Long-term Turnaround Planning for Integrated Chemical Sites

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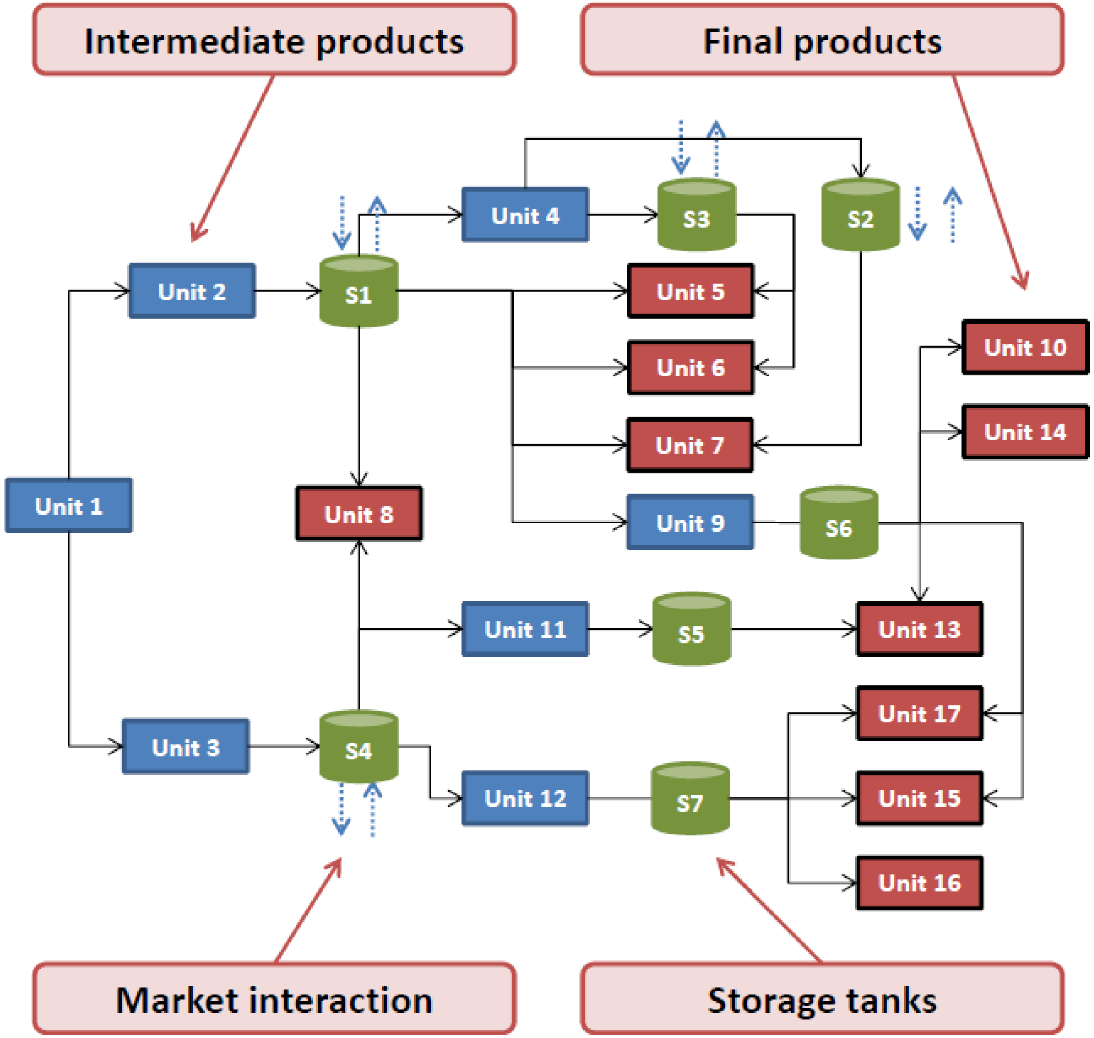
Motivation

- **Large companies spend on the order of hundreds of millions of dollars on turnarounds annually**
- **Coordinating maintenance in integrated sites is a potential for significant savings while providing a long-term turnaround plan**
- **Practical limitations on manpower**
  - **Maintenance personnel typically contract workers**
  - **Infrequent spikes in manpower utilization**
- **Most scheduling is done using scenario-based analyses**

