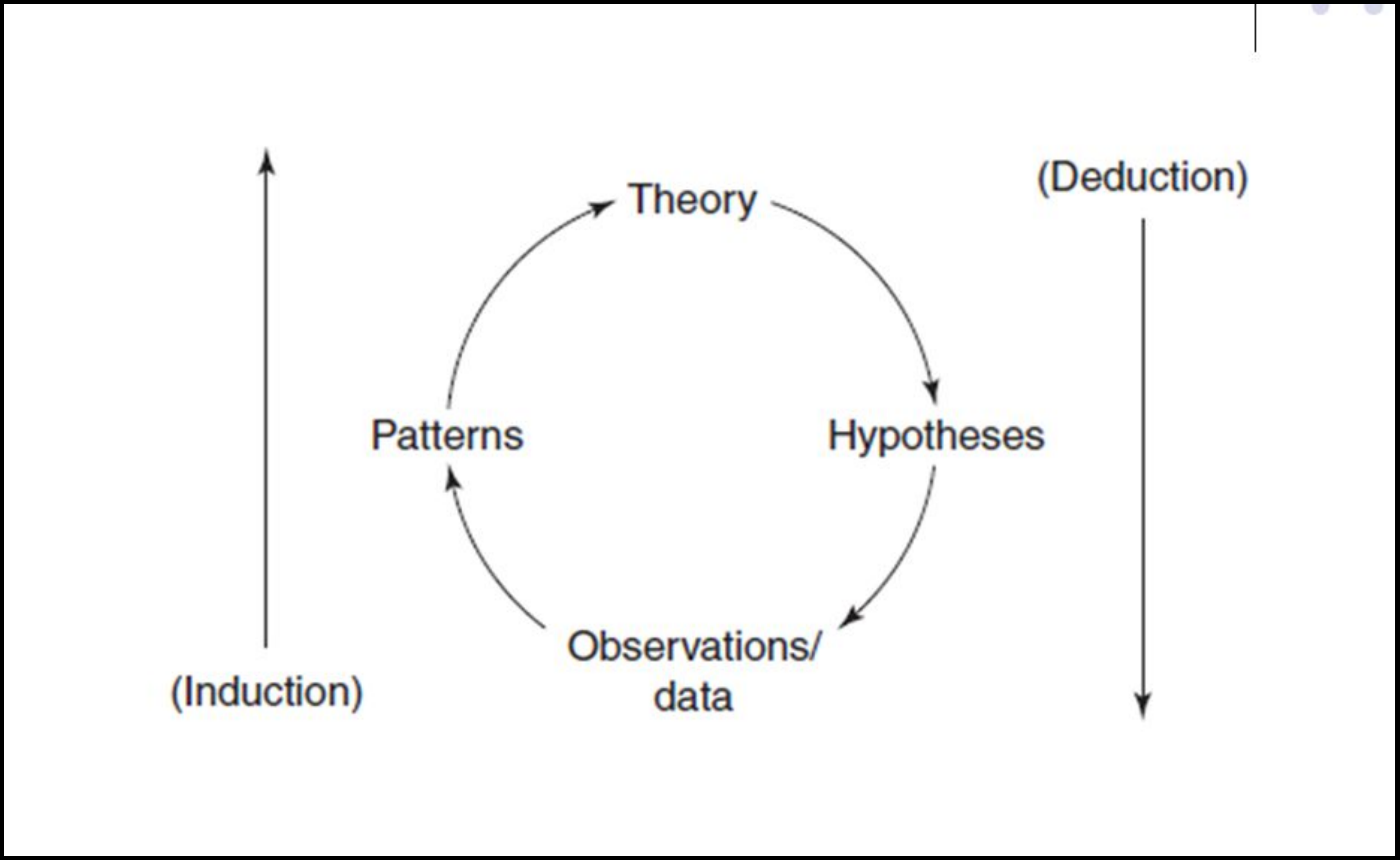
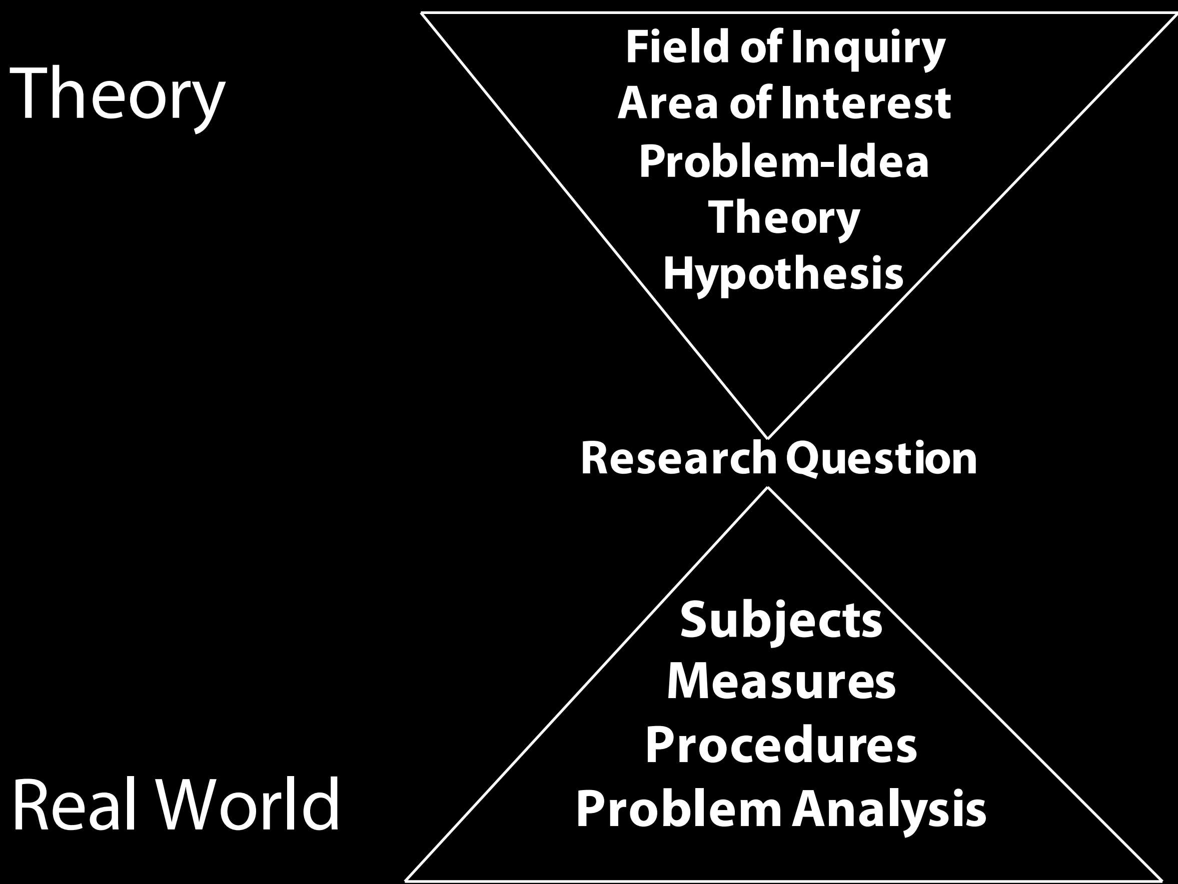
Lecture 3: Research Questions

