Engineering Options Analysis for Infrastructure Decision-Making

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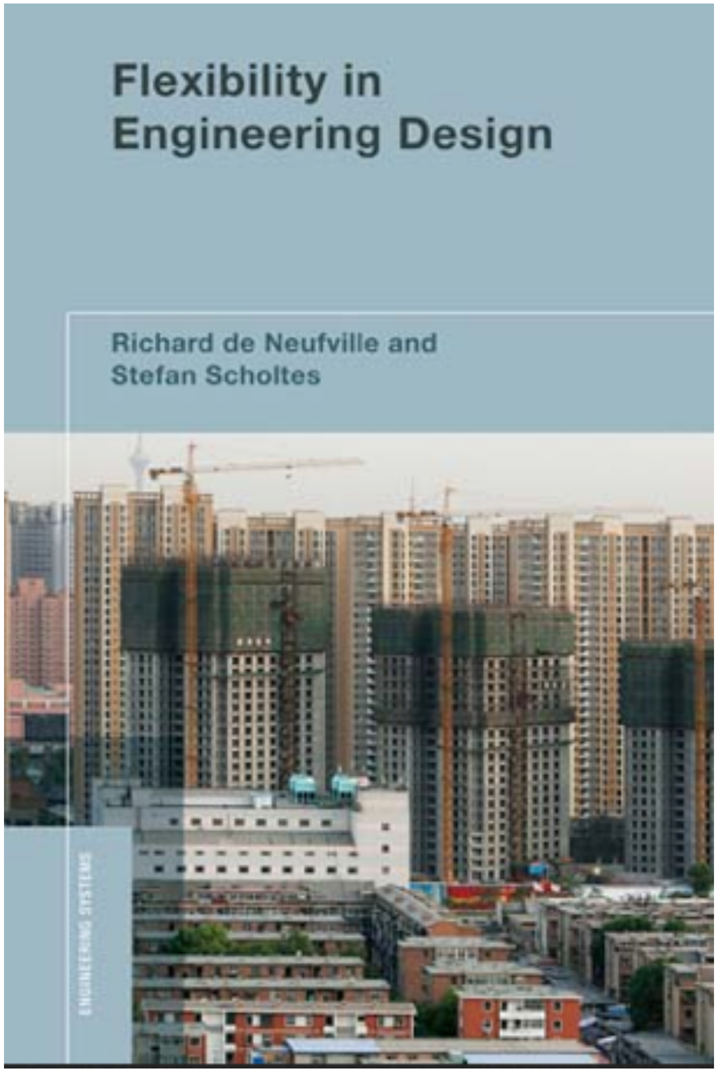
Texts on Flexibility in Design



MIT Press, 2011

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Wiley Blackwell 2018

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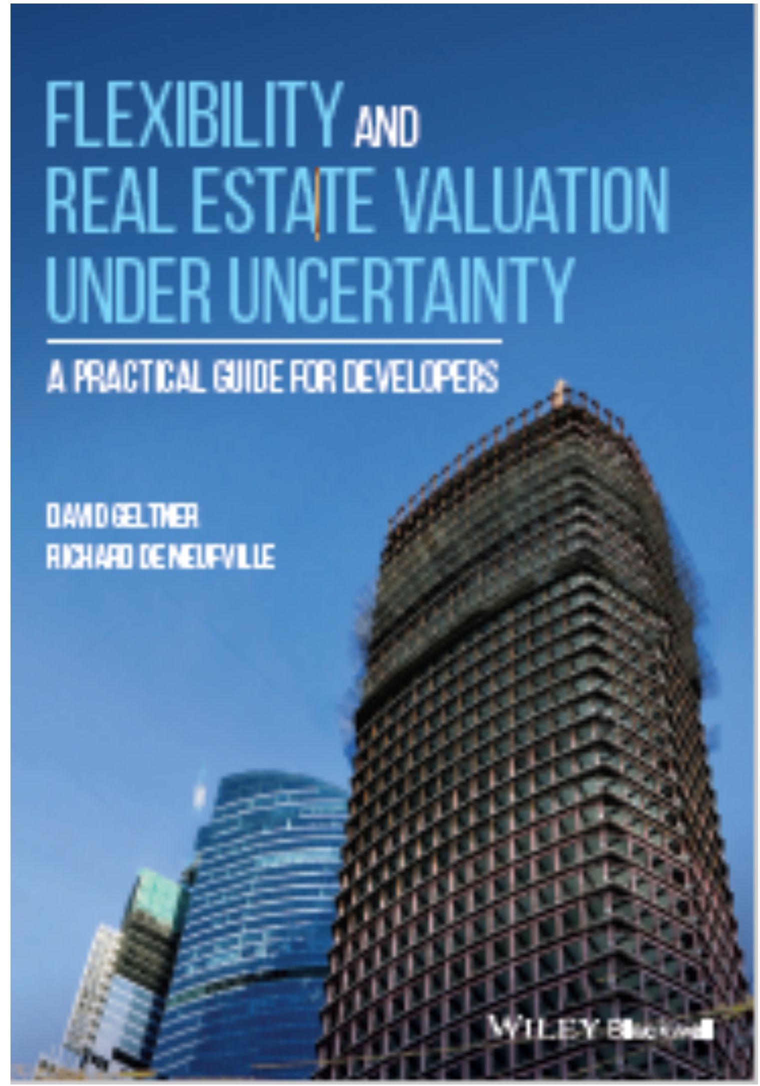

