Economic Risk and Decision Analysis for Oil and Gas Industry
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Presented by
Dr. Thitisak Boonpramote

Department of Mining and Petroleum Engineering, Chulalongkorn University

Probability Assessment

Probability Assessment

Theoretical models

- probability theory
- statistical analysis

Empirical Evidence

- observation data

Classical view of probability

- relies on ***condition of symmetry***; i.e., in the absence of information, all events are regarded as equally probable.
- criticisms of this view
  - extremely unlikely that situations will arise in which individuals will *not have some experience or knowledge*.
  - it is not always obvious when the appropriate symmetry condition exists (equally likely assumption)
  - more often than not a condition of symmetry does not exist.
  - determining the existence of symmetry requires judgment.

Probability Assessment

Relative frequency view of probability

- collecting data by counting how many times an event occurs in a fixed number of trials.
- probability of an event occurring is taken to be the relative frequency as the number of trials becomes large.
- provides a more intuitive concept of probability.
- relative frequency requires a certain amount of judgment al also.
  - appropriate number of trials
  - comparability between data sets
- major criticism to this approach is that it requires situations in which a ***large number of repeated***, ***independent trials*** are available
  - catastrophic nuclear holocaust?
  - corporate acquisition

Probability Assessment

Means of Probability Assessment

- **Subjective**
  - judgmental process
  - incorporates knowledge and experience.
  - assumes the basic notion of probability is intuitive.
  - a quantification of personal uncertainty
  - *degree of belief* that an event will occur.
  - **Note: Adoption of the subjectivist view does not preclude the consideration of objective evidence**.

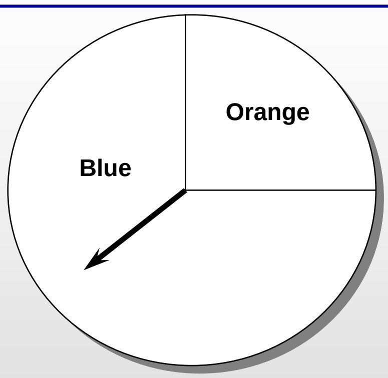
Probability Assessment

- Examples
  - **Objective based** - rely on idealized ***conditions of symmetry or a large number of trials***; characteristics of identifiable physical processes.
    - actuarial tables
    - statewide lotteries
  - **Subjective based -** acceptance of probabilities really reflects the ***knowledge of the person*** using them.
    - medical prognosis
    - new product technology
    - weather forecasting
    - horse-racing

Assessing Discrete Probabilities

- Direct assessment
  - “What is your belief regarding the probability that a certain event will occur?”
  - Simplest approach
  - May not be effective because of different interpretations of probability values.
  - DM is simply unable to convert ***beliefs*** to probability statements.
- Indirect assessment Methods
  - Obtained from a ***series of choices under conditions*** of uncertainty
  - Allows analyst to deduce probability data form this series of choices.
  - Enables individual to “code” his/her feelings about possible outcomes into probability terms.

Probability Wheel



Ask: **“**Would you prefer to bet that the exploration project will be successful, or that the wheel will stop on orange?”

Assessing Continuous Probabilities

- Apply the technique of assess individual probabilities and then use these to **plot a rough CDF**.
- The easiest way to use a **continuous distribution** in a decision tree or influence diagram is to approximate it with a **discrete distribution**.

Assessing Continuous Probabilities

Successive subdivisions method

- **Question:** Give me a price so that it is equally likely that the actual price of oil/barrel next year will be below or above that estimate?

  Answer: $92.00
- **Question:** If the price of oil is below $92.00/bbl next year, at what price is it equally likely to be below that price and between that price and $92.00/bbl.?

  Answer: $86.00
- **Question:** If the price of oil is above $92.00/bbl next year, at what price is it equally likely to be above that price and between that price and $92.00/bbl.?

  Answer: $95.00

. . . and so on.

Assessing Continuous Probabilities

Fixed Probability or **Fractile Method**

1. Establish a range by identifying the 0.05 and 0.95 fractiles.

- **Question:** What is the value of reserve outcome such that there is only a 5% chance that the reserves will be less than or equal to $x_{0.05}$.

  Answer: 50,000 BOE

- **Question:** What is the value of reserve outcome such that there is a 95% chance that the reserves will be less than or equal to $x_{0.95}$.