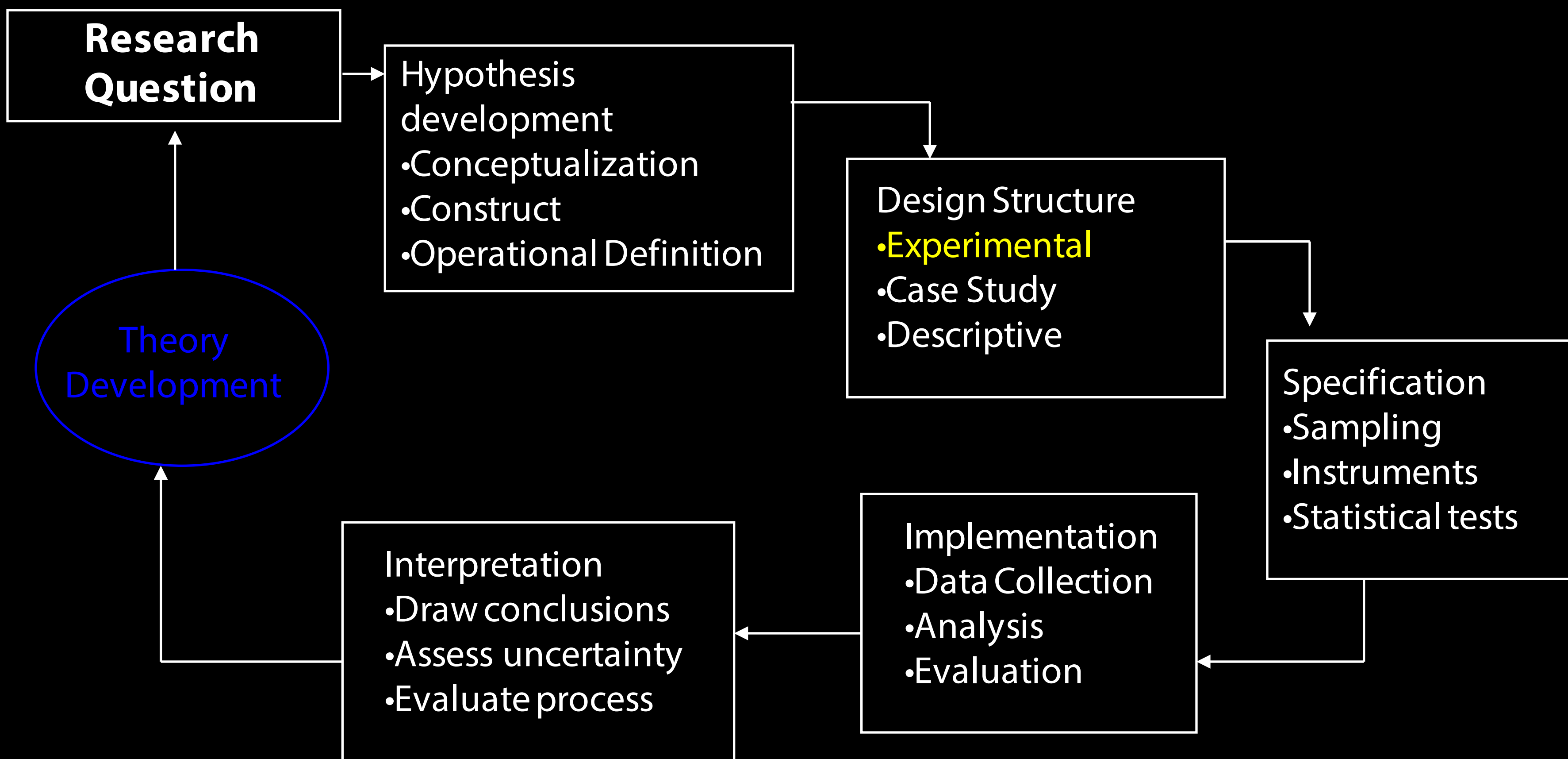
Scientific Reasoning



Research Connects Theory and Real World



Research Process



Types of Research Projects

1. Theory building: Explanting a phenomenon
2. Fact-finding/filling gaps in knowledge
3. Testing hypotheses with empirical observations
4. Establishing a relationship between variables
5. Examining adequacy of models or theories
6. Evaluation of a policy intervention
7. Critical analysis of theoretical positions
8. Contributing to an understanding of a concept

Good Research Questions

- Grounded in theoretical and empirical literature
- Testable by empirical methods
- Stated clearly and simply
- Not too abstract
- Not too complex

Some Advice from Experience

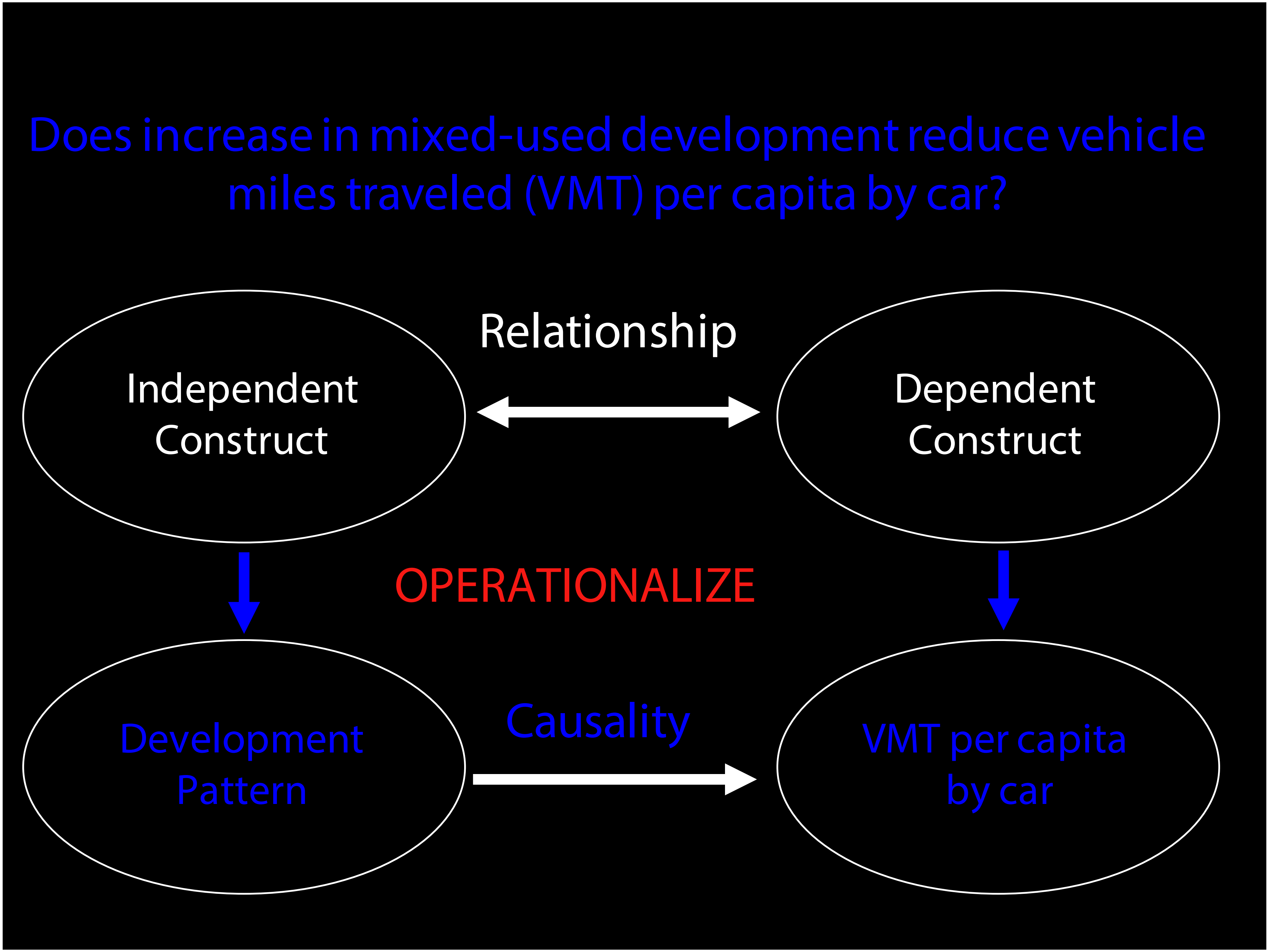
- Develop a research problem that matches your interests, training, and skills you are willing to learn.
- Base research on current evidence.
- The research question should logically present each step from what is known to filling a gaps.
- Do not follow a trend but focus on your scientific curiosity. What you want to find out and how it will add to the knowledge base.
- Avoid topics. Look at clearly defined research problems and questions instead.
- Stay focused. You will find many things of interest along the path, but ask yourself: 'Is this related to what I want to uncover or just a point of interest?'

