

Lecture 17: Case Studies

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Adapted from Perry, Sim & Easterbrook, *Case Studies for Software Engineering*, ICSE 2004 Tutorial

What is a case study?

- A case study is an empirical research method.
 - ↳ It is not a subset or variant of other methods, such as experiments, surveys or historical study.
- Best suited to applied problems that need to be studied in context.
 - ↳ Phenomena under study cannot be separated from context. Effects can be wide-ranging.
 - ↳ How and why questions
- Settings where researcher has little control over variables, e.g. field sites.
- Effects take time to appear.
 - ↳ Days, weeks, months, or years rather than minutes or hours.

What is not a case study?

→ Not an exemplar or case history

- ↳ In medicine and law, patients or clients are “cases.” A review of interesting instance(s) is called a case study.
- ↳ Not a report of something interesting that was tried on a toy problem

→ Not an experience report

- ↳ Retrospective report on an experience (typically, industrial) with lessons learned

→ Not a quasi-experiment with small n

- ↳ Weaker form of experiment with a small sample size
- ↳ Uses a different logic for designing the study and for generalizing from results

Why conduct a case study?

→ To gain a deep understanding of a phenomenon

- ↳ Example: To understand the capability of a new tool
- ↳ Example: To identify factors affecting communication in code inspections
- ↳ Example: To characterize the process of coming up to speed on a project

→ Objective of Investigation

- ↳ Exploration- To find what's out there
- ↳ Characterization- To more fully describe
- ↳ Validation- To find out whether a theory/hypothesis is true

→ Subject of Investigation

- ↳ An intervention, e.g. tool, technique, method, approach to design, implementation, or organizational structure
- ↳ An existing thing or process, e.g. a team, releases, defects

When to use case studies

Strategy	Form of Research Question	Requires Control of Behavioral Events?	Focuses on contemporary events?
Experiment	How, why?	Yes	Yes
Survey	Who, what, where, how many, how much?	No	Yes
Archival Analysis	Who, what where, how many, how much?	No	Yes/No
History	How, why?	No	No
Case Study	How, why?	No	Yes

How can I tell it's a case study?

- Has research questions set out from the beginning of the study
- Data is collected in a planned and consistent manner
- Inferences are made from the data to answer the research questions
- Produces an explanation, description, or causal analysis of a phenomenon
 - ↳ Can also be exploratory

What is a case study?

→ A case study is an empirical inquiry that

- ↳ Investigates a contemporary phenomenon within its real-life context, especially when
- ↳ The boundaries between phenomenon and context are not clearly evident.

→ The case study inquiry

- ↳ Copes with the technically distinctive situation in which there will be many more variables of interest than data points, and as one result
- ↳ Relies on multiple sources of evidence, with data needing to converge in a triangulating fashion, and as another result
- ↳ Benefits from the prior development of theoretical propositions to guide data collection and analysis.

Parts of a Case Study Research Design

→ A research design is a “blueprint” for a study

- ↳ Deals more with the logic of the study than the logistics
- ↳ Plan for moving from questions to answers
- ↳ Ensures that the data is collected and analyzed to produce an answer to the initial research question
- ↳ Strong similarities between a research design and a system design

→ Five parts of a case study research design

- ↳ Research questions
- ↳ Propositions (if any)
- ↳ Unit(s) of analysis
- ↳ Logic linking the data to the propositions
- ↳ Criteria for interpreting the findings

Part 1: Study Questions

- Case studies are most appropriate for research questions that are of the “how” and “why” variety
- The initial task is to clarify precisely the nature of the study questions (i.e. make sure they are actually “how” or “why” questions)
- Examples:
 - ↪ “Why do 2 organizations have a collaborative relationship?”
 - ↪ “Why do developers prefer this tool/model/notation?”
 - ↪ “How are inspections carried out in practice?”
 - ↪ “How does agile development work in practice?”
 - ↪ “Why do programmers fail to document their code?”
 - ↪ “How does software evolve over time?”
 - ↪ “Why have formal methods not been adopted widely for safety critical applications?”
 - ↪ “How does a company identify which software development projects to start?”