Preliminary: Options and Risk

- **Option in this context:**
- **"Right but not obligation to do something"**
  - Technical Meaning – not "Alternative"
  - 'Insurance' a "put" to mitigate bad outcome
  - A "call" to take advantage of opportunities,

- **Uncertainty ≠ Risk, bad outcomes!**
  - Often means opportunities!!
  - START-UPS, NEW TECHNOLOGIES
  - UNEXPECTED FAVORABLE GROWTH…

Flexibility in Infrastructure Design

Examples of Flexibility as "options = right but not obligation" to change or adapt:

- Spare tire for automobile (a "put")
- Ports on laptop computers (a "call")

Many infrastructure examples…

Expandable Dam

File:Ross Dam USACE 20031022.jpg

From Wikipedia, the free encyclopedia

Ross Hydropower Dam, Washington State, USA

Designed so it could be made 42 m higher

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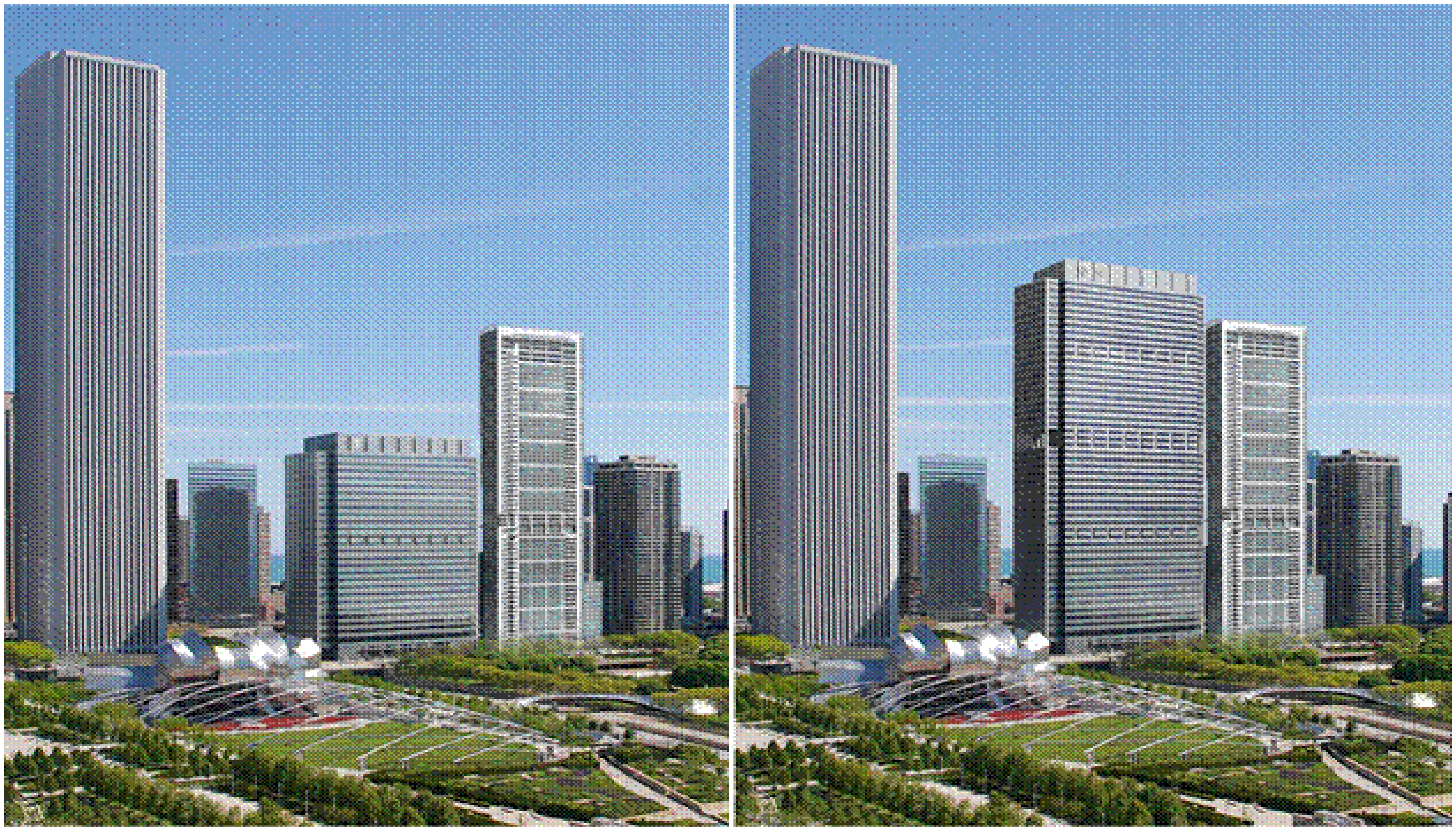
HCSC Building in Chicago



