Private Fleet Optimization

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Overview

Introduction
• Private Fleet Optimization

Problem
• Inefficient shipping scheduling

Design Strategy
• Integer Programming

Deliverable
• Excel VBA Macro
• CPLEX Optimization Model

Project Value
• Compare historical vs. improved transportation costs

Introduction → Problem → Design → Deliverable → Value
Private Fleet Optimization

- Web-based software
- Railcar scheduling
- Decrease transportation costs

Introduction ➔ Problem ➔ Design ➔ Deliverable ➔ Value
Scrap Processing

Scrap Metal
E.g. Crushed cars
   Heavy machinery
   Steel beams
   Pipes

Recycling Companies

Introduction → Problem → Design → Deliverable → Value
Rocky Mountain Recycling Routing Network

Introduction ➔ Problem ➔ Design ➔ Deliverable ➔ Value
OmniSource Routing Network

Introduction → Problem → Design → Deliverable → Value
**Daily Decisions**

**Processing Facility**
- Danville, IL

**Buyer Location**
- Adrian, MI

**Number of Railcars**
- 0

**Type of Railcar**
- Low-Sided

**Commodity**
- Wire Bundles

**Route**
- 3
## Monthly Options

<table>
<thead>
<tr>
<th>Rocky Mountain Recycling</th>
<th>OmniSource</th>
</tr>
</thead>
<tbody>
<tr>
<td>• 1 processing facility</td>
<td>• 16 processing facilities</td>
</tr>
<tr>
<td>• 15 buyers</td>
<td>• 37 buyers</td>
</tr>
<tr>
<td>• 2 types of railcars</td>
<td>• 4 types of railcars</td>
</tr>
<tr>
<td>• Number of railcars</td>
<td>• Number of railcars</td>
</tr>
<tr>
<td>• 3 routing options</td>
<td>• 3 routing options</td>
</tr>
<tr>
<td>• ~20 operational days</td>
<td>• ~20 operational days</td>
</tr>
<tr>
<td>~16,000 options/month</td>
<td>~12 commodities</td>
</tr>
<tr>
<td></td>
<td>• Rerouting</td>
</tr>
</tbody>
</table>

~16,000 options/month  ~14,000,000 options/month
Daily Decision Effects

• The effect of decisions on future options
  – Extremely difficult to assess ALL consequences
• Rail Track and Trace (RTT)
  – Real-time railcar tracking
  – Aid to determine future permanent railcar availability
• What is a “good” decision?
Propagation of Early Decision Effects

Introduction → Problem → Design → Deliverable → Value
Integer Program (IP)

Objective
• Minimize total transportation costs

Variables
• *Which* railcars to send out *when*

Constraints
• Daily permanent railcar availability
• Daily loading capacity
Rocky Mountain Recycling IP

\[
\min_{X,Y} \sum_i \sum_j \sum_k (p_{jk}X_{ijk} + f_{jk}Y_{ijk})
\]

subject to

- Permanent railcar availability
  \[
  V_1 = a_1
  \]
  \[
  N_i = V_i - \sum_j \sum_k X_{ijk}
  \]
  \[
  V_{i+1} = a_{i+1} + N_i + \sum_j \sum_k X_{(i+1-t_{jk})jk}
  \]

- Loading capacity
  \[
  \sum_j \sum_k X_{ijk} \leq V_i
  \]
  \[
  \sum_j \sum_k (X_{ijk} + Y_{ijk}) \leq 9
  \]

- Demand
  \[
  \sum_j \sum_k (90X_{ijk} + 95Y_{ijk}) \geq d_k
  \]

- Integer
  \[
  X_{ijk}, Y_{ijk} \in Z^+
  \]

Introduction → Problem → **Design** → Deliverable → Value
Daily Permanent Railcar Availability

\[ V_{i+1} = a_{i+1} + N_i + \sum_j \sum_k X(i+1-t_{jk}) jk \]

Current availability = Returning from Last Month + Not used on previous day + Returning from Current Month
OmniSource IP

\[
\min_{N,X,Y,W} \sum_i \sum_\alpha \left[ \sum_\beta \sum_j \left( \sum_s p_{\alpha j} X_{\alpha ij s} + p_{\alpha j} W_{\alpha ij s} \right) + f_{\alpha ij} Y_{\alpha ij} \right] + h_{\alpha} N_{i\alpha}
\]

subject to

\[
\begin{align*}
V_{1s\alpha} &= a_{1s} \\
N_{i\alpha} &= V_{i\alpha} - \sum_\beta \sum_j X_{\alpha ij s} \\
V_{i+1,\alpha s} &= a_{i+1,ks} + N_{i\alpha} + \sum_\beta \sum_j W_{\beta a(i+1-t_{\beta j})js}
\end{align*}
\]

