Composite Simulation Modeling of Complex Service Systems: Example and Research Challenges

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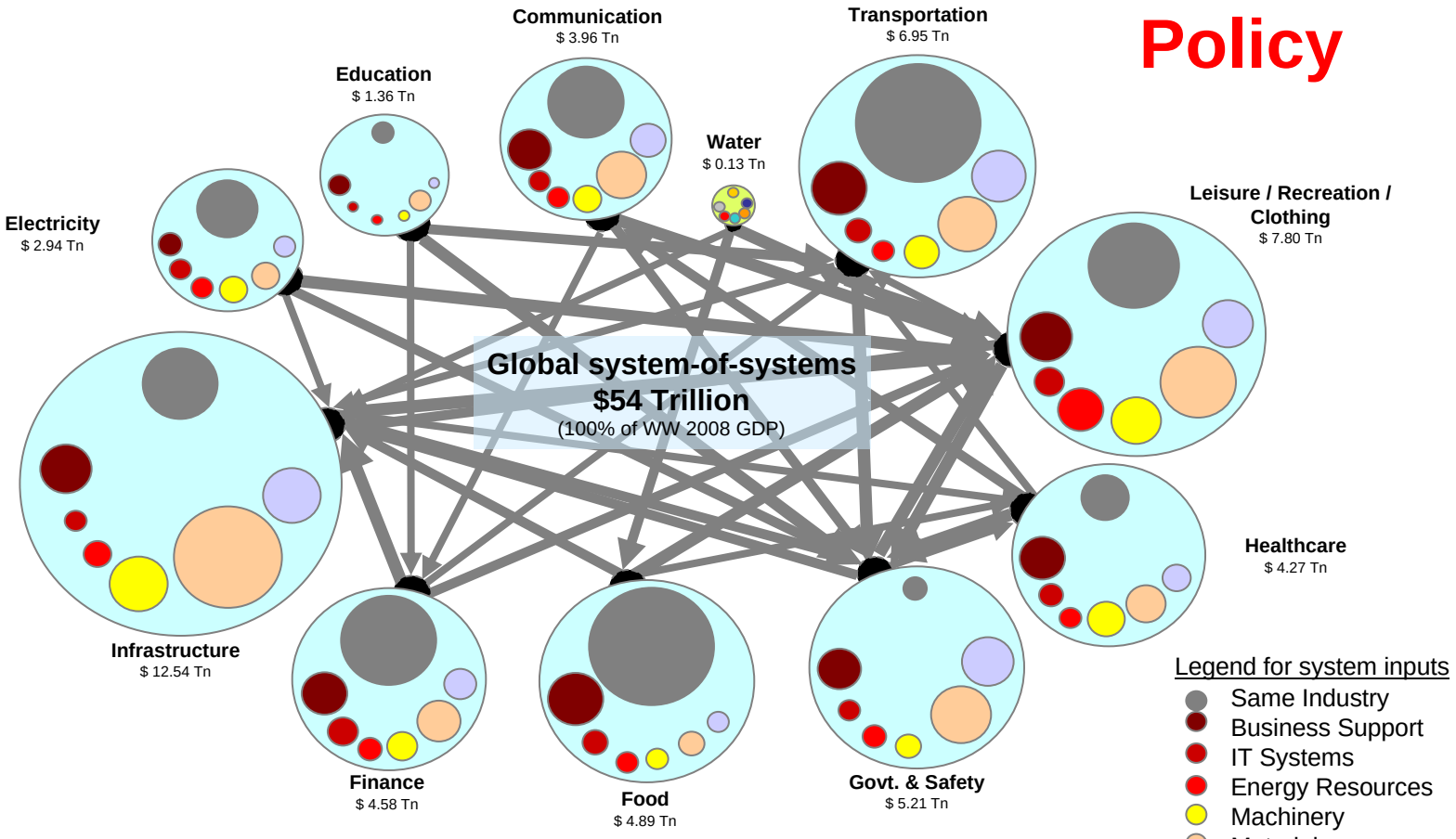
Decision-making in a complex system of systems



IBM analysis based on OECD data.

Example: Health

World Health Organization

Health is a state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity.

Example: Health

World Health Organization

Health is a state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity.

Determined by a complex system of systems

PREVENTING CHRONIC DISEASE
PUBLIC HEALTH RESEARCH, PRACTICE, AND POLICY
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EDITORIAL

A Systems-Oriented Multilevel Framework for Addressing Obesity in the 21st Century

Terry T. Huang, PhD, MPH; Adam Drewnowski, PhD; Shiriki K. Kumanyika, PhD, MPH; Thomas A. Glass, PhD

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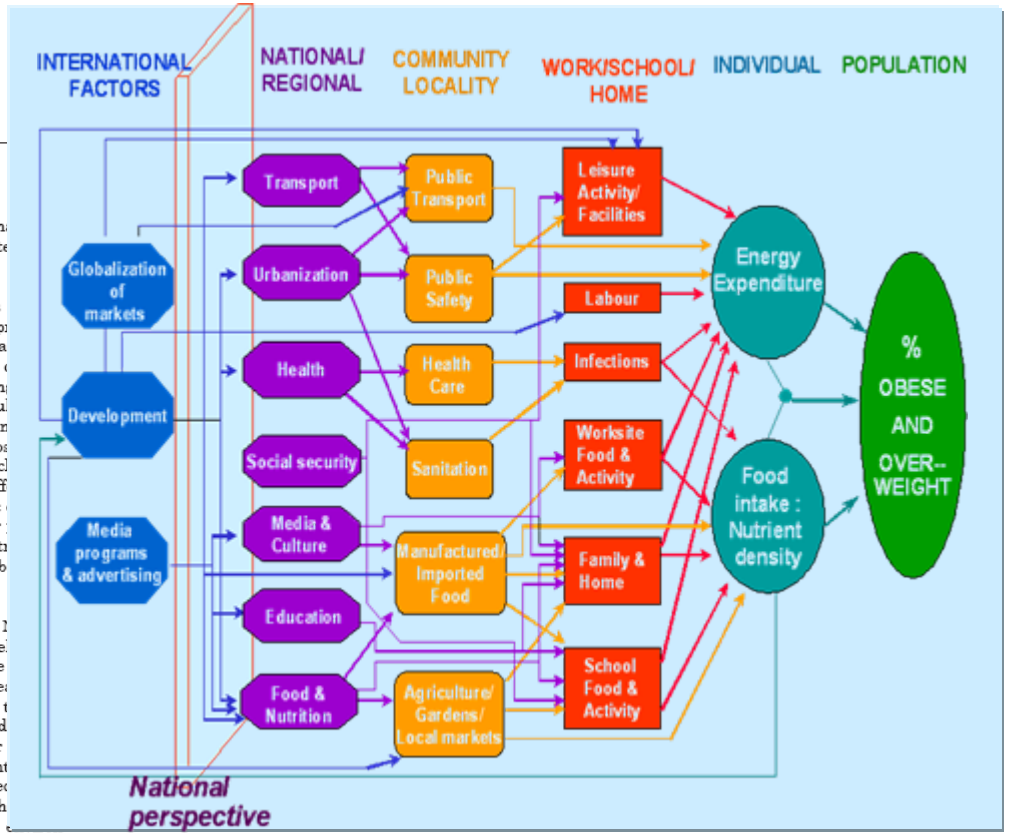
PEER REVIEWED

Effective or sustainable prevention strategies for obesity, particularly in youths, have been elusive since the recognition of obesity as a major public health issue 2 decades ago. Although many advances have been made with regard to the basic biology of adiposity and behavioral modifications at the individual level, little success has been achieved in either preventing further weight gain or maintaining weight loss on a population level (1). To a great extent, this is the result of the complex task of trying to change the way people eat, move, and live, and sustaining those changes over time.

The most immediate cause of obesity is an imbalance of energy intake and energy expenditure in the body. This energy imbalance, on the magnitude seen in today's population, arises from the complex interactions of biological susceptibilities and socioenvironmental changes (2). Evidence in behavioral economics suggests that these powerful biological and contextual forces often place eating and exercise behavior beyond an individual's rational control (3). Therefore, the solution to the obesity epidemic lies in policies and interventions that alter those contextual features, taking individual biology and preferences into account. Historically, obesity research has been conducted within individual disciplines. Now, for both scientific inquiry and for public policies, obesity should be framed as a complex system in which behavior is affected by multiple individual-level factors and socioenvironmental factors (ie, factors related to the food, physical, cultural, or economic environment that enable or constrain human beh
both). These factors are heterogeneous and inte
dent, and they interact dynamically (4).

