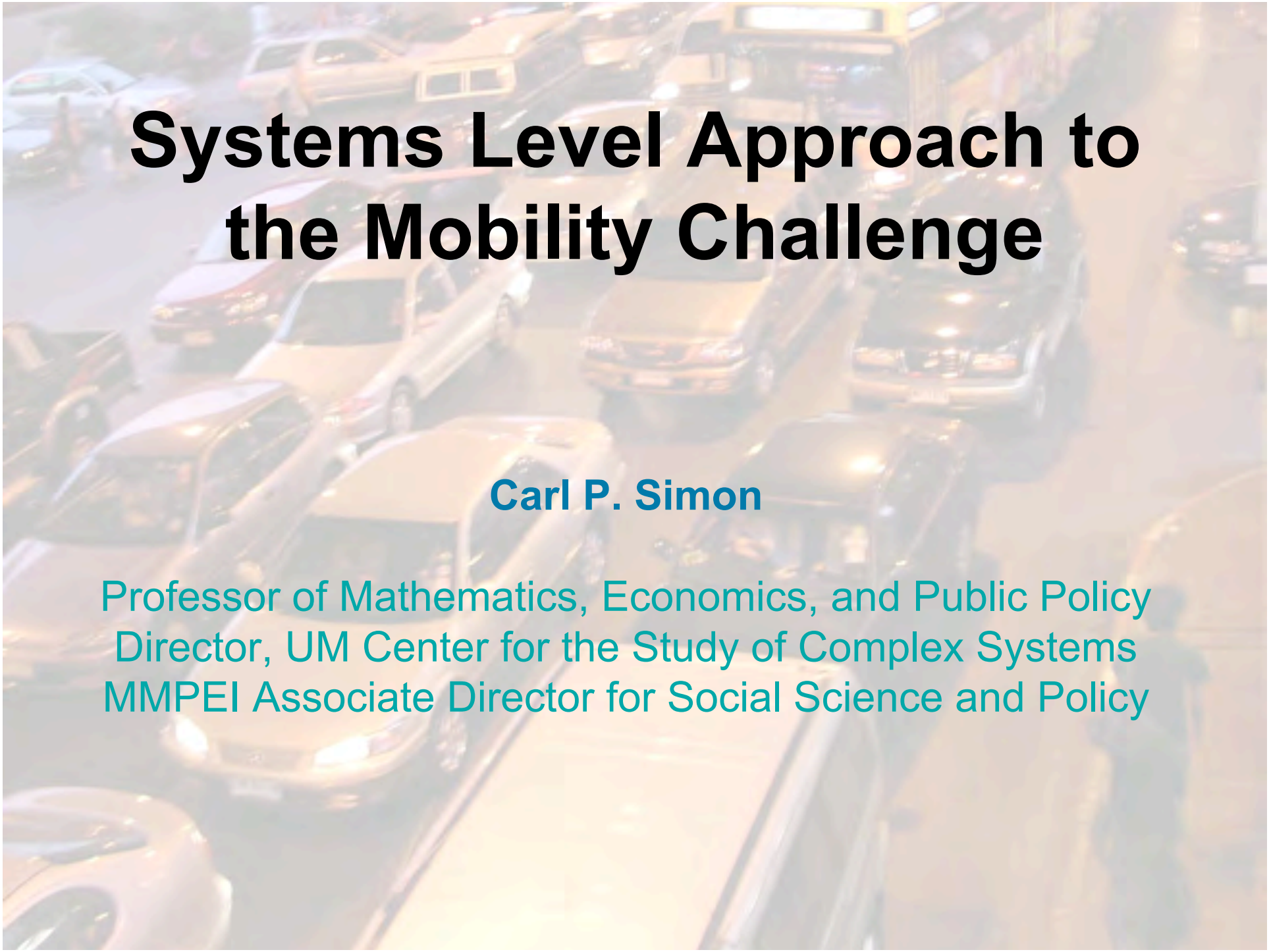


Systems Level Approach to the Mobility Challenge

Carl P. Simon

Professor of Mathematics, Economics, and Public Policy
Director, UM Center for the Study of Complex Systems
MMPEI Associate Director for Social Science and Policy

Edwin Chadwick

- London Sanitation Commissioner in 1840s
- had several ideas on how to improve public health.
- a system of carrying sewage, especially human feces, out of the smelly streets
- …and into the River Thames

Unintended Consequence

- London's worse cholera epidemic in 1854

- John Snow's birds-eye "Ghost Map"
- The Broad Street Pump

- See: Steven Johnson: The Ghost Map

Key insight about problem-solving:

Everything is a ***system***,

composed of interdependent and interacting components.

