Sampling

Presentation to the Audit Forum

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Course Objectives

To familiarize participants with factors to consider in:

- deciding whether a probability or nonprobability sample is appropriate, and
- selecting a sample.

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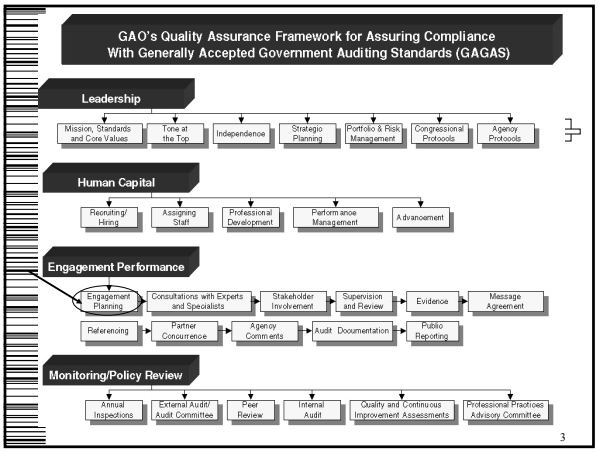

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Engagement Performance: Engagement Planning

Consider developing a design matrix

- A design matrix clearly identifies:
  - The researchable question (audit objective)
  - Sources of information
  - Methods of data collection
  - Limitations
  - Types of statements and outcomes of the audit
- If appropriate, identify stakeholders and reach agreement on the study design

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Key Terms

- Target Population
  - The complete collection of units we want to study.
- Sampling Frame
  - A list of a population's sampling units from which a sample is selected.
- Sample Design
  - A sampling plan and estimation procedures.
- Sample
  - A subset of cases selected from the entire population, usually referred to as a probability sample, if appropriate.

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Key Terms

- Materiality or Criteria
  - The magnitude of an item's omission or misstatement in a financial statement that, in the light of surrounding circumstances, makes it probable that the judgment of a reasonable person relying on the information would have been changed or influenced by the inclusion or correction of the item.
- Precision
  - The range within which a sample result is expected to be accurate. Example, +/- 5%. Also called Margin of Error or Sampling Error.
- Confidence Level
  - A sample-based estimate expressed as an interval or range of values within which the population value is expected to be located, with a specified confidence level. Same as Upper Bound and Lower Bound.

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Probability and Nonprobability Sampling

- A sample is a subset of the population:
- Probability sample—a sample chosen so each member of a population has a known, non-zero chance of being selected
- Nonprobability sample—a sample that chosen from a population deliberately with reasons that can be articulated and defended. Not an arbitrary or convenience sample. Cannot generalize to the population.
- The decision depends on the objectives of the job.

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Features of Probability Sampling

- Can make statements about the population [generalize]
- Can quantify amount of error due to sampling
- May indicate presence and extent of condition in population
- Provide unbiased procedure for selecting cases

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Features of Nonprobability Sampling

- Can make statements only about the sample units selected
- May be a viable option when probability sampling not feasible
  - Due to time, resources, cannot establish a reliable and valid population
- May indicate presence but not extent of condition in the population

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Probability or Nonprobability Sampling

If sample information is needed for a job:

- FIRST consider probability sampling
- If probability sampling is not appropriate or feasible, THEN consider nonprobability sampling

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Some Reasons to Use Nonprobability Sampling

- Need detailed, specific information
- Time or resource constraints
- May not be necessary to achieve the goals of the job
- May be preferred if you need to talk to a variety of informants to gather the necessary information

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Frequent Applications of Nonprobability Sampling

Need to specify the unit of analysis (subject of your study), then select:

- Site visit locations
- Agency files
- Interview participants
- Regions or field offices

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Nonprobability Sampling: Goal in selecting cases

Systematic (no longer using the word judgmental sample because it implied it was arbitrary)

- Carefully considered; you can articulate your selection approach
- Valid and reliable (valid means what you select is what you intended to select; reliable means if you repeated the selection process you would have the same outcome; consistent and stable)

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Probability and Nonprobability Sampling : Example

What were the lessons learned from the Census 2000 Outreach and Promotion efforts?

