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The Value of Information

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How Do We Reduce Uncertainty?

- A Monte Carlo simulation based on calibrated estimates is capturing your *current* level of uncertainty about a problem.
- Of all the things we could do to reduce uncertainty, what is the best way? (i.e. Where is the highest "Value of Information?")
- Chances are, if you aren't doing this simple calculation, you are measuring all the wrong things

The Value of Information

The Formula For The Value of Information:

$$EVI = \sum_{i=1}^{k} p(r_i) \max\left[\sum_{j=1}^{z} V_{1,j}\, p(\Theta_j | r_i), \sum_{j=1}^{z} V_{2,j}\, p(\Theta_j | r_i), \ldots \sum_{j=1}^{z} V_{l,j}\, p(\Theta_j | r_i),\right] - EV^*$$

OR, in its simplest form:

"The cost of being wrong times the chance of being wrong"

The formula for the value of information has been around for almost 60 years. It is widely used in many parts of industry and government as part of the "decision analysis" methods – but still mostly unheard of in the parts of business where it might do the most good.

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The EOL Method

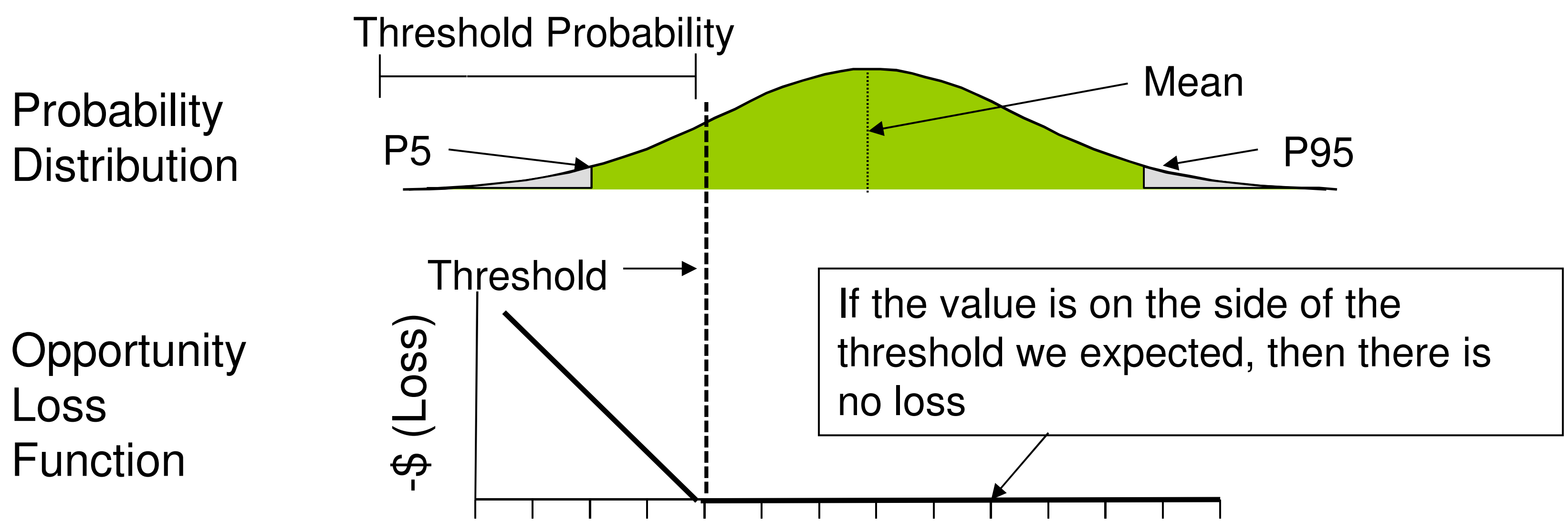
- The simplest approach computes the change in "Expected Opportunity Loss" (EOL)
- Simple Binary Example:

You are about to make an investment in some new project. If the new project succeeds, you net \$5 million (present value) in benefits. If not, you lose (net) \$1 million. There is a 20% chance of the new project "failing."

- What is the opportunity loss in this case?
- What is the EOL?
- What is the value of perfect information?

Information Value w/Ranges

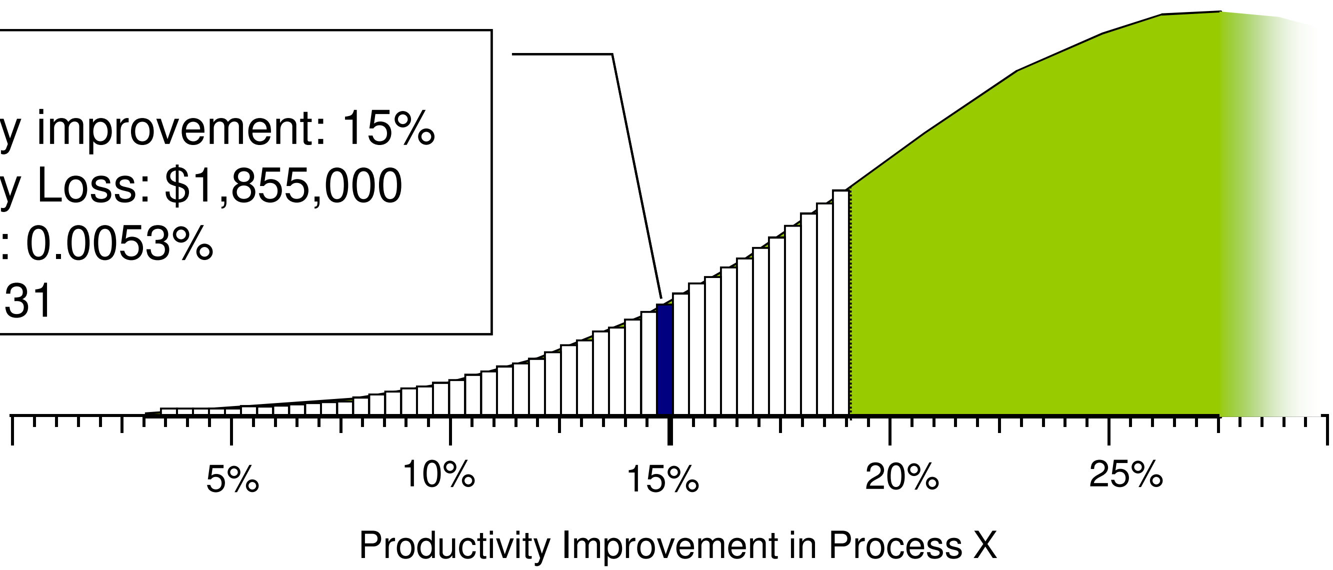
- Estimate a range and distribution of expected occupancy
- There is a point below which investor would lose money
- The less rooms rented below that point, the greater the loss



