Integrated planning in the pulp and paper supply chain
Outline of the presentation

• Global pressure and value proposition
• Architecture of an advanced planning and scheduling (APS) system for the pulp & paper industry
• Examples of interesting research problems:
  – Value creation network design
  – Tactical & operational planning
  – Transportation planning
• Collaboration with customer and business models
• Conclusion
Socio-economic context

• The industry is faced with:
  – Increased global competition (Asia, Eastern Europe, Scandinavia, South America, etc.):
    • Increased pressures to lower prices;
    • Expected consolidation in NA.
  – Growing market pressures
    • for higher service level and guaranteed volume;
    • for direct delivery and more responsibility at the supplier;
    • for increased customer value (e.g. quality, new product, e-business).
  – Environmental concerns:
    • Certification;
    • Sustainable development.
  – Substitute products.
The industrial challenges

• Need for capturing new business opportunities
  – extending the value creation network
  – developing new profitable and sustainable business models

• Difficulties
  – long and variable production cycle times (harvesting and transformation)
  – natural characteristics of wood and associated supply uncertainties (e.g. fiber quality)
  – divergent process
  – access capital
Life cycle of certain products in the pulp and paper industry

Sources: Ministère des Ressources naturelles, de la Faune et des Parcs and Université du Québec à Trois-Rivières, March 2003
## Qualifiers versus order winners

<table>
<thead>
<tr>
<th>Development</th>
<th>Expansion</th>
<th>Rapid growth</th>
<th>Maturity</th>
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</tbody>
</table>
A different value proposition

• **Product**
  – Specialized (knowledge)
  – Quality
  – Reliability
  – Customized, etc.

• **Service**
  – Fast and reliable deliveries
  – Multi-site deliveries
  – 24 hour technical assistance, etc.

• **Relationship**
  – Consignment
  – Vendor Managed Inventory
  – Collaborative planning, etc.
Research objective

• Capture new **business opportunities** by deploying the proper value creation network.
• Improve **profitability** through **cost** reduction and increased **customer satisfaction**.
• Improve the **synchronization** of all operations.
• Improve the **integration** of information flows between all business units using web-based technologies.
All enterprises do not design and plan their networks the same way.

In collaboration with Paprican and Domtar, Glenn Weigel, Paul Watson, Alain Martel, Sophie D’Amours, Wissem M’Barek.
Agility: business by demand

Delivery by demand: stock

Finishing on demand: make sheet

Paper production by demand: make roll

Pulp production by demand: "certified pulp"

Procurement by demand: species selection from the forest

Engineering by demand: new products

Delivery time
The decoupling point at the warehouse (sheets)

Make to stock

“Cyclic production”

Parent roll

Cut sheets
CI : internal, CE : external

Finished product

Client

Select the sheets to keep in stock in every location

Deliver on demand

Client

Client

Client

Plan production of rolls on the paper machine

JUMBO

Q

t

"Cyclic production"
The decoupling point at the warehouse (rolls)

- **Make to stock**
  - "Cyclic production"
  - Plan production of rolls on the paper machine

- **Select the rolls to keep in stock in every location**

- **Deliver on demand**
  - Customer
  - Customer
  - Customer
  - Customer

- **Q**
  - JUMBO
- **t**
  - Rolls
The decoupling point at the winder

Determine the type of parent roll and the quantity to remain in stock

Make to stock

“Cyclic production”

Convert on demand

Promise a date “2 to 5 days”

Client

Client

Client

Client

Client

Fill the parent roll order in the right production block

JUMBO

Q

t

Select the cut sheets and the parent rolls

Parent roll

Cut sheets

CI : internal, CE : external

Finished product

Client
The decoupling point at the paper machine

Produce and deliver on demand

- JUMBO
- Parent roll
- Cut sheets
  - CI: internal, CE: external
- Finished product

Optimize production plan
Optimize parent roll cutting
Schedule the converting process

Advanced Planning System for the Pulp and Paper Industry (APS-PPI)

Procurement → Production → Distribution → Sales

**Long-Term**
- Strategic Network Planning (*Design*)
  - (Sourcing decisions, externalization decisions, technology-capacity decisions, transportation means decisions, mills-DCs deployment and mission, product-market selection)
  - Suppliers, Mills, Converters, DC Network with Available Capacity and Selected Product-Markets with Price Service Policy

**Mid-Term**
- Aggregate Planning
  - (On a seasonal basis: Product family assignment and sequencing for paper machines, external converter contracts, product mix for pulp mills, converting facilities and distribution centers, sourcing contracts...)