- The team selected sample included LA Metro area, the state of WY, and the city of Detroit. Because:
  - LA was a challenging population (non-native speakers and had made significant improvements in participation)
  - WY was rural and had a variety of challenges (e.g., high fences and guard dogs)
  - Detroit was innovative and had effective efforts as reported by Census officials (added to the face validity of the study)

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Steps to Take in Selecting a Nonprobability Sample (1)

- Define what your sample covers (and what it does not cover)
- Determine which type of sample (probability or nonprobability)
- Specify the case/unit(s) of analysis (will you be reporting about people (participants and/or non-participants), records of events, offices or program)

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Steps to Take in Selecting a Nonprobability Sample (2)

- Develop criteria to select initial group of cases
- Determine number of cases to select
- Consider ways to maximize the validity and reliability of your findings
  - Triangulation (additional supporting evidence or collaboration), seeking out disconfirming cases
- If a list of cases is not available, consider alternative means

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Nonprobability Sample Selection (1)

Methods based on using a Population List

- Best Case
- Worst Case
- "Bracketing"—one city with competition and one without
- "Typical" case
- Intense case– accidents or severe wildfires
- Unique case
- "Cluster"– take a few small, a few medium, and few large

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Nonprobability Sample Selection (2)

Techniques to Use When a List of the Population is Not Available

- Snowball-- Homeless shelter families referring other families that they know
- Expert Referral-- Asking experts for literature references
- Convenience– Attend a conference

- And you can combine these methods

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Describing Nonprobability Samples in Our Products (1)

- Appropriate language to describe how sample was selected
- Appropriate wording describing the cases
- Appropriate caveats in body of the report
- Detailed description is typically in Objectives, Scope and Methodology (OSM) for GAO reports

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Describing Nonprobability Samples in Our Products (2)

- Footnote usually in body of report:

"Results from nonprobability samples cannot be used to make inferences about a population, because in a nonprobability sample some elements of the population being studied have no chance or an unknown chance of being selected as part of the sample."

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Describing Nonprobability Samples in Our Products (3)

Refer to cases from a nonprobability sample in the body of the report as:

- "GAO's large grant study cases"
- "The two largest grant programs"
- "Grants for New York and Los Angeles"

NOT

- "Large grant cases" or "Large grants"

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Characterizing Results from Nonprobability Samples

- Use accurate language and caveats to describe results
- Generally avoid percentages—use numbers instead
  - Percentages create the impression that you are referring to the entire population
  - Small differences appear large when percentages are used
- Don't generalize beyond nonprobability sample

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Documenting Nonprobability Samples

- Document details about what was done, including
  --how nonprobability sampling decision was made
  --selection criteria
  --other details, such as what nonprobability sample covers

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Handling Requester "Suggestions"

- Guidance document on handling requester's or sponsor's suggestions for locations or items to test

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More about Using Probability Samples

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Learning Objectives

- To better understand probability sampling approaches and their uses
- To better understand sources of error associated with probability sampling

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Characteristics of a probability sample from a population

- One of a number of potential samples
- Each element in the population must belong to at least one potential sample
- Each potential sample has a chance of being selected
- The chosen sample is selected by a random process in accordance with the chances of selection
- Technical Reference: Cochran (1977) p. 9, or Sarndal, Swensson, and Wretman (1992)

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Probability and Nonprobability Samples
Why consider probability samples?

- To be able to make estimates about a population
- To determine whether a threshold was met
- Probability samples may be necessary if:
  - The results are sensitive
  - The outcomes are a main focus of the report
  - Probability samples allow an analyst to quantify the error in an estimate because a sample (instead of a census) has been selected.

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Probability and Nonprobability Samples
Why consider Nonprobability samples?

- Difficult to develop an appropriate sampling frame
- Data not a central component of the report
  - (Data derived from nonprobability sampling can be used as a central component of a report as long as probability sampling was considered and discarded for appropriate reasons.)