Types of Research Questions

- Descriptive: What events are occurring? What are the characteristics of a place, person, organization? How prevalent are certain phenomena?
- Explorative: Which characteristics relate to certain phenomena?
- Correlative: What are the relationships between variables or phenomena?
- Predictive: What will happen if one variable change?
- Explanatory: What are the causes of certain phenomena?
- Evaluative: How well does a certain process or intervention work?
- Interpretative: What does it mean? how is it understood in human experience?
- Prescriptive: How can it be transformed for the better?
- Critique : What are the limitations and hidden assumptions? How can these be challenged?

Sample Research Questions

- Descriptive: How prevalent is the use of private cars for commuting to work in Seattle?
- Explorative: Do households with more cars have higher vehicle miles traveled (VMT) per capita?
- Correlative: Is there a relationship between development patterns and travel behavior measured in VMT per capita by car?
- Predictive: Will increase in mixed-used development reduce VMT per capita by car?
- Explanatory: Does gasoline price affects VMT per capita by car?
- Evaluative: Which policy is more effective in reducing VMT per capita by car?


Does increase in mixed-used development reduce vehicle miles traveled (VMT) per capita by car?
Relationship
Independent Construct
Dependent Construct
OPERATIONALIZE
Development Pattern
Causality
VMT per capita by car

Building Blocks of a Theory

David Whetten (1989) suggests that there are four building blocks of a theory: constructs, propositions, logic, and boundary conditions/assumptions.

Constructs capture the "what" of theories (i.e., what concepts are important for explaining a phenomenon).

Propositions capture the "how" (i.e., how are these concepts related to each other).

Logic represents the "why" (i.e., why are these concepts related).

Boundary conditions/assumptions examines the "who, when, and where" (i.e., under what circumstances will these concepts and relationships work).

Properties of Theory

- Testable/Falsifiable
- Logically sound (deductive validity)
- Explanatory & Accurate (inductive validity)
- Parsimonious: Necessary and Sufficient conditions

Parsimony

Parsimony examines how much of a phenomenon is explained with how few variables.

Ockham's razor principle states that among competing explanations that sufficiently explain the observed evidence, the simplest theory (i.e., one that uses the smallest number of variables or makes the fewest assumptions) is the best.

Parsimonious theories have higher degrees of freedom, which allow them to be more easily generalized to other contexts, settings, and populations.

Hypothesis

A hypothesis is a tentative statement, subject to empirical testing, of the expected relationship between variables. A hypothesis is grounded in preliminary observations, yet sometimes in practice it is little more than "an educated guess."

Research Hypotheses

Hypotheses derived from the researcher's theory about some phenomenon (social, ecological, environmental etc.) are called research hypotheses.

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Null hypotheses serve to refute or deny what is explicitly indicated in the research hypothesis. They are also statements about the reality of things.

Statistical hypotheses

Research hypotheses and null hypotheses transformed into numerical quantities = statistical hypotheses.

For example, statistical hypotheses concerning the differences in average ages between groups A and B:

Ho: $X_a = X_b$ (null hypothesis); H_a: $X_a \neq X_b$ (research hypothesis).

To test the research hypothesis that group A is older than group B:

H_o: $X_a < X_b$ (null hypothesis); H_a: $X_a > X_b$ (research hypothesis).

Hypothesis formulation

One way of evaluating hypotheses generally is in terms phenomena.

1 Y and X are associated (or, there is an association between Y and X).

2 Y is related to X (or, Y is dependent on X).

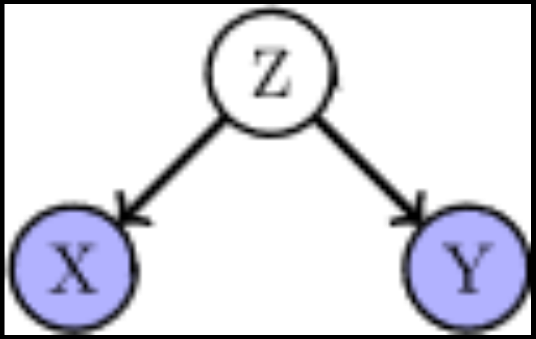
3 As X increases, Y decreases (or, increases in values of X appear to effect reduction in values of Y).

Variables

What are variables?

- Properties of objects and events that can take on different values.

Kinds of variables:



- Discrete & Continuous
- Independent, Dependent, & Confounding

Operationalization

A procedure by which one selects observable indicators (variables) to represent theoretical concepts.

A variable is a theoretically relevant concept which may be observed to take different values in different cases

1. Independent variable (explanatory variable) - taken as a given, used to explain other phenomena.

2. Dependent variable (outcome, response variable) - values we try to explain by looking at other variables.

Operationalization of a variable

Operationalization of a variable defines how the variables we have identified and defined will be measured with real (available) data.

Obstacles to operationalizing variables

1. Conceptual
2. Practical

   a. Reliability: a reliable measure yields the same values for a particular case in repeated measurements

   b. Validity: a valid measure is an appropriate measure of the concept in which you are interested

Problem Variables

The fundamental research design problem of social science: lurking variables:

a. Lurking variable ("omitted variable"): a variable which has an important effect on the relationship among variables in the study but is not included in the study.

b. Confounding variables: two variables whose effects cannot be distinguished from each other

Types of Relation

Relation between variables can be described in a variety of ways:

- No relationship (Null hypothesis)

- Direction of Relation: Positive or Negative

- Magnitude of Relation: Strong, weak, unrelated.
- Causal, Predictive, Association

Testing hypotheses

Testing hypotheses means subjecting them to empirical scrutiny to determine if they are supported or refuted by observations.

Decision rules specify conditions under which the researcher will decide to refute or support the hypothesis.

Decision rules relate to

- the level of significance, and
- the specification of the sampling distribution.

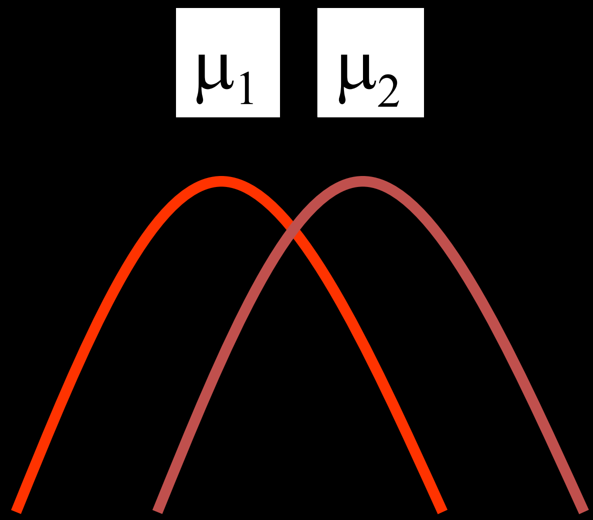
Hypothesis testing

- Step 1: Set up hypothesis
  - determine whether it is 1-tailed or 2-tailed test
- Step 2: Compute test statistics
- Step 3: Determine p-value of the test statistic
  - for a pre-determined alpha, you can find the corresponding critical limit
- Step 4: Draw conclusion
  - reject H_0 if p-value < alpha (ie greater than the critical limit)
  - accept H_0 if p-value > alpha (ie less than the critical limit)

A statistical hypothesis is a statement about the parameters of a probability distribution.

Null hypothesis H_o: $\mu_1 = \mu_2$

Alternative hypothesis H_a: $\mu_1 \neq \mu_2$



μ is the mean of a distribution

Level of significance

- When a difference in characteristics (e.g., median income, VMT, land value etc.) between two groups is observed, at what point do we conclude that the difference is significant?
- To answer this, probability theory defines the likelihood that one's observations or results are expected.