Ignoring these interconnections often leads to ***unanticipated consequences.***

Examples of Systems

Natural Systems	*Man-made systems*
Immune system	Legal Systems
Circulatory system	Economies
Respiratory system	Business organizations
Body itself	Automobiles, airplanes
Ecosystems	Cities

TRANSPORTATION

Other Failures for Lack of Systems Thinking

- Overuse of DDT
- Indiscriminate prescription of medications
- Build a new highway lane to address congestion
- Leaded gasoline
- Total reliance on bio-fuels
- Beat urban decay by tearing down neighborhoods and moving the occupants into isolated high-rises

Systems thinking: first steps

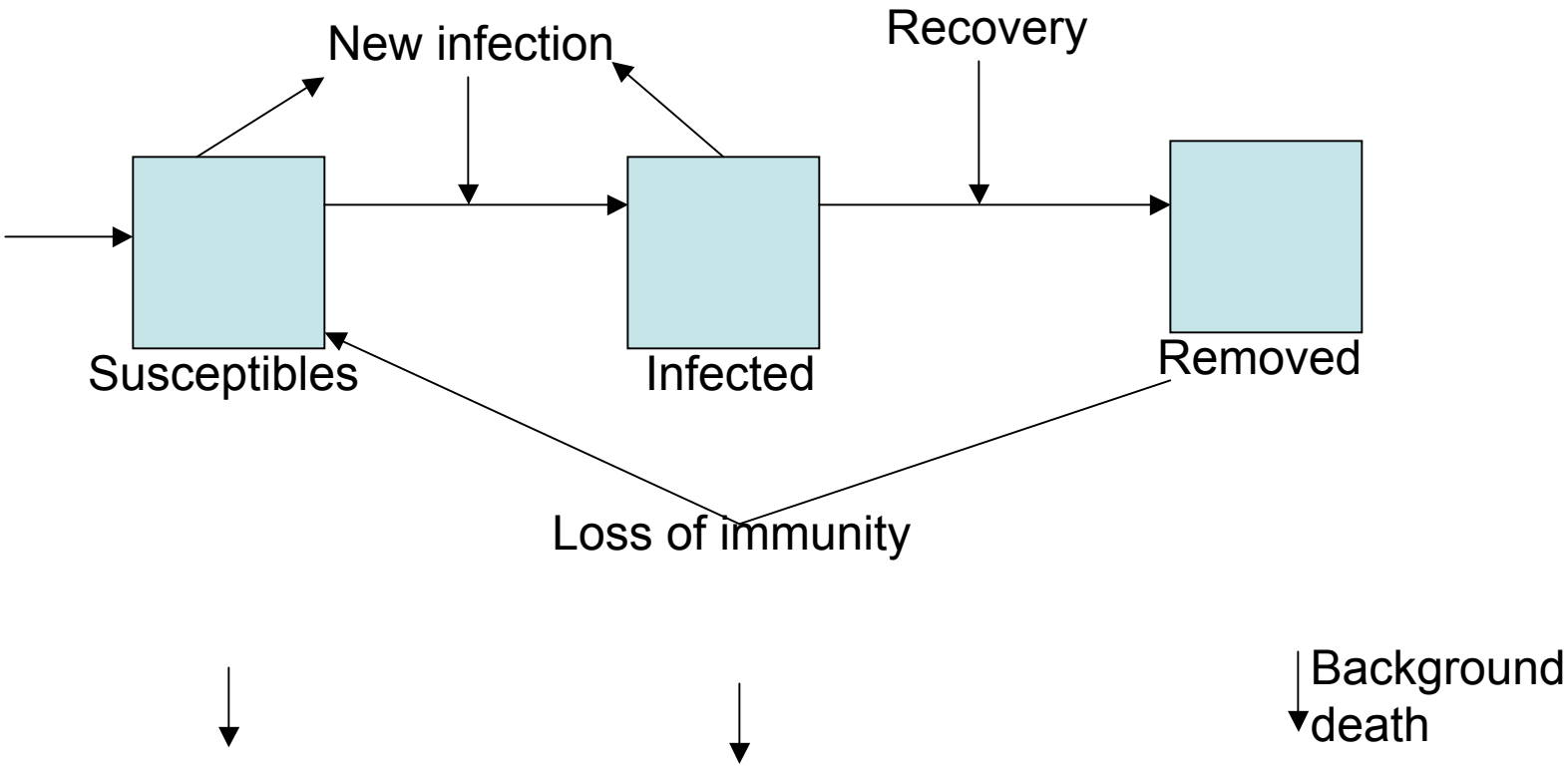
- **Identify key variables and main actors**
  - Especially those in the problem under consideration
- **Draw (causal) diagrams** to illustrate connections and feedbacks
- If possible, **quantify** some of those connections
- Result: a ***model***
  - heuristic, computer, mathematical
  - e.g., Sim City

Example: Spread of Contagious Infection in a Population

- Standard biostatistical approach
  - linear correlation-based approach
  - Focus on risk factors
  - NIH

- Dynamic Model
  - Variables
    - S = number of susceptibles
    - I = number of infectives (infecteds)
    - R = number immune (or removed)

Simple system of disease spread



- Parameters
  - c = contacts per person per year
  - b = infection transmission probability
  - a = recovery rate = 1/d
  - m = background birth/death rate

- Equations

$$\Delta I = c \cdot S \cdot (I/N) \cdot b - a \cdot I - m \cdot I$$

Threshold or tipping point

$R_0 = cb/(a+m)$

basic reproduction number

"how many infections does an infective cause in the course of his infection"

$R_0 \leq 1$ ➔ disease dies out

$R_0 > 1$ ➔ endemic disease

BENEFITS OF MODELING THE SPREAD OF INFECTION

- shed light on large-scale dynamics
- provide conceptual framework for data collection
- estimate biological and sociological parameters.
- simulation experiments.
- comparison and contrast.
- careful formulation of the assumptions.
- cross-checking diverse pieces of information.
- Forecasts.

