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# Flexibility versus Robustness What's in a Name?

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## Flexibility versus Robustness

- **Robustness:** the ability of the system to respond to fluctuations in the behavior of its components or its environment with minimal degradation in its performance [Taguchi].
- **Flexibility:** the ability of the system to be actively managed against uncertainty by hedging risk and exploiting upside opportunities in order to maximize a system's value over its lifecycle [inspired by RO literature].


System Characteristic Responding to Uncertainty	Analysis Methods
Robustness	Probabilistic Design
Flexibility	Flexibility in Design

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## Case Study

### Embedding Flexibility in Off-Shore Oil Pipeline Networks Deployment

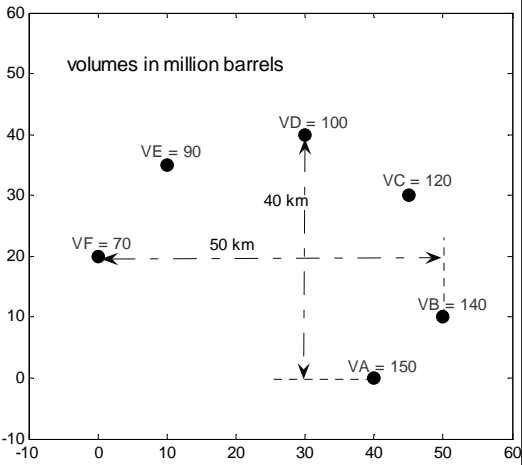


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## Off-Shore Oil Pipeline Networks

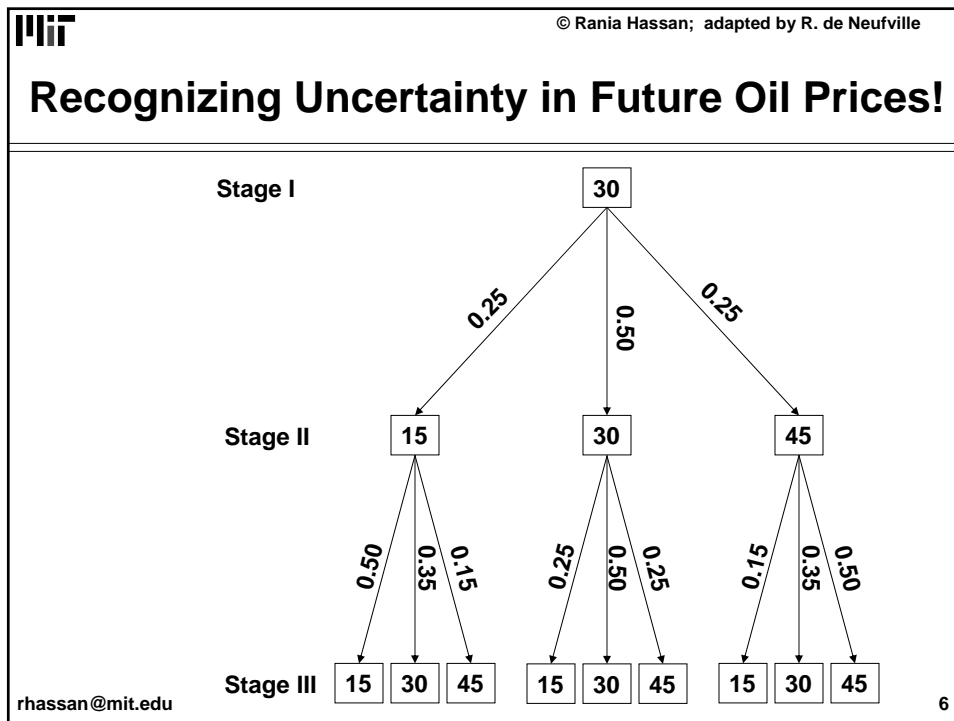
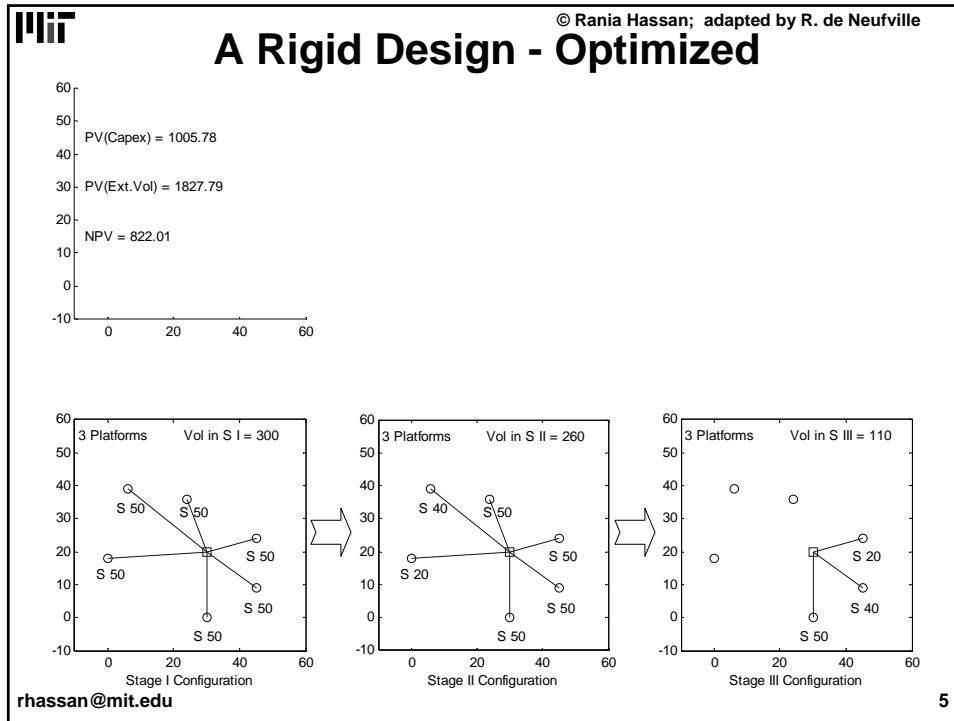
- Maximize NPV
- Determine
  - production facility location
  - pipeline sizes
  - production rates over 3 stages