Statistical Significance

- If we set a probability level or significance level at <0.05

- the difference is statistically significant if the probability of the difference occurring by chance is less than 5 times out of a hundred (i.e., something else other than chance has affected the outcome).

Type I and Type II errors

We use the level of significance to help us to decide whether to accept or reject the null hypothesis.

Statistical decision	True state of null hypothesis	
	Ho True	Ho False
Reject Ho	Type I error	Correct
Do not reject HO	Correct	Type II error

- If we reject the null hypothesis when it is true and should not be rejected, we have committed a Type I error.
- If we accept the null hypothesis as true when it is false and should be rejected, we have committed a Type II error.

Experiments to control Type I error: Significance test

- The P-value calculated in most familiar statistical tests indicates the probability of obtaining a test statistic at least as extreme as the one calculated from the data, if H_O were true.

- The significance level is a critical value of alpha --the maximum probability of Type I error (rejecting H_O when it is true) that the scientist is willing to tolerate.

Experiments to control Type II error: Power Analysis

Power analysis is used to estimate

Beta, the probability of Type II error, and its complement, statistical power (1- beta), the probability of detecting a specified treatment effect when it is present.

Statistical power is a function of several variables:

- sample size, N;
- variance of the observed quantities;
- effect size (the treatment effect the experimenter wants to be able to detect); and
- alpha (the maximum rate of Type I error tolerated).

Confidence Intervals and Power

We Conclude ↓ / In Reality →	H0 (null hypothesis) true H1 (alternative hypothesis) false	H0 (null hypothesis) false H1 (alternative hypothesis) True
We accept H0 We reject H1	1- alpha (e.g., .95) THE CONFIDENCE LEVEL The probability we say there is no relationship when there is not	beta (e.g., 20) Type II Error The probability we say there is no relationship when there is one
We reject H0 We accept H1	alpha (e.g., .05) Type I Error The probability we say there is a relationship when there is not	1- beta (e.g., 80) THE POWER The probability we say there is a relationship when there is one

Confidence Intervals and Power

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The Four Components to a Statistical Conclusion

sample size the number of units (e.g., people) In the study

effect size the effect of the treatment or independent variable relative to the noise

alpha level the odds the observed result is due to chance

power the odds you'll observe a treatment effect when it occurs

Types of Validity

Measurement is a tool of research. Validity is the attempt to determine whether a type of measurement measures what it is presumed to measure.

A. Construct validity: the degree to which the construct itself is actually measured. It makes use of the traits of convergence and discriminability.

B. Internal validity: freedom from bias in forming conclusions in view of the data. It seeks to ascertain that the changes in the dependent variable are the result of the influence of the independent variable.

C. External validity: generalizability of the conclusions reached through observation of a sample to the universe.

D. Statistical validity: appropriate choice of statistical test.

Reliability

Reliability: the extent to which a measurement procedure yields the same answer however and whenever it is carried out.

1. Quixotic reliability: Refers to the circumstances in which a single method of observation continually yields an unvarying answer.

2. Diachronic reliability: Refers to the stability of an observation over time. This type of reliability is only appropriate when the phenomenon observed is not assumed to change over time.

3. Synchronic reliability: Refers to the similarity of results from the use of multiple measures within the same time period.

Measurement Reliability and Validity

Reliability

The extent to which the variables are free from random error, usually determined by measuring the variables more than once.

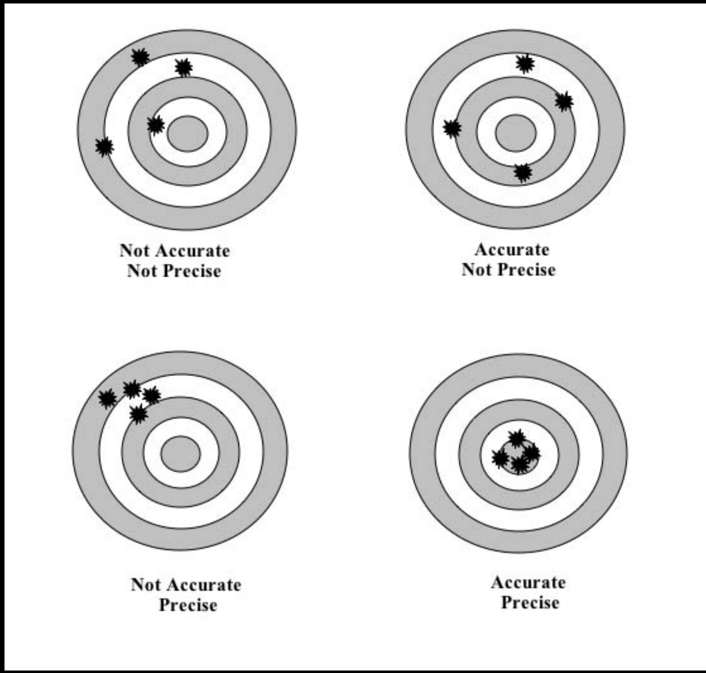
Validity

The extent to which a measured variable actually measures the conceptual variables that it is designed to assess.

The Classical Theory of Measurement

- Reliability (=precision): the extent to which measurement is consistent or reproducible

- Validity (=accuracy): the extent to which what is measured is what the investigator wants to measure



What is Reliability

- the “repeatability” of a measure
- the “consistency” of a measure
- the “dependability” of a measure

Components of an Observed Score

Observed Score = True Score + Measurement Error

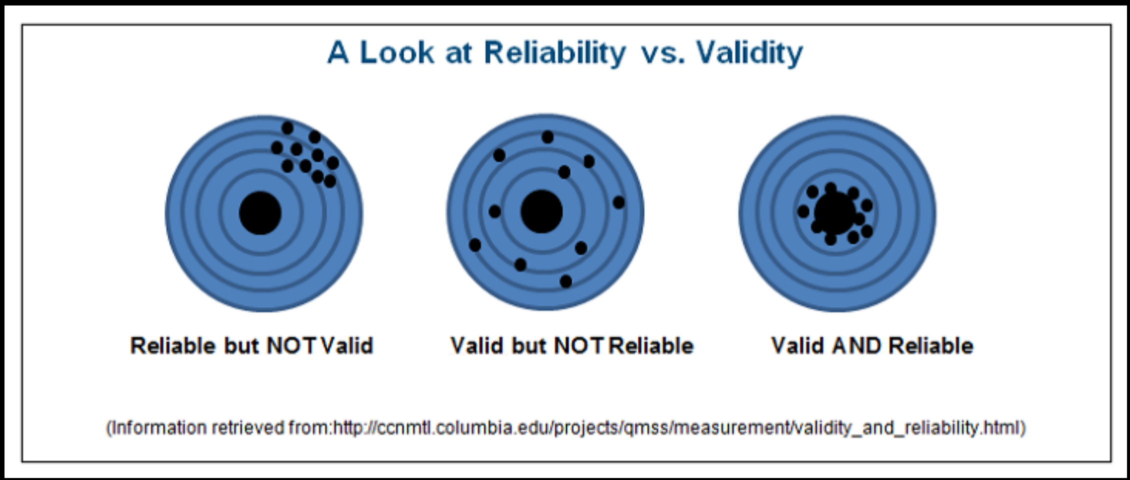
- The best approximation to the true score is obtained by making multiple independent observations and averaging the results
- Reliability of measurement is increased (and error decreased) by increasing the number of observations
- Note that the true score is not all its name implies