Characteristics of "Simple" Systems

(economics, ecology, biology, business, physics…)

1. **Homogeneity** ("representative agent")
2. **Equilibrium** (no or simple dynamics)
3. **Random mixing** (no structure or organization)
4. **No feedback**; no learning/adaptation
5. **Deterministic**
6. **No connection** between micro and macro phenomena

Complex System Approach

1. Heterogeneous agents/ diversity
2. Nonlinear dynamics
3. Contact structure; networks; organization
4. Feedback, adaptation, learning, evolution
5. Stochastic with concern for “tails”
6. Emergence

Why study of complex systems

- Some systems are inherently complex
  - Brain
  - Energy
- Check out “rules of thumb” and panaceas suggested by simple systems approach

UM Center for the Study of Complex Systems

John Holland,	Psych/Engineering	Genetic Algorithms
Scott Page,	Political Science	Diversity
Michael Cohen,	Information	Organizations
Bob Axelrod,	Public Policy	Cooperation
Rick Riolo,	Computer	Computer simulation
Mark Newman,	Physics	Networks
Carl Simon,	Math/Econ/Policy	Dynamics
Mercedes Pascual	Ecology	Multiscale interactions

Energy is a Complex System

The problem is ***dynamic***

Networks play important role:

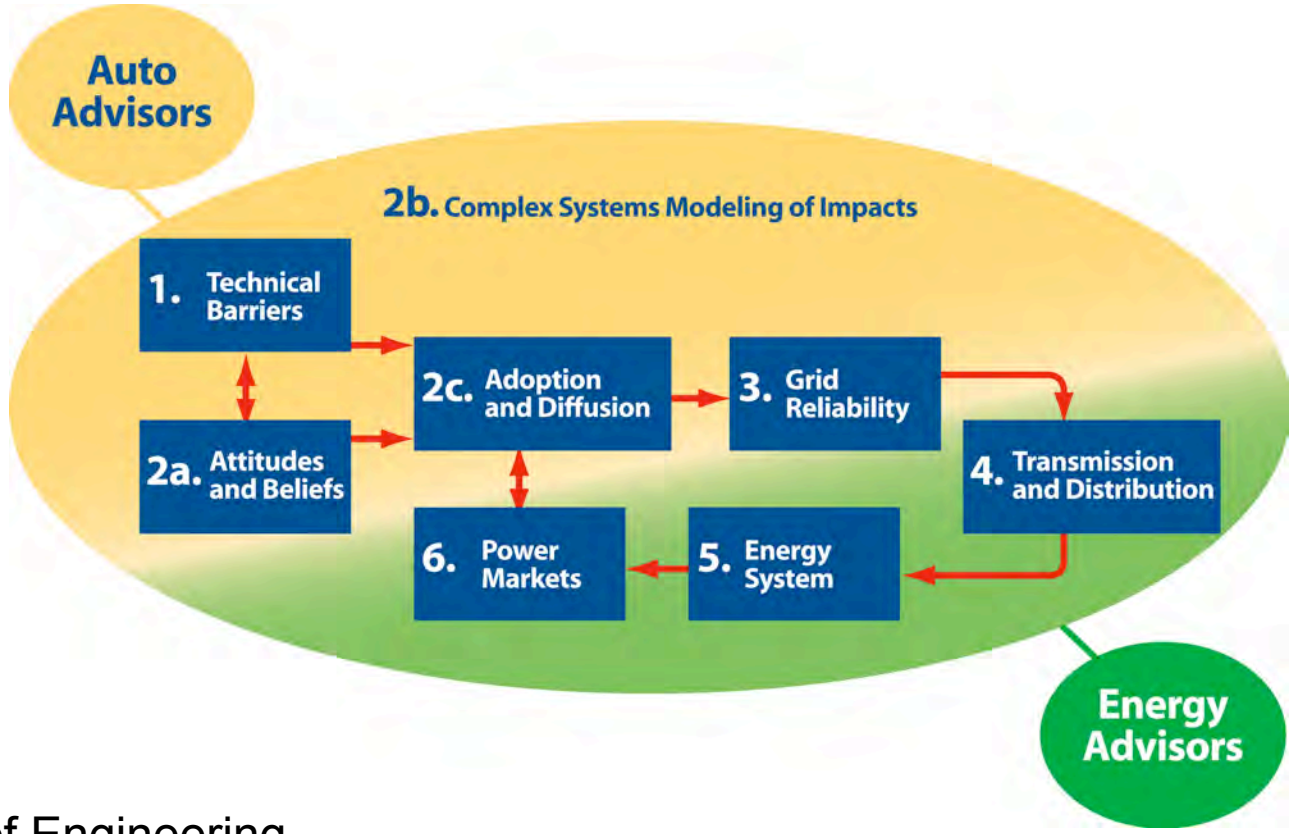
- Electric grid
- Highway system
- Gas pipelines
- Consumer word of mouth

