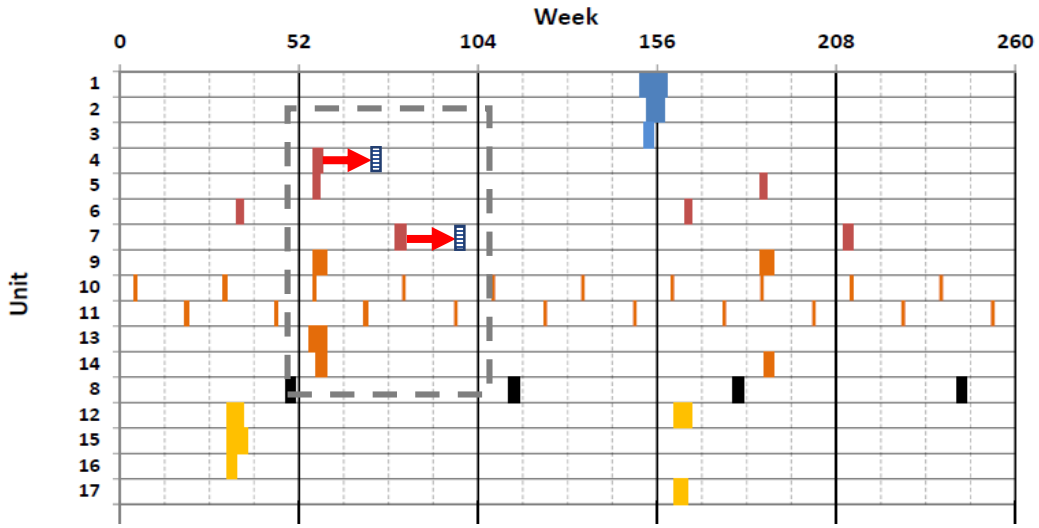
# Optimization models for reliability-based turnaround planning in integrated sites

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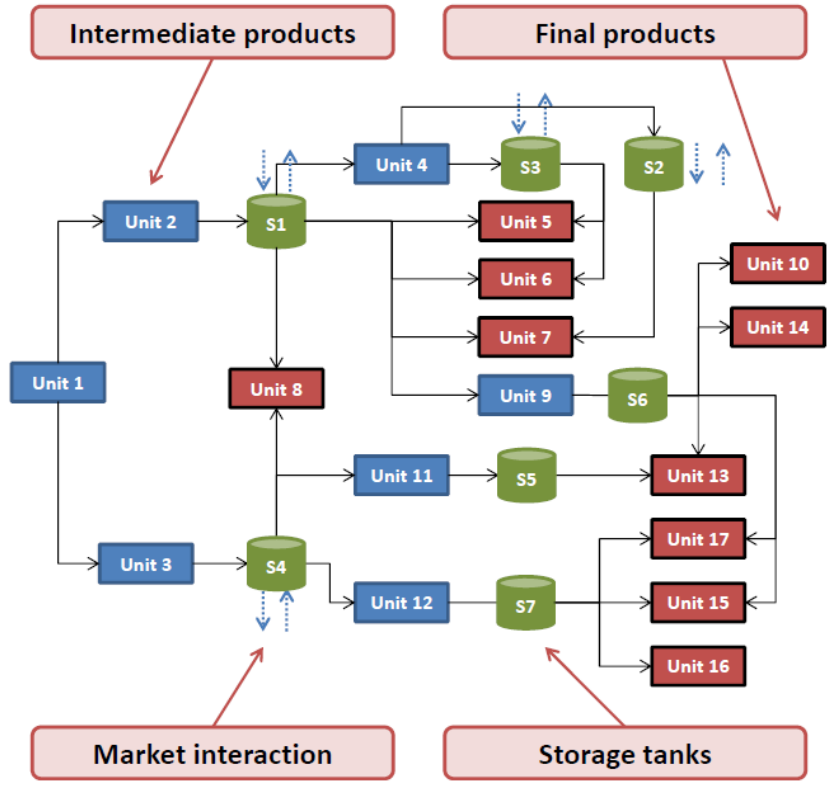
# Site-wide turnaround planning models

- Turnarounds: complex maintenance projects
- Site-wide model: an abstraction of large network of processing plants
- Idea: exploit network interactions to coordinate turnarounds