Reliability and Validity

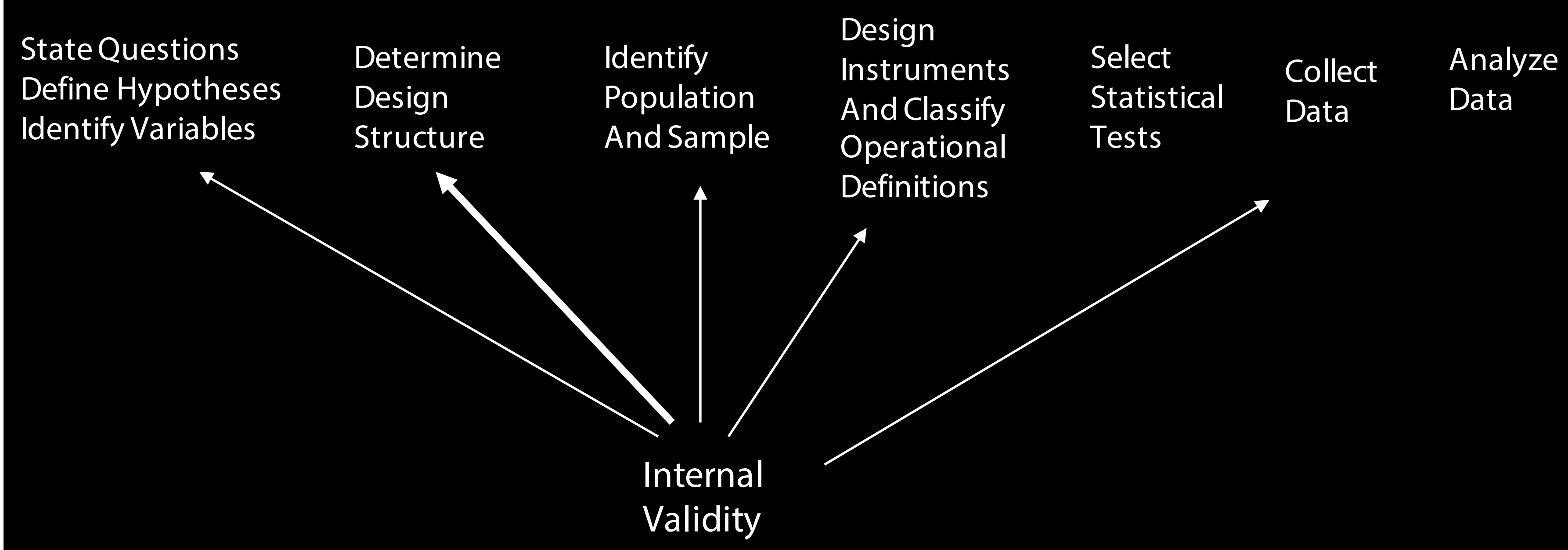
When a measure is VALID, $E_S + E_R = 0$, and $X_0 = X_t$

When a measure is RELIABLE, $E_R = 0$, and $X_0 = X_T + E_S$

RELIABILITY is a necessary but not a sufficient condition for VALIDITY



Relationships between Validity and the Research Process



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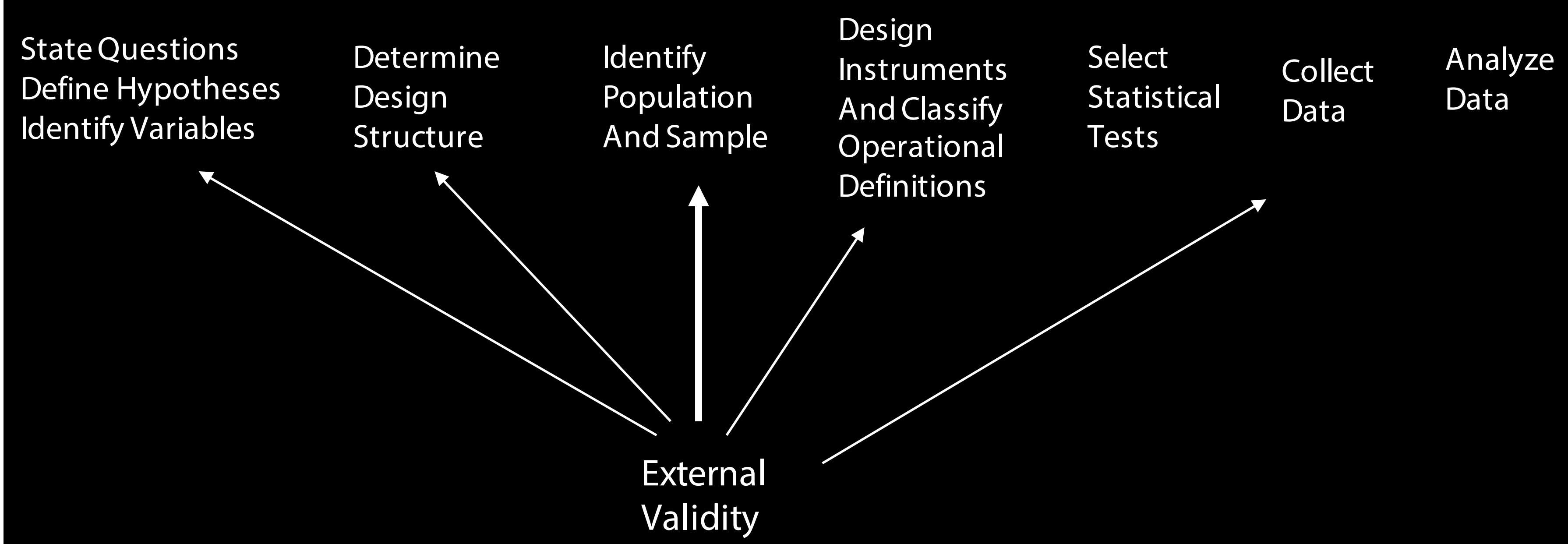


Relationships between Validity and the Research Process

State Questions
Define Hypotheses
Identify Variables

Determine
Design
Structure

Identify
Population
And Sample

Design
Instruments
And Classify
Operational
Definitions

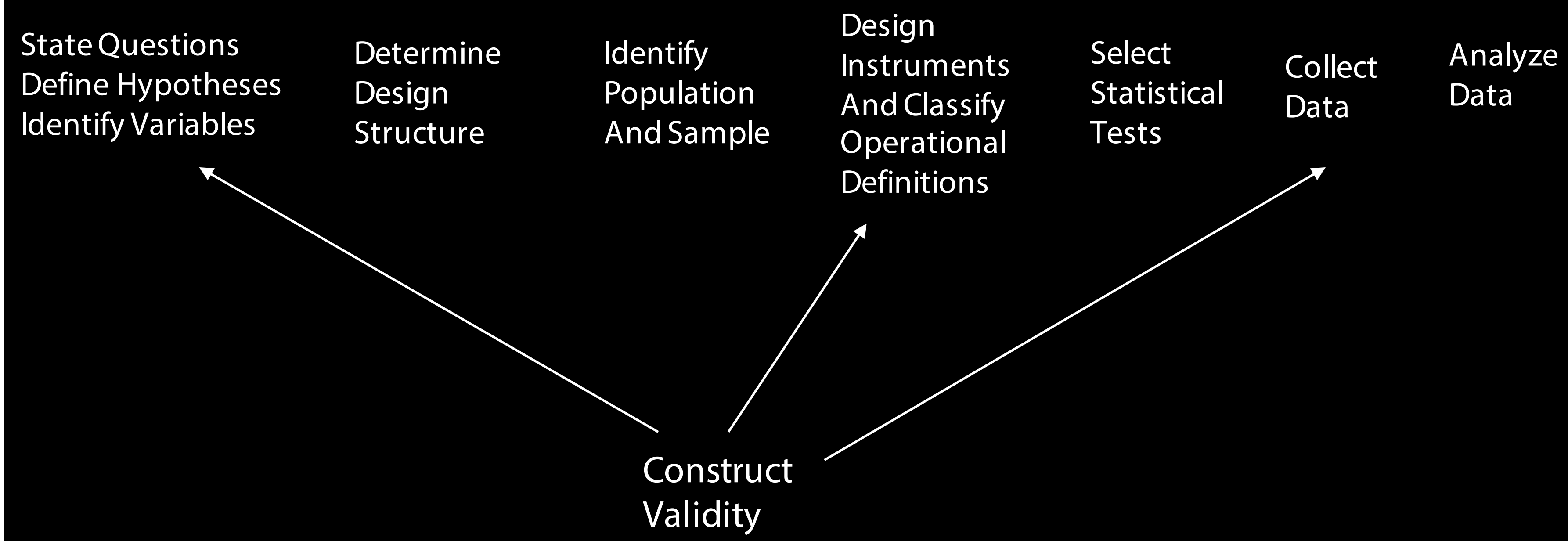
Select
Statistical
Tests

Collect
Data

Analyze
Data

Statistical
Validity

Relationships between Validity and the Research Process



Research Approaches

General Purpose	Explore relationships between variables				Describe variables
General Approach	Experimental		Non-Experimental		Descriptive
Specific Approach	Randomized Experimental	Quasi-Experimental	Comparative	Associational	Descriptive
Specific Purpose	Determine Cause	Examine Cause	Compare Groups	Find Associations	Summarize Data
Type of Hypothesis	Difference			Relate variables	Descriptive
Statistics	Difference Inferential Statistics e.g. ANOVA			Associational Inferential Statistics (eg. Correlation, Multiregression	Descriptive Statistics Eg, Histograms, Means etc.

