

Complex systems approaches in population health: understanding the impact of neighborhood environments on health

Ana V. Diez Roux
Dornsife School of Public Health
Drexel University
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Why neighborhoods?

- Insufficiency of purely individual-based explanations
- Neighborhoods as contexts for:
 - Physical exposures
 - Social exposures
- Contribute to health inequalities
- Public health and policy relevance

General Process	Example neighborhood differences in physical activity
I. Health is affected by features of neighborhood	Availability of places to be physically active promotes physical activity
II. Persons are sorted into neighborhoods based on individual attributes	Persons of lower income and minorities live in neighborhoods with less resources

General process	Example neighborhood differences in physical activity
III. Persons select neighborhoods based on preferences for certain attributes	Physically active persons choose to live in neighborhoods with more PA resources
IV. People change their behavior in response to the behavior of others around them	Seeing more people walk in the neighborhood stimulates individuals to walk
V. Neighborhoods change in response to the behavior of residents	The presence of more physically active residents increases the availability of recreational resources

Spatial patterning of health emerges from the functioning of a system:

- individuals interact with their environment
- individuals interact with each other
- individuals and environments adapt and change over time.

Utility of agent-based models to neighborhood effects research

- Bidirectional person-environment relations
 - Selection
 - Endogeneity
- Interactions between agents
 - Networks/norms
- Interrelations/interactions between environments
 - Physical- social
- Spatial patterning (segregation) of individual and environmental characteristics

Auchincloss AH, Diez Roux AV. A new tool for epidemiology: the usefulness of dynamic-agent models in understanding place effects on health. *Am J Epidemiol* 2008;168:1-8.

An Agent-Based Model of Income Inequalities in Diet in the Context of Residential Segregation

Amy H. Auchincloss, PhD, MPH, Rick L. Riolo, PhD, Daniel G. Brown, PhD,
Jeremy Cook, BA, Ana V. Diez Roux, MD, PhD

Background: Low dietary quality is a key contributor to obesity and related illnesses, and lower income is generally associated with worse dietary profiles. The unequal geographic distribution of healthy food resources could be a key contributor to income disparities in dietary profiles.

Purpose: To explore the role that economic segregation can have in creating income differences in healthy eating and to explore policy levers that may be appropriate for countering income disparities in diet.

Methods: A simple agent-based model was used to identify segregation patterns that generate income disparities in diet. The capacity for household food preferences and relative pricing of healthy foods to overcome or exacerbate the differential was explored.

Results: Absent other factors, income differentials in diet resulted from the segregation of high-income households and healthy food stores from low-income households and unhealthy food stores. When both income groups shared a preference for healthy foods, low-income diets improved but a disparity remained. Both favorable preferences and relatively cheap healthy foods were necessary to overcome the differential generated by segregation.

Conclusions: The model underscores the challenges of fostering favorable behavior change when people and resources are residentially segregated and behaviors are motivated or constrained by multiple factors. Simulation modeling can be a useful tool for proposing and testing policies or interventions that will ultimately be implemented in a complex system where the consequences of multidimensional interactions are difficult to predict.

