Rethinking the Strategic Model

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If, in addition to its role in evaluating and planning landscape level ecosystem strategies, the strategic forest management modelling involves wood supply to the forest industry, then it seems obvious that it needs to include a reasonable representation of the industry capacity and how it might change over time. This paper discusses what this means for the mathematical structure for the model. We also raise questions about the appropriate time horizon for analysis. There are good reasons that this time horizon should be much shorter than it has been conventionally.
Organization

- Recent work looking at spatial content of strategic model
- Some comments on forest strategy
Strategy Areas

Forest Management Strategy

Environmental Management Strategy

Industrial Capacity Strategy

Industrial Logistics Strategy
Strategy Areas

- Forest Management Strategy
- Environmental Management Strategy
- Industrial Capacity Strategy
- Industrial Logistics Strategy
Public Policy Strategy Areas

- Biodiversity
- Ecosystem Condition
- Soil and Water

Environmental Management Strategy

- Global Cycles

Forest Management Strategy

- Multiple Benefits
- Accepting Societies

Rural Development Strategy

Industrial Logistics Strategy

Industrial Capacity Strategy
Mineral Resource Development - a digression

To claim that a resource exists under NI-43-101 must demonstrate

- How it will be accessed
- How it will be processed
- That it is profitable under a reasonable scenario of
  - Mineral prices
  - Exchange rates
  - Operating costs
  - Capital costs
Mine Resource Definition Model

\[ V^k = C(Cap^k) + \frac{1}{(1+i)^T^k} RCst(Z) \]

\[ \text{Max} \sum_{t=1}^{T^k} \sum_{b \in B} \frac{1}{(1+i)^t} \left[ \left( v_t(g_b^k O_b) - m_t^k(O_b) - h_t^k(O_b) \right) Z_{bta} + \left( -m_t^k(O_b) - d_t^k(O_b) \right) Z_{bta} \right] \]

\[ \text{S.T.} \quad \sum_{t=1}^{T^k} \sum_{a \in \{o,w\}} Z_{bta} \leq 1 \quad b \in B \]
\[ \sum_{a \in \{o,w\}} Z_{bta} \leq \sum_{\beta \in P(b)} Z_{\beta ta} \quad \beta \in P(b), \quad b \in B, \quad t = 2, T^k \]
\[ \sum_{b \in B} \rho_t^k(O_b) Z_{bta} \leq Cap_t^k \quad t = 1, T^k \]

- \( O_b \): amount of ore in block \( b \)
- \( g_b^k \): ore recovery rate under mill scenario \( k \)
- \( v_t(g_b^k O_b) \): value of the recovered ore, block \( b \) period \( t \), mill scenario \( k \)
- \( m_t^k(O_b) \): mining costs, block \( b \) period \( t \), mill scenario \( k \)
- \( h_t^k(O_b) \): handling/processing costs, block \( b \) period \( t \), mill scenario \( k \)
- \( d_t^k(O_b) \): disposal costs (waste), block \( b \) period \( t \), scenario \( k \)

- \( Z_{bta} \): action \( a \) is taken on block \( b \) in period \( t \)
- \( o \)- ore and \( w \)- waste.

- \( C(Cap^k) \): capital cost
- \( RCst(Z) \): restoration cost

OMNR Workshop - Sault Ste. Marie
Features of Model

- Need to account for sequence of mine developments and cash flows over time
- Need to remove less valuable blocks to access more valuable blocks
- Need to account for capacity of processing facilities
- Need to account for land restoration costs after mining

- Many of these features have some commonality with forestry
What is the Case for Considering Demand When Setting Supply Levels

Supply models have assumed that:

- Certain stand types are harvested in order to achieve regeneration
- Everything harvested in model is counted as “supply”
- Access costs and timing of access don’t matter
- Transport costs of supply to demand don’t matter
- Variability in location, cost, wood quality don’t matter

Demand depends on:

- Markets
- Industrial capacity
  - Amount
  - Wood Species, Types, Quality
- Location of Capacity
  - Relative to harvest
  - Relative to other mills
- Cost of acquisition
  - Access, harvest, transportation
- Collaboration of users
If forest management plans use unrealistic harvest scenarios that don’t meet industrial needs,

the plans won’t come true

If industrial harvests are inconsistent with the forest management plans,

the plans won’t come true
Complications:
Joint Economics: Who pays, Who benefits?

