Emerging Topics in Dow Supply Chain

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Dow Supply Chain Complexity - Network

Internal Plant-Product Digraph

- Indirect users of Top 10 shown
- Edges show primary paths only
- 60,000+ Plant-Product nodes
- 175,000+ Production or Transportation Edges

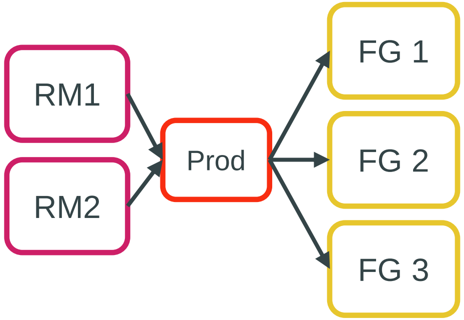
Dow Supply Chain Complexity – Production Types

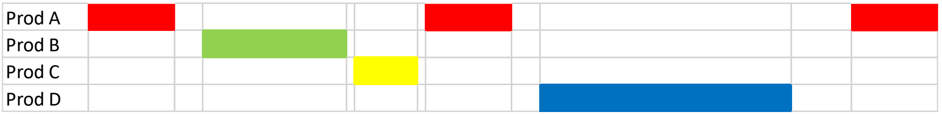
- **Continuous Reactors**
  - One product or set of co-products produced constantly
  - Concerned with rate, turnarounds, and co-product mix
- **Wheel Reactors**
  - Continuously made product until changeover
  - Concerned with product cycling and contamination between products
- **Batch Reactors**
  - Product made in fixed lot sizes with changeovers
  - Concerned with contamination, networked reactors, and logistics constraints

Dow Supply Chain Complexity – Multi-Product Planning

Shared Reactors

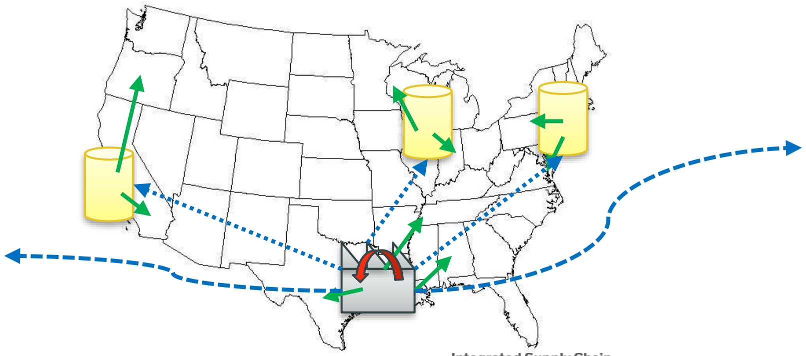
- Co-Products
- Wheel & Batch Production





Multi-Usage

- Direct Sales
- On-Site Consumption
- Off-Site Consumption
- Terminals/Warehousing



Potential Solutions

- Single Product Planning – Simpson (1958), Clark & Scarf (1960)
- Rationing Policies – Deshpande, Cohen, & Donohue (2003)
- Sequencing & Scheduling – Pierskalla & Deurmeyer (1978), Graves (1980)
- Stochastic Optimization – Almeder, Preusser, & Hartl (2009)

Single Product Planning Issues

- Simpson (1958) models are arborescent
  - Need demand nodes for safety stock setup
  - Difficult to scale
  - Lack of centralized decision making
- Clark & Scarf (1960) models are serial
  - Transshipment and other extensions are insufficient with Dow's network complexity
  - Echelon stock calculation difficult in MRP
  - Downstream inventory needs balancing to use echelon stock
- Multi-Product network reality
  - Product transition driven by service level differences
  - Product dependencies and priorities increase single product variance

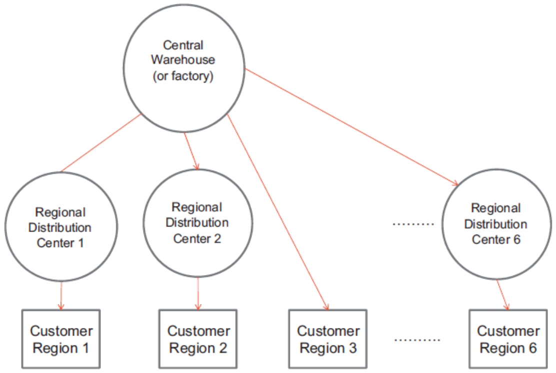
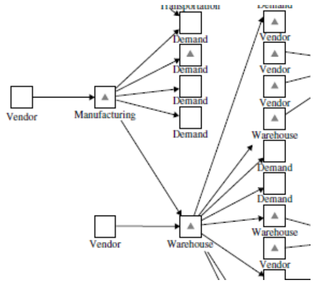


Fig. 2. A supply chain with a dual-role central warehouse.