- Site-wide models: long-term model and medium-term models (Amaran et al., 2015-16)

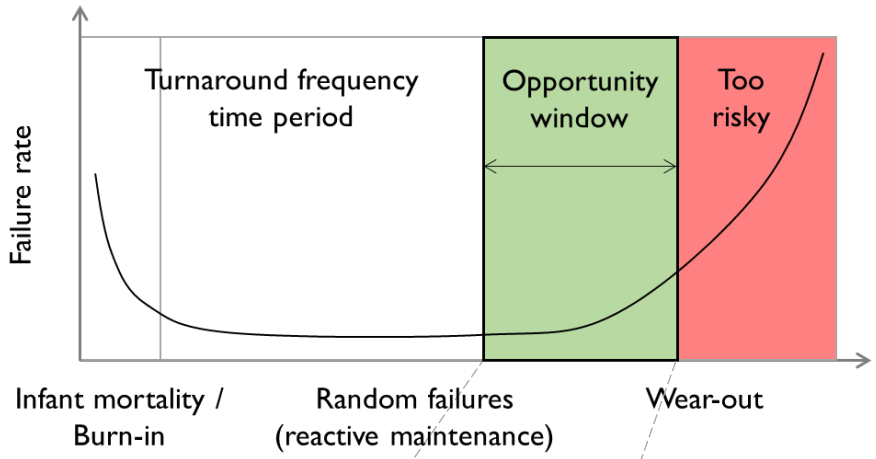


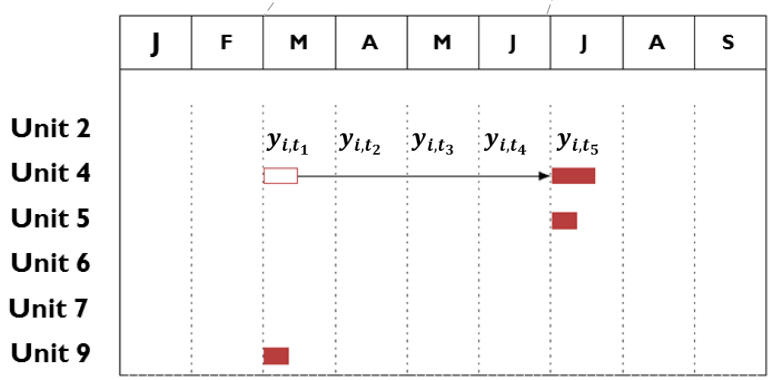

Amaran et al., 2015

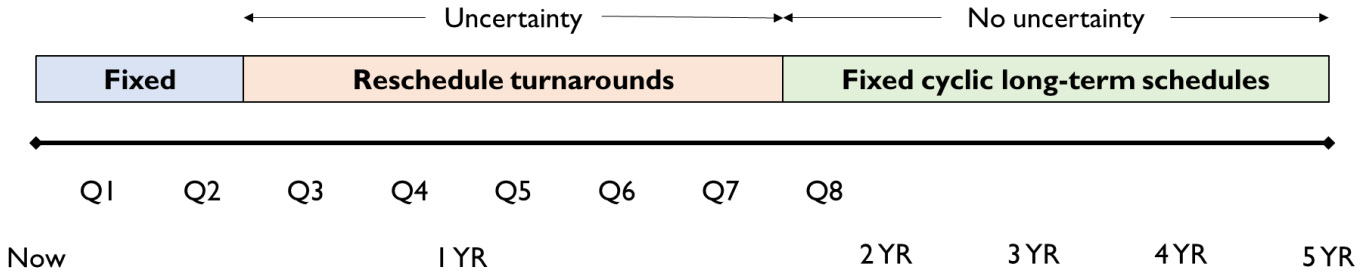
Process map

# Reliability based turnaround planning

- Economic objective
- Reliability drivers – unplanned outages, yield degradation, selectivity changes
- Short-term benefits and long-term interval extensions