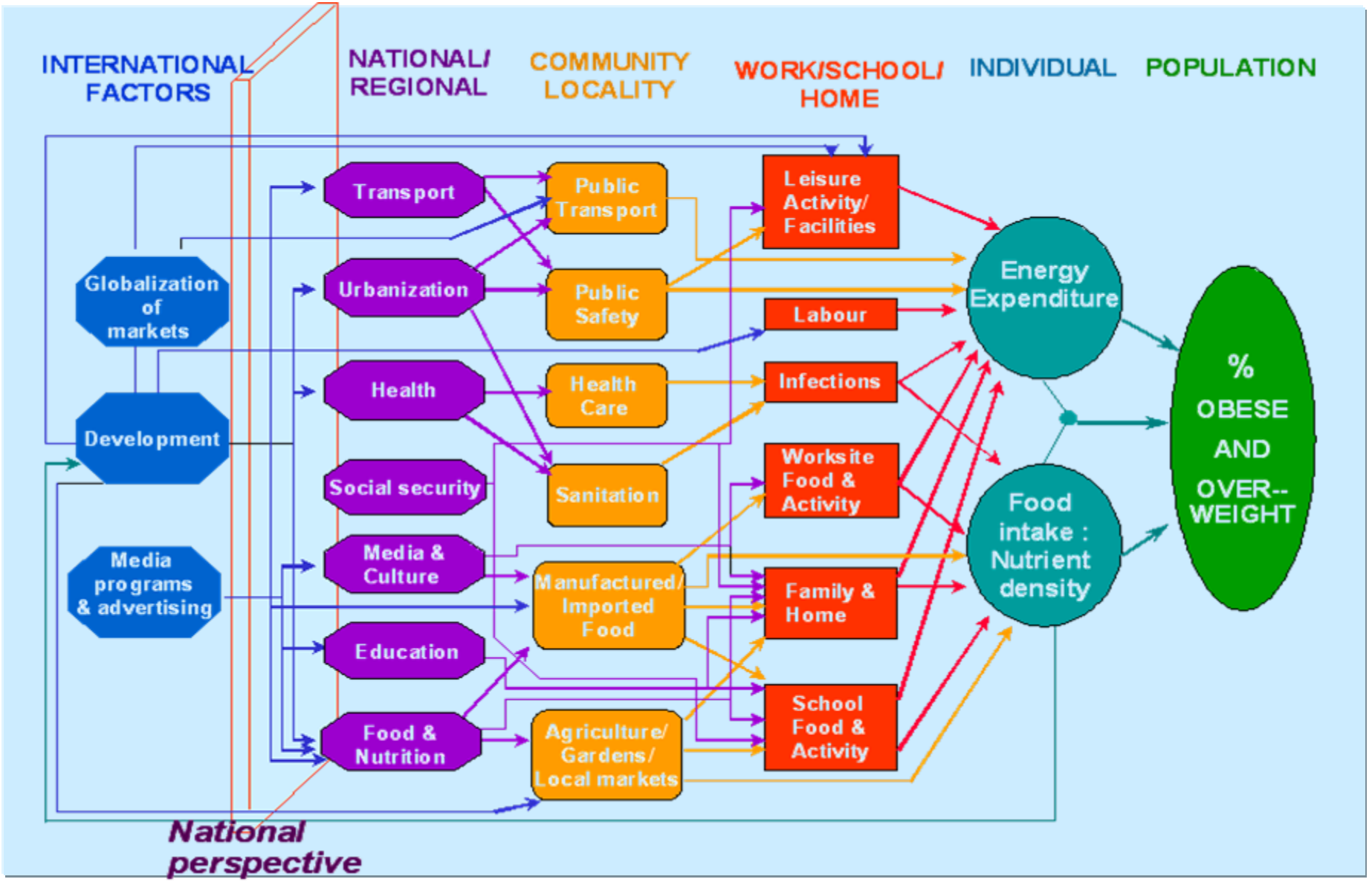
Because of the complex system that affects
researchers need to use a systems-oriented appr
address the multiple factors and levels. Whereas
disciplinary research consists of teams with
expertise that can contribute to the understandin
ticular aspects of a larger research question, tru
disciplinary research asks a priori questions ar
hypotheses that cut across disciplines and acros
of influence. For example, how do biological mec
of energy metabolism react to or how are they aff
different features of the built, social, or economic
ment to produce a given distribution of eating or
activity? How do these conditions enable or constr
ing and physical activity, and how are they emb
biological systems to affect these behaviors?

In October 2007, the Eunice Kennedy Shriver
Institute of Child Health and Human Deve
(NICHD) convened the international conference
Individual Behavior: Multidimensional Rese
Obesity Linking Biology to Society. The goal was
a climate of training, funding, and academic and
tional support for obesity research that will offer
able solutions to the obesity problem. Participant
to bridge the factors that influence obesity-relate
iors at the macro level (typically policies that sh
govern the food, physical, social, and economic
ments in which we live) and the micro level (typically vari-
ables within people or their immediate surroundin
influence health outcomes). The conference was su
by the National Institutes of Health (National
Institute; National Institute of Diabetes and Di
and Kidney Diseases; National Heart, Lung, and

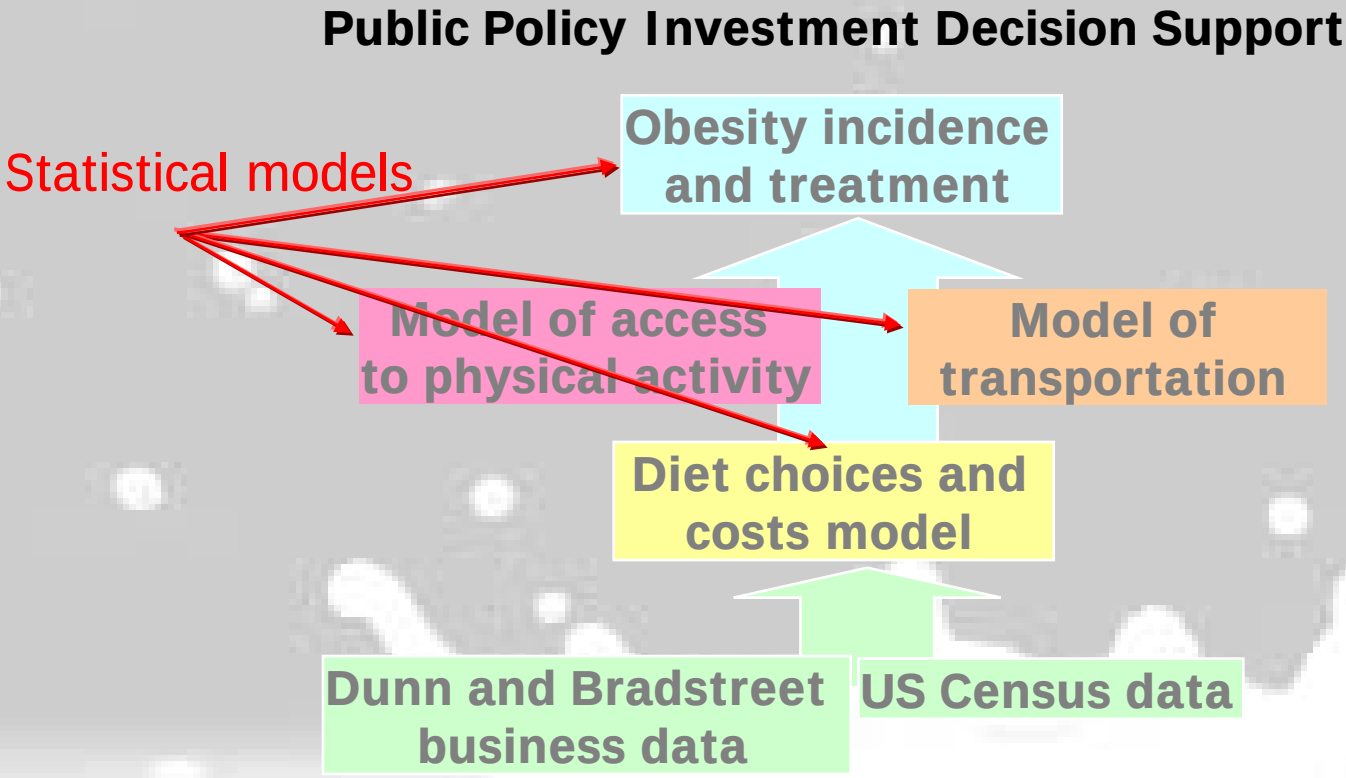


Factors can range from the **individual level** to the **international level**, and the sectors of influence include **education**, **agriculture**, **transportation**, **urban developments**, and **media**, among others, in addition to the health sector.

Huang, T. T, Drewnowski, A., Kumanyika, S. K., & Glass, T. A., 2009, "A Systems-Oriented Multilevel Framework for Addressing Obesity in the 21st Century," Preventing Chronic Disease, 6(3).

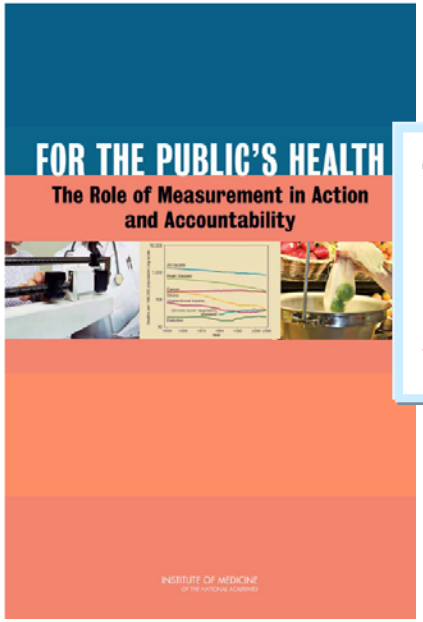


State of the art in health system model composition



Insight: Nearby location of large chain grocery stores reduced obesity rates
Tax incentives for chain stores to move to obesity "hotspots"?

