Smart Energy Systems
Winter 2020-2021

Optimization Project Group Milestone 2

supervised by Ogün Yurdakul

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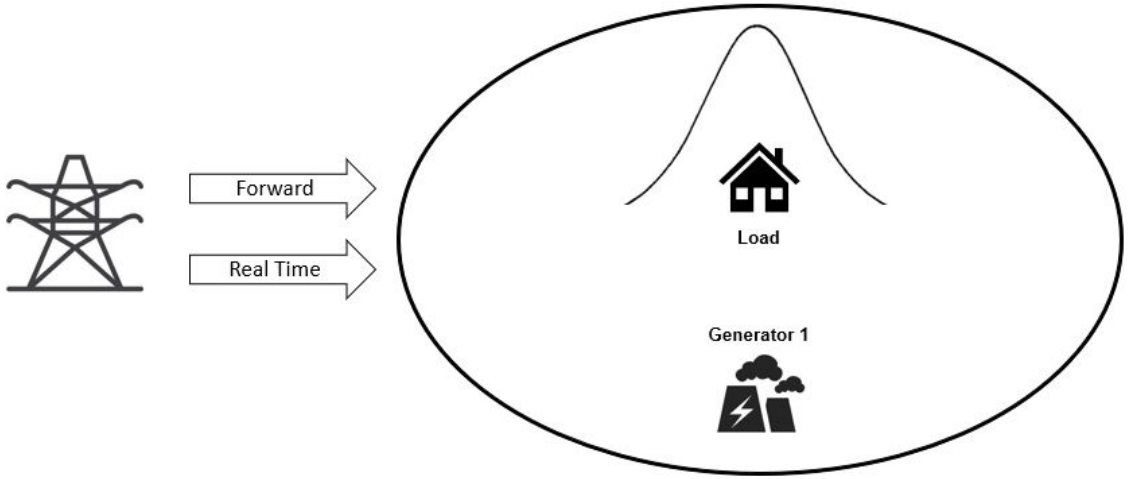
Structure

1. The problem
2. The L-shaped Method
3. Implementation
4. Results & Interpretation
5. Scrum board

The problem: stochastic unit commitment

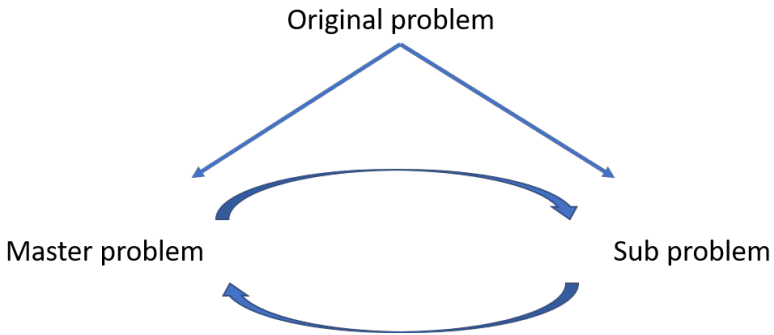
- Optimization of dispatch schedule of all power generation units to match the electricity demand and to minimize total cost

- Assumptions:
  - load values are independent random variables
  - no minimum uptime, downtime and ramping constraints



The L-shaped Method

- decomposition into master and sub problem
- solve subproblem: complicating variables are treated as parameters to get a candidate solution
- insert optimality cut into the master problem
- optimality cut is a proxy for the 1st stage decision on 2nd stage costs
- master problem: lower bound (less constraints)
- sub problem: upper bound
- optimal solution when upper and lower bound are sufficiently close
- L-shaped method:
  - uncertainty
  - multiple subproblems



First stage problem

Objective function: minimization of costs with expected value of uncertain second-stage costs

$$\underset{u^{\mathsf{i}}_{\gamma_g}[h], p^{\mathsf{i}}_{\dagger}[h]}{\text{minimize}} \left\{ \sum_{h \in \mathscr{H}} \left[c_{\gamma_g} u^{\mathsf{i}}_{\gamma_g}[h] + \lambda_{\dagger}[h] p^{\mathsf{i}}_{\dagger}[h] \right] + \mathbb{E}\left[F(\boldsymbol{x}, \tilde{\boldsymbol{\ell}}) \right] \right\}$$

