Allocation of Bridge Deck Preservation Budget Using Optimization

Hyung S. Shim

Wyoming Department of Transportation

Overview

1. General concept of optimization process.
2. Models needed in optimization.
3. Implement single objective optimization using two different scenarios. (Using two different objectives in optimization)
4. Introduction to multi-objective optimization.

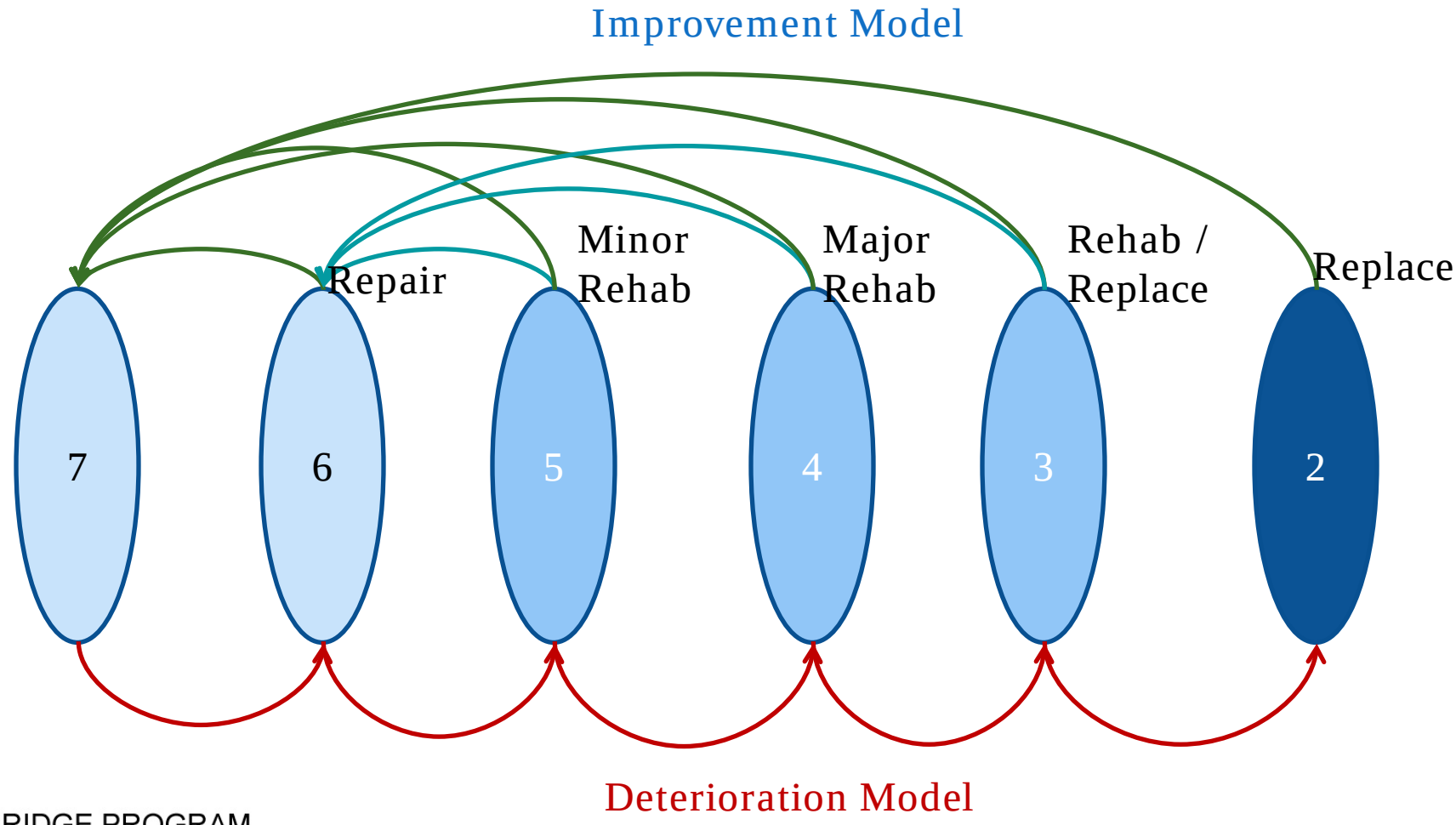
Optimization

- Compares deterioration of bridge deck with improvements along with associated costs to meet the objectives.
- Determines what percentage of the budget should be allocated for specific preservation actions.
- Optimization performed at a network level.
- Specific bridges are to be selected at the project level based on result of budget allocation.

Components needed in optimization

1. BMS models - Deterioration models, Improvement models, and Cost models.
2. What are the objectives for optimization? (Objective Function)
3. What are the constraints in optimization?
4. Economic factors. (Inflation rate, Discount factor, etc.)

Optimization for Budget Allocation



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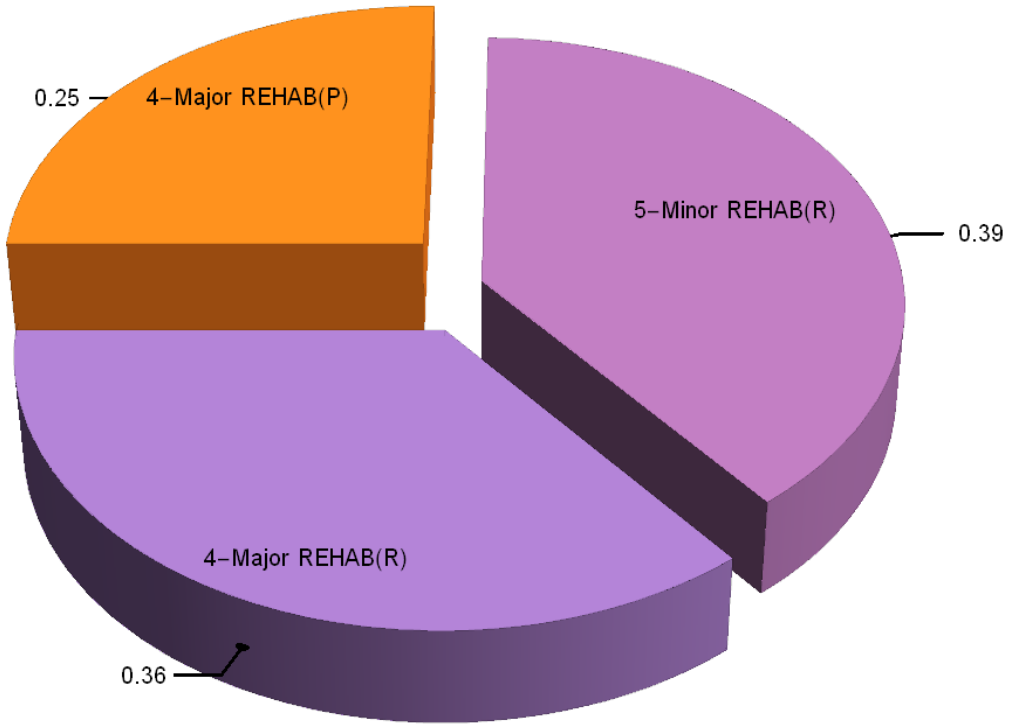
Improvement Strategy

NBI Rating before MR&R	MR&R Action	Cost (Probability of cost)
7	Do nothing	$ 0.0
6	REPAIR	$ 9.2 (μ)
5	REHAB	$ 20.5 (μ)
4	REHAB	$ 25.0 (70%)
3	REHAB/REPLACE	$ 57.6 (30%)
2	REPLACE	$ 63.8 (μ)
1	REPLACE	$ 63.8 (μ)

