Optimization of Pooled Log Transport

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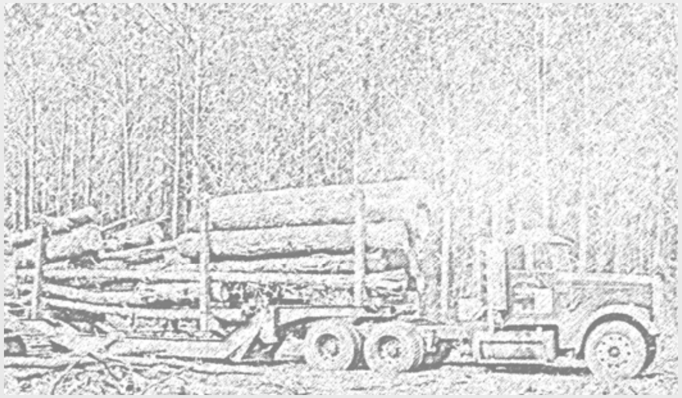

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Pooled Log Transport Logistics

- Optimization Model
- Route Generation
  - Comparison to existing
  - Large, small delivery systems

Optimization of Tree-Length Delivery

- Numerous system models developed
- Very efficient solution techniques

Optimization Benefits

- Glen Murphy (2003, *SJAF*) 25 - 50% reduction in fleet size to haul the same amount of wood
  - Tactical analysis tool for small problems
- Weintraub and others (1996, *Interfaces*) 32% reduction in fleet size, 31% increase in productive hours

Tree-Length Transport

- Pooled systems beginning to be implemented
- Human dispatch accepted
  - Improvements seen
  - Reliable, flexible
- Optimal allocation – not so much

System Model

- Treated as a combinatorial routing problem
- Minimize unloaded mileage
  - Subject to constraints
- Time not explicitly accounted for

$$Min \quad F = \sum_{i=1}^{T} \sum_{l=1}^{L} \sum_{m=1}^{M} \sum_{j=1}^{N} Y_{imlj} D_{lm}$$

$$\sum_{l=1}^{L} \sum_{m=1}^{M} X_{ilmj} \le 1 \quad i = 1..T, j = 1..N)$$

$$\sum_{l=1}^{L} \sum_{m=1}^{M} Y_{imlj} \le 1 \quad i = 1...T, j = 1...N$$

$$\sum_{k=1}^{L} Y_{imkj} \le \sum_{k=1}^{L} X_{ikmj} \quad i = 1..T, m = 1...M, j = 1...N$$

$$\sum_{k=1}^{M} X_{ilkj+1} \le \sum_{k=1}^{M} Y_{iklj} \quad i = 1 \cdots T, l = 1 \cdots L, j = 1 \cdots N-1$$

$$\sum_{i=1}^{T} \sum_{j=1}^{N} X_{ilmj} = S_{lm} \quad l = 1...L, m = 1...M$$

$$\sum_{l=1}^{L} \sum_{m=1}^{M} \sum_{j=1}^{N} (X_{ilmj} + Y_{imlj}) d_{lm} \le 360 \quad i = 1...T$$

$$X_{ilmj}, Y_{imlj} \in (0,1)$$

Constraints

$$\sum_{l=1}^{L}\sum_{m=1}^{M} X_{ilmj} \le 1 \quad i=1..T, j=1..N)$$

One trip at a time to a mill

$$\sum_{l=1}^{L}\sum_{m=1}^{M} Y_{imlj} \le 1 \quad i=1...T, j=1...N$$

One trip at a time to a logger

$$\sum_{k=1}^{L} Y_{imkj} \le \sum_{k=1}^{L} X_{ikmj} \quad i=1...T, m=1...M, j=1...N$$

Go to mill *m*, leave mill *m* and go to a logger

$$\sum_{k=1}^{M} X_{ilkj+1} \le \sum_{k=1}^{M} Y_{iklj} \quad i=1\cdots T, l=1\cdots L, j=1\cdots N-1$$

