# An optimization tool for urban drainage network design under uncertainty

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# Optimization of UDN Under Uncertainty

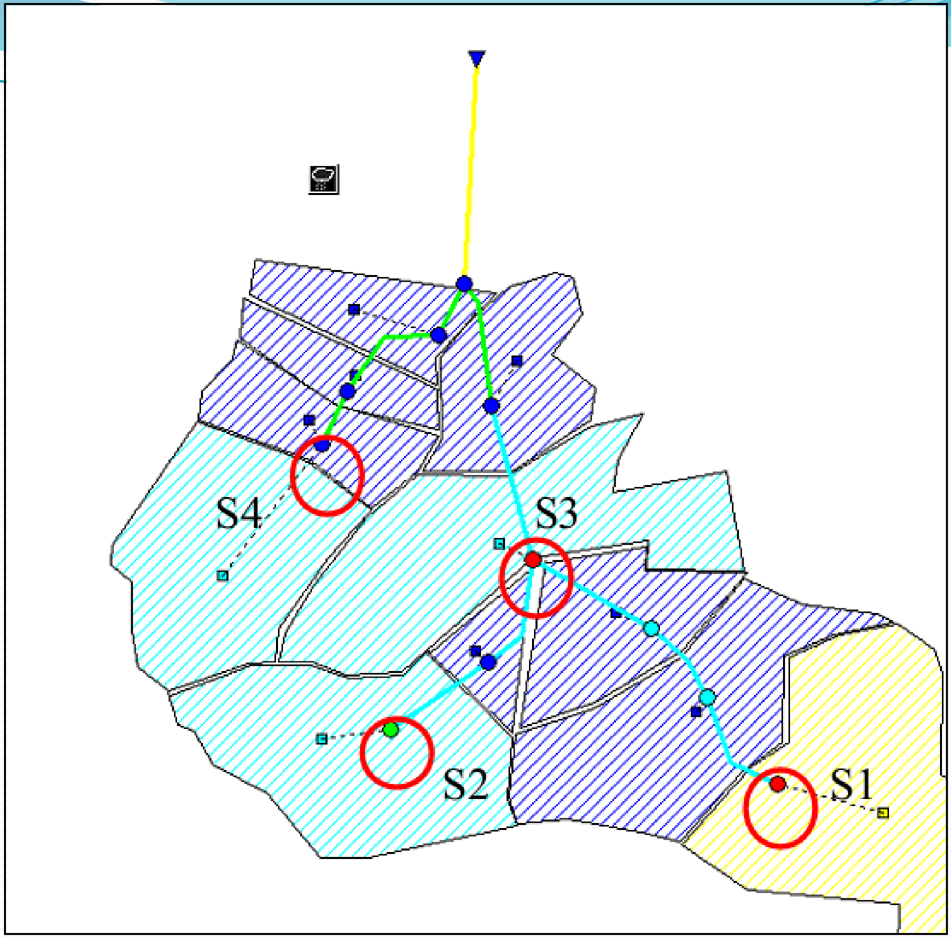
- Optimization
- Multi-Objective Optimization
- Adding uncertainty (Robustness)
- Nuts-and-Bolts
- Case Study
- Discussion

# Optimization

- Sizing four reservoirs.
- Larger reservoirs: Costly construction.
- Smaller reservoirs: Costly floods.
- Optimal size where total

cost= Flood + Construction

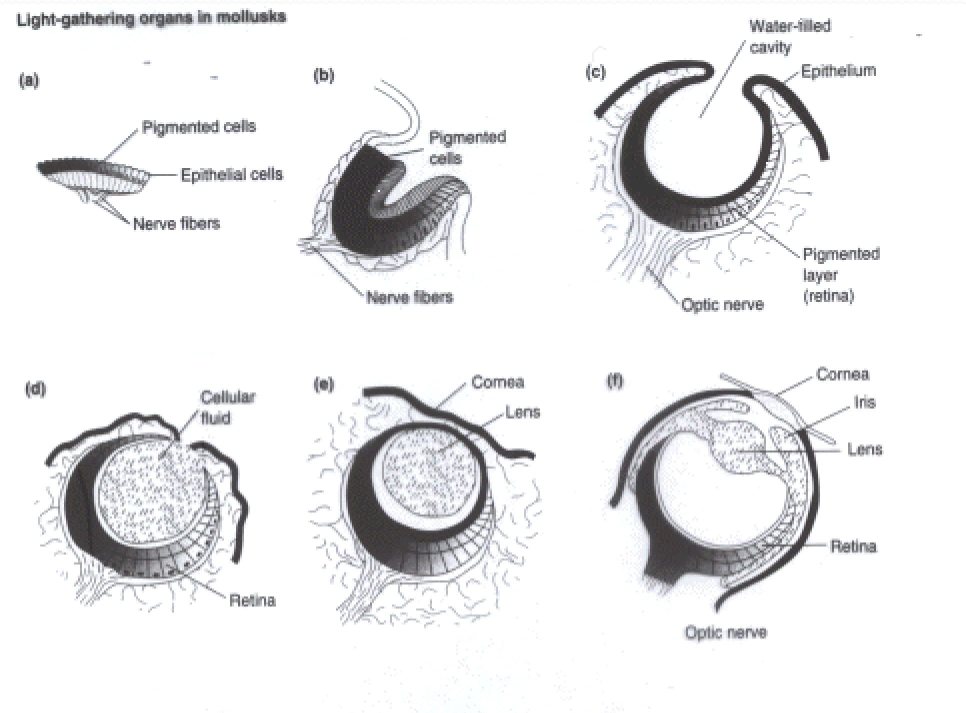
minimized.



