Garage Case: Concepts

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Background

The "garage case" is a prototype example that presents the essential parts of the course.

The technology is simple enough so we can see through it and gain insights into the how flexibility in design increases expected value

Presentation in two parts

First presentation focuses on concepts
The emphasis is on:
How flexibility paradigm is different;
Why flexibility increases expected value;
How to implement effectively.

The second presentation (next session) examines the details of the analysis

Outline of Concepts lecture

1: Motivation: examples of real cases
- => HCSC building, Tufts Dental School, etc

2: The Case itself
- => Logic of Analysis; description of case
- => Analysis Structure and Results

3: Interpretation of Results
- => Better quantitatively and qualitatively
- => "win-win" solution

4: Implementation Issues

1. Motivation

1: The Garage Case is representative of a broad class of architectural designs

=> HCSC building, Tufts Dental School, etc

2: Health Care Services Corporation Bldg. in Chicago

3: Tufts Dental School in downtown Boston

4: Major Bridges: George Washington, NYC

Ponte 26 de Abril, Lisbon, Portugal

5: Parking Structure, Blue Water Mall, UK

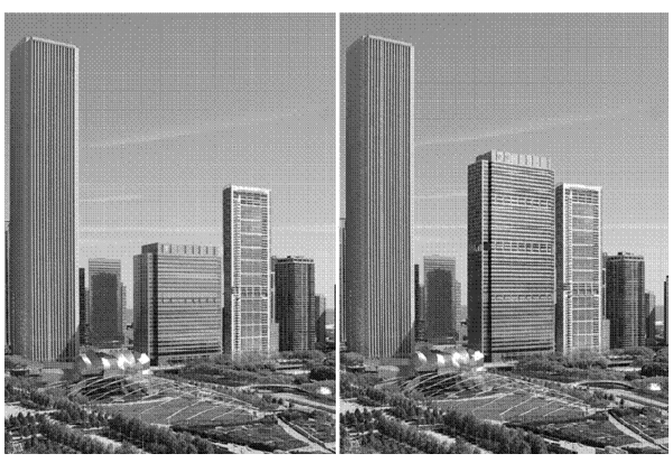
References on web site

- "Vertical Phasing as a Corporate Real Estate Strategy and Design Option", A. Guma, J. Pearson, K. Wittels, R. de Neufville, and D. Geltner, Journal of Corporate Real Estate, Vol. 11, no. 3, pp. 144-157, 2009.
- A. Guma thesis
- J. Pearson and K. Wittels thesis

HCSC Building

- Original Building erected in 1997 with 30 stories
- 27 storey expansion for 2010
- Original design had to have
  - Strength to carry double load
  - Empty space for possible future elevators
  - Planning permission from City, etc.
- 2.3 Million Sq.ft., 2nd largest in Chicago after Sears tower

Before and after picture



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

Tufts Dental School

- 10 storey building completed in 1973
- But School knew it would want more and built in structural strength
- 5 storey addition ready for 2010
- Construction on top of building in middle of city obviously problematic
- Can be seen in downtown Boston, behind theater district

Ponte 26 de Abril, Lisbon

- Built under dictatorship, 1966
  - With strength for second deck, allowances for possible rail service (pre-built station)
- Situation 30 years later very different
  - Portugal is in European Union
  - Receives money from community, especially for Metro
  - New Conditions lead to new solutions, within flexible framework

25 de Abril Bridge, Lisbon

Sources:
Estudio Mario Novais

Biblioteca de Arte-Fundação Calouste Gulbenkian

Photo c 1966

25 de Abril Bridge in 2009

de Neufville photo

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Blue Water Shopping Mall, UK

- Blue Water one of biggest in UK,
- Southeast of London, in Kent
- Parking facility made of precast reinforced concrete
- Built for possible addition of several extra levels
- Could be expanded rapidly using precast columns, panels

Take-away from these cases

- Vertical phasing of major facilities is a serious business
- Practical, not "academic" idea
- Therefore
  - Although "garage case" is simple, for clarity of presentation.
  - It is definitely not simple-minded!