Results of Optimization

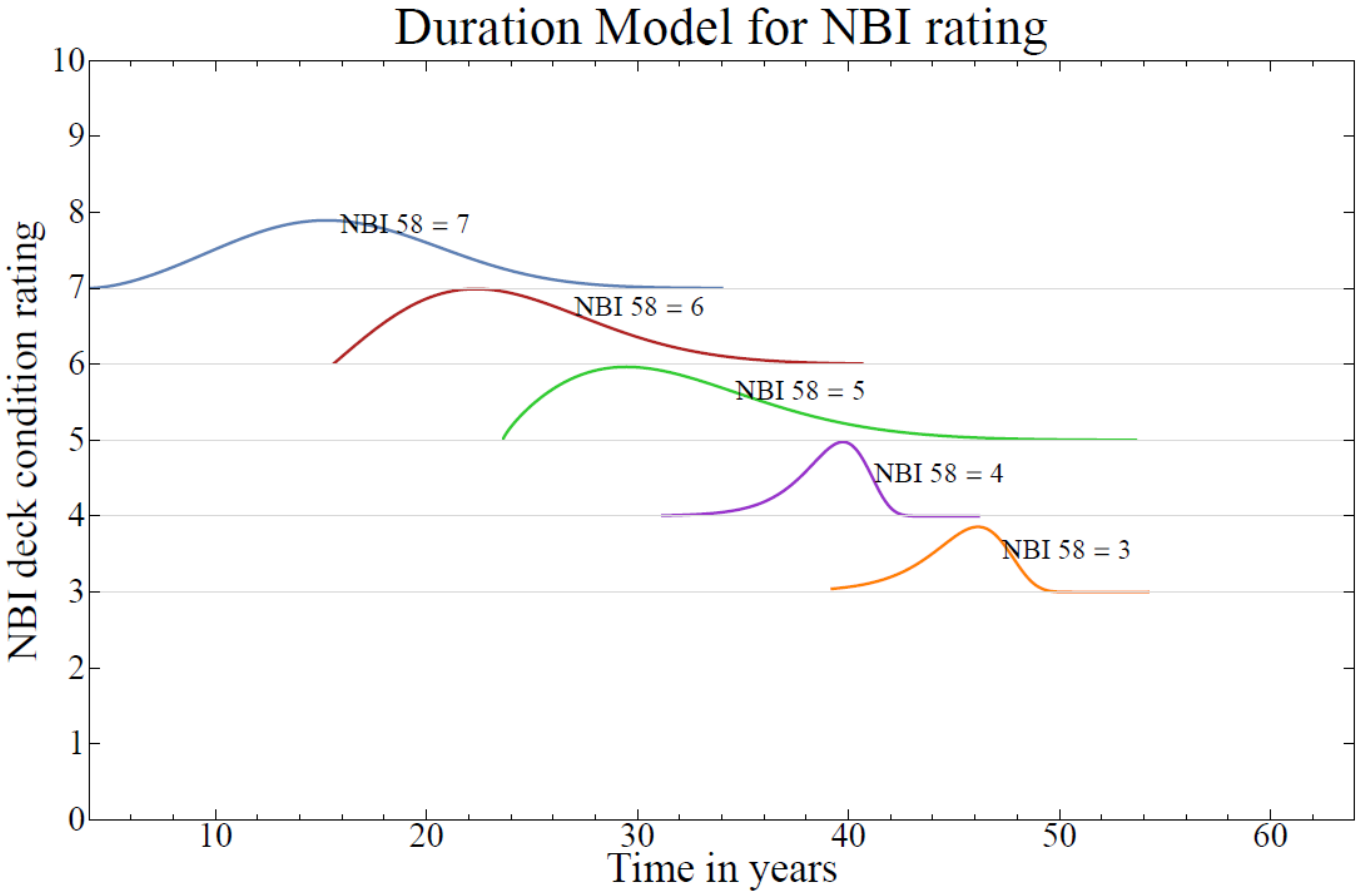


P stands for pure deck without rehabilitation history and R stands for rehabilitated deck

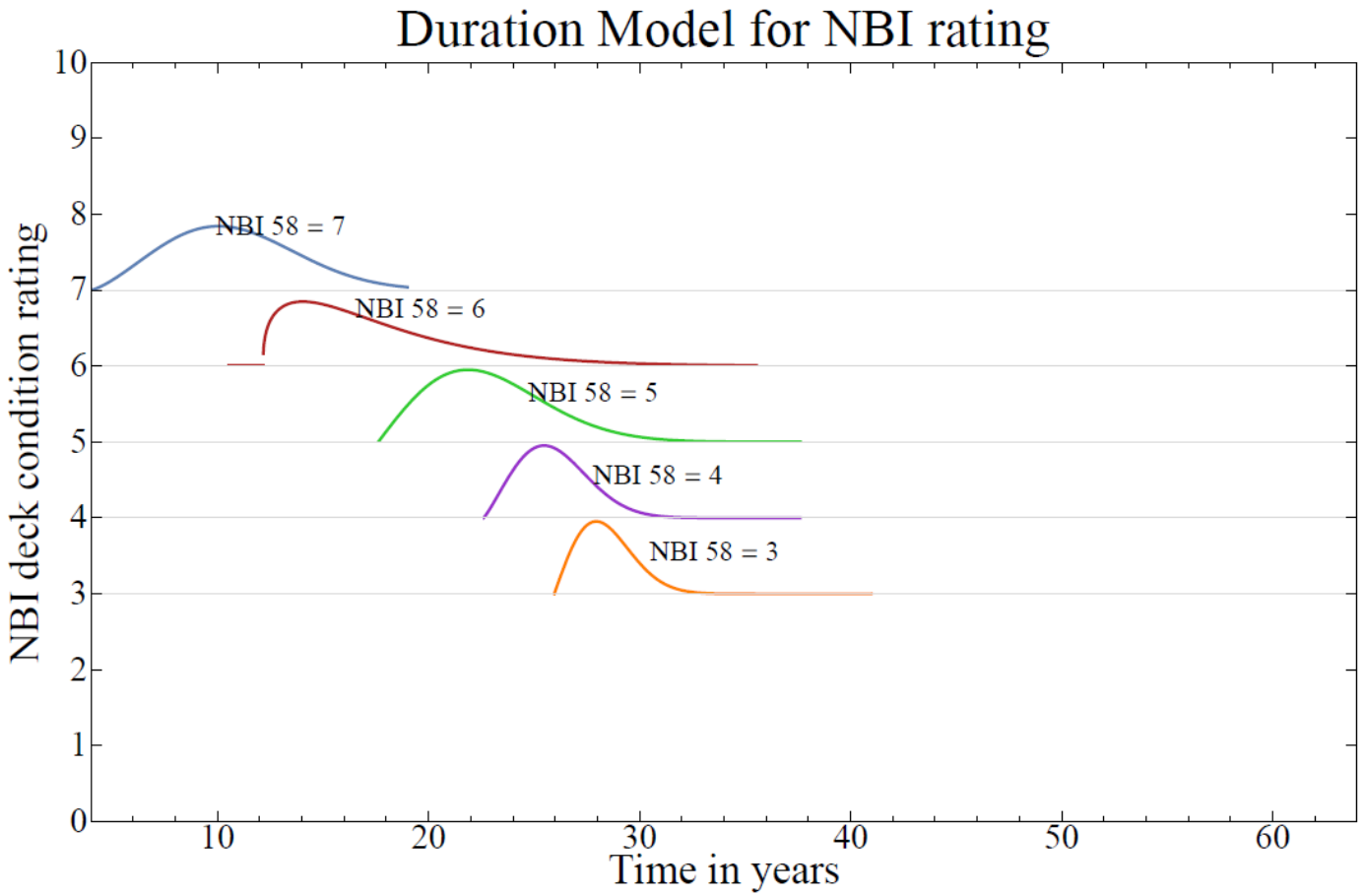
Deterioration Model

- WYDOT uses historical NBI deck condition rating data for deterioration modeling.
- Rather than producing deterministic modeling, probable duration model that remains in each of NBI condition ratings are used.
- Markov chain deterioration model are formed from probable duration models.
- Two different deterioration models are produced for bridge decks without / with rehabilitation history.

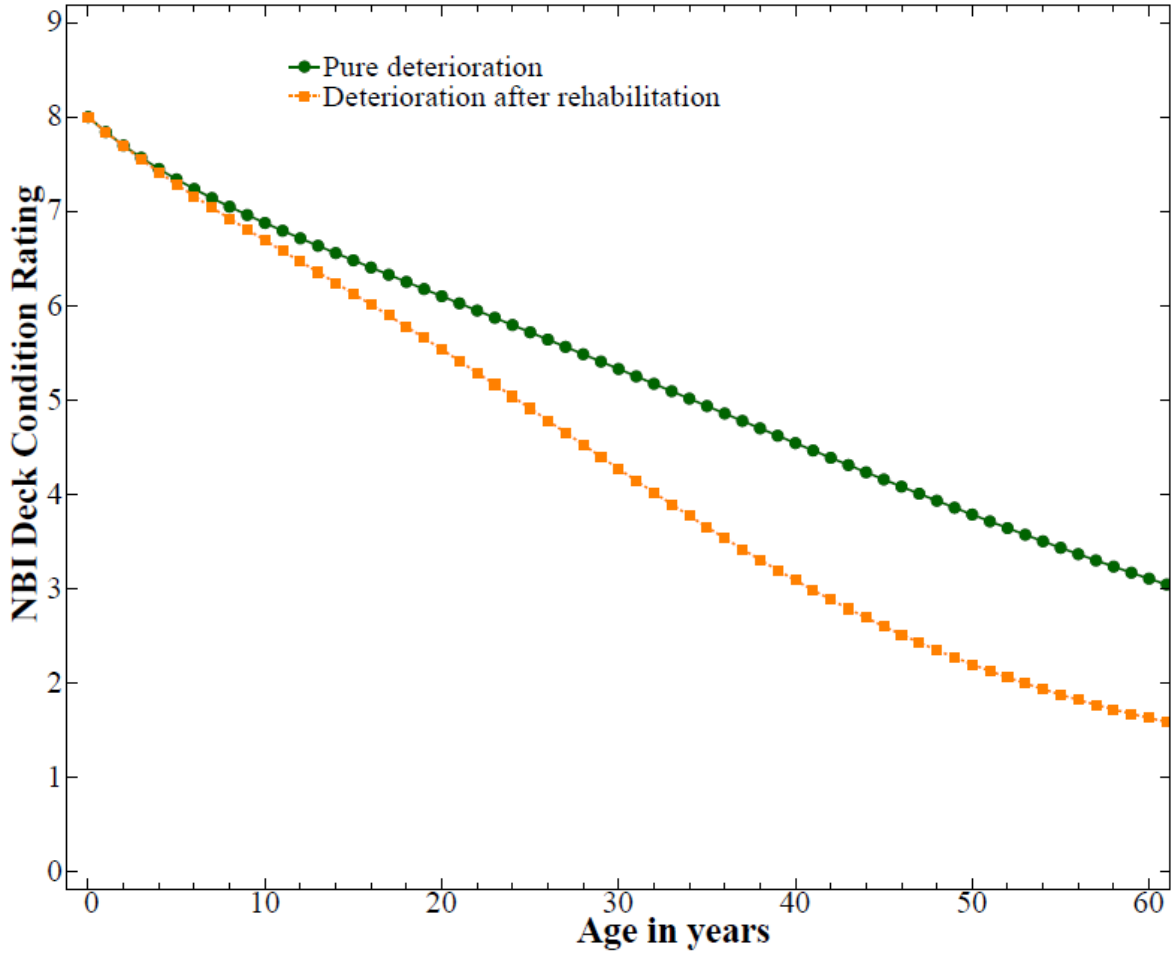
Probable durations (Do nothing)



