Extracting travel behavioral sensitivities to time-varying influences using aggregate data sources

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3rd Symposium on Activity-Based Modeling
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Some thoughts about activity-based travel models, aggregate data analyses & evidence, and micro/macro-level models

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Chapter 1: Introduction

Why I am interested in this?

Data

Rich data

- "Thick" or Wide: Many variables, fewer observations.

- More likely to be:
  - Cross-sectional or panel
  - Disaggregate (micro)
  - Individual or household level
  - Sample of the population

Big data

- "Thin" or Long: Many observations, fewer variables.

- More likely to be:
  - Longitudinal or time series
  - Aggregate (macro)
  - Location level
  - Census of the population

Thesis of my presentation

- Big data and aggregate/macro modeling could be a (somewhat?) useful resource for travel ABMs.
  - Especially when evidence about causality/effect is hard to determine from disaggregate studies, using rich data and micro models of individuals.
  - Especially for representing time-varying influences on behavior related to the decision setting (rather than the decision-maker).

- Questions and ideas
  - How to use aggregate-level evidence for ABMs?
  - Is there a role for macro models in travel ABMing?

Carpooling / Vanpooling

Public Transit

Trip Chaining

Plan Ahead

Skip the Trip

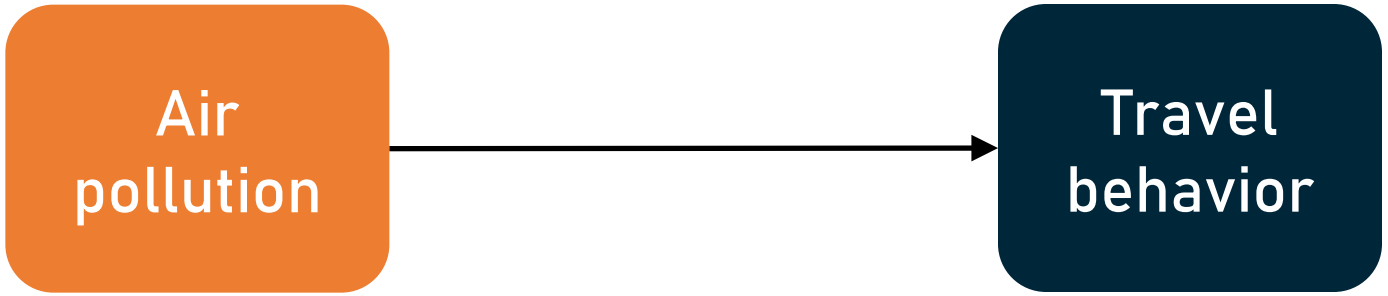
Teleworking

Active Transportation

Alternative Work Schedules

Travel behavior & air pollution

- We know a lot about how transportation emissions cause air pollution.
  We know less about how (much) air pollution affects activity/travel behavior.
- Air pollution is a time-varying influence, and (mostly) a characteristic of the decision setting.
- How to study this topic? ~~Experiment?~~ Natural experiment?



Analysis methods

1. Travel diaries (disaggregate)

- What: 3 × 2-day travel diary survey + survey on attitudes & perceptions
- When: winter (Jan–Mar) 2019
- Where: Cache County, Utah
- Who: 230 households, 403 adults
- Why: Individual travel & activity behavior change? Drive less? Travel less? Why or why not?

2. Traffic volumes (aggregate)

- What: daily volumes of automobile & pedestrian traffic, transit ridership
- When: 2018–2019
- Where: 5 urban counties, Utah
  - ~75 automobile count locations
  - +1,500 pedestrian count locations
  - 3 transit systems (1 bus, 2 rail)
- Why: Aggregate travel behavior change? Mode shift? Locations?