2. Garage Case

Reference on web:

"Valuing Options by Spreadsheet: Parking Garage Case Example," R. de Neufville, S. Scholtes, and T. Wang, Am. Soc. of Civil Engineers, Journal of Infrastructure Systems, Vol.12, no.2, pp. 107-111, 2006

Logic of Analysis

- **Consider engineering base case design**
  - **for fixed objective (mission or specifications)** i
- **Recognize reality of uncertainty**
  - **different values, due to system non-linearities**
  - **Different designs are also possible, likely**
- **Incorporate flexibility**
  - **A design with high expected value**
  - **Avoids downside losses, takes opportunities**
  - **Win-win solutions**

Parking Garage Case

- Major garage serving mega-mall
- Actual demand necessarily uncertain:
  - Population growth, demographics speculative
  - Mall success chancy (in case of Blue Water, a major competitor opened up nearby)
  - Competition from other parking facilities
- Engineering design assumes a fixed forecast

Parking Garage Case details

- Demand
  - At start is for 750 spaces
  - Over next 10 years is expected to rise exponentially by another 750 spaces
  - After year 10 may be 250 more spaces
- Annual revenue/space used = $10,000
- The discount rate is taken to be 12%

Parking Garage details (Cont)

- **Costs**
  - **annual operating costs (staff, cleaning, etc.) = $2,000 /year/space available**

    (note: spaces used < spaces available)
  - **Annual lease of the land = $3.6 Million**
  - **construction cost = $16,000/space + 10% for each level above the ground level**
- **Can accommodate 200 cars per level**

Engineering Base Case

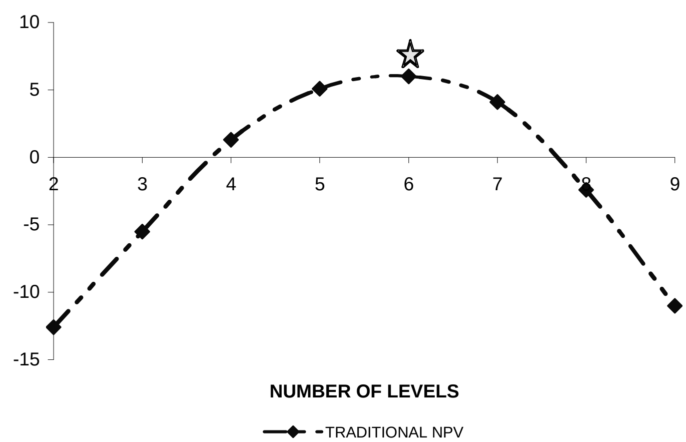
Demand growth as predicted, no variability

Year	0	1	2	3	19	20
Demand		750	893	1,015	1,688	1,696
Capacity		1,200	1,200	1,200	1,200	1,200
Revenue		$7,500,000	$8,930,000	$10,150,000	$12,000,000	$12,000,000
Recurring Costs						
Operating cost		$2,400,000	$2,400,000	$2,400,000	$2,400,000	$2,400,000
Land leasing cost	$3,600,000	$3,600,000	$3,600,000	$3,600,000	$3,600,000	$3,600,000
Cash flow		$1,500,000	$2,930,000	$4,150,000	$6,000,000	$6,000,000
Discounted Cash Flow		$1,339,286	$2,335,778	$2,953,888	$696,641	$622,001
Present value of cash flow	$32,574,736					
Capacity costs for up to two levels	$6,400,000					
Capacity costs for levels above 2	$16,336,320					
Net present value	**$6,238,416**					

Optimizing the base case

- Optimization = find highest value for all designs
  - Solution: consider each major design alternative
  - In this case, number of floors
  - Typically, a "sweet spot"
- What does graph of floors vs value look like?

Optimal design for base case (no uncertainty) is 6 floors



Recognizing Uncertainty

- Many things uncertain
  - Costs may be easier to estimate, contractors may give fixed bids
- Focus on Demand, more uncertain, farther in future
  - Assume: could be 50% off the projections, either way;
  - Annual volatility for growth is 10%