Probable durations after REHAB



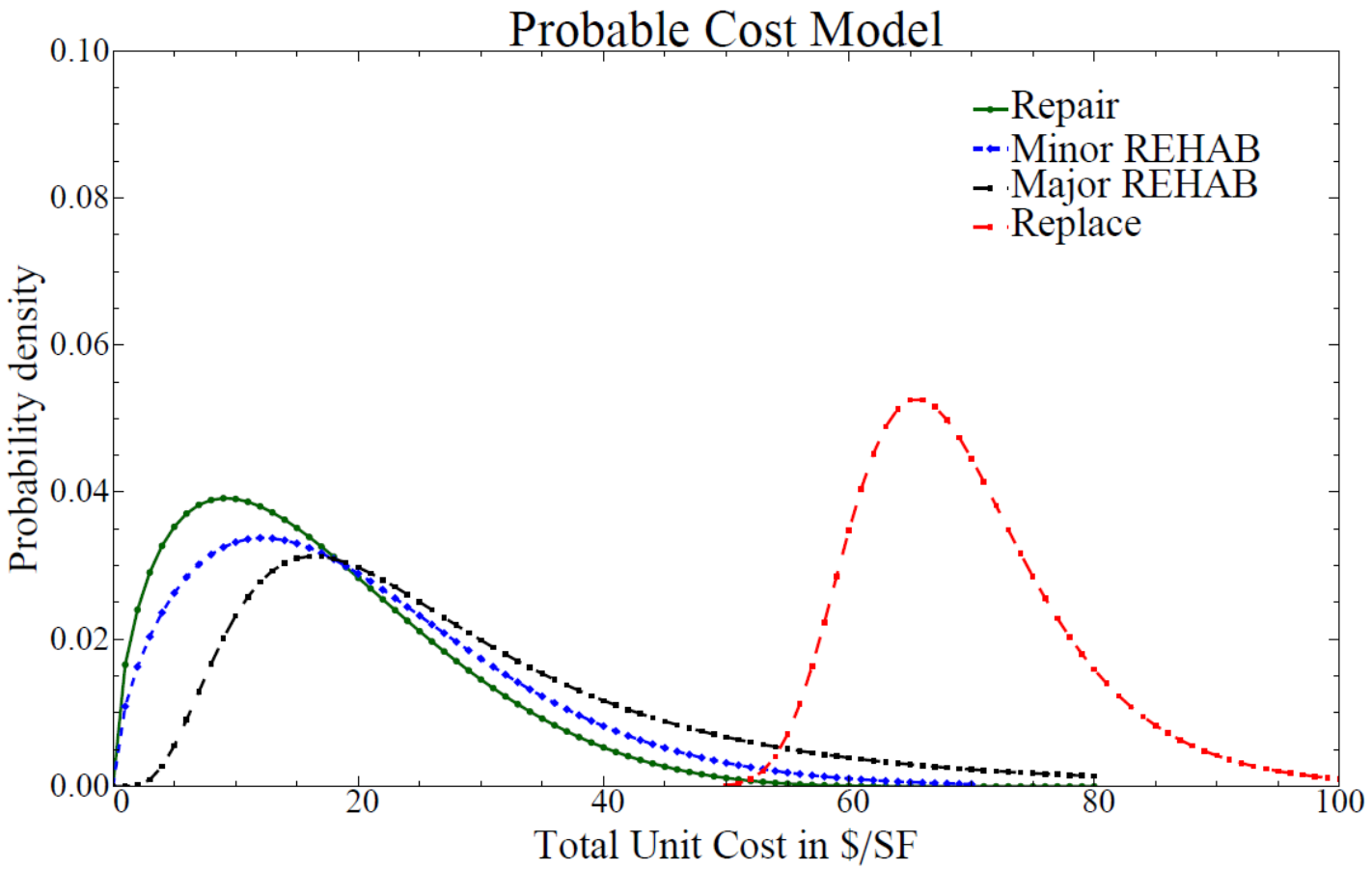
Deterioration Models



Cost Models

- Estimate costs associated with typical preservation actions .
- Developed by analyzing historical rehabilitation and new construction cost data.
- Developed by a probabilistic approach due to variability and uncertainty in estimation of costs.
- Continually being evaluated, refined and updated as necessary.

Probable Cost Model



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Improvement Models

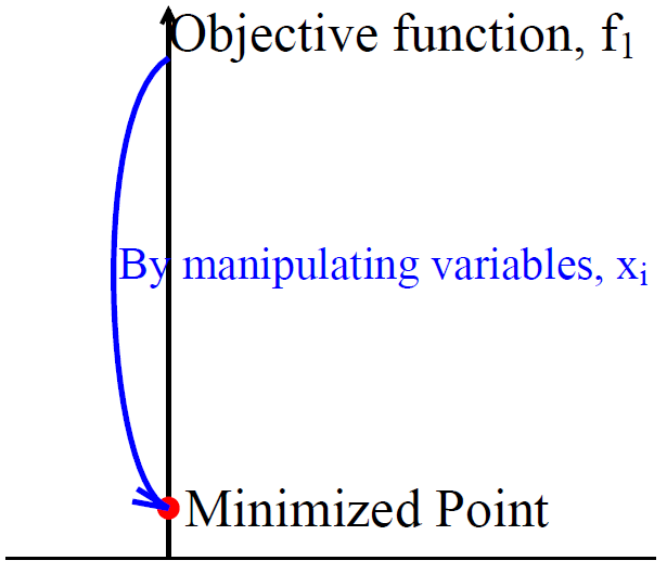
- Simulate the effects of preservation actions in terms of increase in NBI condition rating at network level.
- Developed by analyzing historical rehabilitation data.
  - NBI condition ratings are compared prior to and after application of preservation actions.
- In the form of Markov chain model.
- Continually being evaluated, refined and updated as necessary

Improvement Model

NBI	8	7	6	5
6		36%	64%	
5		53%	47%	
4		49%	38%	13%
3	30%	70%		
2	100%			
1	100%			

Objectives and Constraints

Single Objective Optimization



Minimizing structural deficiency / Annual budget

Manipulating variables - Allocation fund on various preservation actions.

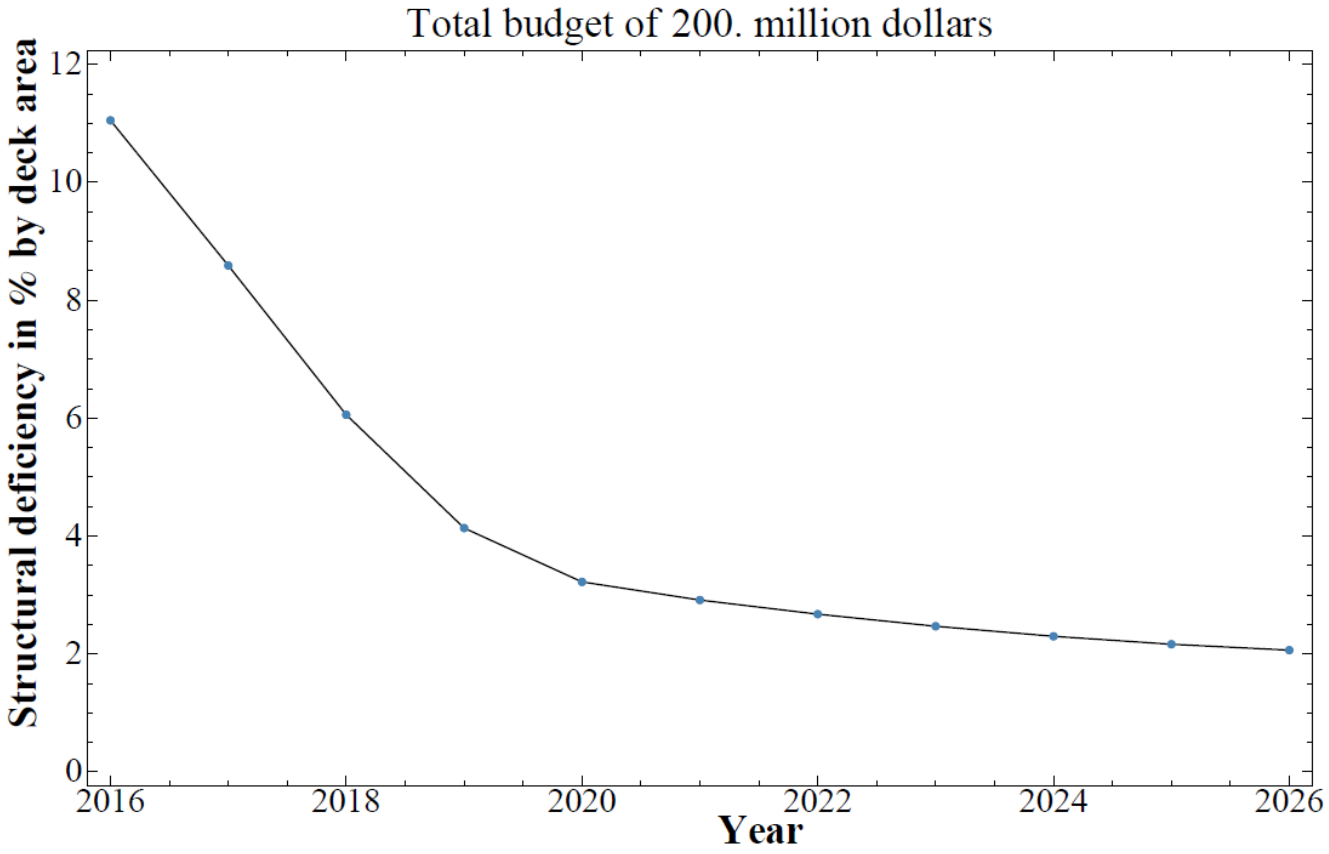
Achievable structural deficiency / Annual budget.