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Sampling Used at GAO

- Performance Audits (may or may not use a questionnaire)
  - Estimating characteristics of a population
  - Internal controls testing
- Financial Audits (e.g., IRS, Public Debt)
  - Financial Statement Audits

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Sample Design

- Simple Random Sampling
- Stratified Random Sampling
- Cluster Sampling
- Systematic Sampling
- Unequal Probability Sampling

- More than one of these strategies can be used in a sample design!
- Each sample design has pros and cons; practical considerations often influence the type of sample design used

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Sample Design
Example: Simple Random Sampling

- Main Characteristic: each subset of a given size has an equal chance of being selected. This implies that every element in the population has an equal chance of being selected.
- Example: Population = (Smith, Brown, Jones). A simple random sample of size two is to be selected. The possible outcomes are:
  - (Smith,Brown)
  - (Smith,Jones)
  - (Brown,Jones)

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Sample Design
Simple Random Sampling

- Suppose the population had 1000 people and you wanted a simple random sample of 50. Listing all possible samples is impractical. How would you select such a sample?

- Use a random number table
- Use a random number generator
- Use software

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Sample Design
Pros and Cons of Sample Designs

- Simple random sampling
  - + has good theoretical properties
  - not practical in some situations (e.g., selecting a sample from the U.S. population)

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Sample Design
Example: Stratified Random Sampling

- Before sampling, each element in the population is assigned to one group, or stratum.
- In <u>each</u> stratum a simple random sample is selected
- Example: stratify people by gender, and then select separate simple random samples of men and women.
- Reasons for stratifying?
  (1) Subgroups (2) Precision (3) Efficiency (4) Administrative Convenience

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Sample Design
Pros and Cons of Sample Designs

- Stratified random sampling
  + often gives better results than simple random sampling
  - not all populations are easily classified into groups (strata)

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Sample Design
Example: Cluster Sampling

- Each population element belongs to a "cluster." Typically, the clusters are the initial sampling units.
- Clusters are not the same as strata. Samples are taken from all strata; in cluster sampling, some but not all clusters are sampled.
- Example: the U.S. has ~3000 counties. Select a sample of counties, then select a sample of persons living in the sampled counties. The U.S. counties are the clusters in this example.
- Reasons for cluster sampling? Often cost and/or time efficiency.

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Sample Design
Comparison of Sample Designs

- Cluster sampling
  - + often is employed because of practical considerations
  - - usually is not as statistically "efficient" as other sample designs

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Sample Design
Example: Systematic Sampling

- The population elements are ordered (e.g., alphabetical, time, or even random). **Select a random starting point.** Include that element and every element at a specified interval thereafter into the sample.
- Example: two names are to be selected from: (Brown, Jackson, Johnson, Jones, Smith, Williams). Randomly pick a number from 1 to 3, select that person, and the name that is 3 places farther down in the list (e.g., Jackson and Smith, if the random number is 2.)
- Reasons for systematic sampling? Records are kept manually; lack of explicit sampling frame.

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Sample Design
Example: Systematic Sampling

- How do you select a systematic sample?
- "Start-with"
- "Take-every"
- For example, population = 100, sample = 25
  Start with a random number between 1 and 4
- Take every 4^{th} case thereafter

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Sample Design
Comparison of Sample Designs

- Systematic sampling
  + easy to use (easy to provide instruction)
  + guarantees a good "spread" through the list
  - should be avoided if characteristic of interest increases or decreases cyclically in the list

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Sample Design
Example: Unequal Probability Sampling

- Uses a measure of size in the sampling process; sometimes called "sampling with probability proportional to size." In audit sampling, sometimes called "dollar unit sampling."
- Example 1: when selecting transactions for an audit sample, give transactions with higher dollar amounts a higher chance of selection.
- Example 2: when sampling U.S. counties, giving counties with larger populations a higher chance of selection. Perhaps select the largest counties with certainty.

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Sample Design
Comparison of Sample Designs

- Unequal probability sampling
  - + efficient if size of sampling element is related to what's being measured
  - - often inefficient if the goal is to estimate the proportion of elements with a characteristic

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What sample size do I need?

Answer depends on a lot of factors, including:

- The precision needed
- The confidence level needed
- The audit objective(s)
- Resource constraints

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How do precision and the confidence level affect sample size?

- Precision—the extent to which estimates from different samples of the same size vary from each other.

High precision means estimates from different samples tend to be similar.

Low precision means estimates from different samples tend to be different.