Permanent railcar availability at each origin

\[
\begin{align*}
V_{1\beta s} &= a_{1\beta s} \\
N_{1\beta s} &= V_{i\beta s} - \sum_\alpha \sum_j W_{\beta ai s} \forall i, \beta \\
V_{i+1,\beta s} &= a_{i+1,\beta s} + N_{i\beta s} + \sum_\alpha \sum_j X_{\alpha \beta (i+1-t_{\alpha \beta j})js}
\end{align*}
\]

Permanent railcar availability at each destination

continued...
OmniSource IP

Loading capacity

\[
\sum_{\beta} \sum_j X_{\alpha\beta ij} \leq V_{\alpha s}
\]

\[
\sum_{\alpha} \sum_j W_{\beta aijs} \leq V_{i\beta s}
\]

\[
\sum_{\beta} \sum_j \left( \sum_s X_{\alpha\beta ijs} \right) + Y_{\alpha\beta ij} \leq l_\alpha
\]

\[
\sum_{\alpha} \sum_j X_{\beta aijs} \leq l_\beta
\]

Demand

\[
\sum_{\alpha} \sum_i \sum_j \left( \sum_s (Q_{ms} X_{\alpha\beta ijs}) \right) + Q_{ms} Y_{\alpha\beta ij} \geq d_{\beta m}
\]

Integer

\[
X, Y, W, V, N \in Z^+
\]
Daily Permanent Railcar Availability

- Permanent railcar availability at an origin
  \[ V_{i+1,\alpha_s} = a_{i+1,\kappa_s} + N_{i\sigma\alpha} + \sum_{\beta} \sum_{j} W_{\beta\alpha(i+1-t_{\beta\alpha}j)j} \]

- Permanent railcar availability at a destination
  \[ V_{i+1,\beta_s} = a_{i+1,\beta_s} + N_{i\beta\alpha} + \sum_{\alpha} \sum_{j} X_{\alpha\beta(i+1-t_{\alpha\beta}j)j} \]

Current availability = Returning from Last Month + Not used on previous day + Returning from Current Month
Private Fleet Optimization

VBA Macro
  Demand
  RTT

Java with CPLEX
  Integer program

Excel
  Shipping schedule

Introduction → Problem → Design → Deliverable → Value
Example of Schedule Output

<table>
<thead>
<tr>
<th>Day 1</th>
<th>Commodity</th>
<th># HS</th>
<th>Route</th>
<th>EDA</th>
<th># MS</th>
<th>Route</th>
<th>EDA</th>
<th># LS</th>
<th>Route</th>
<th>EDA</th>
<th># FR</th>
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<th>EDA</th>
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</tr>
</tbody>
</table>

** HS: High-Sided permanent railcar; MS: Medium-Sided; LS: Low-Sided; FR: Free-runner; EDA: Est. Day of Arrival
Project Value

RMI’s Earnings

20% of customers’ savings

Rocky Mountain Recycling’s Savings

OmniSource’s Savings

Introduction ➔ Problem ➔ Design ➔ Deliverable ➔ Value
### Estimated Savings for Rocky Mountain Recycling

<table>
<thead>
<tr>
<th>Month</th>
<th>Actual Cost</th>
<th>Cost Using IP</th>
<th>Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>May 2011</td>
<td>$493,880</td>
<td>$446,174</td>
<td>$47,706</td>
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<tr>
<td>June 2011</td>
<td>$513,433</td>
<td>$456,869</td>
<td>$56,564</td>
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<tr>
<td>July 2011</td>
<td>$545,470</td>
<td>$481,533</td>
<td>$63,937</td>
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<tr>
<td>August 2011</td>
<td>$530,980</td>
<td>$466,377</td>
<td>$64,603</td>
</tr>
<tr>
<td>May-August</td>
<td></td>
<td></td>
<td>$233,000</td>
</tr>
</tbody>
</table>

**Annual Savings**

$233,000 \times 3 \approx $700,000
Estimated Savings for OmniSource

<table>
<thead>
<tr>
<th></th>
<th>Actual Cost</th>
<th>Cost Using IP</th>
<th>Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>June</td>
<td>$14.21 M</td>
<td>$13.35 M</td>
<td>$860,000</td>
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<tr>
<td>July</td>
<td>$14.89 M</td>
<td>$14.09 M</td>
<td>$800,000</td>
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<td>Aug</td>
<td>$15.04 M</td>
<td>$14.27 M</td>
<td>$770,000</td>
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<tr>
<td>June-August Savings</td>
<td>$2.43 M</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Annual Savings

$2.43 M x 4 ≈ $9.72 M
Estimated Project Value for Railcar Management Inc.

RMI earns ~20% of its customers’ savings

RMI’s Annual Earnings from Rocky Mt. and OmniSource

$10.42 M x 20% = $2.1 Million

Introduction → Problem → Design → Deliverable → Value