Types of Case Studies

→ Explanatory

↪ Adjudicates between competing explanations

↪ Example: How important is implementation bias in requirements engineering?

➤ Rival theories: existing architectures are useful for anchoring, vs. existing architectures are over-constraining during RE

→ Descriptive

↪ Describes sequence of events and underlying mechanisms

↪ Example: How does pair programming actually work?

↪ Example: How do software immigrants naturalize?

→ Causal

↪ Looks for causal relationship between concepts

↪ Example: Requirements errors are more likely to cause safety-related defects than programming errors are

➤ See study by Robyn Lutz on the Voyager and Galileo spacecraft

→ Exploratory

↪ Criteria or parameters instead of purpose

↪ Example: Christopher Columbus' voyage to the new world

↪ Example: What do CMM level 3 organizations have in common?

Part 2: Study Propositions

- Propositions are statements that help direct attention to something that should be examined in the case study, i.e. point to what should be studied
 - ↳ Example: "Organizations collaborate because they derive mutual benefits"
- Propositions will tell you where to look for relevant evidence
 - ↳ Example: Define and ascertain the specific benefits to each organization
- Some studies may not have propositions - this implies a topic of "exploration"
 - ↳ Note: Even exploratory studies should have both clearly-stated purposes and clearly-stated criteria for success

Part 3: Unit of Analysis

- The unit of analysis defines what a “case” is in a case study
 - ↳ Example: a unit of analysis (case) may be an individual, and the case study may be the life history of that person
- Other units of analysis include decisions, social programs, processes, changes
 - ↳ Note: It is important to clarify the definition of these cases as they may be subjective, e.g. the beginning and end points of a process
- What unit of analysis to use generally depends on the primary research questions
- Once defined, the unit of analysis can still be changed if desired, e.g. as a result of discoveries based on data
- To compare results with previous studies (or allow others to compare results with yours), try to select a unit of analysis that is or can be used by others

Examples of Units of Analysis

→ For a study of how software immigrants naturalize

↳ Individuals

↳ Development team

↳ Organization

→ For a study of pair programming

↳ Programming episode

↳ Pairs of programmers

↳ Development team

↳ Organization

→ For a study of software evolution

↳ Modification report

↳ File

↳ System

↳ Release

↳ Stable release

Part 4: Linking Logic

- Logic or reasoning to link data to propositions
- One of the least well developed components in case studies
- Many ways to perform this, but none as precisely defined as the treatment/subject approach used in experiments
- One possibility is pattern matching
 - ↳ Describe several potential patterns, then compare the case study data to the patterns and see which one is closer

Part 5: Interpretation Criteria

- Need criteria for interpreting a study's findings
- Also a relatively undeveloped component in case studies
- Statistical tests not possible when only single data points are captured (as is the case with single-case studies)
 - ↳ Currently there is no precise way of setting the criteria for interpreting these types of findings

Generalizing from Case Study to Theory

- “The appropriately developed theory is also at the level at which generalization of the case study results will occur”
- Theory for case studies is characterized as analytic generalization and is contrasted with another way of generalizing results known as statistical generalization
- Understanding the difference between these two types of generalization is important