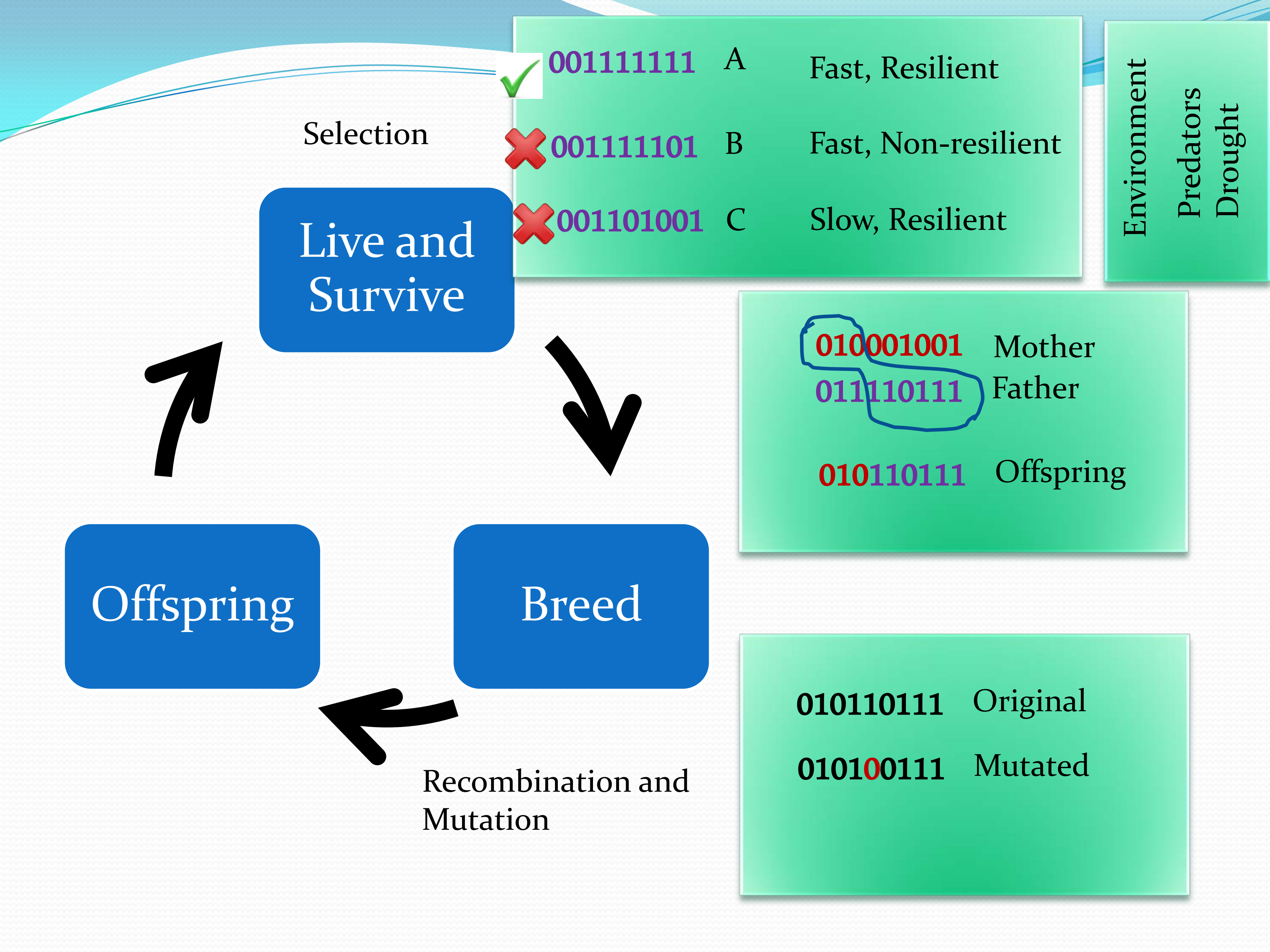

Optimal capacity of four reservoirs.
(After Maharjan, et al, 2009)

# Evolutionary Algorithms

- Based on (Darwinian) evolution.
- Good for complex or unknown relationships between input and output.
- GA, NSGA-II, etc.