- Access roads
  - (first in?)

- Harvest
  - logs, stud, pulp, biomass, mixed species stands?

- Logistics
  - sorting, information and trucking?

- “Byproducts”
  - Biomass, chips, sawdust, shavings, bark
Complications: Now vs Future

Harvest Now
- Low cost stands
- Well located stands
- Pure stands
- High quality stands

Harvest later
- High cost stands
- Poorly located stands
- Mixed wood stands
- Low Quality Stands

Economics (NPV) work ⇔ Business model doesn’t work
Some Issues!

### Forest Management Strategy
- **AAC ↔ Constant Yield**
  - What is constant in life?
  - What should be?
- **What Can Be Highly Variable**
  - Location of Harvest
    - Transportation cost
  - Composition of Harvest
    - Species mix
  - Quality of Harvest
    - Size and species

### Industrial Capacity Strategy
- **Current Mills**
  - Small, old, inefficient
- **Location of Mills**
  - Relative to forests
  - Relative to Markets
  - Relative to Each Other
- **Mix of Mills**
  - Wood type requirements
- **Financial Structure**
  - Liquidity challenges
Present Inconsistencies

- **Forest Management**
  - Wood volumes produced by species, dimension and quality
  - Silviculture needed for growth and regeneration
  - Location of harvest planned
  - Access to planned harvest

- **Industrial Capacity**
  - Wood volumes used by species, dimension and quality
  - Silviculture achieved in harvest, thinnings and planting
  - Location of mill usage
  - Road building and logistics systems
The forest value chain is a flow network

- Starts in forest
- Logistics of flows through capacity
- Flows to markets and customers

(yes, there are other forest values)
Environmental Management Policy Documents

IFORS 2014 Barcelona
Fundamental spatial entities
- 20 counties
- 46 watersheds
- 38 ecodistricts
- 4 NDR

$20 \times 46 \times 38 \times 4 = 13,984$

Other Management Attributes
- 3 ownerships
- 12 cover types
- 5 site classes

$13,984 \times 3 \times 12 \times 5 = 2517120$
Not Quite that Bad

- St Mary’s River
  - 3 NDR, 3 counties, 5 ecodistricts => 45 combinations

- East/West/Middle Pictou
  - 3 NDR, 1 county, 5 ecodistricts => 15 combinations

- Lahave River
  - 3 NDR, 3 counties, 2 ecodistricts => 18 combinations

- Overall
  - 46 watersheds, 15-20 combinations per wshd

=> 700 – 900
Basic Forest Management Attributes

*THEME {7 - FOREST COMMUNITIES}

;Forest Communities

;----------------------

;Hardwood

H1HV  _INDEX(f=-101) ;Intolerant Hardwood
H1H1v _INDEX(f=-102) ;Mixed Intolerant/Tolerant Hardwood
H1HV  _INDEX(f=-103) ;Tolerant Hardwood

;softwood

M1HMS _INDEX(f=-201) ;Intolerant Hardwood - Hardwood Leading
M1HMS _INDEX(f=-202) ;Intolerant Hardwood - Softwood Leading
M1HMS _INDEX(f=-203) ;Tolerant Hardwood

;softwood

SrSbDom _INDEX(f=-301) ;Red/Black Spruce Dominant
SwSDom  _INDEX(f=-302) ;White/Other Spruce Dominant
SbFDom  _INDEX(f=-303) ;Balsam Fir Dominant
SPFDom  _INDEX(f=-304) ;Spruce/Fir Dominant
SPIDom  _INDEX(f=-305) ;Pine Dominant
SMHePisDom _INDEX(f=-306) ;Mixed Spruce/Pine/Hemlock

;Managed Stand Types

;----------------------

SrSPL  _INDEX(f=-401) ;Softwood Plantation: Native Red Spruce
SbSPL  _INDEX(f=-402) ;Softwood Plantation: Native Black Spruce
SPSPL _INDEX(f=-403) ;Softwood Plantation: Native Pine
SwSPL _INDEX(f=-404) ;Softwood Plantation: White Spruce
SExPL _INDEX(f=-405) ;Softwood Plantation: Exotic Species - Norway Spruce / xLarch