Normal Distribution VIA

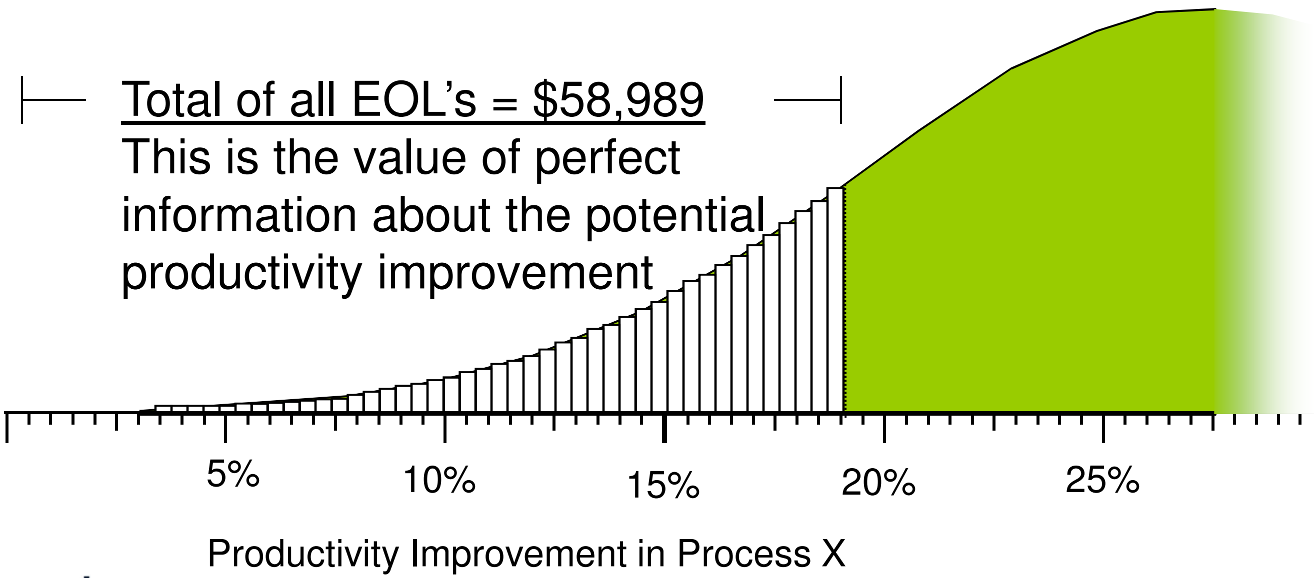
- The curve on the other side of the threshold is divided up into hundreds of "slices"
- Each slice has an assigned quantity (such as a potential productivity improvement) and a probability of occurrence
- For each assigned quantity, there is an Opportunity Loss
- Each slice's Opportunity Loss is multiplied by probability to compute its Expected Opportunity Loss

Example:
Productivity improvement: 15%
Opportunity Loss: $1,855,000
Probability: 0.0053%
EOL: $98.31



Normal Distribution VIA (Continued)

- Total EOL for all slices equals the EOL for the variable
- Since EOL=0 with perfect information, then the Expected Value of Perfect Information (EVPI) =sum(EOL's)
- Even though perfect information is not usually practical, this method gives us an upper bound for the information value, which can be useful by itself
- Many of the EVPI's in a business case will be zero
- We do this with a macro in Excel but it can also be estimated



The Measurement Inversion

In a business case, the economic value of measuring a variable is usually inversely proportional to the measurement attention it typically gets.

Lowest Information Value

Highest Information Value

- Initial cost
- Long-term costs
- Cost saving benefit other than labor productivity
- Labor productivity
- Revenue enhancement
- Technology adoption rate
- Project completion

Most Measured

Least Measured

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Real Examples of Measurement Inversion

Subject	What they would have measured	What they needed to measure
New Procurement System for Government	Detailed "time and motion" study of procurement process	The price savings from using reverse auctions
Battlefield Fuel Forecasting	Chance of enemy contact, forecasts vehicle maintenance	The difference in mileage between paved and gravel roads
Risks of flooding in mining operations	Drilling test holes all over the mine	How much water the main pumps can handle
Market for new pharmaceutical products	The adoption rate of the new drug in all global regions	The duration of phase 1 testing, chance of a particular clinical outcome
Impact of pesticides regulation	The value of saving endangered species	Whether pesticides regulation ever saves any endangered species
IT security	People who attended training, external threats	Internal theft incidents

