Participatory System Dynamics Modeling: Applications for Prevention Research

May 29, 2012
8:30 AM – 5:00 PM
Hyatt Regency Washington
Washington, DC

Background and Purpose:

Our team introduced systems science methodologies as analytic tools for addressing complex problems, like those found in prevention science, at the past two SPR conferences. All of the methods presented were well received, and System Dynamics (SD) in particular, seemed to generate a great deal of enthusiasm among audience members. This year we propose to build on our previous efforts and deliver a workshop that will provide an introduction to System Dynamics (SD) modeling for prevention science researchers in greater depth than was possible in our previous forums. Following a general introduction to SD methods, and a brief review of the historical context and of role of SD in the larger space of systems science methods, we will illustrate with in-depth case examples in public health research. Specifically, we will present an SD model examining the potential impact of one or more tobacco control policies under consideration by FDA. We will also hear from a researcher who will describe how she has used SD to inform policymakers about the potential future impact of various health policies under consideration by a state legislature. We will next introduce software used in SD model building (Powersim), showcasing all of the basic features via public health examples. In this way, we will be both demonstrating the software, while at the same time, illustrating how the SD method works with relevant case examples. Next, we will engage the audience in a participatory model building exercise involving prevention science implementation research examples, so that audience members will have an opportunity for experiential learning. We will conclude with a 45 minute interactive session in which SD experts outline steps for building and using a model for problems selected by the audience. This final session is intended to help participants understand how they can implement an SD approach to address prevention science research questions and also gain an appreciation for the types of problems this tool is best suited for as well as its limits (i.e., in situations where a problem nominated might not be well suited for the SD method, an explanation for why would be provided). Each session will include facilitated, interactive discussion among session participants and workshop speakers, regarding how the methods might be used in prevention science research.

Specific learning objectives:

- Understand the unique capabilities of System Dynamics (SD) modeling for prevention science and how it can complement and extend traditional methods.
- Understand what types of prevention research questions might be appropriate for SD modeling.
- Become familiar with and understand the main capabilities of System Dynamics modeling.
- Become familiar with the basic features of one prominent and powerful SD software (Powersim) as well as with what early and more developed models look like “under the hood.”
- Become familiar with participatory modeling techniques, including the rationale for their use.
- Shape, with SD experts, an outline for next steps for 2-3 prevention science research projects selected by audience members.
PRECONFERENCE WORKSHOP

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DRAFT AGENDA:

8:30-8:35
Welcoming remarks – 5 mins

Elizabeth Ginexi, Ph.D., Behavioral Research Program, Division of Cancer Control and Population Sciences, National Cancer Institute.

Dr. Ginexi will outline the planned schedule and format/logistics for the day.

8:35-8:55
What is systems science and why do we need it? - 20 mins

Patricia L. Mabry, Ph.D., Office of Behavioral and Social Sciences Research (OBSSR), National Institutes of Health.

Dr. Mabry will explain what systems science methods are and why interest and funding of such approaches is growing at NIH and will provide some funding opportunity announcement information for participants.

8:55-9:00 Q&A – 5 mins

9:00-9:30

A Basic Primer on System Dynamics (SD) Modeling - 30 mins

Kristen Hassmiller Lich, Ph.D., MHSA, Assistant Professor, Department of Health Policy and Management at the University of North Carolina at Chapel Hill

Dr. Hassmiller Lich will explain how System Dynamics (SD) modeling fits in modeling space, including strengths and limitations. The audience will be introduced to all aspects of the SD modeling process: stakeholder engagement, identification of the problem, identifying model inputs and boundaries, parameterizing the model, model validation, model output and interpretation. Core SD concepts and terminology will be taught including stocks, flows, feedback/feedforward loops, delays, and threshold phenomena (aka “tipping points”).

9:30-9:35 Q&A – 5 mins

David Mendez, Ph.D., Associate Professor, Department of Health Management and Policy at the University of Michigan School of Public Health.

Dr. Mendez will describe his use of System Dynamics modeling to characterize the public health impacts of smoking cessation policies around the country.