  Answer: 850,000 BOE

2. Next, assess the median of the continuous distribution.

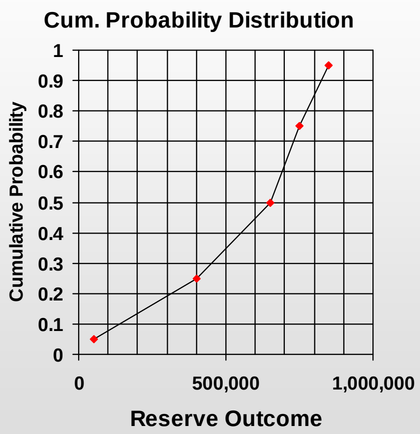
- **Question:** Give me a reserve outcome so that it is equally likely that the actual reserve outcome will be below or above that estimate.

  Answer: 650,000 BOE

- **To this point, we have determined the extreme points as well as the median of the distribution of reserve outcomes.**

Subjective Probability Assessment Results

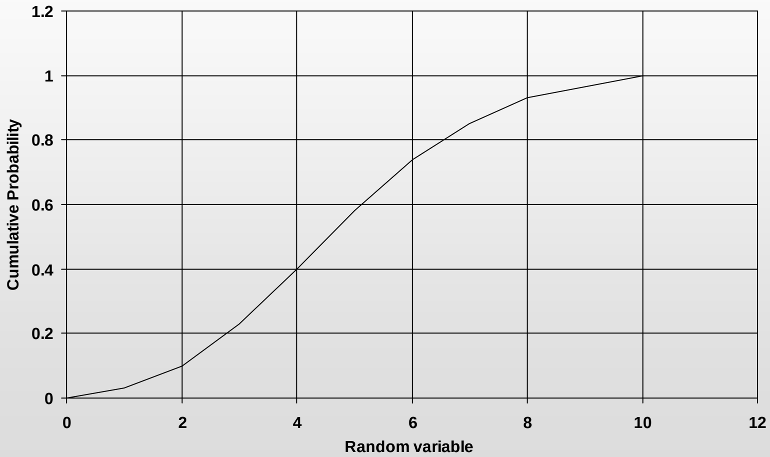
- 0.05 fractile = 50,000 BOE
- 0.95 fractile = 850,000 BOE
- Reserves are as likely to be above 650,000 BOE as below or equal to 650,000.
- There is a 0.25 chance that reserves will be below 400,000 BOE.
- There is a 0.75 chance that reserves will be below 750,000 BOE.



Discrete Approximations

- If a **continuous probability distribution** is approximated by a **discrete distribution**, we can use all the calculation procedures developed for discrete variables.
- Overall modeling strategy:
  - Use **continuous probability distributions** to represent uncertain events with continuous outcomes.
  - Utilize **discrete approximation techniques**.
  - Discrete approximations can be made as accurate as desired.
- Two Basic Approaches:
  1.) Equally Probable Interval Approximation
  2.) Specific Interval Approximation

1.Equally Probable Method



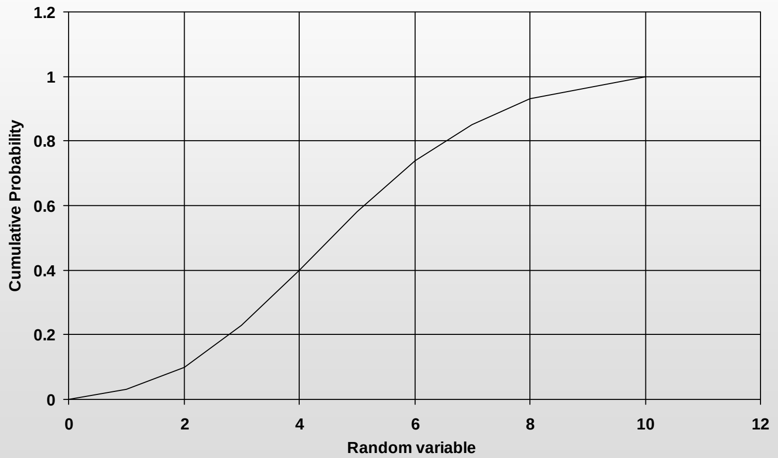
1.Equally Probable Method

Interval	Representative Point	Probability
$0 \le x \le 2.8$	$x_1 = 2.0$	$P(x_1 = 2.0) = 0.20$
$2.8 \le x \le 4.0$	$x_2 = 3.5$	$P(x_2 = 3.5) = 0.20$
$4.0 \le x \le 5.1$	$x_3 = 4.5$	$P(x_3 = 4.5) = 0.20$
$5.1 \le x \le 6.5$	$x_4 = 5.8$	$P(x_4 = 5.8) = 0.20$
$6.5 \le x \le 10.0$	$x_5 = 7.5$	$P(x_5 = 7.5) = 0.20$

1.Equally Probable Interval Approximation Procedure

- Obtain the **cumulative distribution function** for the continuous random variable.
- Decide on the **number of intervals** to be used in the approximation; let **n** equal the number of intervals.
- **Define the intervals** for the random variable by dividing the cumulative probability scale into **n** equal intervals and obtaining the corresponding intervals for the random variable.
- **Select a single point in each interval** to represent the entire interval by finding the point that divides the interval into two equally probably intervals.
- **Assign probability 1/n** to each of the points selected.