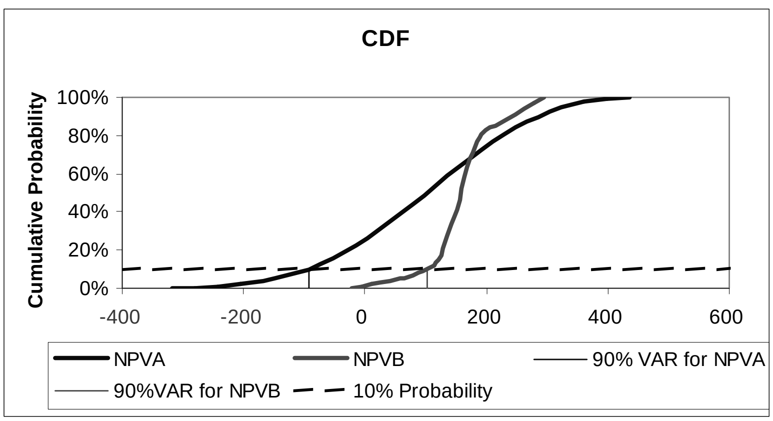
Distribution of Outcomes

- Recognizing Uncertainty => implies many possible future scenarios
- We calculate possible value of system for each possible scenario
- We obtain a distribution of outcomes (as indicated in ESD70)
- Also Cumulative distributions or "target curves"

Target Curves

- **Represent cumulative chance of getting a result below any specific level**
  - **Going from below lowest value (no chance)**
  - **To at or below the highest value (100% chance)**
- **Allows read on Value at Risk (VAR) :**
  - **Definition: VAR is A loss that will not be exceeded at some specified confidence level**
  - **"We are *p* percent certain that we will not lose more than *V* dollars for this project."**

Target curves graphically



Look at distribution of NPV of designs A, B:

- **90% VAR for NPVA -$91; for NPVB, $102**

A few notes on VARG

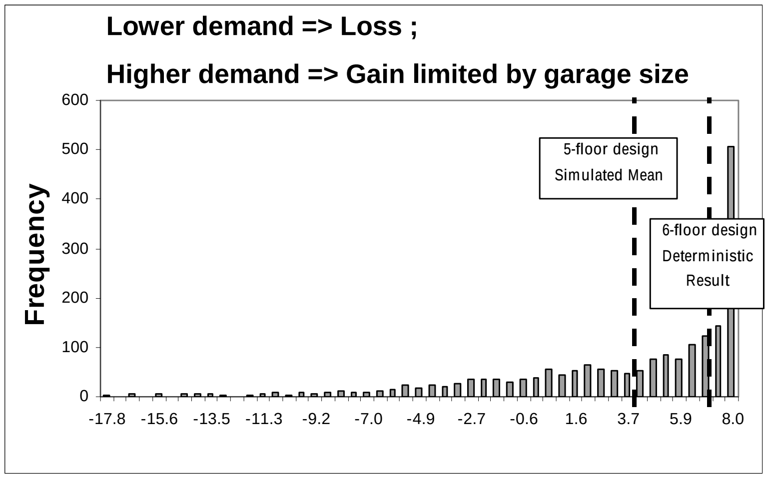
- VAR is a common financial concept
- It stresses downside losses, risks
- However, designers also need to look at upside potential: “Value of Gain”
- So we expand VAR to VARG
  - Value at Risk and Gain

Effect of uncertainty on analysis

- Changes results – Why?
  - Non-linearities in model
- Lowers results in this case -- Why?
  - Capacity constraints systematically limit ability to profit from good opportunities
- Changes design – Why?
  - Above encourages lower investment

