Transport Economics, Logistics And Optimizing Wood Flows
Eric Jessup
The road ahead.....

- Who am I? Who are you?
- Why does transportation matter?
- Transportation economic fundamentals
- What does it mean to “optimize wood transport”?
- Industry structure, how it affects flows
- Transportation optimization examples
- Discussion / questions
Why is Transportation Important?

- Affects practically all aspects of your life, including:
  - Where you live, how you live, what you eat, what you buy, what you sell, how much you sell it for, etc.

- Transportation creates time and place utility

- Creation of markets.......and value that otherwise wouldn’t exist

- This isn’t a recent phenomenon

- Transportation Matters.......a great deal!
  - It always has......
  - It always will.......
Transportation and Logistics

- What is the value of a tree standing in the middle of a forest?

- Logistics involves the movement of products from point-of-origin to point-of-consumption.
  - Includes
    - Raw materials
    - Parts
    - Supplies
    - Finished goods
    - Farm produce

- Logistics involves everything from scheduling, inventory management, information systems, transportation and supply-chain management.
Transportation and Logistics

Managing product and information flow through the supply chain
Transportation Influences.....

- Product
  - Physical characteristics
- Pricing
- Supply Markets
- Target Markets
- Facility Location
Factors Influencing Transportation Costs

- **Product-Related**
  - **Density**
    - Refers to a product's weight-to-volume ratio.
  - **Stowability**
    - The degree to which a product can utilize available space in transport vehicle.
  - **Handling Ease**
    - Uniform sizes or odd shapes.
  - **Liability**
    - Important for products with high value-to-weight ratios.
  - **Perishability**
    - Degree to which the product may be damaged in transit.
Who is Malcolm McLean?
Creator of the Box?
Factors Influencing Transportation Costs

- Market-Related
  - Degree of Intra- and Inter-Modal competition
  - Location of Markets
    - Distance goods must be transported
  - Government Regulation
  - Seasonality
# Mode Comparison by Economics

<table>
<thead>
<tr>
<th>Economic Characteristics</th>
<th>Truck</th>
<th>Rail</th>
<th>Air</th>
<th>Water</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cost</strong></td>
<td>Moderate</td>
<td>Low</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td><strong>Market Coverage</strong></td>
<td>Point-to-point</td>
<td>Terminal-to-terminal</td>
<td>Terminal-to-terminal</td>
<td>Terminal-to-terminal</td>
</tr>
<tr>
<td><strong>Degree of Competition</strong></td>
<td>Many</td>
<td>Few</td>
<td>Moderate</td>
<td>Few</td>
</tr>
<tr>
<td><strong>Traffic Type</strong></td>
<td>All types</td>
<td>Low to moderate value, relatively high density</td>
<td>High value, relatively low density</td>
<td>Low value, High density</td>
</tr>
<tr>
<td><strong>Length of Haul</strong></td>
<td>Short to long</td>
<td>Medium to long</td>
<td>Medium to long</td>
<td>Medium to long</td>
</tr>
<tr>
<td><strong>Capacity (tons)</strong></td>
<td>10-25</td>
<td>50-12,000</td>
<td>5-125</td>
<td>1,000-60,000</td>
</tr>
</tbody>
</table>
**Mode Comparison by Service**

<table>
<thead>
<tr>
<th>Service Characteristics</th>
<th>Truck</th>
<th>Rail</th>
<th>Air</th>
<th>Water</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Speed</strong></td>
<td>Moderate</td>
<td>Slow</td>
<td>Fast</td>
<td>Slow</td>
</tr>
<tr>
<td><strong>Availability</strong></td>
<td>High</td>
<td>Moderate</td>
<td>Moderate</td>
<td>Low</td>
</tr>
<tr>
<td><strong>Consistency (delivery time)</strong></td>
<td>High</td>
<td>Moderate</td>
<td>Moderate</td>
<td>Low</td>
</tr>
<tr>
<td><strong>Loss and damage</strong></td>
<td>Low</td>
<td>High</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td><strong>Flexibility</strong></td>
<td>High</td>
<td>Moderate</td>
<td>Low</td>
<td>Low</td>
</tr>
</tbody>
</table>
Distance-Transportation Costs Relationships