**Short-Term**
- Material Procurement Planning
  - Procurement quantities

**Execution**
- Logs-Chips Transportation Scheduling
- Production Scheduling
- Picking, Loading and Transportation Scheduling
- Demand Fulfilment (Stock) and ATP (Make)

FORAC Platform

Sophie D'Amours, Alain Martel and Alain Rousseau, May 2003
Distributed decision systems

Schneeweiss (2003).
Advanced Planning System for the Pulp and Paper Industry (APS-PPI)

**Procurement** > **Production** > **Distribution** > **Sales**

**Long-Term**
- Strategic Network Planning (*Design*)
  - (Sourcing decisions, externalization decisions, technology-capacity decisions, transportation means decisions, mills-DCs deployment and mission, product-market selection)
  - Suppliers, Mills, Converters, DC Network with Available Capacity and Selected Product-Markets with Price-Service Policy

**Mid-Term**
- Aggregate Planning
  - (On a seasonal basis: Product family assignment and sequencing for paper machines, external converter contracts, product mix for pulp mills, converting facilities and distribution centers, sourcing contracts...)
- Supply Contracts (fiber, chemicals...)
- Mills, Converters and DC Product Mix and Capacity, Paper Machine Production Sequences

**Short-Term**
- Material Procurement Planning
  - Procurement quantities
- Production Plan
- Daily production plan
- Daily Shipments
- Availability

**Execution**
- Logs-Chips Transportation Scheduling
- Production Scheduling
- Picking, Loading and Transportation Scheduling
- Demand Fulfilment (Stock) and ATP (Make)

**FORAC Platform**

Sophie D'Amours, Alain Martel and Alain Rousseau, May 2003
Designing the value creation network

Decisions relate to: facility location, capacity, technology selection, site mission and transportation means.
The value creation network
SCOPE, Alain Martel and Modellium
Type of problems

• One or many facilities
  – In-bound and out-bound transportation is an issue.

• One period or multi-period
  – Cyclic inventory is an issue.

• Deterministic or stochastic
  – In the stochastic model, exchange rates, demand and supply variations are important issues.
Mathematical model

Maximize after tax net revenues

• Subject to
  – Demand constraints
  – Facility layout, space and options constraints
  – Upper bound on the number of facilities
  – DC throughput definition constraints
  – Production centers flow equilibrium constraints
  – Production facilities capacity constraints
  – Raw materials flow equilibrium constraints
  – Distribution centers inventory accounting constraints
  – Lower bounds on the distribution centers flow
  – Facilities storage capacity constraints
  – Facilities shipping (receiving) capacity constraints
  – External supply constraints

Source: Martel 2000, Supply chain management courses notes
Inventory holding cost

Usually defined through regression analysis of past activities

Source: Martel 2000, Supply chain management courses notes
The model

Weigel, Watson, D’Amours and Martel
Collaborative work between Paprican and FOR@C
The model

\[ I_s \rightarrow Y_{s,i} \rightarrow S_{J_p}^{\text{int}} \rightarrow F_{p,c,s} \rightarrow C_p \]

\[ h_{p,s,i} F_{s,i} - F_{p,c,s} \]

\[ I_s \rightarrow Y_{s,i} \rightarrow S_p \rightarrow F_{p,c,s} \rightarrow C_p \]

\[ h_{p,s,i} F_{s,i} - F_{p,c,s} \]

\[ S_{J_p}^{\text{ext}} \rightarrow F_{p,s} \rightarrow \text{Chipping} \]

\[ g_{p,p',m} X_{p',m} \rightarrow \text{Chip handling} \]

\[ g_{p,r} X_r \rightarrow \text{Pulp production} \]

Weigel, Watson, D'Amours and Martel
Collaborative work between Paprican and FOR@C
The model