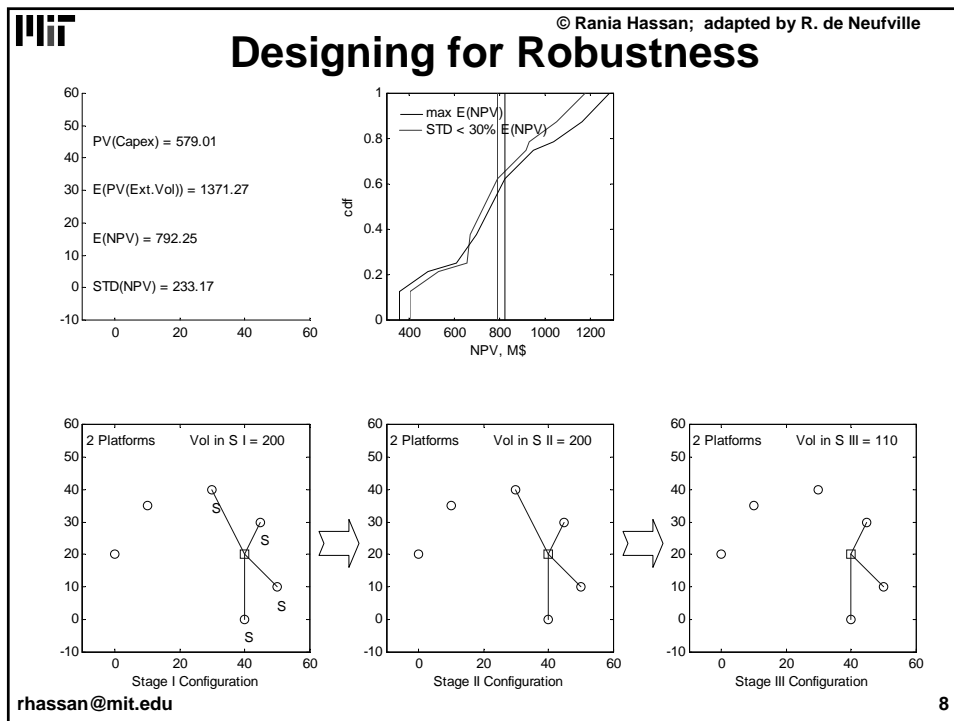
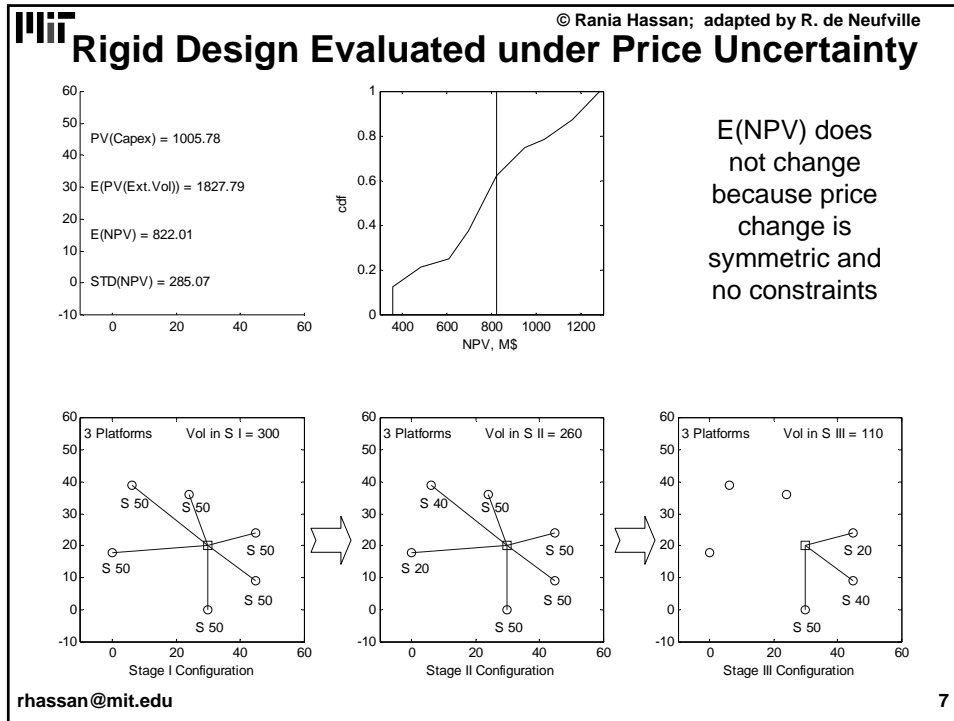