Natural ***heterogeneity***

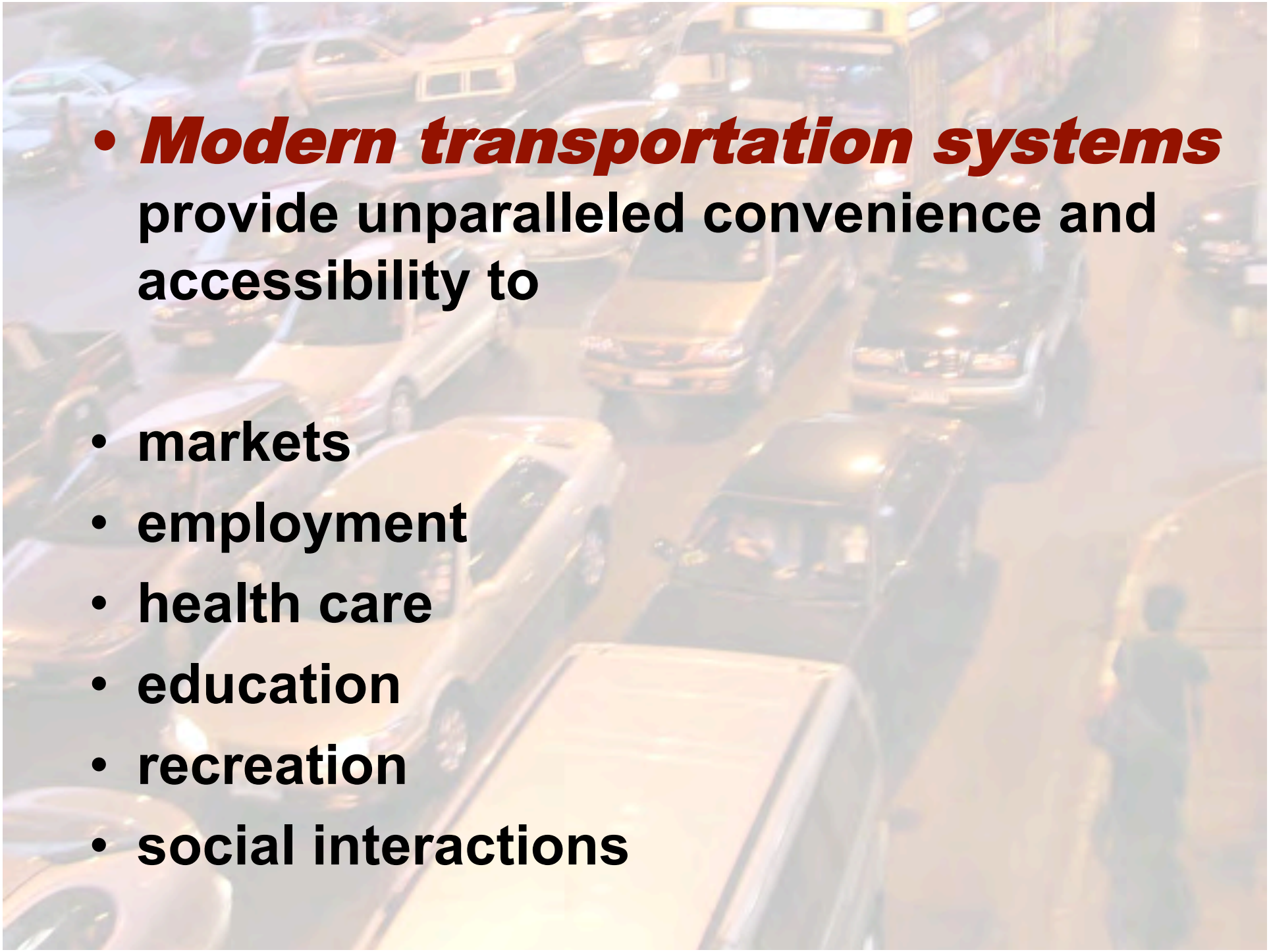
Adaptation

Uncertainty

PPNL-UM PHEV Modeling Project



School of Engineering
Transportation Institute
Inst. For Social Research
Ctr. For Complex Systems



- ***Modern transportation systems*** **provide unparalleled convenience and accessibility to**

- **markets**
- **employment**
- **health care**
- **education**
- **recreation**
- **social interactions**

- ***BUT***
- **mobility brings unintended consequences:**
- ***Environmental***
  - **pollution,**
  - **climate change**
  - **fossil fuel depletion**
- ***Socioeconomic***
  - **urban sprawl**
  - **congestion and delays**
  - **injuries,**
  - **fatalities**
  - **economic inequality**

- **The sustainable mobility/accessibility challenge:**

- **Ensure that future generations have *access to adequate resources* to meet their mobility needs and aspirations**
- **while maintaining the *integrity and resilience* of supporting environmental and social systems**

- **This is *not* only a technological or a fuel-oriented problem.**
- **It involves important social dilemmas:**
  - **TRAGEDY OF THE COMMONS**
  - **consumers and producers focus on short-run private costs and benefits,**
  - **while ignoring the long run and societal consequences in decision-making about mobility options**
- **We must consider**
  - **land use**
  - **city design**

Current trends affecting mobility and accessibility

- Gridlock
  - Mexico City
  - Bangkok
- Rising gas prices
  - Affecting choice of vehicle and home site

Current trends affecting mobility and accessibility

- Energy transitions
  - Peaking of fossil fuel availability
  - Mid-east tensions
  - New technologies: ethanol, electric (Segway), hybrids, hydrogen

Current trends affecting mobility and accessibility

- Aging population
  - Inability to access needs, even if healthy enough to live alone
  - my 94+ year old father in suburban Chicago
- Sprawl
  - Making cars more and more necessary
  - Land use makes a difference!