Constraints:

$$u^{\mathsf{i}}_{\gamma_g}[h] \in \{0, 1\} \quad \forall \gamma_g \in \mathscr{G},\ \forall h \in \mathscr{H}$$

$$p^{\mathsf{i}}_{\dagger}[h] \geq 0 \quad \forall h \in \mathscr{H}$$

Second stage problem

Objective function: minimization of costs (with realization of the load in constraints)

$$F(\boldsymbol{x}^{\star}, \boldsymbol{\ell}^{\boldsymbol{\omega}}) :=$$

$$\underset{p^{\mathrm{i}}_{\gamma_g}[h], p^{\mathrm{i}}_{\ddagger}[h]}{\text{minimize}} \sum_{h \in \mathscr{H}} \left[\overline{c}_{\gamma_g} p^{\mathrm{i}}_{\gamma_g}[h] + \lambda_{\ddagger}[h] p^{\mathrm{i}}_{\ddagger}[h] \right]$$

Min-max constraint

$$(u^{\mathrm{i}}_{\gamma_g}[h])^{\star}[p^{\mathrm{i}}_{\gamma_g}]^{m} \leq p^{\mathrm{i}}_{\gamma_g}[h] \leq (u^{\mathrm{i}}_{\gamma_g}[h])^{\star}[p^{\mathrm{i}}_{\gamma_g}]^{M} \quad \forall \gamma_g \in \mathscr{G}\ \forall h \in \mathscr{H},$$

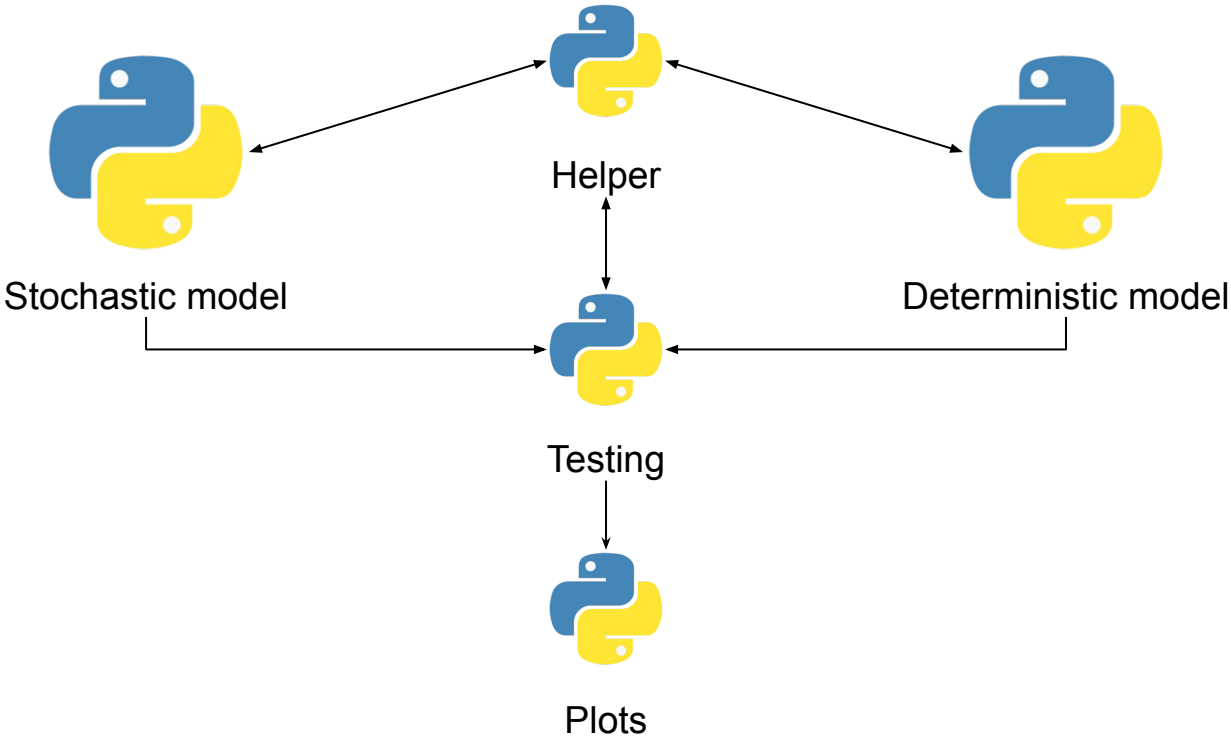
Load constraint

$$\sum_{\gamma_g \in \mathscr{G}} p^{\mathrm{i}}_{\gamma_g}[h] + (p^{\mathrm{i}}_{\dagger}[h])^{\star} + p^{\mathrm{i}}_{\ddagger}[h] \geq \ell^{\omega}_{h} \quad \forall h \in \mathscr{H},$$