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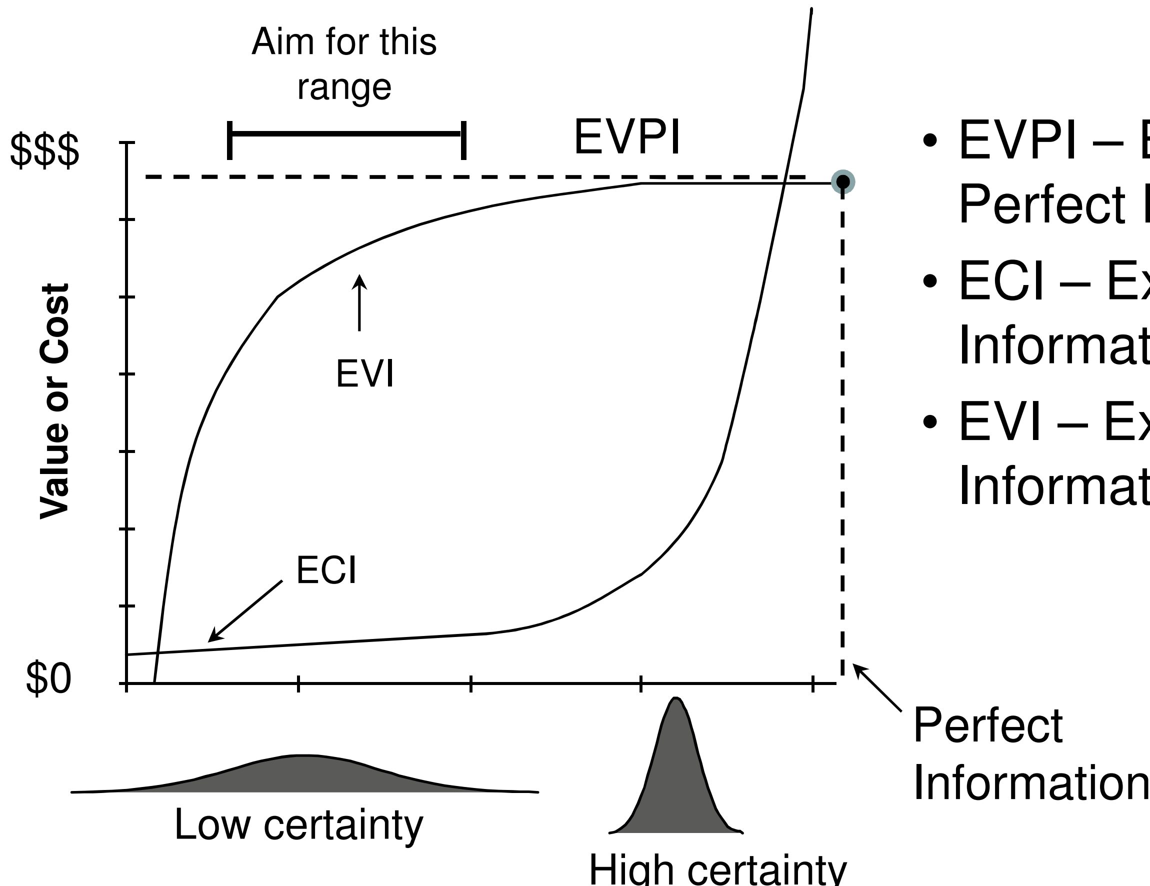
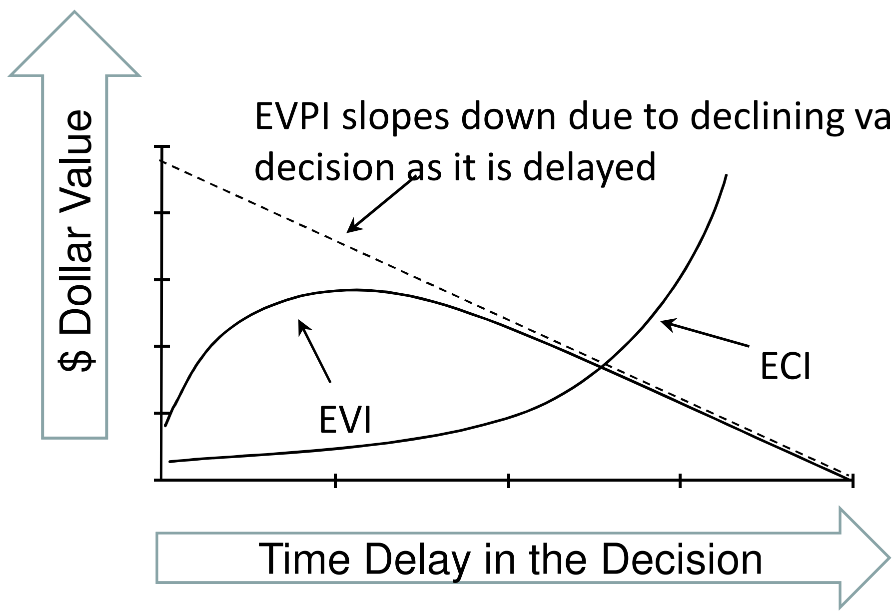
Increasing Value & Cost of Info.



- EVPI – Expected Value of Perfect Information
- ECI – Expected Cost of Information
- EVI – Expected Value of Information