Analytical and Statistical Generalization

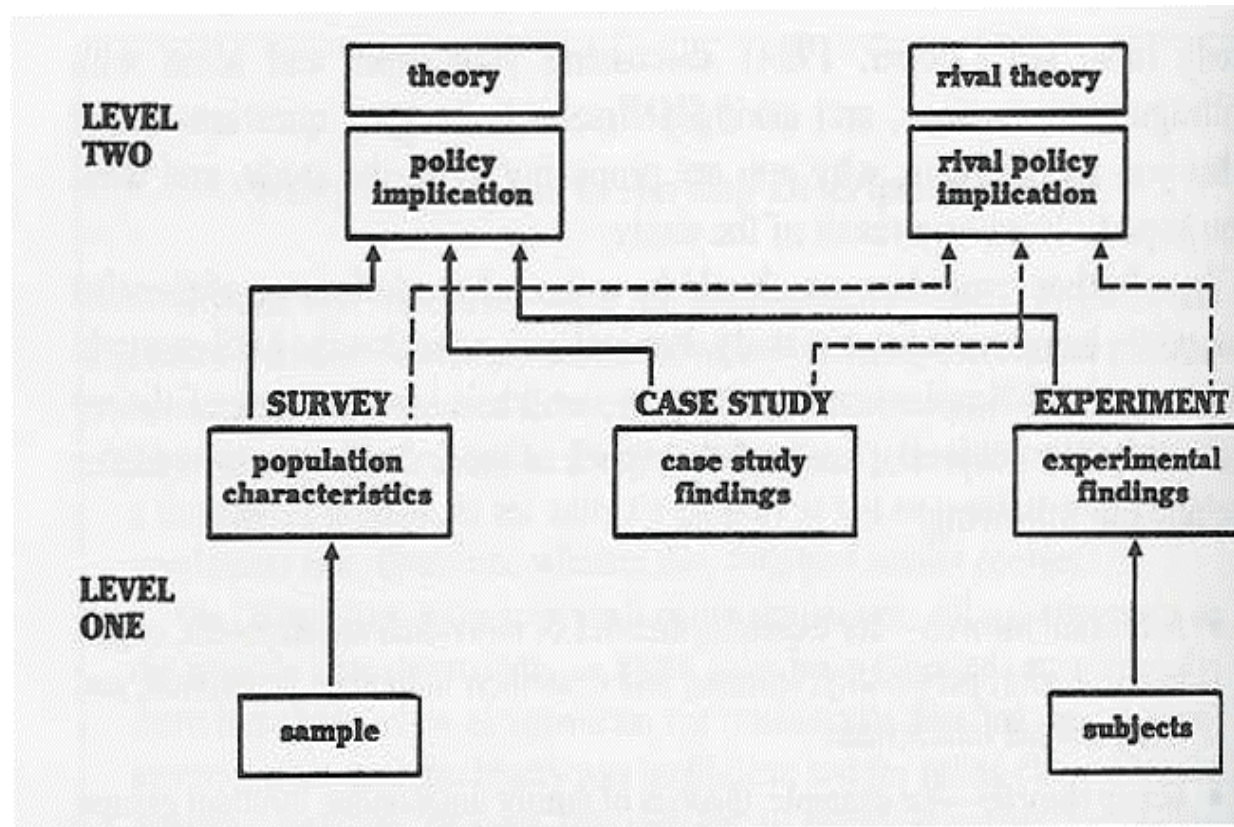


Figure 2.2 Making Inferences: Two Levels

Statistical Generalization

- Making an inference about a population on the basis of empirical data collected about a sample
- This method of generalization is commonly recognized because research investigators have quantitative formulas characterizing generalizations that can be made
 - ↳ Examples: significance, confidence, size of the effect, power of test
- Using this as a method of generalizing the results of a case study is a “fatal flaw”, since cases are not sampling units, nor should they be chosen for this reason
- Statistical generalizations are considered a Level One Inference

Analytical Generalization

- Previously developed theory is used as a template with which to compare the empirical results of the case study
- If 2 or more cases support the same theory, replication may be claimed
- Results may be considered more “potent” if 2 or more cases support the same theory but don’t support the same rival theory
- Analytical generalizations are considered a Level 2 Inference
- Aim toward analytical generalization in doing case studies
 - ↳ Avoid thinking in terms of samples when doing case studies

How can I evaluate a case study?