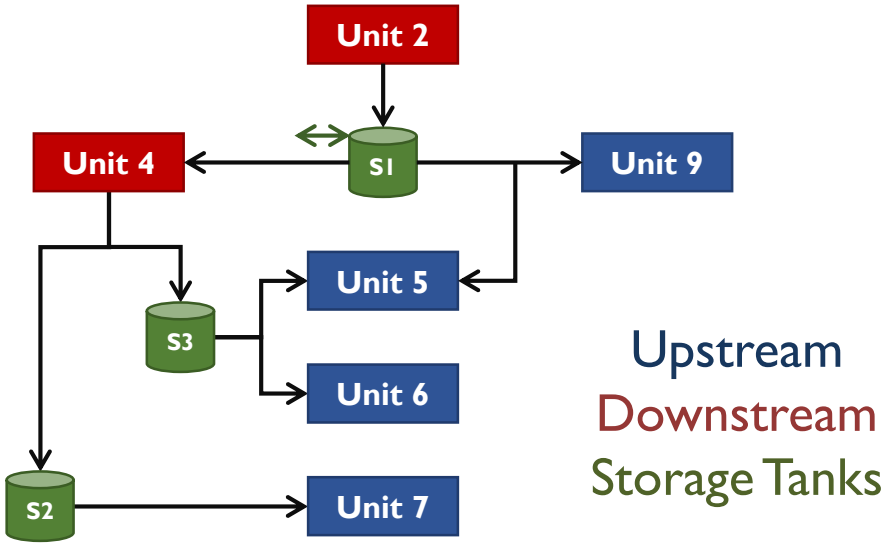



# Turnaround rescheduling

## Problem statement

- Benefit of moving Unit 4 turnaround from March to July?
- Risk of loss in rescheduling?




## Drivers

- Respond to changes in demands
- Unfavorable market conditions
- Additional resource constraints
- Continue operations to push turnaround intervals

# Production planning: mathematical optimization model

Assumptions:

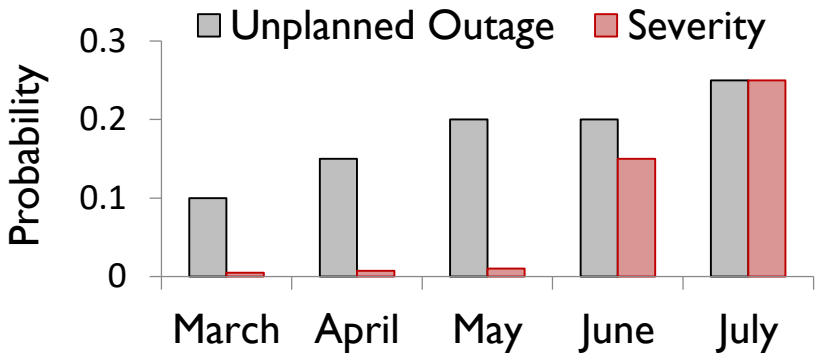
- Continuous plants
- Storages are modeled as tanks with known capacity and location
- Linear flow relationships
- Discrete-time model
- Good market forecasts

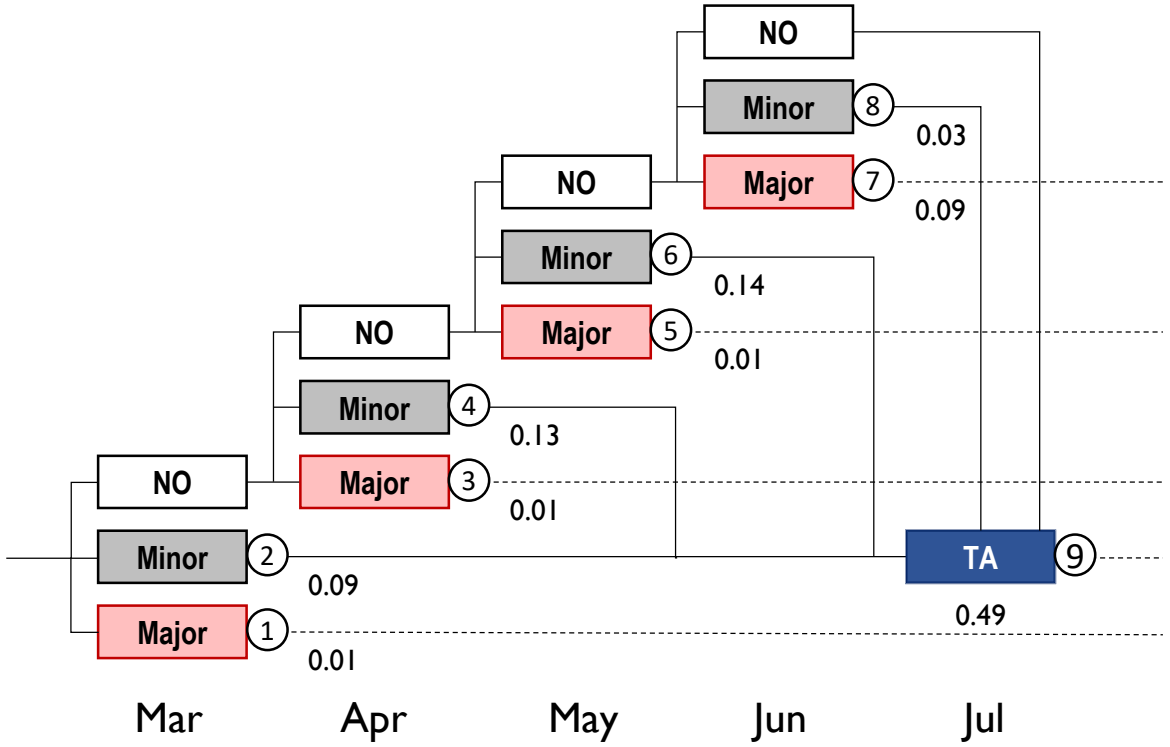
| | |
|---|---|
| *Maximize* | NPV of profit for the site |
| *subject to* | Material balances including ratios of flows |
| | Storage balances |
| | Turnaround constraints |
| | Demand constraints |
| | Limits – capacities, storages, import |