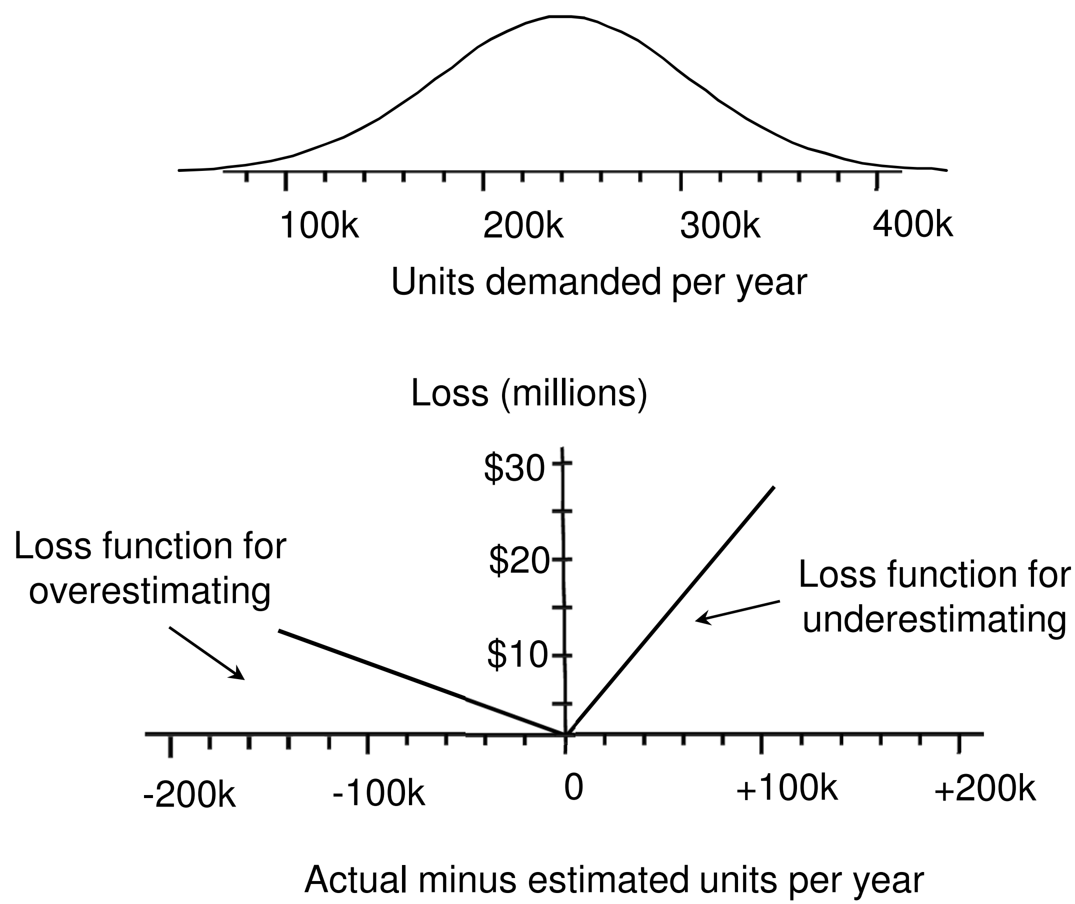
Time Dependent Information Values

- The value of information can also decrease with time (acting on a one-time offer, measuring the market for a new product in a rapidly changing industry, etc.)
- This accelerates the point of diminishing returns on information

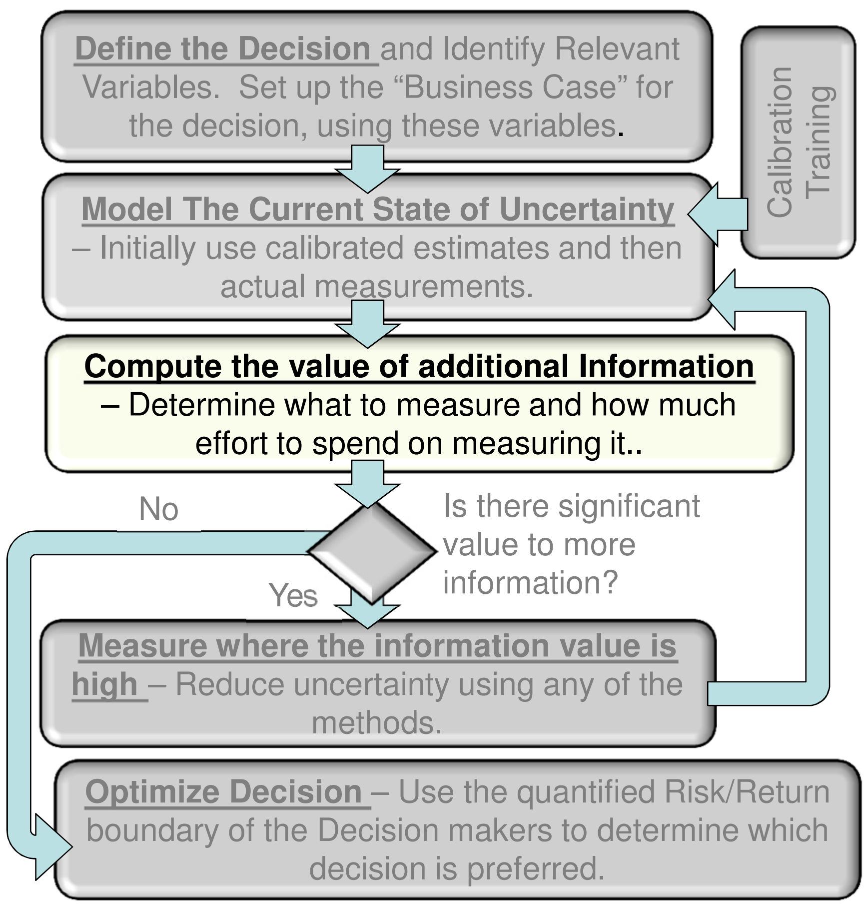


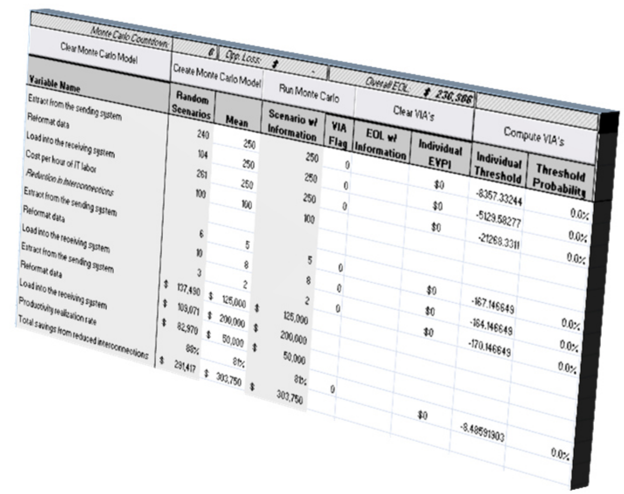
Loss Functions for Over- or Underestimating

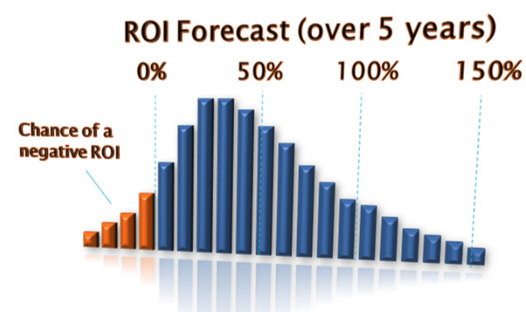
- We can also think of a loss function being bi-directional.
- Example: What is the demand for a new piece of hardware?
- If we underestimate we may plan on too little production capacity
- If we overestimate we may plan on too much



Making the Best Decisions





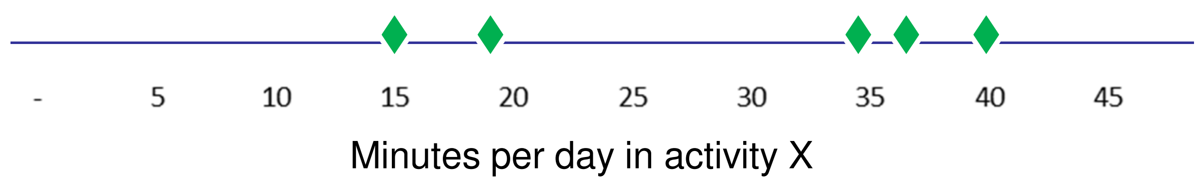


Next Step: Observations

- Now that we know what to measure, we can think of observations that would reduce uncertainty.
- The value of the information limits what methods we should use, but we have a variety of methods available.
- Take the "Nike Method": Just Do It – don't let imagined difficulties like "exception anxiety" get in the way of starting observations.
- The next module will go deeper into using observations to reduce uncertainty.

