# Turnaround Optimization of Continuous Chemical Plants

Satya Amaran, Nick Sahinidis (CMU)
Bikram Sharda, Scott Bury, Matt Morrison, Scott Miller (Dow)

## Turnaround optimization

- Maintenance is defined as

  *"the combination of all technical and associated administrative actions intended to retain an item in, or restore it to a state in which it can perform its required function"* [1]
- Turnaround optimization—Finding the optimal sequence of tasks in a turnaround envelope
- Involves consideration of:
  - Site-wide network structure
  - Flows and inventory levels
  - Turnaround resources

[1] Dedopoulos and Shah (1995)

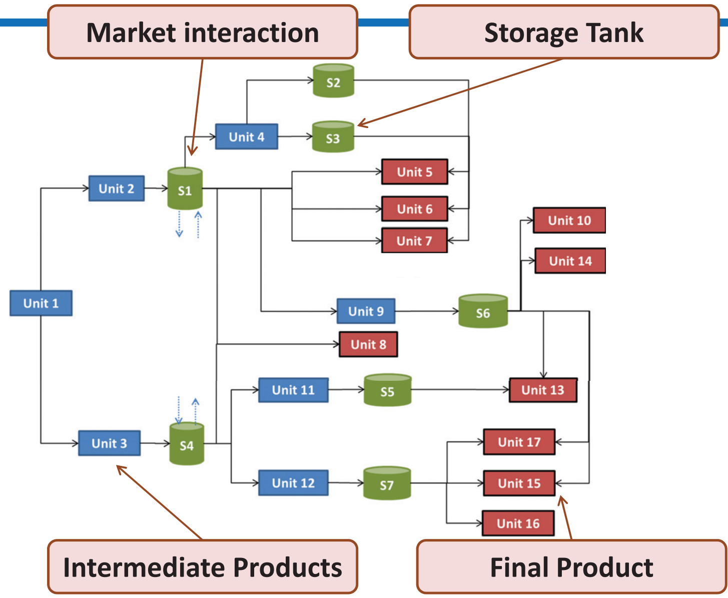
## Motivation

- Large companies spend millions on turnarounds annually
- Potential for significant savings
- Practical limitations on manpower
  - Maintenance personnel typically contract workers
  - Infrequent spikes in manpower utilization
- Most scheduling is done using scenario-based analyses

## Scope of study

- Problem features
  - Continuous processes
  - Multi-year horizon
  - Planned maintenance
  - Intermediate inventory buffers
  - Site-wide scope
- Objective: Maximize NPV subject to
  - Network flow constraints
  - Inventory constraints
  - Manpower limits
  - Turnaround durations and frequencies

## Example network



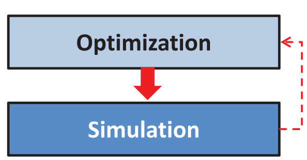

## Challenges

- Combinatorics
  - Scheduling requires discrete decisions
  - Large number of units, and large time horizon ➔ large number of binaries
- Uncertainty
  - Component failure rates, Lengths of turnarounds
  - Unit reliability, supply and demand variability within plant network
  - > 100 uncertain parameters ➔ potentially too large for stochastic programming
- How do we
  - Choose right level of network abstraction?
  - Choose right time discretization?
  - Capture uncertainties?

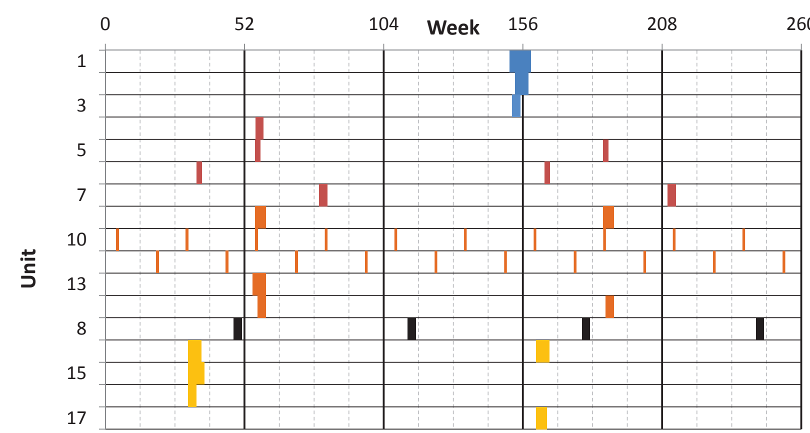
## Approach

- MILP
  - Useful for finding solutions to large-scale combinatorial problems with constraints
- Discrete-event simulation
  - Useful for capturing rule-based logic, priorities, variability in operations

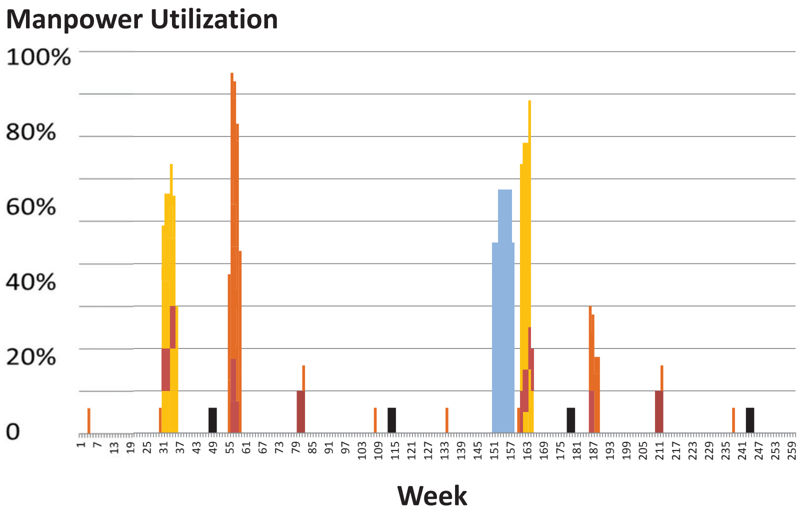
Use best features of both approaches




## Results – Gantt chart



# Results – Manpower utilization




# Analysis of results

- Envelope turnarounds occur together
  - Intuitive, as they are adjacent in site network
- Red envelope decoupled
  - Possibly due to potential of market interaction for raw materials
- Staggering of turnarounds (Unit 17)
  - Due to manpower limitations
  - Manpower intensive unit coupled 2nd turnaround
- Separation of turnarounds across years
  - Spread helps short-term financial results
  - Balances use of manpower

# Summary and future work

- Demonstrated a hybrid optimization and simulation strategy to trade-off tractability and real-world practicality
- Provided general-purpose tool for analyzing sites for long-term turnaround planning
- Future work
  - Short-term scheduling to capture hourly/daily effects such as ramping, manpower allocation, etc.
  - Rolling horizon scheme as opposed to cyclic schedule