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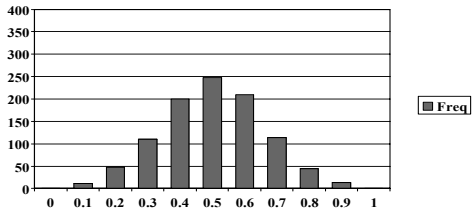
Sample Size, Precision, and Confidence

Flip a coin 10 times (1000 repetitions)



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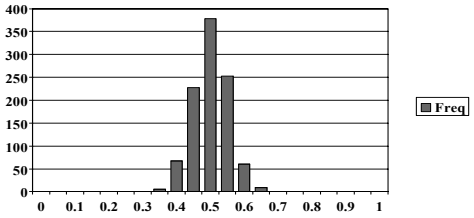
Sample Size, Precision, and Confidence

Flip a coin 50 times (1000 repetitions)



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Sample Size, Precision, and Confidence

- Sample size impact-All else equal, higher levels of precision require larger sample sizes.

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Sample Size, Precision, and Confidence

- Confidence Level-The probability that an inference about an estimate, as expressed by a confidence interval around that estimate, will contain what it claims to contain.
- Confidence Interval-A range of values (e.g. “25% to 45%”) within which the population value is expected to be located with a specified confidence level (e.g. 95 percent).
- Higher confidence levels provide more assurance that confidence intervals contain what they claim to contain.

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Sample Size, Precision, and Confidence

- GAO uses 95% confidence levels for performance (non-financial) audits.
- Confidence levels for financial audits vary-see GAO’s Financial Audit Manual for more details.
- Sample size impact - all else equal, higher confidence levels require larger sample sizes.

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Sample Size, Precision, and Confidence

- Joint impact of precision and confidence levels on sample sizes, using simple random sampling, for an attribute that occurs about **50%** of the time

Precision→ Conf. Level	+/- 10 pct. points	+/- 5 pct. points
90%	68	271
95%	97	385

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Sample Size, Precision, and Confidence

- Joint impact of precision and confidence levels on sample sizes, using simple random sampling, for an attribute that occurs about **25%** of the time

Precision→ Conf. Level	+/- 10 pct. points	+/- 5 pct. points
90%	51	203
95%	73	289

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Sample Size, Precision, and Confidence

- The type of audit objective also affects the sample size. Two common types of objectives are:
  - Does what we're estimating exceed a threshold or a materiality?
  - What is our best guess of the value of the item we are estimating?

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Sample Size, Precision, and Confidence

- Confidence intervals are provided with estimates in GAO reports. Sometimes only the confidence intervals are provided.

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Confidence Interval Statements

- We are 95 percent confident that the actual proportion of participants meeting the guidelines was between 13 and 31 percent.
- We estimate that the total revenue was $43.4 million, plus or minus $6.5 million.
- We are 95% confident that at least 10 percent of the vouchers did not have proper supervisory approval.

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Sample Size, Precision, and Confidence in Financial Audit Settings

- In financial audit settings we generally assess whether dollars are adequately controlled.
- If non-statistical assessments indicate that controls are poor, these findings will be reported.
- If non-statistical assessments indicate that controls are adequate, statistical tests may subsequently be conducted to see whether the non-statistical assessments can be supported.

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Sample Size, Precision, and Confidence in Financial Audit Settings

To Test for Adequate Controls

- Specify total dollars, expected dollars in error, the dollar amount above which we would say that dollars are not adequately controlled (a.k.a. the materiality), and the confidence level.
- Determine sample sizes so that if the expected error dollars are found, we can state with the specified confidence level that total dollars in error in the population does not exceed the materiality threshold.

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Weighting

- What is weighting?
  - A sample weight is the reciprocal of the probability of selecting the element.
- Why weight sample data?
  - Sample weights are used to take into account different chances of selection
  - To make sure that, when aggregating the sample data together, they properly reflect the population from which they were sampled.
  - Sometimes weights can be used to compensate for nonresponse.

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Nonsampling Error

- Nonsampling errors: errors other than those due to the fact that a sample rather than a census was taken. Some sources include:
- Some of the target population is not in the sampled population.
  - Undercoverage -- failing to include all of the target population in the sampling frame.
  - Nonresponse -- failing to obtain responses from the entire sample.
- The measuring instrument is imprecise, is misunderstood, and/or has a tendency to differ from the true value in one direction.
- Data processing has logic or other errors.

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Conclusion

- This completes the presentation on sampling
- We'll take a 15 minute break and return to a presentation on
- Surveys

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