Annual budget / Target structural deficiency.

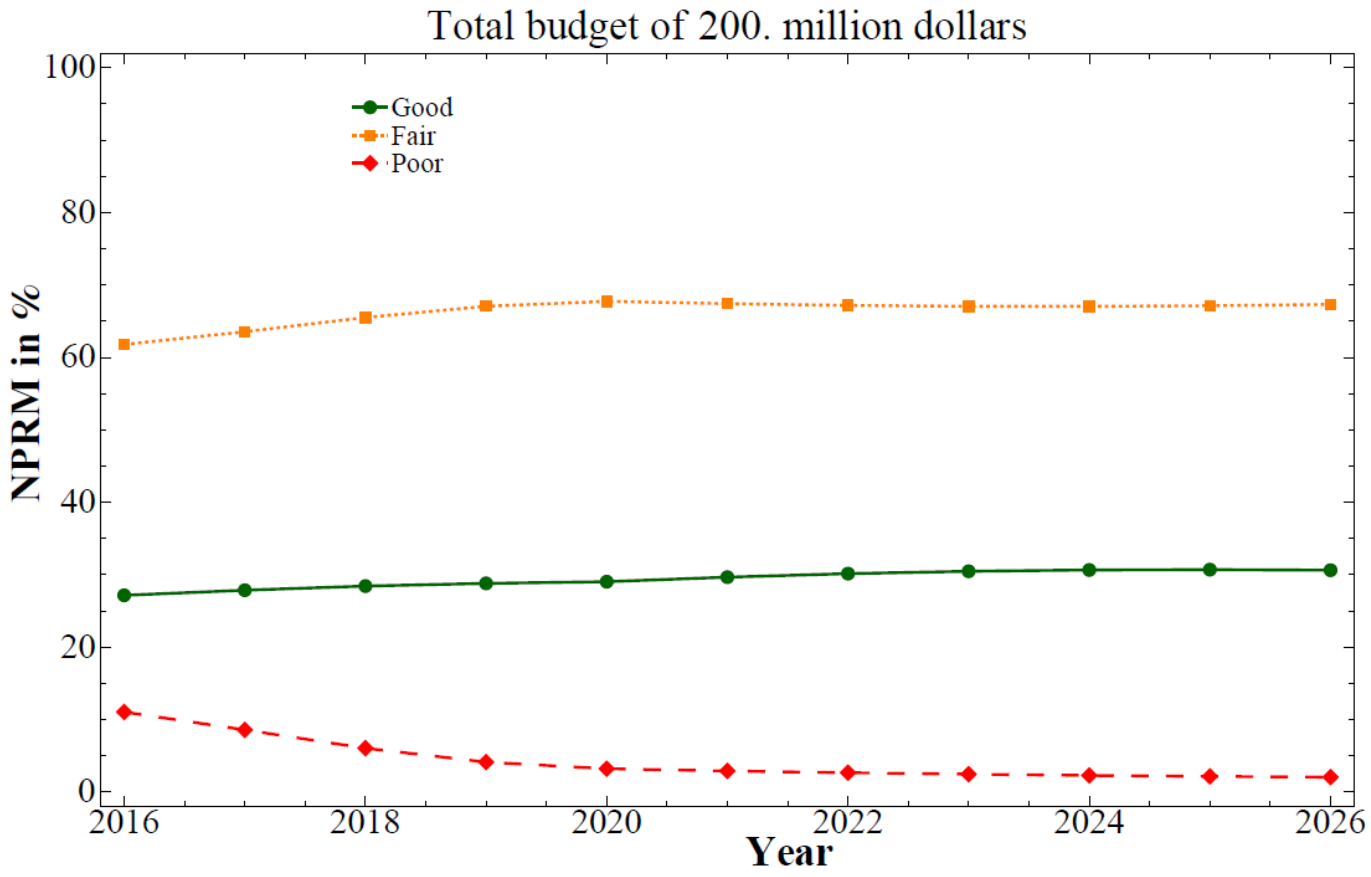
Optimization-Scenario 1

- Objective Function - Minimizing Structural Deficiency (SD%)
- Constraint - Annual budget of 20 million dollars
- Planning horizon - 10 years.
- Agency Policy - Replace the deck for condition rating equal to or less than 2 prior to other actions.
- Achieve the as minimum as possible structural deficiency with allowable maximum annual budget using agency policy.