Trip taken to logger, then next trip must be to mill

$$\sum_{i=1}^{T}\sum_{j=1}^{N} X_{ilmj} = S_{lm} \quad l=1...L, m=1...M$$

Load conservation

$$\sum_{l=1}^{L}\sum_{m=1}^{M}\sum_{j=1}^{N} (X_{ilmj} + Y_{imlj}) d_{lm} \le 360 \quad i=1...T$$

Speed, trip limit for trucks

$$X_{ilmj}, Y_{imlj} \in (0,1)$$

0,1 decision variables

Model Solution – Simulated Annealing

- Give any feasible solution, generate new one based on rules
  - Evaluate ‘fitness’ of new one, and replace old if better

$$Z = K_1 M_u + K_2 L_u + K_3 L_o + K_4 T_w + K_5 N$$

where :

M_u = Unloaded miles

L_u = Unserved loads

L_o = Over - served loads

T_w = Waiting time

N = Number of routes not finished

Generating New Solutions

- Search for solutions in the feasible range – feasibility evaluated using a simulator
- Changes made using ‘improvement’ operators

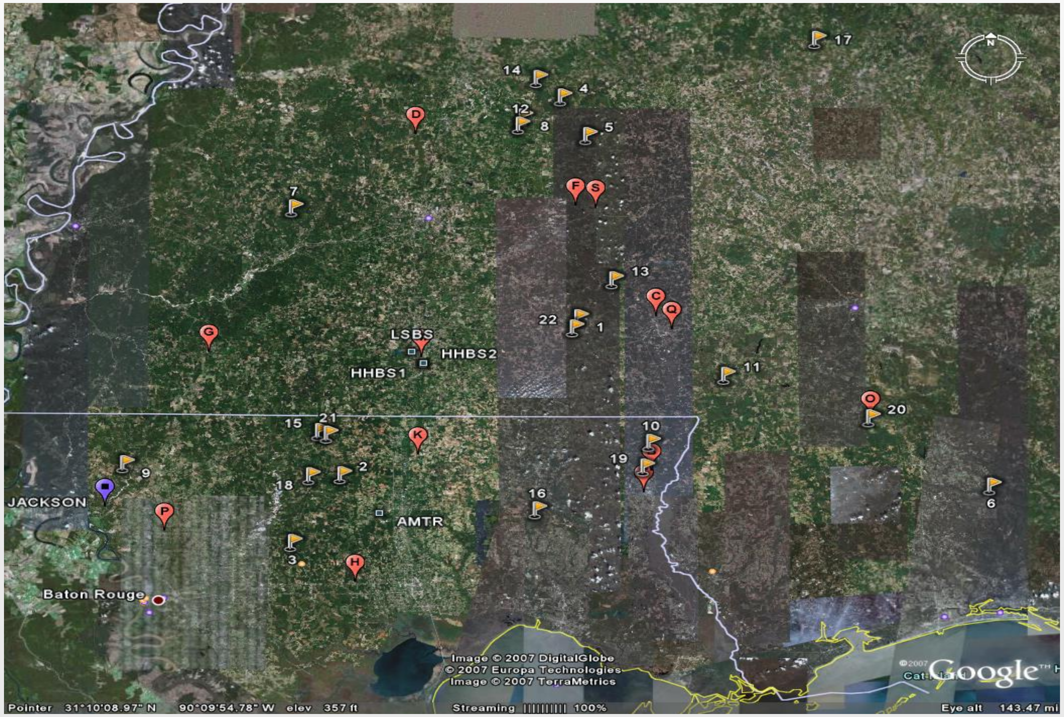
Stop – after random number of trips

Shorten operator / lengthen operator

Transfer – trips between trucks

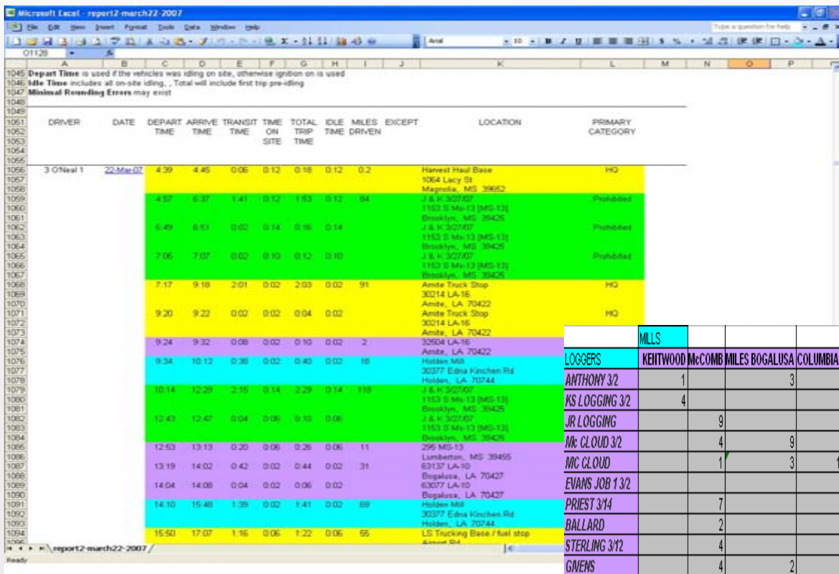
Case Study 1

- 68 trucks – centralized dispatch
  - Return to dispatch yard every night
- 22 loggers
- 13 mills



Truck Routing Data

- GPS records from all trucks



20,630 miles driven,
10,602 unloaded miles =
48.6% loaded

	MILLS												
LOGGERS	KENTWOOD	McCOMB	MILES BOGALUSA	COLUMBIA	SILVERCREEK	TEMPLE BOGALUSA	HOLDEN	ONEAL	CHARLES DONALD	GOLDEN CHIPS	GEORGIA PACIFIC, MS	GEORGIA PACIFIC, LA	MONTICELLO