2.Specific Interval Method



2.Specific Interval Method

Interval	Representative Point	Probability
$0 \le x \le 2.0$	$x_1 = 1.0$	$P(x_1 = 1.0) = 0.10$
$2.0 \le x \le 4.0$	$x_2 = 3.0$	$P(x_2 = 3.0) = 0.30$
$4.0 \le x \le 6.0$	$x_3 = 5.0$	$P(x_3 = 5.0) = 0.32$
$6.0 \le x \le 8.0$	$x_4 = 7.0$	$P(x_4 = 7.0) = 0..20$
$8.0 \le x \le 10.0$	$x_5 = 9.0$	$P(x_5 = 9.0) = 0..08$

Probability Calculations:

$P(x \le 2) - P(x \le 0)$ = 0.10 - 0 = **0.10**

$P(x \le 4) - P(x \le 2)$ = 0.40 - 0.10 = **0.30**

$P(x \le 6) - P(x \le 4)$ = 0.72 - 0.40 = **0.32**

$P(x \le 8) - P(x \le 6)$ = 0.92 - 0.72 = **0.20**

$P(x \le 10) - P(x \le 8)$ = 1.00. - 0.92 = **0.08**

2.Specific Interval Approximation Method Procedure

- Obtain the **cumulative distribution function** for the continuous random variable.
- **Select the values of the random variable** that you wish to use as your representative points (i.e., integers).
- **Select the equally spaced intervals** about these representative points directly on the axis representing the random variable.
- Determine the **probability associated with each interval** using the cumulative distribution function.
- **Assign the probability** to the representative point.

Three Point Approximation

- As an alternative, use the Pearson-Tukey three point approximation
  - the median is assigned probability 0.63
  - the 0.05 fractile is assigned probability 0.185
  - the 0.95 fractile is assigned probability 0.185
- Discuss the discrete approximation with the Expert, and determine if he agrees with it

Experts and Probability Assessment

- In complex problems, expert risk assessment plays a major role in the decision-making process.
- The procedures for acquiring expert probability assessment has been established.
- Every assessment protocol should include the following steps:

Experts and Probability

- Background: The first important step
- Identification and recruitment of experts
- Motivating Experts
- Structuring and Decomposition, this step identifies specific variables for which judgments are needed.
- Probability-Assessment training

Experts and Probability

- Probability Elicitation and Verification, in this step the experts make the required probability assessment.
- As part of this process, an expert may provide detailed chains of reasoning for the assessments.
- Aggregation of Expert's Probability Distribution

Effectiveness of Assessments

- **No overall "best method"**
- The **DM's preferences** should motivate the **assessment techniques utilized.**
- Improving accuracy of subjective judgments
  - **Training of Assessors**
    - requires knowledge of probability and statistics
    - requires knowledge of biases.
    - requires experience in subjective assessments.
  - **Using several assessors**
    - probability elicitation by a number of people
    - requires aggregation of assessments
  - **Using an appropriate assessment procedure**
    - motivation, coding and checking for consistency

Some Final Comments on Subjective Probabilities

- The assertion is often made that subjective assessments are less “scientific” than other methods.
- In the context of a decision, subjective estimates are better than ignoring uncertainty.
- Don’t confuse numerical accuracy w/scientific validity which does involve the use of subjective judgments.
- If “scientific” includes logical, rational and consistent, then subjective estimates can be scientific in nature and application.

Decision Biases and Heuristics

- **Biases**: **systematic and predictable discrepancies** between the individual’s ***statement*** and his or her ***underlying knowledge***.
- **Motivational Biases**: Discrepancy, usually conscious, motivated by ***personal situation***.
  - Product champion understates cost and overstates sales.
  - Development geologist overestimates p(success)
- **Cognitive Bias**: Subconscious discrepancy introduced by the ***manner*** in which the individual processes information.
  - Biases due to the recency effect
  - Biases due to insensitivity to sample size
  - Biases due to ignoring the notion of regression to the mean

Heuristics

- **Heuristics** can be thought of as rules of thumb for accomplishing tasks.
- They are easy and intuitive ways to deal with uncertain situations
- It takes considerable practice before one is comfortable making probability assessments.
- ***Awareness of the heuristics and biases*** may help individuals make better probability assessments.