Weigel, Watson, D’Amours and Martel
Collaborative work between Paprican and FOR@C
Typical benefits:

12-20 % at the distribution level

Weigel, Watson, D’Amours and Martel
Collaborative work between Paprican and FOR@C
Research issues

- Multi-facility strategic design:
  - market/product selection,
  - close-open facility,
  - technology investment,
  - outsourcing strategies for supply and transformation,
  - distribution network design,
  - transportation modes (contract based approach),
  - transfer price setting,
  - operational exposure…
Although the value creation network is designed to “optimality”, will it be agile enough to face demand and competition?
Parent rolls design

In collaboration with Domtar, Corporate, Claude Bélanger, Satyaveer Chauhan, Alain Martel, Sophie D’Amours
Advanced Planning System for the Pulp and Paper Industry (APS-PPI)

**Procurement**
- Strategic Network Planning (Design)
  - Sourcing decisions, externalization decisions, technology-capacity decisions, transportation means decisions, mills-DCs deployment and mission, product-market selection
- Suppliers, Mills, Converters, DC Network with Available Capacity and Selected Product-Markets with Price-Service Policy

**Production**
- Aggregate Planning
  - On a seasonal basis: Product family assignment and sequencing for paper machines, external converter contracts, product mix for pulp mills, converting facilities and distribution centers, sourcing contracts...
- Mills, Converters and DC Product Mix and Capacity, Paper Machine Production Sequences
- Daily production plan
- Daily Shipments
- Availability
- Current Orders

**Distribution**
- Synchronized Production-Distribution planning
  - Paper machines daily production plan, mills daily carrier selection and shipping plan and plant-DCs inventory planning
- Daily Forecasts, Safety Stocks
- Daily Forecasts, Safety Stocks

**Sales**
- Demand Fulfilment (Stock) and ATP (Make)
- Daily Forecasts, Safety Stocks
- Life cycle management

**Execution**
- Logs-Chips Transportation Scheduling
- Production Scheduling
- Picking, Loading and Transportation Scheduling
- Availability
- Shipment

**FORAC Platform**

Sophie D'Amours, Alain Martel and Alain Rousseau, May 2003
Processes to plan the decoupling point and integration with the paper machine

Determine the type of parent roll and the quantity to remain in stock

Make to stock → Convert on demand → Promise a date

- JUMBO Parent roll
- Cut sheets
- Finished product

CI: internal, CE: external

Number of PR

Inventory holding cost
Trim cost

Q

Fill the parent roll order in the right production block

Chauhan, D'Amours et Martel, FOR@C
The decision variables

\( X_{pr} = 0 \text{ or } 1 \)
Parameters

Trim lost $c_{pr}$

Qty relation $f_{pr}$

Inventory holding cost $h$

Safety service level $k$

Average demand of product $p$ over a production cycle $(\mu, \sigma)$
Industrial potential

- Total number of parent rolls stocked when using old approach: 75
- Total number of parent rolls stocked when using the new technique: 53
- Inventory cost saving (%): 29.34%
- Trim cost saving (%): 1.72%
Block scheduling

In collaboration with Domtar, Windsor, Hanen Bouchriha, Annie Larochelle, Mustapha Ouhimmou, Sophie D’Amours
The decoupling point at the warehouse (sheets)

Make to stock

“Cyclic production”

Plan production of rolls on the paper machine

JUMBO

Q

t

Parent roll

Cut sheets

CI : internal, CE : external

Select the sheets to keep in stock in every location

Deliver on demand

Client

Client

Client

Client

Finished product
Block scheduling

- Establish production cycle (length of campaign)
  - A production cycle defines a period within a set of products are being systematically produced.

- Establish volume within each cycle
  - For each product the quantity to be produced within each cycle is defined taking into account demand and capacity constraints as well as set-up (costs and capacity lost).

- Establish procurement plan
  - Fibre
  - Chemicals
  - Energy
  - Etc.
Graph of the deliveries, regrouped by two week periods (without the deliveries to warehouses)

+ set-ups are sequence dependent
Optimal cycle period under variation of inventory holding cost.

