How To Measure Anything

The Principles of Applied information Economics

Module 2

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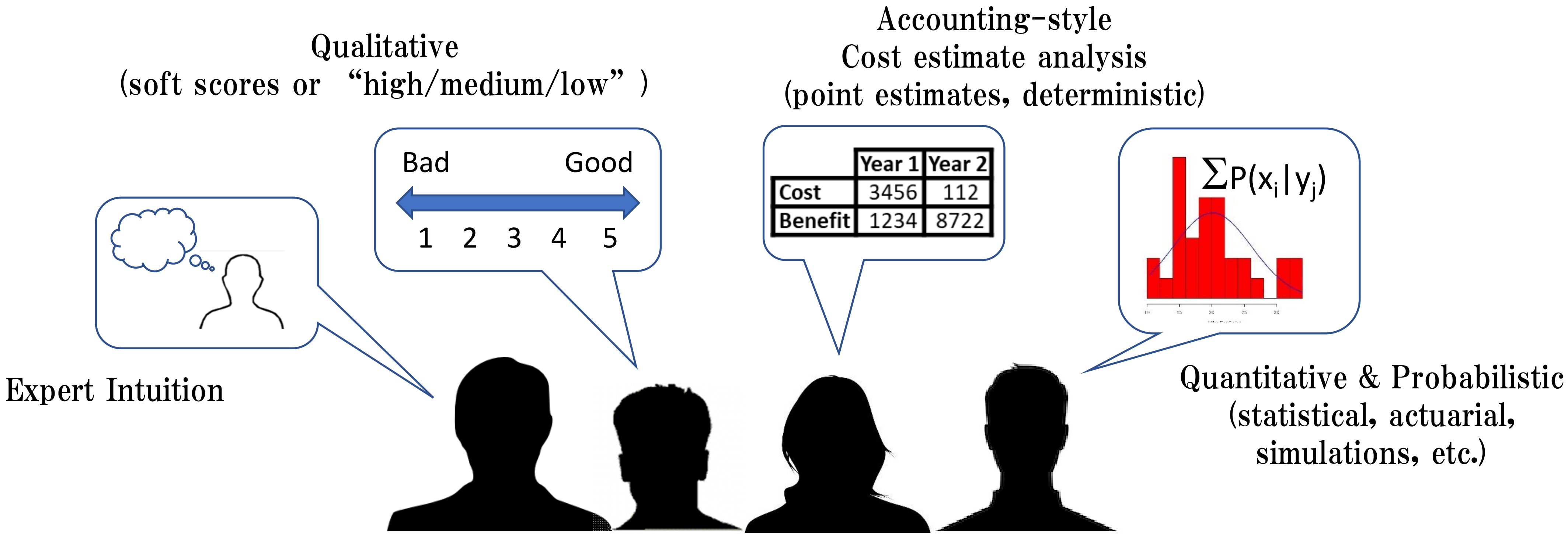
- **Deciding How to Decide**
  The Meta-Decision

- **How to Measure Anything**
  Overcoming the Illusion of Intangibles

- **Applied Information Economics**
  Putting What Works Together

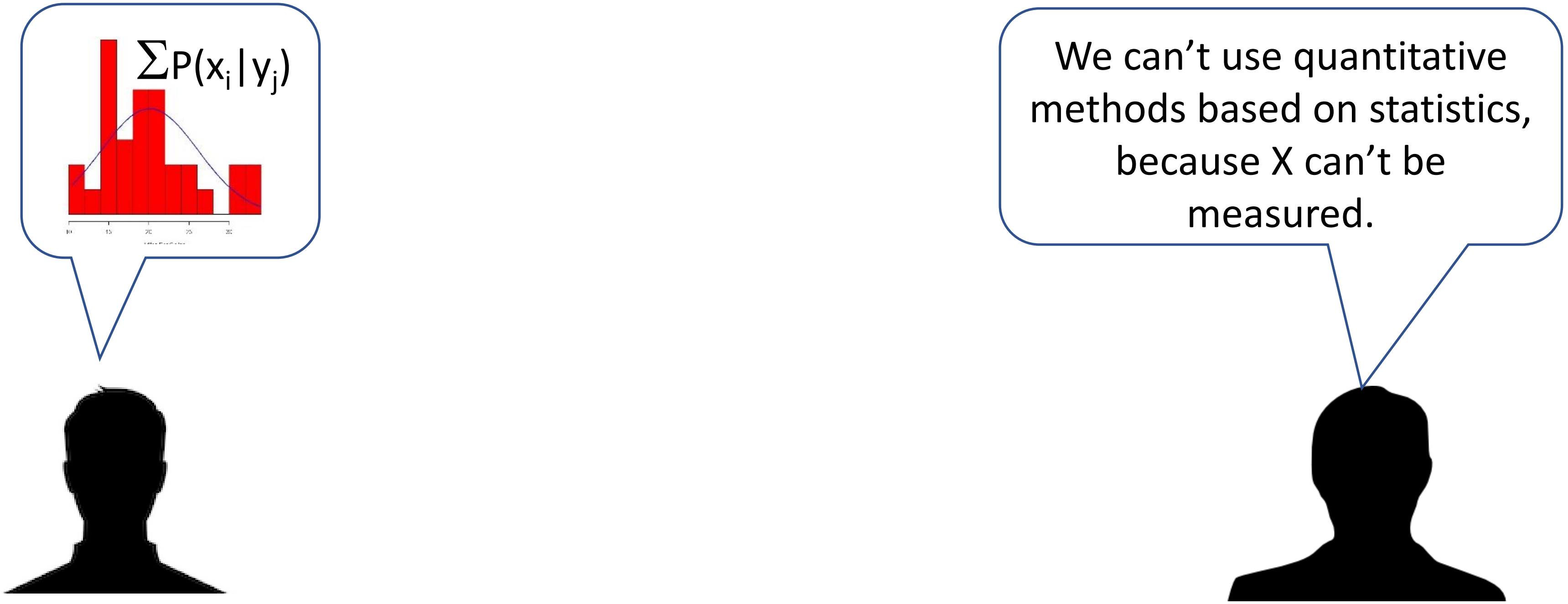
Introduction

Reviewing Where We Are



Obstacles to Better Decisions

The Myth of Immeasurability



The Three Misconceptions Behind Any Perceived “Immeasurable”

The Illusions of Immeasurability

CONCEPT of Measurement — The definition of measurement itself is widely misunderstood.

OBJECT of Measurement — The thing being measured is not well defined.

METHOD of Measurement — Many procedures of empirical observation are misunderstood.