Analysis methods

1. Travel diaries (disaggregate)

- Dependent variables (20)
  - Stayed at home (or not)
  - Activity participation (#)
    - Total & by purpose (mandatory, semi-mand./disc., discretionary)
  - Travel outcomes, overall & by mode:
    - Used mode (or not)
    - Number of trips (#)
    - Distance traveled (miles)
    - Travel time (minutes)
- Linear, logistic, & quasi-Poisson

2. Traffic volumes (aggregate)

- Dependent variables
  - Automobile volumes
    - Daily, by count location
  - Pedestrian volumes
    - Daily, by count location
  - Transit ridership
    - System-wide
- Multilevel regression

Analysis methods

1. Travel diaries (disaggregate)

- Independent variables
  - Daily Air Quality Index (AQI)
  - AQI category (green, yellow, orange+)
  - Perception of daily air quality
- Control variables
  - Personal
  - Household
  - Neighborhood

2. Traffic volumes (aggregate)

- Independent variables
  - Daily Air Quality Index (AQI)
  - AQI category (green, yellow, orange+)
- Control variables
  - Temporal
  - Weather
  - Neighborhood

Comparing the results

1. Travel diaries (disaggregate)

2. Traffic volumes (aggregate)

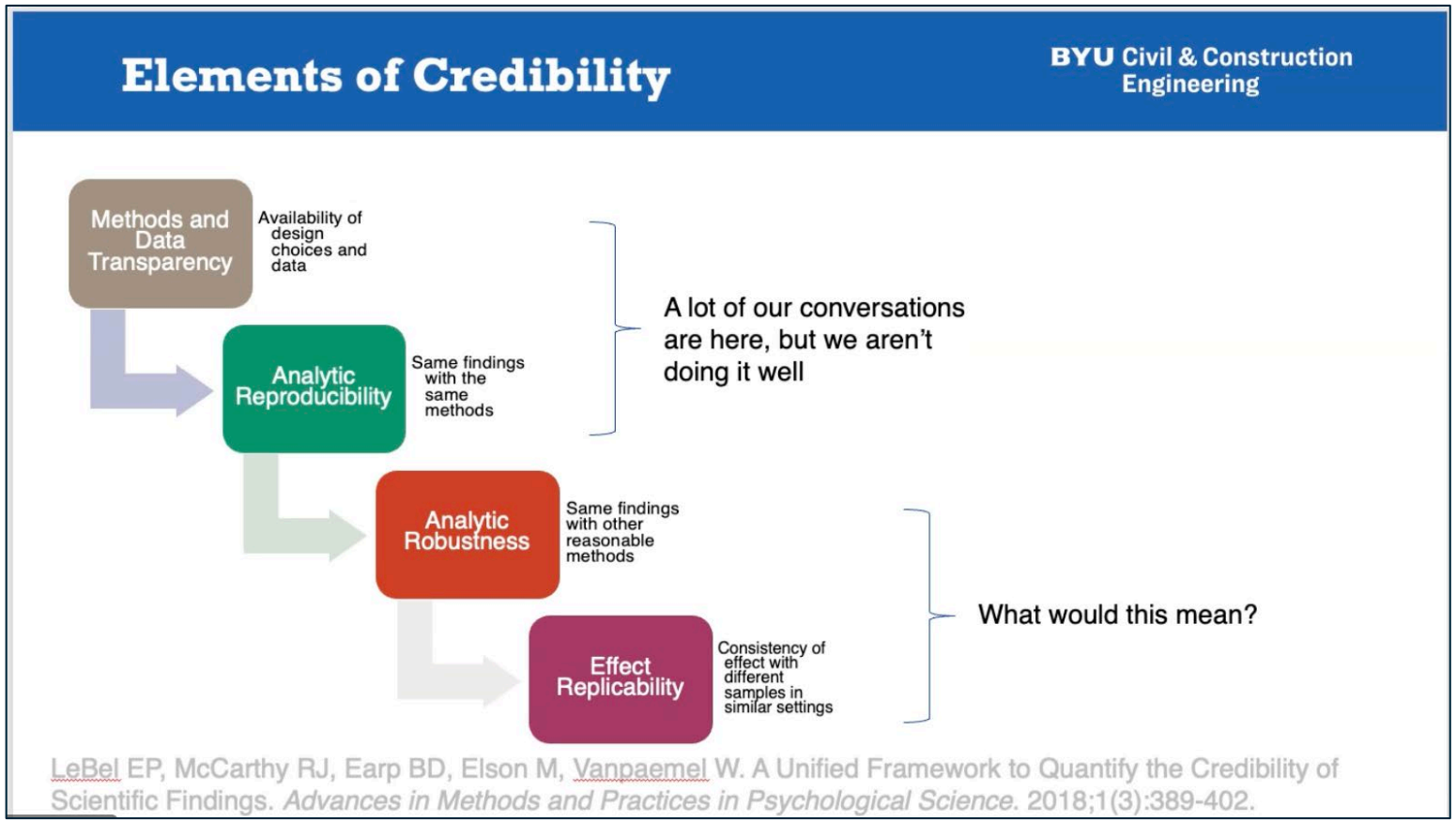
Comparing the results

1. Travel diaries (disaggregate)

- Small sample size
- Limited geographic area
- Biases
  - Sampling & selection
  - Social desirability
- Lack of variation in treatment
  - Unknown effects for higher treatment levels