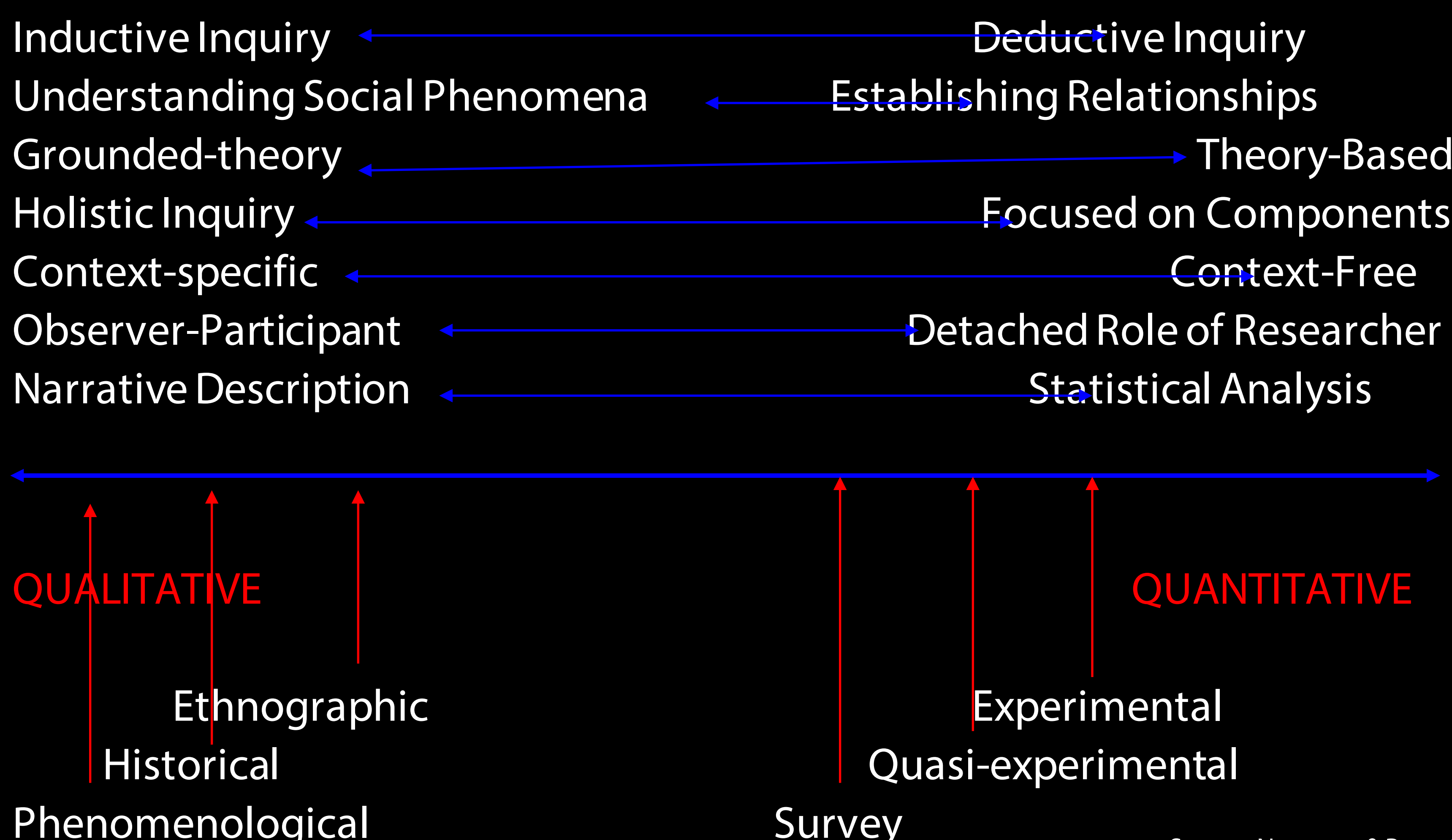
Selecting a research method for data collection

Experiment, Quasi-Experiment, Cross-Section, Longitudinal, Case study

Selecting a methods depends on:

- the research question/purpose
- the operational definition of the construct of interest (difference/associational)
- the required protocols for reliability and validity
- a balance between redundancy and the tendency to overdesign

Qualitative/Quantitative Research Continuum



Source: Newman & Benz 1998

Mixed-Method

- Triangulation: tests the consistency of findings obtained through different instruments.
- Complementarity: clarifies and illustrates results from one method with the use of another method.
- Development: results from one method shape subsequent methods or steps in the research process.
- Initiation: stimulates new research questions or challenges results obtained through one method.
- Expansion: provides richness and detail to the study exploring specific features of each method.

Early detection of problems in the study design

Adequate number of subjects

- Comprehensive and detailed theory frame work but impractical
- Estimation of sample size in order to answer to your questions.
- Realistic estimate of number of subjects likely to be available.

Adequate technical expertise

- Skills, equipment and experience

Affordable in time and money

- Available resources

Manageable in scope

- Too ambitious, too many measurements, too many questions

Research Curiosity and Distractions
(How to use them to make progress)

Literature: Thousands of papers are published daily that relate to your research question.

Data tools: Learning new data tools and methods to study your topic and conduct data analysis.

Great talk: Attending a fascinating talk on the big picture of the topic you are studying.

Field work: In your field work things are more complex and messy and do not fit your framework.

Travel abroad: A coincidental trip to different country uncover your cultural bias in your approach.

The Nature of Good Design

1. Theory-Grounded. Good research strategies reflect the theories which are being investigated.
2. Situational. Good research designs reflect the settings of the investigation.
3. Feasible. Good designs can be implemented.
4. Redundant. Good research designs have some flexibility built into them. Often, this flexibility results from duplication of essential design features
5. Efficient. Good designs strike a balance between redundancy and the tendency to overdesign.

Why Review the Literature

- Become familiar with previous research
- Understand how your idea fits existing theory
- Determine the existing knowledge base
- Relates your study to a larger body of knowledge
- Shows importance of your study
- Traces the history of the topic
- Identify studies to replicate
- Use tested instruments and methods
- Identify testable hypotheses

Why citations are used in a scientific paper

- Substantiate statements that are not your ideas, and give credit.
- Allow the reader to verify your interpretations.
- Substantiate facts or data of others' research.
- Refer to previous related studies, to compare.
- Provide detailed justification of methods.
- Give the reader material to go deeper into a topic.

What is a Literature Review

A systematic, explicit, and reproducible method for identifying, evaluating and interpreting an existing body of research.

