Recognizing who you know, what you know and you don’t know:
Key factors in using OR to address global issues

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Themes

• Operations research (OR) is a powerful tool for analyzing and designing policies to improve the lives of many people in many different ways
• OR is, however, largely not recognized as a contributor to important social concerns
• Some of the OR achievement (and awareness) gap is due to not fully appreciating the individual and social context of decision making (who), assimilating all available information (what you know), and recognizing uncertainty (what you don’t know)
OR and its Successes

• Working definition: The science of optimal decision making
• Visible uses:
  • Defense (e.g., WWII/Battle of Britain)
  • Energy
  • Food/agriculture
  • Transportation
  • Communications
  • Imaging/radiation therapy
  • Productivity tools (e.g., Excel/Project)
  • Sports (e.g., Moneyball, F1) …
• Why isn’t the science here visible? Could it do more?
Hypotheses

OR is not more visible or not more effective because:

• We may not have the right “who”,
• We may not be using what we already know (or can observe),
• We may not acknowledge what we do not (or cannot) know.
Finding the Right “Who”

- Two implementations:
  - NBA scheduling (Bean, JRB 1980)
  - Michigan State Senate (JRB 1983)

- Common story:
  - Knowing the decision-maker is critical
  - The decision-maker can always change his or her mind
NBA Schedule

Problem (as imagined):
Find a schedule of 82 games for 30 teams played over 165 days with minimum distance (cost) and:
- Available arena
- No road trips over 5 games
- <=2 games in 3 days….

Travelling salesperson problem (TSP) plus much more…

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League Schedule
Decision Making Reality

• Schedule determined by league office
• League office does not pay for travel
• League office does not see the same issues
• Priorities for league:
  • Have flexible schedule
  • Satisfy each team (and especially “important” markets)
Michigan State Senate

- Background: at each census, states must re-define political districts to protect “one person-one vote”
- Michigan Supreme Court decides that State Senate district should “minimize the number of existing county lines broken to form districts subject to the one person-one vote restriction”
Using What We Know

• Examples
  • AIG’s role in the financial crisis
  • Over-crowded hospital emergency departments

• Our models may not use all that we can see when we make decisions or give advice on making decisions
### AIG's Income Statement

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<thead>
<tr>
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</thead>
<tbody>
<tr>
<td><strong>Revenues</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>General Insurance</td>
<td>$35,854</td>
<td>$51,708</td>
<td>$49,206</td>
<td>$45,174</td>
</tr>
<tr>
<td>Life Insurance &amp; Retirement</td>
<td>14,271</td>
<td>53,570</td>
<td>50,878</td>
<td>48,020</td>
</tr>
<tr>
<td>Financial Services</td>
<td>(16,016)</td>
<td>(1,309)</td>
<td>7,777</td>
<td>10,677</td>
</tr>
<tr>
<td>Asset Management</td>
<td>658</td>
<td>5,625</td>
<td>4,543</td>
<td>4,582</td>
</tr>
<tr>
<td>Other</td>
<td>531</td>
<td>457</td>
<td>483</td>
<td>344</td>
</tr>
<tr>
<td>Consolidation &amp; Eliminations</td>
<td>(436)</td>
<td>13</td>
<td>500</td>
<td>(16)</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>$34,862</td>
<td>$110,064</td>
<td>$113,387</td>
<td>$108,781</td>
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</tbody>
</table>

| **Operating Income (Loss)**             |                           |        |        |        |
| General Insurance                       | $(393)                    | $10,562| $10,412| $2,315 |
| Life Insurance & Retirement             | (19,561)                  | 8,186  | 10,121 | 8,965  |
| Financial Services                      | (22,880)                  | (9,515)| 383    | 4,424  |
| Asset Management                        | (2,709)                   | 1,164  | 1,538  | 1,963  |
| Other                                   | (2,899)                   | (2,140)| (1,435)| (2,765)|
| Consolidation & Eliminations            | 237                       | 722    | 668    | 311    |
| **Total**                               | $(48,205)                 | $8,943 | $21,687| $15,213|

What Can We See from AIG?

• Even in 2007, large changes in their net income from financial services
• Evidence of involvement in activities with very volatile cash flows
• Decisions that do not recognize that would not be effective
• Result?
CDS Insurance – AIG story

- Credit Default Swaps (CDSs) protect against default on underlying securities
- AIG sold $526 billion in CDSs
- Many at AAA level (1 in 10,000 default odds?)
- Problems? Large collateral requirement changes (+$6B in one month out of $18B for all uses)
Dow Jones path: 80 years ago and today

Only the losses in the Great Depression rivaled the loss in equity value during the current crisis.