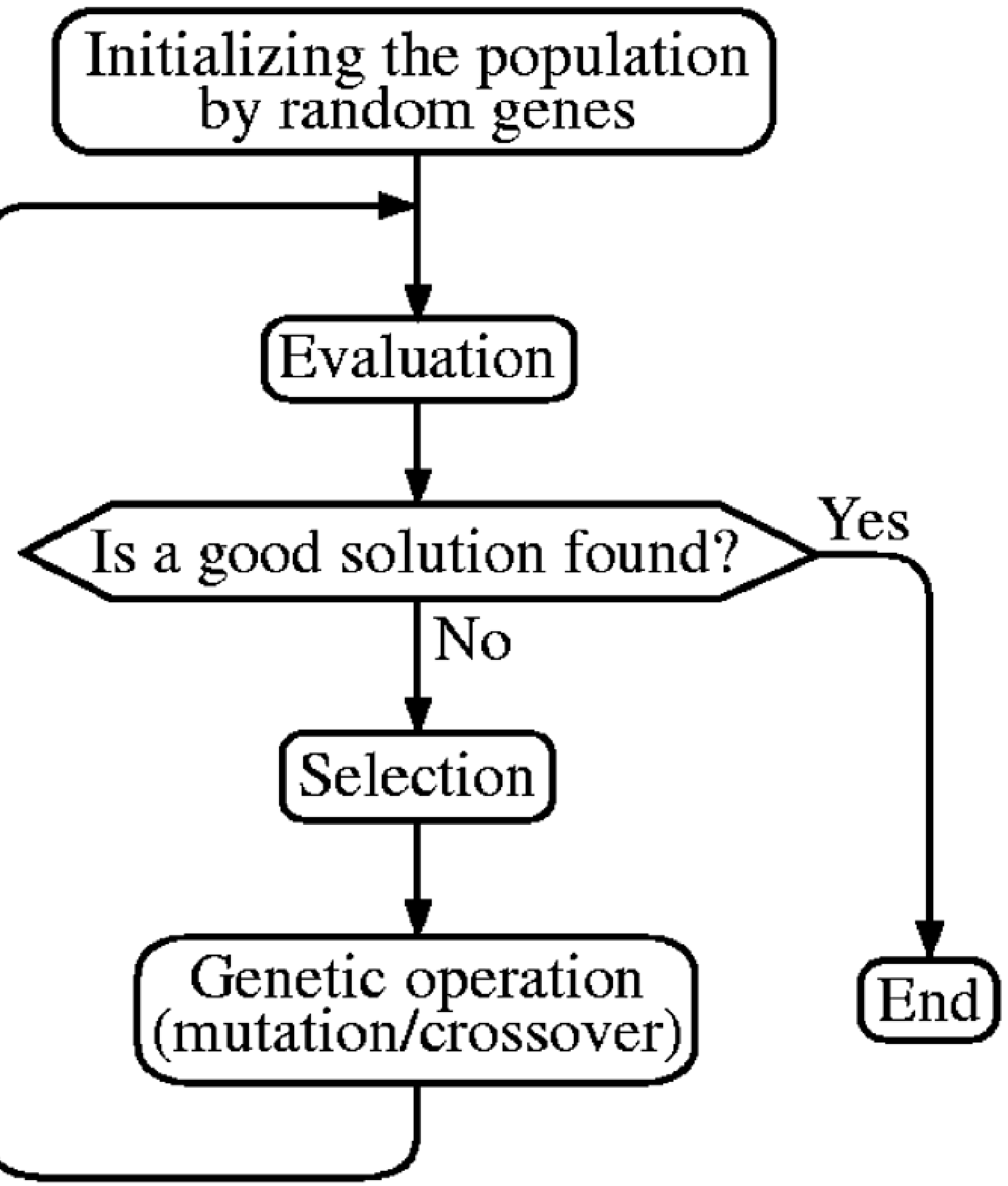



Nature's milestones indicating evolution of the eye.



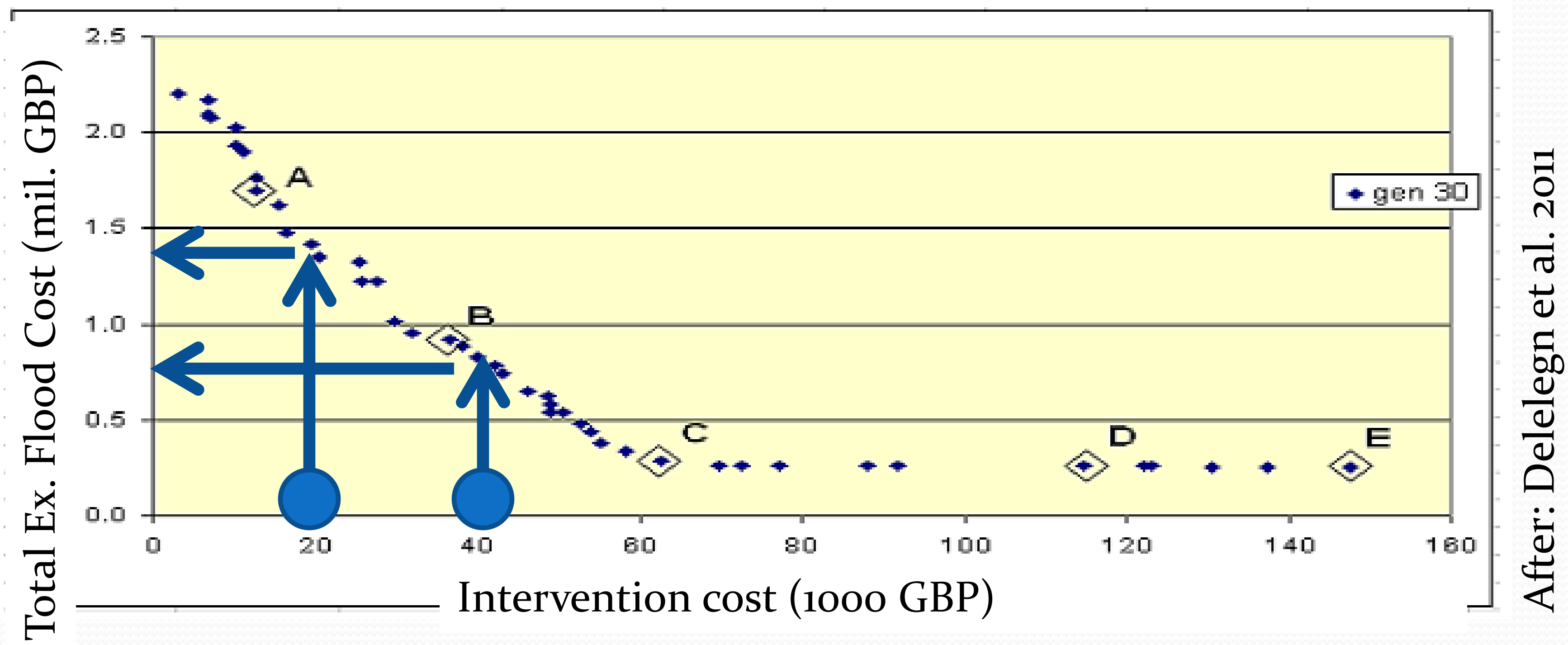
Selection
001111111 A Fast, Resilient
001111101 B Fast, Non-resilient
001101001 C Slow, Resilient
Environment
Predators
Drought
Live and Survive
010001001 Mother
011110111 Father
010110111 Offspring
Breed
Offspring
Recombination and Mutation
010110111 Original
010100111 Mutated

# Genetic Algorithms



# Mutli-Objective Optimization

- What is the minimum expected damage for each level of investment?
- A good negotiation/communication instrument.