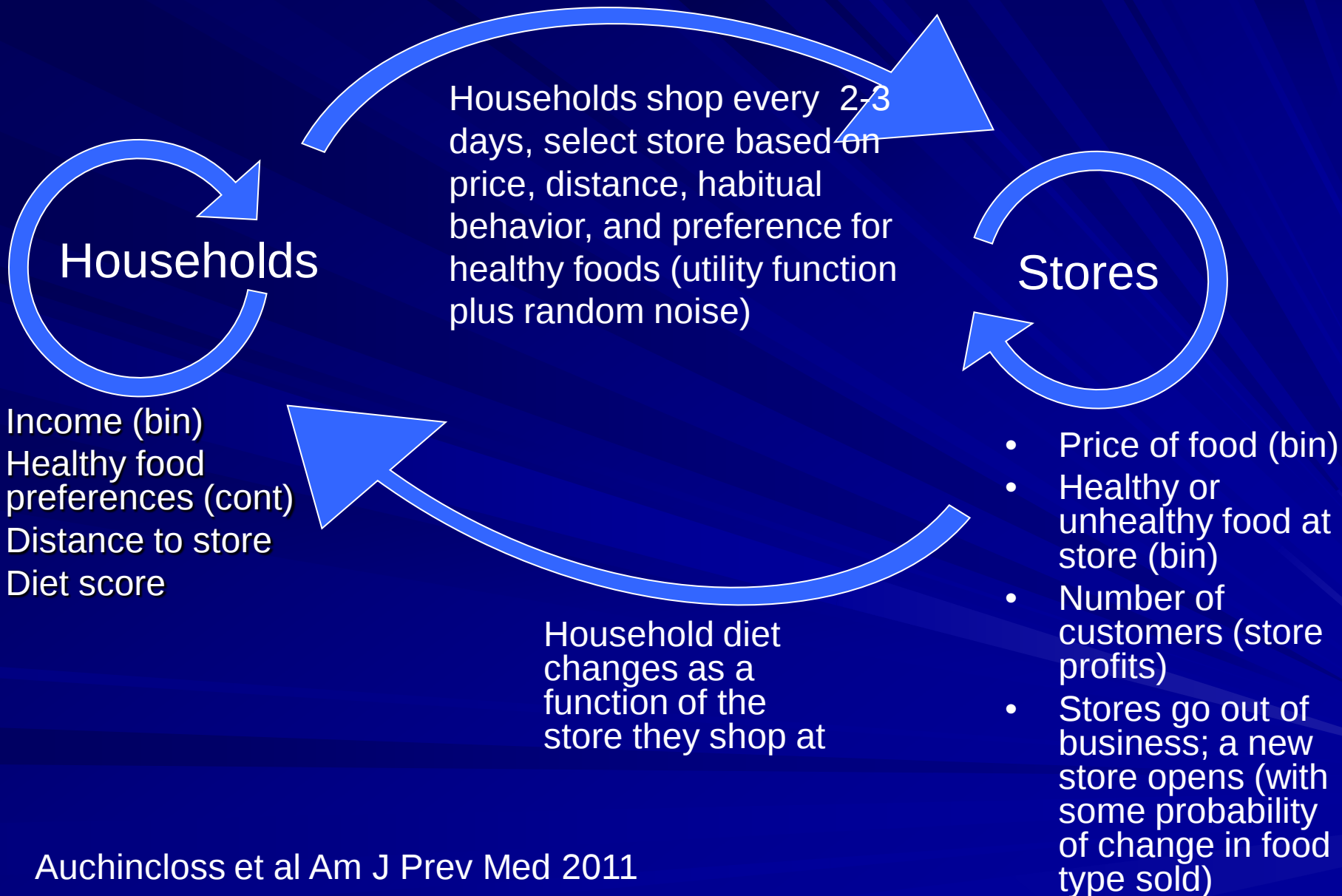
(Am J Prev Med 2011;40(3):303–311) © 2011 American Journal of Preventive Medicine

Background

- Income differences in diet well established
→ potential contributor to health disparities
- Spatial segregation of healthy foods repeatedly documented
- Questions regarding causality (selection) and policy implications

Two exploratory questions

- Does spatial segregation contribute to income disparities in diet absent price or preference differentials?
- How do price and preference manipulations (both possible interventions) affect these disparities?



- Compare income differentials under various spatial segregation scenarios (assuming constant price and preferences)
- Compare income differentials holding segregation constant but varying price and preferences

Spatial segregation scenarios

	Households	
Stores	No segregation	Spatial seg by income
No segregation of stores	1	4
Spatial seg of all stores	2	5 (w/high inc) 8 (w/low inc)
Spatial seg healthy vs. unhealthy stores	3	6 (healthy w/high inc) 7 (healthy w/low inc)

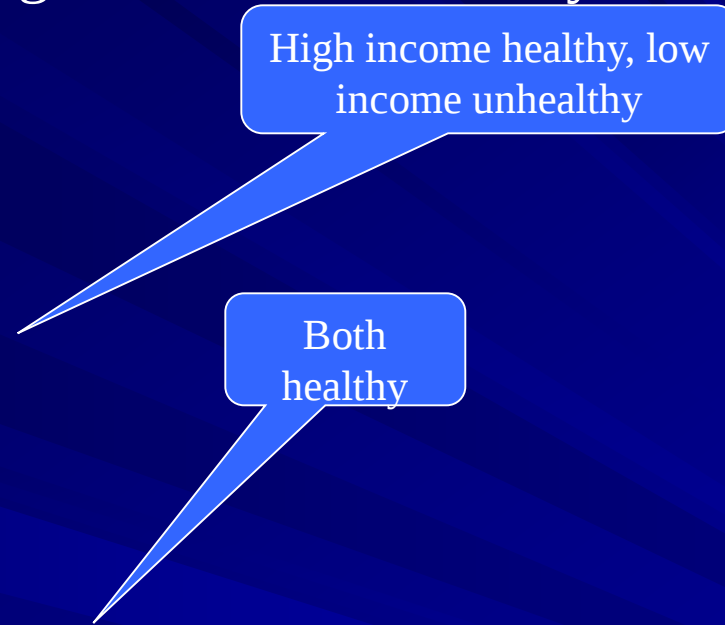
Income differentials in diet and absolute diet levels under various segregation scenarios