Current trends affecting mobility and accessibility

- China
  - explosion in automobile ownership and gasoline demand
    - 5M cars in 2001
    - 20-40M cars in 2020
  - global effect (a la coal)
  - Beijing (gridlock and pollution)
  - 300 autos deaths a day

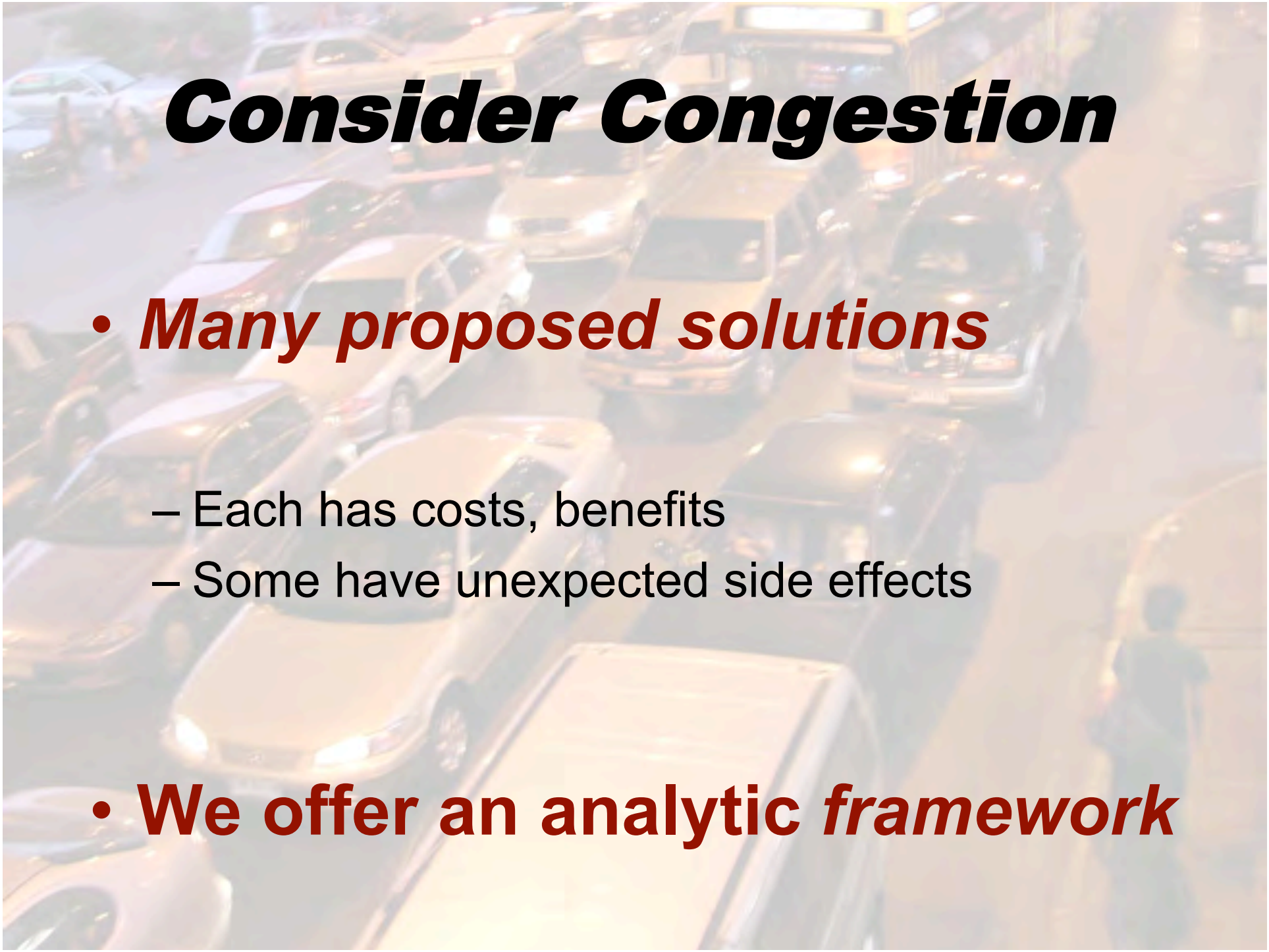
Consider Congestion

- Build new roads?
- Add lanes to existing roads?
- Charge user fees? Tax extra cars?
- Dedicated rapid-bus lanes?
- Build/expand elevated rapid transit, subways?
- Encourage bicycles? Ban them?
- Car pool lanes on highways?