Positivity constraint

$$p^{\mathrm{i}}_{\ddagger}[h] \geq 0 \quad \forall h \in \mathscr{H}.$$

Implementation: Overview



Implementation: Deterministic Model

Deterministic model

```
<DEFINE MODEL PARAMETERS>
for realtime_price in realtime_prices:
    <CREATE MASTER>
    <SOLVE MASTER>
    <CREATE SUB>
    <SOLVE SUB>
    <CONVERGENCE CHECK>
    while not converged:
        <CALCULATE OPTIMALITY CUT AND ADD TO MASTER>
        <SOLVE MASTER>
        <RECONSTRUCT SUB DUAL CONSTRAINTS>
        <SOLVE SUB>
        <CONVERGENCE CHECK>
```

Initialization

Iteration

Implementation: Stochastic Model

Stochastic model

```
<DEFINE MODEL PARAMETERS>
<DRAW 1000 SAMPLES FROM CRUDE MONTE CARLO>
for realtime_price in realtime_prices:
    <CREATE MASTER>
    <SOLVE MASTER>
    <CREATE SUB>
    for i, sample in enumerate(SAMPLES):
        <RECONSTRUCT LOAD CONSTRAINT WITH sample>
        <SOLVE SUB>
    <CONVERGENCE CHECK>
    while not converged:
        ...
```

Initialization

Implementation: Stochastic Model

Stochastic model

```
...
<CONVERGENCE CHECK>
while not converged:
    <CALCULATE OPTIMALITY CUT AND ADD TO MASTER>
    <SOLVE MASTER>
    <RECONSTRUCT SUB DUAL CONSTRAINTS>
    for i, sample in enumerate(SAMPLES):
        <RECONSTRUCT LOAD CONSTRAINT WITH sample>
        <SOLVE SUB>
    <CONVERGENCE CHECK>
```