# Incorporating unplanned events

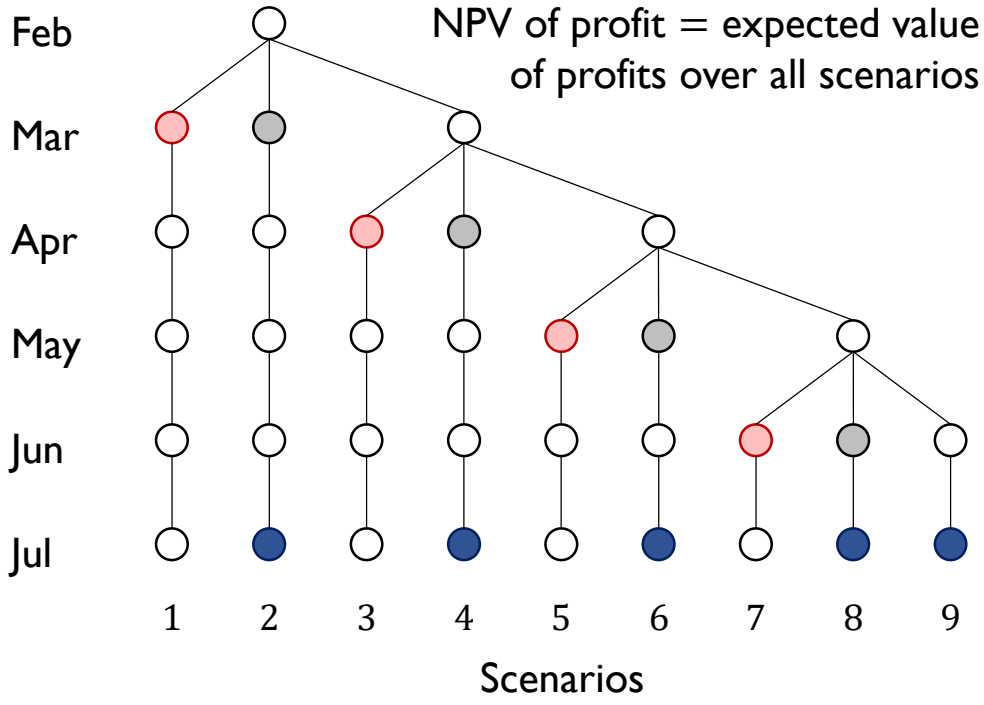
Assumptions:

- Consider only unplanned events in two modes
- Probabilities and severities are known
- Deterministic degradation in yield if known