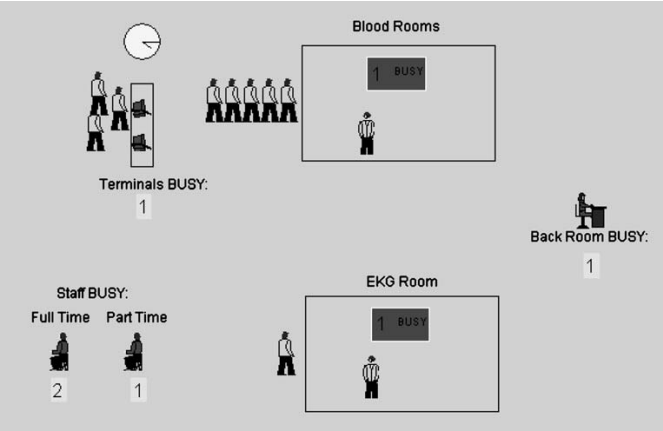
Chaloupka FJ, Powell LM. Price, availability, and youth obesity: evidence from Bridging the Gap. *Prev Chronic Dis* 2009; 6(3).



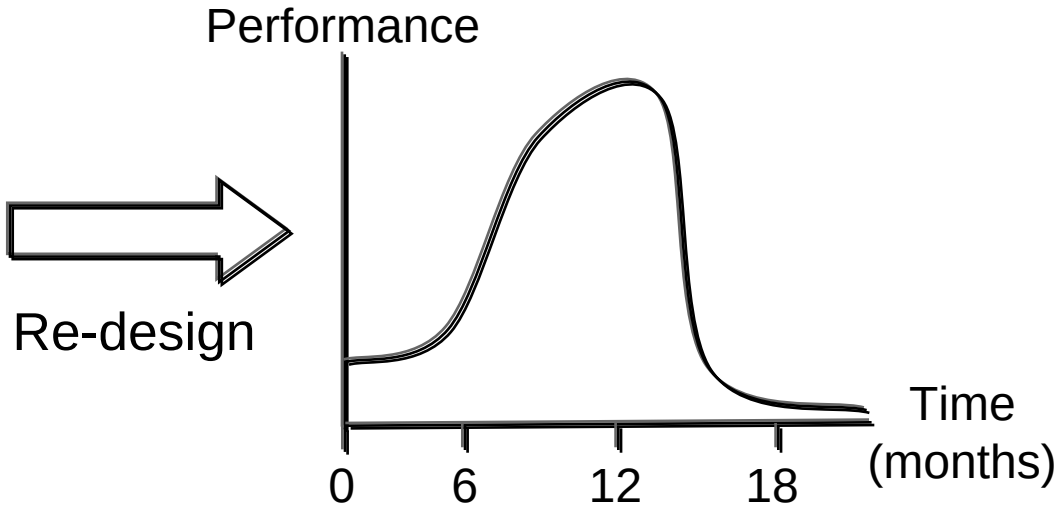
The committee recommends that the Department of Health and Human Services (HHS) coordinate the development and evaluation and advance the use of **predictive and system-based simulation models** to understand the health consequences of underlying determinants of health. HHS should also **use modeling to assess intended and unintended outcomes** associated with policy, funding, investment, and resource options.

http://www.iom.edu/Reports/2010/For-the-Publics-Health-The-Role-of-Measurement-in-Action-and-Accountability.aspx

Ex: Unintended Outcomes in Healthcare

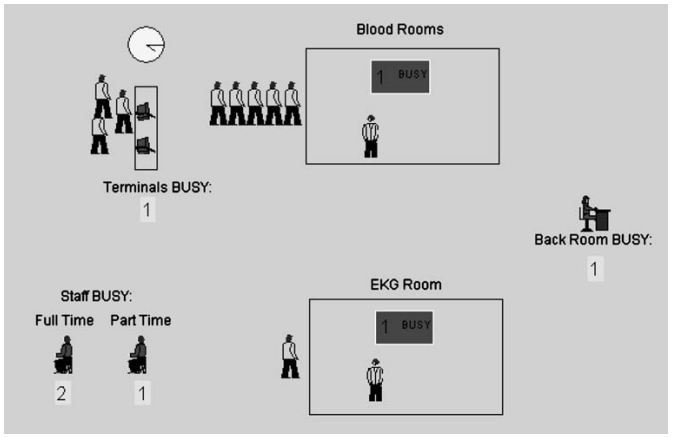


DES model of
Calgary Lab Services



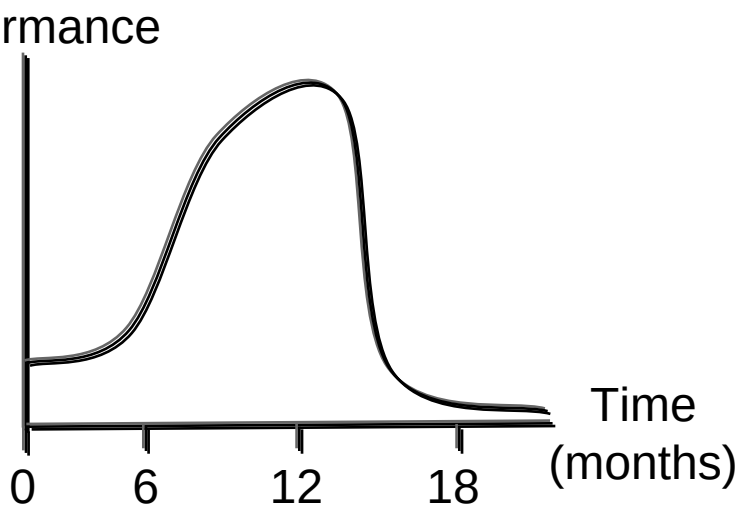
T. R. Rohleder & D. P. Bischak & L. B. Baskin (2007). Modeling patient service centers with simulation and system dynamics. Health Care Manage. Sci., 10:1–12.

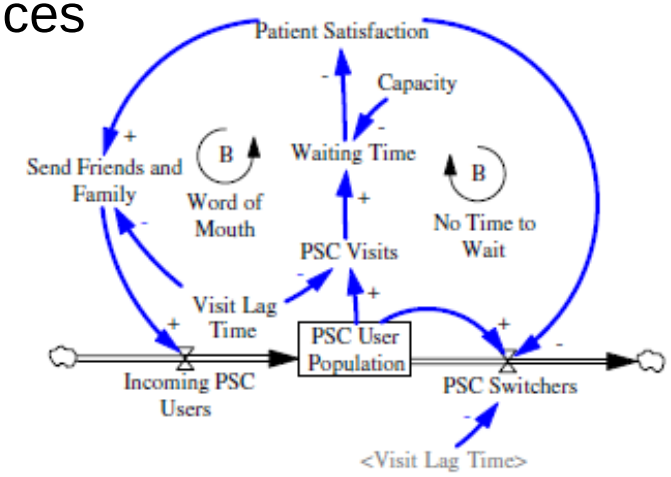
Ex: Unintended Outcomes in Healthcare



DES model of
Calgary Lab Services

Re-design





SD social model of center use

T. R. Rohleder & D. P. Bischak & L. B. Baskin (2007). Modeling patient service centers with simulation and system dynamics. Health Care Manage. Sci., 10:1–12.

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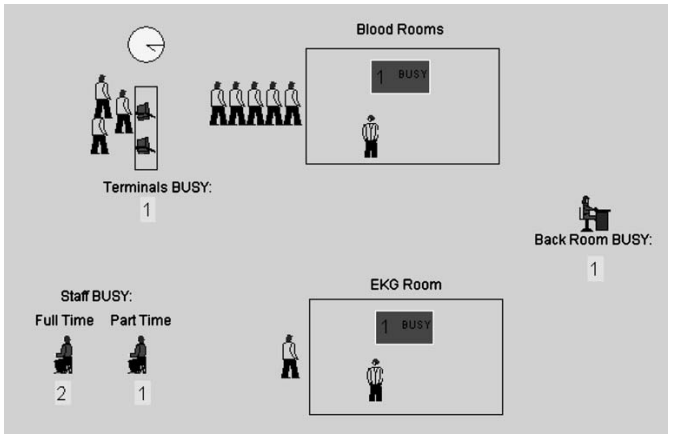

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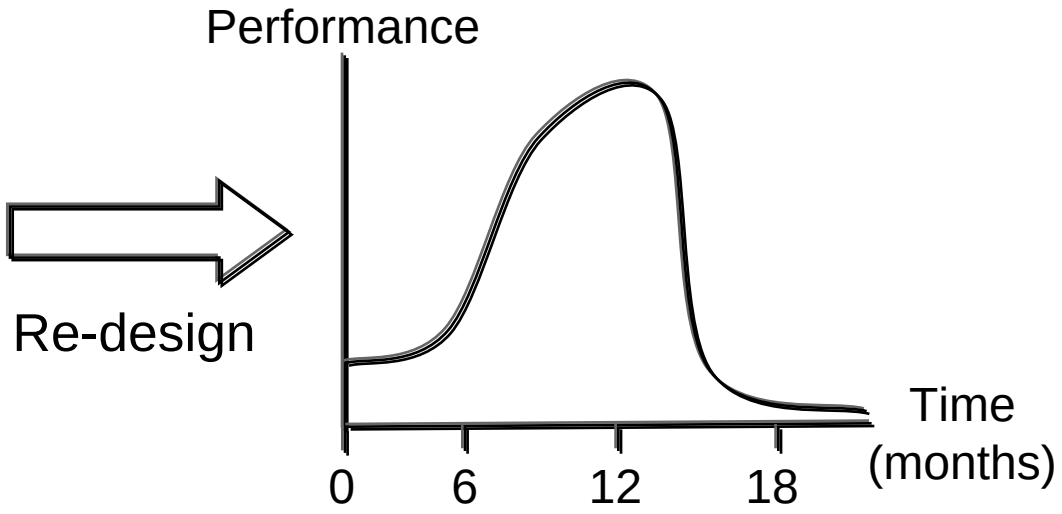
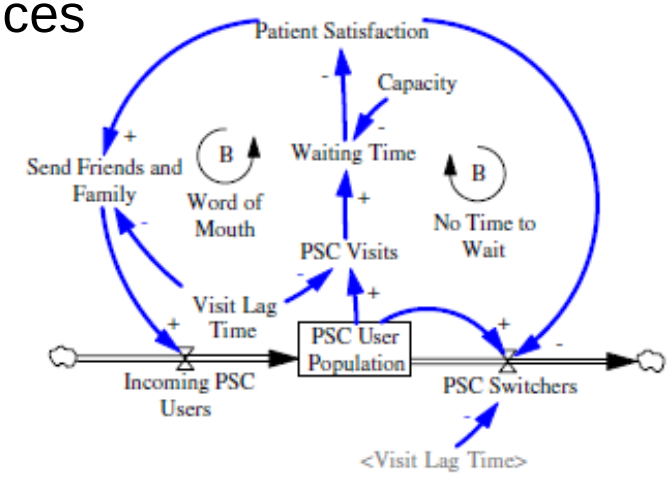