The Three Misconceptions Behind Any Perceived "Immeasurable"

The Concept of Measurement

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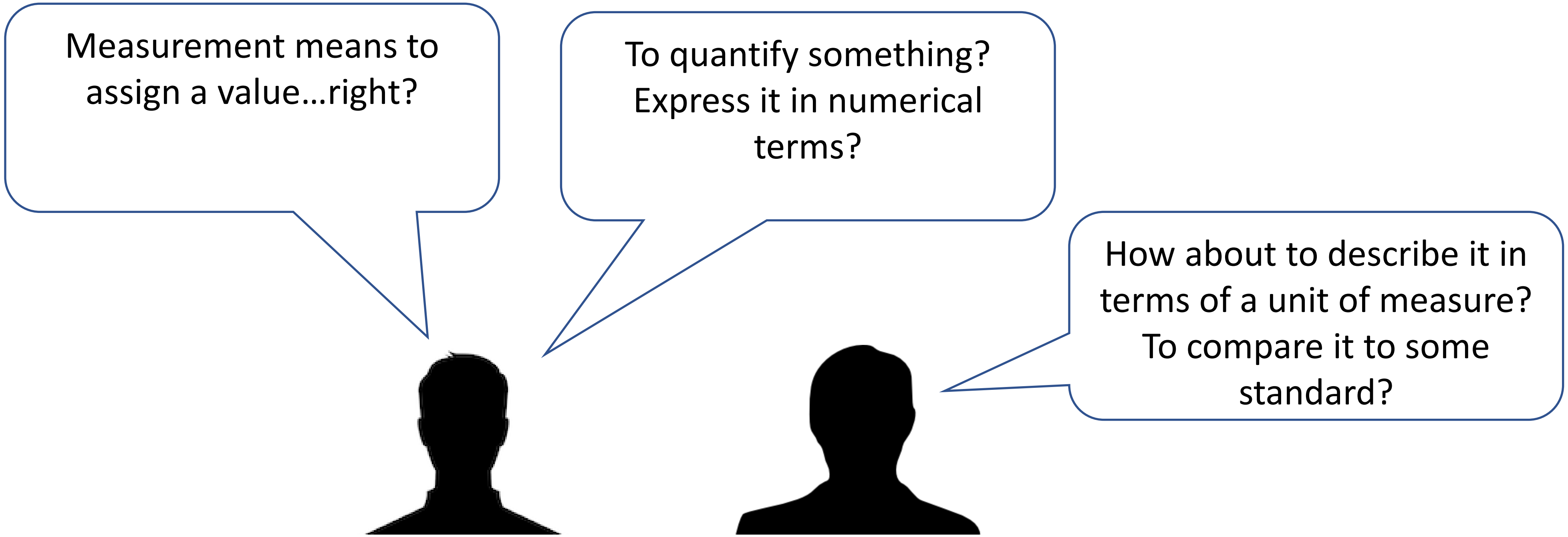
The Concept of Measurement

What Does Measurement Mean?

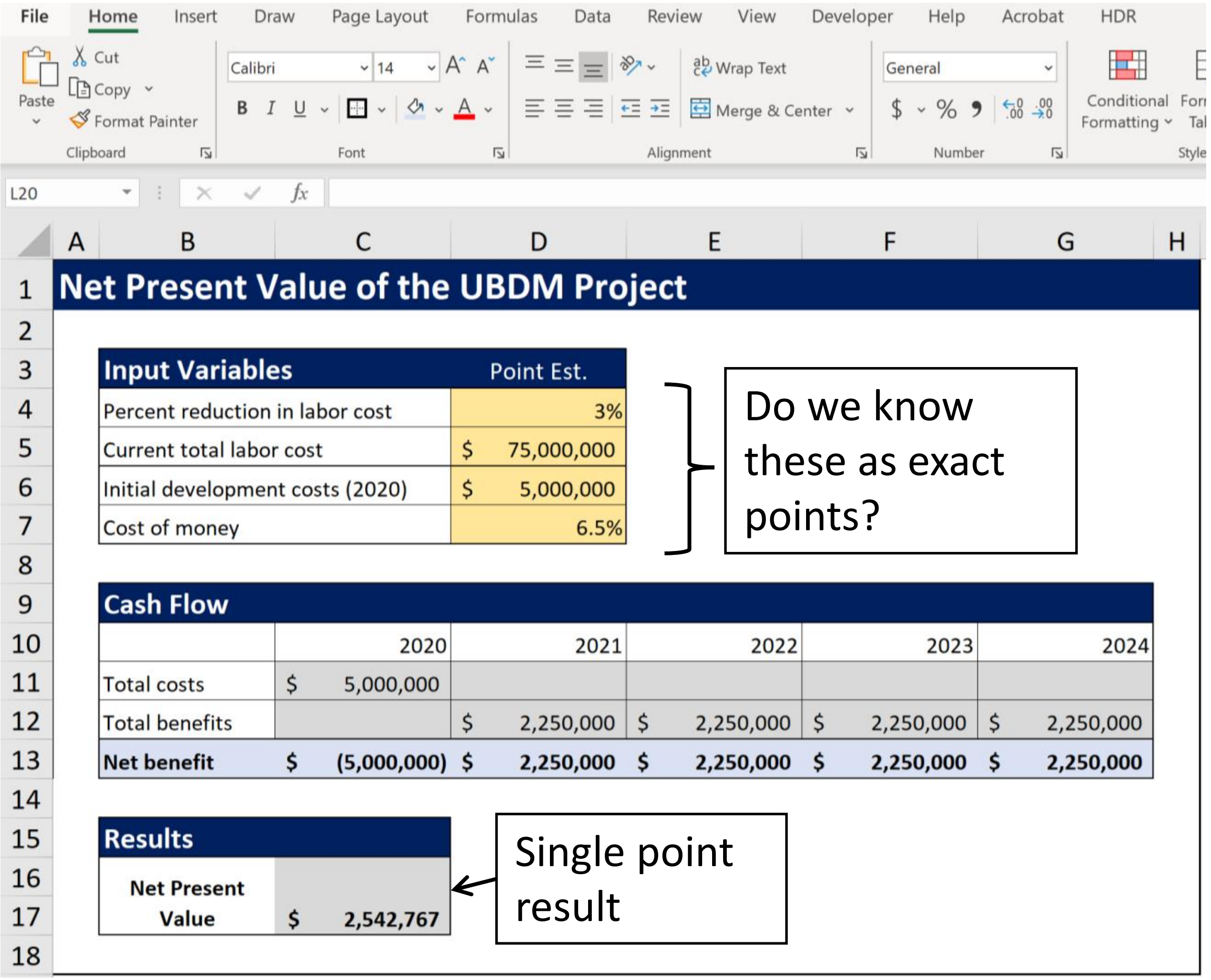


The Concept of Measurement

Misunderstanding Measurement

Accounting-style
Cost estimate analysis
(point estimates, deterministic)

	Year 1	Year 2
Cost	3456	112
Benefit	1234	8722



Net Present Value of the UBDM Project

Input Variables	Point Est.
Percent reduction in labor cost	3%
Current total labor cost	$ 75,000,000
Initial development costs (2020)	$ 5,000,000
Cost of money	6.5%

Do we know these as exact points?