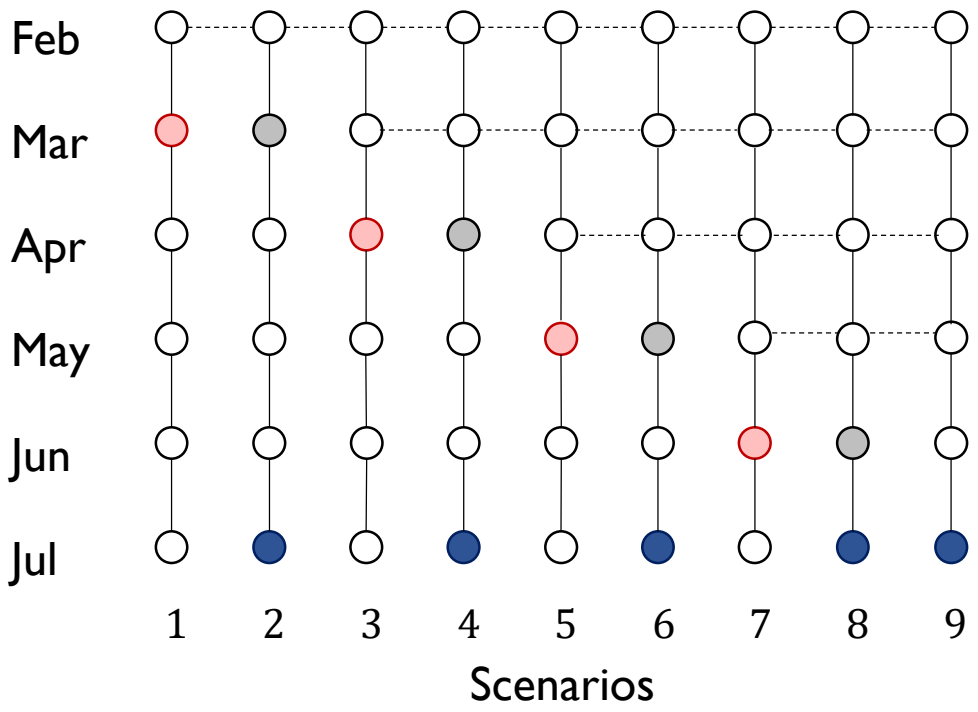




Stochastic programming: scenario tree



# Production planning strategies under uncertainty

- Simulation
- Reactive approach
- **Proactive approach**

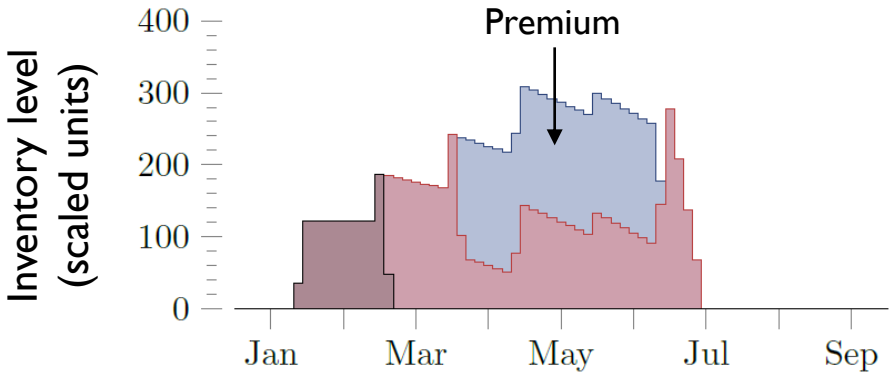


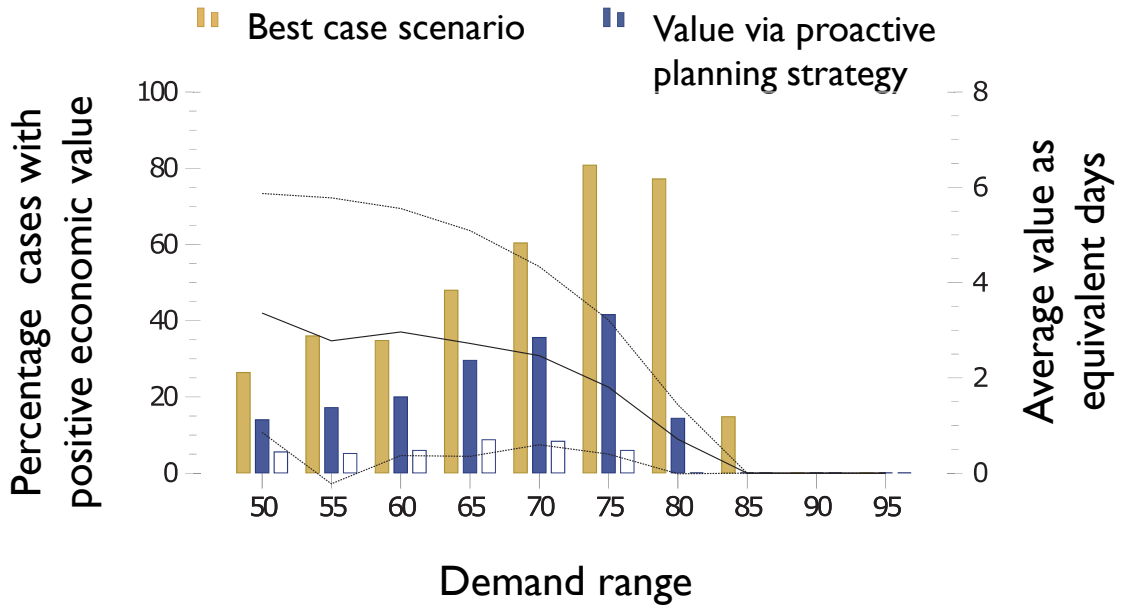