![Graph showing the relationship between transportation cost per unit and length of haul. Lines A, B, C, and D represent different cost structures at various lengths of haul: TA, TC, TD, and TB.](image)
Transportation Cost Surface

Assuming Linear Costs

Market Center

Isocost Contours

Transportation Cost Function

Length of Haul
Transportation Cost Surface
Assuming Increasing Costs at a Decreasing Rate
Alternative Mode Cost Relationships

Transportation Cost Per Unit vs. Length of Haul

- Zone 1
- Zone 2
- Zone 3
- Zone 4

Optimal Transport

Small - Medium - Large
Freight Mode Comparison

Cargo Capacity

- **One Barge**
  - 1,500 ton
  - 52,500 bushels
  - 453,600 gallons

- **One 15 Barge Tow**
  - 22,500 ton
  - 787,500 bushels
  - 6,804,000 gallons

- **Jumbo Hopper Car**
  - 100 ton
  - 3,500 bushels
  - 30,240 gallons

- **100 Car Train**
  - 10,000 ton
  - 350,000 bushels
  - 3,024,000 gallons

- **Large Semi**
  - 26 ton
  - 910 bushels
  - 7,865 gallons

Equivalent Units

- **One Barge**
  - 15 Jumbo Hopper Cars
  - 58 Large Semis

- **One 15 Barge Tow**
  - 2.25 100 Car Trains
  - 870 Large Semis

Equivalent Lengths

- **One 15 Barge Tow**
  - .25 mile
- **2.25 100 Car Trains**
  - 2.75 miles
- **870 Large Semis**
  - 11.5 miles (bumper to bumper)

Source: Iowa Department of Transportation, 800 Lincoln Way, Ames, IA 50010, 515.239.1520
Energy Use Per Freight Mode

- Rail
- Barge
- Truck

BTU / Ton-mile

Graph showing the energy use per freight mode from 1970 to 2006.
Forest Products Supply Chain

Source/Forest

Wood Mills

Saw Mill
(hardwood, softwood, pallet mill)

Composite Mill
(particle board, chip mill, OSB, MDF)

PlyVen Mill
(Hardwood, softwood, veneer and plywood mills)

Post and Pole Mill
(posts, poles, pilings)

Pulp / Paper Mill

Product Markets
(Domestic / Export)
Optimize what? And for who?

- Structure of the industry differs, depending on where you are (examples)
  - Ownership
  - Industry concentration
  - Degree of product differentiation
  - Size/scale
  - Degree of vertical integration on the supply-chain
  - Cultural values (what’s important/valued)
The most basic/simplest structure?

- What can be optimized?
  - Product Identification
    - Species
      - Oak
      - Cherry
      - Spruce
      - Fir
    - Quantity/Quality
    - Geographic/Spatial Location
    - Growth Curves over time
  - Harvest / Route Optimization

How would we approach this?
Example

**What would we need?**

- Geographic Info. System
  - Spatial Representation of:
    - Wood Characteristics
    - Topography
    - Transport Network (specification of origins)
    - Mill Locations

**How would we use it?**

- Creation of all possible routes
- Calculated cost of each route
- Calculate the optimum routes subject to the prevailing constraints
How might this relatively easy optimization (one destination) become complicated?

- Complicated Constraints:
  - Seasonal harvest restrictions due to:
    - Road access (closed during certain periods)
    - Wildlife Migratory protections
    - Habitat protection
    - Weather / Restrictions
    - Watershed / Soil erosion protection
  - Variation in Wood Demand (price)
Slightly more complicated….

What can be optimized now?

- Same as before….but a larger system of alternatives……

- Product Identification
  - Species
    - Oak
    - Cherry
    - Spruce
    - Fir
  - Quantity/Quality
  - Geographic/Spatial Location
  - Growth Curves over time

- Harvest / Route Optimization is now more complicated..
Increasing in complexity.....