Motivation Biases

- Often easier to detect, but may be harder to counteract.
- Cause: Adjustment of response motivated by perception of reward.
- Examples:
  - Individual suppresses uncertainty to appear as "expert"
  - Sales manager gives low estimate, easy to succeed.
- Corrective Measures
  - Design reward system to encourage truthful responses.
  - Use formal assessment techniques making it difficult for subject to serve own interests.
  - Disqualify subject.

Cognitive Biases & Heuristics

- **Availability Heuristic**: Individuals/managers assess the probability or likely causes of an event by the ***degree to which instances are readily "available" in memory.***
- Examples:
  - Geologist bases her assessment of P(success of exploration well) on her recollection of success or failure of analog wells.
  - The product manager bases her assessment of the P(new product's success) on her recollection of the successes and failures of similar products during the recent past.
- Can be useful decision strategy; instances of more frequent events are generally revealed more easily than instances of less frequent events.
- Fallibility lies in the fact that availability of info is systematically affected by other factors uncorrelated with the objective frequency of the judged event.

Availability Heuristics - Biases

- Biases due to the ***retrievability of instances***.
  - The ***ease with which information is recalled*** or visualized influences the subject's assessment.
  - The more ***information available***, the higher the probability.
  - Bias associated with ***limited data*** and the ease with which that data comes to mind.

Examples

  - Probabilities are overestimated for recent, dramatic, redundant or certified information; e.g.. the corporate plan is certified.
  - Probabilities are underestimated in the opposite cases.
  - Which is riskier? Driving a car or flying on a commercial airline on a 400 mile trip?
    - Demonstrates that a particularly vivid event will systematically influence the probability assigned to that event by an individual.

Availability Heuristics - Biases

- Biases due to the ***effectiveness of a search set***.
  - Individuals are biased in their assessments of the frequency of events based on ***how the structure of memory affects the search process***.

Examples

  - Are there more words in the English language that (A) start with an "r" or (B) for which "r" is the third letter?
  - The existence of a hierarchy within an organization is likely to bias the effectiveness of your search set inappropriately.

Availability Heuristics - Biases

- Biases due to ***illusory correlation***
  - Individuals tend to ***overestimate*** the probability of two events co-occurring when they generate former mutual occurrence of the two events.

Examples

  - Consider the problem of determining whether a productive zone is related to a particular geologic structure. Proper analysis would include:
    - productive zone where structure exists
    - productive zone where no structure exists
    - a structure that is has no productive zone
    - no structure and no productive zone
  - Observations indicate that we generally recall several productive zones where structure exists and conclude there exists a correlation.
  - There are always at least four separate situations to be considered in assessing the association between two dichotomous events.

Representative Heuristic - Biases

- Representative Heuristic: Individuals/Managers assess the likelihood of an occurrence by the similarity of that occurrence to the stereotype of a set of occurrences.
- Examples
  - Product manager predict the success of a new product based on the similarity of that product to successful and unsuccessful products.

Representative Heuristic - Biases

- Bias associated with ***insensitivity to prior probability of outcomes***.
  - Individuals tend to **ignore prior probabilities**, or base rates, when any (even worthless) representative information is provided.

Example

  - Mark is finishing his MBA at a prestigious business school. He is very interested in the arts and at one time considered a career as a musician. Is Mark more likely to take a job in (A) management of the arts or (B) with a management consulting firm?
  - Using the ***representativeness heuristic***, people tend to analyze the degree to which Mark is representative of their image of individuals who take jobs in each of the two areas - generally selecting A.
  - What is wrong with this logic?
    - Overlooking the relevant base information
    - Much larger number of MBAs take jobs in management consulting.
    - Incorporating prior probabilities, it is more reasonable to select B.

Representative Heuristic - Biases

- Bias associated with ***insensitivity to sample size.***
  - Individuals fail to appreciate ***the role of sample size*** in evaluating the accuracy of sample.