→ Using the same criteria for other empirical research

→ **Construct Validity**

↳ Concepts being studied are operationalized and measured correctly

→ **Internal Validity**

↳ Establish a causal relationship and distinguish spurious relationships

→ **External Validity**

↳ Establish the domain to which a study's findings can be generalized

→ **Experimental Reliability**

↳ Demonstrate that the study can be repeated with the same results

Embedded Designs

→ Strengths

↳ Introduces higher sensitivity to “slippage” from the original research questions

→ Weaknesses

↳ Can lead to focusing only on the subunit (i.e. a multiple-case study of the subunits) and failure to return to the larger unit of analysis

Multiple-Case Designs

- If the same study contains more than a single case, it is a multiple-case design
- Advantages
 - ↳ Evidence is considered more compelling
 - ↳ Overall study is therefore regarded as more robust
- Disadvantages
 - ↳ Rationale for single-case designs usually cannot be satisfied by multiple cases
 - ↳ Can require extensive resources and time

Replication in Multiple-Case Studies

- When using multiple-case studies, each case must be carefully selected so that it either:
 - ↳ Predicts similar results (literal replication)
 - ↳ Predicts contrasting results but for predictable reasons (theoretical replication)
- If all cases turn out as predicted, there is compelling support for the initial propositions
- Otherwise the propositions must be revised and retested with another set of cases
- With replication procedures, a theoretical framework must be developed that states the conditions under which a particular phenomenon is likely to be found (a literal replication) and the conditions when it is not likely to be found (a theoretical replication)
 - ↳ This framework is used to generalize to new cases

Replication Logic vs. Sampling Logic

- Consider multiple-cases analogous to multiple experiments (NOT analogous to multiple subjects within an experiment or multiple respondents in a survey)
- This replication logic used in multiple-case studies must be distinguished from the sampling logic commonly used in surveys
 - ↳ Sampling logic requires defining a pool of potential respondents, then selecting a subset from that pool using a statistical procedure
 - ↳ Responses from the subset are supposed to accurately reflect the responses of the entire pool
 - ↳ This procedure is used to determine the prevalence or frequency of a particular phenomenon
- Sampling logic is not for use with case studies
 - ↳ Case studies are not the best method for assessing the prevalence of phenomenon
 - ↳ Case studies would have to cover both the phenomenon of interest and its context, yielding a larger number of potential variables, and thus requiring an impossible number of cases
 - ↳ Sampling logic simply cannot be used for all types of empirical investigations