Consider Congestion

Each solution has benefits, costs

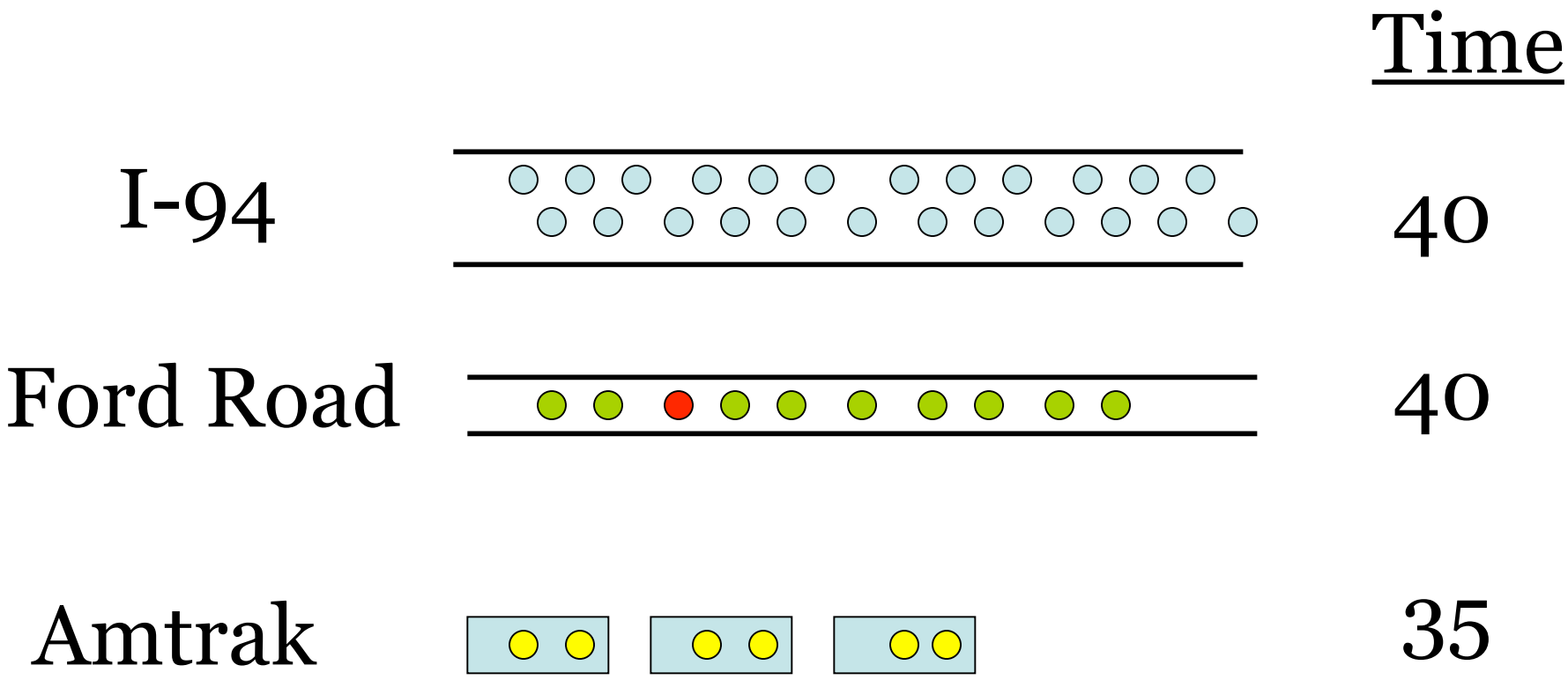
- Add lanes to existing roads?
  - *Usually increases vehicles on road; doesn't affect congestion*
- Car pool lanes on highways?
  - *Decreases lanes for other transport*
- Toll ways, usage/extra vehicle taxes?
  - *Income equity effect*
- Build new systems?
  - *Expensive & disruptive*