2. Traffic volumes (aggregate)

- Population-level effect
  - Obscures most heterogeneity
  - Simpson's paradox
- Sampling of locations
  - Unable to see full travel patterns
- Less certain about WHY
  - Not linked to WHO
  - Infer from locational differences



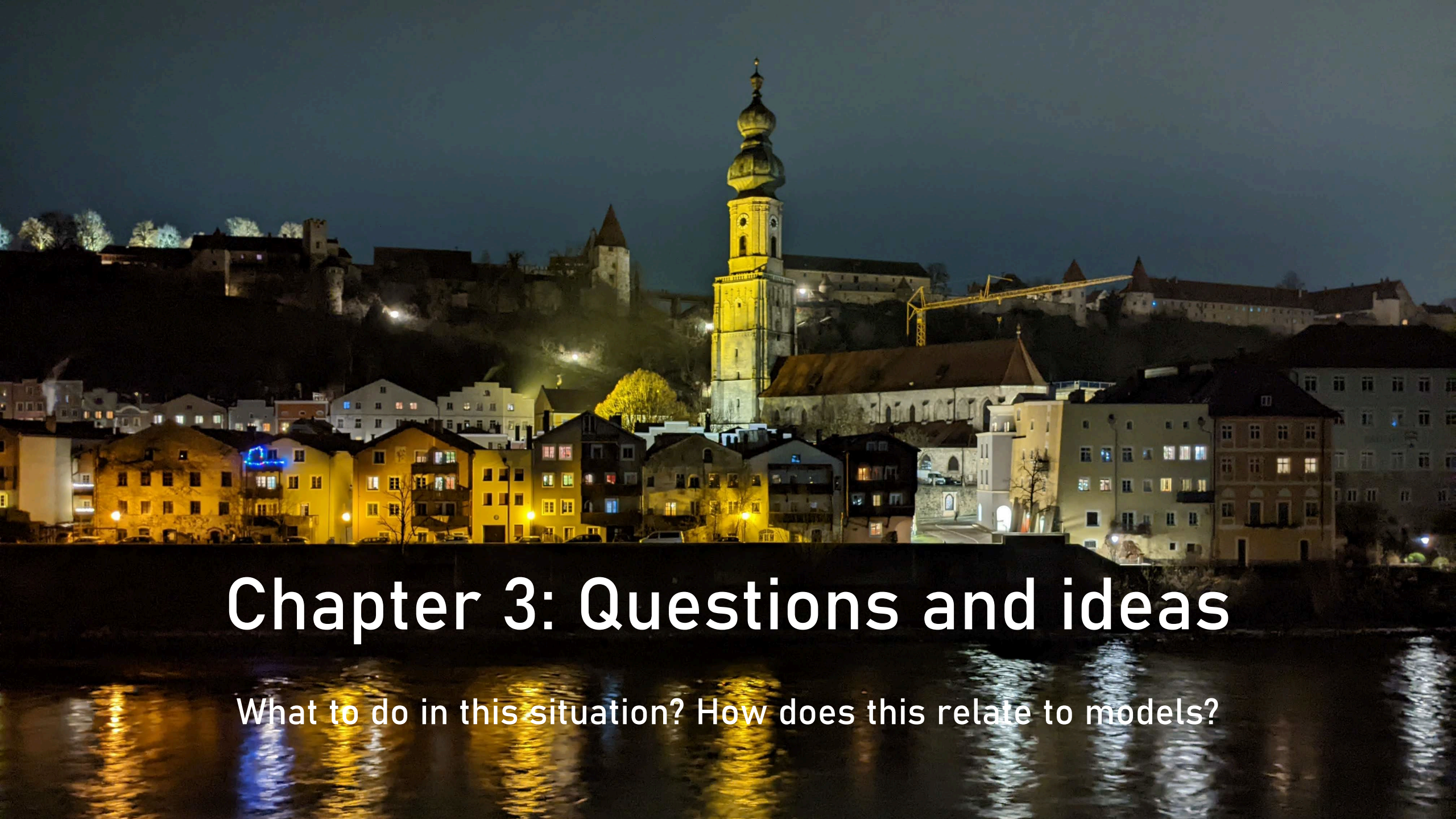
1. Singleton, P. A. (2024). singletonpa/2019-winter-transportation-survey [Data set]. Zenodo. https://zenodo.org/doi/10.5281/zenodo.11640318