Owner

Large Forest

Hardwood Mill

Post and Pole Mill

Customer

Customer

Customer

Customer
More complex.....
### Third Party Logistics Providers

#### What they do

- **Transportation/Freight Services (all modes)**
  - Cost/Service advantage.....scale leads to better bargaining
  - Foreign Trade Zones
    - Duty Deferral
    - Import/Export without Duty
  - Manage Customs Inspections/Process and required paperwork

- **Warehousing / Inventory Control**
  - Public /Contract Warehousing
  - Storage/Handling
  - Package labeling and bar coding
  - Specialized certification for specialized products (food or haz mat)

- **Information Systems Management**
  - Provide detailed product flow and inventory control information

#### Why it’s good

- **Improved**
  - Costs
  - Service
  - Flexibility
    - Space elasticity
    - Scale economies
  - Information
  - Positive Cash Flow Impact
  - Focus on Core Business
Managing (modeling) systems (networks) to achieve a defined goal, by

- Leveraging a vast array of information
- Applying optimization tools/techniques
Assume we wish to Maximize Profits

**Objective Function**

\[ \Pi = 3x_1 + 4x_2 \]

**Subject to these Constraints**

- **Constraint # 1**
  \[ 2.5x_1 + x_2 \leq 20 \]

- **Constraint # 2**
  \[ 3x_1 + 3x_2 \leq 30 \]

- **Constraint # 3**
  \[ x_1 + 2x_2 \leq 16 \]

- **Constraint # 4 (Non-Negativity)**
  \[ x_1, x_2 \geq 0 \]
Constraints: Graphically
Feasible Space

Non-Feasible Space

Feasible Space

Non-Feasible Space
Optimality

Optimal Point

Profit Function
Suppose a Cost Minimization

- Constraint #1
- Constraint #2
- Constraint #3
Minimize Costs
Constraints: Graphically

Cost Function

Optimal Point
Suppose you own or manage a forest with three potential shipping points (origins) and five different mills (destinations) from which to choose. Being cost conscious, you’d like to allocate shipments in such a way that would minimize total transportation costs. The only constraints are that you cannot ship more quantity than is available at each origin point, the quantity demanded at each mill must be met, and there cannot be negative shipments.

<table>
<thead>
<tr>
<th>Origin Points</th>
<th>Total Supply Available</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>310</td>
</tr>
<tr>
<td>B</td>
<td>260</td>
</tr>
<tr>
<td>C</td>
<td>280</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mills</th>
<th>Total Quantity Demanded</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>180</td>
</tr>
<tr>
<td>2</td>
<td>80</td>
</tr>
<tr>
<td>3</td>
<td>200</td>
</tr>
<tr>
<td>4</td>
<td>160</td>
</tr>
<tr>
<td>5</td>
<td>220</td>
</tr>
</tbody>
</table>
Steps to Setup the LP Problem

1. Determine the objective.

2. Identify the decision variable which will be determined to satisfy the objective.

3. Specify all constraints.

4. Setup Matrices in Excel

5. Solve using Excel’s LP Solver
1. The Objective…….

\[ MIN \ TC = \sum_{i=1}^{m} \sum_{j=1}^{n} C_{ij}X_{ij} \]
2. The Decision Variable \( \ldots = X_{ij} \)

<table>
<thead>
<tr>
<th>Origins “i”</th>
<th>Destinations “j”</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>A</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
</tr>
<tr>
<td>B</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3</td>
</tr>
<tr>
<td>C</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>5</td>
</tr>
</tbody>
</table>
3. Specify all constraints....

- Total shipments from any supply point cannot exceed the supply available from that supply point.
  \[ \sum_{j=1}^{n} X_{i,j} \leq S_i \]

- Total shipments to each final destination must meet the quantity demanded at each destination point.
  \[ \sum_{i=1}^{m} X_{i,j} \geq D_j \]

- Total supply must be greater than or equal to total demand.
  \[ \sum_{i=1}^{m} S_i \geq \sum_{j=1}^{n} D_j \]

- Only positive shipments.
  \[ X_{i,j} \geq 0 \]
Step 4 and 5

- Setup the problem in Excel and solve.

!!! See Demo !!!