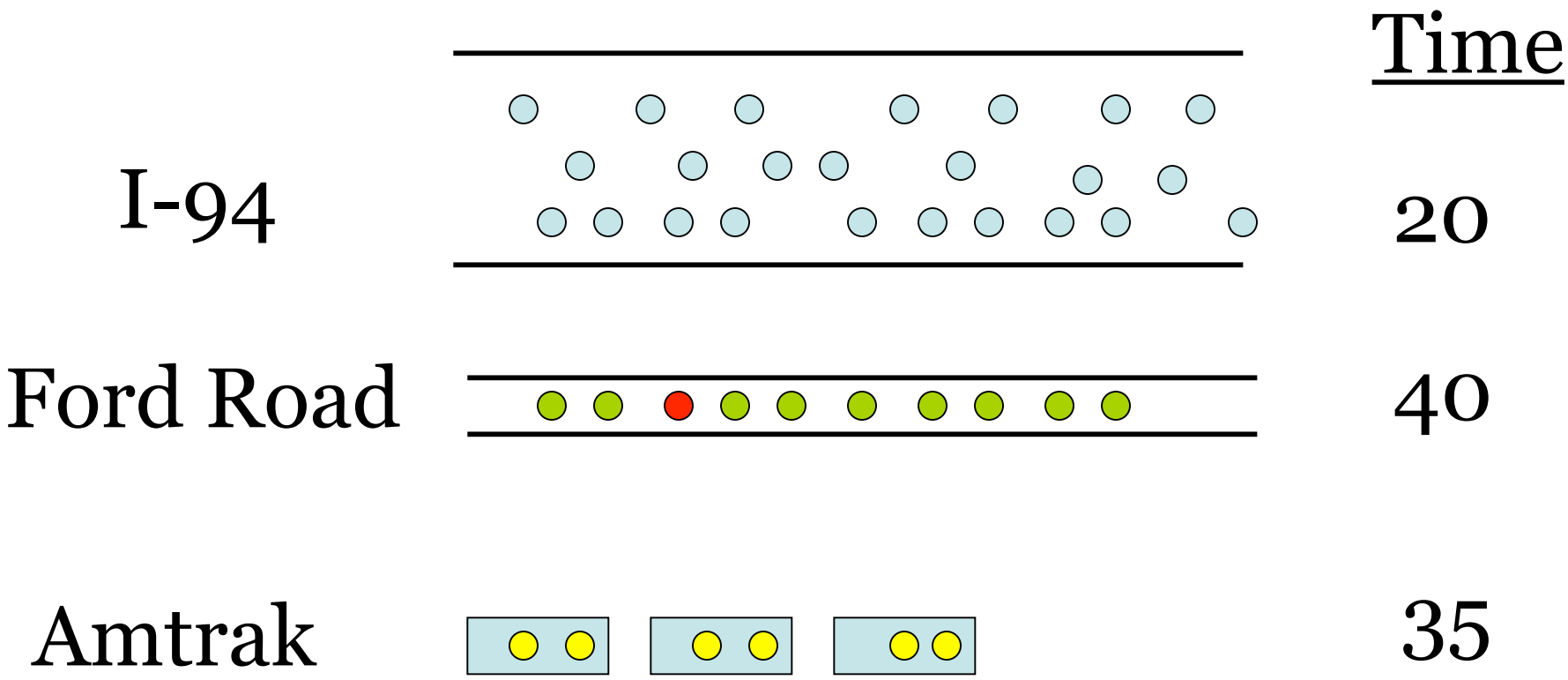
Consider Congestion

- ***Many proposed solutions***
  - Each has costs, benefits
  - Some have unexpected side effects
- **We offer an analytic *framework***