Bouchriha, D’Amours, Ouhimmou, FOR@C
Defining block scheduling

2 weeks program

La définition des tailles des lots dans le cas d'un cycle de deux semaines

Impact of not using a campaign versus using a campaign approach

12-15 % cost reduction

Bouchriha, D'Amours, Ouhimmou, FOR@C
Synchronize production and distribution

Nafee Rizk, Alain Martel, Sophie D’Amours
Advanced Planning System for the Pulp and Paper Industry (APS-PPI)

Strategic Network Planning (Design)
(Sourcing decisions, externalization decisions, technology-capacity decisions, transportation means decisions, mills-DCs deployment and mission, product-market selection)

Aggregate Planning
(On a seasonal basis: Product family assignment and sequencing for paper machines, external converter contracts, product mix for pulp mills, converting facilities and distribution centers, sourcing contracts...)

Syncronized Production-Distribution planning
(Paper machines daily production plan, mills daily carrier selection and shipping plan and plant-DCs inventory planning)

Logistics and Transportation

Long-Term

Mid-Term

Short-Term

Execution

FORAC Platform

Sophie D'Amours, Alain Martel and Alain Rousseau, May 2003
Synchronized Lot-Sizing

Production

Transportation

Inventory

Dynamic Demand

Dynamic Demand
Production example

<table>
<thead>
<tr>
<th>SK1</th>
<th>SK2</th>
<th>SK3</th>
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</table>

Production changeover Planning horizon

BOM

Capacity

Production time

Production changeover

1ₘ 1ₘ 2ₘ 3ₘ 3ₘ

t = 1 t = 2 t = 3 t = 4 t = 5
Transportation Costs

Shipments by truck

Shipments by train
Contributions

• Different mathematical formulations techniques
  – Reduced solution time significantly (2 hours to 12 min)

• Gains of including Rail
  – Overall total cost reduction of 17%

• Decomposition approach
  – Excellent quality solutions (within 0.05% of the optimal solution)
Material requirement planning
Advanced Planning System for the Pulp and Paper Industry (APS-PPI)

**Procurement** → **Production** → **Distribution** → **Sales**

### Strategic Network Planning (Design)
- (Sourcing decisions, externalization decisions, technology-capacity decisions, transportation means decisions, mills-DCs deployment and mission, product-market selection)
- Suppliers, Mills, Converters, DC Network with Available Capacity and Selected Product-Markets with Price-Service Policy

### Aggregate Planning
- On a seasonal basis: Product family assignment and sequencing for paper machines, external converter contracts, product mix for pulp mills, converting facilities and distribution centers, sourcing contracts...

### Material Procurement Planning
- Procurement quantities

### Syncronized Production-Distribution planning
- (Paper machines daily production plan, mills daily carrier selection and shipping plan and plant-DCs inventory planning)

### Logs-Chips Transportation Scheduling
- Daily production plan
- Daily Shipments
- Availability
- Shipments

### Production Scheduling
- Picking, Loading and Transportation Scheduling
- Current Orders

### Demand Fulfilment
- (Stock) and ATP (Make)
- Long Term Forecasts for Potential Product-Markets
- Mid-Term Forecasts
- Daily Forecasts, Safety Stocks

### Demand Planning
- (forecasting, forecast error distributions, safety stocks, life cycle management)

**FORAC Platform**

Sophie D'Amours, Alain Martel and Alain Rousseau, May 2003
The decision

- Establish the minimum cost procurement plan:
  - chips + inventory + transportation.
- Defining for all suppliers:
  - the type of fibre, the quantity, the volume to be delivered per period as well as the contracts to be signed (annual guarantee) in order to meet demand.
- Taking into consideration:
  - capacity constraints, inventory holding constraints, production constraints, quality requirements and a desirable contract/spot ratio.
Challenges

• Two alternatives for the pulp and paper mill:

  ✓ Sign contracts
    ✓ Assure volume guarantee
    ✓ Stabilize price
    ✓ Best price and finance terms
    ✓ Risk of accumulating volume

  ✓ Spot market
    ✓ Buy extra volume
    ✓ No protection against unavailability (volume or quality) or price increase
    ✓ No stable source of procurement (increase transaction costs)
Model