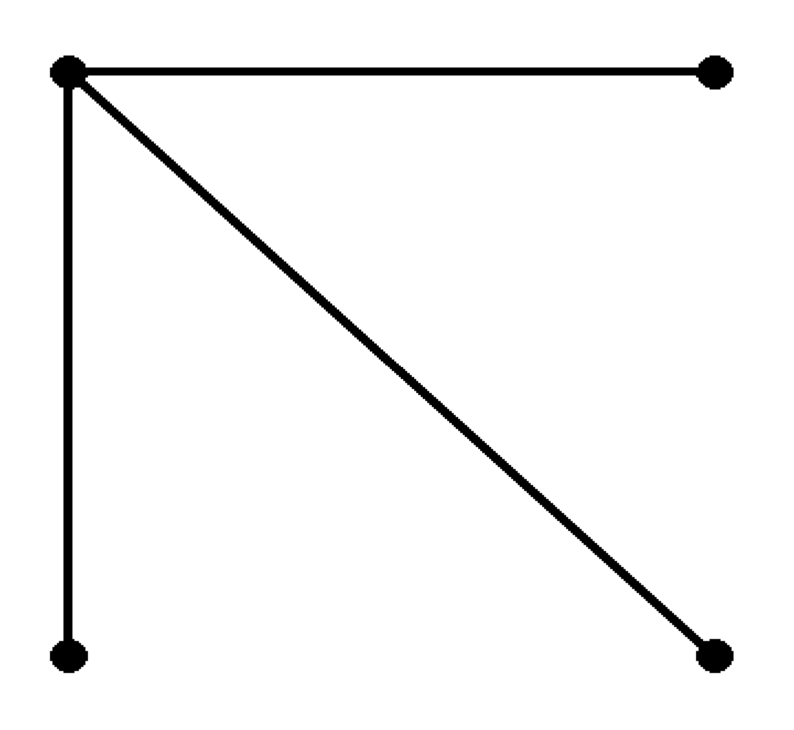


# Dangers of Optimization

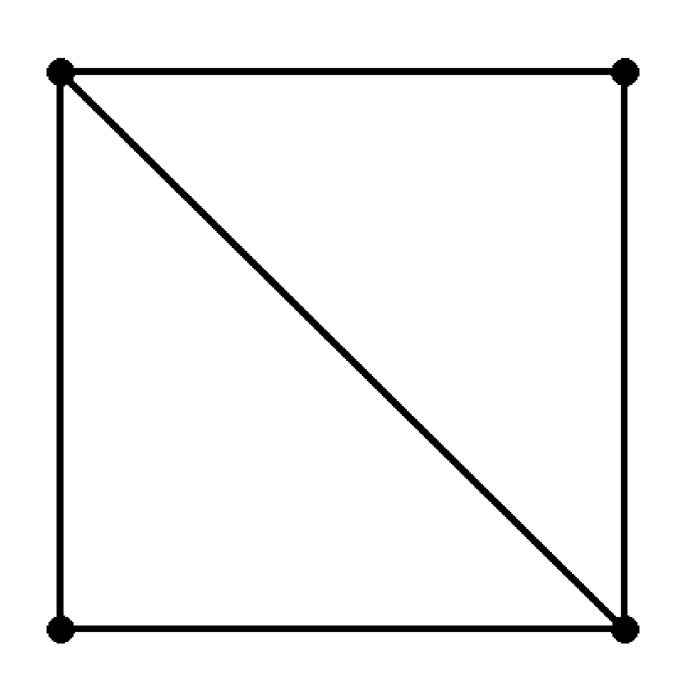
$$optimal = \frac{1}{redundant}$$

# Networks

- Connecting four nodes.



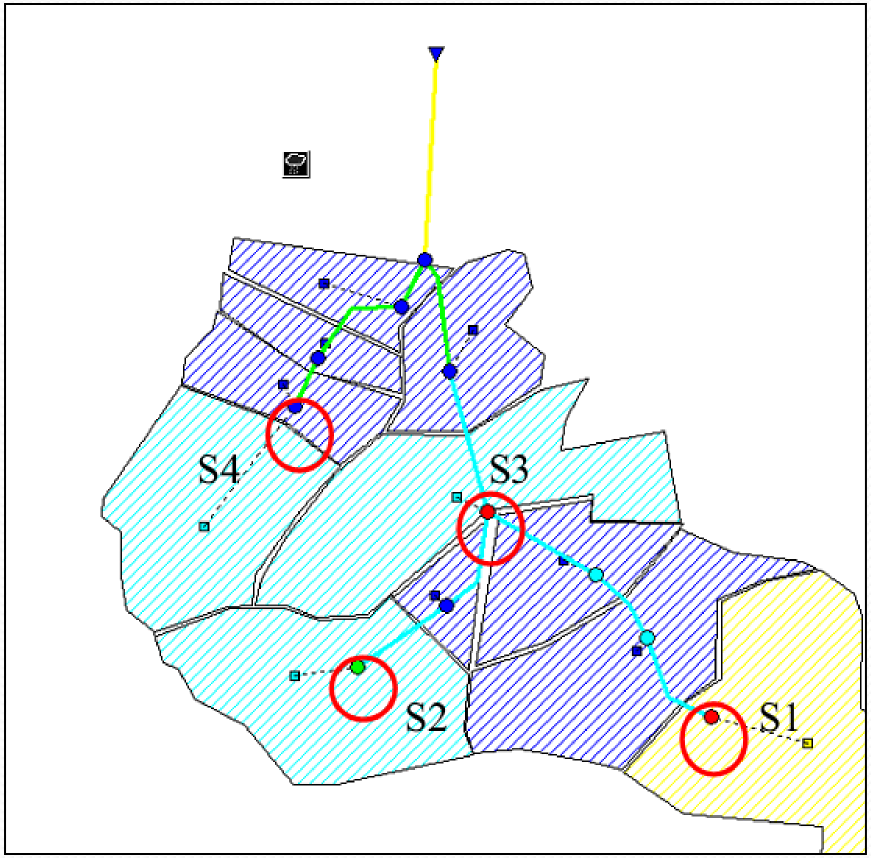
Optimal network. Zero redundancy.