2. Singleton, P. A. (2023). [Data set]. https://github.com/singletonpa/usu-course-transport-data-safety/tree/main/Data/Traffic_AQ

Recap & reframe

- There is a phenomenon or behavior that is…
  - Really difficult to measure using individual, disaggregate, rich data.
    - Difficult to collect data.
    - Experimental treatment is unethical.
    - Effect size is small.
    - Uncertain time-varying.
  - Appears easier to measure using population, aggregate, big data.

- What to do?



Chapter 3: Questions and ideas

What to do in this situation? How does this relate to models?

Question 1

How to use aggregate-level evidence for ABMs?

- Should we link or embed these relationships with/into our travel ABMs?
- If so, how?

Idea 1

Aggregate-level evidence gives the average effect.

- Use this evidence (population-level average effect, elasticity, sensitivity) directly in an ABM equation.
- Concerns
  - Heterogeneity
    - Effect may differ for different population subgroups, in different contexts.
  - Causality / Decomposability
    - There may not be a single model (parameter) for the effect to be built into, since it represents the cumulative effect of several linked models.

Idea 2

Aggregate-level evidence is for model validation.

- Examples
  - Traffic volumes → screenline validation of traffic assignment.
  - O-D matrices from LBS data → baseline for trip distribution models, validation of destination choice models.
  - Compare value of travel time savings to wage rate.
- Concerns
  - Not satisfactory.
  - Must wait until developed the rest of the travel model to compare outputs versus reality/prediction.
  - Wasting information?
  - Wasting time?

This is what agent-based modelers recommend.

Question 2

Is there a role for macro models in travel ABMing?

- How do other fields & disciplines think about micro vs. macro modeling?

Macroeconomics

Bloom, D. E., Canning, D., Kotschy, R., Prettner, K., & Schünemann, J. (2024). Health and economic growth: Reconciling the micro and macro evidence. *World Development*, *178*, 106575. https://doi.org/10.1016/j.worlddev.2024.106575

- Micro-level models usually focus on the direct effect.
- Macro-level models usually focus on the total effect.
- The discrepancy includes the indirect effects, “which macro-based approaches usually capture but micro-based approaches omit by design.”
  - (Unless micro models are broad enough in scope to encompass all indirect effects.)

- What do we care about? What do our clients care about?
  - Direct effect? Indirect effects? Total effect? All of the above?

Social science

Rutherford, M. (1996). *Institutions in economics: The old and the new institutionalism*. Cambridge University Press.

Individualism

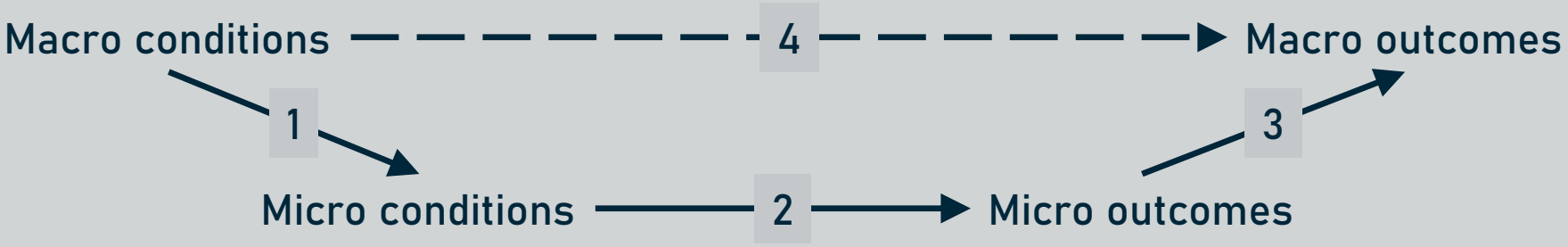
- The whole is just the sum of its parts. (Reductionist.)
- Only individuals have motivations.
- Social system (changes) result from individuals' actions.
- All large-scale phenomena can be explained by theories that refer only to individuals, their relationships, and their interactions.