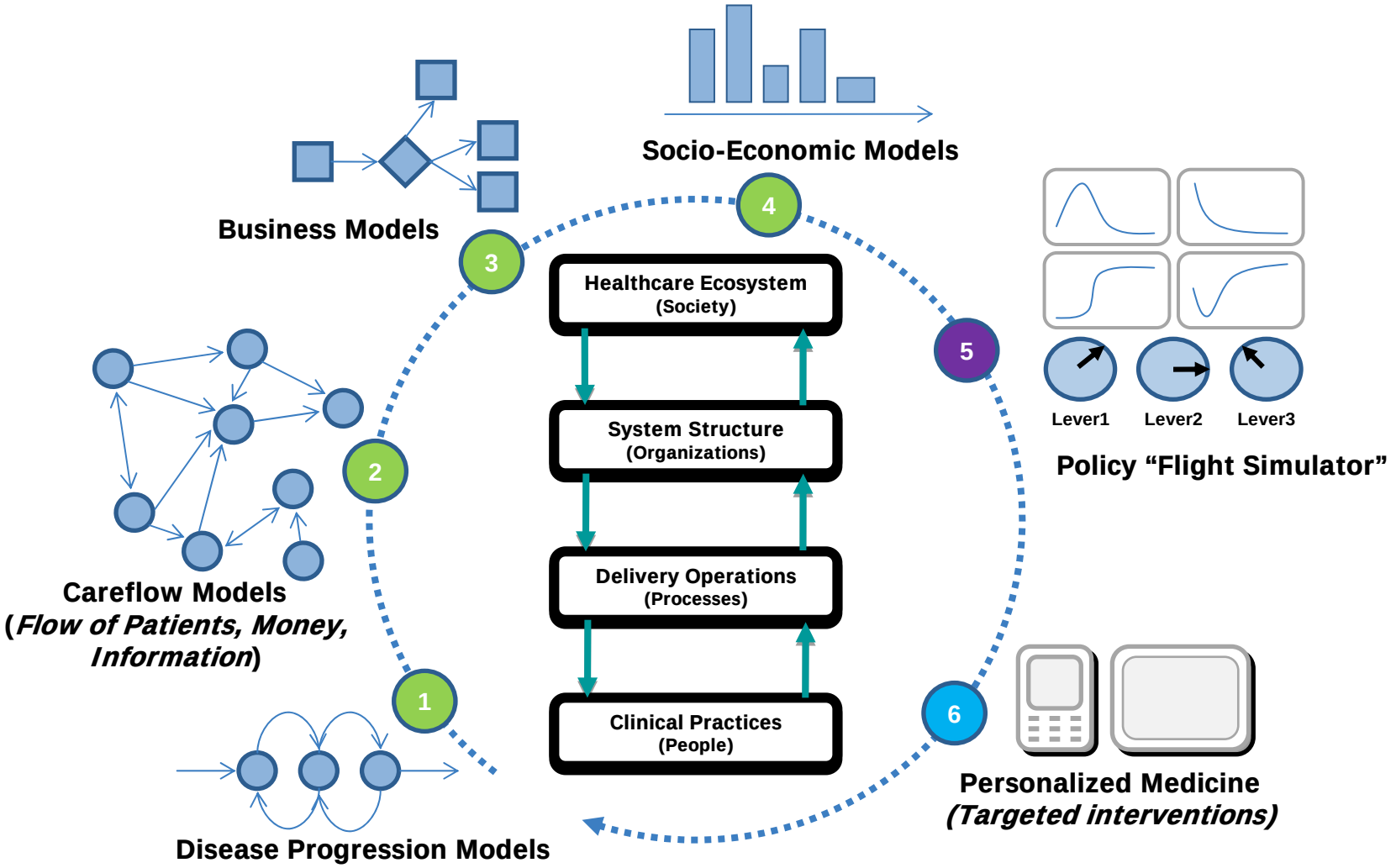


SD social model of center use

Other examples:
- Corn subsidies
- Rural health clinics
- Gaming state health insurance

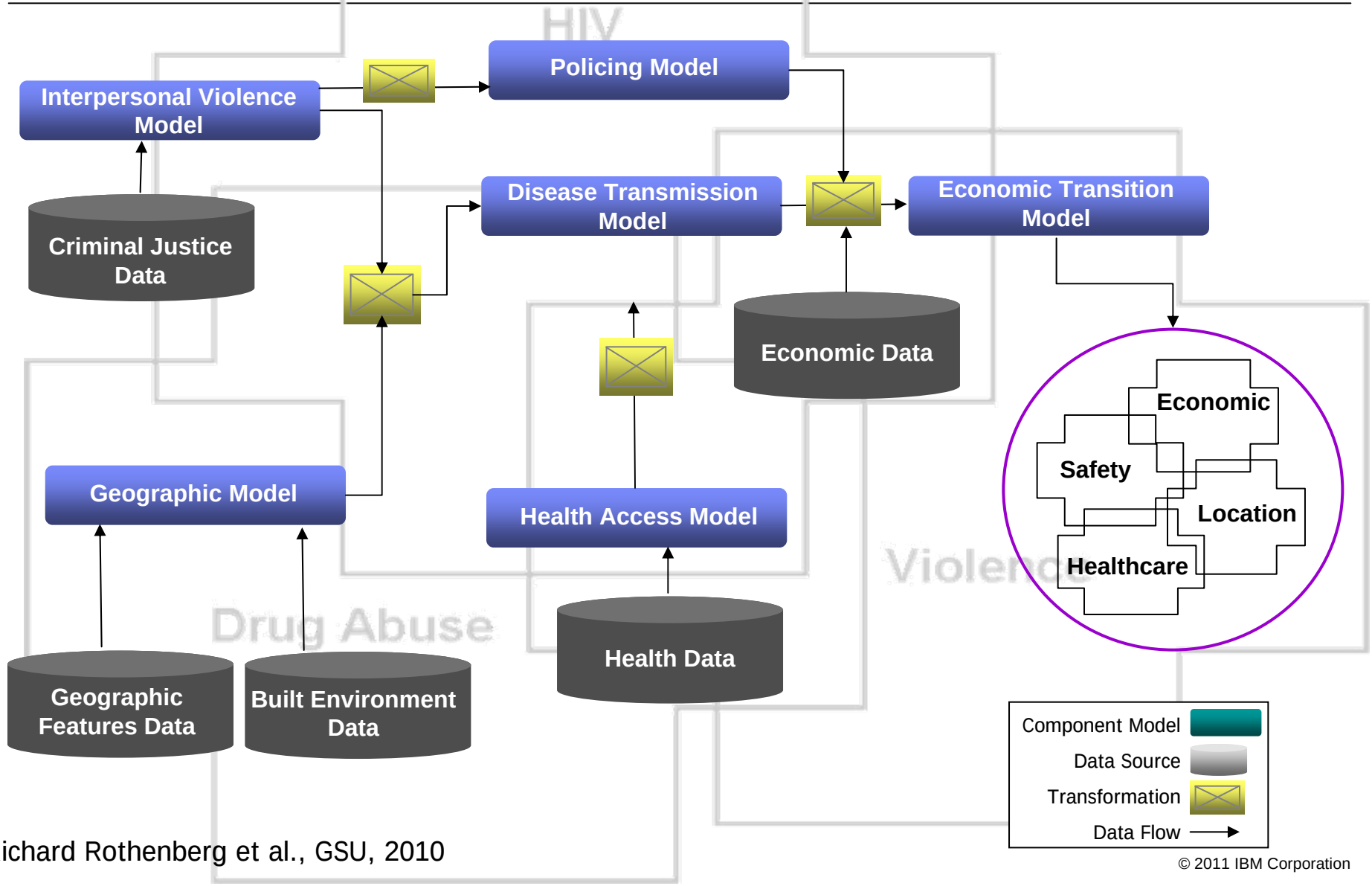
T. R. Rohleder & D. P. Bischak & L. B. Baskin (2007). Modeling patient service centers with simulation and system dynamics. Health Care Manage. Sci., 10:1–12.

Multi-level, End-to-End Modeling



Rouse, W. B. & Cortese, D. A. (2010). Introduction, in W. B. Rouse & D. A. Cortese (Eds.), *Engineering the System of Healthcare Delivery*. IOS Press.