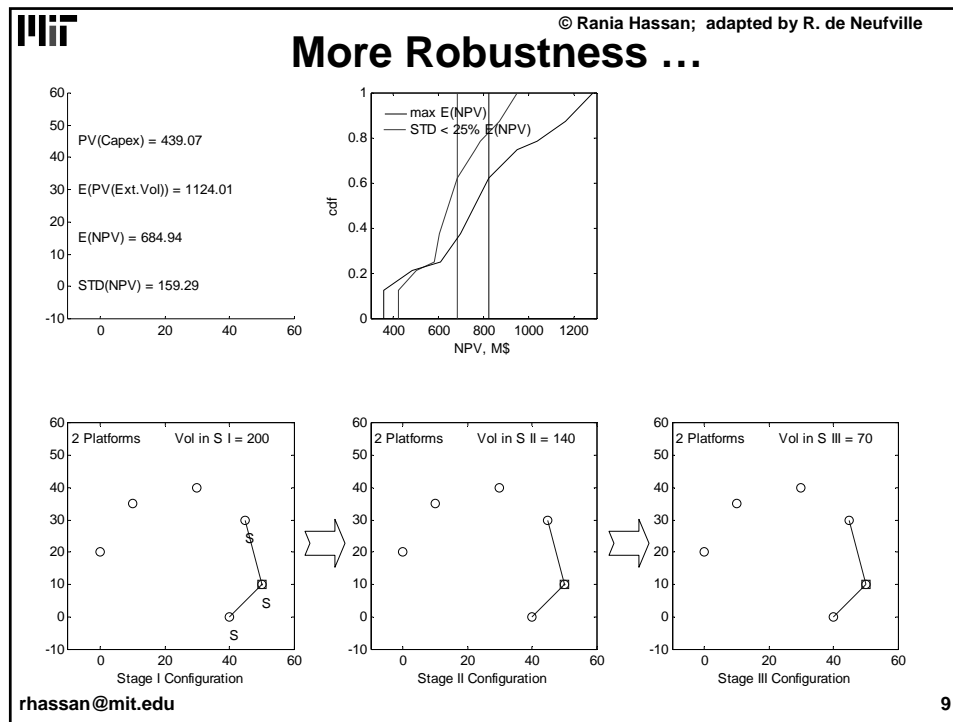
volumes in million barrels

Stage	Volume (million barrels)
VF	70
VE	90
VD	100
VC	120
VB	140
VA	150