Holism

- The social (macro) whole is more than the sum of its (micro) parts.
- The whole influences and conditions the behavior of its parts.
- Individual behavior should be deduced from macro or social laws that apply to the whole system, as well as information about how individuals fit within the whole.

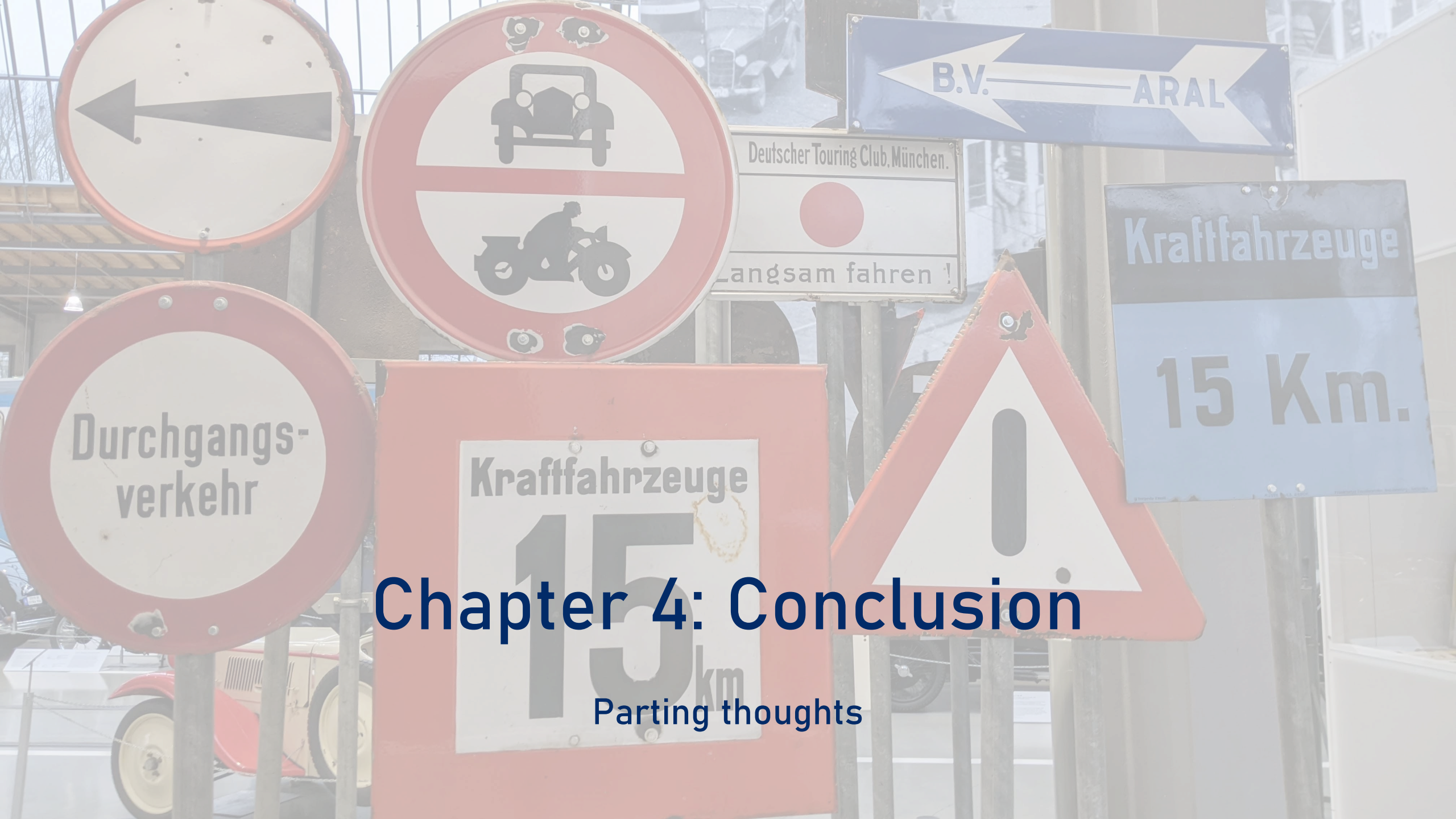
Sociology

Coleman, J. S. (1990). *Foundations of social theory*. Harvard University Press.