Literature review should

- lead to comprehension of your research area
- position your study in a broader research effort
- indicate how your study provides a logical extension of the existing knowledge

The definition of a scientific paper

(from Council of Science Editors)

An acceptable primary scientific publication must be the first disclosure containing sufficient information to enable peers to:

- assess observations
- repeat experiments
- evaluate intellectual processes

It must be:

- essentially permanent
- available without restriction
- available for regular screening by major citation service providers

Structure of Literature Review

- State your research question: specify variables, define conceptual model
- What other researchers have asked
- How other researchers approached their questions
- What methods/techniques other researchers have used
- What results other researchers have found

Research Sources

PRIMARY SOURCES

- Journals
- Dissertations
- Theses
- Books
- Newspapers
- Conference papers
- Patents & Standards
- Reports

SECONDARY SOURCES

- Indexes
- Abstracts

TERTIARY SOURCES

- Catalogues
- Bibliographies

Why use Journals?

- Articles on the latest news, trends and research
- Primary research
- Authors and sources of data identified
- Refereed, peer reviewed
- Specialized topics
- Notice of work in progress

Literature Resources

- Library Catalogues
- Databases, Abstracts and Indices
- On-line Journals
- Governmental Publications
- US Census
- Datasets

Web Resources - Library

Conducting a literature review

- Step 1 after selecting an idea
- Limit the search to certain key words, years, research areas
- Access information, including one or two good review articles
  - Social Science Citation Index
  - General Science Index
  - Current Contents
  - Extended Academic Index
  - LEXIS-NEXIS academic universe
  - ProQuest
- Read & organize the results of your search
- Critique your literature
- Summarize the results

Steps in the Literature Review Process

1- Context for the search
- define the problem
- gather background information
- identify key concepts
- develop a scheme for reviewing and critically
- evaluate the articles

2- Prepare for the search
- created concept lists
- use Boolean operators
- determine where to perform search

Steps in the Literature Review Process

3- Perform the search

- learn conventions of the databases
- search databases
- start with most general sources

4- Summarize the results

- create a summary chart
- compare & contrast the findings

Important Information

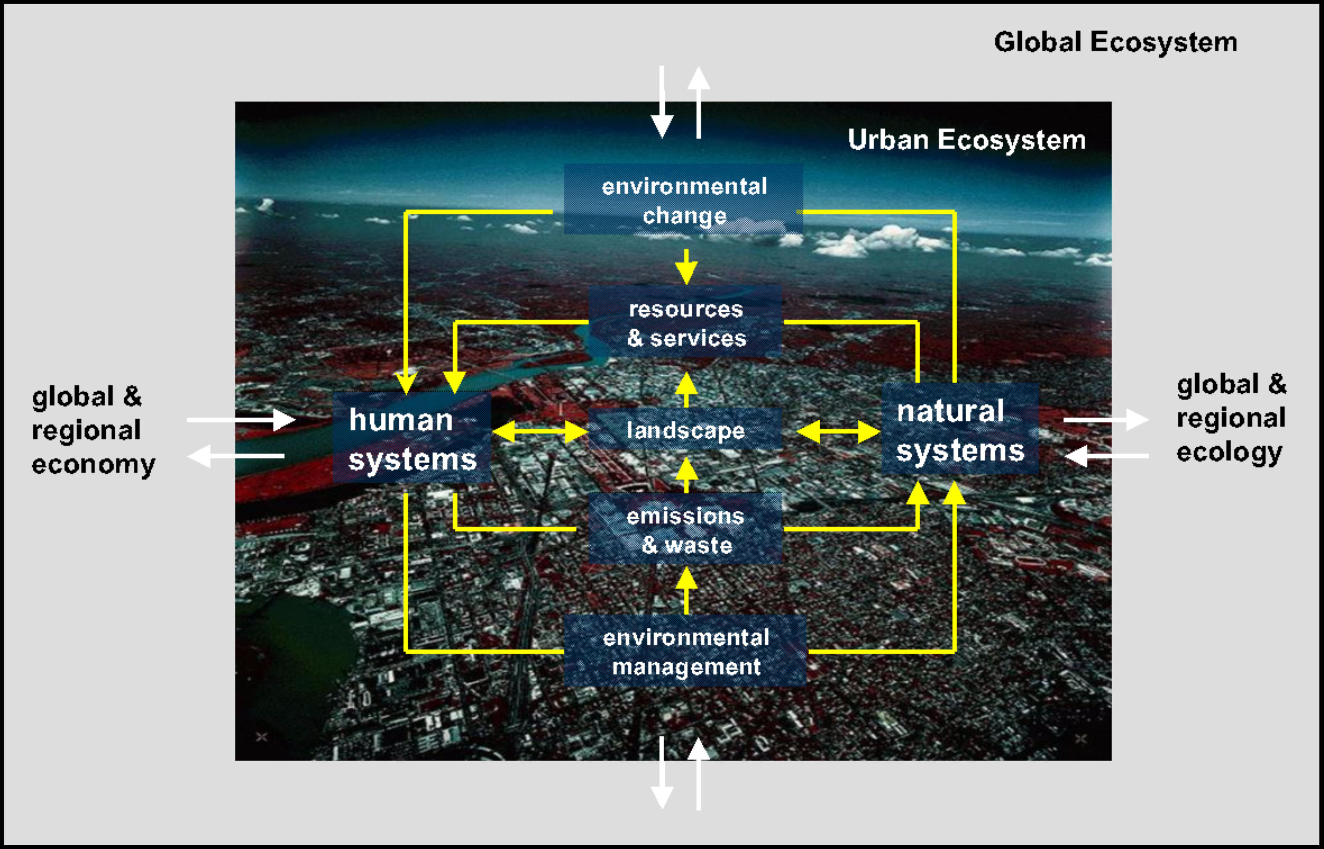
Publication
Language
Journal
Author
Setting of study
Participants
Program

Research design
Sampling method
Date of publication
Date of data collection
Duration of data collection
Source of support

Urban patterns and environmental performance: What do we know?

Marina Alberti

Journal of Planning Education and Research. Vol. 19(2): 151-163.



Urban Patterns

Form is the degree of centralization/decentralization of the urban structure.

Density is the ratio of population or jobs to the area.

Grain indicates the diversity of functional land uses such as residential, commercial, industrial and institutional.

Connectivity measures the interrelation and mode of circulation of people and goods across the location of fixed activities.

Environmental Performance

Sources include natural resources stocks and flows.

Sinks are the capacity of ecosystems to absorb pollution and waste.

Ecological support systems
are life support services ranging from climate regulation and nutrient recycling to the maintainance of biodiversity.

Impacts on human health and well-being
are the direct effects on human population through polluted air, water, food etc.

Environmental Performance Urban Patterns	Sources	Sinks	Support Systems	Human-Well-being
Form	Energy is the only *source* studied in relation to form. Posited that urban form affect energy flows by: -redistributing solar radiation; -influencing energy use of urban activities; -determining energy supply and distribution systems. Studies disagree as regards to how monocentric, polycentric, or dispersed form affect transportation energy use. Trade-offs between measures of travel patterns.	The urban heat island, which in turns serves as a trap for atmospheric pollutants is a well known example of climate modification caused by altering the nature of the surface and generation of heat. Well known also the ability of green areas and water bodied to mitigate the urban heat island and absorb emissions. While urban form may have impact on these processes, not systematically studied.	The urban heat island affects climate and air pollution throughout the urban airshed. Since urban form rearrange the biophysical elements and modifies the hydrological cycle it can reduce the ability of ecological systems to control flooding and increase runoff, but its impact depends on the local conditions of the site. Urban form influences habitat fragmentation in urban areas which is correlated to extinction of native birds.	Relationships extrapolated from the study of population exposure to major pollutant in urban environment.
Density	Population and job density are the most studied in relation to transportation-related energy use. Density is found to decrease the number of trips and use of private vehicles, but the results as regards total travel and energy uses are contradictory; Methodological problems in using aggregated density.	The direction of impacts varies across air pollutants. High density areas generate greater urban heat island effects and are less able to capture air pollutants, however it depends on the size of the area. Density is also related to impacts on hydrological regimes, runoff, and water quality.	Density may intensify the urban heat island effects, the hydrological effects, and habitat fragmentation; but it may depend on the urban form Methodological problem with using aggregated measures of density.	Relationships extrapolated from the study of population exposure to major pollutant in urban environment.
Grain	Posited to account for difference in travel related energy use; Effect depends on other factors.	Land use patterns affect air pollution (a) directly by the location of activities and (b) indirectly through travel patterns. Direction of impacts varies across air pollutants.	No systematic studies on the relationship between land use mix and ecological support systems.	No systematic studies on th relationship between grain an well-being.
Connectivity	Transportation	Connectivity may affects air	No systematic studies on	No systematic studies on th