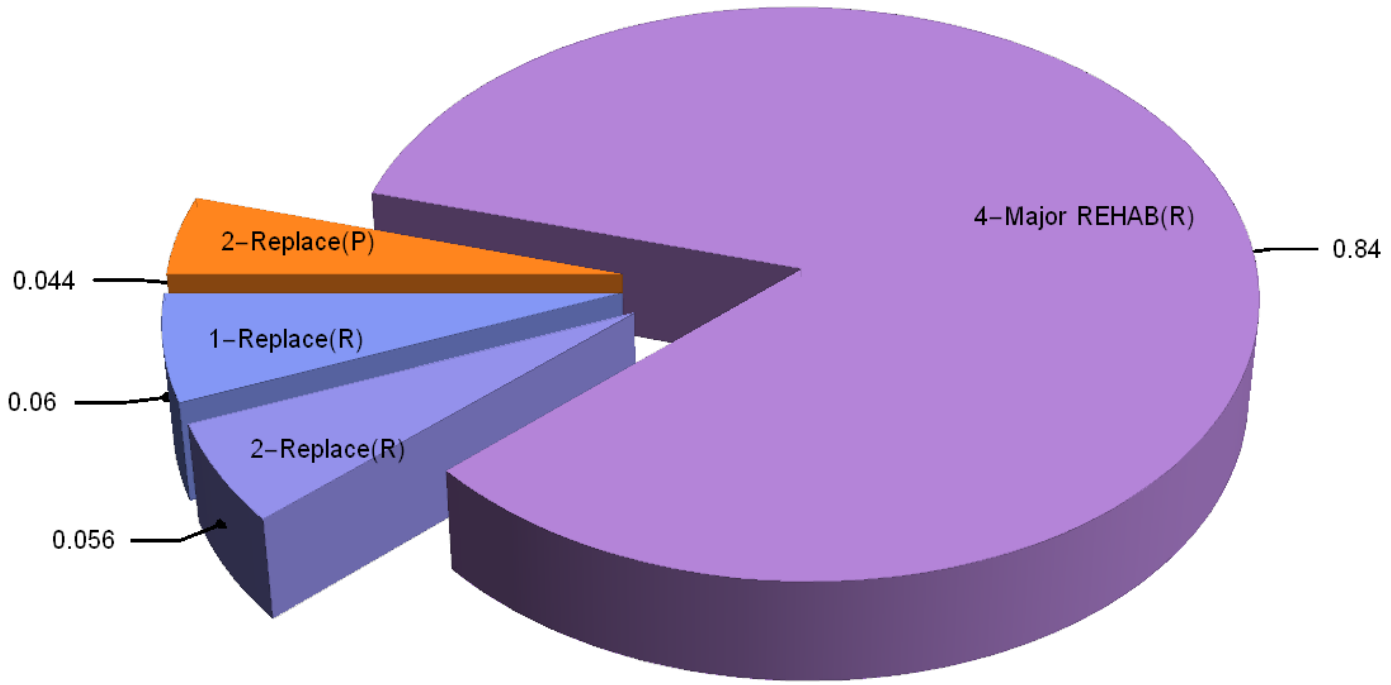
Structural Deficiency – Scenario 1



NPRM Measure - Scenario 1



Budget Allocation – 1st Year



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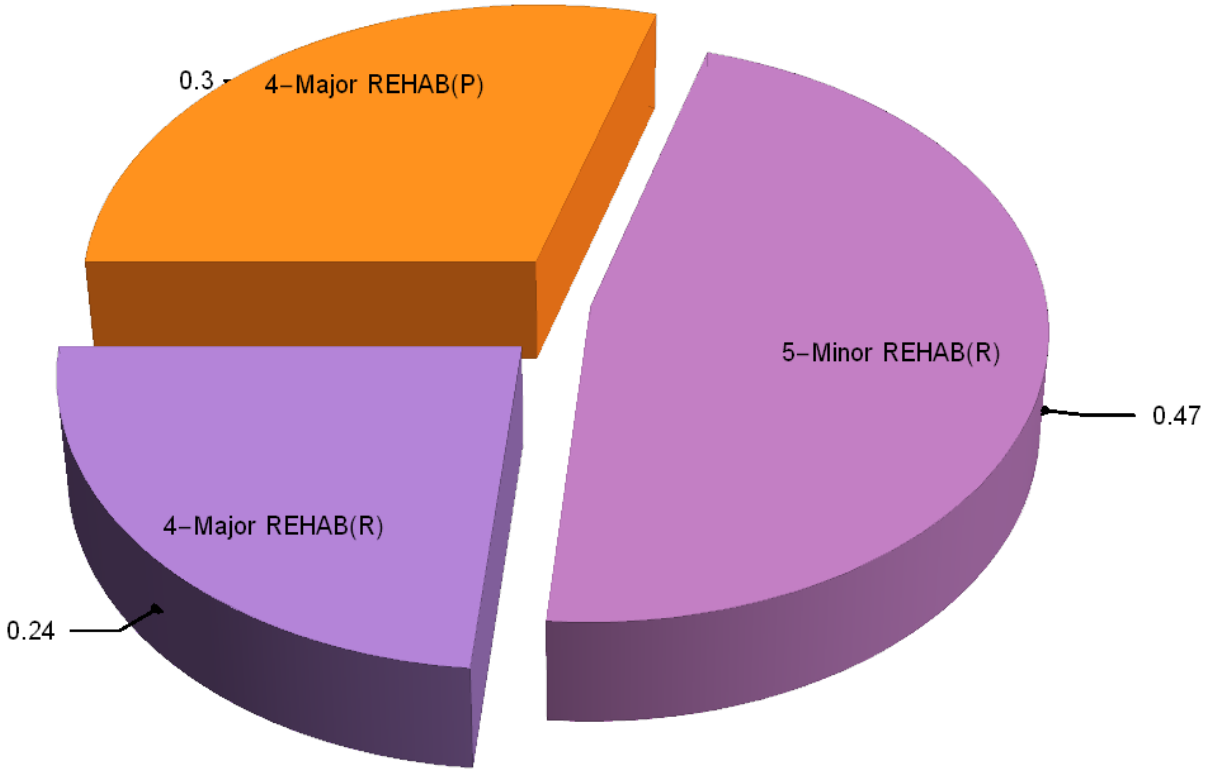
Budget Allocation – 10th Year



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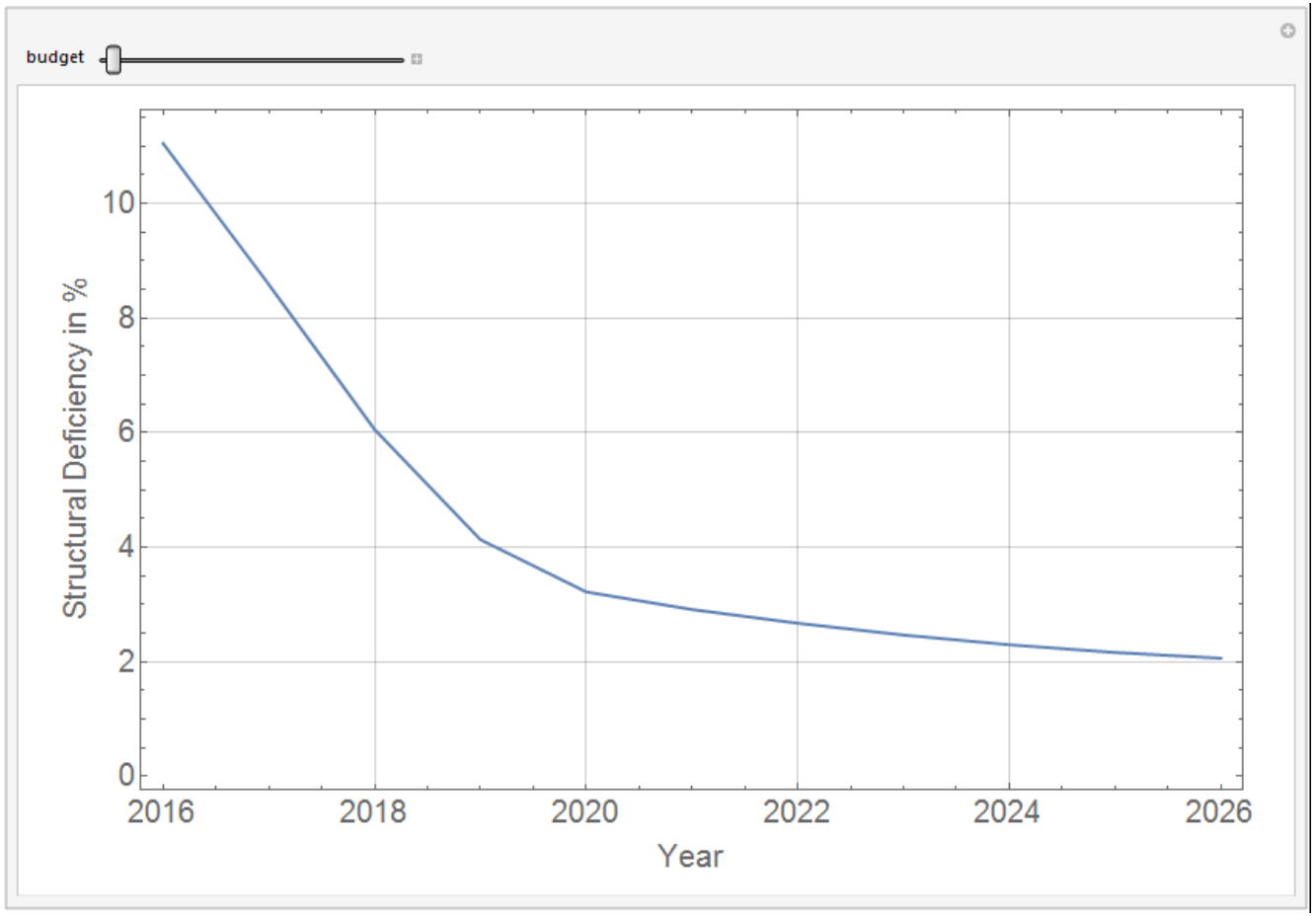
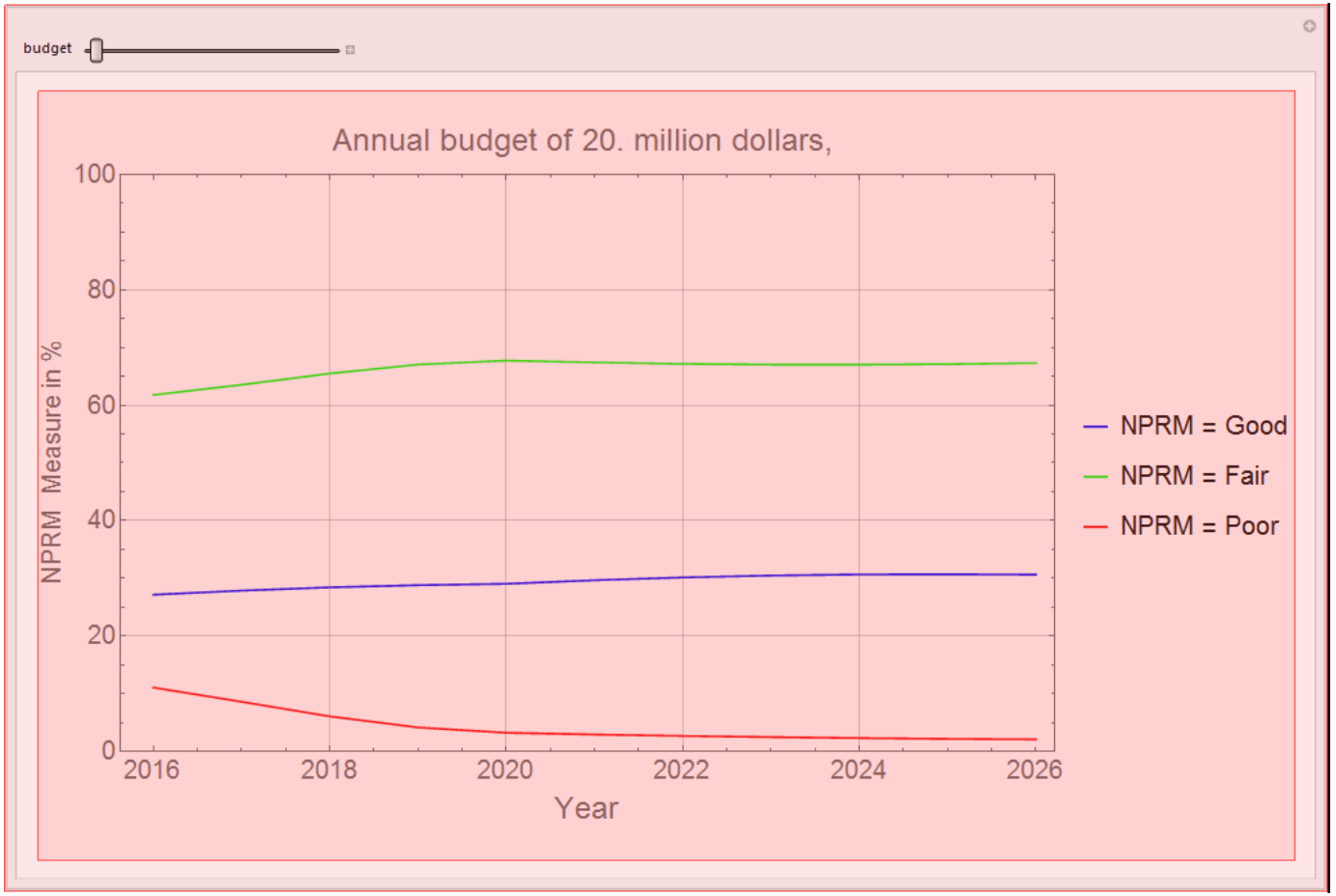
Structural Deficiency vs. Year