10:05-10:20 Q&A – 15 mins

10:20-10:35 BREAK – 15 mins

An Applied Example: Systems Thinking in the Legislative Health Policy Arena – 30 mins

Karen Minyard, Ph.D., Director, Georgia Health Policy Center at Georgia State University’s Andrew Young School of Policy Studies.

Dr. Minyard will describe the use of system dynamics models as a way to approach complex policy problems involving state and local public health programming.

11:05-11:20 Q&A – 15 mins

11:20-12:00

An Introduction to Systems Dynamics Software: Using Powersim – 40 mins

Imrana Umar, President, Powersim Solutions, Inc., Herndon, VA.

Mr. Umar will introduce the software Powersim, showcasing all of the basic features via relevant examples.

12:00-12:15 Q&A – 15 mins

12:15-1:15 BREAK – LUNCH ON YOUR OWN – 1 hour
1:15-2:45

**Participatory Dynamic Modeling Exercise** – 1 hour

Kristen Hassmiller Lich, Ph.D., University of North Carolina, Chapel Hill
Imrana Umar, Powersim Solutions, Inc.
Patricia L. Mabry, Ph.D., Office of Behavioral and Social Sciences Research (OBSSR), National Institutes of Health.

Dr. Hassmiller Lich, Mr. Umar, and Dr. Mabry will lead a group participatory modeling exercise with the workshop participants while utilizing the Powersim software in real time.

2:45-3:00 Q&A – 15 mins

3:00—3:15 BREAK

3:15-4:40

**Solicitation of Prevention Research Questions from Audience** – 1 hour 20 mins

Kristen Hassmiller Lich, Ph.D., University of North Carolina, Chapel Hill
Imrana Umar, Powersim Solutions, Inc.
Elizabeth Ginexi, Ph.D., Behavioral Research Program, Division of Cancer Control and Population Sciences, National Cancer Institute.

In a highly interactive format with the workshop participants, the Panel will discuss a set of real world prevention research questions participants nominate as potentially well-suited for addressing with SD methods. The group will select examples to “delve into” – outlining next steps and beginning to build early (rough but insight-generating) models live using Powersim. Depending on the chosen examples, the panel should have time to work through 2-4 prevention questions to illustrate how to apply systems thinking and how to use SD modeling tools to approach and frame research questions.

4:40-4:45 Concluding remarks

4:45-5:00 Complete feedback survey and adjourn

**Audio-visual requirements** – projector, microphones for speakers and audience members

**Target Audience**
This workshop will be accessible to prevention investigators with and without exposure to systems science methodologies

**Methods**
The workshop will be educational, but very interactive. There will be opportunity for open discussion and for participants to ask questions about incorporating these methods into prevention science research.

**Materials**
Participants will receive a complete set of slides.

Maximum number of attendees – 40
Meeting Chairs

Elizabeth M. Ginexi, Ph.D. (Primary contact)
Program Director
Tobacco Control Research Branch (primary appointment)
Science of Research and Technology Branch (secondary appointment)
Behavioral Research Program
Division of Cancer Control and Population Sciences
National Cancer Institute
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email: LGinexi@mail.nih.gov

Elizabeth M. Ginexi, Ph.D. is a Program Director in the Tobacco Control Research Branch, Behavioral Research Program, Division of Cancer Control and Population Sciences at the National Cancer Institute where she serves as the Project Coordinator for the State and Community Tobacco Control Policy and Media Research initiative. Dr. Ginexi is an Applied Social Psychologist with expertise in family- and community-based etiology and prevention research. From 2003-2010 she directed the Transdisciplinary Prevention Research program at the National Institute on Drug Abuse. Before that, as a Senior Study Director at Westat, Dr. Ginexi worked on community-based drug abuse treatment and prevention evaluations funded by the National Institute on Alcohol Abuse and Alcoholism and the Substance Abuse and Mental Health Services Administration. She served as Research Assistant, Postdoctoral Fellow and Research Scientist at the George Washington University Center for Family Research from 1994-2000.