S6: segregation of low inc hh w/unhealthy foods and high inc hh w/healthy food

- Income differentials emerge in the presence of co-segregation of low income and unhealthy stores (or high income and healthy stores) even when food preference and price are held constant
- What happens when we manipulate price and preferences?

Income differentials in diet for different manipulations of preference and price for the scenario involving co-segregation of low income and unhealthy stores

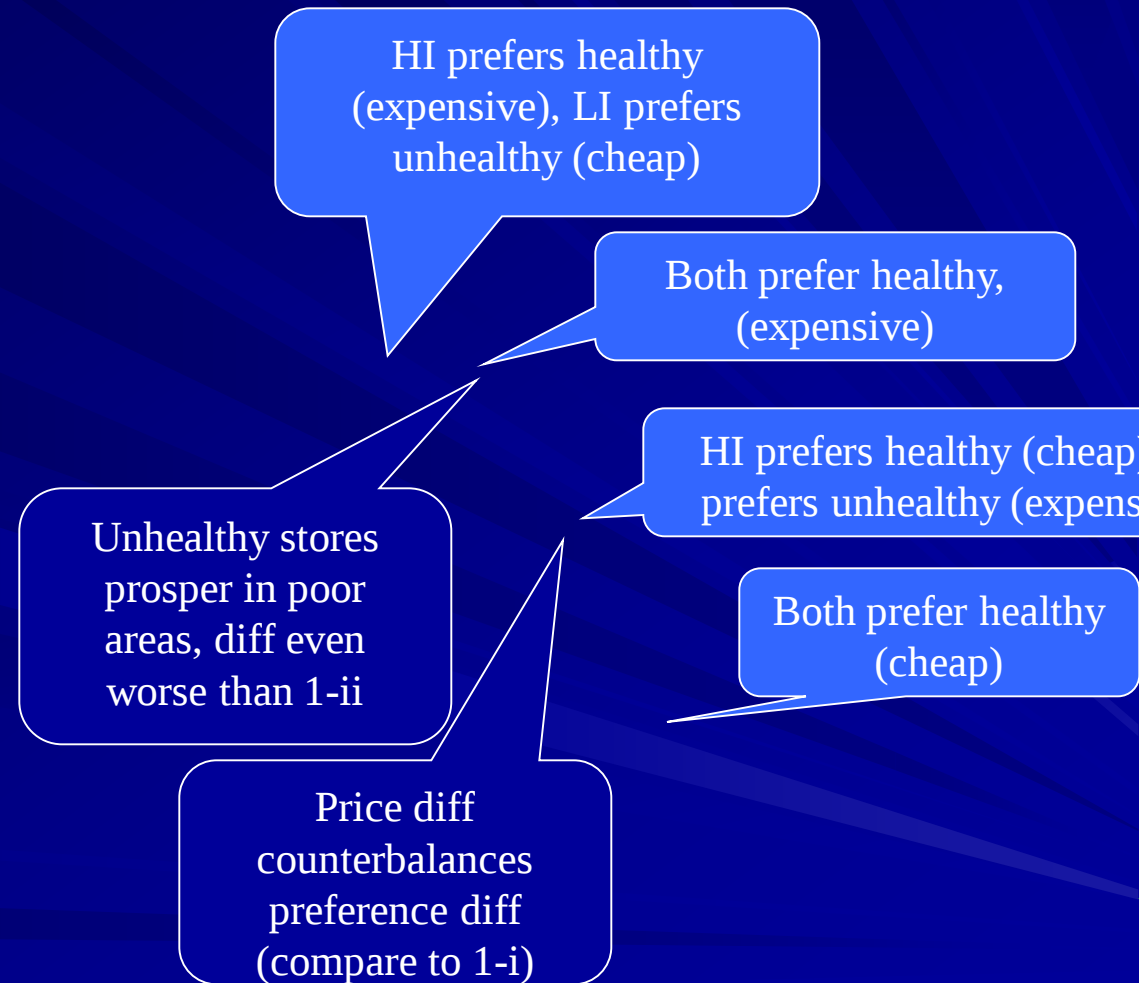
Income differentials in diet for different manipulations of preference and price for the scenario involving co-segregation of high income and healthy stores



Income differentials in diet for different manipulations of preference and price for the scenario involving co-segregation of high income and healthy stores



Income differentials in diet for different manipulations of preference and price for the scenario involving co-segregation of high income and healthy stores



What have we learned?