Cross-domain, Syndemic Modeling



Richard Rothenberg et al., GSU, 2010

Splash: Smarter Planet Platform for Analysis and Simulation of Health

IBM Research

www.almaden.ibm.com/asr/projects/splash

Splash Vision

A platform and service through which IBM and partners can integrate existing data, models, and simulations to gain insight needed for complex decision making related to health policy, planning, and investment.

Key Research Question

Can such integration of independently created deep-domain models be made feasible, practical, flexible, cost-effective, attractive, and usable?

The landscape of model combination

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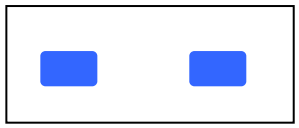
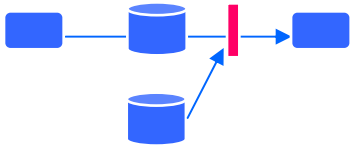


Integrated models (STEM, …)

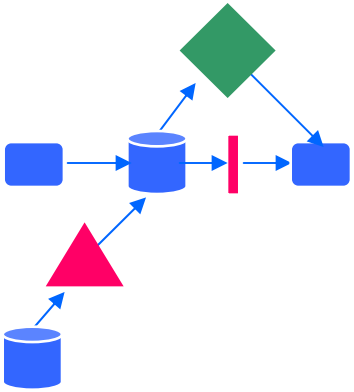
Tightly coupled models (DOD HLA, …)

Tightly coupled models + transformations



Loose coupling of models through data exchange

- File and database I/O, web service calls
- Leverage existing work
- Facilitate collaboration



Simulation model

Statistical model

Decision/optimization model

Dataset

Transformer

Splash Platform (Vision)

Multi-disciplinary users

Provide models and data

Use models and data

Model and Data Registration

Model, Data, and Mapping Discovery

Model and Data Composition

Experiment Manager

Model Execution

Collaborative Reporting & Visualization

Splash Modules

Splash Repository

Splash Platform

Metadata on:
- Model inputs/outputs
- Schemas
- Location
- Access/execution
- Semantics

Model

Data

Composite Model

Model

Data

Mapping

Technologies to exploit in Splash

Data integration
(mapping tools, XSLT, ...)

Functionality descriptions
(WSDL, UML/MARTE,...)

Simulation interoperability
(HLA, SISO-BOM...)

Ontologies (OWL,...)

Web-service mashups
(IBM Mashup Center,...)

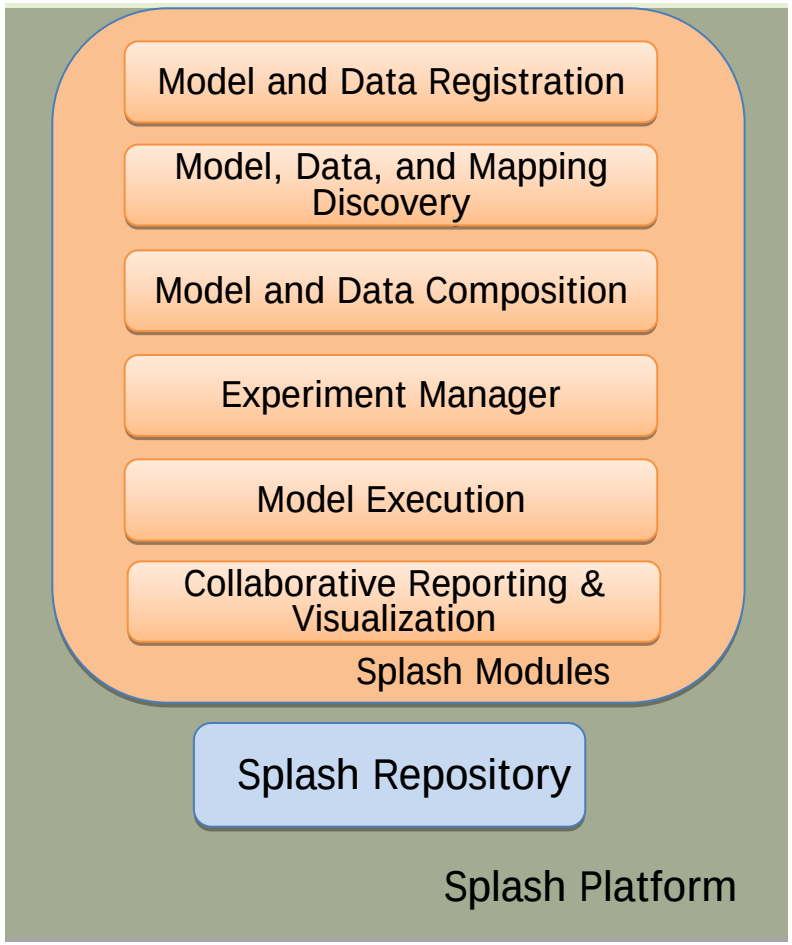
Massive-scale analytics
(Hadoop, JAQL,...)

Collaborative analytics
(ManyEyes,...)