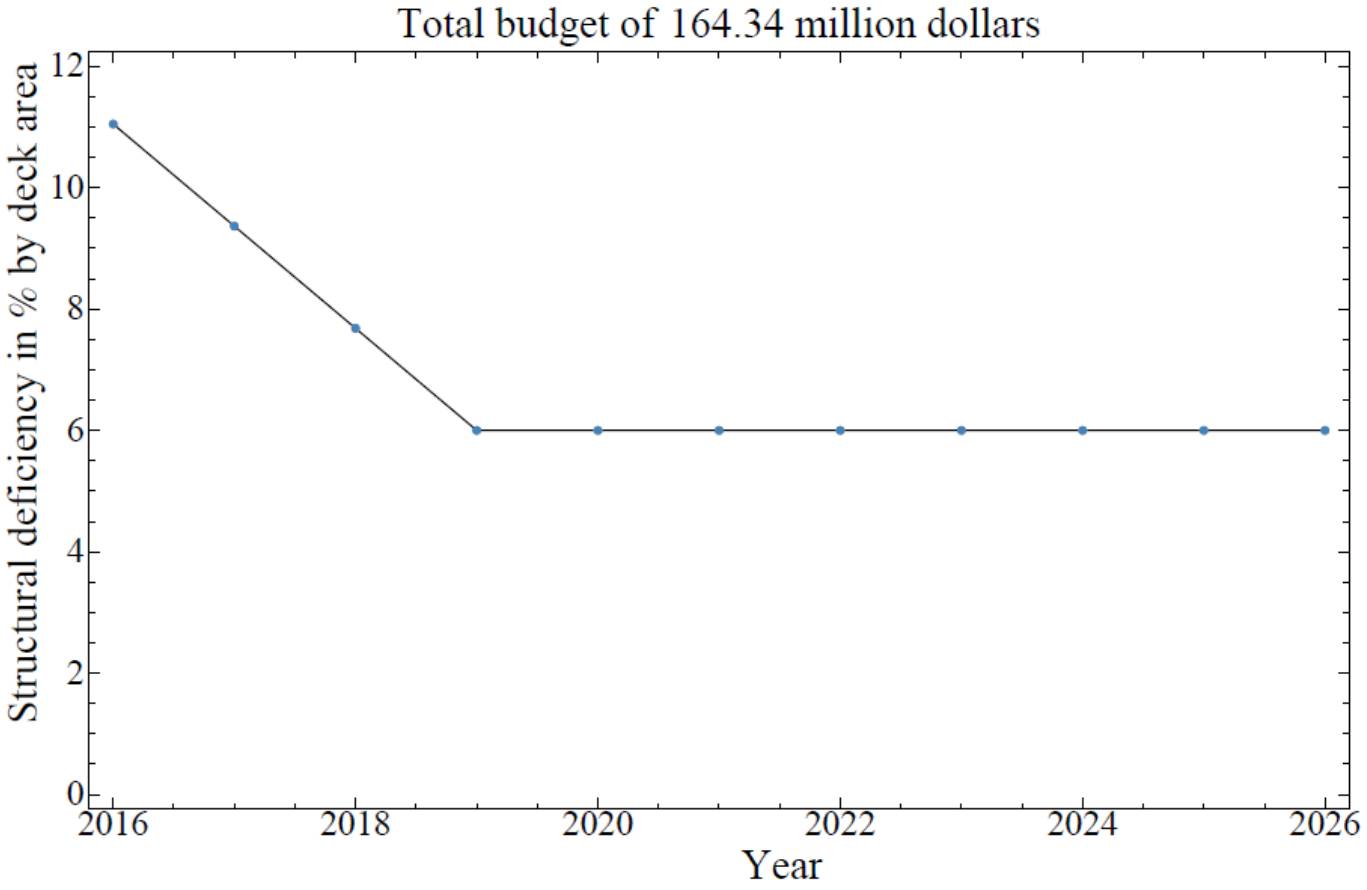
NPRM Measure for Scenario 1



Optimization-Scenario 2

- Objective Function - Minimizing annual budget.
- Constraint - Achieve structural deficiency of 6% within 3 years and then maintain on 6%.
- Planning horizon - 10 years.
- Agency Policy - Replace the deck for condition rating equal to or less than 2 prior to other actions.
- Spend as minimum as possible annual budget to achieve the target structural deficiency using agency policy.

Structural deficiency-Scenario 2



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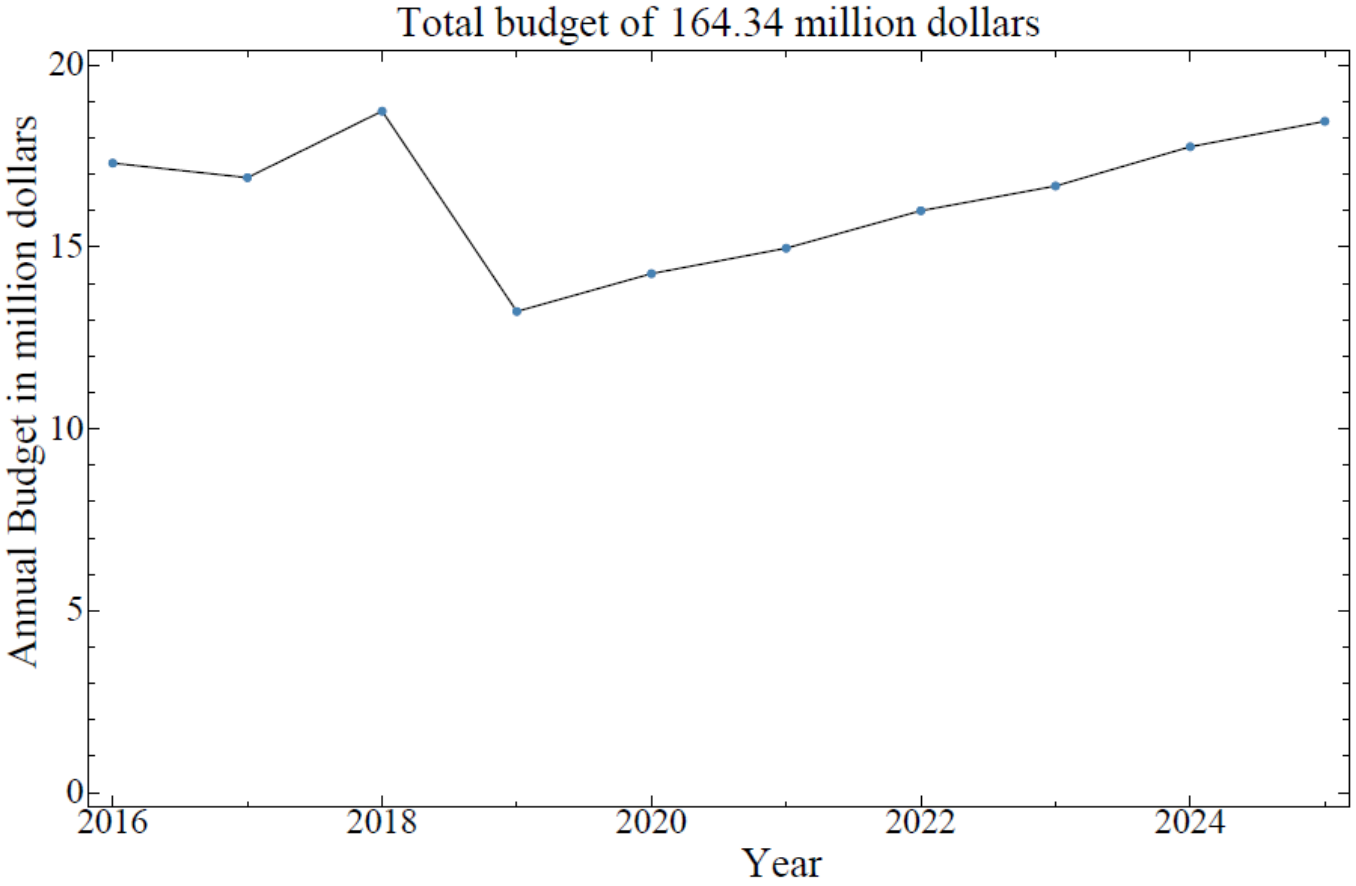
Required annual budget