*THEME {18 - FOREST STATE INDICATOR}

NAE  _INDEX(f=-18) ;NATURAL UNMANAGED STAND - EVENAGED
NAU  _INDEX(f=-20) ;NATURAL UNMANAGED STAND - UNEVENAGED
NPG  _INDEX(f=-30) ;2ND ROTATION UNMANAGED
PLT  _INDEX(f=-40) ;MANAGED STAND - PLANTATION
PCT  _INDEX(f=-50) ;MANAGED STAND - PRECOMMERCIAL THINNING
CTH  _INDEX(f=-61) ;MANAGED STAND - COMMERCIAL THINNING IN NATURAL STANDS (NAE OR NRG)
CPTH  _INDEX(f=-62) ;MANAGED STAND - COMMERCIAL THINNING IN COMMERCIAL STANDS (NRT)
CTPT  _INDEX(f=-63) ;MANAGED STAND - COMMERCIAL THINNING IN PRECOMMERCIAL STANDS
CCTPT _INDEX(f=-60) ;MANAGED STAND - COMMERCIAL THINNING IN PLANTATIONS
CCTPL _INDEX(f=-66) ;MANAGED STAND - COMMERCIAL THINNING IN PREVIOUSLY COMMERCIAL STANDS

SELNE _INDEX(f=-71) ;MANAGED STAND - SELECTION HARVESTING IN NATURAL EVENAGED STANDS (NAE OR NRG)
SELNP _INDEX(f=-72) ;MANAGED STAND - SELECTION HARVESTING IN NATURAL EVENAGED PCT'S STANDS (PCT)
SELNR _INDEX(f=-73) ;MANAGED STAND - SELECTION HARVESTING IN NATURAL UNMANAGED STANDS (NAU)
ESC  _INDEX(f=-80) ;TRACK MANAGED STANDS THAT ESCAPE NORMAL WINDOW

SML  _INDEX(f=-90); Shelterwood Harvest 1st pass removes 40% SOURCE TM
Transportation

perhaps the biggest spatial issue
Model II

\[
\max \sum_{i \in I, a \in T, k \in K} c_{iak} x_{iak} + \sum_{a \in T, b \in T, k \in K} d_{abk} y_{abk}
\]

\[
\sum_{b \in T, k \in K} y_{abk} = \sum_{i \in I, k \in K} x_{iak} \quad a \in T, a < b
\]

\[
\sum_{a \in T, k \in K} y_{abk} = \sum_{f \in T, k \in K} y_{bfk} \quad b \in T
\]

\[
\sum_{a \in T, k \in K} x_{iak} = area_i \quad i \in I
\]

+ side constraints on entire region
Model II spatial

\[
\begin{align*}
\text{max} & \quad \sum_{i \in I, a \in T} c_{iakw} x_{iakw} + \sum_{a \in T, b \in T} d_{abkw} y_{abkw} \\
\sum_{b \in T, k \in K} y_{abkw} &= \sum_{i \in I, k \in K} x_{iakw} \quad a \in T, a < b, w \in S \\
\sum_{a \in T, k \in K} y_{abkw} &= \sum_{f \in T, k \in K} y_{bfkw} \quad b \in T, w \in S \\
\sum_{a \in T, k \in K} x_{iakw} &= \text{area}_i \quad i \in I(w), w \in S
\end{align*}
\]

+ side constraints on entire region
+ side constraints on each \( w \)
The Crown Central forest covers 379,000 ha, divided among 3 ownerships, 22 Ecodistricts, 24 watersheds, and covers 5 counties: Halifax, Hants, Colchester, Cumberland, Pictou.

Table 4.1: Model One and Model Two Comparison Descriptions

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Constraints</th>
<th>Spatial Resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>none</td>
<td>none</td>
</tr>
<tr>
<td>2</td>
<td>4.4, 4.5, 4.6</td>
<td>Ownership</td>
</tr>
<tr>
<td>3</td>
<td>run 2 and 4.8, 4.9</td>
<td>Ownership and Ecodistrict</td>
</tr>
<tr>
<td>4</td>
<td>run 3 and 4.11</td>
<td>Ownership, Ecodistrict and Watershed</td>
</tr>
</tbody>
</table>