Interpreting Limited Data and Probabilities

1. A sample of 5:
   – Suppose you are extremely uncertain about how much time per day is spent in some activity in a company of 10,000 people
   – Imagine you randomly sample 5 people out of a company and they spend an amount of time in this activity as as shown by the data points below
   – Is this statistically significant?
   – Is it possible to estimate the chance the median time spent per person per day is between 15 and 40 minutes?



2. A sample of one:
   – Imagine a crate full of marbles.
   – Green marbles make up a randomly chosen share (a uniform distribution of 0%-100%), the rest are red.
   – If you randomly choose one marble without seeing the rest, and it turns out to be red, what is the chance the majority are red?

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Your Intuition About Sample Information Is Wrong

- Experts are not immune to widely held misconceptions about probabilities and statistics – especially if they vaguely remember some college stats.
- These misconceptions lead many experts to believe they lack data for assessing uncertainties or they need some ideal amount before anything can be inferred.

"Our thesis is that people have strong intuitions about random sampling…these intuitions are wrong in fundamental respects...[and] are shared by naive subjects and by trained scientists"

Amos Tversky and Daniel Kahneman, *Psychological Bulletin,* 1971

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"Impossible" Measurements?

WWII German Tank Production Estimates

Month of Production	Intelligence estimate	Statistical estimate	Actual (Based on captured documents after the war)
June 1940	1000	169	122
June 1941	1550	244	271
August 1942	1550	327	342

Several clever sampling methods exist that can measure more with less data than you might think

Examples:

- Estimating the number of tanks created by the Germans in WWII
- Clinical trials with extremely small samples
- Measuring *undetected* computer viruses or hacking attempts
- Estimating the population of fish in the ocean
- Measuring unreported crimes or the size of the black market
- Using "near misses" to measure catastrophic but rare events

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Practical Assumptions

- Its been measured before
- You have more data than you think
- You need less data than you think
- You probably need different data than you think

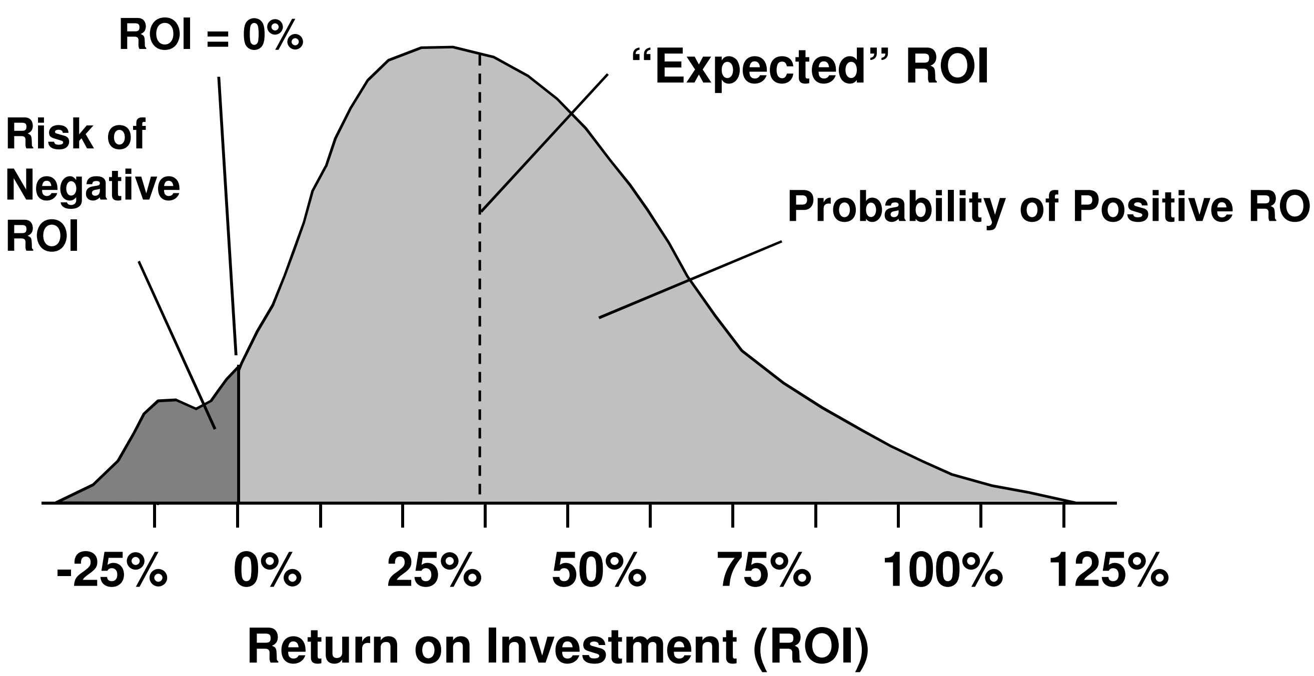
"It's amazing what you can see when you look"
Yogi Berra

Modeling Risk Aversion

- What is a good distribution?
- Inconsistency in risk aversion
- Quantifying risk aversion
- Creating an risk/return boundary

Optimizing The Decision

- How are you assessing the resulting histogram from a Monte Carlo simulation?
- Is this a "good" distribution or a "bad" one? How would you know?