Vertical Expansion of Health Care Service Corporation Building, Chicago. Phase 1 (left) and Phase 2 (right) in center of image.

Source: Goettsch Partners, 2008 and Pearson and Wittels, 2008.

Engineering Options Analysis

1. Flexibility in Design is the Objective – ability to adapt infrastructure to events
   Which Options are Desirable?
2. Engineering Options Analysis (EOA) as Means to explore this issue
3. EOA not same as Financial Real Options
4. Example: LNG Plant in Australia

Engineering Options Analysis Steps

1. **Recognition of Uncertainty** …
   and its general characterization

2. **Simulation** of Performance for Range of Scenarios => Distributions of Performance

3. **Evaluation**… necessarily multi-dimensional, one number not enough to describe a distribution

4. Result: **Strategy Guidance** about which Planning and Design options desirable

Recognition of Uncertainty

- Best estimates of established trends and procedures – what is the record? Error rate? Standard deviation?
- Judgment about important, possible but unprecedented scenarios. For example, new environmental regulations, technological change, mergers of competitors, etc.

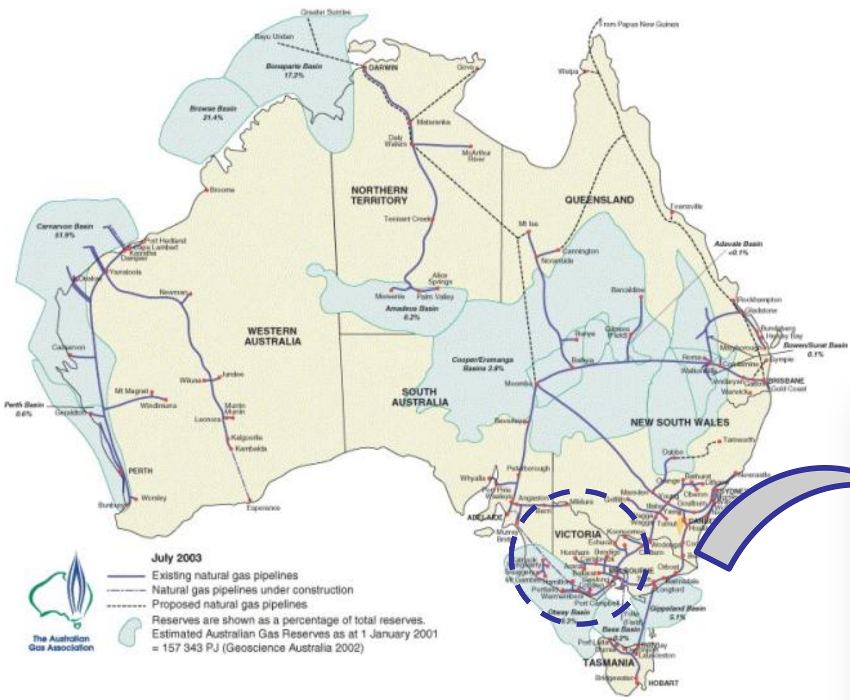
Evaluation

- Analysis results are distributions
  - This is as it should be; if future is a distribution, results must be also
- Evaluation must be multi-dimensional
  - Because several numbers needed to characterize distributions
- Multi-dimensional metrics
  - Average expectation
  - Extremes such as P_5 , P_{95}
  - Others: Initial Capex (capital expenditure)