- Flow conservation at the paper mill
- Demand (Chips consumption)
- Recipe (% of specie within each recipe)
- Sourcing capacity
- Transportation capacity (number of trip)
- Minimum and maximum inventory level
- Minimum contract percentage

Minimize procurement, transportation and inventory holding cost taking into account the supply quality

Which option: Contract and/or Spot
Signing volume for each contract
Optimal quantity to buy from each supplier
Inventory level
Impact of fibre quality on the procurement plan

variation du coût objectif en fonction de la qualité

coût pondéré (en $ CA)

scénario avec score de qualité
scénario de base

Contribution de chaque type de scierie au total des approvisionnements en fonction de la qualité

scénario avec score
scénario de base

cout pondéré

externe
spot
partenaire
echange
interne
externe contrat

variation du coût objectif en fonction de la qualité

coût pondéré (en $ CA)

scénario avec score de qualité
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Contribution de chaque type de scierie au total des approvisionnements en fonction de la qualité

scénario avec score
scénario de base

cout pondéré

externe
spot
partenaire
echange
interne
externe contrat
Impact of demand variation on the procurement plan

Augmentation du coût objectif en fonction de l'augmentation de la demande

Demande historique | Demande + 5% | Demande + 10% | Demande + 15%
---|---|---|---
0.9 | 1 | 1.1 | 1.2
1.05 | 1.15 | 1.25 | 1.35

Contribution de chaque type de scierie au total des approvisionnements en fonction de la variation de la demande

Demande

historique | 5% | 10% | 15%
---|---|---|---
0% | 20% | 40% | 60% | 80% | 100%

externe spot | partenaire | echange | interne | externe contrat
And what about transport?

Audy, Michaelson, Marier, Favreau, Rousseau and more, Collaboration FERIC-FOR@C
Advanced Planning System for the Pulp and Paper Industry (APS-PPI)

Procurement | Production | Distribution | Sales

Long-Term

Supply Contracts (fiber, chemicals...)

Mid-Term

Aggregate Planning

(Sourcing decisions, externalization decisions, technology-capacity decisions, transportation means decisions, mills-DCs deployment and mission, product-market selection)

Mills, Converters and DC Network with Available Capacity and Selected Product-Markets with Price-Service Policy

Long Term Forecasts for Potential Product-Markets

Mid-Term Forecasts

Material Procurement Planning

Production Plan

Syncrondized Production-Distribution planning

(Paper machines daily production plan, mills daily carrier selection and shipping plan and plant-DCs inventory planning)

Daily production plan

Daily Shipments

Daily Forecasts, Safety Stocks

Current Orders

Short-Term

Demand Planning

(mid-term forecasts, forecast error distributions, safety stocks, life cycle management)

Logs-Chips Transportation Scheduling

Production Scheduling

Picking, Loading and Transportation Scheduling

Demand Fulfilment (Stock) and ATP (Make)

FORAC Platform

Sophie D'Amours, Alain Martel and Alain Rousseau, May 2003
VTM a joint project: FERIC, FOR@C and Transforêt

- Provides transportation capacities
  - Transporter 1
  - Transporter 2
  - Transporter 3
  - ....
  - Transporter n

- Provides transportation needs
  - Sawmill 1
  - Plant 2
  - Pulp & paper mill 3
  - ....
  - Facility m

- Provides transportation itineraries

*Estimated cost reduction: 5-15% of transportation cost*
Plateforme VTM

Lots à transporter pour Transforêt

Sites origine
- Bishopton
- Disraeli
- HPL
- LennoxVille
- Montauban
- Saint-Étienne-de-Lauzon
- Saint-François-de-Madawaska
- Ste-Gertrude

Expédition au plus tôt
Date début: 3/2/2004 12:00:00 AM  
Date fin: 5/12/2004 12:00:00 AM

Expédition au plus tard
Date début: 3/2/2004 12:00:00 AM  
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Sites destination
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- Ste-Gertrude

Livraison au plus tôt
Date début: 3/2/2004 12:00:00 AM  
Date fin: 5/12/2004 12:00:00 AM

Livraison au plus tard
Date début: 3/2/2004 12:00:00 AM  
Date fin: 5/12/2004 12:00:00 AM
Collaboration with customer
The wood supply game
Satisfy demand
Minimize inventory
There is always an equilibrium where players demonstrate collaborative behavior. This equilibrium is almost always as good as the minimum cost solution.