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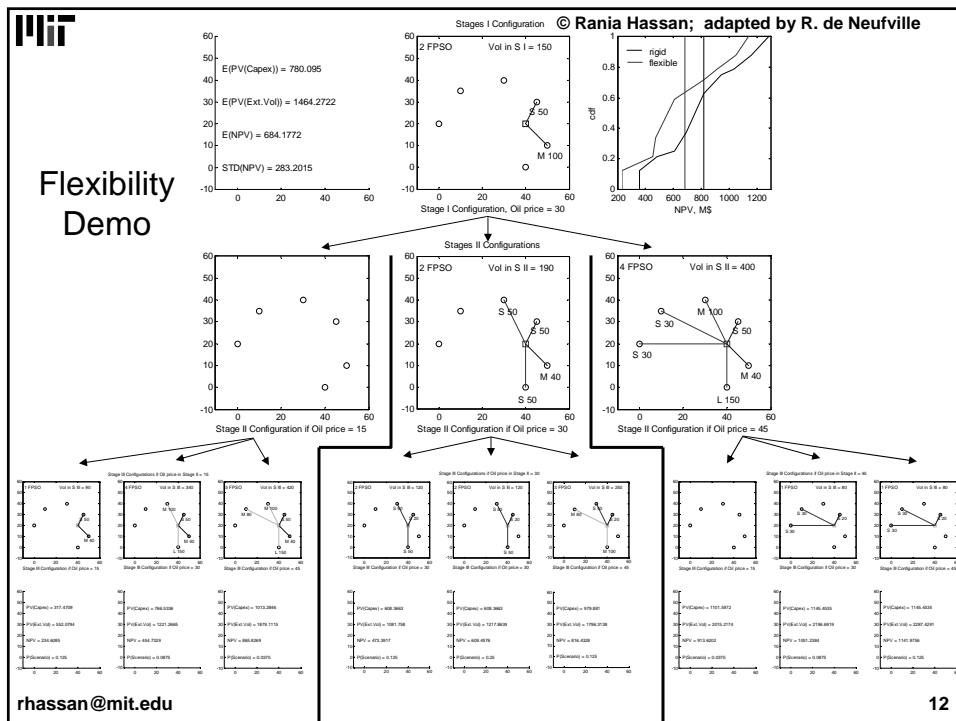
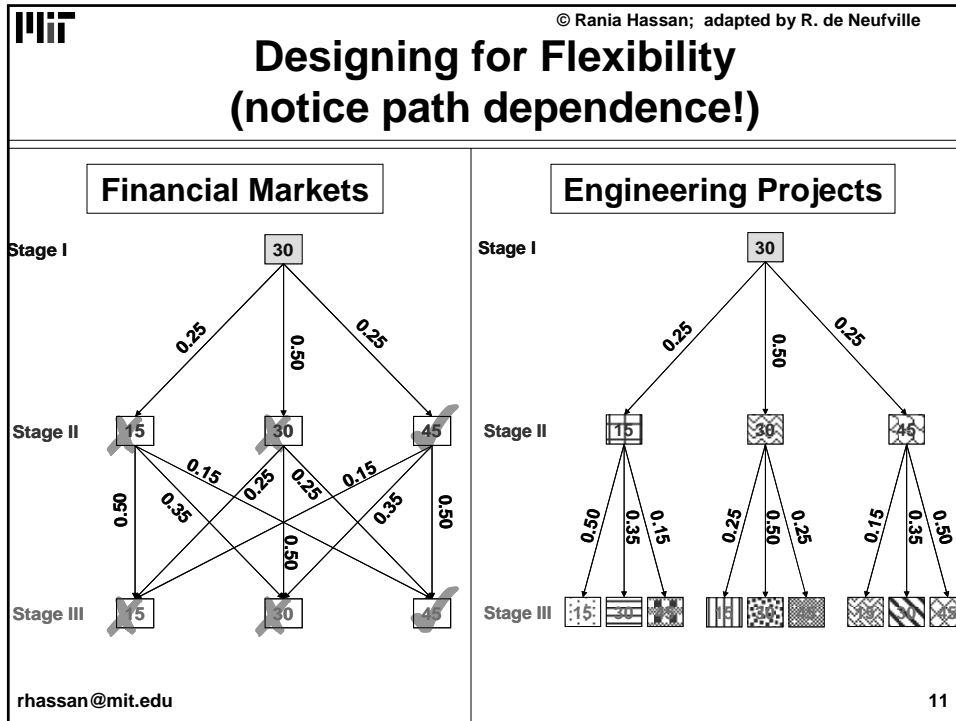


