Production-Distribution Coordination for Optimal Operational Planning of an Industrial Gases supply-chain

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Enterprise-Wide Optimization (EWO) Meeting, Oct. 2011
- Multiple Plants
- Multiple Products (LIN Liquid Nitrogen, LOX Liquid Oxygen etc.)
- Over-the-fence, call-in and distributed customers (some shared customers)
- Storage facilities at production sites and customer locations
- Delivery Modes and Routes
Sequential vs. Simultaneous Approach: Key Differences

**Sequential Strategy**
- **Production Model**
  (based on given truck withdrawal or demand forecast)
- **Distribution Model**
  (based on product availability)
- Optimum Production Schedule
- Optimum Distribution Schedule
- Total Cost

**Simultaneous Strategy**
- **Integrated Model**
  (truck withdrawal amounts and time are variables)
- Optimum Production and Distribution Schedule
- Total Cost

**Goal**

*To quantify and access the savings associated with the Production-Distribution Coordination at Operational Level using an approximate model*
Production-Distribution Coordination: Multi-plant Level

Multi-plant Sequential (Multiple Sourcing)
Currently used

 Coordination among plants for production and for Distribution Individually

Multi-plant Simultaneous (Multiple Sourcing)

 Coordination among plants as well as Production-Distribution (Fully Integrated)
Production-Distribution Coordination Levels

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<thead>
<tr>
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<th>Sequential</th>
<th>Simultaneous</th>
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<td></td>
<td><strong>Based on Truck Withdrawal Forecast</strong></td>
<td><strong>Based on Demand Forecast</strong></td>
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<td><strong>Single Plant</strong></td>
<td><strong>No Coordination b/w plants and production-distribution</strong> (production depends on truck forecast)</td>
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<td>(Single Sourcing)</td>
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<td><strong>Coordination b/w production-distribution but No coordination b/w plants (partially integrated)</strong></td>
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<td><strong>Multi-plant</strong></td>
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<td>(Multiple Sourcing)</td>
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<td><strong>Truck withdrawal is a given parameter</strong></td>
<td><strong>Freeze the product demand instead truck withdrawals</strong></td>
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<td><strong>Truck withdrawal is a variable in the optimization model</strong></td>
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Toys Problem Statement

**Given**
- 3 Plants, 2 main products (LIN, LOX)
- 3 modes for each plant and respective capacities (hi LOX, hi LIN, shut-down)
- 17 Customers (truck delivery), 42 Pick-up customers, 2 alternate sources
- 14 time periods (peak and off-peak), 20 trucks (10 for LIN, 10 for LOX)
- Demand, min/max inventory, distance, Electricity price etc. data

**Decisions in each time period t**
- Production rates at each plant
- Inventory levels at customer locations and plants
- How much product to be delivered to each customer through which route

**Objective Function**
- Minimize total production and distribution cost over planning horizon (1 week)
Results: Multi-plant Simultaneous vs. Sequential Models

Comparison: Shared Customers Deliveries

- **P**: Plant
- **C**: Customer
- **A**: Alternate

- LIN Customer
- LOX Customer
- Shared Customers
Results: Toy problem (Production-Distribution Coordination Levels)
Conclusions

- Simultaneous and Sequential MILP Models are proposed for optimal operational planning of industrial gases.
  - Multiproduct
  - Multi-plant
  - Variety of customers
  - Routing decisions

- Numerical results on test case show significant potential savings (~10%) and different production/distribution schedules with the coordination due to switching sourcing/routing strategies, electricity price differences, better inventory management...

- Simultaneous Model will further be extended to include other details on production and distribution sides to be more realistic. This will allow to further confirm the promising results obtained till now.