Table 4.2: Phase 1 Model One Model Two Comparison Data

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Solution Time (secs)</th>
<th>Objective ($10^7$)</th>
<th>Solution Time (secs)</th>
<th>Objective ($10^7$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>417.81</td>
<td>4.715</td>
<td>4.41</td>
<td>4.790</td>
</tr>
<tr>
<td>2</td>
<td>1623.81</td>
<td>3.788</td>
<td>663.44</td>
<td>3.869</td>
</tr>
<tr>
<td>3</td>
<td>1615.70</td>
<td>3.574</td>
<td>9754.32</td>
<td>3.744</td>
</tr>
<tr>
<td>4</td>
<td>2488.03</td>
<td>3.573</td>
<td>12,032.67</td>
<td>3.744</td>
</tr>
</tbody>
</table>

Figure 4.1: The Crown Central

Figure 4.7: Model One (solid) and Model Two (hatched) Phase 1 Solution Times

Figure 4.8: Model One (solid) and Model Two (hatched) Phase 2 Solution Times
## Illustration of Growth Problem

| Scenario | Model One | | Model Two | |
|----------|-----------|-------------------|-----------|
|          | Rows      | Columns           | Non-Zeroes| Rows      | Columns           | Non-Zeroes |
| 1        | 100,679   | 665,381           | 60,435,407| 260,296   | 787,506           | 1,700,820 |
| 2        | 100,910   | 665,381           | 60,435,959| 262,723   | 788,952           | 8,927,070 |
| 3        | 106,190   | 665,381           | 60,446,519| 511,513   | 1,360,729         | 60,268,649|
| 4        | 106,790   | 665,381           | 60,447,119| 722,002   | 1,823,163         | 100,002,631|

**Table 4.4:** Phase 1: Model One and Model Two Matrix Sizes

| Scenario | Model One | | Model Two | |
|----------|-----------|-------------------|-----------|
|          | Rows      | Columns           | Non-Zeroes| Rows      | Columns           | Non-Zeroes |
| 1        | 100,679   | 768,427           | 71,227,495| 322,852   | 821,549           | 1,646,491 |
| 2        | 100,910   | 768,427           | 71,228,047| 325,279   | 822,995           | 6,999,298 |
| 3        | 106,190   | 768,427           | 71,238,607| 738,450   | 1,855,004         | 59,330,090|
| 4        | 106,790   | 768,427           | 71,239,207| 1,156,015 | 2,900,105         | 120,417,153|

**Table 4.5:** Phase 2: Model One and Model Two Matrix Sizes
Problems with Model II

- Model growth as spatial issues are added
  - Need to add more spatial entities to deal with transport/logistics

- Model II is a puzzle solver, not a prescription generator
  - Many of the potential action sequences do not correspond to prescriptions a forester would assign to a stand.
Model I

- MaxMillion, FORPLAN (original), SPECTRUM
- HEUREKA (Sweden), JLP (Finland)

- Basic Model does not grow with spatial detail
  - Side constraints do

- Main problem
  - Potentially lots of prescriptions
    - Combinatorics over horizon
    - Initial conditions don’t fit prescriptions
  - Solution – prescription generator/simulator
    - Heureka (part of system)
    - SIMO (Finland - input to JLP)

- Spatial detail
  - Combinations of spatial zones
  - Explicit within Heureka

- Model Compression
  - Stands that share all growth attributes and all spatial attributes can be combined

Figure 6. Illustration of when stands can be combined
Does harvest location matter

- Crown central stands as before
  - 8 mills
  - 6 timbersheds

<table>
<thead>
<tr>
<th>Species</th>
<th>Log Value ($/m³)</th>
<th>Pulp Value ($/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sugar-Maple/Yellow Birch</td>
<td>35.00</td>
<td>10.00</td>
</tr>
<tr>
<td>Intolerant Hardwood/Red Oak/Beech</td>
<td>10.00</td>
<td>10.00</td>
</tr>
<tr>
<td>Spruce-Fir</td>
<td>35.00</td>
<td>15.00</td>
</tr>
<tr>
<td>Pine/Eastern Hemlock/Tamarack Larch</td>
<td>20.00</td>
<td>15.00</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mill</th>
<th>Accepts</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>all softwood sawlogs</td>
</tr>
<tr>
<td>2</td>
<td>all softwood pulp</td>
</tr>
<tr>
<td>3</td>
<td>valuable hardwood sawlogs</td>
</tr>
<tr>
<td>4</td>
<td>all softwood sawlogs</td>
</tr>
<tr>
<td>5</td>
<td>all softwood sawlogs</td>
</tr>
<tr>
<td>6</td>
<td>all softwood pulp</td>
</tr>
<tr>
<td>7</td>
<td>low-value softwood and all hardwood</td>
</tr>
<tr>
<td>8</td>
<td>all softwood sawlogs</td>
</tr>
</tbody>
</table>
A Model I Framework

