Value chain modeling and pulp and paper industry competitiveness

UBC
March 23, 2007

Research Seminar facilitated by the BC Forum on Forest Economics and Policy
Outline

• Paprican and FPInnovations
• Fibre properties and pulp and paper production
• Mathematical programming and value chain models
• Modeling applications
• Industry competitiveness
Paprican overview

- Non-profit, membership-based research institute established by the Canadian pulp and paper industry in 1925
- Staffed by 269 employees in three laboratories
  - Pointe Claire, Québec
  - Vancouver, British Columbia
  - Prince George, British Columbia
- Supported by 31 member companies operating over 100 mills
- Annual budget of $36.1 million
  - Membership fees ($29.3 million)
  - Contract revenues ($5.9 million)
  - Licenses and royalties ($0.6 million)
  - Federal government contributions ($0.3 million)
Paprican research

- Core research programs
  - Fibre supply and quality (ELE-01 and 04)
  - Mechanical pulping (ELE-05)
  - Chemical pulping (ELE-08, 09 and 10)
  - Papermaking (ELE-12 and 13)
  - Product performance (ELE-14 and 15)
  - Sustainability and environment (ELE-18, 19, 20 and 21)
- Transformative technology research elements
  - Forest-based biorefinery (ELE-81)
  - Forest-based nanomaterials (ELE-82)
  - Advanced papermaking (ELE-83)
  - Advanced fibre delivery (ELE-84)
Paprican research

• Multi-client research elements
  – (ELE-24, 25, 26, 27, 28, 29 and 30)

• Business units
  – EvaluTree
  – Corrosion control
  – Boiler optimization and emissions control
  – Fibreline benchmarking
  – Bleaching pilot plant
  – Pilot paper machine
  – Roll testing facility
  – Dimensional stability analysis
  – Environmental services
  – Analytical services and standards
FPInnovations

- Canadian wood fibre centre (forest resources)
- Feric (forest engineering)
- Forintek (lumber and engineered wood products)
- Paprican (pulp and paper products, forest-based biorefinery, and forest-based nanomaterials)
Wood fibre

\[ T \approx 3\mu m \]

\[ D \approx 50\mu m \]

\[ L \approx 3mm \]
Fibres in wood

James Drummond (Paprican)
Mechanical pulping

Hymac Andritz HXD 64 refiner (Papermaking science and technology)
Chemical pulping

Kvaerner two-vessel hydraulic digester (Papermaking science and technology)
Fibres in pulp

James Drummond (Paprican)
Papermaking

Nicolas-Louis Robert continuous sheet former - 1798 (Papermaking science and technology)
Fibres in paper

James Drummond (Paprican)
Implications of fibre properties

- Product properties and end-use performance
- Fibre properties
- Sheet structure
- Process parameters
Key fibre properties

- Chemistry
- Length
- Transverse dimensions
- Microfibril angle
Fibre chemistry effects

Ashif Hussein (Paprican)
Implications of fibre length
Implications of fibre length

Aspen cross-section

Aspen surface

Black spruce cross-section

Black spruce surface

James Drummond (Paprican)
Implications of fibre collapse

James Drummond (Paprican)
Implications of fibre collapse

James Drummond (Paprican)
Transverse dimensions and collapse
Microfibril angle

James Drummond (Paprican)
Microfibril angle and collapse

- $\theta = 0^\circ$: Maximum reinforcement
- $\theta = 90^\circ$: No reinforcement
- $\theta = 45^\circ$: Intermediate reinforcement
Fibre geometry effects

\[ CI = 1 - e^{-k \left[ \frac{1}{E} \right]^2 \left[ \frac{P}{2\pi(T)} \right]^2} \]
Fibre geometry effects

Specific refining energy (MJ/kg)
- Subalpine fir
- Spruce
- Lodgepole pine

Fibre geometry effects

Ashif Hussein (Paprican)
Fibre geometry effects

Subalpine fir

Tensile index (N*m/g)
- 128
- 124
- 120
- 116
- 112

Spruce
Lodgepole pine

Ashif Hussein (Paprican)
Forest product industry value chain

Trees → Harvesting → Sort yard → In-woods chipping

- Logs
  - Chipping
  - Generation
  - Power
  - Customers

- Residues
  - Chipping
  - Generation
  - Power
  - Customers

- Lumber and engineered wood products
  - Processing
  - To sawmill
  - To pulp mill

- Customers
  - Internal use

- Chips
  - Chipping
  - Generation
  - Power
  - Customers

- Hog fuel
  - Chipping
  - Generation
  - Power
  - Customers

- Chips
  - To pulp mill
  - To sawmill
  - To generator

- Recycling

To pulp mill

Customers
Mathematical programming

- A methodology for modeling and optimizing systems elaborated by George Dantzig in 1947
- A typical mathematical program consists of:
  - An “objective function” describing the goal of the model (maximization of profits or minimization of costs)
  - A set of “constraint” functions describing the structure of the system or the valid solution space
Mathematical programming