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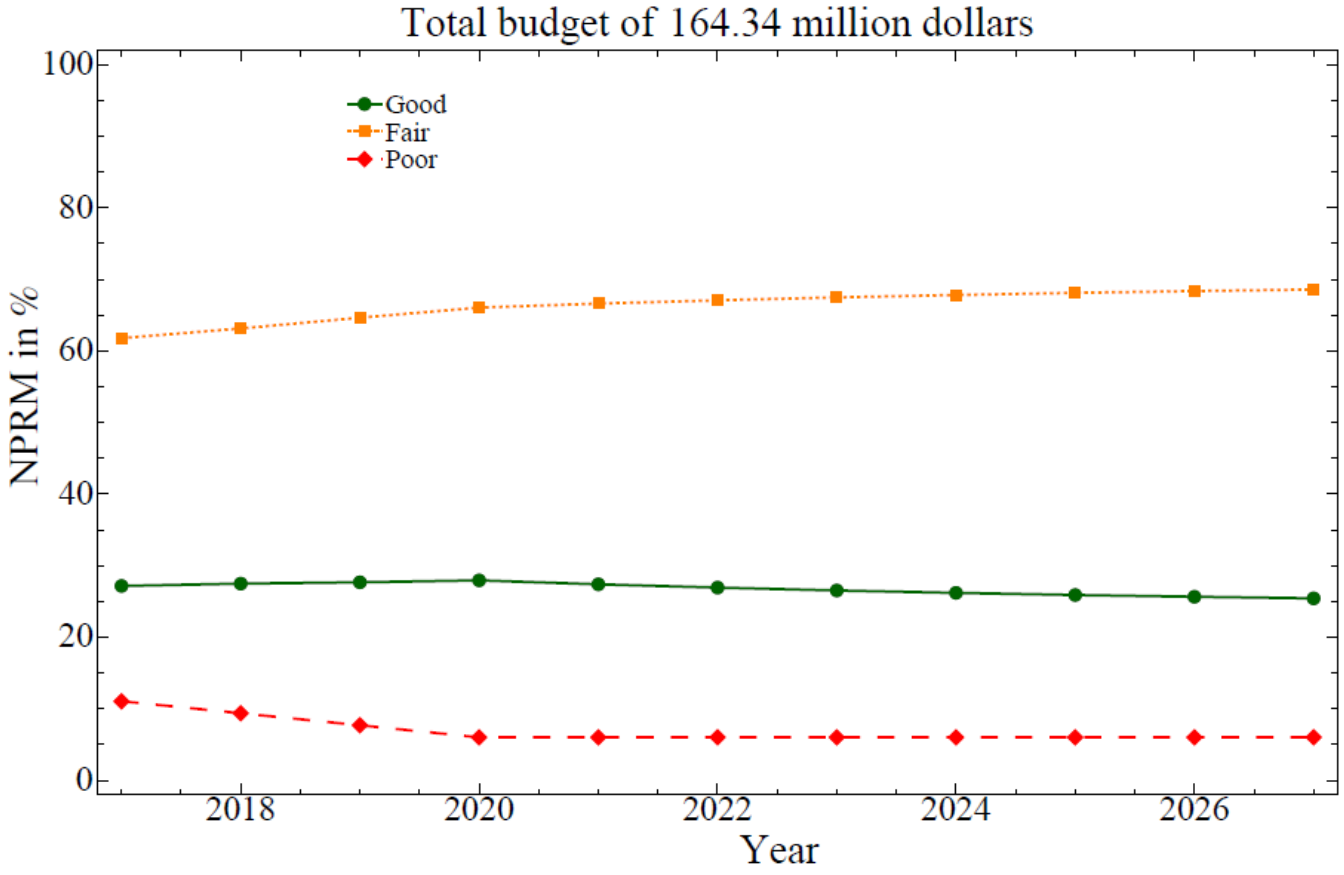
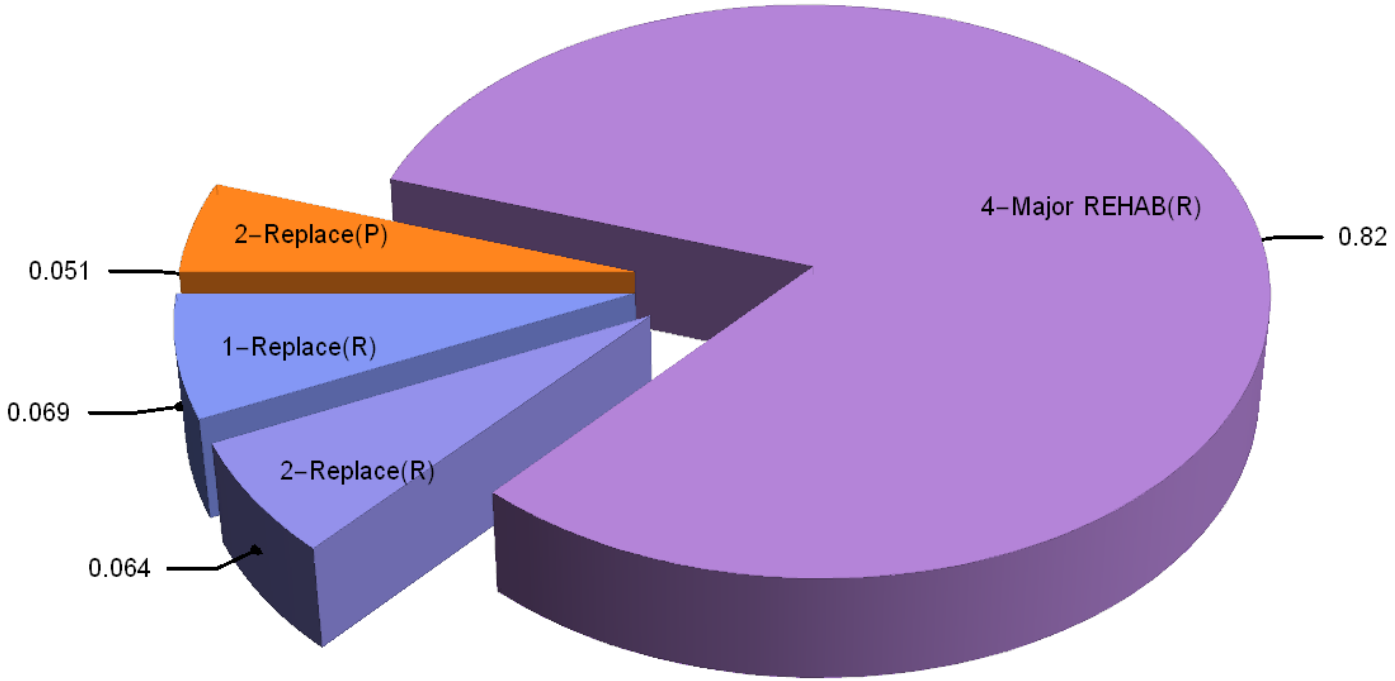
NPRM Measure – Scenario 2



Budget Allocation – 1st Year



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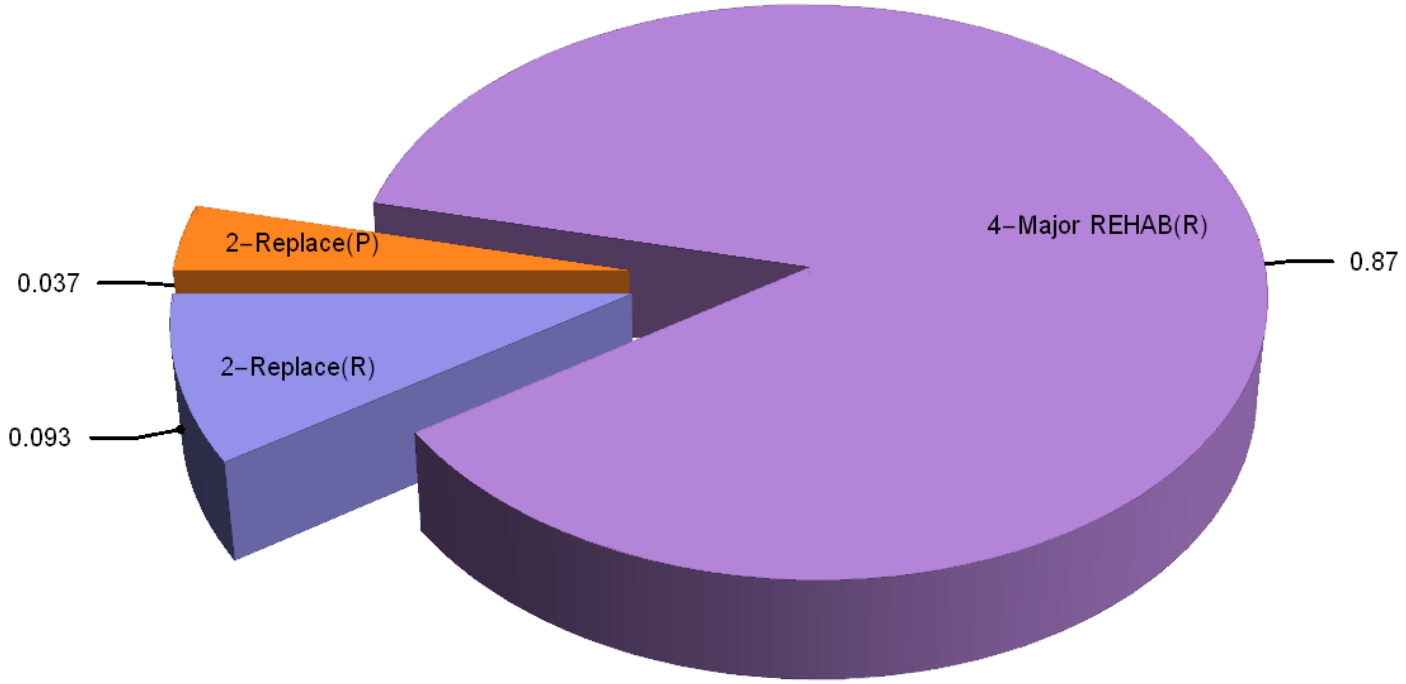
Budget Allocation – 10th Year