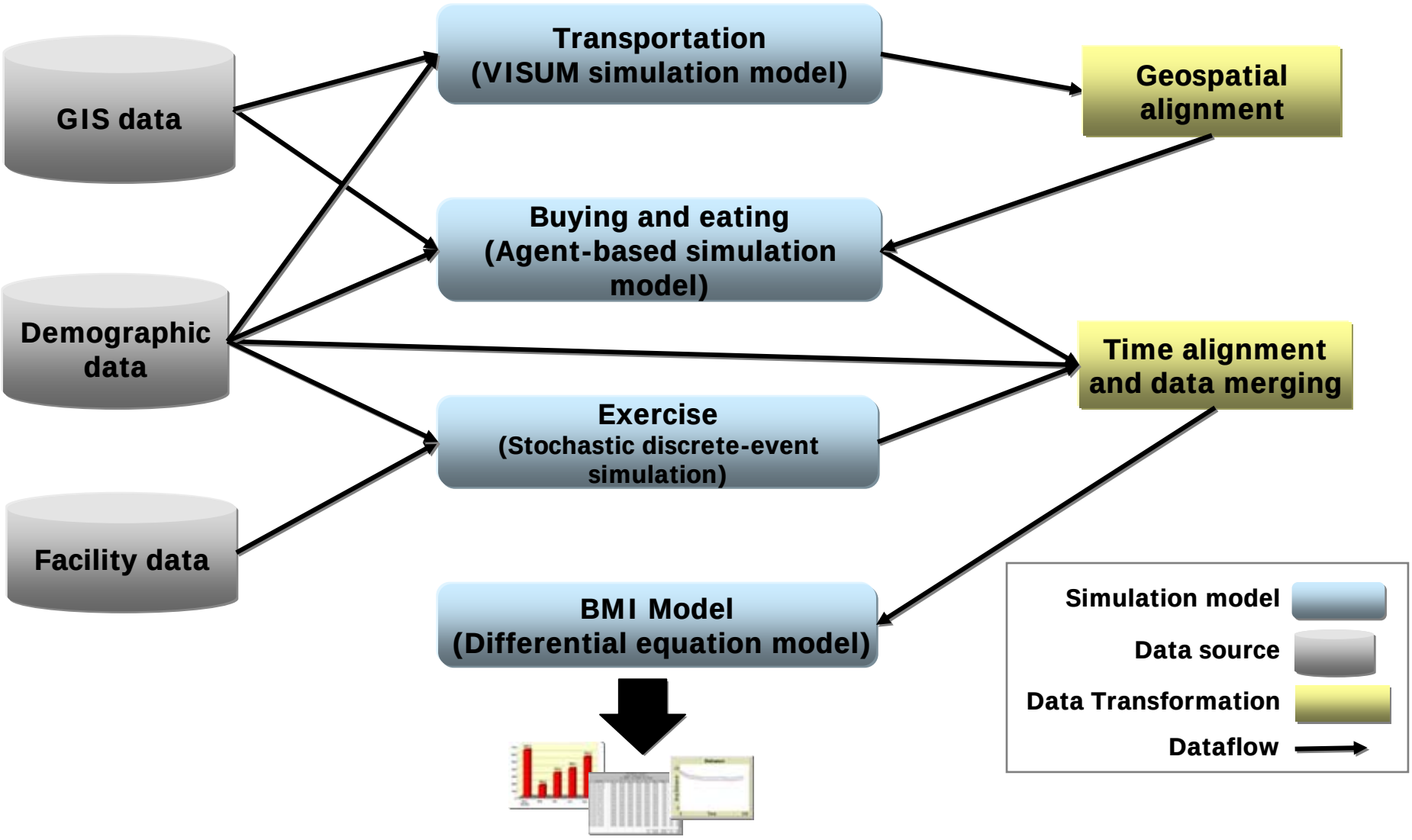
Scientific workflow mgmt

Query optimization

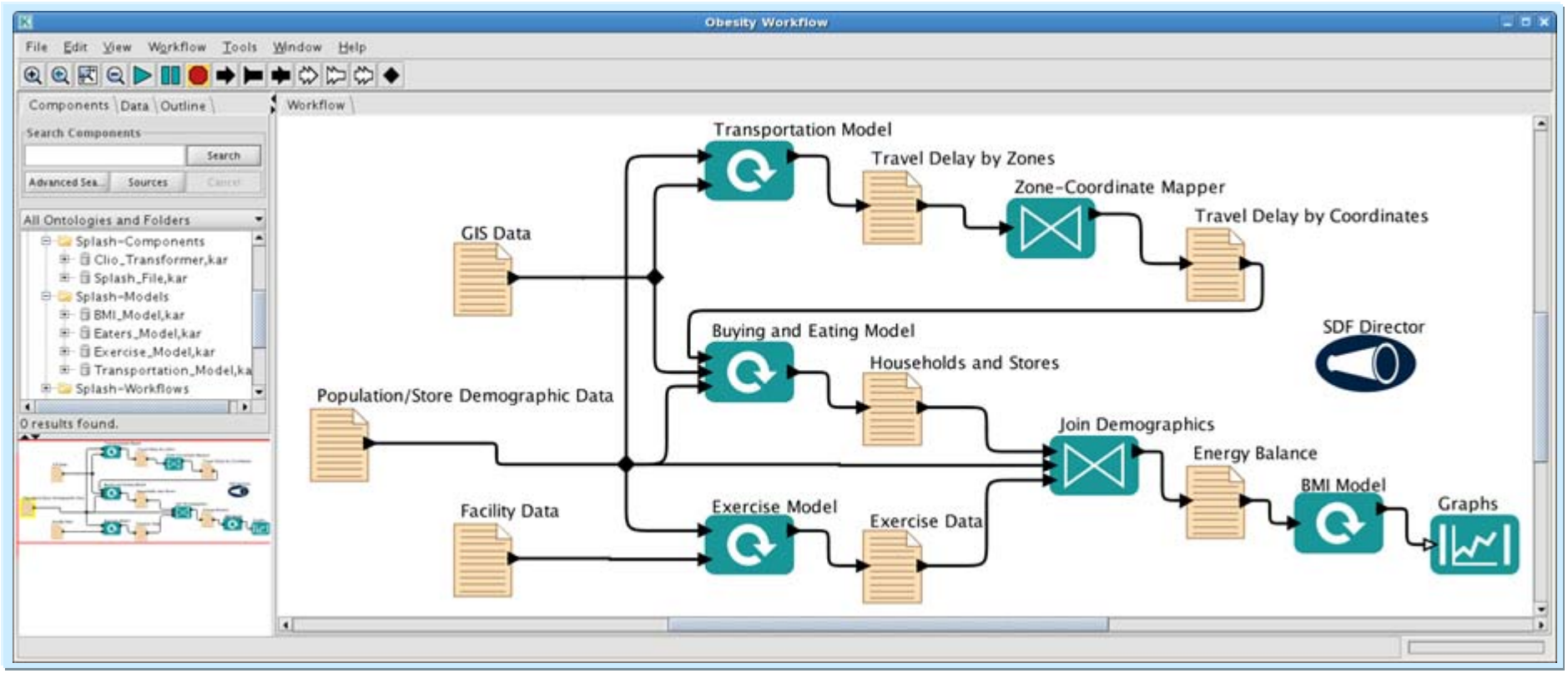
Simulation-based
sensitivity analysis and
optimization



Hypothetical obesity scenario

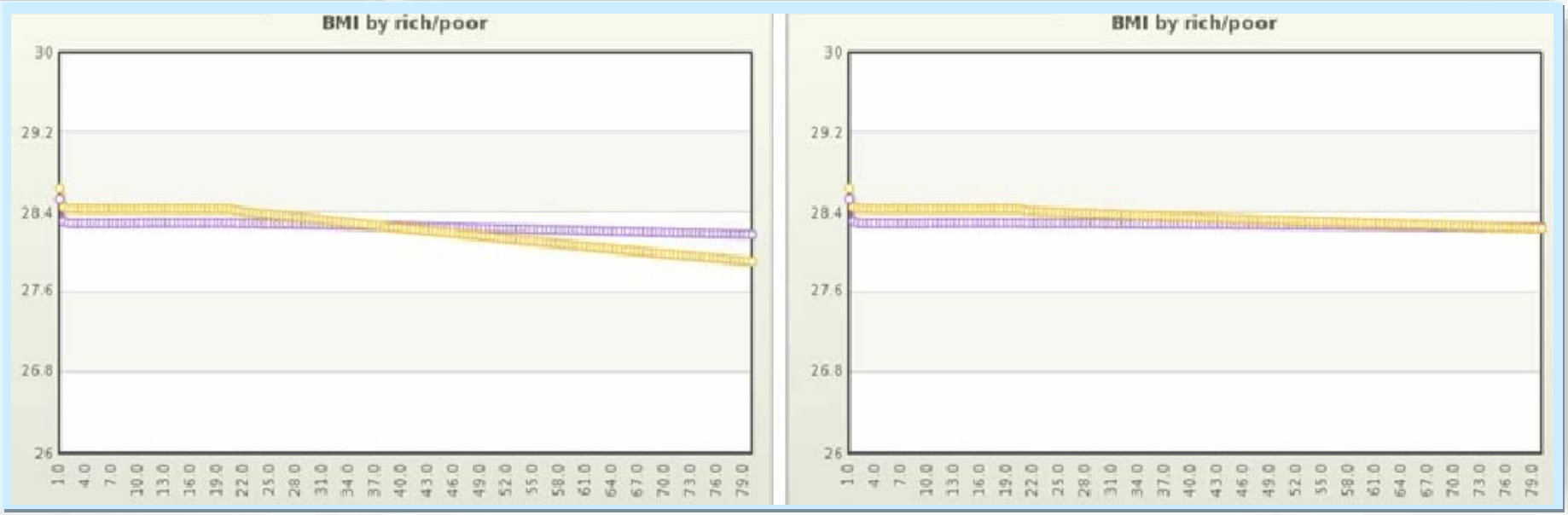


Splash Demo



Sample result

New Healthy and Inexpensive Store located in Poorer neighborhood at time 20



No increase in traffic

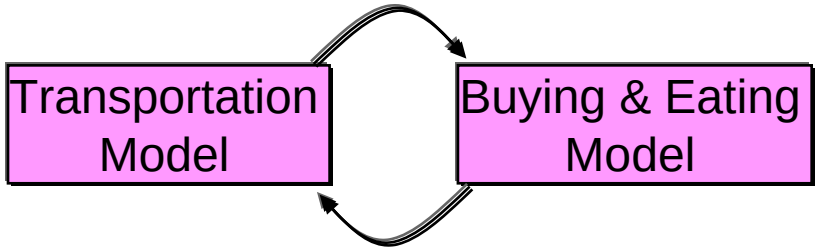
Increase in traffic

* Many assumptions, sample only, your mileage may vary...

Simulation Issues

- “Grey box” environment
- Engineering and statistical issues abound
- Examples follow...

Simulation Issues: Bidirectional Causality



- Possible approaches:
  - Fixed point

$$\dot{f}_n(t) = \Lambda_1\left(f_n(t), g_{n-1}(t)\right)$$

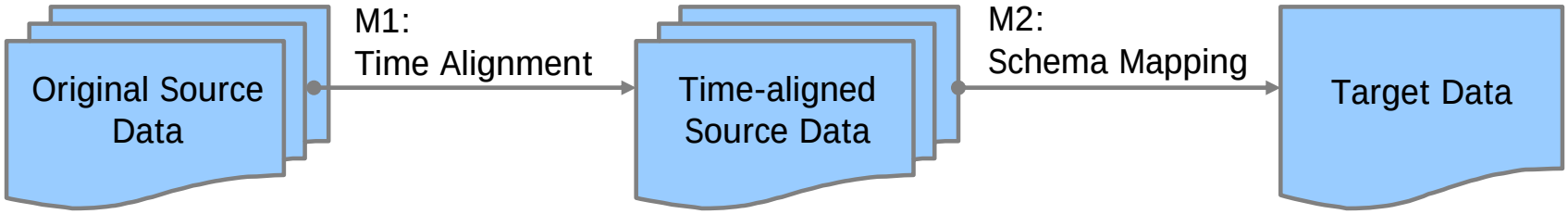
$$\dot{g}_n(t) = \Lambda_2\left(f_{n-1}(t), g_n(t)\right)$$

  - Perturbation:

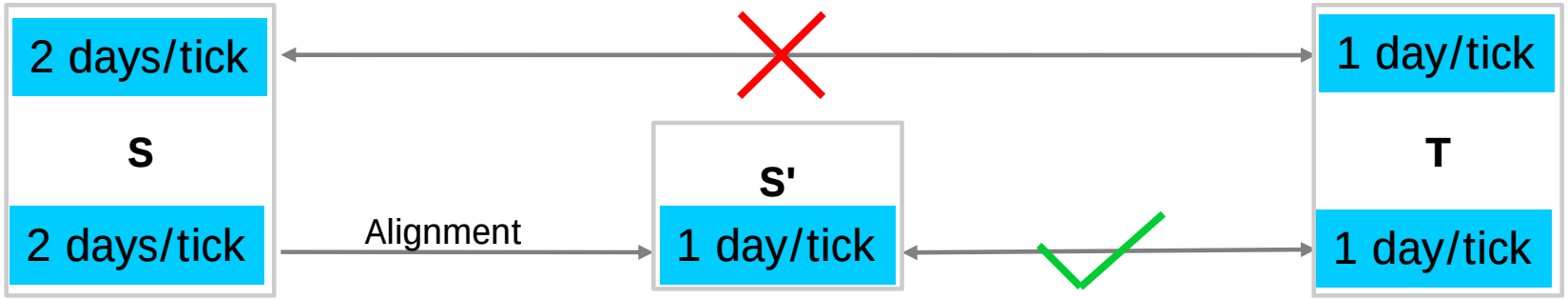
$$\left.\begin{aligned}\dot{f}(t) &= \Lambda_1\left(f(t), g(n\Delta t)\right)\\ \dot{g}(t) &= \Lambda_2\left(f(n\Delta t), g(t)\right)\end{aligned}\right\} \text{ for } t \in \left[n\Delta t, (n+1)\Delta t\right)$$