Inconsistent Risk Aversions

- Our actual risk aversion is unstable and changes daily.
- Some reasons for decisions have more to do with arbitrary external factors than stable risk preference.
- Studies have shown risk aversion changes due to what should be irrelevant external factors including:

Factor	Risk Aversion
Being around smiling people	↓
Recalling an event causing fear	↑
Recalling an event causing anger	↓
A recent win in an unrelated decision	↓
A recent loss in an unrelated decision	↑

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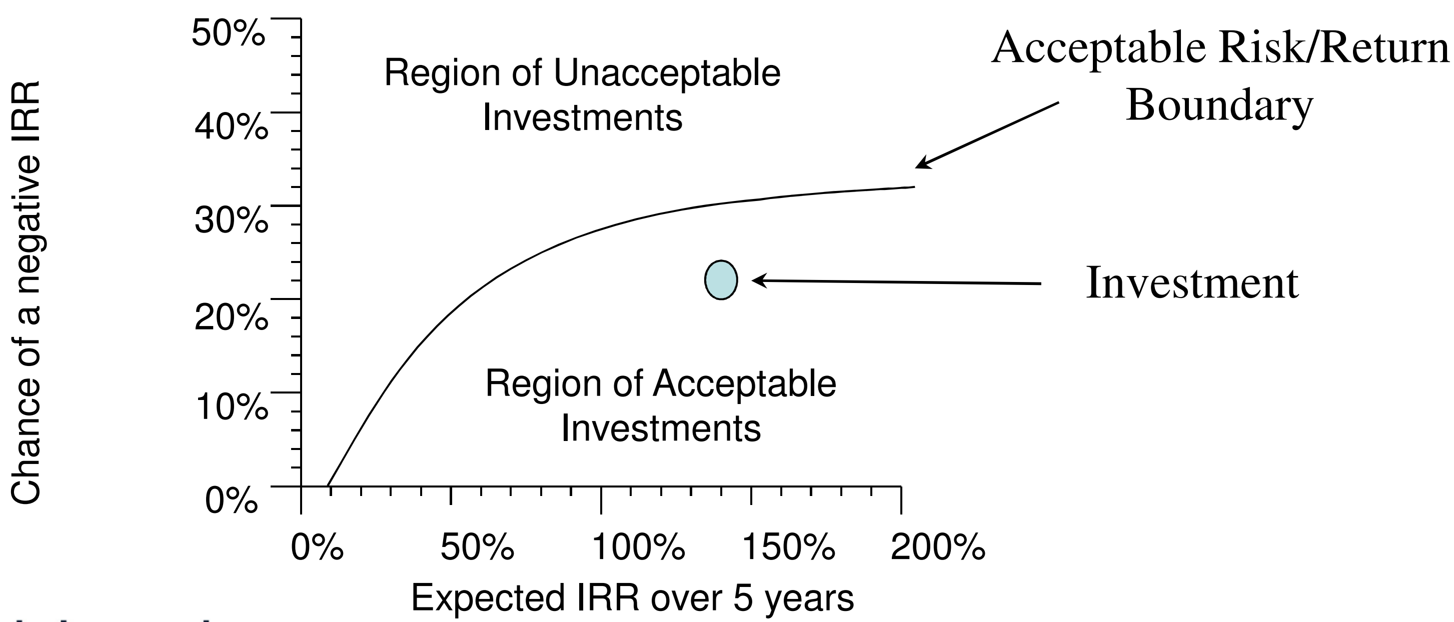
Quantifying Risk Aversion

- The simplest element of Harry Markowitz's Nobel Prize-winning method "Modern Portfolio Theory" is documenting how much risk an investor accepts for a given return.
- The "Investment Boundary" states how much risk an investor is willing to accept for a given return.
- For our purposes, we modified Markowitz's approach a bit.



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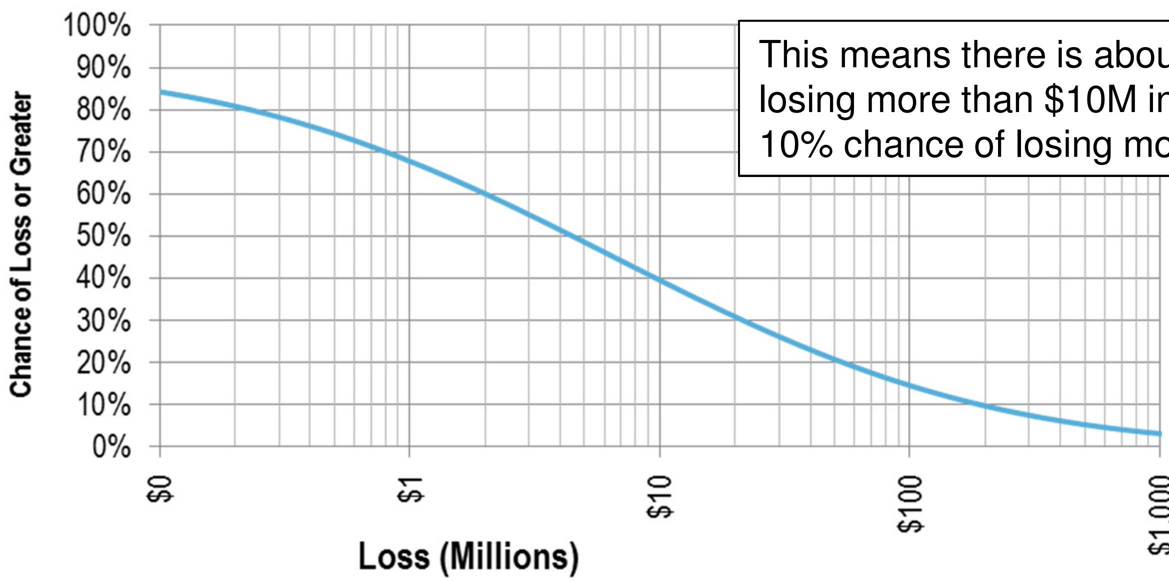
Putting it All Together: Communicating Risks Quantitatively

