Reengineering of Forest Road Networks

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Content

- Problem
- Conceptual Model
- Mathematical Model
- Application
- Results
Problem

• Forest Roads constructed mainly between 1950 and 1980

• Today:
  – different requirements and harvesting technology
  – Budget restrictions

• Question: How to adapt forest road networks for actual requirements?
Foto: Fritz Frutig WSL
2.30 – 2.50m
Problem

Actual Situation

- 18t
- 20-25t
- 28 - 40t
- Possible constr. (Expert defined)
- Timber parcel

Volume [m3]

[35 m3] [90 m3] [200 m3]

Main Road

Minimize Life Cycle Cost

- Road Network
- Harvesting
- Hauling

Existing Roads

28 - 40t
- Not used anymore

Timber parcel

Volume [m3]
Decisions

Model Components
1. Harvesting System
2. Hauling Path
3. Road Standard

Forest Road

Main Road

20t Weight Limitation

Timber parcel, Timber Pile
Harvesting system

Terrain Analysis

Cost Model

Yarding Distance
Yarding Direction [↑/↓]
Yarder Type

Volume [m3] → Cost Model

Harvesting Alternative
/Dummy Exit
**Road Standard / Cost**

**New Road**
- Terrain (DEM)
- Geological Layer

**Upgrade**
- Actual State
- Upgrade State
  - Earthwork
  - Pavement
  - Drainage

**Maintenance**
- Flat Cost
  [no model available]
Hauling Paths & Costs

<table>
<thead>
<tr>
<th>Design Standard [t]</th>
<th>Hauling Cost [CHF/m3/km]</th>
</tr>
</thead>
<tbody>
<tr>
<td>18</td>
<td>1.28</td>
</tr>
<tr>
<td>28</td>
<td>0.8</td>
</tr>
<tr>
<td>40</td>
<td>0.54</td>
</tr>
</tbody>
</table>

Hauling Cost [CHF/m3]

<table>
<thead>
<tr>
<th>Path</th>
<th>18</th>
<th>28</th>
<th>40</th>
</tr>
</thead>
<tbody>
<tr>
<td>r1</td>
<td>1.9</td>
<td>1.2</td>
<td>0.8</td>
</tr>
<tr>
<td>r2</td>
<td>2.6</td>
<td>1.6</td>
<td>1.1</td>
</tr>
<tr>
<td>r3</td>
<td>1.3</td>
<td>0.8</td>
<td>0.5</td>
</tr>
<tr>
<td>r4</td>
<td>1.5</td>
<td>1</td>
<td>0.6</td>
</tr>
</tbody>
</table>
Objective Function

Minimize Life Cycle Cost (over 40 years)
- Road Network (New Construction, Upgrade, Maintenance)
- Harvesting
- Hauling

Constraints:
- Harvest all Timber Parcels

Frame conditions:
- Men Transportation is not considered
Mathematical model

Combinatorial Problem

e.g. 10’000 Variables => 100 Millions Combinations

Mixed Integer Linear Programming
Application

Source: Swisstopo
**Initial Situation**

- Length Road: 28'410 m
- Road Density: 27 m'/ha

**Optimal Solution**

- Length Road: 12'968 m
- Road Density: 12 m'/ha
- Volume accessed: 95'595 m³ (95%)

**Road Upgrades**

- Main Road 40 t
- 28 – 32 t
- 4 – 16 t
- Possible New Constr.
- Forest
- Road Upgrade to 40t
- Only Helicopter Access
Optimal Solution (Timber Parcels on Terrain Model)
Computation Time

Problem Size:
5000 – 10’000 Variables
10’000 – 100’000 Constraints

<table>
<thead>
<tr>
<th>Perimeter</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Computation Time</td>
<td>15 – 20h</td>
<td>5 – 10 min</td>
<td>17h</td>
</tr>
</tbody>
</table>
Conclusions

Scientific

• First spatial explicit optimization method
• Detects mathematical optimal solution
• Applicable for areas up to 50 km²

Practical

Recommendation Gian Cla Feuerstein, District Forest Officer Zernez

“Check all «old» Road Networks, especially if some investments will be done”

“Without Optimization Tools, this will not be possible for large areas under objective criteria”