A network with degree of redundancy

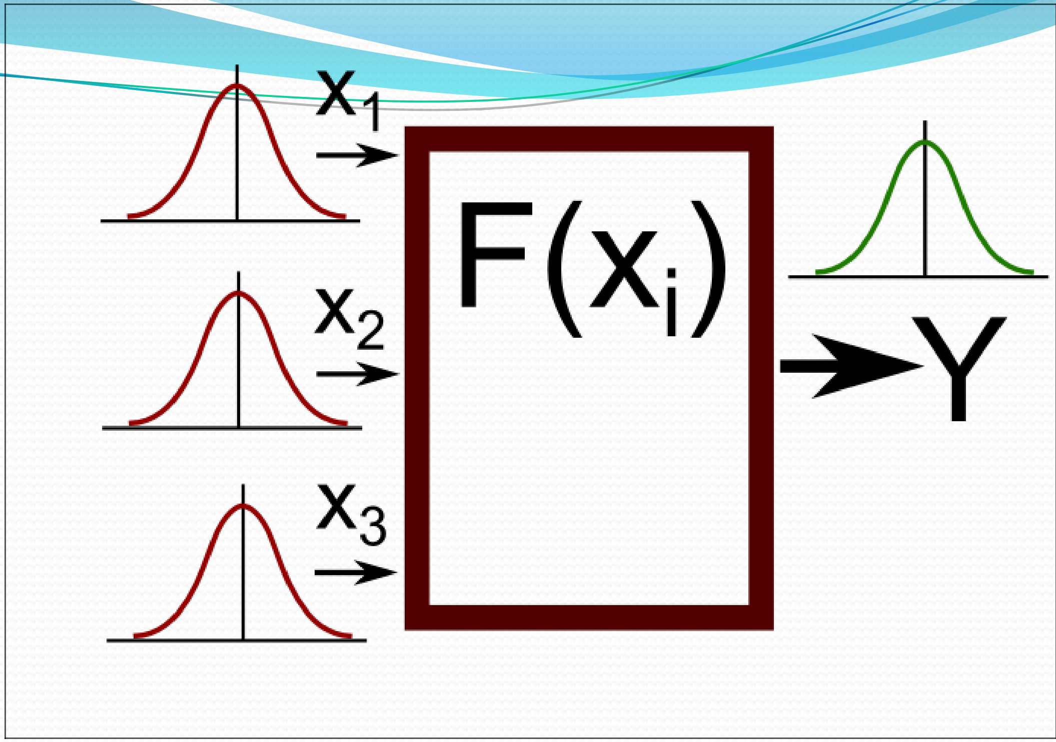
# Problem

- Input parameters uncertain!!!!
- Slight change should not topple over the edge



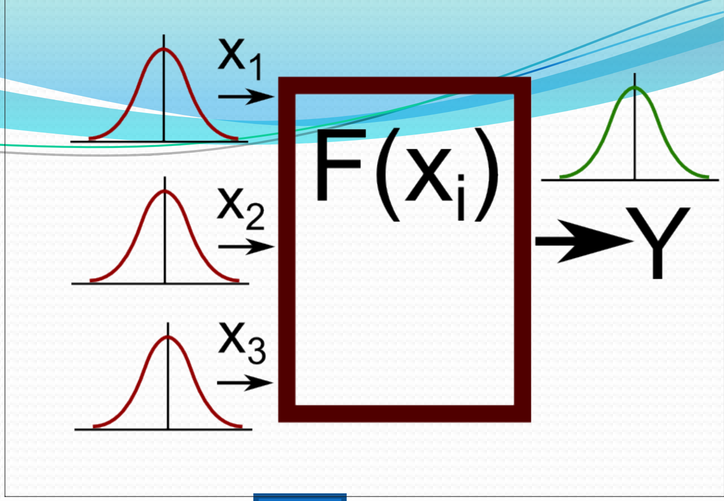
# Traditional Recourse

1. Optimize
2. Apply Factor of Safety (FOS)

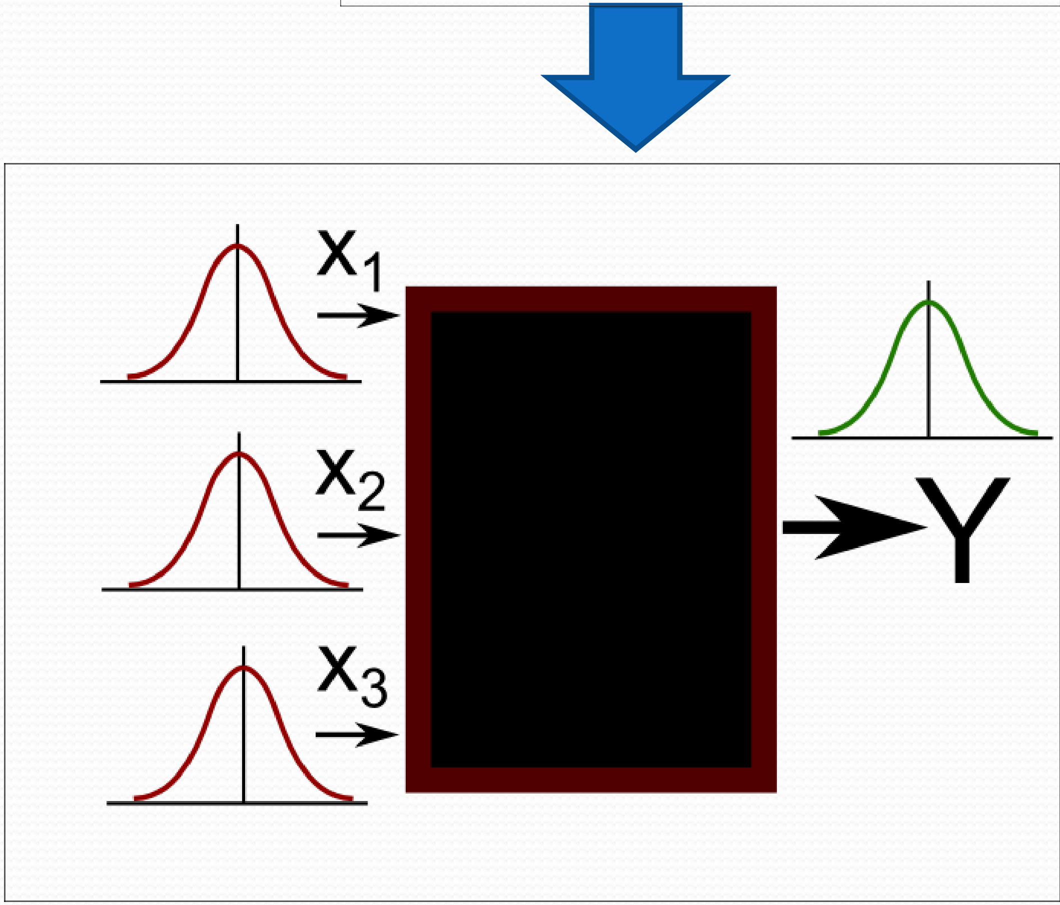



- Fine when ‘model’ is known, and
- … simple.