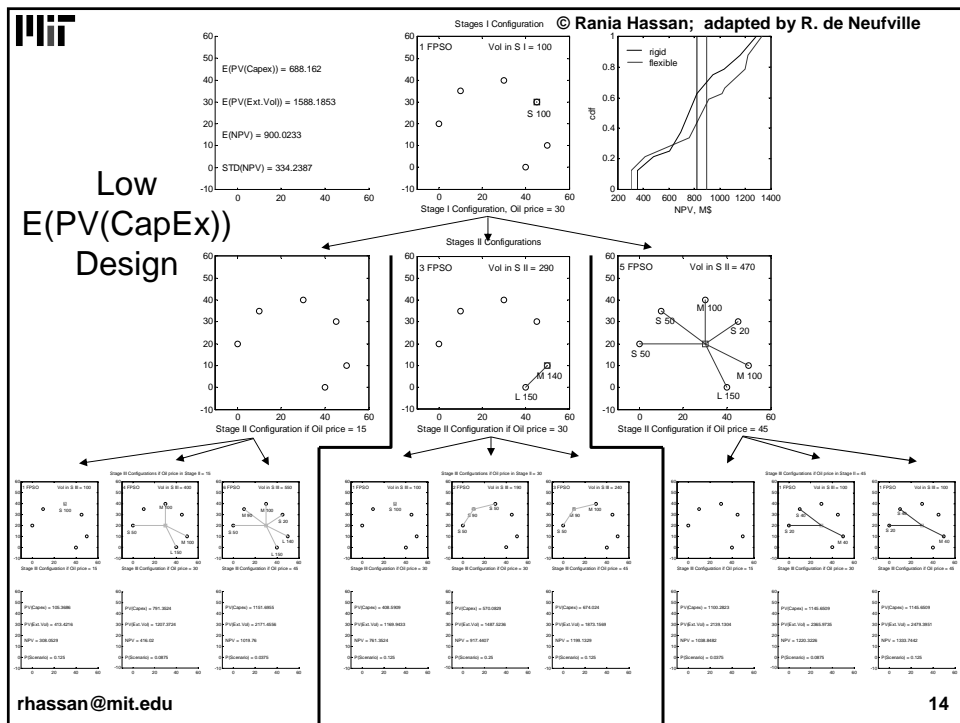
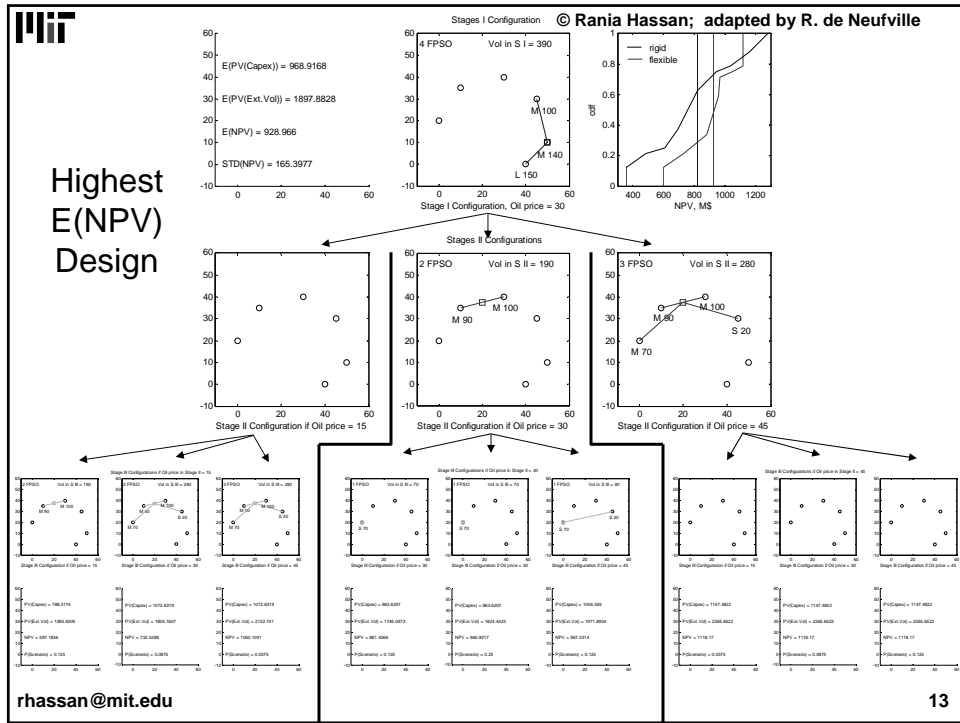
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## Designing for Flexibility