- 4. Macro → Macro: Social regularities/patterns. Mechanisms "do not exist."
- 1. Macro → Micro: Situational or environmental mechanisms (determinants).
- 2. Micro → Micro: Individual action (behavior) or cognitive mechanisms.
- 3. Micro → Macro: Transformational or relational mechanisms.
  - Critical importance of structural and institutional factors → societal configuration.

Mayntz, R. (2004). Mechanisms in the analysis of social macro-phenomena. *Philosophy of the Social Sciences, 34*(2), 237-259. https://doi.org/10.1177/0048393103262552



Chapter 4: Conclusion

Parting thoughts

Why care about the macro level?

- Many things we care about in “evolutionary” travel behavior and ABMs are (at least somewhat) about macro-level societal, political, or environmental trends and changes.
  - Climate change
  - Air pollution
  - Winter storms
  - COVID-19 pandemic
  - Teleworking policies
  - Incentives for vehicle electrification
  - NYC congestion pricing
  - Attitudes and social norms

Why care about the macro level?

- These are just a portion of the broader set of large-scale societal changes, evolutions, and challenges:
  - Climate change
  - Evolving attitudes about the role of government in society
  - Distrust of learned expertise / institutions
  - Individualism versus collectivism; preparedness vs. “preppers”
  - (US) Legal perspectives on affirmative action as reverse discrimination
  - Political upheaval (South Korea, Syria, Ukraine, etc.)

- There are a lot of things that are happening in society that we aren’t talking much about in this setting. Should we be?

More Questions

- Are there any macro mechanisms in travel behavior?
- Are we modeling the right kinds of agents? (levels of organization)
  - Wimsatt, W. C. (1994). The ontology of complex systems: Levels of organization, perspectives, and causal thickets. *Canadian Journal of Philosophy Supplementary Volume, 20*, 207–274. https://doi.org/10.1080/00455091.1994.10717400
- Should we care that computer scientists are using ML/AI and big data to answer travel behavior questions? (disciplinary boundaries, “perspectives”)
  - Wimsatt, W. C. (1994). The ontology of complex systems: Levels of organization, perspectives, and causal thickets. *Canadian Journal of Philosophy Supplementary Volume, 20*, 207–274. https://doi.org/10.1080/00455091.1994.10717400
- Should our ABMs only embed causal relationships? (causal inference)
  - Graham, D. J. (2025). Causal inference for transport research. *Transportation Research Part A: Policy and Practice, 192*, 104324. https://doi.org/10.1016/j.tra.2024.104324
- Can the macro be causally superior to the micro? (emergence)
  - Hoel, E. P., Albantakis, L., & Tononi, G. (2013). Quantifying causal emergence shows that macro can beat micro. *Proceedings of the National Academy of Sciences, 110*(49), 19790–19795. https://doi.org/10.1073/pnas.1314922110
- What can we learn from the field of complex systems?

Questions?

Views of Logan, Cache Valley, Utah (Left: USU, 2013) (Right: Dayton Crites, 2013).

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Question 3

Are there any macro mechanisms in travel behavior?

- If yes, then macro models are justified on theoretical grounds.
- If not, then the justification for macro models must rely on other reasons (e.g., practical).

- When aggregating across individuals? Across space? Across time?

Idea 3

Macro models change ABM inputs/parameters.

- Higher-level models could be used to model changes (over time) in…
  - Model inputs: travel times, costs, attitudes,
  - Behavioral sensitivities: model coefficients, distributions, etc.

- Concerns
  - Isn't this just what we do when we define scenarios?
  - Can't this already be accomplished between ABM model runs, using transition probabilities and agent memories?

Questions

- How to use aggregate-level evidence in our ABMs?
- Is there a role for macro models in travel ABMing?
- Are there any macro mechanisms in travel behavior?

Why care about the macro level?

- Kinds of changes we tend to think about / work on with our travel ABMs is biased by the kinds of spaces we inhabit and the kinds of incentives we face.
- Closeness of our work (practical justification, funding) to planning and public policymaking in the transport / land use sectors → prioritizes stability, underemphasizes change/evolution.
- More “hidden” or other sources of change are probably of less interest to current travel ABM stakeholders.

- What aren’t we talking about now that—from 30-years in the future—we should be?