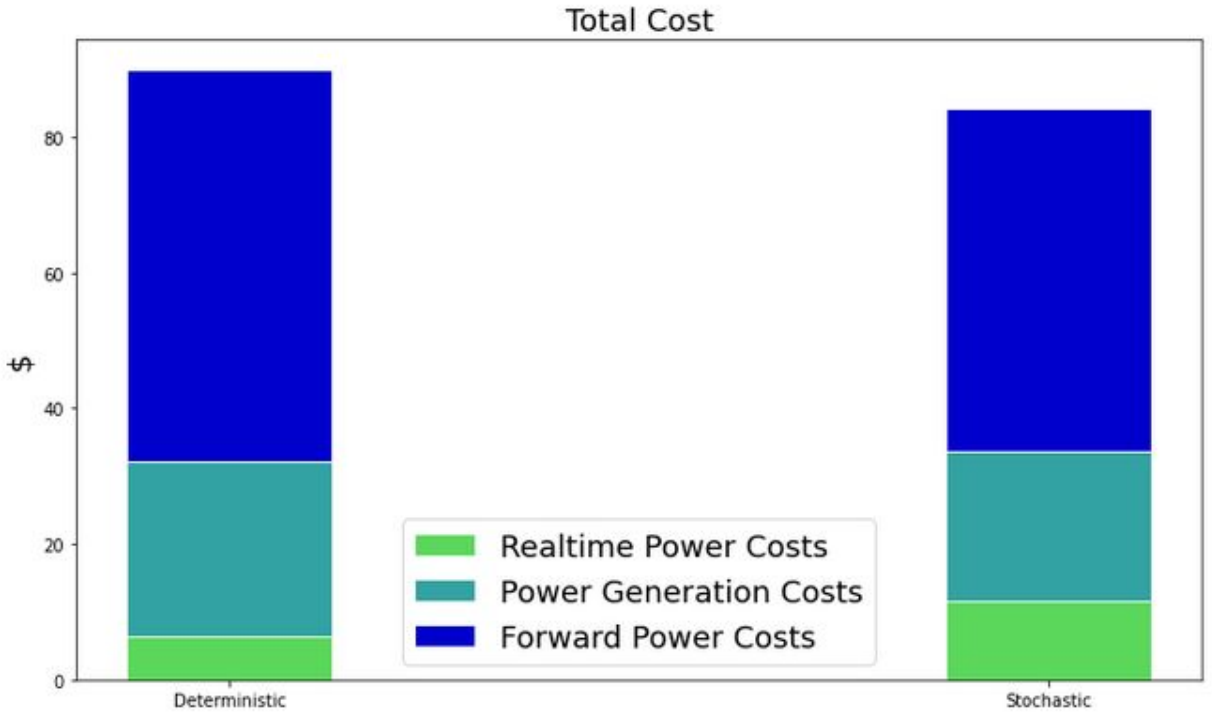
Iteration

Results | Deterministic vs. Stochastic

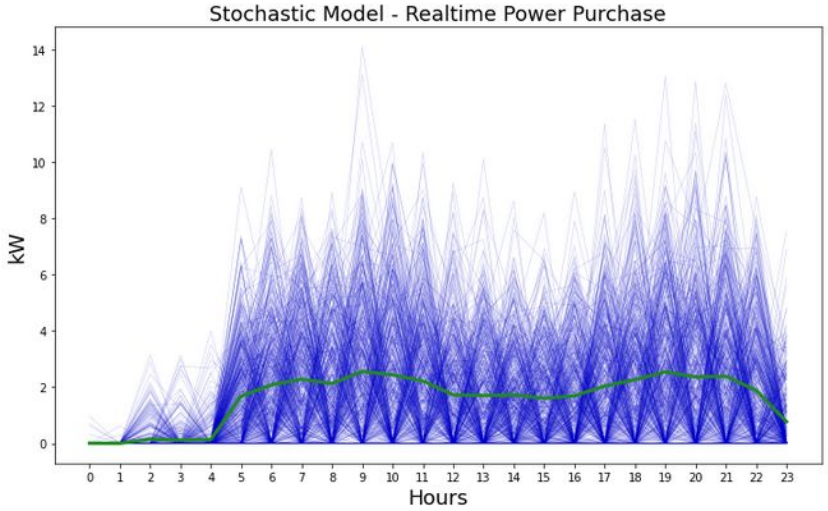
- Solve each model for optimal values
- test with fixed first stage variables on 500 Sample test set

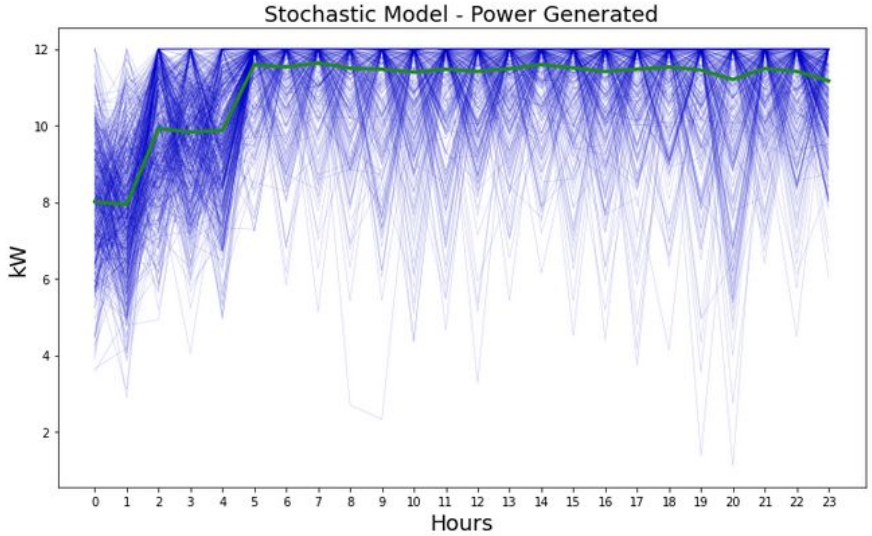
Deterministic OBJ	Stochastic OBJ
96.264 $	95.745 $