Engineering vs. Real Options Analysis

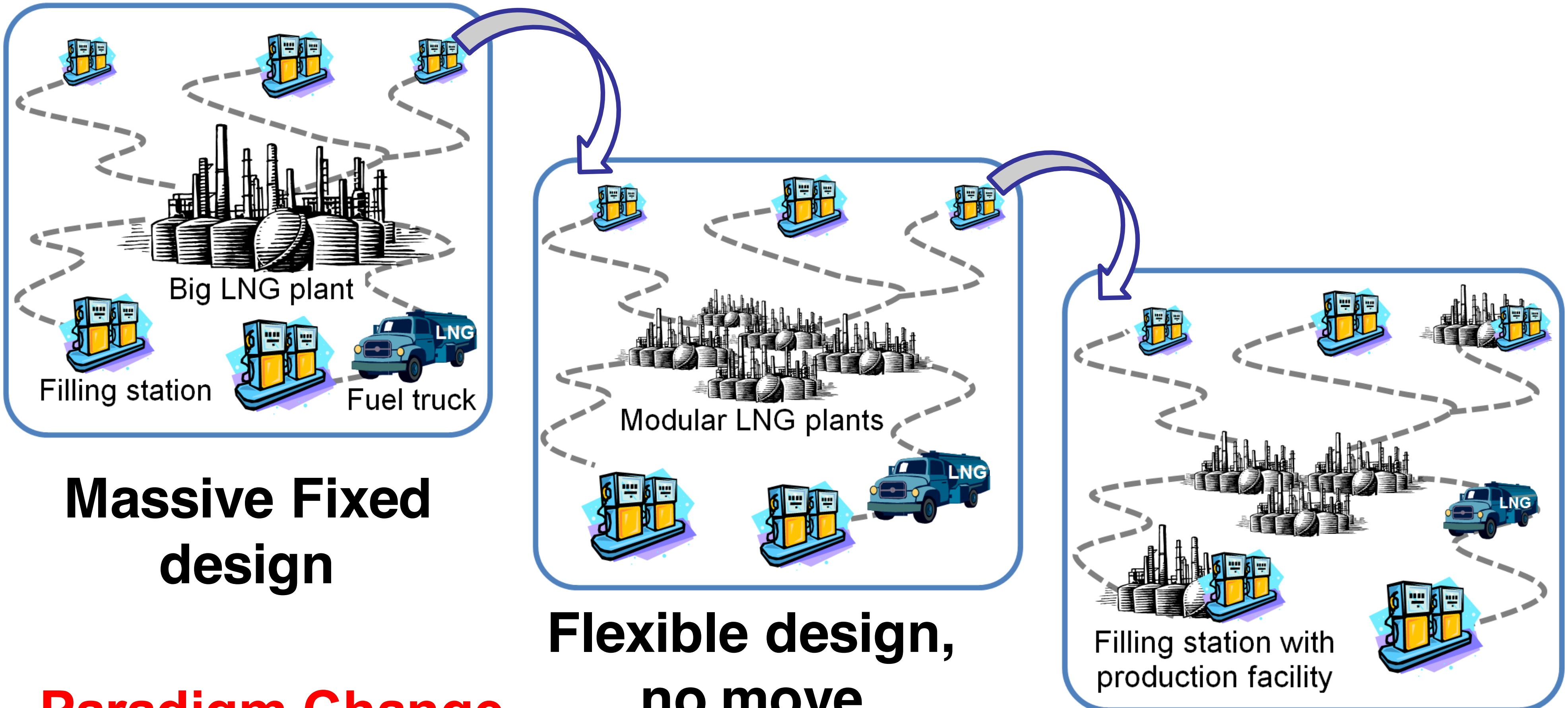
Characteristics		Engineering Options	Financial Real Options
Analysis Basis		Simulation	Optimization
Options	Number	Many	1
Uncertainty	Distribution	Any	Random Walk, etc.
	Assumptions	Can vary over time	Past defines future
Quantitative Results	Types	Distributions	1: Price
	Dimensions	Many	1
Qualitative Results	D - Makers	Can choose	No choice
	Guidance	Strategy	Buy or not