Cash Flow	2020	2021	2022	2023	2024
Total costs	$ 5,000,000				
Total benefits		$ 2,250,000	$ 2,250,000	$ 2,250,000	$ 2,250,000
Net benefit	**$ (5,000,000)**	**$ 2,250,000**	**$ 2,250,000**	**$ 2,250,000**	**$ 2,250,000**

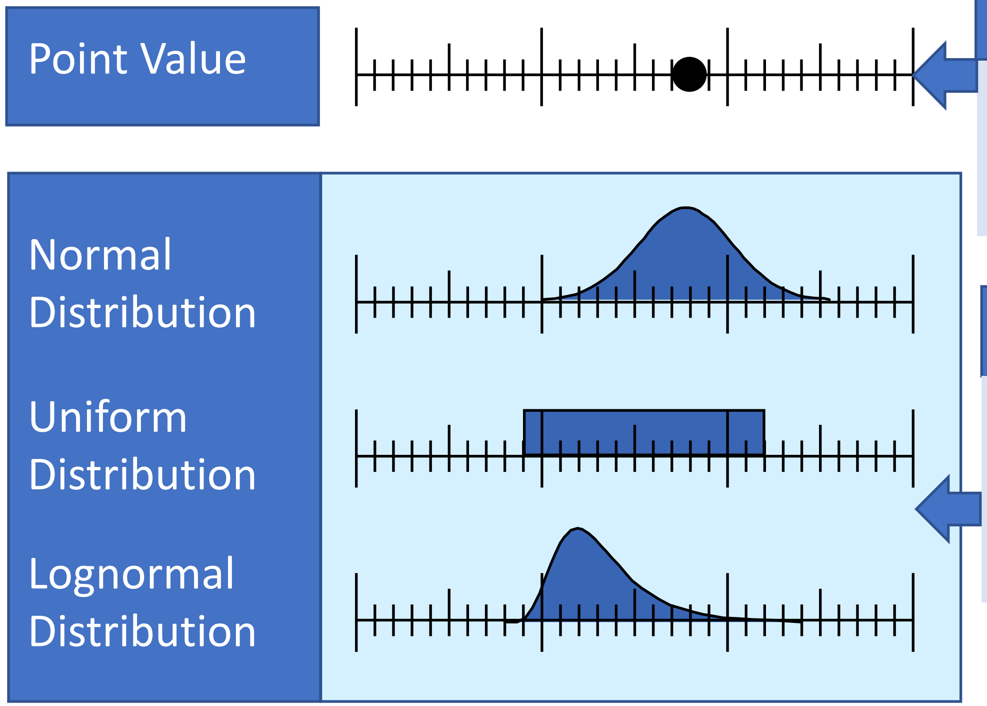
Results	
Net Present Value	**$ 2,542,767**

Single point result

The Concept of Measurement

The Need to Express Uncertainty

Risk analysis should be part of your business cases. You don't know all of the assumptions in the business case exactly. We need to be able to quantify that uncertainty.



Idealized Assumptions

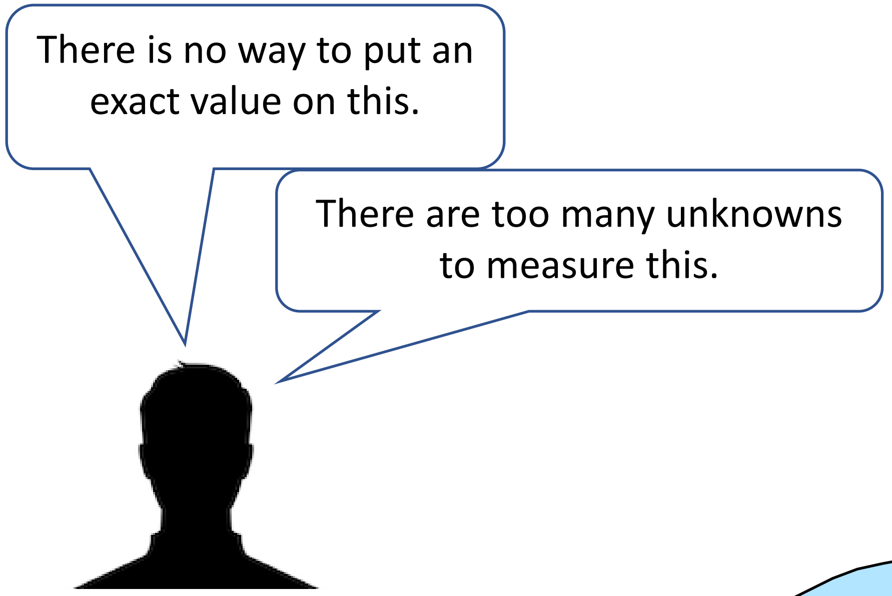
Most values in business cases are represented as exact values – even though exact values are almost never known.

Real-World Uncertainties

Most things we DO know are better represented by ranges and probabilities — we don't have to assume anything we don't really know.

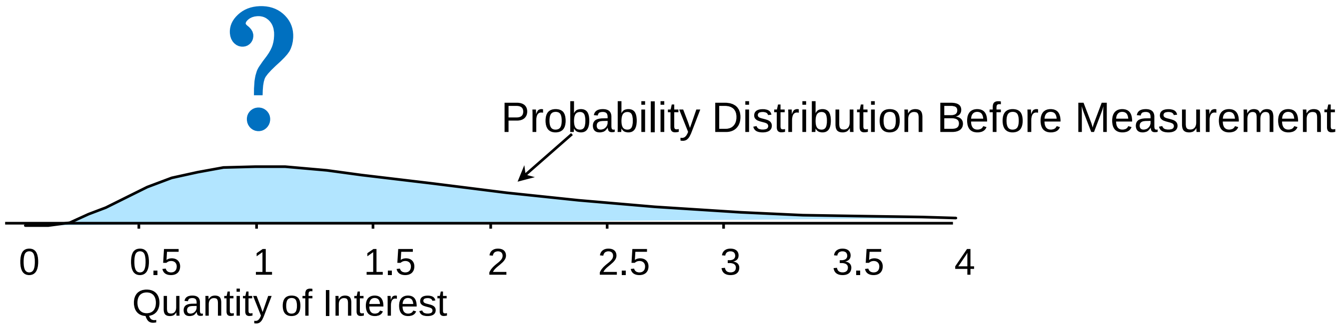
The Concept of Measurement

What Measurement Really Means



It's not a point value.

Measurement: a quantitatively expressed reduction in uncertainty based on observation.



The Concept of Measurement

What Measurement Really Means

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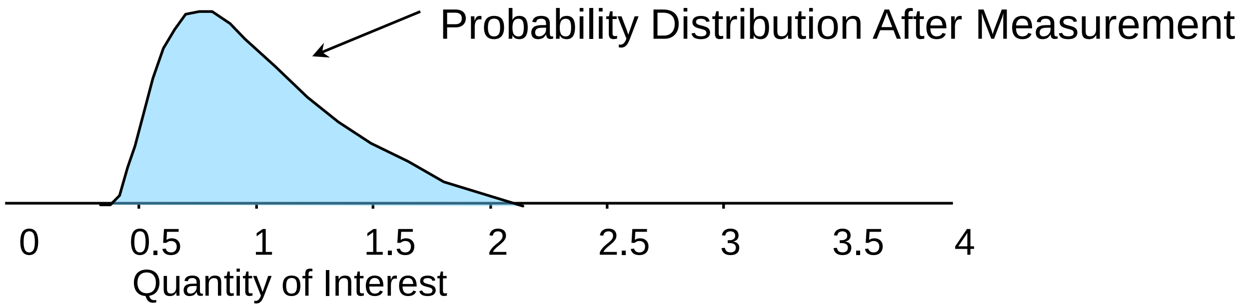