# Problems with FOS in complex problems.

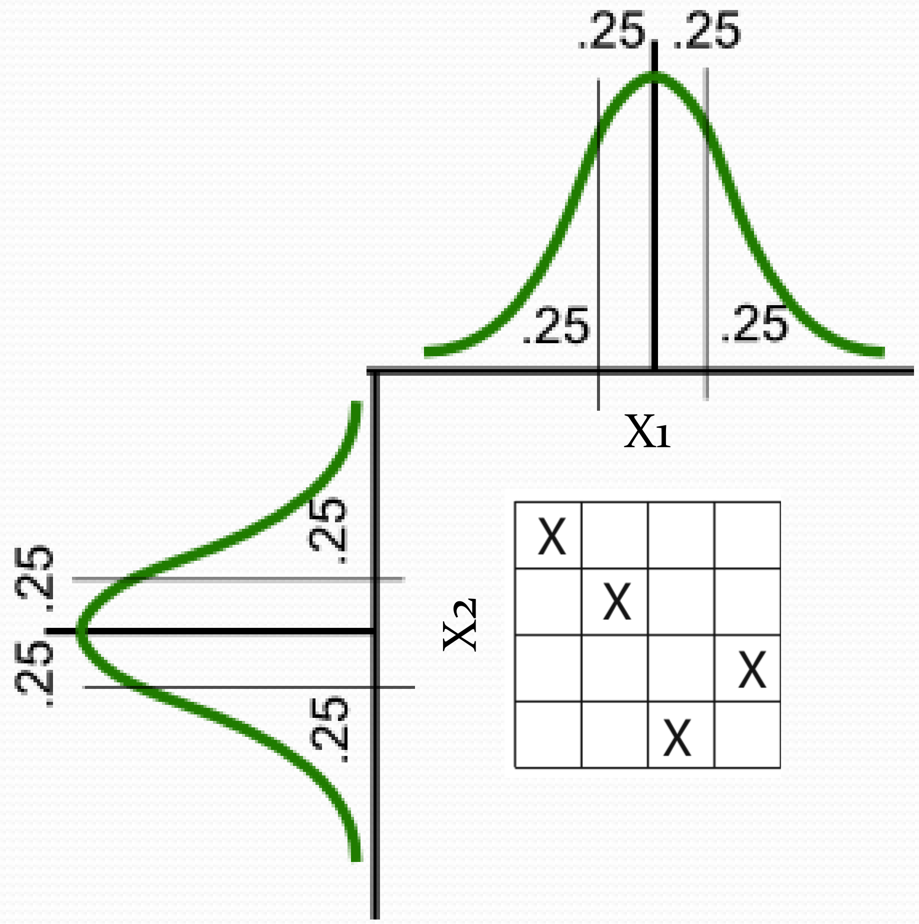



- Arbitrary
- Input uncertainty not linked to FOS.



# Explicitly handling Uncertainty

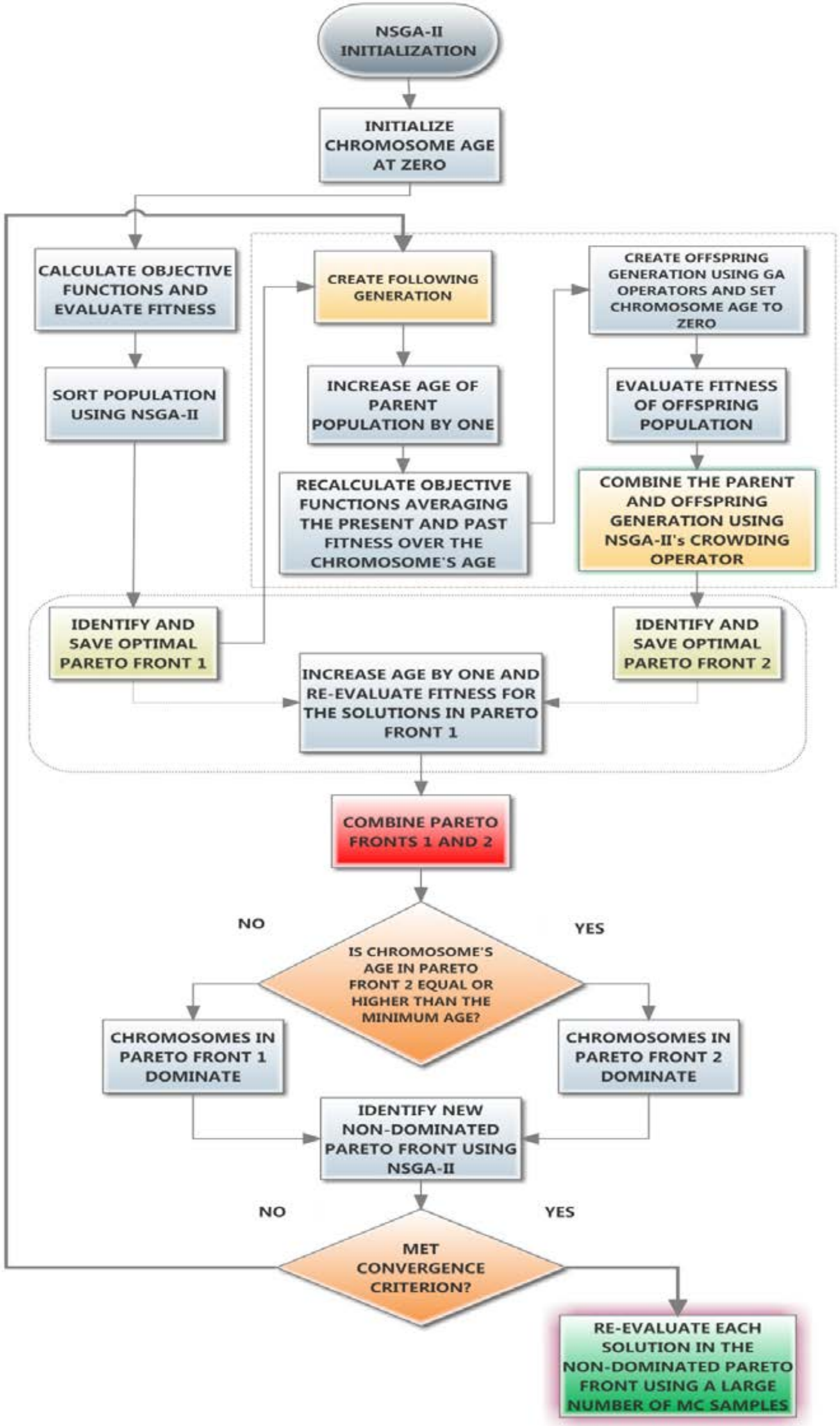
- Monte-Carlo experiments.
  - A number of random samplings of Xi
  - Evaluate Y
- "Robust-Optimization"
- More efficient way of sampling.