Replication Approach for Multiple-Case Studies

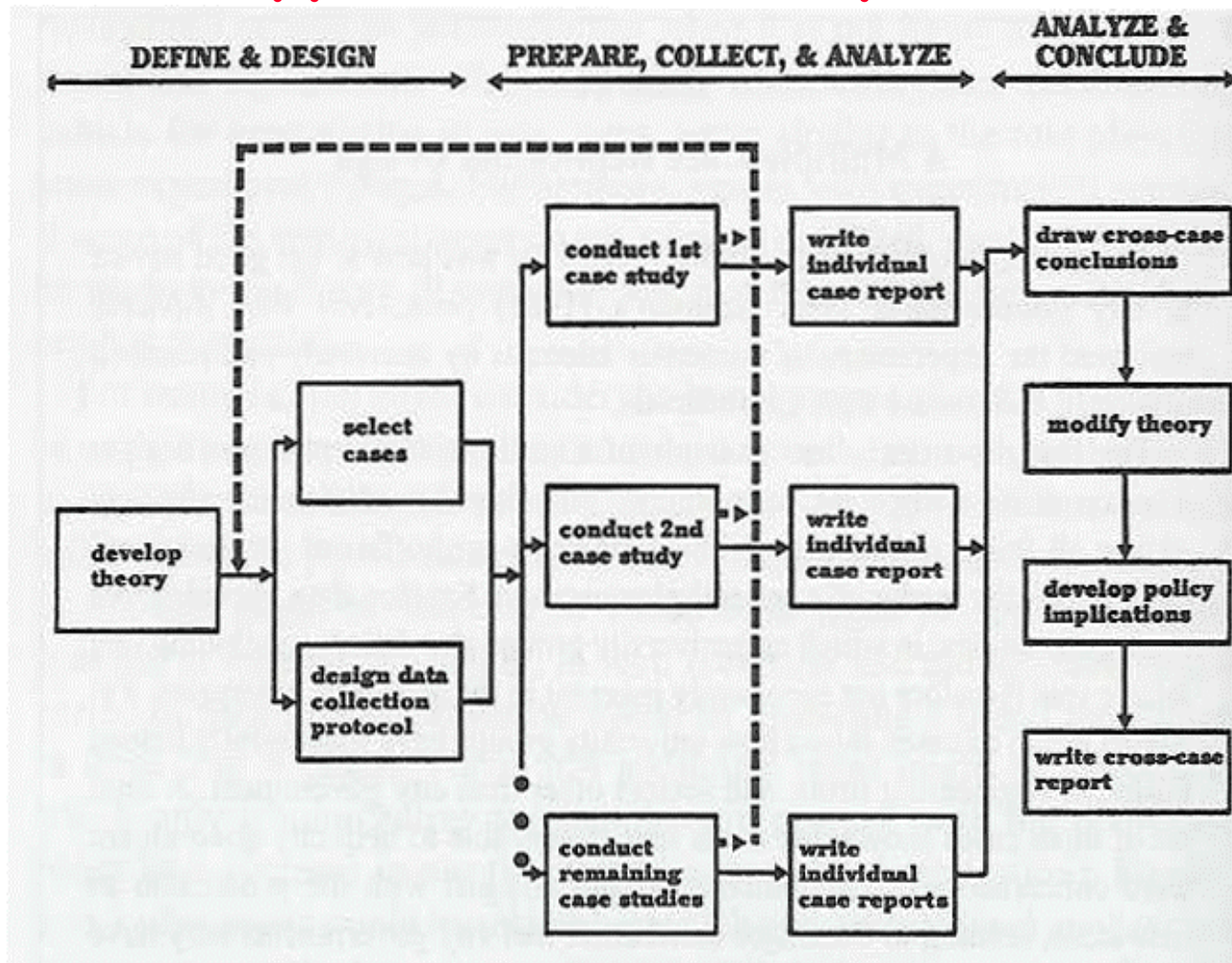


Figure 2.5 Case Study Method (page 50)

Rationale for Multiple-Case Designs

- Multiple-case designs are useful when literal or theoretical replications would provide valuable information for the study
- More results that back your theory typically adds more credibility to your case study

Multiple-Case Designs: Holistic or Embedded

- A multiple-case study can consist of multiple holistic cases or multiple embedded cases, depending on the type of phenomenon being studied and the research questions
- Note there is no mixing of embedded and holistic cases in the same multiple-case study
- It is also important to note that for embedded studies, subunit data is NOT pooled across the subunits, but is used to draw conclusions for the subunit's case only

Selecting Case Study Designs - Single/Multiple?

- If you have a choice and the resources, multiple-case designs are preferred
 - ↪ Analytic conclusions independently arising from two cases will be more powerful than from a single case
 - ↪ The differences in context of multiple cases that have common conclusions provide for expanded generalizability of findings
 - ↪ If two deliberately contrasting cases are selected and findings support the hypothesized contrast, the results represent theoretical replication and strengthen external validity
- Single-case studies are often criticized due to fears about uniqueness surrounding the case
 - ↪ Criticisms may turn to skepticism about your ability to do empirical work beyond a single-case study
 - ↪ If you choose single-case design, be prepared to make an extremely strong argument justifying your choice for the case

Selecting Case Study Designs - Closed/Flexible?

- A case study's design can be modified by new information or discovery during data collection
- If you modify your design, be careful to understand the nature of the alteration:
 - ↳ Are you merely selecting different cases, or are you also changing the original theoretical concerns and objectives?
 - ↳ Flexibility in design does not allow for lack of rigor in design

Data Analysis

- Analytic Strategies
- 3 general strategies
- 5 specific analytic techniques
- Criteria for high quality analysis

Characteristics of Case Study Analysis

- Data analysis consists of examining, categorizing, tabulating, testing and recombining both quantitative and qualitative evidence to address the initial propositions of a study
- Analyzing case study evidence is difficult because strategies and techniques have not been well defined
- Every case study should have a general analytic strategy to define priorities for what to analyze and why

Criteria for High Quality Analysis

- Present all the evidence
- Develop rival hypotheses
- Address all major rival interpretations
- Address most significant aspect of the case study
- Use prior or expert knowledge