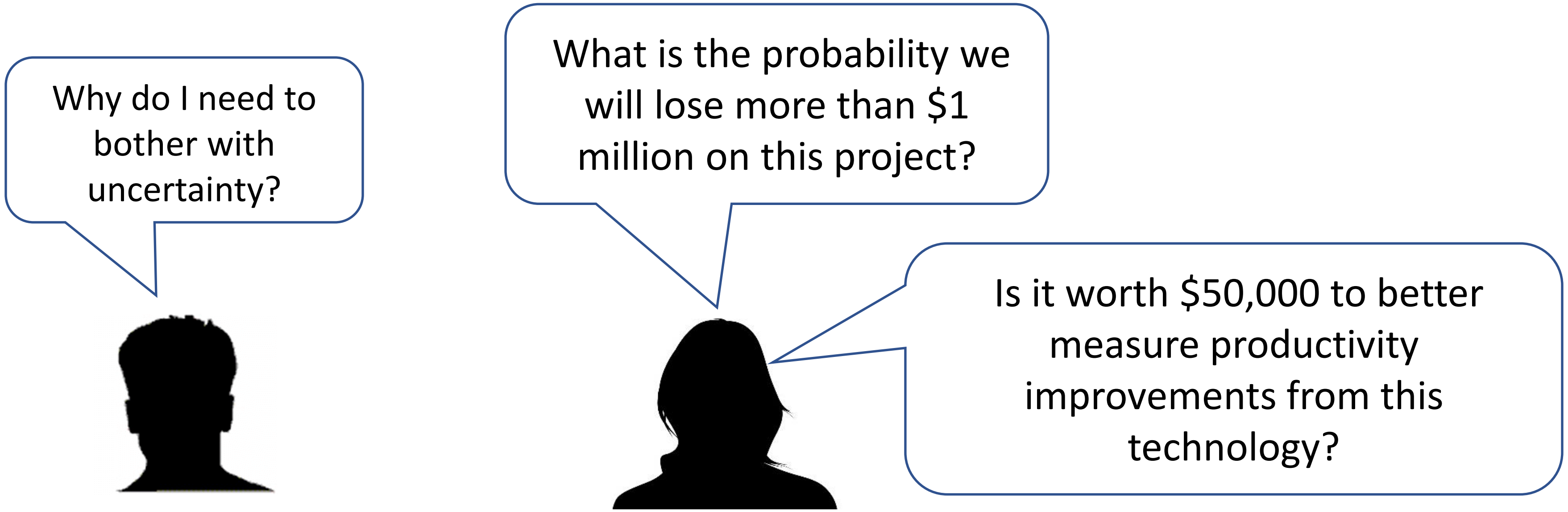
The Concept of Measurement

Expressing Uncertainty

Explicitly stating uncertainty is the only way to…

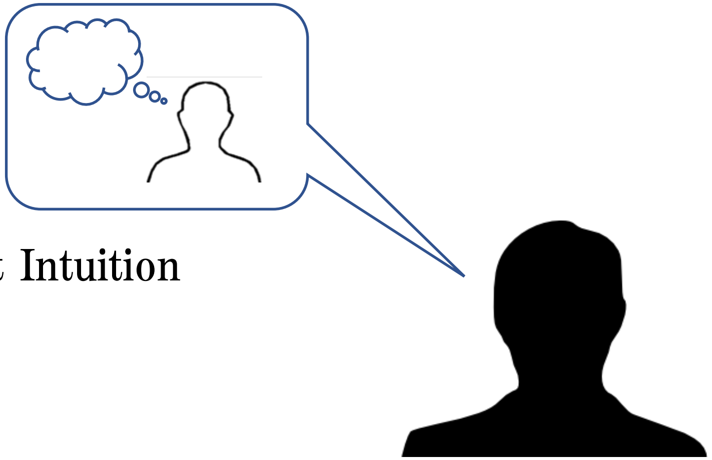
1)…quantify risks;

2)…compute the value of information.