Objective

\[
\text{max } \sum_{m \in M} \sum_{t \in T} 0.95^t \cdot PROF_{mt} - 3000 \cdot \sum_{d \in D, e \in E} \sum_{n \in N, t \in T} J_{d,e,n,t} - 3000 \cdot \sum_{c \in C, e \in E} \sum_{n \in N, t \in T} G_{c,e,n,t} \tag{5.1}
\]

Constraints

\[
\sum_{j \in P_i} x_{ij} = \text{area}_i, \quad i \in I \tag{5.2}
\]

Timber Constraints

\[
\begin{align*}
SPBF_{ut} & \leq SPBF_{u,t+1} & u \in U, t \in T \\
OTHER_{ut} & \leq 0.25TOT_{ut} & u \in U, t \in T \\
SPBFINV_{ut} & \leq SPBFINV_{u,t+1} & u \in U, t \geq 12
\end{align*} \tag{5.3}
\]

\[
\sum_{i \in I(n,e)} y_{ij} \cdot x_{ij} = \text{DEVCLS}_{d,e,n,t} \quad d \in D, e \in E, n \in N, t \in T \tag{5.6}
\]

Ecosystem Constraints

\[
\begin{align*}
DEVCLS_{d,e,n,t} + J_{d,e,n,t} & \geq A_{d,e,n} \text{area}_{en} & d \in D, e \in E, n \in N, t \geq 11 \\
SERALCLS_{e,n,t} + G_{e,n,t} & \geq B_{e,n} \text{area}_{en} & e \in C, e \in E, n \in N, t \geq 11
\end{align*} \tag{5.7}
\]

Environmental Policy Variables are computed as follows:

\[
\begin{align*}
\text{COVER}_{w,t} & = \sum_{i \in I(w)} y_{ij} \cdot x_{ij} & w \in W, t \in T \tag{5.9} \\
\text{CLEARCUT}_{e,t} & = \sum_{j \in P(e)} x_{ij} & e \in E, t \in T \tag{5.10} \\
\text{SHELTHARV}_{e,t} & = \sum_{j \in P(e)} x_{ij} & e \in E, t \in T \tag{5.11}
\end{align*}
\]

Environmental Policy Constraints

\[
\begin{align*}
\text{COVER}_{w,t} & \geq 0.6 \text{area}_w & w \in W, t \geq 5 \tag{5.12} \\
\text{CLEARCUT}_{e,t} & \leq 0.5 \text{area}_e & e \in E, t \in T \tag{5.13} \\
\text{SHELTHARV}_{e,t} & \leq 0.15 \text{area}_e & e \in E, t \in T \tag{5.14}
\end{align*}
\]

Figure 5.4: Integrated Industry Model Formulation: Shipping Network

Figure 5.3: Integrated Industry Model Formulation: Objective and Constraints
Some Results
Max Volume vs Max Profits

NDY - Max Volume vs Max Profit

Spruce-Fir
m$^3$

Period

0
5
10
15
20

1400000
1500000
1600000
1700000
1800000
1900000
2000000
2100000
2200000

IFORS 2014 Barcelona
Some Results
Clearcut and Shelterwood Restrictions

**Figure 5.9:** Clearcut and Shelterwood Restriction: Profit - Base (triangles), Shelterwood Restricted (circles)

**Figure 5.10:** Clearcut Restriction: Spruce-Fir Harvests - Base (triangles), Shelterwood Restricted (circles)
Some Results
Watershed Management (doesn’t matter - at 60%)

Figure 5.11: Watershed Management: Profit-Base (triangles), 60% Cover Condition (circles)

Figure 5.12: Watershed Management: Spruce-Fir Harvests-Base (triangles), 60% Cover Condition (circles)
Some Results
New Mill Capacity Added (In right location)