Problem Statement



- **Exploit network interactions, storage availability, and prices to schedule maintenance over a multi-year horizon**
- **Scope:**
  - **Max. profit**
  - **Continuous processes**
  - **Time horizon: 5-15 years**
  - **Site-wide (each unit is an entire plant)**

Mixed Integer Linear Programming Model

- **Objective: Max. profit**

  Revenue – maintenance costs – cost of raw materials

- **Constraints**
  - **Network flow constraints**
    - **Inventory and mass balance**
    - **Nonnegativity constraints**
    - **Upper and lower bounds on inventory levels**
    - **Ratio constraints**

MILP model (continued)

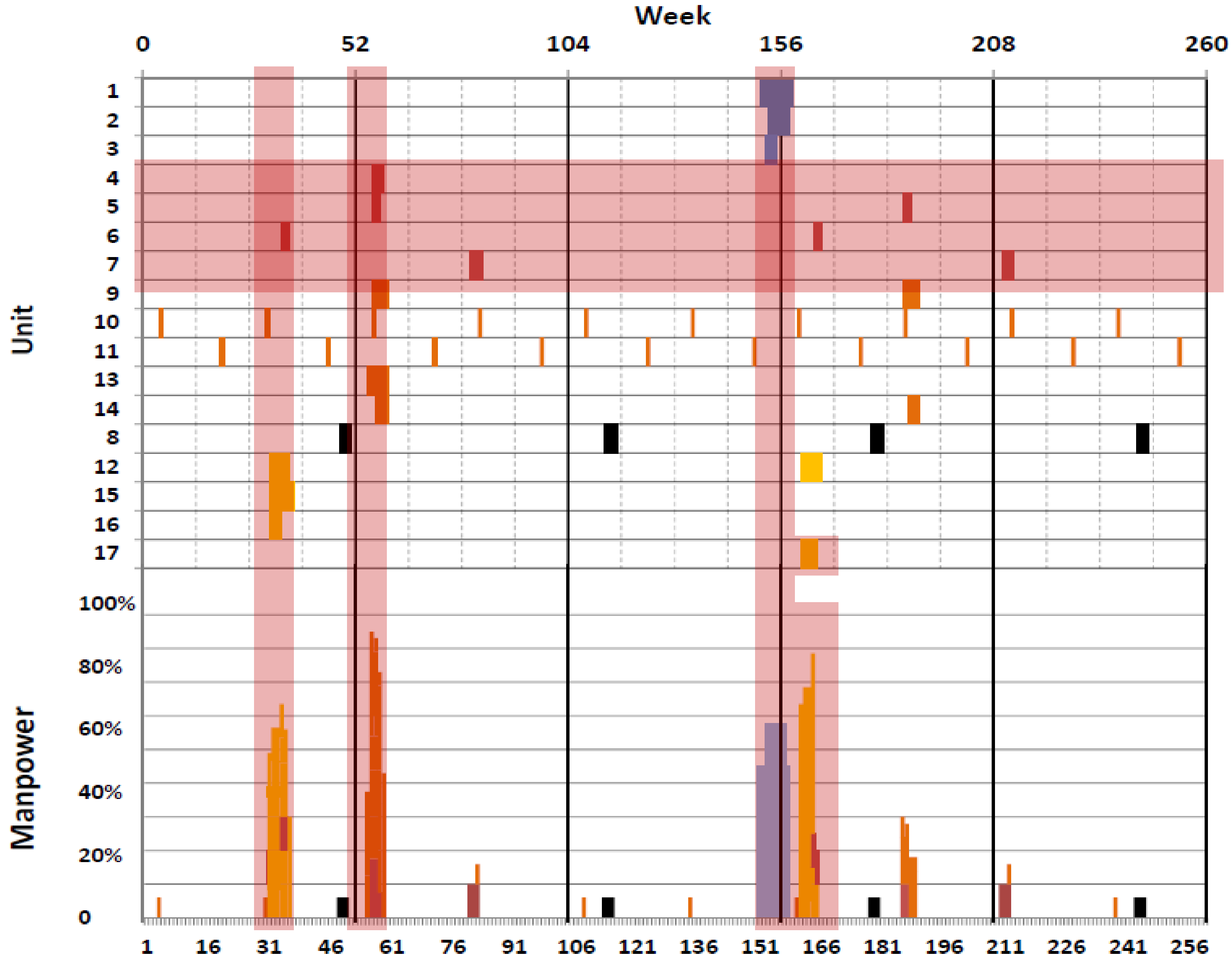
- **Constraints**
  - **Big-M constraints on flow between units**
    - Ensure that flow is zero when unit is down; natural upper bound derived from pipe capacities
  - **Financial constraints**
    - Profit in each period is some fraction of average quarterly profit
  - **Manpower constraints**
    - Cumulative manpower needed in each time period is bounded (safety reasons, availability, negotiation)
  - **Turnaround constraints**
    - Required frequencies and durations of turnarounds respected