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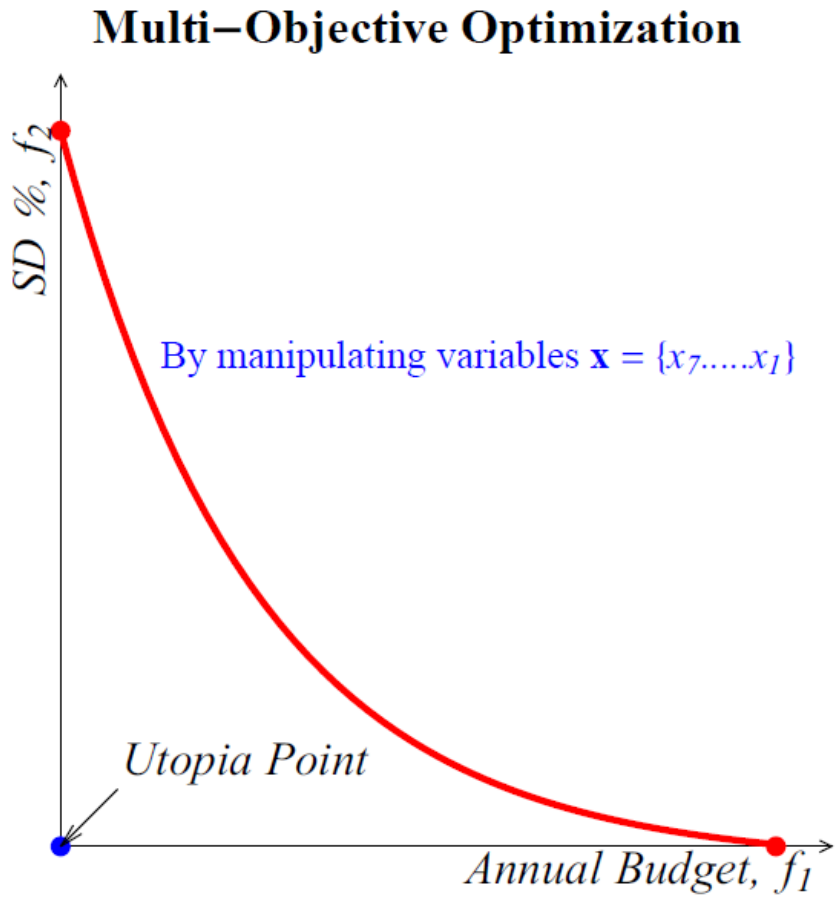
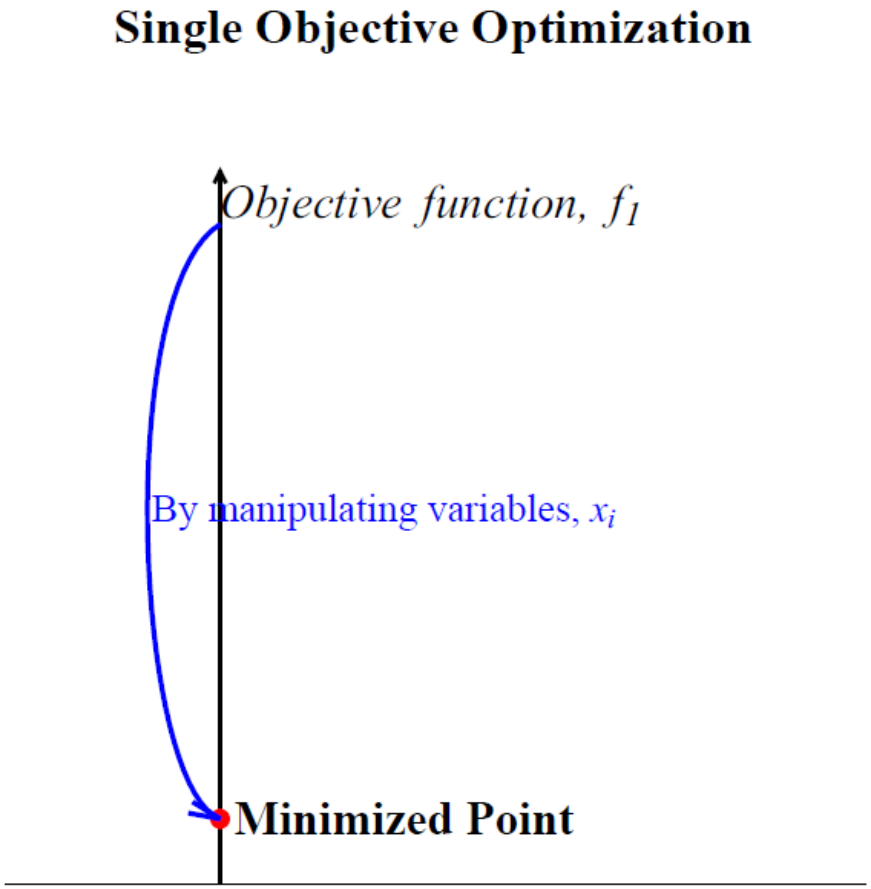
Considerations

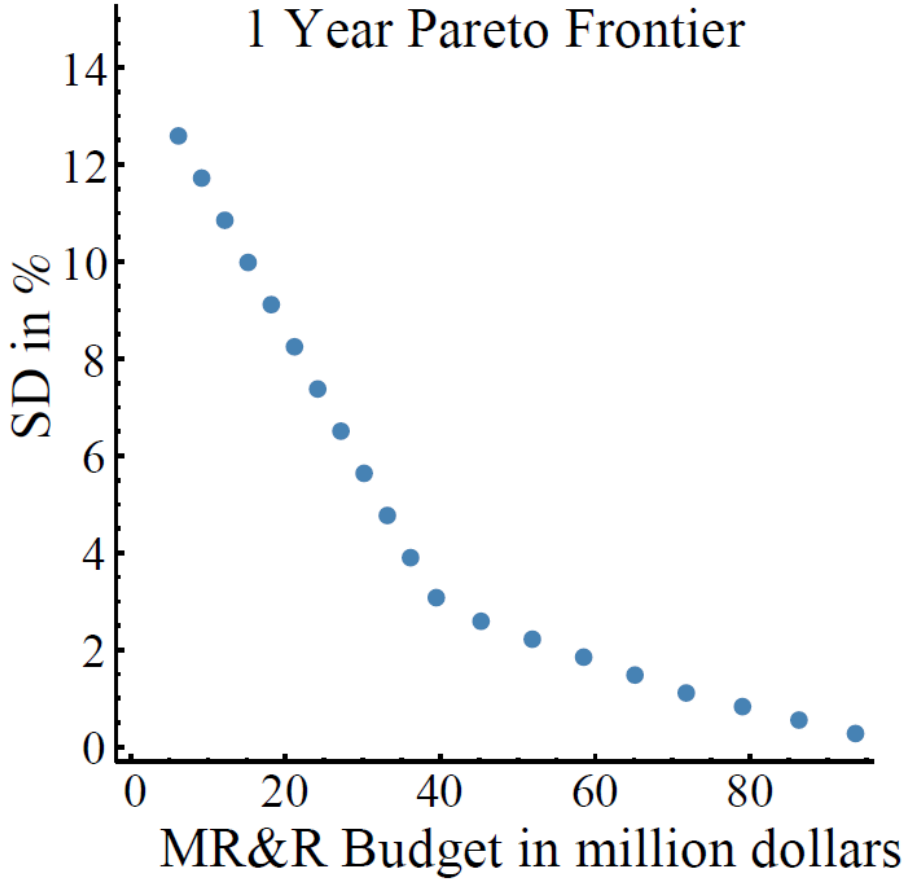
- The single objective optimization produces the focused result to the its objective function.
- There is only one optimal solution point at each year. Therefore there is no trade-off analysis.
- Balanced solution point is necessary to satisfy the multiple objectives in certain level at the same time.
- Number of objective functions can be more than 2.
- There are multiple solution points which satisfy optimality condition.

Multi-Objective Optimization





1st Year multi-objective optimization



Thank you…