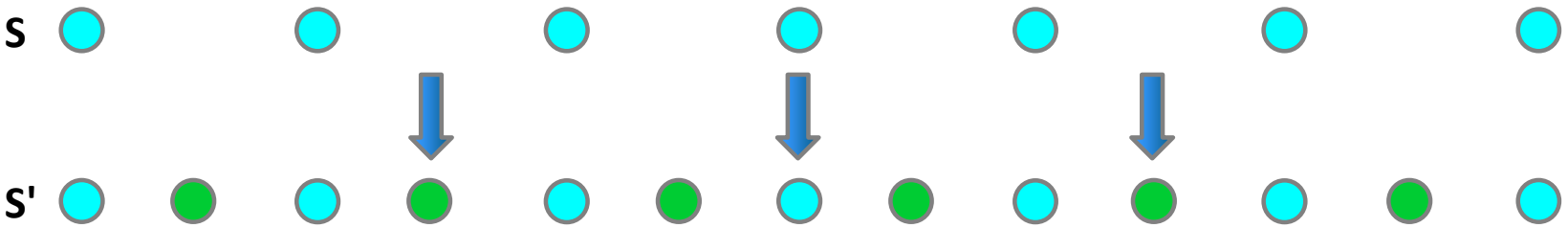
    Similarly for GSMPs (Whitt 1980, perturbation analysis)
  - Else “reasoned” decoupling or fully integrated model

Simulation Issues: Time and Space Alignment



Why Time Alignment?





Simulation Issues: Efficient Sample Path Construction

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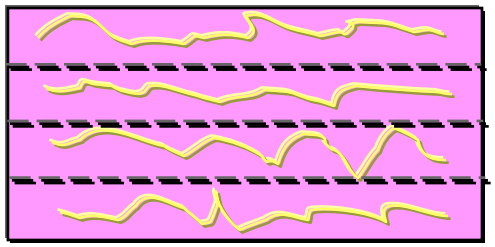

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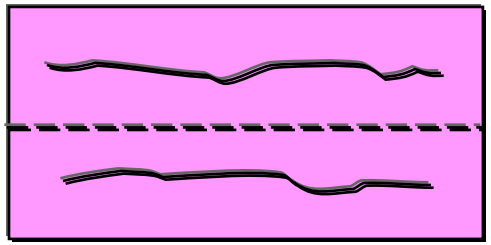
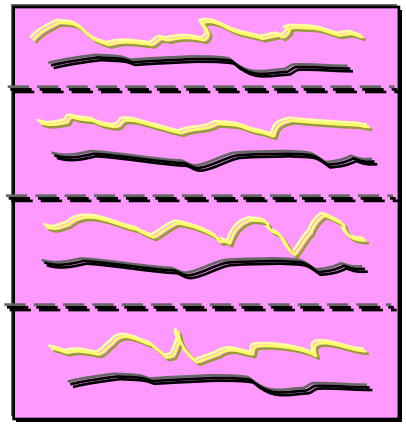
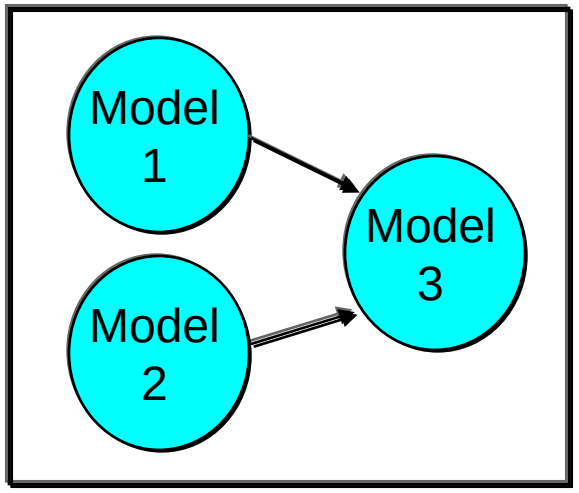


Model 1
(high variability)

Model 2
(low variability)

=





Optimal ratio for simple cases: “splitting”
(Bratley, Fox, and Schrage 1987)

Simulation Issues: Experiment Management

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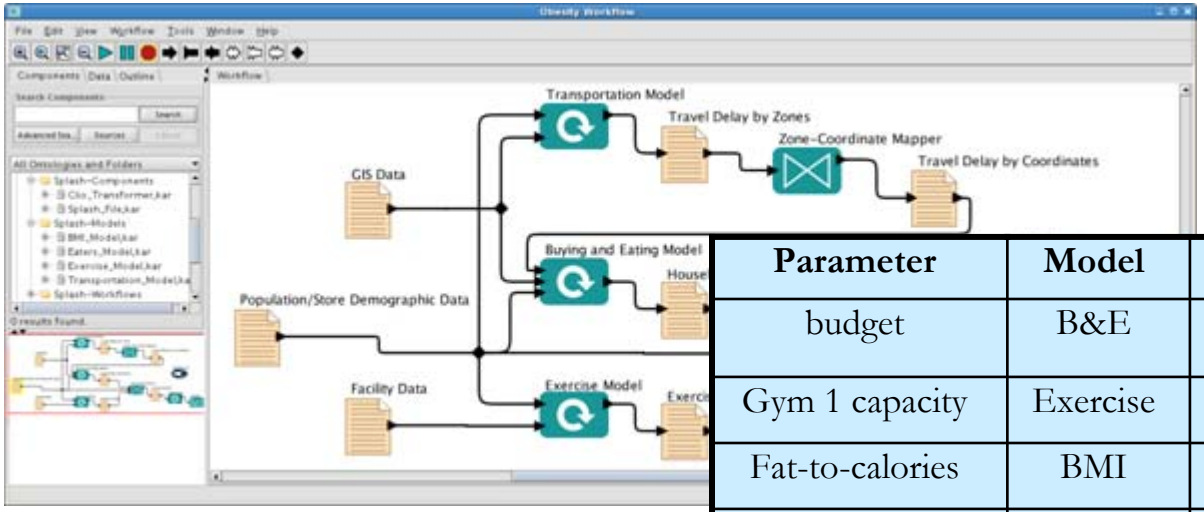
- Needed for
  - Sensitivity analysis
  - Experimental design
  - Simulation optimization
- Dashboarding mechanism?
- Experiment data storage, analysis, and visualization
  - Root cause analysis and other “explanation” of outputs
  - Monitoring for “unusual” outputs

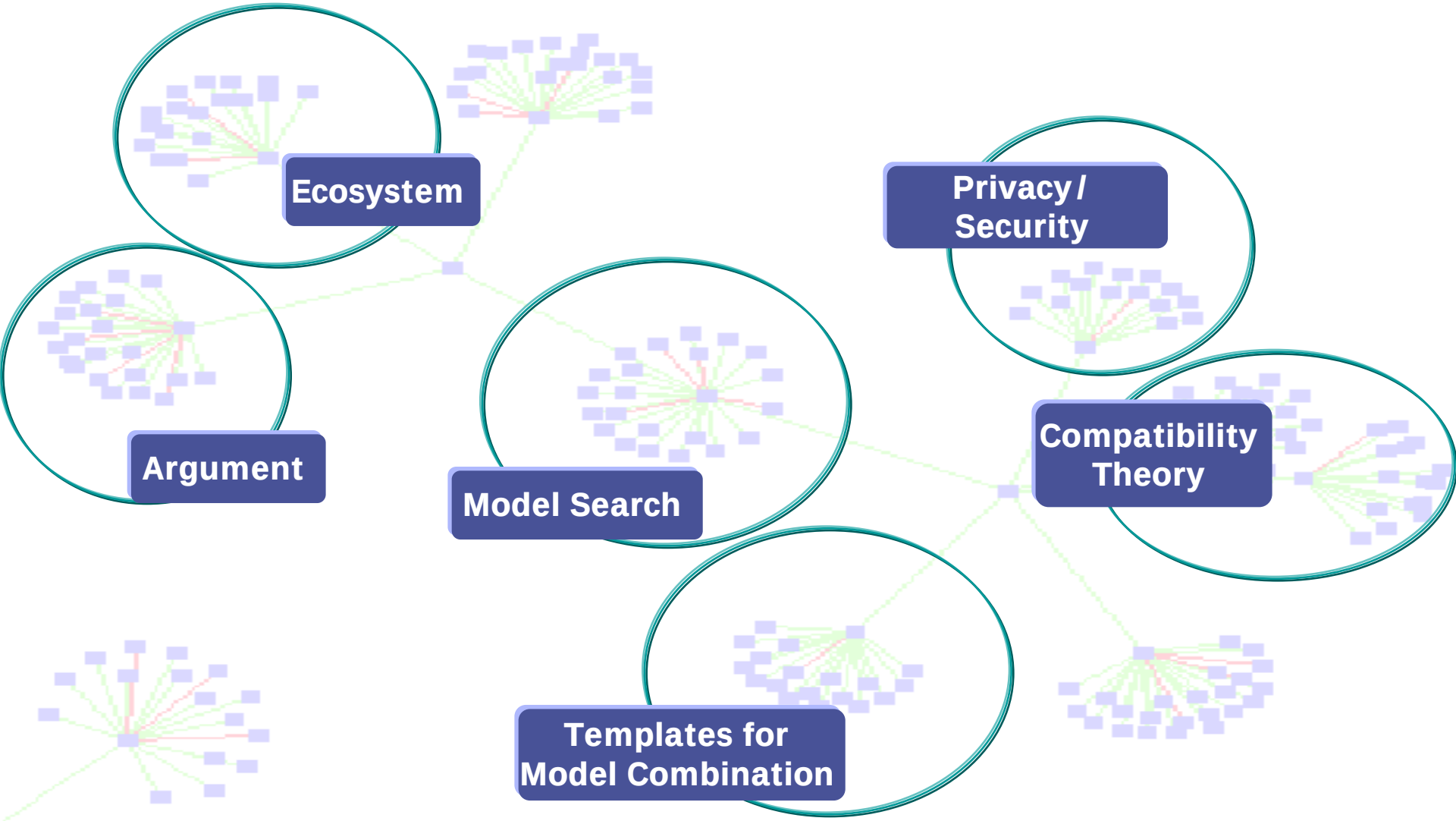


Parameter	Model	Value	Units
budget	B&E	200	dollars
Gym 1 capacity	Exercise	50	people
Fat-to-calories	BMI	0.25	kCal/kg
Hwy 280 max flow	Transport.	500	Cars/hr