Figure 5.13: Industrial Expansion: Profit - Base (triangles), Expanded Industry (circles)

Figure 5.14: Industrial Expansion: Spruce-Fir Harvests - Base (triangles), Expanded Industry (circles)
Some Results
Alternative Regulation Strategies

**Figure 5.15:** Alternate Regulation Strategies to Non-Declining Yield: Profit - NDY (triangles), Mill Regulation (circles), Mean Regulation (x)

**Figure 5.16:** Alternate Regulation Strategies to Non-Declining Yield: Spruce-Fir Harvests - NDY (triangles), Mill Regulation (circles), Mean Regulation (x)
Some Results
Alternative Regulation Strategies

Figure 5.17: Leaving Wood in the Forest: Profit - Ship Everything (triangles), Ship Selectively (circles)

Figure 5.18: Leaving Wood in the Forest: Spruce-Fir Harvests - Ship Everything (triangles), Ship Selectively (circles)
Some notes

- Although model is “big”, can do a lot of analysis quite quickly
- Model Generation - AMPL (GMPL)
- Model Solution – GUROBI
  - Python routines permit modifying model constraints and re-running without leaving GUROBI
    - `mm=read('Model1.lp')`
    - `mm.optimize()`
    - ...
    - interactive Python routines
    - ...
    - `mm.optimize()`

- Key to eventual strategic planning usage
  - Encourage playing with strategy
Technical issues
- solving big Model I models

- How big (NS provincial)
  - 6 million polygons in GIS
  - Disolvable to about 1 million stands
  - Stand compression (within spatial combinations) about $3 \Rightarrow 1 \Rightarrow 300-400,000$ “stands”
  - 10-20 prescriptions per stand
  - 3-4 million variables
  - 300-400,000 GUB (area) constraints
  - 30-50,000 side constraints

- Key issue is exploiting the GUB’s
  - JLP based on this
What should be in the strategic model

- All the strategic spatial issues
  - Biodiversity
  - Ecosystem condition and productivity
  - Soil and Water
  - Multiple Economic benefits
    - Markets
    - Transportation
  - Accepting responsibility
    - Obey the law
    - First Nations

- Good forestry
  - Alternative prescriptions that meet the forest conditions
    - Species associations
    - Site
    - Current stocking
    - Current stand quality

- Good Economics
  - Scale and location of mills
  - Cash flow requirements
  - Harvest, Transport costs
  - Product markets
    - Local, export

- Good infrastructure and logistics
  - Merchandizing yards
  - Multi-modes
    - Forest, highway trucking
    - Rail, seaborn
Comments on Strategy

- Strategic decisions are made now!
  - Stakeholders
  - Landowners (65+20=85?)
  - Governments (4 years)
  - Companies (.90^{20}=0.15)
  - Forests
    - Every tree to be harvested in the next 30 years is growing now

- Planning for long term (100 years) is a myth
  - Economy
    - Wood Products: markets, prices
    - Fuel, energy, biochemicals
  - Technologies
    - Harvesting, transport
    - Solid wood processing and products
    - Fibre processing
    - Thermochemical and biochemical processes
  - Workforce
    - Population, skills, education
  - Large scale Natural Disturbance
Planning for the Immediate Does Not Mean Ignoring the Future

- Investing in Plants changes:
  - future capital/labour costs
  - Product Mix
  - Logistics cost structure
  - Material utilization

- Investing in logistics
  - Reduces future acquisition costs
  - Improves future supply chain possibilities

- Harvesting, silviculture:
  - Creates the young forest
  - removes decadent, poorly stocked stands
  - Changes species, age, spacing distributions
  - Changes harvest productivity
  - Determines habitat for biodiversity
  - Determines ecosystem measures measures
  - Determines watershed cover
Nature of the Strategic Model

- Relatively short term
  - 20-30 year

- Highly focussed on good forestry prescriptions

- Highly focussed on short spatial issues

- Highly focussed on economics:
  - Harvesting
  - Logistics
  - Markets

- Strong focus on end conditions
  - Specifications of DFC
  - Models of future value
    - Ecosystem productivity
    - Forest growth productivity
    - Forest harvesting productivity
    - Industrial labour productivity
    - Industrial Capital Productivity
Need to think a lot more about what goes into the Strategic Model
A Sandbox to Play in