The Concept of Measurement

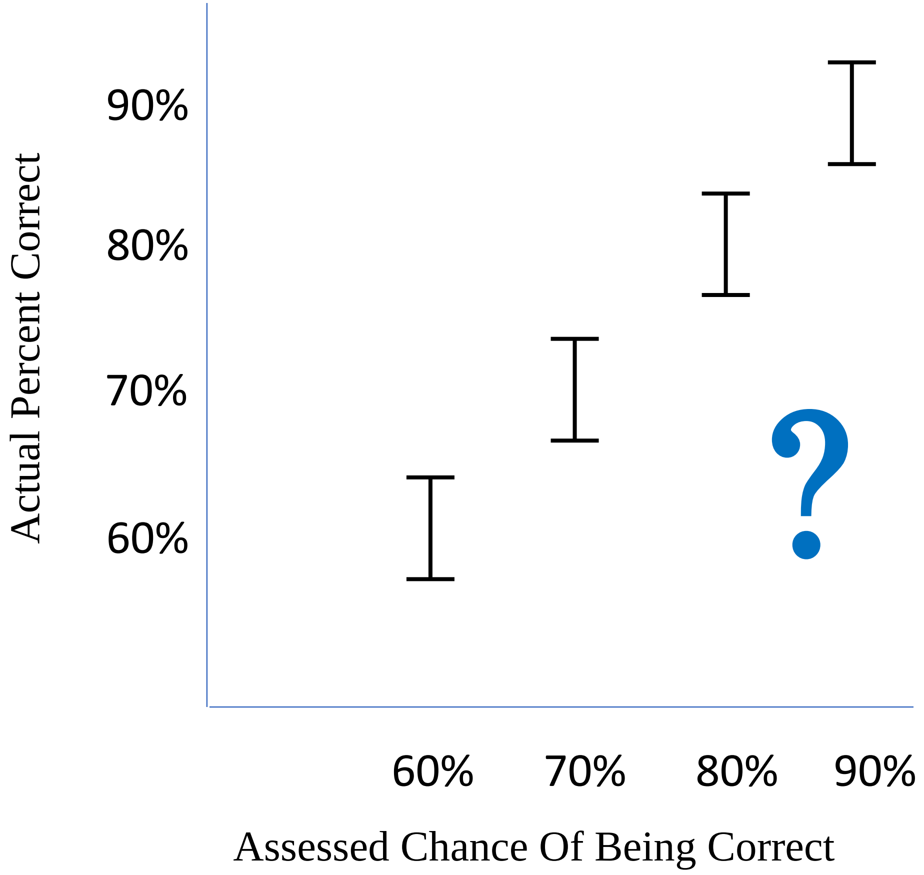
Expressing Uncertainty

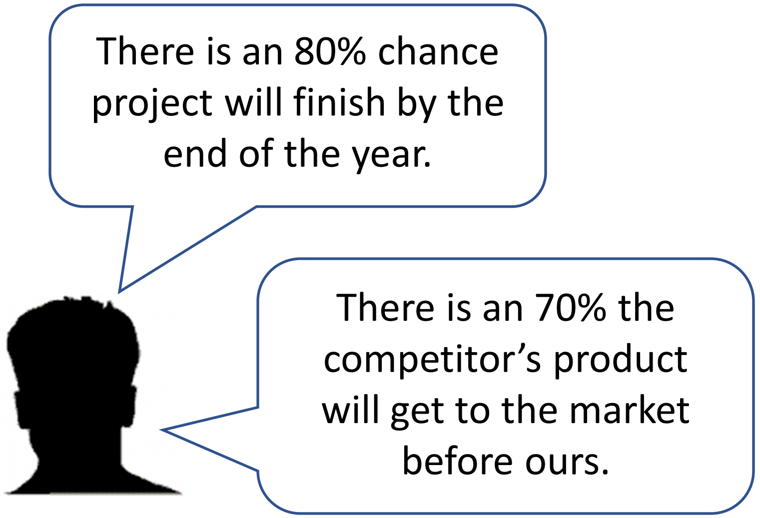


Expert Intuition

The Concept of Measurement

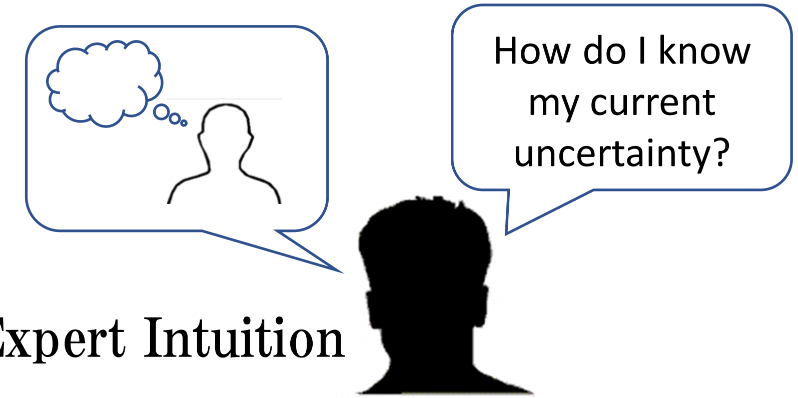
Comparing Expectations to Reality





The Concept of Measurement

Overconfidence and the Need to be "Calibrated"



"Overconfident professionals sincerely believe they have expertise, act as experts and look like experts. You will have to struggle to remind yourself that they may be in the grip of an illusion."

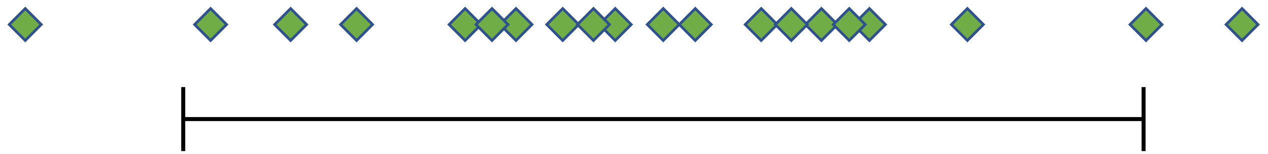
Daniel Kahneman, Psychologist, Economics Nobel

- Studies also show that measuring *your own* uncertainty about a quantity is a general skill that can be taught with a ***measurable*** improvement.
- HDR has calibrated over 1,500 people in the last 22 years.
- 85% of participants reach calibration within a half-day of training.

The Concept of Measurement

Calibrating Probabilities for Continuous Values

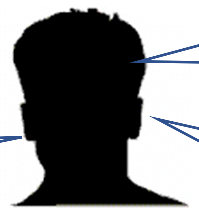
A 90% Confidence Interval



If you express uncertainty like this:

There is a 90% chance that our clients spend between 10% to 25% of their time in task X.

There is a 90% the sales for this product next quarter will be between 100k and 180k .



You can compute useful values like this:

The value of measuring the time spent in this activity is $825,000 per year. So we should measure it if the measurement only costs $40,000

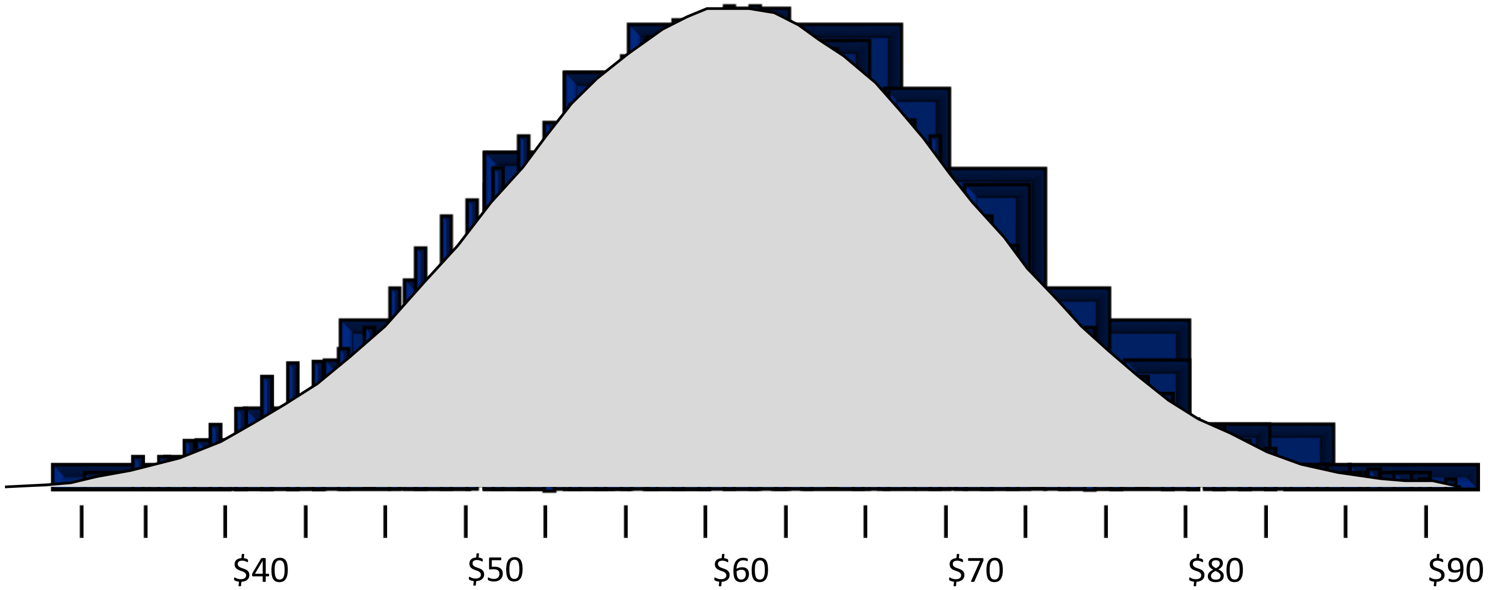
There is a 35% chance of losing more than $1 MM on this project. The return is not high enough to justify that risk.

The Concept of Measurement

Building an Example Probability Distribution

Uncertainty about "either/or" events are expressed as "discrete" probabilities (e.g. "35%).

Uncertainty about continuous values can still be thought of as sets of discrete probabilities.



Example: Cost per kg of a particular raw material two years from now

The Three Misconceptions Behind Any Perceived "Immeasurable"

The Object of Measurement

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The Object of Measurement

Defining Things

If a thing seems like an immeasurable “intangible” it may just be ill-defined.

Often, if we can define what we mean by a certain “intangible” we find ways to measure it.

Examples: Brand image, Security, Safety, etc.

The Object of Measurement

A Few Examples

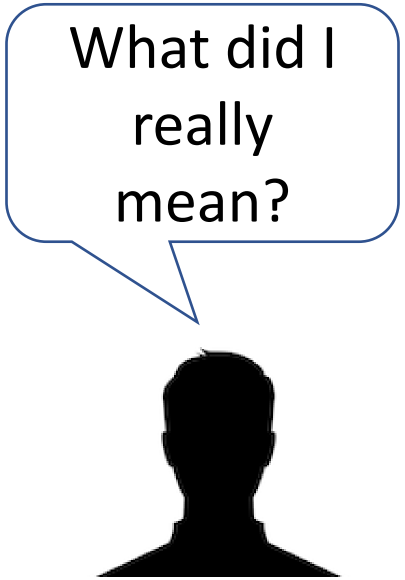
The Object of Measurement

A Few Questions to Consider

1. What is it? (What do you see when you see more of it? Can I separate it into parts?)
2. Why do you care? (What decision could depend on the outcome of this measurement?)
3. How much do you know about it now?
4. At what point will the value make a difference?
5. How much is additional information worth?