Environmental Performance Urban Patterns	Sources	Sinks	Support Systems	Human-Well-being
Centralization	Solar radiation ↔ Energy use ↔ Energy supply ↑ Number of trips by auto ↓ Trip length ↔	Urban heat island ↑ Atmospheric pollution ↔ Water pollution ↔	Climate & air pollution ↔ Flooding ↑ Pollutants runoff ↑ Habitat fragmentation ↓	*No systematic studies*
Density	Solar radiation ↓ Energy use ↔ Number of trips and VMT by auto ↓ Total travel ↔	Urban heat island ↑ Atmospheric pollution ↔ Water pollution ↑	Climate & air pollution ↑ Flooding ↑ Pollutants runoff ↑ Habitat fragmentation ↓	Population exposure to air pollutants ↑
Grain	Travel patterns ↔	Urban Heat Island ↔ Atmospheric pollution ↔	*No systematic studies*	*No systematic studies*
Connectivity	Energy use by private transportation ↓	Atmospheric pollution ↓	Habitat fragmentation ↑	*No systematic studies*

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Modeling the urban ecosystem: a conceptual framework

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Abstract. In this paper I build on current research in urban and ecological simulation modeling to develop a conceptual framework for modeling the urban ecosystem. Although important progress has been made in various areas of urban modeling, operational urban models are still primitive in terms of their ability to represent ecological processes. On the other hand, environmental models designed to assess the ecological impact of an urban region are limited in their ability to represent human systems. I present here a strategy to integrate these two lines of research into an urban ecological model (UEM). This model addresses the human dimension of the Puget Sound regional integrated simulation model (PRISM)—a multidisciplinary initiative at the University of Washington aimed at developing a dynamic and integrated understanding of the environmental and human systems in the Puget Sound. UEM simulates the environmental pressures associated with human activities under alternative demographic, economic, policy, and environmental scenarios. The specific objectives of UEM are to: quantify the major sources of human-induced environmental stresses (such as land-cover changes and nutrient discharges); determine the spatial and temporal variability of human stressors in relation to changes in the biophysical structure; relate the biophysical impacts of these stressors to the variability and spatial heterogeneity in land uses, human activities, and management practices; and predict the changes in stressors in relation to changes in human factors.

Table 1 Urban Models

Model	Sub-systems	Theory /Approach	Population/Sectors	Time	Space	Environmental factors	Source
CLARKE	Land use/cover	Complex systems Cellular automata MonteCarlo simulation	Aggregated	Dynamic	Dynamic Grid-cell	Land cover Topography Hydrography	Clarke et al. 1996.
CUFII	Population Employment Housing Land use	Random utility Multinomial Logit	Aggregated	Static	Static 100x100 m gird-cell	Percent slope	Landis and Zhang 1998a 1998b.
IRPUD	Population Employment Housing Land use	Random utility Network Equilibrium Land use Equilibrium MonteCarlo microsimulation	Partially Disaggregated	Quasi-dynamic	Static Zone	Zone space constraints CO_2 emissions by transport	Wegener 1986; 1995.
ITLUP	Population Employment Land use Travel	Random utility Maximization Network equilibrium	Partially Disaggregated	Static	Static Zone	Zone space constraints Mobile source emissions	Putnam 1983;1991.
KIM	Population Employment Transport Travel	Random utility General equilibrium Input-Output	Aggregated	Static	Static Zone	Zone space constraints	Kim 1989.
MASTER	Population Employment Housing Land use Travel	Random utility Maximization MonteCarlo microsimulation	Disaggregated	Quasi-dynamic	Static Zone	Zone space constraints	Mackett 1990
MEPLAN	Population Employment Housing Land use Transport Travel	Random utility Maximization Market clearing Input-Output	Aggregated	Static	Static Zone	Zone space constraints	Echenique et al. 1985.
POLIS	Population Employment Housing Land use Travel	Random utility Optimization	Aggregated	Static	Static Zone	Zone space constraints	Prastacos 1986.
TRANUS	Population Employment Housing Land use Transport Travel	Random utility Netework equilibrium Land use equilibrium Input-Output	Aggregated	Static	Static Zone	Zone space constraints	de la Barra 1989.
URBANSIM	Population Employment Housing Land use	Random utility Partial equilibrium Multinomial logit	Partially disaggregated	Quasi-dynamic	Static Parcels	Topography Stream buffers Wetlands 100 floodplain area	Waddell 1995.

Table 2. Environmental Models

Model	Class	Media/Sub-systems	Scale	Time	Space	Human factors	Source
NCAR	Ocean-Climate General Circulation Model	Climate-Ocean	Global	Dynamic Minutes 100 years	Dynamic 4.5 x 7.5 9 layers	CO_2 concentration scenarios	Washington and Meehl 1996
CMAQ	Atmospheric Model	Meteorological-Emissions, Chemistry-Transport	Local/Regional	Dynamic 8- to 72- hour period	Dynamic Variable 3-D grid	Emissions of atmospheric pollutants	Novak et al. 1995.
UAM	Atmospheric Model	Photochemical processes	Local/Regional	Dynamic 8- to 72- hour period	Dynamic Variable 3-D grid	Emissions of photochemical pollutants	EPA 1990.
OBM	Biogeochemical Model	Terrestrial biosphere	Global	Dynamic One year	Dynamic 2.5 x2.5	Land use CO_2 concentration scenarios	Esser 1991.
HRBM	Biogeochemical Model	Terrestrial biosphere	Regional	Dynamic Six days	Dynamic 0.5x.05	Land use CO_2 concentration scenarios	Esser et al. 1994.
DHSVM	Distributed Hydrology Soil Vegetation Model	Hydrology	Regional	Dynamic Hours	Dynamic 30-100 m	Land cover	Wigmosta 1994.
JABOWA/FORET	Population/ Community Dynamic Model	Trees	Local	Dynamic Up to 500 years One year	Dynamic 10x10 m grid	Land cover	Botkin 1993
CENTURY	Biogeochemical Model	Nutrient cycles	Local	Dynamic One month Thousands years	Dynamic 1x1 m grid cell	Land cover CO_2 concentration	Parton et a. 1992.
GEM	Process-Oriented Ecological Model	Ecosystems	Local	Dynamic 12 hours	Dynamic 1 km cell	Land cover	Fitz et al.
PLM	Process-Oriented Landscape Model	Terrestrial landscape	Regional	Dynamic One week	Dynamic 200 m grid 1 km grid	Land cover	Costanza et al. 1995
IMAGE2	Process-Oriented Integrated Simulation Model	Energy-Industry Terrestrial Environment Atmosphere-Ocean.	Global, 13 regions.	Dynamic One day to five years	Dynamic Variable from 0.5 x 0.5 degree grid to region.	CO_2 emissions Land use	Alcamo et al. 1994.
ICAM-2	Optimization/ Simulation Model	Climate Economy Policy	Global, 7 regions	Dynamic Five-year	Static Latitude bands	Explicit treatment of uncertainties	Dowlatabadi and Ball 1994.
RAINS	Optimization/ Simulation Model	Emissions Atmospheric transport Soil acidification	Continental, Europe	Dynamic One year	Static 150x150 km in deposition sub-model and 0.5 lat. x 1.0 long. impact sub-model	Energy use Sulphur emissions	Alcamo, Shaw, and Hordijk 1990.
TARGETS	Integrated Simulation Model	Population/Health Energy/Economics Biophysics/Land/ Soils/Water	Global, 6 regions	Dynamic One year	Static Regions	Energy use Water use Emissions Land cover	Rotmans et al. 1994.