**Optimal (risk-neutral sense)**

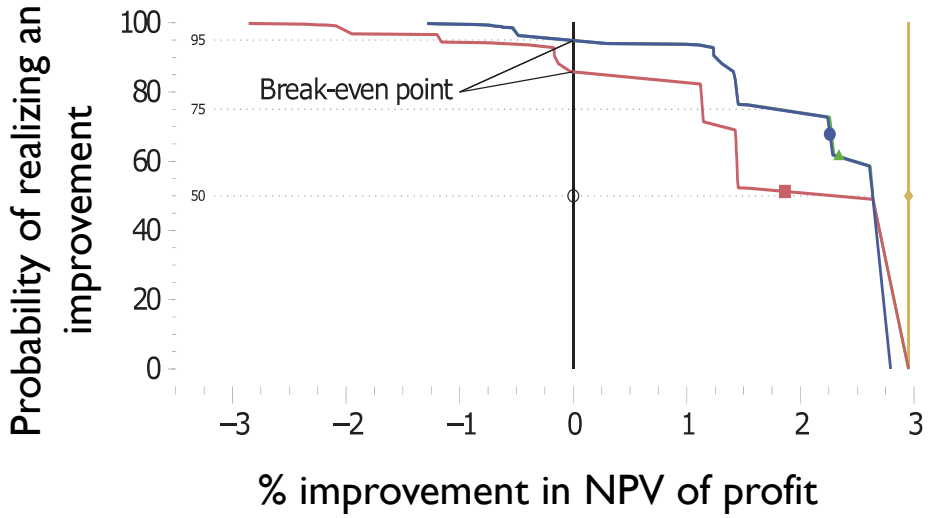
NPV of profit = expected value of profits over all scenarios

# Novelty of the approach

1. Contingency plans: production and inventory
2. Profitability or risk of loss profiles
3. Computationally tractable for different sensitivity studies