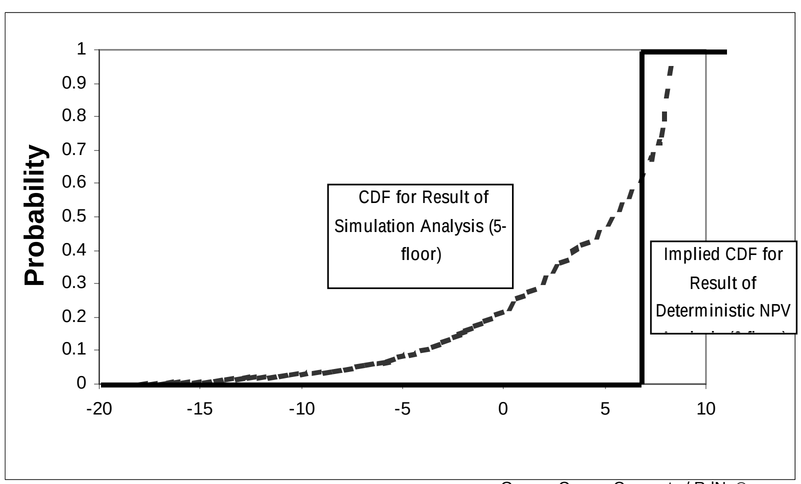
Simulated results uncertainty

- **Why is Right-hand side "gone"?**

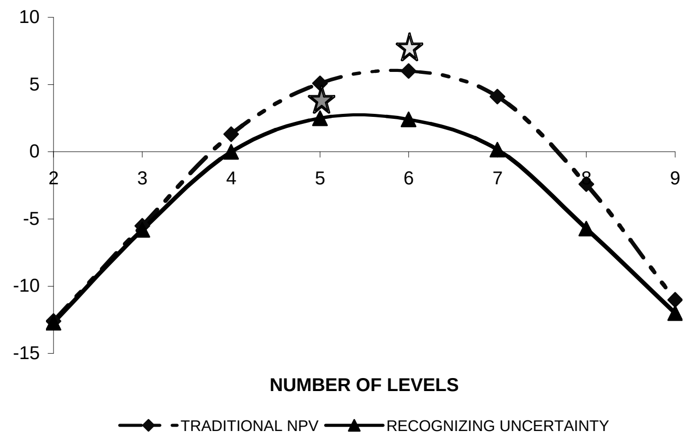


NPV Target Curve (CDF)

Compare Actual (5 Fl) with unrealistic fixed 6 Fl design



Recognizing uncertainty => different design: 5 floors



Introduce flexibility into design

- **How can we make garage "flexible"?**
  - **Not the floors, please!**
- **What is flexibility?**
  - **Ability to adjust project to needs, opportunities**
- **How do we do this here?**
  - **Make it possible to add more levels as needed**
  - **Stronger columns, foundations**
  - **More cost than for inflexible garage with same number of floors.**

Result – greater expected value

Year	0	1	2	3	19	20
Demand		820	924	1,044	1,519	1,647
Capacity		800	800	1,200	1,600	1,600
Decision on expansion			expand			
Extra capacity			400			
Revenue		$8,000,000	$8,000,000	$10,440,000	$15,190,000	$16,000,000
Recurring Costs						
Operating cost		$1,600,000	$1,600,000	$2,400,000	$3,200,000	$3,200,000
Land leasing cost	$3,600,000	$3,600,000	$3,600,000	$3,600,000	$3,600,000	$3,600,000
Expansion cost			$8,944,320			
Cash flow		$2,800,000	-$6,144,320	$4,440,000	$8,390,000	$9,200,000
Discounted Cash Flow		$2,500,000	-$4,898,214	$3,160,304	$974,136	$953,734
Present value of cash flow	$30,270,287					
Capacity cost for up to two levels	$6,400,000					
Capacity costs for levels above 2	$7,392,000					
Price for the option	$689,600					
Net present value	**$12,878,287**					

Including Flexibility => Another, better design:

4 Fl with stronger structure enabling expansion

Summary of design results from different perspectives

Perspective	Simulation	Option Embedded	Design	Estimated Expected NPV
Deterministic	No	No	6 levels	$6,238,416
Recognizing Uncertainty	Yes	No	5 levels	$3,536,474
Incorporating Flexibilty	Yes	Yes	4 levels with strengthened structure	$10,517,140

Why is the optimal design much better when we design with flexibility?

Multi-dimensional valuation

For uncertainty, 1 dimension is not enough

Design	Design with Flexibility Thinking (4 levels, strengthened structure)	Design without Flexibility thinking (5 levels)	Comparison
Initial Investment	$18,081,600	$21,651,200	Better with options
Expected NPV	$10,517,140	$3,536,474	Better with options
Minimum Value	-$13,138,168	-$18,024,062	Better with options
Maximum Value	$29,790,838	$8,316,602	Better with options

Everything is better! How did it happen?

Root cause: change the framing of design problem

From: focus on a (mythical) forecast or set of specs

To: managing (realistic) uncertainties by flexibility

3. Interpretation of results

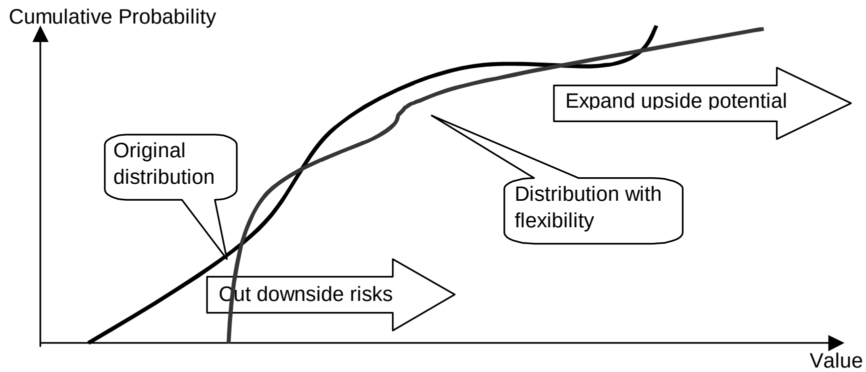
- **Why do Flexible designs systematically provide better value?**
- **What is the insight?**