Cattani, Jacobs, & Schoenfelder (2011)

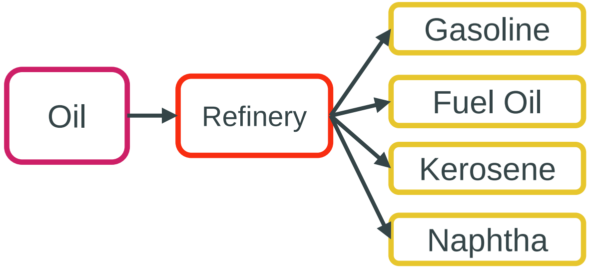


Bossert & Willems (2007)

Rationing Policies Issues

- Rationing policies are difficult to codify
  - Eventual profitability unknown
  - Customer prioritization is political
  - What caused need to ration
- System limitations
  - MRP handles allocation, not thresholds
  - Maintenance of thresholds would need automation
- Multi-echelon considerations
  - Need to incorporate echelon stock of consumers for the threshold

Co-Product Scheduling Issues



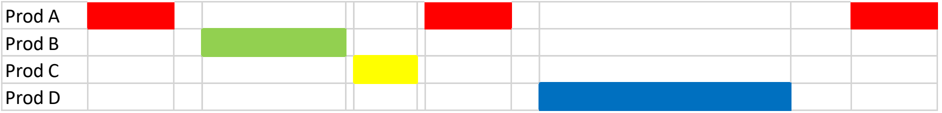
Co-Product rate setting problem

- For a set of raws, a mix of output products is made
- There might be control over production mix
- With stationary demand, loss or waste is necessary
- Set rate to profit maximize, but need *outlets* for excess product
- Order-up-to and sell-down-to policies are optimal with salvage – Liu, Zhang, Cheng, & Ru (2020)

Literature Gaps

- Vertical co-production is prevalent for semiconductors – Chen, Tomlin, & Wang (2013)
- Horizontal co-production needs more work on actual outlets
  - Pricing, multi-echelon impact, cost allocation for activity-based costing, planning & sales behavior

Product Cycling Issues



- Graves (1980) could not a prove a form of the optimal policy
- Solutions are heavily MILP – Karimi, Ghomi, & Wilson (2003)

Places to explore

- Model development complexity – general models vs specific uses
- Network design: multiple plants with similar capabilities and geography-based demand
- Non-stationary demand
- Demand constrained vs. resource constrained models

Stochastic Optimization Issues

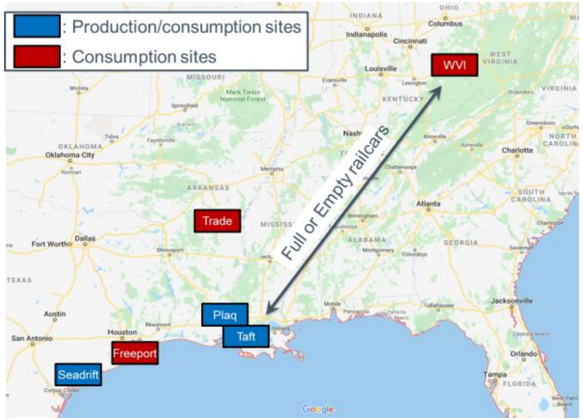
- Product envelope design
- Development cost vs. benefit
- Enterprise standards for stochastic processes
  - Demand quantity & time
  - Capacity quantity & time
  - Network connections
  - Disruption propagation

What’s needed

- Reactive & proactive systems
- Use general distributions for forecasts
  - How much?
  - When?
  - Capacity and Demand
- How to generate distributional forecasts to describe uncertainty
- Pricing
- Right-sized information sharing

Example Solution – EO Railcar Scheduling

- Ethylene Oxide (EO) has 3 Continuous Reactors at 3 geographically distinct locations
- Must be stored in railcars with hard limits on total full cars (safety)
- Developed MILP to minimize cost
  - Determine full and empty railcar routing
  - Determine production rates
  - Predict site inventory
- Used in Reactive & Proactive Modes
  - Run on-demand ~ 2 minutes
  - Linked to MRP and Rail data
  - Can update capacity and usage on the fly



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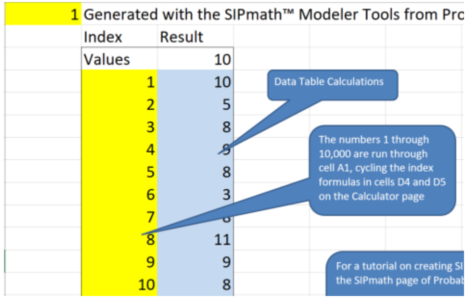
Example Solution – Monte Carlo of Global Demand

- High margin product with known global demand
- Customer volume known, timing uncertain, getting sale uncertain
- For Rough Cut Capacity Plan, need demand scenarios
- Use salesperson knowledge to describe uncertainty
- Simulate uncertainty with Monte Carlo
- Use demand profiles to create production plans

Under Development – Forecast Standards

- Probability Management (probabilitymanagement.org)
- Values can be scenarios
- Input agnostic
  - ML, AI, DRL
  - ARIMA, GLM
  - Knowledgeable sales rep
- Supports time-varying cumulative distribution
- Can be updated quickly to changing business conditions



Under Development – Graph Analysis

- End-to-end information for a product
  - Margins
  - Inventory time
  - Product prioritization
- Faster notification of cost changes
- Bottleneck identification
- Tradeoff analysis
- Automation vs Intelligent Agent

Follow up

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