Latin Hypercube Sampling (For Efficiency)

# The Algorithm

- Evaluate individual solutions over number of generations.
- To be ‘Fit’ has to survive a minimum number of generations.

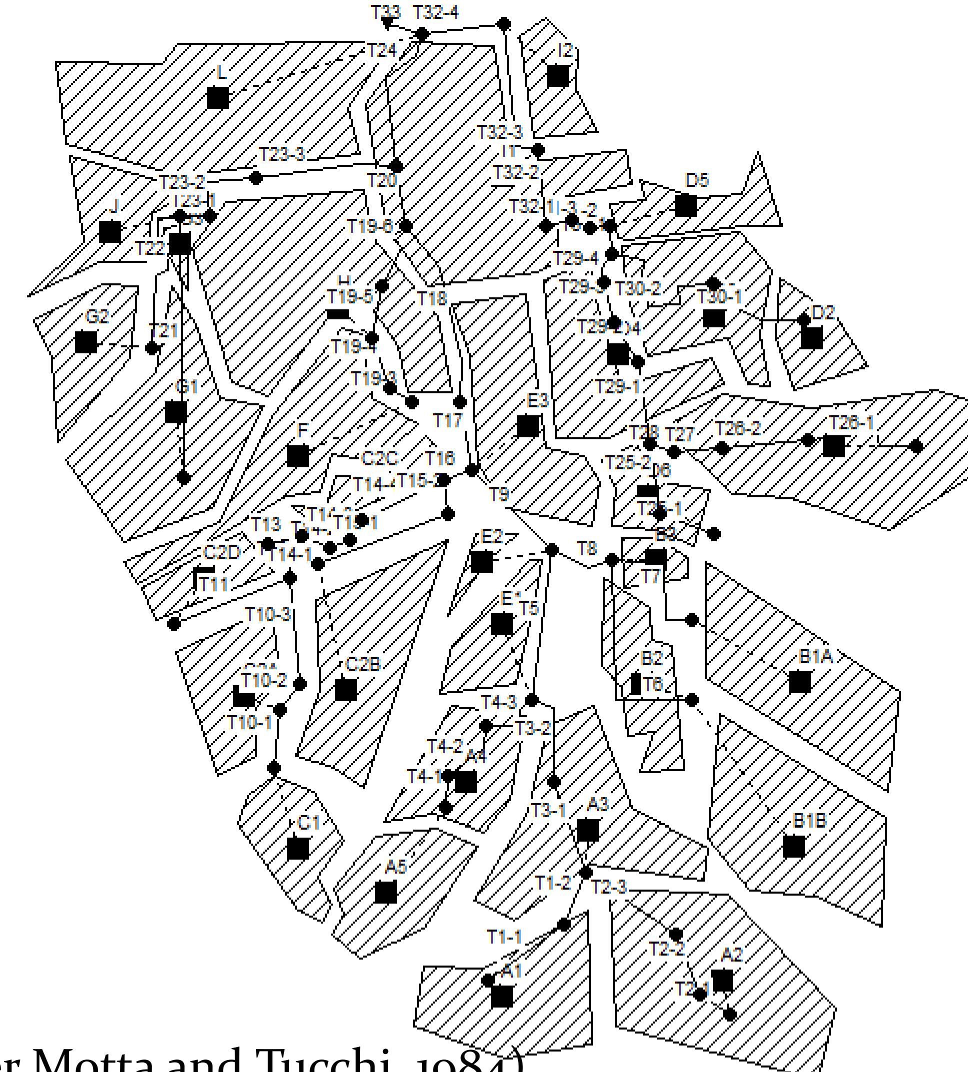


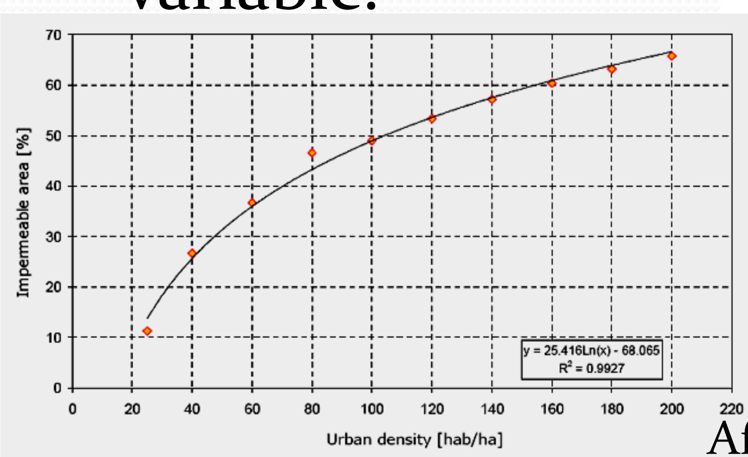
# The case study

# Porto Alegre, Brazil

# Areia Basin

- 35 circular conduits.
- Planning for future.
- Catchment hydrology linked to population density.
- P.D. used as input variable.