ANTHONY 3/2	1		3		2								
KS LOGGING 3/2	4						3						
JR LOGGING		9					2						
Mc CLOUD 3/2		4	9			1							
MC CLOUD		1	3	1									
EVANS JOB 1 3/2							3						
PRIEST 3/14		7											
BALLARD		2			3				4				
STERLING 3/12		4										1	
GIVENS		4	2				6						
RANDY CARTER			2										
WALL JOB 2	2			3	9		4						
RUTHLAND		4	2		7								
BALLARD 3/1		1							1				
CHARLES AVANTS							1						
PAUL STEWART	2		4			3	4						
STUART BROS JO		1			2								
WALL PRIVATE 3/1	6												
HARRELSON 3/26			9			2	4						
J &K 3/27/ 7			4				10						
WALL JOB 1		1					2						
S&S										2	1		

Results of Optimization

	EXISTING SYSTEM	OPTIMAL SYSTEM	PERCENTAGE IMPROVEMENT
Total Miles	20630	17127	17%
Loaded Miles	10028	9509	5.17%
Unloaded Miles	10602	7618	28.14%
% Loaded Miles (Loaded Miles/ Total Miles)	49	56	14.28%
% Unloaded Miles	51	44	13.72%
Total Waiting time (hours)	21	13.88	33.9%

Changing 'K' Factors Changes Solution

- Waiting time factor

PARAMETERS	USING SIMULATOR	SIMULATED ANNEALING K=0.01	SIMULATED ANNEALING K=1	SIMULATED ANNEALING K=50	SIMULATED ANNEALING K=1000	SIMULATED ANNEALING K=5000	SIMULATED ANNEALING K=10000
UNLOADED MILES	10602	10346	10359	10461	11484	11713	12101
WAITING TIME	10.5 hr	9.52 hr	9.68 hr	9.56 hr	4.84 hr	4.12 hr	2.54 hr

Case 2

- 13-17 trucks, 3-5 loggers, 6-9 mills
  - GPS data – 6 days worth
- No central dispatch yard
  - ‘Intra-day’ routing only
  - Equipment, feed moves mixed in