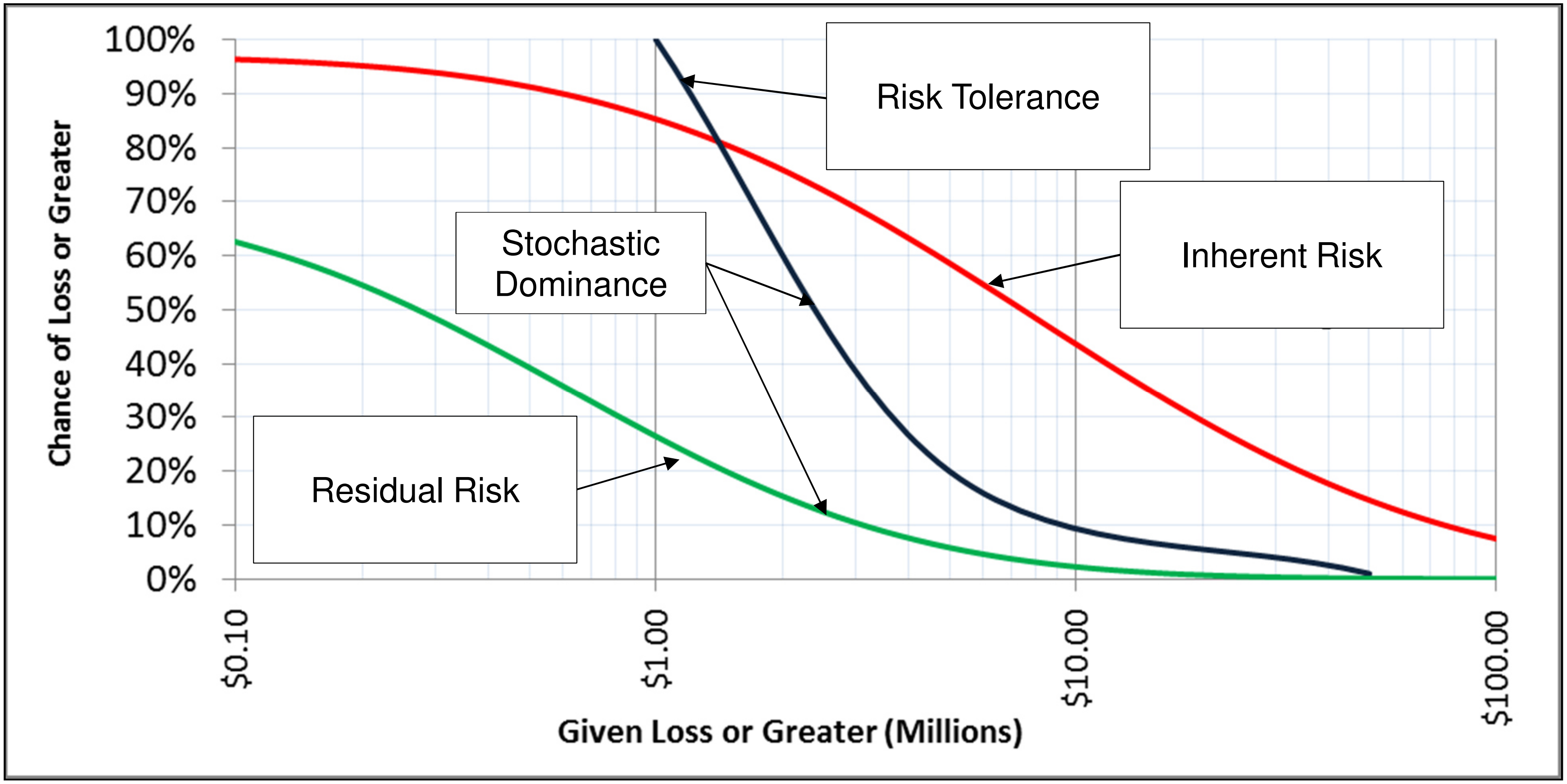
- If we can express uncertainty of individual risk events quantitatively, we can answer quantitative risk questions like "What is the chance a given risk will result in more than $5 million in losses in a given year?"
- The curve on this chart is based on calibrated estimates and the new model
- It represents the chance that a loss for a given risk equal to or greater than some amount will occur in a given year.
- These can also be added up into project and portfolio risk in a meaningful way.



This means there is about a 40% chance of losing more than $10M in a year and about a 10% chance of losing more than $200M.

Loss Exceedance Curves: Before and After

How do we show the risk exposure after applying available mitigations?



Supplementary Material for The Value of Information

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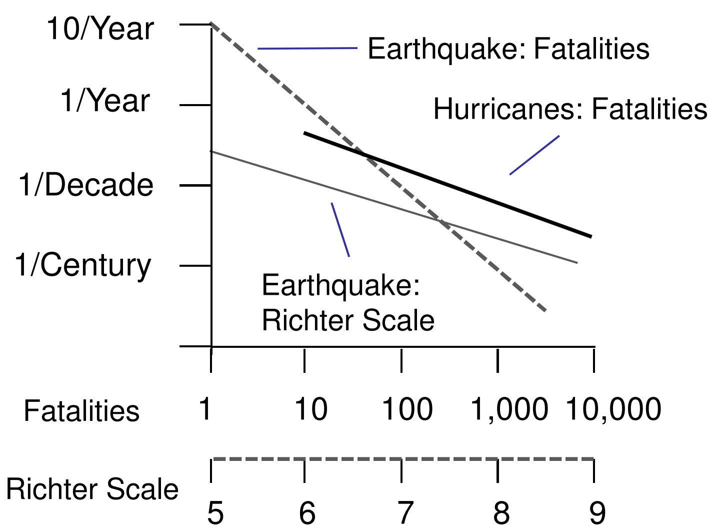
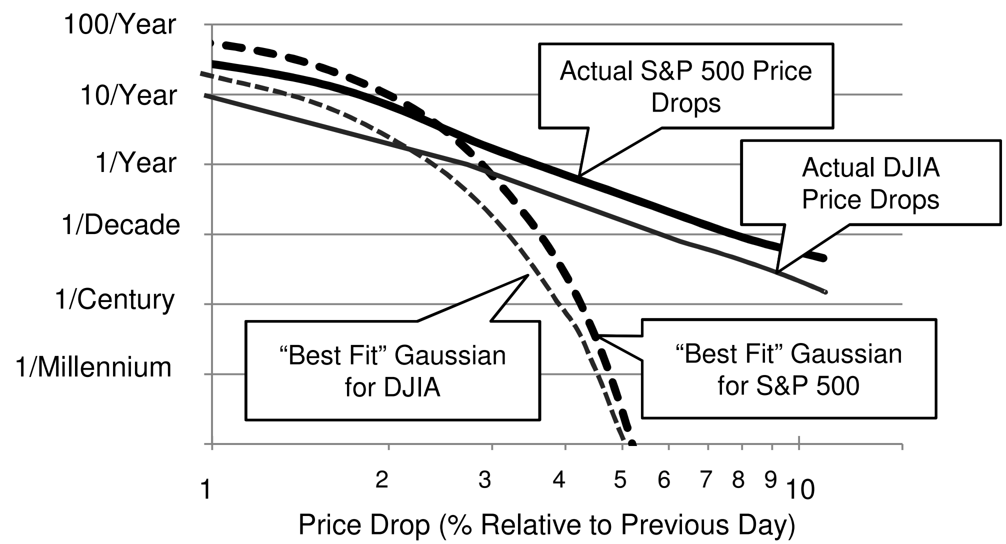
"Misunderestimating"