Patricia L. Mabry, Ph.D.
Senior Advisor
Office of Behavioral and Social Sciences Research
Office of the Director, NIH
31 Center Drive, Building 31, Room B1-C19; MSC 2027
Bethesda, MD  20892-2027
Phone: (301) 402-1753
email: mabryp@od.nih.gov

Dr. Mabry is a Senior Advisor in the Office of Behavioral and Social Sciences Research (OBSSR) at the National Institutes of Health (NIH) where she is facilitating the emergence of a new field that integrates systems science with health-related behavioral and social science research. Dr. Mabry’s specific achievements include issuing funding opportunity announcements in systems science (e.g., PAR-11-314 (R01)/PAR-11-315 (R21), Systems Science and Health in the Behavioral and Social Sciences) and leading the development of an annual training course, the Institute on Systems Science and Health (ISSH). Dr. Mabry has authored a number of peer reviewed publications including articles in The Lancet, the American Journal of Public Health, and the American Journal of Preventive Medicine. She is a Guest Editor of the March 2010 supplement of the American Journal of Preventive Medicine entitled, Increasing Tobacco Cessation in America: A Consumer Demand Perspective and is also a Guest Editor for the 2011 Special Issue of Research in Human Development entitled, Embracing Systems Science: New Methodologies for Developmental Science.

Dr. Mabry has been recognized for her leadership in systems science and health. She was a member of the team that received the inaugural Applied Systems Thinking Prize from the Applied Systems Thinking Institute in 2008, and received an individual Merit Award from NIH in 2008 for her leadership in systems science. In 2011, she received the NIH Director’s Award for her contributions to NCCOR. Dr. Mabry runs the Behavioral and Social Sciences Research-Systems Science Listerv as a means of disseminating information to her constituency. To subscribe, please email your request to mabryp@od.nih.gov.
Kristen Hassmiller Lich, Ph.D., MHSA.
University of North Carolina at Chapel Hill
Phone: 919-966-7350
Email: hassmill@email.unc.edu

Dr. Hassmiller Lich is an Assistant Professor in the Department of Health Policy and Management at the University of North Carolina at Chapel Hill. She received her Master in Health Services Administration (MHSA, 2000) and PhD in Health Services Organization and Policy (2007) from the University of Michigan School of Public Health. Dr. Lich specializes in the application of operations research and complex systems modeling techniques to health policy and management decision making. She has worked most extensively on tobacco control, including two key modeling projects. In the first, she built a dynamic simulation model to predict and compare the benefits of various tobacco-control policies in the US. In the second, a dynamic infectious disease model was built to advance understanding of the relationship between smoking and tuberculosis, and to estimate the effects of tobacco (and tobacco control) on population-level tuberculosis outcomes such as incidence and mortality rates. Other current research projects include: using decision support models to improve systems of mental health care in North Carolina and applying System Dynamics methods to improve stroke-related strategic planning in the Veterans’ Health Administration. Dr. Lich’s research passion is to advance the way we use models (both quantitative and qualitative) to improve policy decision making, and to engage system stakeholders in the process. She has been invited to talk about the use of models to inform policy in a variety of settings, including the Centers for Disease Control and Prevention, the National Institutes of Health, and numerous meetings and workshops.

Invited Speakers

David Mendez, Ph.D.
Associate Professor
Department of Health Management and Policy at the University of Michigan School of Public Health.
Email: dmendez@umich.edu

David Mendez is an Associate Professor in the Department of Health Management and Policy at the University of Michigan School of Public Health. His research involves developing mathematical/computer models to help policy makers explore solutions to public health problems in the areas of smoking control, residential radon, and HPV vaccination. He has written several papers on the role of systems science in public health policy research, and has implemented systems science tools extensively in the area of tobacco control. He has brought this work to bear through serving on the CDC Healthy People 2020 Objectives Tobacco Use Workgroup and as a consultant with the Institute of Medicine.