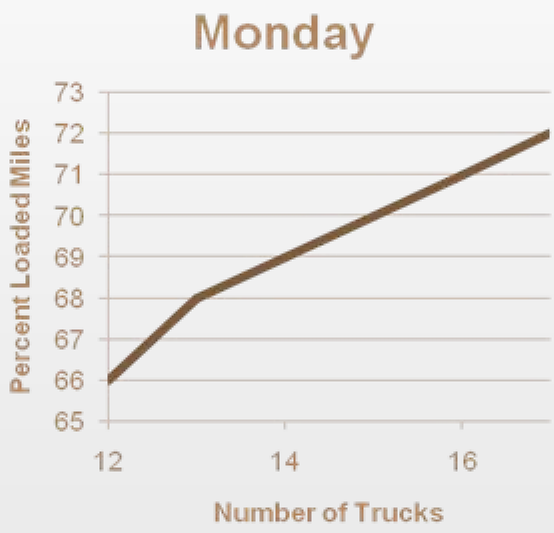
Case 2 Results

- 3 days only

Day	Percent Loaded		Total Miles	
	Actual	SA	Actual	SA
Monday	58	72	2662	2157.3
Tuesday	56	67	2544.2	2136.4
Wednesday	51	63	2639	2269.7

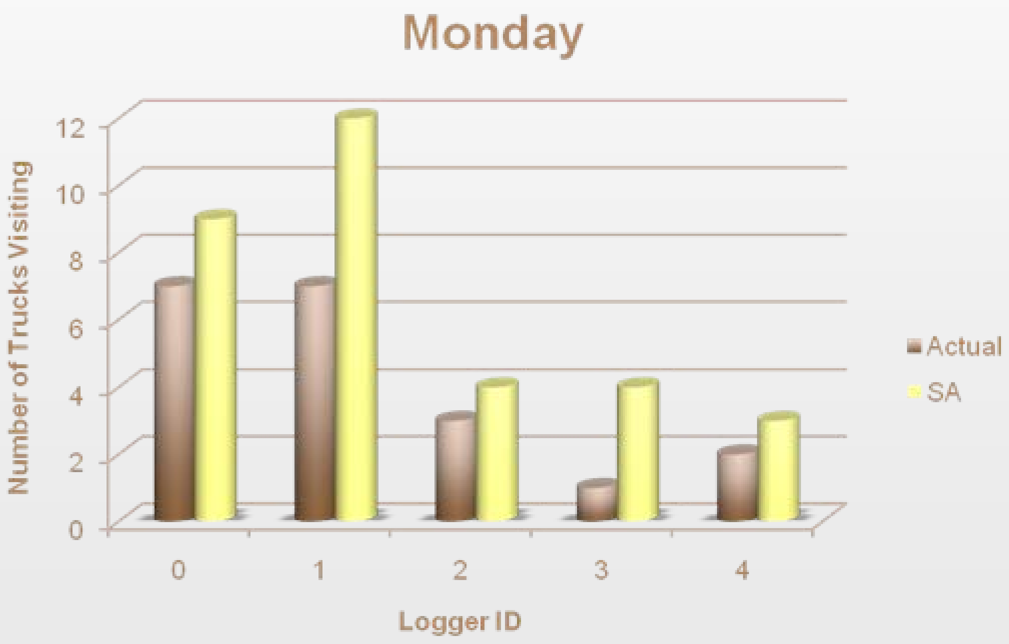
Feasible?

- Where are the savings?



Are Routes Changed?

- Route diversity – how many *different* trucks visit a single logger?



Timing Issues?

- First logger visit of the day
  - Monday: 2
  - Tuesday: 1 (8)
  - Wednesday: 1 (6)
- Beginning/End of the day
  - Take advantage of 'home' locations

Conclusions

- Dispatch optimization improvements seem significant
  - Routes are likely different from what a human might assign
- Problems with feasibility
  - Should be able to address, but testing on real data is tedious