.06 * (KoalaInventory.Average + BrightInventory.Average + PaperTechInventory.Average)`
- **Q4__LowInventoryPenalties:** `KoalaPenalty + BrightPenalty + PaperTechPenalty`
- **Q5__MuddyDays:** `MuddyDaysTotal.Value`
- **Q6__NumStockOuts:** `KoalaStockOut + BrightStockOut + PaperTechStockOut`
- **Q7__MaxWood:** `MaxLogPerCounty`
- **Q8__AvgWood:** `AvgLogCounty`
- **Q9__ScaleWait__Koala:** `KoalaIn.AllocationQueue.AverageTimeWaiting`
- **Q9__ScaleWait__Bright:** `BrightWeighIn.AllocationQueue.AverageTimeWaiting`
- **Q9__ScaleWait__PT:** `PaperTechWeighIn.AllocationQueue.AverageTimeWaiting`
- **Q10__CrawlerRepairs:** `KoalaOffLoad.Failure.NumberOccurrences + BrightOffLoad.Failure.NumberOccurrences + PaperTechOffload.Failure.NumberOccurrences`

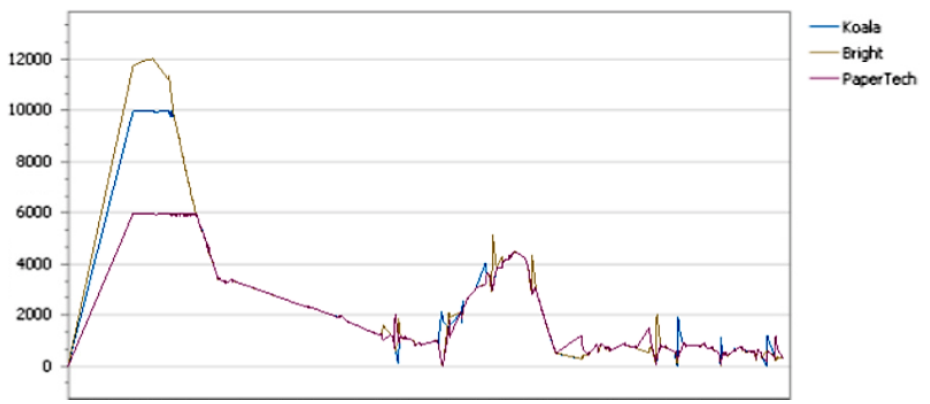
The results of running this experiment for 10 replications of 2 years each, with no warm-up period, are presented below:

Questions	Value
1	$80,593,384
2-Koala	27,560 tons
2-Bright	28,259 tons
2-PT	23,699 tons
3	$238,573
4	$3,000,000
5	6 days
6	81 stockouts
7	113,576.81 tons
8	100,330.65 tons
9-Koala	6.26 minutes
9-Bright	6.39 minutes
9-PT	4.76 minutes
10	52 repairs
11-Koala	90 days
11-Bright	90 days
11-PT	56 days

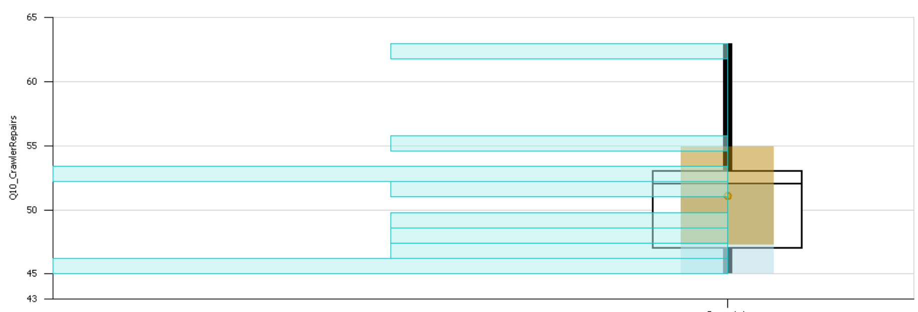
Discussion

Over the two years of the simulation of the model, roughly 6.9 million tons of wood were produced. The total cost of the system was approximately $83.83 M.

The model yielded an approximately equal average inventory across the three mills – this follows from the add-on process used to route trucks, which sought to minimize the number of stockouts by each mill.



Despite this logic, 81 stockouts were observed, yielding an average of 77.5 days of production lost (assuming a 3 ± 1 day outage per stockout). The inventory per plant (in tens of tons) is presented in the plot below. The cost of transportaion for all trucks through the system is roughly $80.6M, with the trucks waiting an average of roughly 5.8 minutes in line for the weigh-in station at each of the mills. This wait time is affected by the temporary increases in offloading time caused by the 52 observed crawler repairs, the distribution of which are visualized above.



Several challenges were encountered during the construction of this logging model. Many of the more complex issues were tackled through use of hierarchical models and processes. These approaches allowed for the addition of flexibility to reflect the randomness faced by the logging and paper production industries in the area of interest. The model was quite large, handling a number of entities, and ran slowly – this could possibly improved through the use of submodels created entirely from processes, as they run more efficiently than facility-based models. Potential future expanded models could include a calculation of the optimal number of trucks per logging operation and starting inventory for each plant. As operational improvements are assessed, they could be compared to this baseline model to quantify financial and logistical improvements.

Even with the inventory-focused logic mentioned, there were large expenses, both monetary and temporal, to the mills related to poor inventory control. Due to the inventory problems and the high cost of transporting wood, the logging and milling operations should likely seek mutually beneficial arrangements to make the process more efficient. This may take the form of a consortium of loggers, pooled inventory, or something capitalizing on the seasonal inventory patterns illustrated above.

References

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