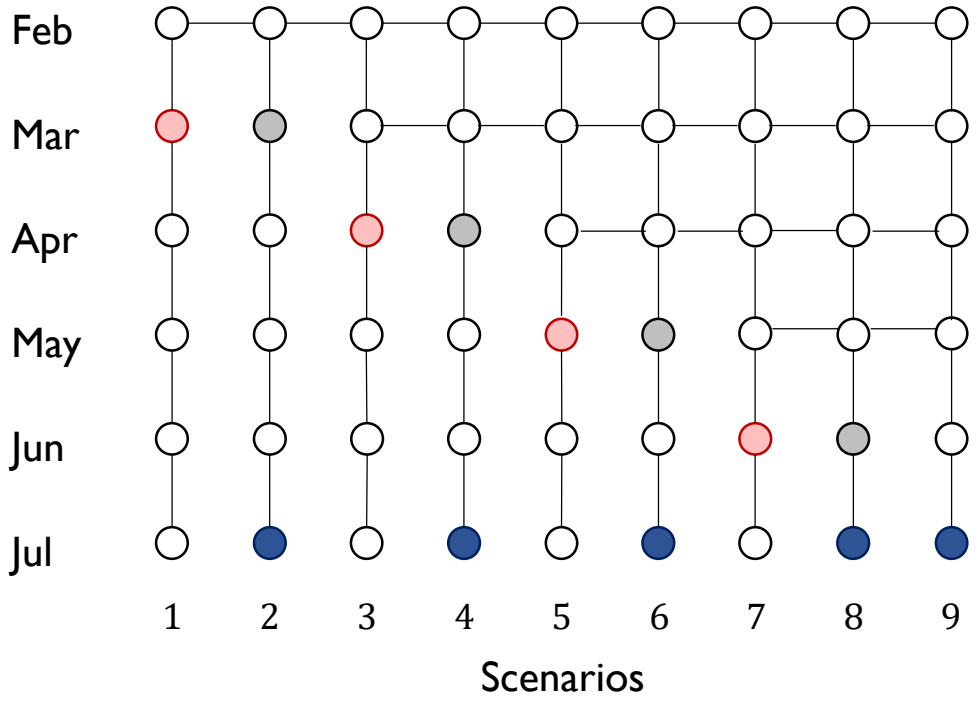



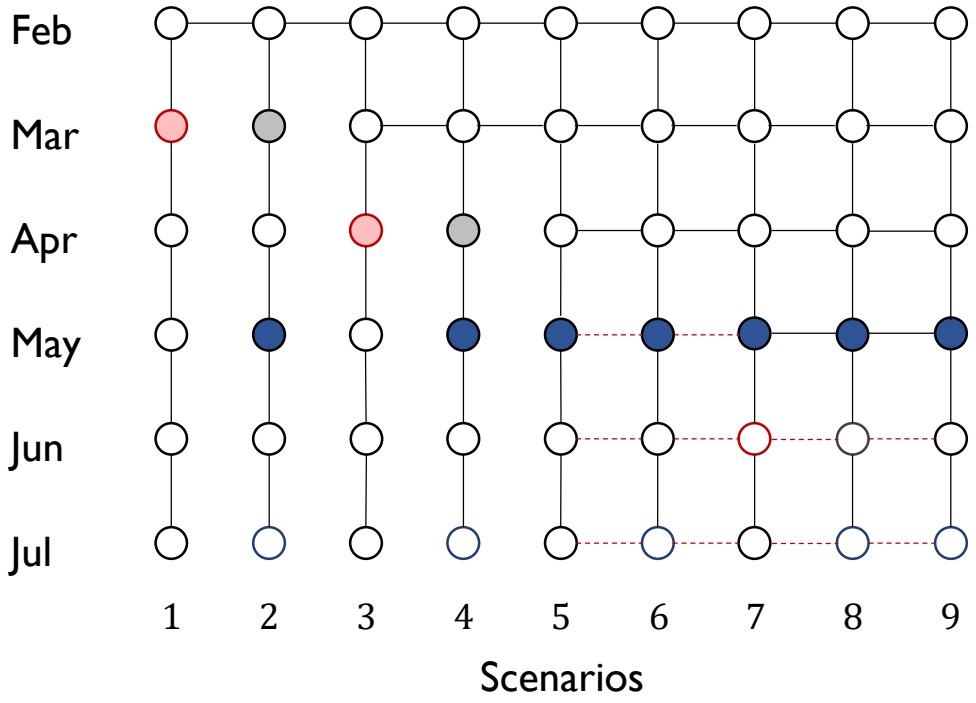

Reactive v. Proactive v. Simulation

# Optimal turnaround rescheduling times

- First stage variables include new turnaround schedule decisions (binaries)
- Nonanticipativity constraints are enforced for maximum interval increase
- Logic constraints to enforce equivalent of scenarios and downtimes




Turnaround moved to July ($y_{i,t_5} = 1$)




Turnaround moved to May ($y_{i,t_3} = 1$)

# Conclusions

- Extended approach to quantify the risk of loss associated with unplanned events to optimally plan turnarounds
- Model considers integration effects, unplanned events, productivity degradation
- Model provides turnaround schedules, production and inventory plans along with risk profiles
- Case study: rescheduling offers production recovery as high as 11-12 days
- Industrial case study: improvements to site model such as production ramping constraints