- Segregation can create disparities in diet even in the presence of no differences in preferences or price
- Changing preferences not enough
- Price manipulation seems to have a stronger impact than preference manipulation, but price and preferences reinforce each other
- We thought about the processes....
- Ideas for new data collection.....empirical studies
 - E.g. shopping behavior, store dynamics, networks

Benefits

■ Dynamic conceptual models

- Force investigators to think about processes: from describing associations to modeling the processes that generate them
- Explicitly account for the interrelatedness of people and environments
- Allow input from various “stakeholders”

■ Tools

- Gain insight through simulation
- Thought experiments and evaluate the effects of hypothetical interventions in the context of SYSTEMS
 - Under conditions different from those observed in real world
 - Accounting for feed back loops and adaptation of people and environments over time

■ Data

- Integrate/synthesize various sources of data
- Identify gaps and data needs

Caveats...

- Keeping it simple but relevant...
 - Boundaries and level of detail (intelligent abstraction)
 - Thought experiments vs. specific prediction
- Assumptions, where is the data?
 - Justify modeled processes
 - Calibrate parameters
 - Validate the model
- Arduous process....
- Transparency and communication
- WHEN DOES IT MAKE A DIFFERENCE???

Types of questions

From:

Are neighborhood characteristics independently associated with health after accounting for individual-level SES?

To:

To what extent (and under what conditions) could residential segregation generate, and reinforce, health disparities by race?

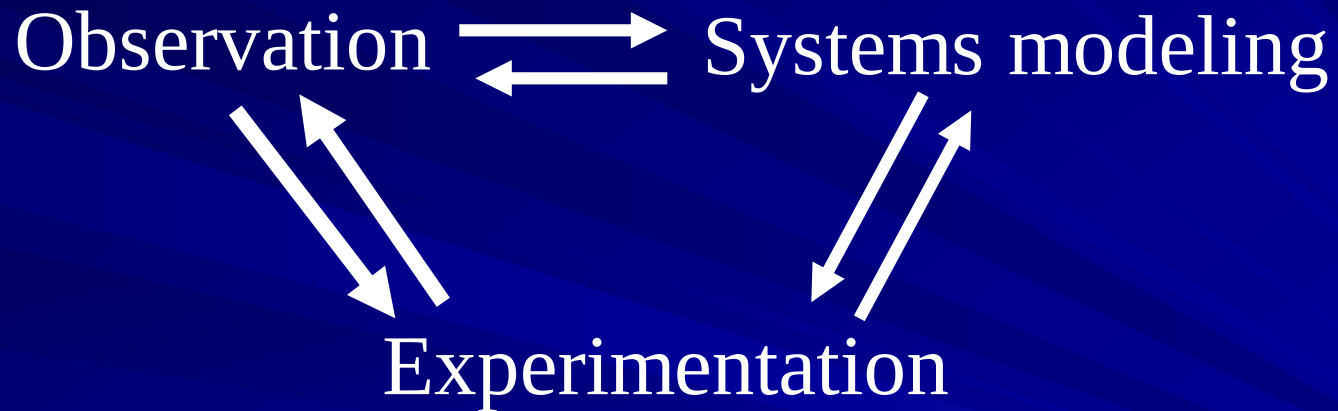
From:

Is proximity to supermarkets (as proxy for healthy food access) associated with better diet after adjustment for individual-level SES?