The Object of Measurement

What Do You See When You See More of It?



The "Intangible"	Possible Meanings After Clarification
"Employee Empowerment"	- Less management overhead - Certain decisions are more accurate and faster
"Information Availability"	- Time and cost of searching is reduced - Certain costly errors are less frequent
"Customer Relationship"	- Increased repeat business

The Object of Measurement

Why Do You Care?

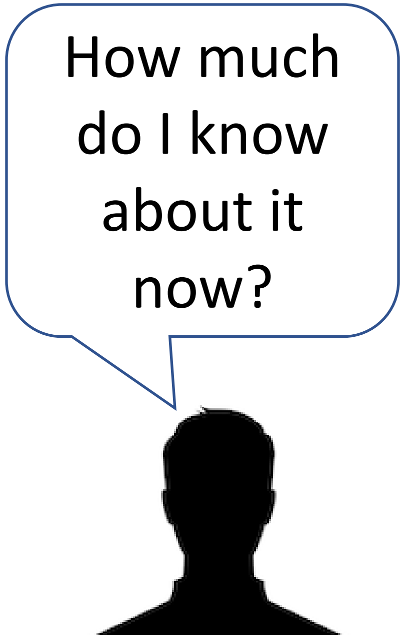
The "Intangible"	Possible Decisions
"Employee Empowerment"	Are you investigating whether to implement a different organizational structure?
"Information Availability"	Are you assessing a major investment in some new information technology?
"Customer Relationship"	Are you considering a new help desk system? Different quality control? A new service?

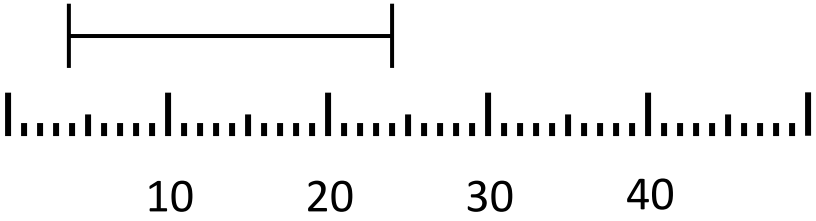
The Object of Measurement

What You Know, When It Makes a Difference, What It's Worth to Measure

Example: **Employee empowerment**

- I'm deciding whether to invest in a new technology to automate approval for common budget requests.
- Part of that decision requires we measure current time spent in that activity.
- The current estimate of time spent in that activity is 4 to 24 hours per month per employee in a particular department.





The Object of Measurement

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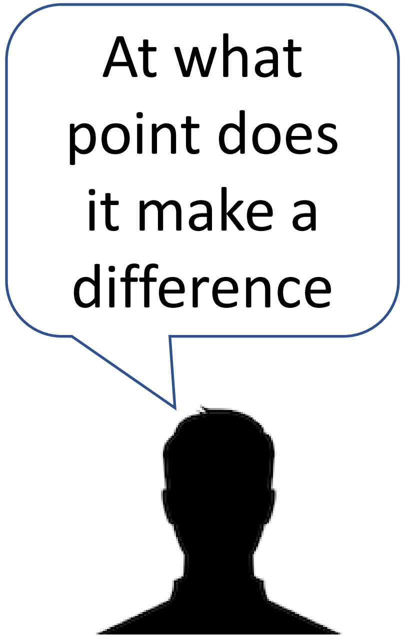
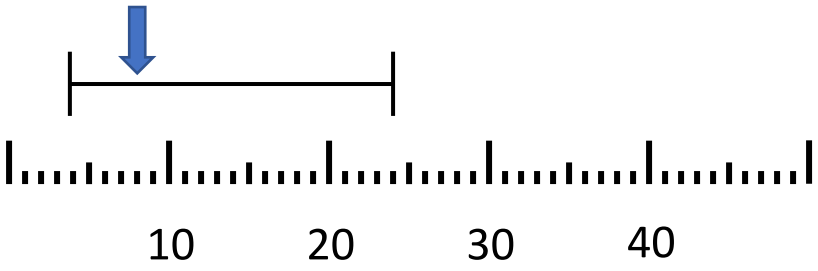
- If we spend more than 8 hours a month in this activity, then the new technology is justified.





The Object of Measurement

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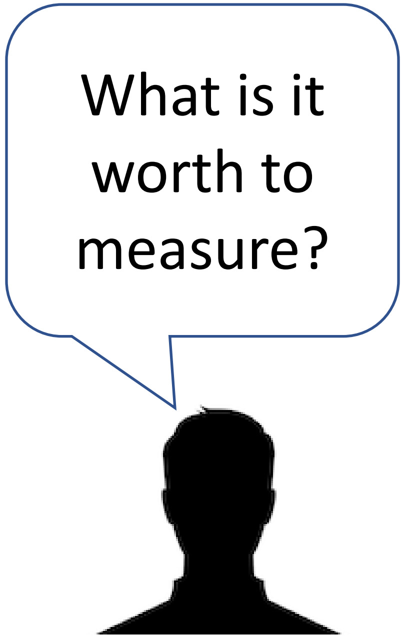
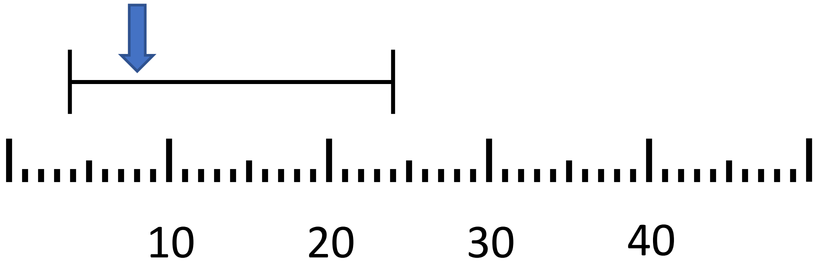


Example: **Employee empowerment**

- I'm deciding whether to invest in a new technology to automate approval for common budget requests.
- Part of that decision requires we measure current time spent in that activity.
- The current estimate of time spent in that activity is 4 to 24 hours per month per employee in a particular department.
- If we spend more than 8 hours a month in this activity, then the new technology is justified.
- Information value: Based on the size of the investment and other uncertainties, it is worth $48,500 to measure this.