Results | Deterministic vs. Stochastic

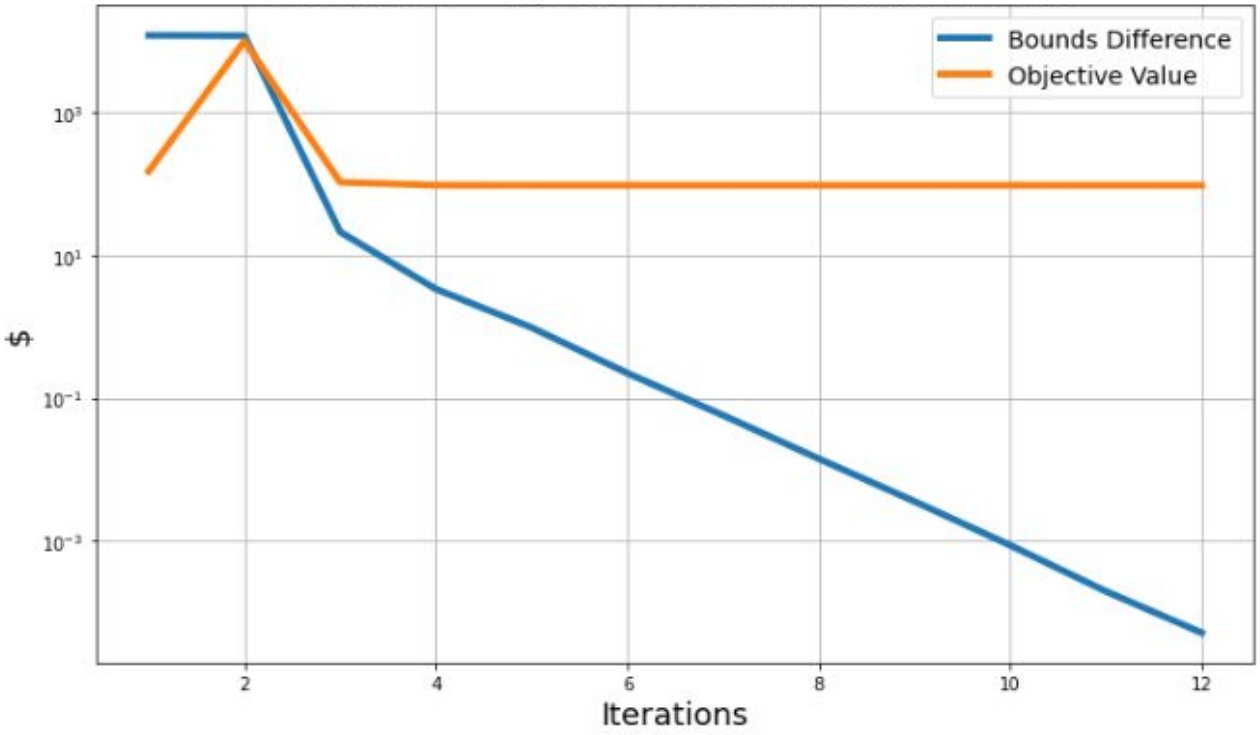


Results | Static λ = 0.3 $

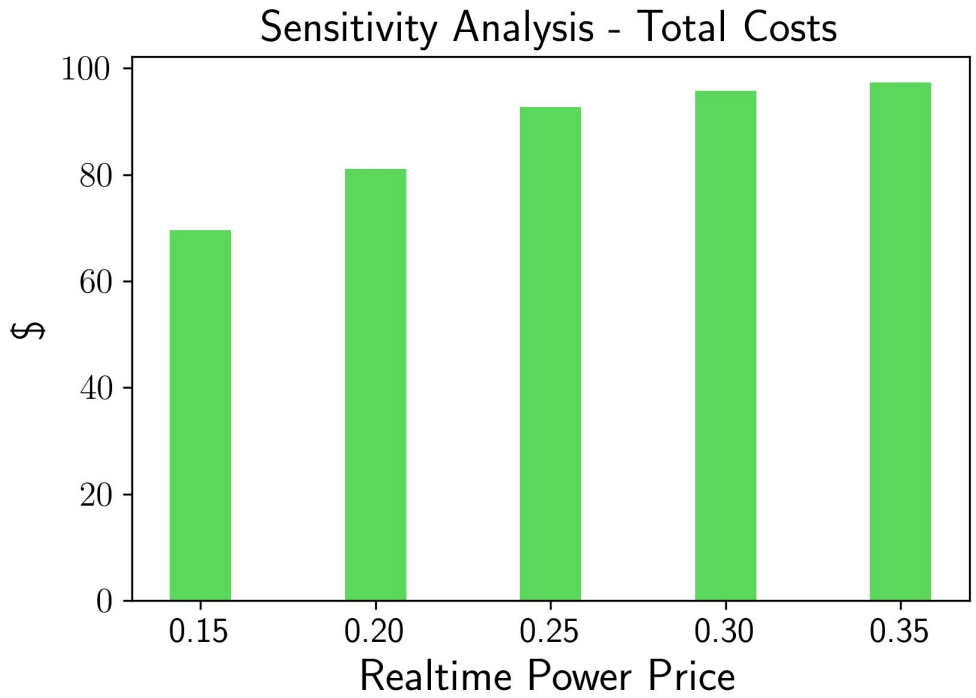




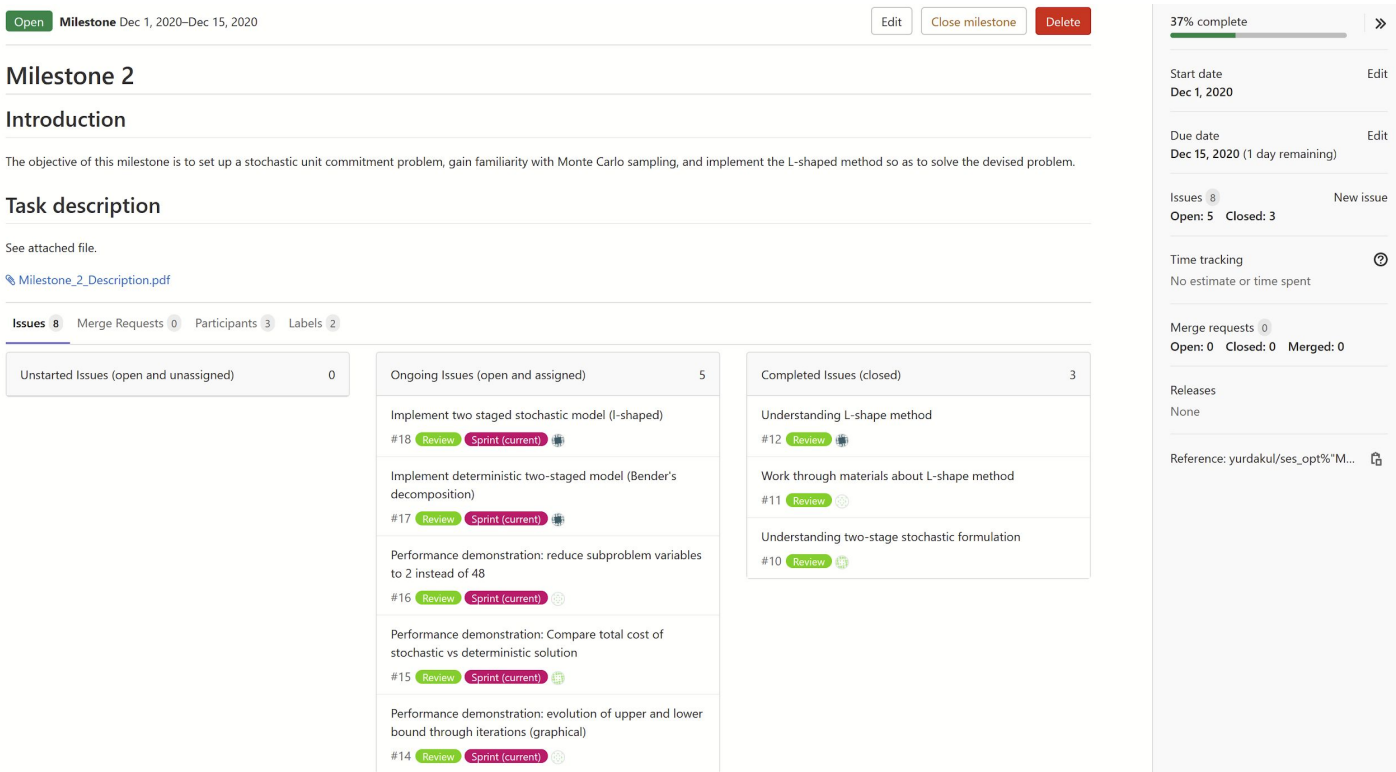
Results | Performance: OBJ and Bounds



Results | Sensitivity analysis



Scrum board - overview Milestone 2



Thanks for your attention

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