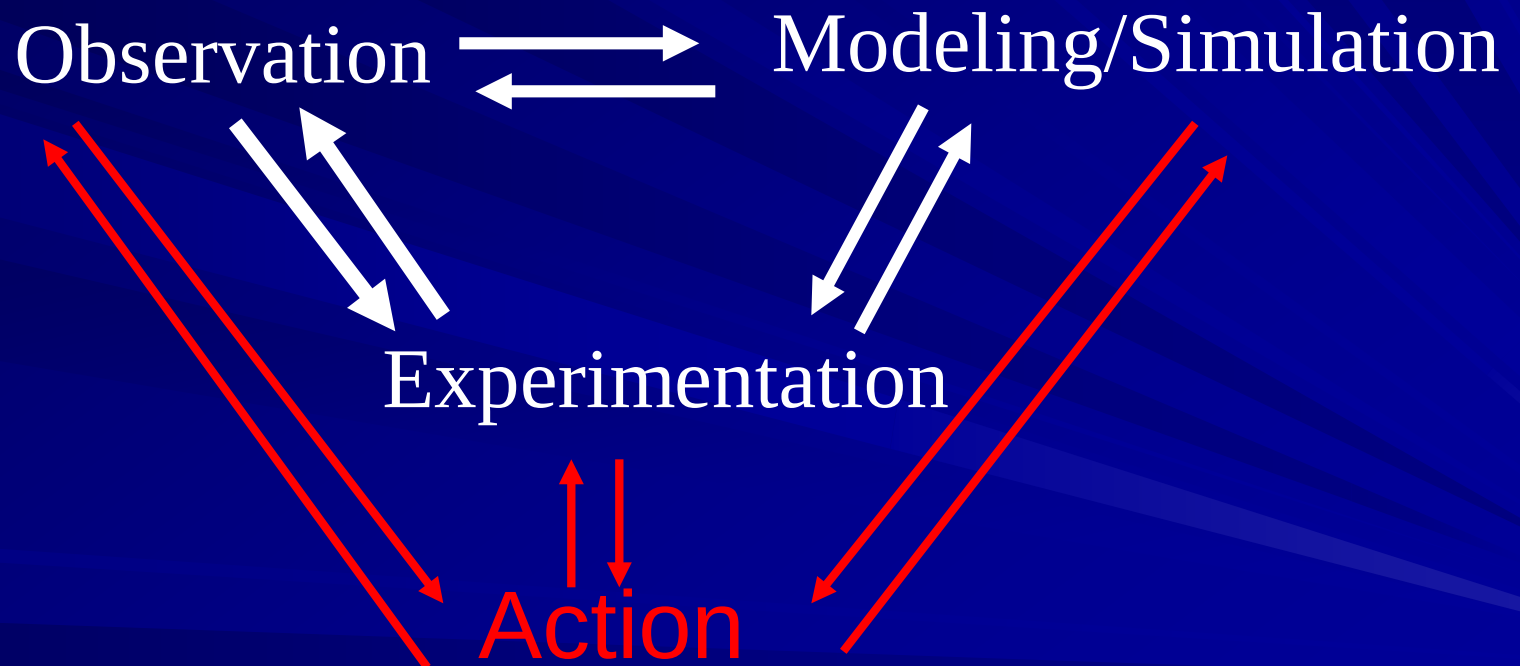
To:

What is the plausible impact on health inequalities of a strategy to subsidize the location of supermarkets under various spatial patterning scenarios?

Knowledge generation and evidence in population health



Evidence-action system



SALURBAL Aims

Aim 1

Identify city and neighborhood drivers of health and health inequalities among and within cities

Aim 2

Evaluate health, environmental and equity impact of policies and interventions

Aim 3

Employ systems-thinking and simulation models to evaluate urban-health-environment links and plausible policy impacts

Aim 4

Engage the scientific community, the public and policy makers to disseminate and translate findings

**Lessons from LA
about what
makes cities
healthier,
equitable and
environmentally
sustainable**

Participatory Systems Approach

Workshop in Lima, Peru (Nov 2017)