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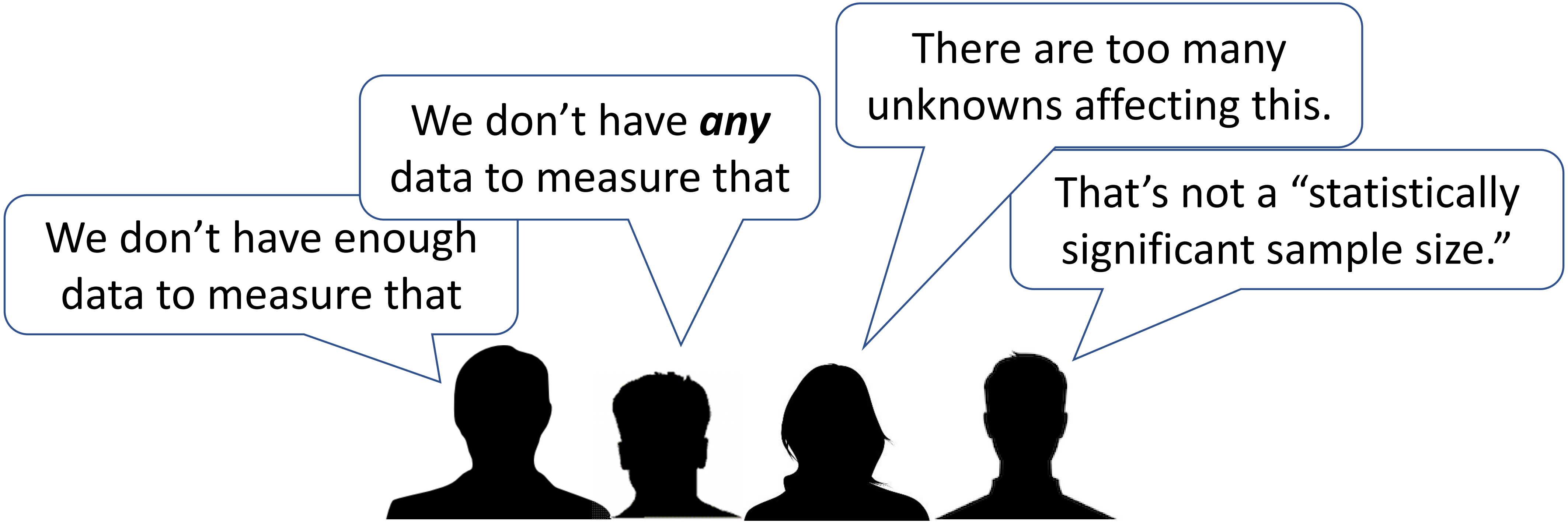
The Methods of Measurement

Common Misconceptions About Methods

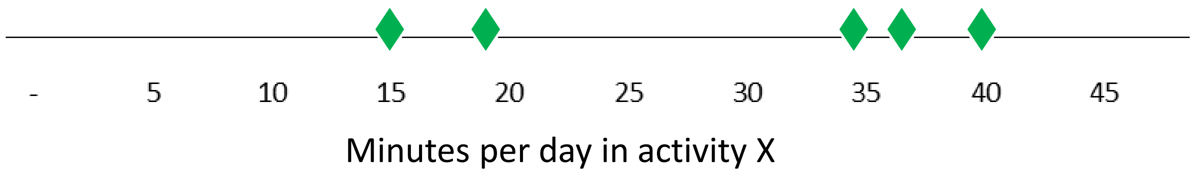


The Methods of Measurement

A Small Sample Example

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 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?



Another Small Sample Example

THE *URN OF MYSTERY* PROBLEM

There is a warehouse full of thousands of urns.

Each urn is filled with over a <u>million</u> marbles, each of which are red or green.

The proportion of red marbles in each urn is unknown – it could be anything between 0% and 100% and all possibilities are equally likely.

Questions:

If you randomly select a single marble from a randomly selected urn, what is the chance it is red?

If the marble you draw is red, what is the chance the majority of marbles are red?

If you draw 8 marbles and all are green, what is the chance that the next one you draw will be red?

The Methods of Measurement

Intuition vs. Math

There are 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

The Methods of Measurement

The "Math-less" Table

Approximate 90% Confidence Interval	
Sample Size	N^{th} largest & smallest sample value
5	1^{st}
8	2^{nd}
11	3^{rd}
13	4^{th}
16	5^{th}
18	6^{th}
21	7^{th}
23	8^{th}

Simple Measurement Takeaway - This table makes estimating a 90% confidence interval of a population median easy.

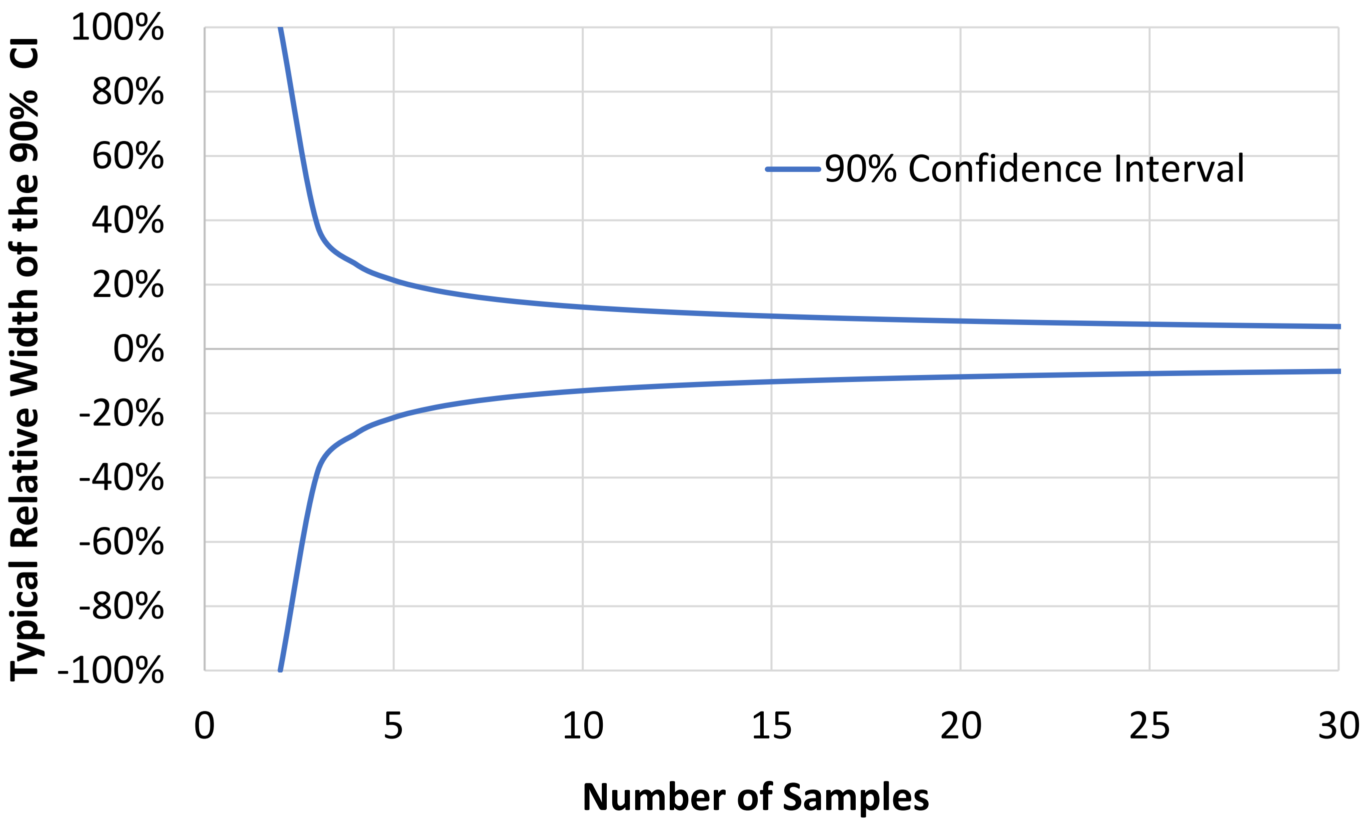
<u>The Rule of Five:</u> There is a 93.75% chance that the median of any population is between the smallest and largest values in a random sample of five.