DJIA from 10/2007 to 3/2009: -52%

Worst all-time 17 months: (1/1931 to 6/1932): -75%

Hospital Emergency Departments

• Problem: Emergency departments appear to be over-crowded and over-used
• Why would this happen if everyone knows how to improve efficiency?
• Given that we observe this, what can be the explanation?
Decision Making for Hospital

• Suppose net income for a patient admitted directly is $2000/day
• Net income from a patient admitted from a patient from ED is -$1000/day
• Admitting from ED is $3000/day in lost opportunity
• Increasing efficiency in ED would increase losses
Recognizing What We Don’t Know

• Example:
  • Global warming and energy policy

• Question: In what technologies to focus investment?

• Set up model of economy and energy and maximize benefits
Model of Economy (Manne-Richels (2000))

Objective: Maximize discounted consumption utility reduced by “economic loss factor” (quadratic in temperature rise)

Decisions and constraints:

- two output forms in each region: energy and “other”
- other output: consumption, investment, energy, damages, net exports
- output depends on past prices
- overall putty-clay approach with capital vintage and new output governed Cobb-Douglas-type production function on capital and labor in energy and aggregate sector
- inter-temporal prices from equilibrium condition
- allows for carbon trading caps or taxes
Form of Model

Scenario Analysis: run model for separate forecast scenarios
Results from Scenario Analysis

• Every scenario leads to a preferred technology choice (e.g., nuclear, coal/sequestration, intensive hydrogen…)
• No mix of technologies across the scenarios
• No diversification of choices
Example

Suppose 3 alternative technology investments: Renewables, Nuclear, Clean Coal

Capacity need: 5 TW; Uncertain investment cost/TW; 2 equally likely states-of-the-world

Investment Cost/TW:

<table>
<thead>
<tr>
<th>SOW</th>
<th>Ren</th>
<th>Nuc</th>
<th>CC</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>8</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>10</td>
<td>5</td>
</tr>
</tbody>
</table>

• If SOW 1, choose Nuc: Cost=5
• If SOW 2, choose Ren: Cost=20
• But, Expected Cost(Nuc)=(5+50)/2=27.5
  Expected Cost(Ren)=(40+20)/2=30
  Expected Cost(CC)=25 (Lowest Expected Cost)
Single Scenario Problems

Solutions for single scenario outcomes pick the best for that scenario without diversification.

Combinations of scenario solutions may not include the best overall investment option.

Consideration of the full set of alternatives and portfolio investment outcomes requires models with uncertainty that resolves over time.
Including Diversification

Actual investments reflect uncertainty and obtain diversification

Policies formed from analyzing single-scenario models miss diversification effects as well as low-risk, high-cost alternatives and may lead to large losses

Including diversification effects requires modeling both marginal returns on individual technologies and joint returns (correlations)
Stochastic Model
-Recognize and Learn over Time
Parameter Estimation and Uncertainty

Existing macro-economic parameters
  • Estimated from current/historical conditions
  • Relatively low error

Return on investment (exploration, new capacity, efficiency)
  • Considerable uncertainty in new technologies
  • High variation in estimates

Model (JRB/Rosa, EnergyJ 96)
  • Consider possible alternatives that span range of estimates
Results

Both cap-trade and carbon-tax

Consider policy effects from single point forecast and stochastic model recognizing uncertainty

Overall difference in US GDP if policies follow best single-point forecast versus stochastic model with multiple alternative future states of the world
Loss in Certainty-equivalent Consumption

With trade:
EVPI = 0.17%
Value of the Stochastic Solution (VSS) = 1.4%
(Difference between stochastic solution and single-point forecast solution)

Without trade:
EVPI = 0.20%
VSS = 2.0%
Consumption Effects

Hedging = stochastic solution

Stabilizes growth and avoids contraction

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UofC Energy Initiative, 12 Nov 2008
What’s an Analyst to Do?

- Recognize the situation
- Model the decision-maker’s self interest (who) and show how to construct systems that align incentives at the outset
- Ensure the use of all the available information (what you know)
- Recognize and model what you do not know
Conclusions

• OR has done a great deal to improve lives of many
• OR is not always visible and not always effective
• Being more effective requires recognizing:
  • Who is making the decision
  • What is known or can be observed
  • What is not known (and including that in the model)
• Using all of these aspects requires a broader view of OR than traditional single models with greater use of behavioral models, uses of data, and learning
Thank you!

Questions?