Moyaux, Chaib-draa, D'Amours, 2004
Customer relationships

Customer driven
Order based
Continuous replenishment
Producer driven
Vendor Managed Inventory
Collaborative
Collaborative planning forecasting and replenishment

Business relationship

Logistics relationship
Order based relationship
(no customer, product, or volume visibility)
Continuous replenishment “transportation based”

- Fixed in time
- Product to be defined

Commitment
- Information exchange
- Volume guarantee
- Number of deliver per period
- Price + financial terms

Facility planning

Customer price + JIT sensitivity

Distribution center

Facility

Central office

Anticipated needs plan

Specification of product to be delivered in next deliveries

Nb trucks

QTY

T

Continuous replenishment “transportation based”

Facility planning

Customer price + JIT sensitivity

Distribution center

Facility

Central office

Anticipated needs plan

Specification of product to be delivered in next deliveries

Nb trucks

QTY

T
Continuous replenishment “capacity based”

- CENTRAL OFFICE
- ANTICIPATED NEEDS PLAN
- SPECIFICATION OF CONVERTING CAPACITY USAGE
- CUSTOMERS
- PRICE + JIT SENSITIVITY
- FACILITIES PLANNING
- CONVERTING ACTIVITIES
- ALLOCATED CAPACITY
- COMMITMENT
  - INFORMATION EXCHANGE
  - CAPACITY GUARANTEE
  - PRICE + FINANCIAL TERMS

Graphical representation of the process:
- FACILITY
- CAPACITY BASED VOLUME
- QTY
- T

Continuous replenishment “capacity based”
VMI Relationship

- COMMITMENT
  - INFORMATION EXCHANGE
  - VOLUME GUARANTEE
  - PRICE + FINANCIAL TERMS

- CUSTOMERS
  - PRICE + AVAILABILITY SENSITIVITY

- FILE
  - HISTORICAL CONSUMPTION RATE

- CENTRAL OFFICE
  - PLAN REPLENISHMENT

- WAREHOUSES
  - Nb TRUCKS
  - HISTORICAL CONSUMPTION RATE
  - PLAN REPLENISHMENT

- FACILITIES
  - INV
  - S
  - SS
  - TL

- FACILITIES PLANNING
  - QTY

- VMI Relationship
  - INFORMATION EXCHANGE
  - VOLUME GUARANTEE
  - PRICE + FINANCIAL TERMS
Collaborative planning, forecasting and replenishment

**Central Office**

**Facility Planning**

**Collaborative planning, forecasting and replenishment**

**Forecast**

**Commitment**
- Team Definition
- Pricing « Everyday Low Price »
- Information Exchange
- Scope of Collaboration
- Practices Planning Forecasting
- Replenishment

**Integartion**
- Promotion Impact
- Capacity Fluctuation
- Contengy Planning « What to Do if Things Don’t Go as They Are Planned »

**Facilities Planning**

**QTY**

**T**
Customizing the value proposition

Value proposition per segment

<table>
<thead>
<tr>
<th>Product</th>
<th>Process/network</th>
<th>Collaboration</th>
<th>Segment</th>
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<tbody>
<tr>
<td>Cut size</td>
<td>Make to stock</td>
<td>Order based</td>
<td>Platinum-price</td>
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<tr>
<td>Folio</td>
<td>Cut sheet to order</td>
<td>CR transport</td>
<td>Gold-price</td>
</tr>
<tr>
<td>Engineered product</td>
<td>Cut roll to order</td>
<td>CR capacity</td>
<td>Platinum-logistics</td>
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<tr>
<td></td>
<td>Make to order</td>
<td>VMI</td>
<td>Platinum-Innovation</td>
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Conclusion

“It is not the strongest species that survive, nor the most intelligent, but those who adapt the best to change”

Charles Darwin
Thank You.

www.forac.ulaval.ca
Related literature

Strategic network design

Tactical planning

Supply Chain decision matrix

MAS