### River Length Experiment

<table>
<thead>
<tr>
<th>Length</th>
<th>Person</th>
</tr>
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<tbody>
<tr>
<td>thou. Km</td>
<td>1</td>
</tr>
<tr>
<td>8</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
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<tr>
<td>0</td>
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</tbody>
</table>

### Population Experiment

<table>
<thead>
<tr>
<th>Population</th>
<th>Person</th>
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</thead>
<tbody>
<tr>
<td>Millions</td>
<td>1</td>
</tr>
<tr>
<td>40</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td></td>
</tr>
<tr>
<td>0</td>
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</table>
Recognition of Risk and Complexity

- Risk: Wide Range of Futures
  - The forecast is "always wrong"

- Complexity: Wide Range of Choices
  - Number of Choices is Enormous
    * “Pure” solutions only 1 or 2% of possibilities
    * Most possibilities are “hybrid”, that combine elements of “pure” solutions
    * “Hybrid” choices provide most flexibility
Recognition of Risk

- The usual error
  - Search for correct forecast
- However: the forecast is "always wrong"
  - What actually happens is quite far, in practically every case, from what is forecast
  - Examples: costs, demands, revenues and production
- Need to start with a distribution of possible outcomes to any choice or decision

Cost Growth Experience
NASA Microgravity Projects

<table>
<thead>
<tr>
<th>Case</th>
<th>Case II</th>
<th>LPE</th>
<th>LIM</th>
<th>DTEC</th>
<th>Zuno</th>
<th>BCE</th>
<th>PSG</th>
<th>SICE</th>
<th>AVG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ratio of Actual or Current to Estimated Cost</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
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</tr>
</tbody>
</table>

4.50  
4.00  
3.50  
3.00  
2.50  
2.00  
1.50  
1.00  
0.50  
0.00
Ratio of Real Costs

Expressed in constant dollars, to estimated costs for routine airport projects

Real/Estimated Cost Ratio

DOE Oil Price Forecasts

Source: M. Lynch, MIT
**DOE Oil Price Forecasts**

Source: M. Lynch, MIT

**EMF6 Oil Price Forecasts**

Source: M. Lynch, MIT
EMF6 Oil Price Forecasts (Low)

Forecasts of 1990 Price of Oil

Source: M. Lynch, MIT

Dynamic Strategic Planning
Richard de Neufville, Joel Clark, and Frank R. Field
Massachusetts Institute of Technology
Recognition of Risk
Slide 11 of 26

Source: M. Lynch, MIT -- IEW Survey

Dynamic Strategic Planning
Richard de Neufville, Joel Clark, and Frank R. Field
Massachusetts Institute of Technology
Recognition of Risk
Slide 12 of 26
DOE Forecasts
Non-OPEC LDC Production

Source: M. Lynch, MIT

Error in OPEC Revenue Forecast
EMF6 1980 - 1995

Source: M. Lynch, MIT
Forecasts of Water Use in Boston
(MWRA Members)

Year

Total Water Purchased from MDC/MWRA (mgd)

100 150 200 250 300 350 400 450 500 550 600

NEWS (1969)
SENEM (1975)
Actual Consumption

Forecasts of Water Use in Boston
(MWRA Service Area)

Year

Consumption Rate (mgd)

100 120 140 160 180 200 220 240 260 280 300 320 340 360 380 400

EMRPP Projection #2 (1967)
MWSP (1978)
EMRPP Projection #1 (1967)
Why we can’t predict well: Surprises!

- Surprises
  - All forecasts are extensions of past
  - Past trends always interrupted by surprises, by discontinuities:
    - Major political changes
    - Economic booms and recessions
    - New industrial alliances or cartels
  - The exact details of these surprises cannot be anticipated, but it is sure surprises will exist!

Why we can’t predict well: Ambiguity

- Ambiguity
  - Many extrapolations possible from any set of historical data
    - Different explanations (independent variables)
    - Different forms of explanations (equations)
    - Different number of periods examined
  - Many of these extrapolations will be "good" to the extent that they satisfy usual statistical tests
  - Yet these extrapolations will give quite different forecasts!
Consequences of Risk

- The Resulting Problem: Wrong Plans
  - Wrong Size of Plant, of Facility
    - Denver Airport
    - Boston Water Treatment Plant (See Case Studies)
  - Wrong type of Facility
    - Although "forecast" may be "reached"…
    - Components that make up the forecast generally not as anticipated, thus requiring
    - Quite different facilities or operations than anticipated

Forecast By Detailed Simulation

![Forecast Chart]

- $\text{Probability \%}
- $\text{\$ Millions}$
Rear View Mirror Analogy

- Relying on forecasts is like driving by looking in a rearview mirror --

- Satisfactory for a while, so long as trends continue, but soon one runs off the road.

Range Of Choices -- Limited View

- The Usual Error
  - Polarized Concept
  - Choices Narrowly Defined around simple ideas, on a continuous path of development

- Examples
  - Mexico City Airport: A Major New One Yes or No?
  - Size of Power Plants: 6 Megawatts Yes or No? (See Case Study of South African Power)
  - Compliance with Laws: As written? Yes or No?
    - Experience of Planning for Electric Vehicles for Los Angeles, California
    - Venezuela (See Case Study)
Range Of Choices -- Correct View

- The Correct View
  - All Possibilities must be considered
  - The Number of Possible Developments, considering all the ways design elements can combine, is very large

- The general rule for locations, warehouses
  - Possible Sizes, S
  - Possible Locations, L
  - Possible Periods of Time, T
  - Number of Combinations: \((S \text{ exponent } L) \text{ exponent } T\)

- Practical Example: Mexico City Airport
  - Polarized View: "Texcoco" of "Zumpango"
  - All Combinations: \((2 \text{ exp } 4)\text{ exp } 3 = 4000+ !!!\)

Problem from Limited View of Choices

- Blindness to "98%" of possible plans of action
  - These are the "combination" (or "hybrid") possibilities that combine different tendencies
  - The "combination" designs allow greatest flexibility -- because they combine different tendencies

- Blindness to many possible developments
  - those that permit a variety of futures
  - because they do not shut off options

- Inability to adapt to risks and opportunities

- Significant losses or lost opportunities
Real Range Of Choices

- **Practical Example: Mexico City Airport**
  - Most of the possible developments are combinations of operations at 2 sites (instead of only 1)
  - The simultaneous development at 2 sites allows the mix and the level of operations to be varied over time
  - The development can thus follow the many possible patterns of development that may occur
  - There is thus great flexibility
  - Also ability to act economically and efficiently

- **Recommended Action**
  - Option on Zumpango Site
  - Wait until next 6-year Presidential term
  - Then decide next step

How to deal with complex choices

- **The Solution**
  - Enumeration of Possible Combinations
  - General: Lists, Exact Numbering of Possibilities
  - Detailed: Simulations

- **Practical Examples**
  - General Enumeration
    - New Airports at Mexico City, Sydney (See Case Study)
  - Detailed Simulation