Example: LNG Plant in Australia



South east Australia

LNG system: from Massive Fixed to Flexible via Timing, Size, and Location



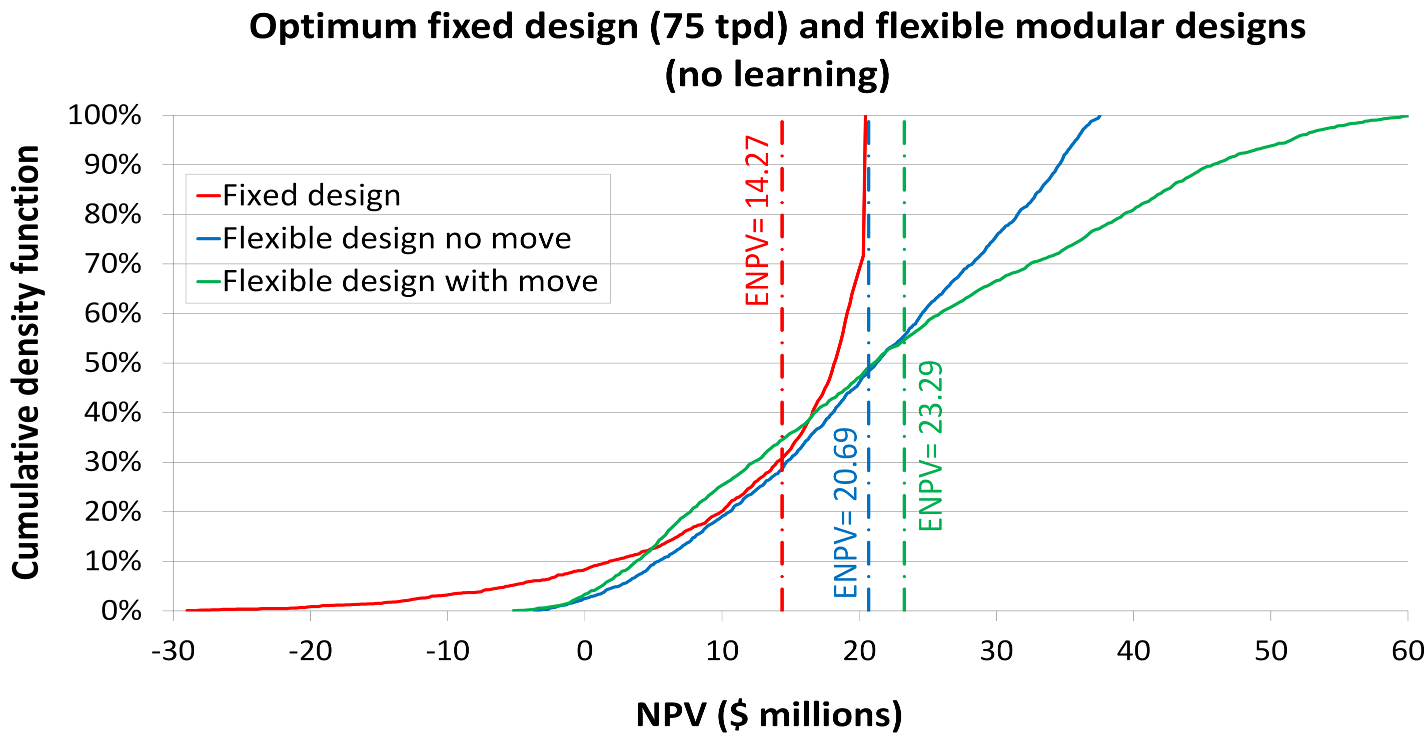
Massive Fixed design

Flexible design, no move

Flexible design with move

Paradigm Change For Engineers !

Flexible modular design outperforms fixed design: less downside, more upside, less initial Capex



Criterion	ENPV Value ($ millions)			Improvement (%)	
	Optimum fixed design	Flexible no move	Flexible with move	Flexible no move	Flexible with move
ENPV	14.27	20.69	23.29	45	63
$VaR_{10\%}$	1.82	5.40	3.74	197	105
$VaG_{90\%}$	20.46	34.54	45.78	69	124