- **Does Flexibility cost?**
- **Why it can be "win-win"**

Sources of value for flexibility

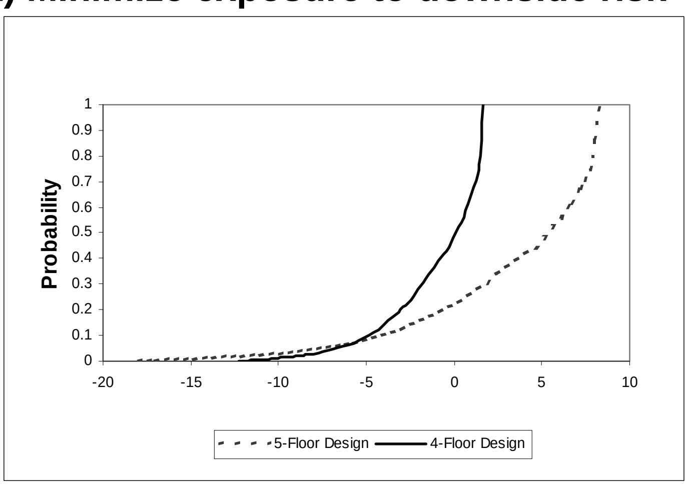
Cut downside ; Expand Upside

Avoid downside ; Profit from Upside



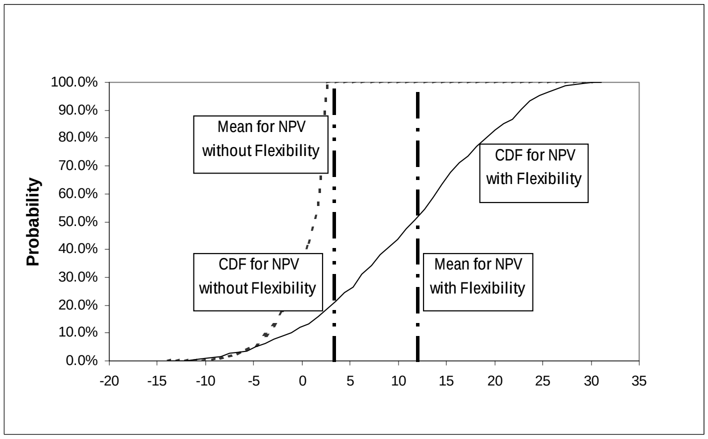
Sources of value for flexibility

1) Minimize exposure to downside risk



Sources of value for flexibility

2) Maximize potential for upside gain



What is cost of flexibility?

- Often said: "Flexibility costs"
- In what sense is this true?

- Clearly 4-storey garage with strength to add floors cost more than an inflexible one that does not have this capability
- Is flexible design more expensive?

What is fair comparison?

- To be fair, compare relative cost of design with flexibility with one without
- So, if you had to make a 1-time decision, what is best choice?
  - 5 or 6 storey garage!!
- Fair comparison is between
  - flexible design 4-stories
  - Inflexible 5 or 6 stories

Flexible Design as Win-Win

Flexible design not only increases value, it saves money 3 ways. You can:

1. Build smaller – don't have to meet future needs right at start
2. Defer costs, and thus decrease their Present Value
3. Avoid costs completely – some projected needs will not occur

4. Implementation

- Caution: We need to make sure that flexible designs can be implemented when needed.
- Example: Bluewater model for this case
- What happened?
  - Ignorance of new owners
  - Ready collaborators (designers, suppliers)
  - Compatible regulations – they can change

Implementation plan needed

- More on this later
- Basics concept is that you have to keep flexibility alive:
  - Knowledge of Possibilities
  - Collaboration of stakeholders
  - Monitoring, anticipating regulatory changes
- An implementation plan necessary part of good design

Summary of Concepts

- Flexibility Design is practical and used by top professionals
- It increases <u>expected</u> value
- It does so by:
  - Reducing downside losses
  - Increasing upside gains
  - Thus improving on many dimensions
- It can be a “win-win” solution
- It requires thoughtful implementation