• Applications
  – Network design (facility locations, product flows, etc.)
  – Inventory planning (replenishment policies, etc.)
  – Scheduling
  – Routing
  – Capacity planning (queueing systems, etc.)
  – Portfolio planning (risk management policies, etc.)
Fibre utilization model framework

- Suppliers → Procurement volumes → Chip grades → Equipment capacities → Pulp grades → Customers

- Sorting strategies
  - Capital investments
    - Product changeovers
      - Product quality effects
      - Process productivity effects
      - Processing cost effects

- Production volumes and product recipe compositions
  - Sorting strategies

- Volume
  - Unit cost
  - Unit revenue

- Product development
  - Sales volumes

- Product changeovers
  - Product quality effects
  - Process productivity effects
  - Processing cost effects

- Capital investments
  - Product changeovers

- Sorting strategies
  - Procurement volumes

- Chip grades
  - Sorting strategies

- Equipment capacities
  - Capital investments

- Pulp grades
  - Sorting strategies

- Customers
Market kraft pulp application

- **Procurement volumes**
  - Suppliers
    - Minimum and maximum procurement volumes
    - Contracts
    - Unit procurement and delivery costs
  - Sales volumes
    - Minimum and maximum sales volumes (demand)
    - Contracts
    - Unit sales revenues after delivery
  - Customers
    - Minimum and maximum sales volumes (demand)
    - Contracts
    - Unit sales revenues after delivery

- **Production volumes**
  - Chip grades
    - Pulp yields
    - Cooking rates (capacity usage)
    - Cooking costs (chemical and energy usage)
    - Upper and lower recipe composition limits (pulp quality effects)
  - Optimal recipe compositions
  - Digester capacities
    - Bleaching yields
    - Bleaching rates (capacity usage)
    - Bleaching costs (chemical and energy usage)
  - Brownstock grades
    - Bleached pulp grades
    - Dried pulp grades
    - Properties (value)
    - Drying rates (capacity usage)
    - Drying costs (steam and energy usage)
    - Drier capacities
    - Properties (value)
    - Drying rates (capacity usage)
    - Drying costs (steam and energy usage)
Multi-period planning application

- **External customers**
  - Chipping
  - Log supply

- **Supplier inventories**
  - Chips
  - Sawmills

- **Mill inventories**
  - Pulping
  - Brownstock
  - Bleaching
  - Bleached pulp

- **Drying**
  - Dried pulp
  - Crumb pulp

- **Inventory management**
  - Seasonal supply and cost variations
  - Seasonal demand and price variations
  - Production plan adjustments

- **Product recipe adjustments**
  - Internal customers
  - External customers

- **Warehouse**
  - Container

Inventory management

---

Multi-period planning application

- **External customers**
  - Chipping
  - Log supply

- **Supplier inventories**
  - Chips
  - Sawmills

- **Mill inventories**
  - Pulping
  - Brownstock
  - Bleaching
  - Bleached pulp

- **Drying**
  - Dried pulp
  - Crumb pulp

- **Inventory management**
  - Seasonal supply and cost variations
  - Seasonal demand and price variations
  - Production plan adjustments

- **Product recipe adjustments**
  - Internal customers
  - External customers

Inventory management
Extended network application
Global competitiveness

- What factors affect the global competitiveness of the Canadian forest products industry?
- How can the Canadian forest products industry achieve sustainable global competitiveness?

Access to natural resources
Access to capital
Access to markets
International market conditions
Trade and tariff regulations
Currency exchange rates
Global competitiveness

• How is a globally competitive forest products industry structured?
• How should individual companies operate within this structure?
Project objectives

• Define the key factors affecting industry competitiveness
• Develop two mathematical programming models (one mill-level and one sector-level) which integrate the effects of the global trade environment, government policies and industry strategies on competitiveness
• Develop suitable solution heuristics
• Elaborate and analyze a set of industrially-relevant scenarios
Background work

• Michael Porter
  – *The competitive advantage of nations*
  – *Canada at the crossroads: The reality of a new competitive environment*
  – *Canadian competitiveness: A decade after the crossroads*

• Provincial government competitiveness council reports
  – *British Columbia*
  – *Saskatchewan*
  – *Ontario*

• Sophie D’Amours and Alain Martel
  – *International factors in the design of multinational supply chains: The case of Canadian pulp and paper companies*

• Paprican’s transformative technology initiatives
Project partners

- Mikael Rönnqvist (Norwegian School of Economics, Bergen)
- Sophie D’Amours and Alain Martel (Université Laval, Québec)
- Paprican (FPInnovations)
- Industrial partners
Acknowledgements

• Sophie D’Amours and Alain Martel (Université Laval)
• HoFan Jang (Paprican)
• James Drummond and Ashif Hussein (Paprican)