- Experts and even some popular quantitative models consistently underestimate the chance of catastrophic outcomes
- Mathematical models often use simplified probability distributions that that don't even match history – more realistic methods exist (such as "power law distributions")
- In addition to overconfidence, people tend to become more risk tolerant as time passes without a catastrophe
- People even apparently misinterpret near misses as evidence that disasters are less common

Power Law Distributions look like straight lines on log/log charts





Misunderestimating…by a Lot

August 2007, the Chief Financial Officer of Goldman Sachs, David Viniar, was quoted in the Financial Times saying:

> "We are seeing things that were 25-standard deviation moves, several days in a row"

- A 25-standard deviation event is a number with a probability so tiny it is smaller than…
- …one divided by the national debt…
- …of every country in the world…
- …measured in yen…
- …divided again by the number of individual bacteria on Earth…
- …divided again by all the atoms in the observable universe.
- In fact, this number would be TOO big…
- …by a factor of about a trillion

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Modeling Hints

- Consider both internal and external events
- Look at a longer historical period for examples of disasters
- Use “Premortems”
- Look up the Form 10-k of competitors and similar companies
- Include all parts of the organization which would have input into the model
- Peer reviews

Modeling Error Checks

- **Spreadsheet errors: studies show 30% to 90% spreadsheet had erroneous results error rates in spreadsheets - about 1 erroneous cell per 100 (The Institute of Chartered Accountants in England & Wales)**
- Check for "Double Counting" costs or benefits
- Use "Auditing" tool in spreadsheet
- Use the Monte Carlo to look for potential errors (sometimes errors produce bizarre results in Monte Carlos that would not otherwise be visible in a traditional spreadsheet)
- Be familiar with basic financial calculations
- Check the known financial procedures and assumptions for the firm

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Historical Models – Still Better Than Experts

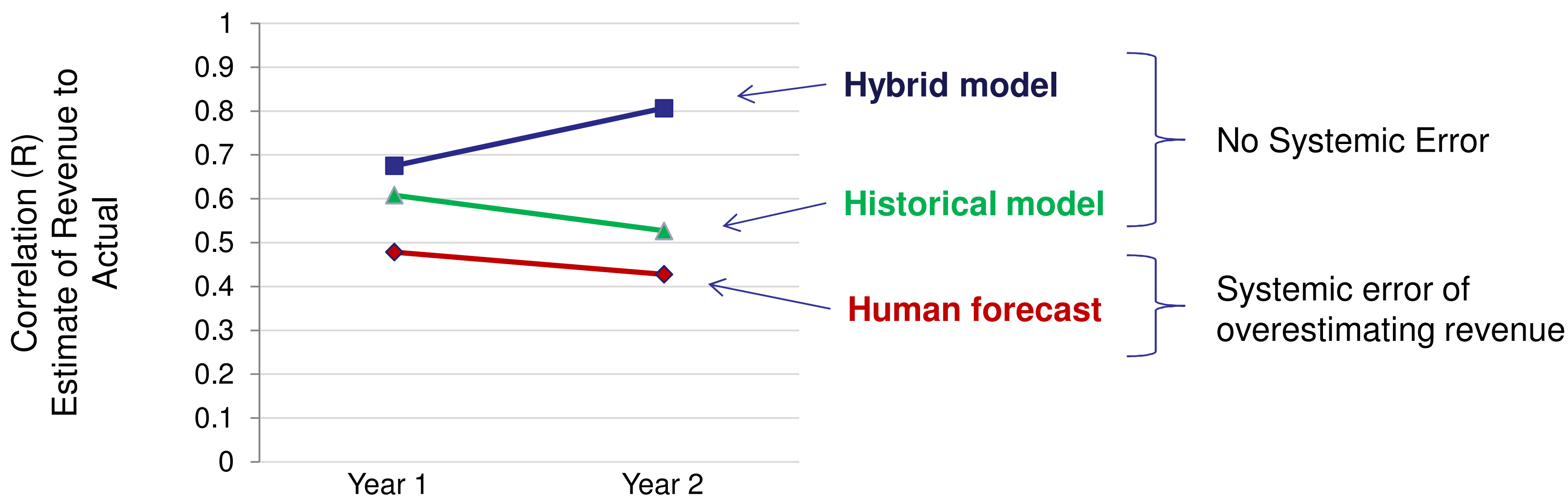
To many experts, when assessing probabilities many events ". . .are perceived as so unique that past history does not seem relevant to the evaluation of their likelihood." Tversky, Kahneman, *Cognitive Psychology* (1973)

Yet, Historical models routinely outperform experts in a variety of fields (even considering "Black Swans")

Paul Meehl assessed 150 studies comparing experts to statistical models in many fields (sports, prognosis of liver disease, etc.).	"There is no controversy in social science which shows such a large body of qualitatively diverse studies coming out so uniformly in the same direction as this one."
Philip Tetlock tracked a total of over 82,000 forecasts from 284 political experts in a 20 year study covering elections, policy effects, wars, the economy and more.	"It is impossible to find any domain in which humans clearly outperformed crude extrapolation algorithms, less still sophisticated statistical ones."

Measuring the Impact of Analysis Example (Cont.)

- The client was forecasting first and second year revenue of new products in the biotech lab equipment industry.
- Given both the improved correlation *and* the elimination of the systemic overestimation error, the overall forecasting error was reduced by 76%.



So Why Don't We Use More Quantitative Methods?

Have you heard (or said) any of these?

"We don't have sufficient data"

"There is too much error and bias in the data for it to be worth the effort to gather it."

"Each situation is too unique and complex to apply scientific analysis of historical data."

"There are so many factors affecting this, this measurement alone tells us nothing."

The implied (and unjustified) conclusion from each of these is….

""…therefore we are better off relying on our experience."

Questions?

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