This table expands on the Rule of Five. If you take 16 random samples of something, the 5^{th} largest and 5^{th} smallest values of that sample set approximate a 90% confidence interval.

The Methods of Measurement

How Much Samples Can Tell Us

The graph below shows the average of relative reduction in uncertainty as sample sizes increase by showing the 90% CI getting narrower and narrower with each sample according to the student-t method.



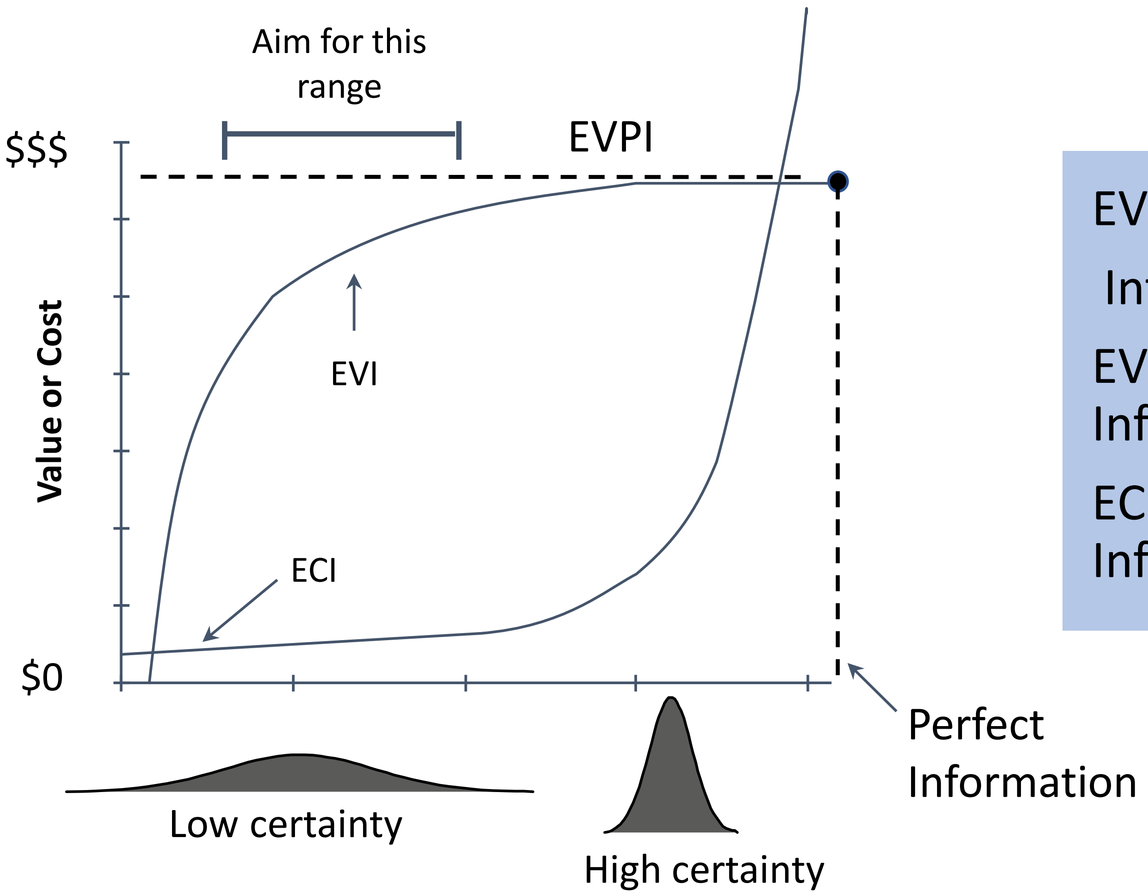
With a few samples, there is still high uncertainty but…

… each new sample reduces uncertainty a lot and the first few samples reduce uncertainty the most when initial uncertainty is high.

As number of samples increases, the 90 % CI get much narrower, but each new sample reduces uncertainty only slightly and beyond about 30 samples you need to quadruple the sample size to cut the error in half.

The Methods of Measurement

Overview of The Value of Information



EVPI – Expected Value of Perfect Information

EVI – Expected Value of Information

ECI – Expected Cost of Information

The Methods of Measurement

Inferences from a "Reference Class"

Danny Kahneman

A reference class is a population from which you draw observations of events to determine their frequency. Your "reference class" is much larger than you.

You can start by making as few assumptions as possible – your "baseline" uses only your reference class

Pierre-Simon Laplace
1749-1827

Laplace's "rule of succession": Given a population of reference class, like company-years, where some number of events occurred:

Chance of X (per year, per draw, etc.) =(1+hits)/(2+hits+misses)

The Methods of Measurement

A Fundamental Equation for Measurement Methods

"Bayesian" methods in statistics use new information to update prior knowledge.

It can answer "What is the chance of X is true if I see Y?"

Bayes Theorem:

$$P(X|Y) = \frac{P(X)P(Y|X)}{P(Y)} = \frac{P(X)P(Y|X)}{\sum_i P(Y|X_i)\, P(X_i)}$$

$P(X)$ = the probability of X

$P(X|Y)$ = the probability of X given the condition Y

$\sum P(Y \mid X_i)\, P(X_i)$ = the sum of the probability of Y under each possible condition

The Simplest Measurement Method

It turns out that calibrated people are already mostly "instinctively Bayesian."

- – Assess your initial subjective uncertainty with a calibrated probability
- – Gather and study new information
- – Give another subjective calibrated probability assessment

- What is your 90% confidence interval for the weight in *grams* of the average *Jelly Belly* jelly bean?
- Be sure the range is wide enough that you believe there is a 90% chance the true value is within it.
- We weigh on a digital scale a randomly sampled jelly bean from this jar. It is 1.41 grams.
- Now provide a new 90% confidence interval. Is it narrower?
- If it is narrower, it is because you had some prior knowledge about jelly beans you were taking into account. What was that prior knowledge?

The Methods of Measurement

Powerful Examples of “Impossible” Measurements

WWII German Tank Production Estimates			
Production Period	Intelligence Estimate	Statistical Estimate	Actual
June 1940	1000	169	122
June 1941	1550	224	271
August 1942	1550	327	342

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

- 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

Three Useful Working Assumptions

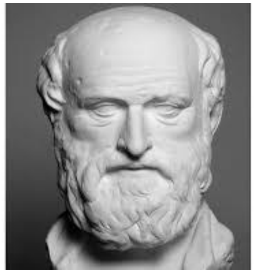
If your measurement is challenged with limited or messy data, consider the following:

- It’s been measured before.
- You have more data than you think.
- You need less data than you think.

“It’s amazing what you can see when you look”
Yogi Berra

The Methods of Measurement

Three Measurement Mentors



Eratosthenes – In ancient Greece, he measured the Earth's circumference to within 3% accuracy.

Enrico Fermi – He is the Nobel Prize-winning physicist who used "Fermi Questions" to break down any uncertain quantity (and was the first to estimate the yield of the first atom bomb).

Emily Rosa – At the age of 11, she was published in JAMA (youngest author ever) for her experiment that debunked "therapeutic touch."

Summary

Course Overview

- **Deciding How to Decide**
  The Meta-Decision
- **How to Measure Anything**
  Overcoming the Illusion of Intangibles
- **Applied Information Economics**
  Putting What Works Together