- In financial markets, options have been adopted as proven mechanisms for coping with uncertainty.
- A financial option gives its owner the right, but not the obligation, to take a particular course of action in the future.
- Options provide flexibility in the decision making process with the objective of limiting downside losses while capitalizing on potential upside opportunities.
- “Flexibility” has been emerging as an approach that applies ideas from quantitative finance to engineering projects.

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## Solution Quality

	Rigid	Robust	Flexible I	Flexible II
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Solution Quality for the Uncertain Oil Price Problem Formulation

E(NPV)	822 M\$	695 M\$	929 M\$	900 M\$
STD	285 M\$	159 M\$	165 M\$	334 M\$
E(PV(CapEx))	1006 M\$	579 M\$	969 M\$	688 M\$

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## Recognizing Uncertainty in Reservoir Volume!

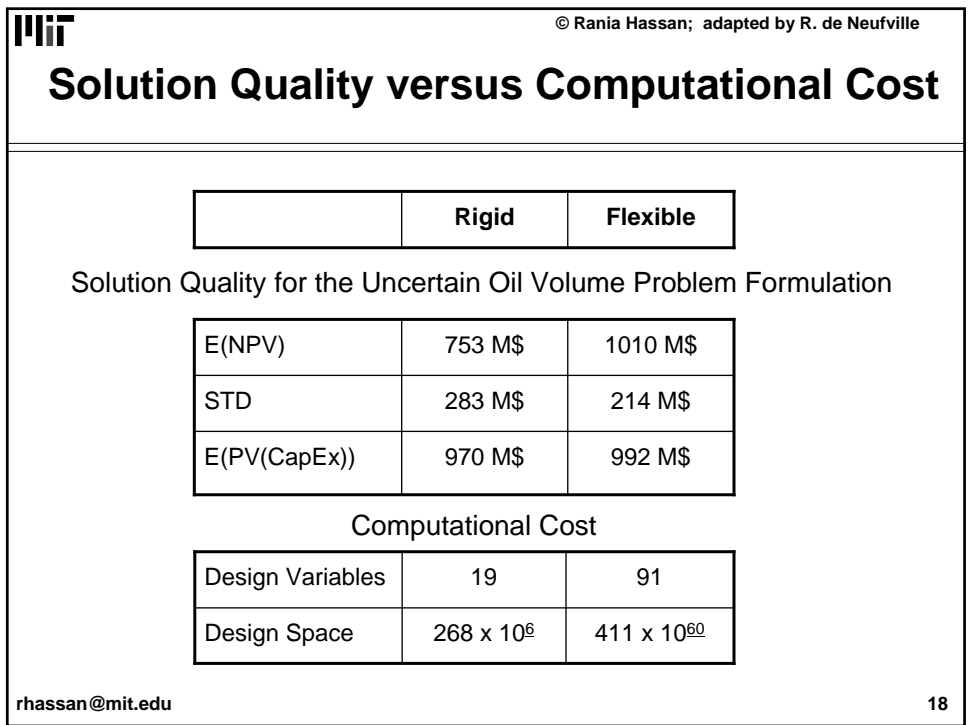
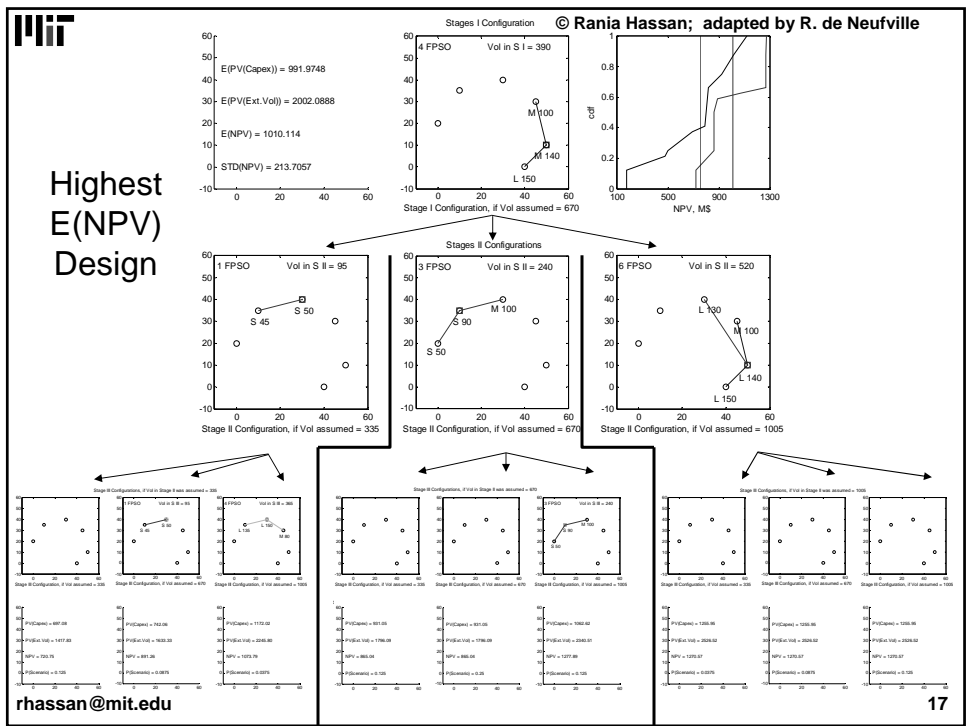
Stage I

Stage II

Stage III

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## Words of Wisdom on Flexibility

- Flexibility is a means, not the objective, which is to improve system performance.
- Flexibility neither means nor is only achievable via staged deployment
- Flexibility is not revenue management in engineering projects
- Traditional financial analysis and valuation approaches, i.e. Black-Scholes formula and derivatives, do not apply to engineering design.
- Target curves offer a simple, transparent, but powerful approach to valuing flexibility in engineering projects.
- Flexible designs do not necessarily require larger initial capital expenditure as compared to rigid designs.
- Flexibility is not the enemy of optimality.

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## Uncertainty Classification

- Robustness: the ability of the system to respond to fluctuations in the behavior of its components or its environment with minimal degradation in its performance [Taguchi].
- Flexibility: the ability of the system to be actively managed against uncertainty by hedging risk and exploiting upside opportunities in order to maximize a system's value over its lifecycle [inspired by RO literature].

**Flexibility = Active Robustness**

Type of Uncertainty	System Characteristic Responding to Uncertainty
Static	Robustness
Dynamic	Flexibility

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