Objectives of Analytical Study

- Produce high quality analyses
- Present all evidence and separate them from any interpretation
- Explore alternative interpretations

Needs for Analytic Strategies

- Investigations on how the evidence is to be analyzed easily become stalled
- Analytic tools can only be helpful if the investigators know what to look for
- Analytic strategies are needed to address the entire case study since verbatim and documentary texts are usually the initial phase

Benefits of Analytic Strategies

- Put the evidence in preliminary order and treat the evidence fairly
- Prevent false starts
- Save time
- Produce compelling analytic conclusions
- Rule out alternative interpretations
- Help investigators use tools and make manipulations effectively

Three General Strategies

- Relying on Theoretical Propositions
- Thinking about Rival Explanations
- Developing a Case Description

GS 1 - Relying on Theoretical Propositions

- Shapes the data collection plan and gives priorities to the relevant analytic strategies
- Helps to focus attention on certain data and to ignore other useless data
- Helps to organize the entire case study and define alternative explanations to be examined

GS 2 - Thinking About Rival Explanations

- Defines and tests rival explanations
- Relates to theoretical propositions, which contain rival hypotheses
- Attempts to collect evidence about other possible influences
- The more rivals the analysis addresses and rejects, the more confidence can be placed in the findings

GS 3 - Developing a Case Description

→ Serves as an alternative when theoretical proposition and rival explanation are not applicable

→ Identifies

- ↳ an embedded unit of analysis
- ↳ an overall pattern of complexity to explain why implementation had failed

Five Specific Analytic Techniques

- Pattern Matching
 - Explanation Building
 - Time-Series Analysis
 - Logic Models
 - Cross-Case Synthesis
-
- Note: They are intended to deal with problems of developing internal and external validity in doing case studies

AT 1 - Pattern Matching

- Pattern matching compares an empirically based pattern with a predicted one
- If the patterns coincide, the results can strengthen the internal validity of the case study

- Types of pattern matching:
 - ↳ Nonequivalent dependent variables as a pattern
 - ↳ Rival explanations as patterns
 - ↳ Simpler patterns

PM 1 - Nonequivalent dependent variables

- Quasi-experiment may have multiple dependent variables (variety of outcomes)
- If, for each outcome, the initially predicted values have been found, and at the same time alternative “patterns” of predicted values (including those deriving from methodological artifacts or threats to validity) have not been found, strong causal inferences can be made

PM 2 - Rival Explanations

- Each case has certain type of outcome, and the investigation has to be focused on how and why this outcome occurred
- This analysis requires the development of rival theoretical propositions, articulated in operational terms
- Each rival explanation involves a pattern of independent variables that is mutually exclusive: If one explanation is to be valid, the others cannot be

PM 3 - Simpler Patterns

- There may be only 2 different dependent (or independent) variables, pattern matching is possible as long as a different pattern has been stipulated for these 2 variables
- The fewer the variables, the more dramatic the different patterns will have to allow any comparisons of their differences

AT 2 - Explanation Building

- Analyzes the case study data by building an explanation about the case
- Stipulates a presumed set of causal links, which are similar to the independent variables in the use of rival explanations
- Has mostly occurred in narrative form
- May lead to starting a cross-case analysis, not just an analysis of each individual case
- Disadvantage: may drift away from original focus

AT 2 - Explanation Building

→ Series of iterations in building explanation

- ↳ Making initial theoretical statement
- ↳ Comparing the findings of the initial case against such a statement
- ↳ Revising the statement
- ↳ Comparing other details of the case against the revision
- ↳ Comparing the revisions to the facts of 2nd, 3rd or more cases
- ↳ Repeating the process if needed

AT 3 - Time Series Analysis

- The objective of time series analysis is to examine relevant “how” and “why” questions about the relationship of events over time
- Time series analysis can follow intricate patterns
- The more intricate the pattern, the firmer the foundation for conclusions of the case study
-
- Three types of Time Series Analyses:
 - ↳ Simple Time Series
 - ↳ Complex Time Series
 - ↳ Chronologies