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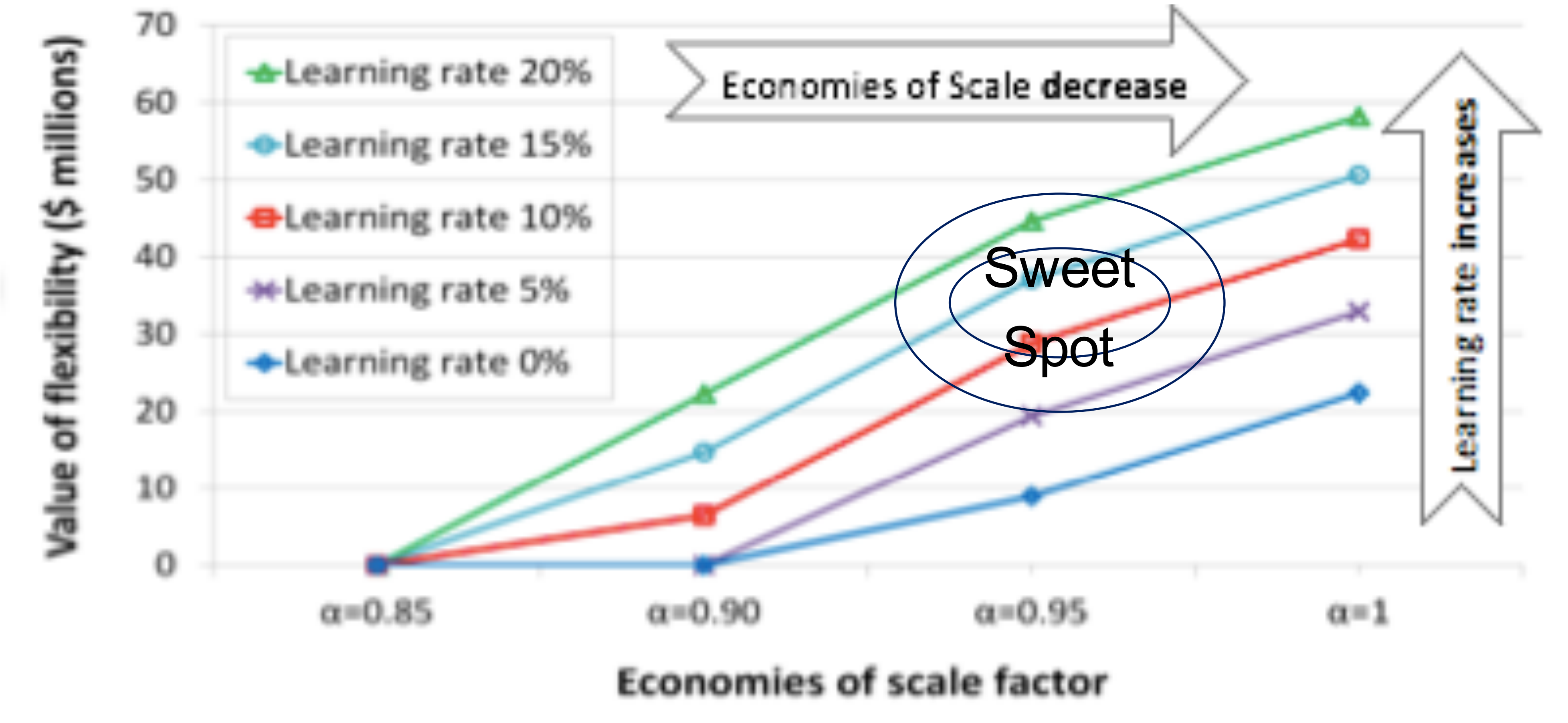
Multi-criteria decision-making table

Flexibility Value =
max[0, (ENPV of flexible design)
– (ENPV of fixed design)]

Criterion	Fixed design	No move option	Move option	Value of flexibility	Best design
ENPV	14.27	36.93	**43.17**	28.80	Move
VaR, 10%	1.82	10.82	**11.06**	9.24	Move
VaG, 90%	20.46	63.17	**80.09**	59.63	Move
STD	**8.78**	18.91	25.31	0.00	Fixed
Capex	60.44	**27.50**	**27.50**	32.94	Flexible

Value of flexibility sensitivity to economies of scale and learning rates



Engineering Options Analysis => Strategy Guidance

- **Indicates good first move (smaller design)**
- **Enables future flexible moves**
  - Timing, Size, Location of expansion, as desirable
  - Takes effort to create option (ports on computers)
- **Does not require precise numbers**
  - Future is uncertain, Forecasts 'always' wrong
- **Efficient, automated computation process**

Comparable to playing expert chess –
Consider range of moves, only commit to first