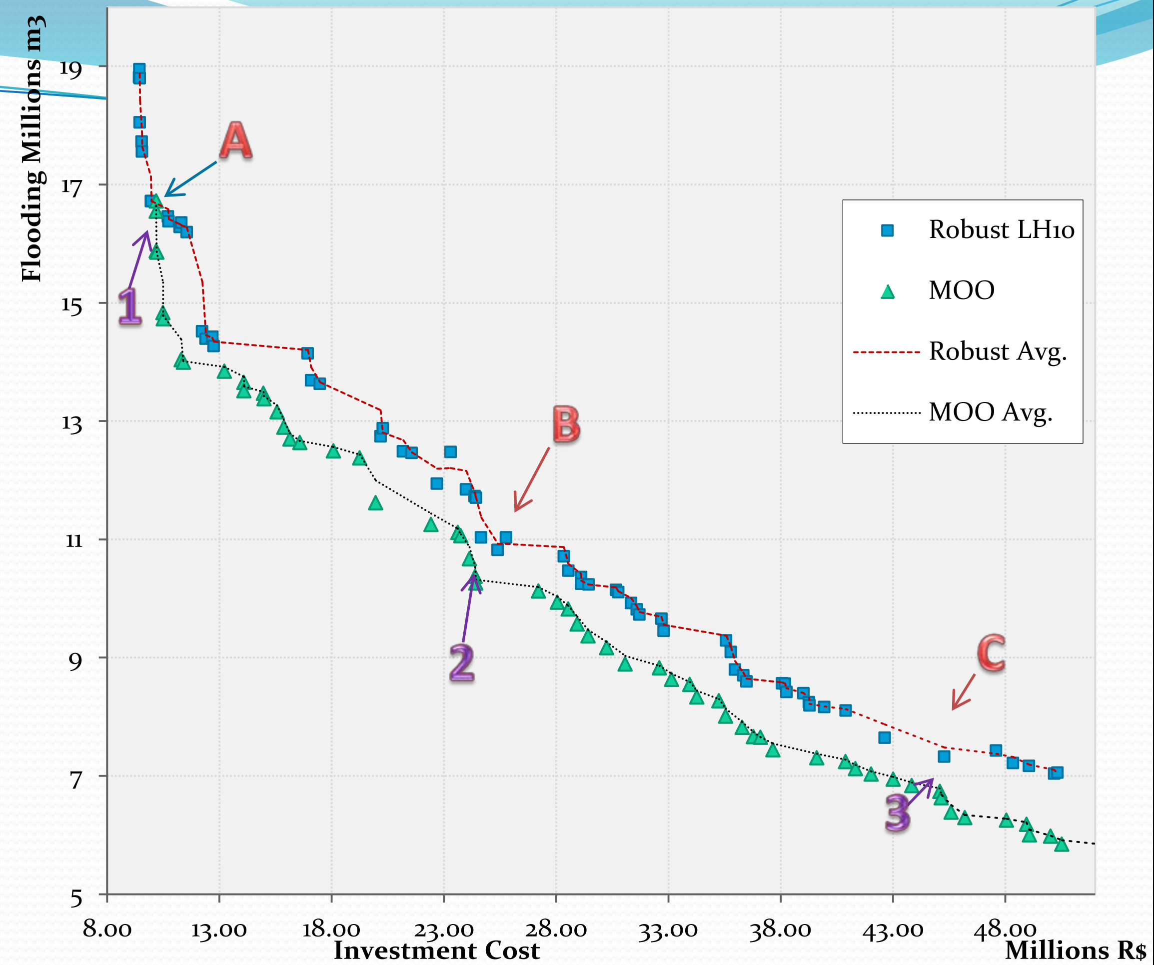



After Motta and Tucchi, 1984)

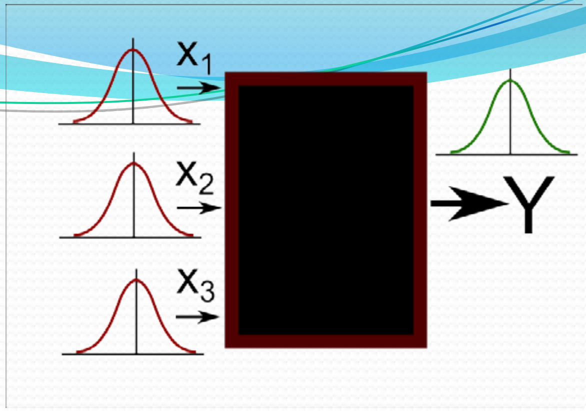
# Results

- Inpt:
  10% uncertainty in PD.
- Robust Optim. Compared with (vanilla) MOO.

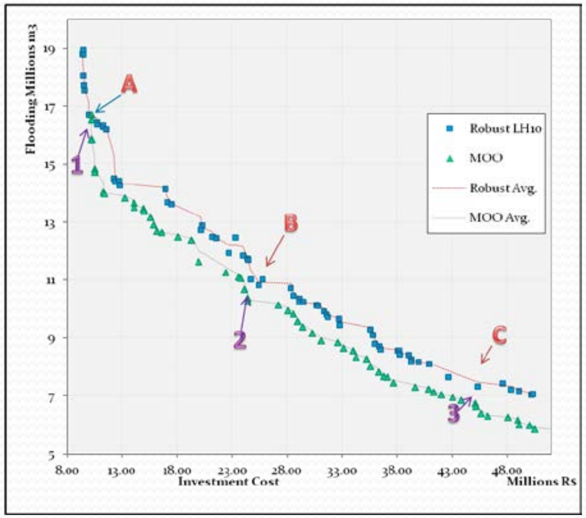



| ROBUST | | | MOO | | |
|---|---|---|---|---|---|
| Point | Cost (R$ Millions) | Flooding ($m^3$) | Point | Cost (R$ Millions) | Flooding ($m^3$) |
| A | 10.710 | 16,453,720 | 1 | 10.180 | 16,549,520 |
| B | 25.403 | 10,815,600 | 2 | 24.387 | 10,376,040 |
| C | 45.284 | 7,322,470 | 3 | 45.087 | 6,735,952 |

# Discussion




- More formal treatment of output uncertainty:
  - Explicitly linked to input
- Feasibility (Computational)
- A lot of scope for future scenario studies.
- Very easy to parallelize (on PC clusters).



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*Thank you!*

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