Details of formulation

- **Model statistics:**
  - 17-plant integrated site
  - Horizon: 15 years
  - Discretization level: 1 week (~800 time periods)
  - Size of model: 16,000 binaries; 600,000 total
  - Solver used: CPLEX

- **Advantages of rolling horizon formulation**
  - Transitioning into new schedules
  - More flexibility in scheduling turnarounds
  - Incorporation of seasonal constraints

Sample schedule



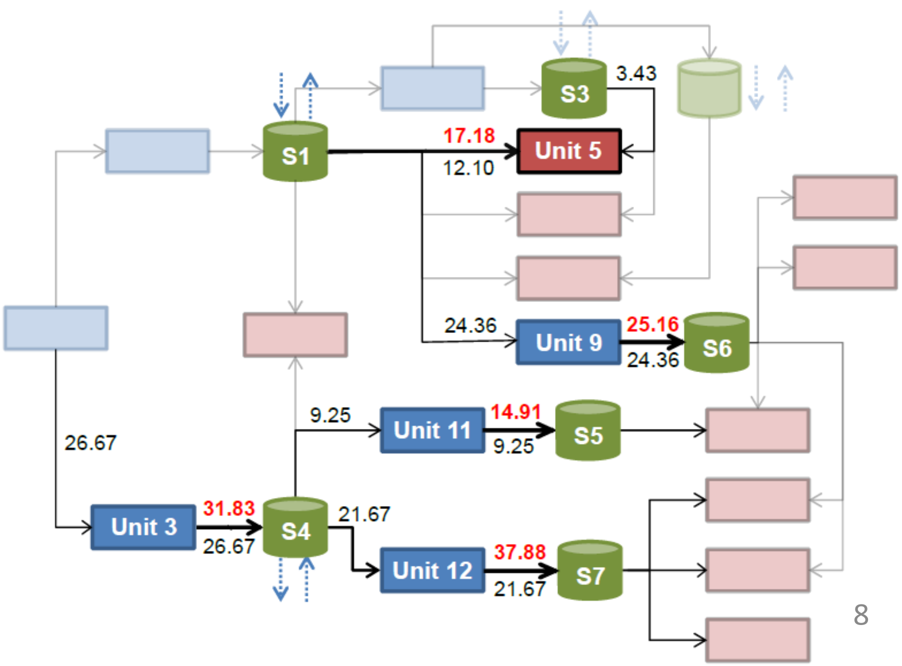
Modeling improvements

- **Transition from cyclic schedule → rolling horizon**

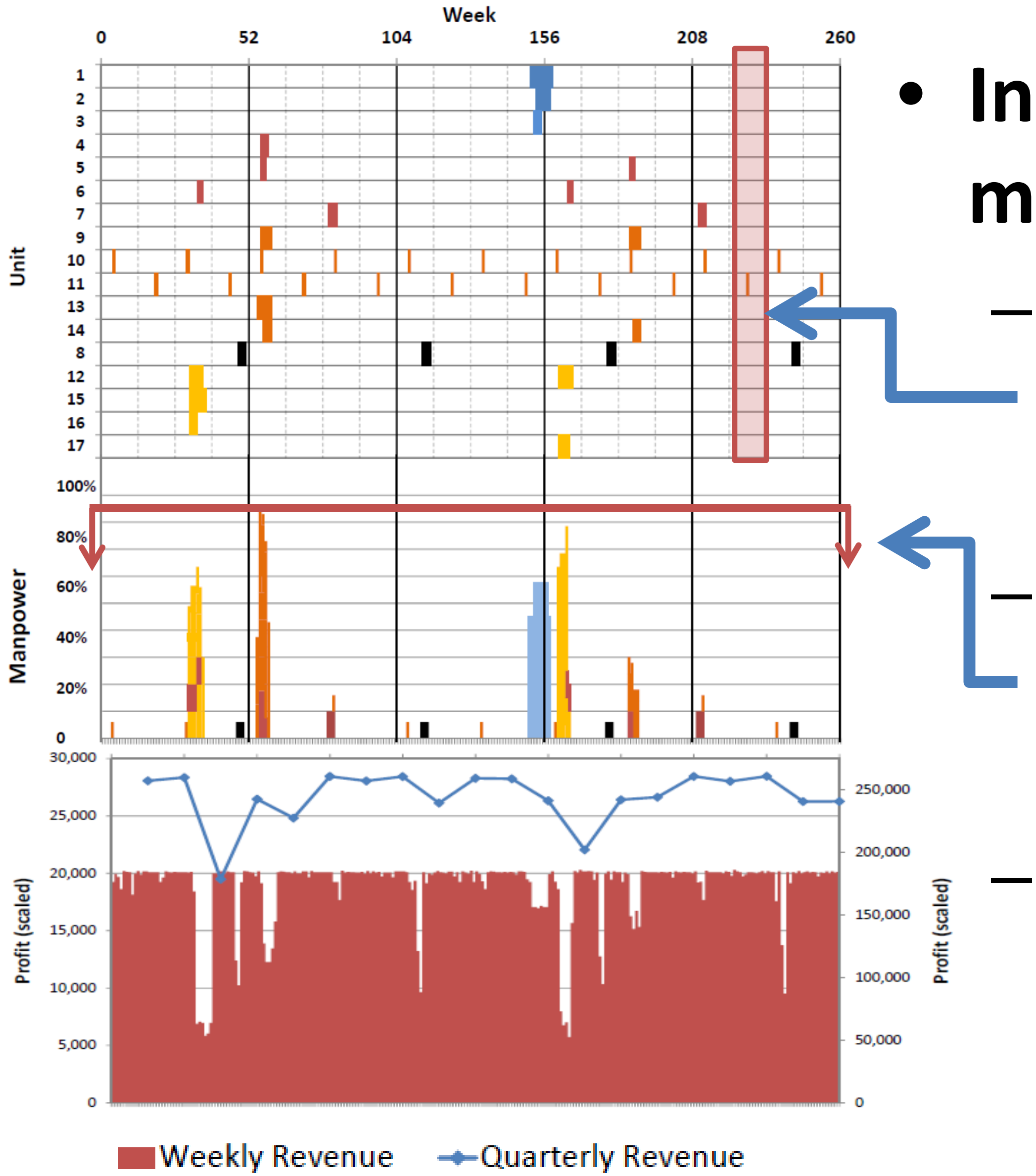
Schedule	Avg. profit units	Relative gap	Time to solve (s)
Cyclic	2,564,801	0.7%	36
Rolling horizon	2,599,788	0.4%	1219 (4 iterations)
Percentage improvement	**= 1.36%**		

- **Updating big-M constraints**

Original network	354	
Modifications	Solve time(s)	% improvement
$x^U_{3,S_4 0}$, x^U_{12,S_7}	315	11.0
$x^U_{S_1,5}$, x^U_{9,S_6}	235	33.6
$x_{11,S5}$	194	45.2



Novelty



- Incorporation of three major concerns:
  - Avoidance of maintenance tasks in unfavorable conditions
  - Bringing down peak manpower requirements
  - Balancing quarterly financial performance

Potential Impact

- **Successfully demonstrated**
  - Turnaround optimization for an industrial-size network
  - Efficient solution while retaining key model features
  - Incorporation of practical considerations
- **Next steps: Use of discrete-event simulation to**
  - Perform sensitivity analysis to identify most uncertain parameters
  - Debottlenecking network
  - Comparing various recommended schedules