TA 1 - Simple Time Series

- Trace changes over time
- Single variable only, so statistical analysis of data is possible
- Match between a trend of data points compared to
 - ↳ significant trend specified before investigation
 - ↳ rival trend specified earlier
 - ↳ any other trend based on some artifact or threat to internal validity

TA 2 - Complex Time Series

- Contain multiple set of variables (mixed patterns) which are relevant to the case study
- Each variable is predicted to have different pattern over time
- Create greater problems for data collection, but lead to elaborate trend that strengthens the analysis
- Any match of a predicted with an actual time series will produce strong evidence for an initial theoretical proposition

TA 3 - Chronologies

- Trace events over time
- Sequence of a cause and effect cannot be inverted
- Some events must be followed by other events on a contingency basis after an interval of time
- Cover many different types of variables
- Goal is to compare chronology with that predicted by the explanatory theory

AT 4 - Logic Models

- Stipulate a complex chain of events over time
- Events are staged in repeated cause-effect-cause-effect patterns
- Match empirically observed events to theoretically predicted events

- Four types of logic models:
 - ↳ Individual-Level Logic Model
 - ↳ Firm or Organizational-Level Logic Model
 - ↳ An alternative configuration for an Organizational-Level Logic Model
 - ↳ Program-Level Logic Model

Logic Models

→ A) Individual-level logic model

↳ Assumes the case study is about an individual person

→ B) Firm or organizational-level logic model

↳ Traces events taking place in an individual organization

→ C) An alternative configuration for an organizational-level logic model

↳ Encounters dynamic events that are not progressing linearly

↳ Changes may reverse course and not just progress in one direction (Transformation and reforming)

→ D) Program-level logic model

↳ Analyzes data from different case studies by collecting data on rival explanations

AT 5 - Cross-Case Synthesis

→ Case study consists of at least 2 cases

→ Using multiple case studies will

- ↳ Treat each individual case study as a separate study
- ↳ Have to create word tables that display data from individual cases according to some uniform framework
- ↳ Examine word tables for cross-case patterns
- ↳ Rely strongly on argumentative interpretation, not numeric properties
- ↳ Be directly analogous to cross-experiment interpretations

What Makes an Exemplary Case Study?

- The exemplary case study goes beyond the methodological procedures
- Mastering the techniques does not guarantee an exemplary case study

Characteristics of an Exemplary Case Study

→ 1. The Case Study Must Be Significant

- ↳ The case should be unusual and of general public interest
- ↳ The issue are nationally important, either in theory or practical terms
- ↳ Prior to selecting a case study, the contribution should be described in detail assuming that the intended case study were to be completed successfully

→ 2. The Case Study Must be "Complete"

- ↳ Completeness can be characterized in at least three ways:
 - The boundaries of the case are given explicit attention
 - Exhaustive effort is spent on collecting all the relevant evidence
 - The case study was not ended because of nonresearch constraints

Characteristics of an Exemplary Case Study

- 3. **The Case Study Must Consider Alternative Perspectives**
 - ↪ The case study should include consideration of rival propositions and the analysis of the evidence in terms of such rivals
 - ↪ This can avoid the appearance of a one-sided case
- 4. **The Case Study Must Display Sufficient Evidence**
 - ↪ The report should include the most relevant evidence so the reader can reach an independent judgment regarding the merits of the analysis
 - ↪ The evidence should be able to convince the reader that the investigator “knows” his or her subject
 - ↪ The investigator should also show the validity of the evidence being presented
- 5. **The Case Study Must Be Composed in an Engaging Manner**
 - ↪ A written case study report should be able to entice the reader to continue reading

Case Study as a Research Method

- The case study is a distinct research method with its own research designs
 - ↳ It is not a subset or variant of research designs used for other strategies (such as experiments)
- Scientific
 - ↳ Synergistic relationship between theory and data
 - ↳ Starting a case study requires a theoretical orientation, which drives data collection
- Useful for answering “how” and “why” questions
 - ↳ In contrast to who, what, when, how many, how much
 - ↳ How, why = explanatory, descriptive
- Does not require control over events
 - ↳ More observational
- Focus on contemporary events
 - ↳ Less historical