- Ability to generate a fairly broad variety of forests
- Ability to look at various capacity cost structures
- Ability to include logistics:
  - Forest to mills
  - By-products at mills
  - Mill to Mill transport
- Examine effects of NDY
- Examine role of discount factors
- Multiple regulation modes
  - System wide periodic revenues
  - Effects of Sharing Revenues
The Forestry

- Many “stands”
- Multiple Cover Types
- Multiple Site Types
- Variable Stocking

- Stands have “locations”
# StandGen

<table>
<thead>
<tr>
<th>Number of stands</th>
<th>Mean area</th>
<th>(exponential)</th>
</tr>
</thead>
<tbody>
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## Other Sections

- GenArea
- Genages
- Gensite
- GenCover
- GenStock
- GenRegion

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## MAI Ylds

|   | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P | Q | R | S |
| LC | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | MaxMAI | 11.75 | 10.0 | 9.9 | 9.1 | 9.1 | 6.1 | 7.2 | 6.2 | 5.2 | 4.2 | 2.2 | 2.2 | 0.8 |
| 100MAI | 8.7 | 8.4 | 7.7 | 7.3 | 6.7 | 6.7 | 6 | 5.5 | 4.8 | 4 | 3 | 2 | 0.8 |
| Age early | 40 | 40 | 45 | 50 | 55 | 55 | 60 | 65 | 75 | 85 | 90 | 99 |
| Age late | 470 | 432 | 445.5 | 455 | 440.6875 | 396 | 372 | 338 | 315 | 272 | 198 | 72.92929 |
| Age yield | 35 | 35 | 40 | 45 | 50 | 55 | 60 | 65 | 75 | 80 | 85 |

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### Annual Increment as a Function of Age and Site

![Graph showing the annual increment as a function of age and site](image-url)
Stand Data Ready To Go
Capacity

- Multiple Capacity Types
  - Softwood Stud
  - Softwood Saw
  - Softwood Pulp
  - Hardwood Saw
  - Hardwood Pulp
  - Bioenergy

- Capacity have locations
  - Euclidian distances
    - Keep it simple

- Economies of Scale
  - $C_j(x_j) = k_j x_j^{\alpha}$

- Modelled as piecewise linear
Simple Situation

15 Regions 50x50 km
8 Mill Sites
Regional Centroids (15 for Transport Calcs.)

6 Mill Types

Capacity Cost Functions
\[ C(x) = Kx^\alpha \]
Simulated Regional Characteristics

Total Area
- Total Area

Avg Age
- Avg Age

Avg Cover
- Avg Cover

Avg Site
- Avg Site

Stocking
- Stocking

Max Productivity
- Max Productivity
Total Harvest Effects

No NDY - No Costs

NDY - No Costs

NDY - with Costs, No Cap

No NDY - with Capacity

NDY with Capacity

$410.8 Million (NPV)

$395.6 Million (NPV)
Regional Harvests

Regional - HWD

Regional - Swd

Base – No NDY, No Costs

NDY – No Cost, No Cap

NDY With Capacity
Installed Capacity

No NDY

NDY

Capacity

Series1

Capacity
Some Ways of Getting at Long Term Sustainability

- **Model 1 Prescriptions**
  - Good prescriptions are inherently sustainable at the stand level

- **Milestone Years**
  - Non-declining standing volumes (t=50, 100, etc)
    - not harvest
    - By species
    - By watershed, ecodistrict, etc
    - By harvest region ??
  - Improving Harvest Productivity
    - At same height
      - Productivity ~ D²
    - Silviculture does not change height much but changes D

- Can we get aggregate long term measures of environment and productivity just like NPV in economics
  - Not so clear that NPV in Economics is that great an idea

- Can we tradeoff long term measures of environment, and productivity and short term economics
  - Mathematically ?
  - Organizationally

- Can we develop End- State Models for short (20-30 years) strategic models
Models Matter in Strategy

- Do not give answers

- Allow examination of tradeoffs if they are constructed properly
  - Model Generation Times can be long
  - Use python within Gurobi to run tradeoffs without regenerating model

- Substantial problems of “who benefits”
  - Even more of who benefits “ when”
That’s It
Thanks for Listening

- Questions
- Comments