Examples

  - A certain town is served by two hospitals. In the larger hospital about 45 babies are born each day and in the smaller hospital about 15 are born each day. As you know, about 50% of all babies are boys. However, the exact percentage varies from day to day. For a period of one year, each hospital recorded the days on which more than 60% of the babies born were boys. Which hospital do you think recorded more such babies?
    - Individuals generally say they are about the same.
    - Sampling theory, however, tells us that the expected number of days on which more than 60% of the babies are boys is much greater in the small hospital, because a large sample is less likely to stray from the mean.
  - Market researchers often **ignore the size of the sub-sample** - drawing erroneous conclusions about the population.

Representative Heuristic - Biases

- Bias associated with ***misconceptions of chance***.
  - Individuals expect that a sequence of events generated from a random process will represent the essential characteristics of that process, even when the sequence is too short for that expectation to be valid statistically.

Examples

  - You are drill a fifth exploratory well this year. You feel that this prospect will be successful because the last four were dry holes and the odds favor having at least one successful well in five.
    - Representativeness heuristic suggests that it is unlikely to have a dry hole because P(five dry holes) is very low.
    - This logic ignores the fact that we have already witnessed four dry holes and that the performance of the fifth is independent of the prior four wells.
    - Chance is commonly viewed as a self-correcting process in which a deviation in one direction induces a deviation in the opposite direction to restore equilibrium. In fact, deviations are not corrected as a chance process unfolds, they are merely diluted.

Anchoring and Adjustment

- Individuals/managers make assessments by ***starting from an initial value*** and adjusting this initial value to yield a final decision.

  Examples
  - Salary negotiations: It is common for an employer to ask a potential job candidate her ***current salary***. Here the employer is searching for an anchor from which to adjust the firm's offer.
  - The **first impression syndrome**: Often, we place so much emphasis on that first impression that we do not adjust our opinion appropriately at a later date.
    - People are found to make an estimate by starting from an initial (somewhat irrelevant) anchor that is provided and adjust it to yield an answer.
    - The initial value, or starting point, may be suggested from historical precedent, the formulation of the problem or random information.
    - Experimental evidence suggests that regardless of the initial value, ***adjustments from the initial value*** tend to be insufficient.

Conjunctive and disjunctive events bias

- Individuals tend to ***overestimate*** **the probability of conjunctive events** and ***underestimate*** **the probability of disjunctive events**.

Which of the following appears most likely? Which appears second most likely?

A. Drawing a red marble from a bag containing 50% red marbles and 50% white marbles.

B. Drawing a red marble seven times in succession, with replacement, from a bag containing 90% red marbles and 10% white marbles.

C. Drawing at least one red marble in seven tries, with replacement, from a bag containing 10% red and 90% white marbles.

  - The most common order selected in experiments is B-A-C.
  - The correct order of likelihood is C-A-B, the exact opposite!

- Overestimate the probability of **conjunctive events (B)**
- Underestimate the probability of **disjunctive events (C)**
- Initial probability of any one event provides a natural "anchor", so, the perceived probability of choice B stays inappropriately close to 0.9 and choice C stays close to 0.1.

General Cognitive Biases

- **Overconfidence**
  - Individuals tend to be ***overconfident*** in their fallible judgment when answering moderately to extremely difficult questions.
  - Subjects typical demonstrate no (some degree of) overconfidence to questions which they are familiar (unfamiliar).
- **The Confirmation Trap**
  - Individuals tend to seek confirming information for what they think is true and exclude disconfirming information from their search process.
- **Hindsight**
  - After finding out whether or not an event occurred, individuals tend to overestimate the degree to which they would have predicted the event without the benefit of outcome knowledge.
  - Research suggests that people are typically not very good at recalling or reconstructing an uncertain event after the fact.
  - Overestimating what you knew and distorting beliefs about what you knew beforehand by what we later found to be true.

General Cognitive Biases

- Unstated Assumptions
  - Assessment **does not** ***reflect full uncertainty*** because subject does not feel responsible for events (unstated) beyond his or her control.
  - Assessments not accounting for labor strikes, war, currrency devaluation, political events, etc.
  - Information flow and outcome assessments are flawed when underlying assumptions about the process are not articulated.

Some Corrective Measures

- **Motivational Biases**
  - Design reward system to encourage truthful responses.
  - Use assessment technique that makes it difficult for subject to serve own interests.
  - Disqualify subject.
- **Availability Bias**
  - Explore and balance the set of possible events such that “availability” effects are lessened.
  - Consider the unlikely scenario retrospectively from the future, and explain how it happened.
- **Anchoring and Adjustment & Unstated Assumptions**
  - Use probability assessment procedure that removes rather than creates anchors.
  - Utilize a “scenario planning” approach to remove “anchor” and articulate assumptions.