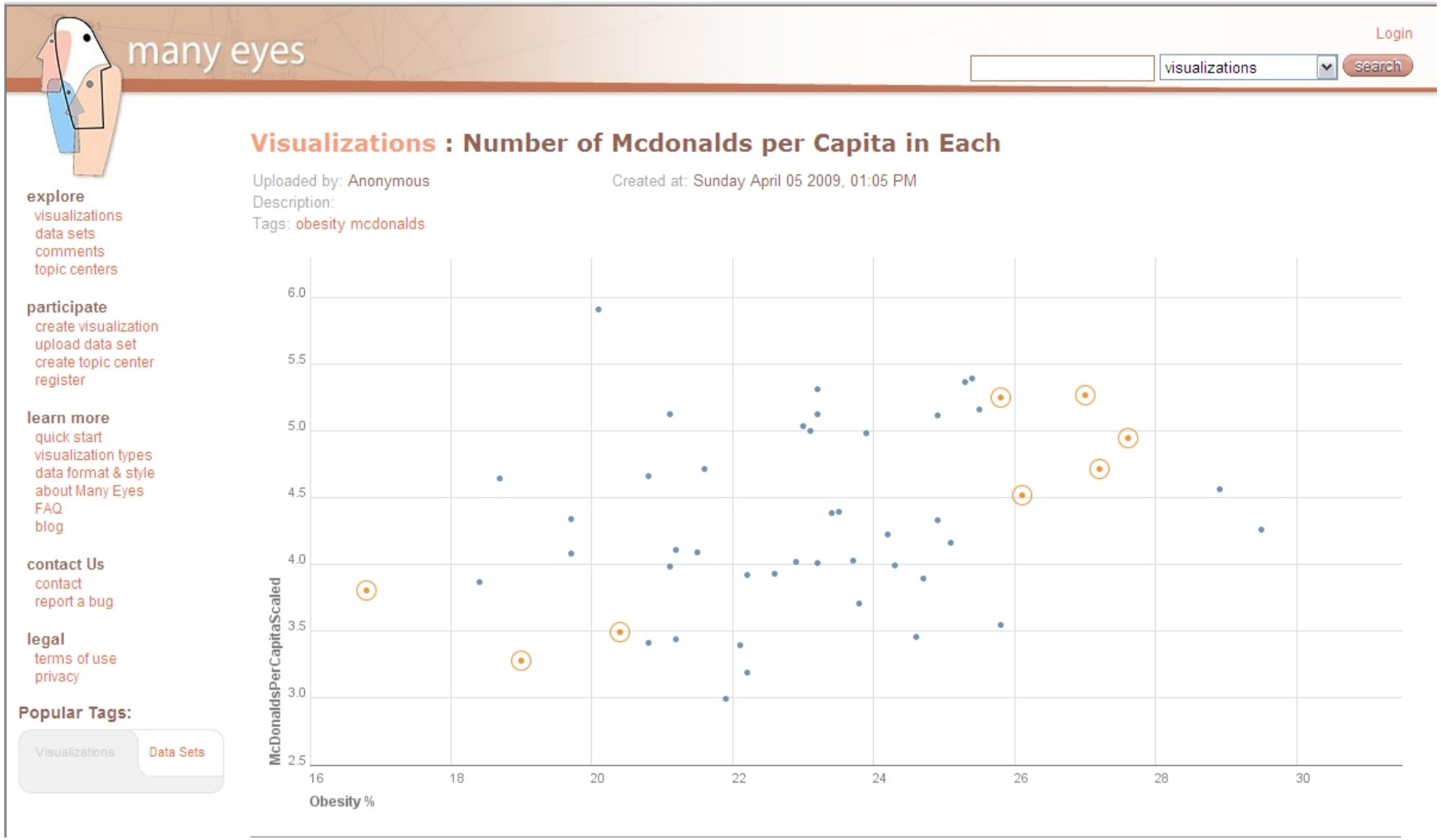
Other Simulation Issues

- **Input distributions**
  - Correlations between inputs to different models?
- **Pseudo-random number issues**
  - Tracking generators and seeds
  - Detecting problems and enforcing independence
- **Variance reduction**
  - Too many likelihood ratios for importance sampling?
  - Distributed importance splitting
  - Distributed common random numbers? Latin hypercube sampling?
- **Validation/Verification**
  - Leveraging prior validation/verification of individual models
  - Determining appropriate level of validation
- **Output analysis**
  - Stability theory, validity of output-analysis methods (e.g., combining Lyapunov functions)
- **Hierarchical modeling and simulation**
  - Different time scales and spatial representations

Other Research Questions



Building trust and collaboration: Many Eyes



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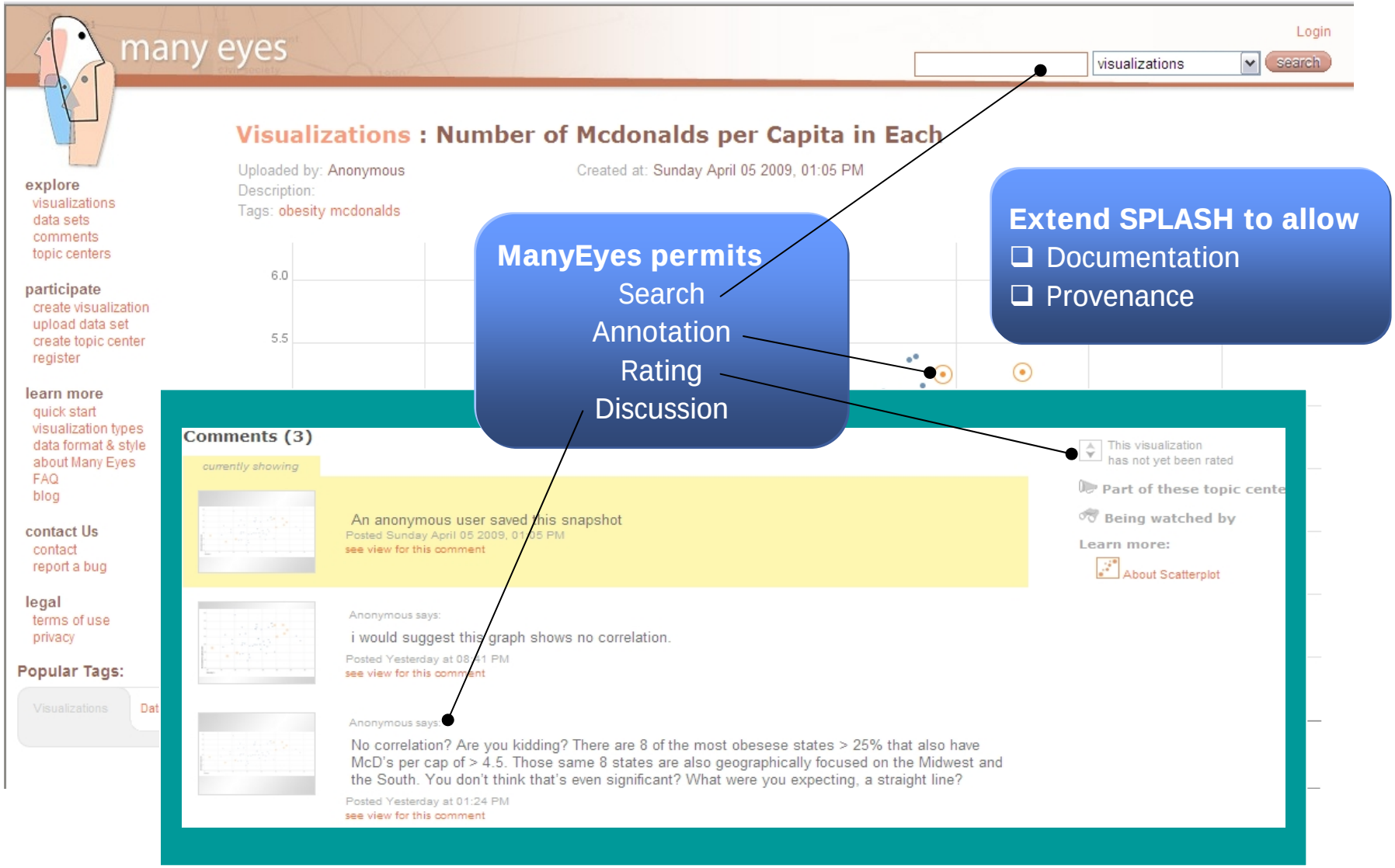

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