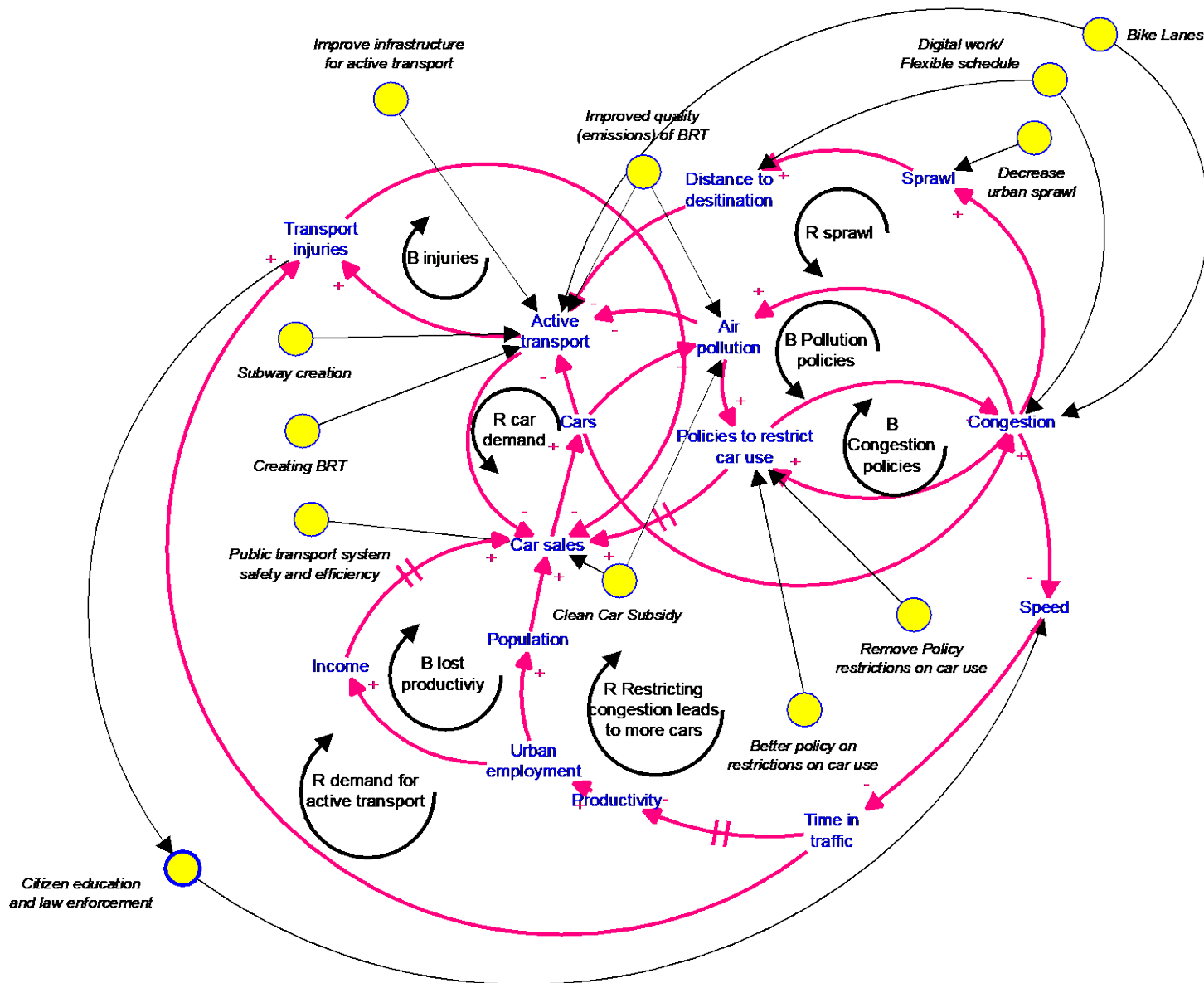
Workshop in Sao Paulo, Brasil (March 2018)



Workshop in Antigua, Guatemala (May 2018)



Group model building



Agent-Based Modeling

- Commuter behavior in a Latin American-inspired city:
 - What combinations of BRT-focused policies, car-focused regulations and taxation, and interventions to improve safety, have the greatest impact on decreasing car use and pollution while increasing active transit and overall physical activity?
- Weekly ultra-processed food (UPF) purchasing in a Latin American city:
 - How can food labeling, advertising, and taxes be most effectively combined to reduce purchasing of ultra-processed food (UPF) in Latin American cities?

“...the burden of disease on a human population is part of an environmental system and the interrelatedness of the components of the system cannot be understood by pursuing research whose rationale is to divide and isolate the components in ever greater detail.”

“ If we consider disease to be embedded in a complex network in which biologic, social, and physical factors all interact, then we are impelled to develop new models and adopt different analytic methods..”

R. Stallones, 1973

Five features of dynamic systems

- Factors at multiple levels
- Heterogeneous and interdependent units
- Recursive relationships and feedback loops
 - endogeneity
- Non linear effects → consequences at other locations and other times , unanticipated effects
- Multiple paths to the same outcome, similar distal causes of multiple different outcomes