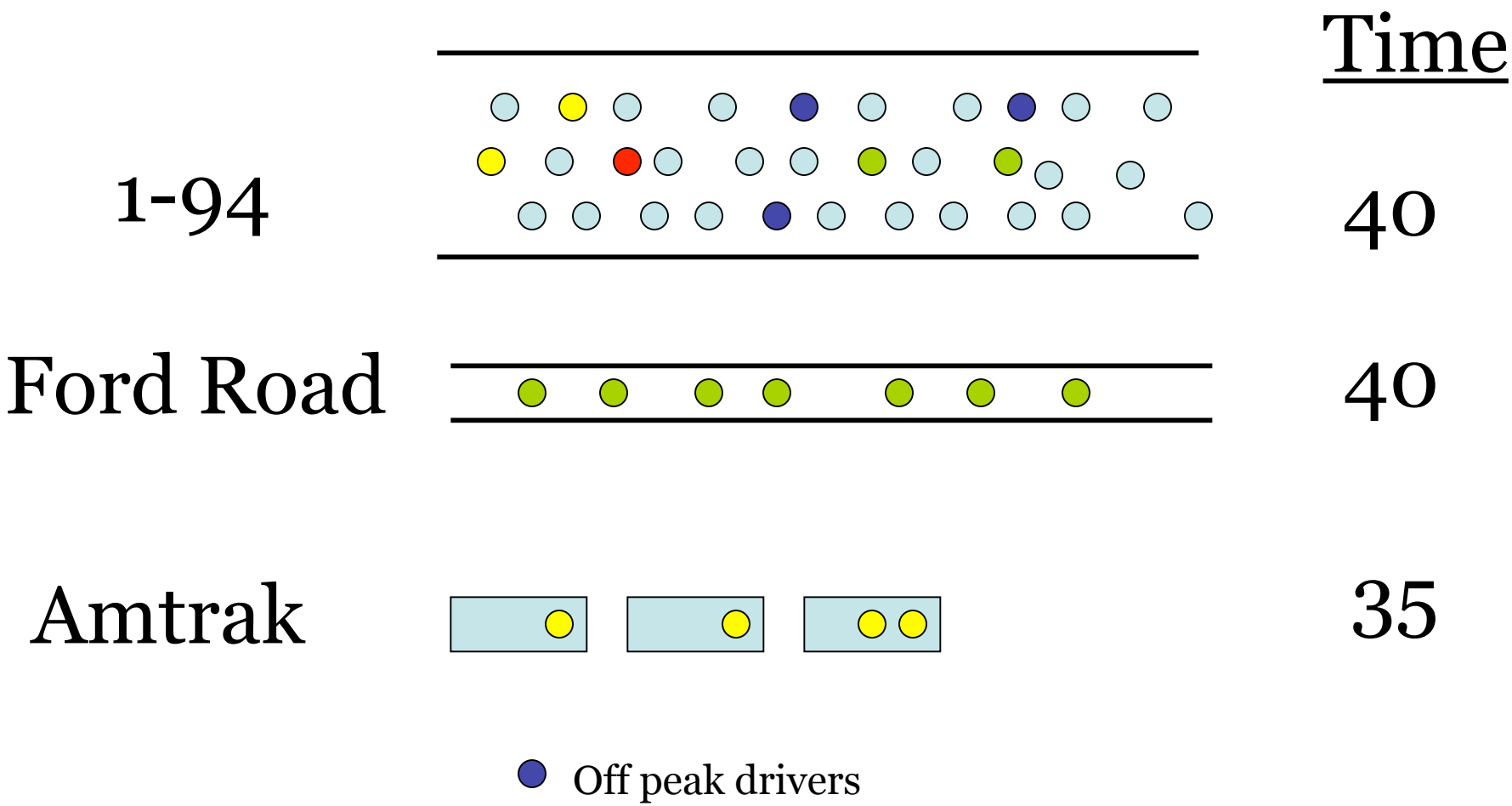
Equilibrium



I's Wide Open



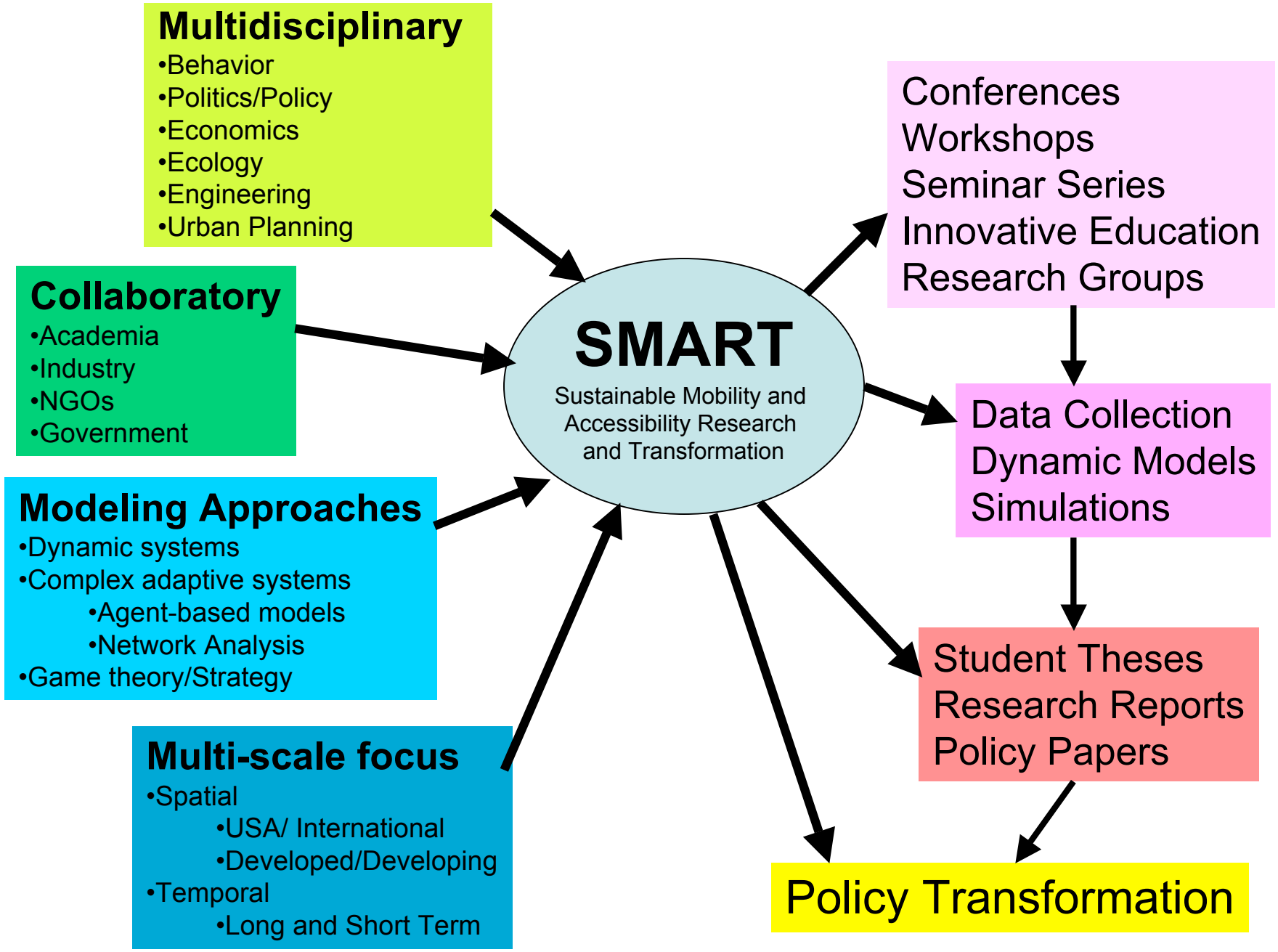
Triple Convergence



1. More people get to city when they want
2. Total utility has increased
3. Traffic time during peak almost the same
4. Congestion never goes away
5. Fragile network

Sustainable Mobility

- This is still an automobile-centric approach.
- A true systems approach to sustainable mobility must include:
  - Public transportation
  - Shared private transportation
  - Alternative energy sources (non-fossil fuel)
  - Walking, bicycling
  - Urban design


Multidisciplinary
•Behavior
•Politics/Policy
•Economics
•Ecology
•Engineering
•Urban Planning
Collaboratory
•Academia
•Industry
•NGOs
•Government
Modeling Approaches
•Dynamic systems
•Complex adaptive systems
•Agent-based models
•Network Analysis
•Game theory/Strategy
Multi-scale focus
•Spatial
•USA/ International
•Developed/Developing
•Temporal
•Long and Short Term
SMART
Sustainable Mobility and Accessibility Research and Transformation
Conferences
Workshops
Seminar Series
Innovative Education
Research Groups
Data Collection
Dynamic Models
Simulations
Student Theses
Research Reports
Policy Papers
Policy Transformation

The University of Michigan
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- **UM ADVANTAGES**
  - Location
  - Strong engineering
  - Strong public policy
  - Strongest social science
  - Strong *systems* environment
  - Thin walls
    - most interdisciplinary US institution
  - Commitment