Karen J. Minyard, Ph.D.
Karen Minyard, Executive Director, Georgia Health Policy Center
Associate Research Professor, Public Management and Policy
Ph.D., Georgia State University
M.S.N., Medical College of Georgia
email: kminyard@gsu.edu

Karen Minyard, Ph.D. has directed the Georgia Health Policy Center (GHPC) at Georgia State University’s Andrew Young School of Policy Studies since 2001. Minyard connects the research, policy, and programmatic work of the center across issue areas including: community and public health, end of life care, child health, health philanthropy, public and private health coverage, and the uninsured. Prior to assuming her current role, she directed the networks for rural health program at the GHPC. She has experience with the state Medicaid program, both with the design of a reformed Medicaid program and the external evaluation of the primary care case management program. She also has 13 years of experience in nursing and hospital administration.
She is an advocate for the importance of community in national, state, and local policy and the power of communities to improve health. Dr. Minyard maintains her connection with communities by working directly with local health collaboratives and serving on the boards of the National Network of Public Health Institutes, Physicians’ Innovation Network, and Communities Joined in Action.

Minyard’s research interests include: financing and evaluation of health-related social policy programs; strategic alignment of public and private health policy on all levels; the role of local health initiatives in access and health improvement; the role of targeted external facilitation and technical assistance in improving the sustainability, efficiency, and programmatic effectiveness of non-profit health collaboratives; and public health systems and financing.

Dr. Minyard frequently makes presentations and acts as a neutral convener and facilitator for groups and organizations. She often provides testimony for the state legislature and recently presented to congressional and executive agency staff on health reform and provisions related to the safety net. She is currently spearheading a team of faculty and staff at Georgia State University dedicated to translating national health care reform.

She received a bachelor’s degree in nursing from the University of Virginia, a master’s degree in nursing from the Medical College of Georgia, and a doctoral degree in business administration with a major in strategic management and minor in health care financing from Georgia State University.

Imrana A. Umar
President of Powersim Solutions, Inc.
Herndon, VA
email: umar@powersimsolutions.com

Imrana A. Umar is the President and Chief Executive Officer of Powersim Solutions, Inc., responsible for guiding the overall vision, strategy and operations of the company. Prior to co-founding Powersim Solutions, Inc., Mr. Umar worked for Powersim Corporation for 11 years, where he held various senior management positions, as well as serving on the board directors of the company from 1999 to 2001. Mr. Umar has several years of experience developing and implementing advanced simulation-based technology solutions in a wide variety of industries and application areas for major organizations in both private and public sectors around the world.


Mr. Umar has also consulted in various application areas, including Organizational Transformation and Change Management, Analysis of Investment Options, Project Evaluation and Risk Assessment, Competitive Strategy, Policy Alignment and Coordination, Scenario-based Strategic Planning, Customer Acquisition, Development and Retention, Resource Planning, Technology and Product Innovation, Human Performance Management, Assessment of risks and options relating to marketing, sales, distribution channels, employee turnover, etc.

Prior to joining Powersim Corporation in 1992, Mr. Umar worked in the banking industry. After a brief break to study Information and Computer Science, he served as a faculty member and PhD research fellow at the University of Bergen between 1994 and 1997.
Mr. Umar is currently an adjunct professor of Performance Management Systems and Business Strategy Simulation in George Mason University’s Executive Education program on Building Business Acumen and Corporate Ventures. He also teaches management courses on Strategic Visioning and Leadership Development. Mr. Umar sits on the System Dynamics Advisory Board, Department of Social Sciences and Policy Studies, Worcester Polytechnic Institute (WPI), Worcester, Massachusetts, he is a member of the System Dynamics Policy Council, and holds board membership on various other non-profit organizations.

Mr. Umar holds a B. Sc. (Honors) in Business Administration with a major in Banking and Finance; B.Sc. in Information and Computer Science; M. Phil. in Information and Computer Science, focusing on the System Dynamics Methodology and Model-based Policy Analyses, and has a 3 years of PhD studies in System Dynamics from the University of Bergen.
NIH ACTIVITIES AND FUNDING OPPORTUNITIES IN SYSTEMS SCIENCE

Patricia L. Mabry, Ph.D
Office of Behavioral and Social Sciences Research
National Institutes of Health

May 30, 2012
Society for Prevention Research
OBSSR in the NIH Context

NIH budget: ~ $31B

Office of the Director

27 Institutes & Centers (ICs):

BSSR @NIH: ~$3.5 B

Division of Program Coordination, Planning, & Strategic Initiatives

Office of Behavioral and Social Science Research

~ $28 M

http://www.nih.gov/about/organization.htm
The OBSSR Mission:

- **Stimulate** behavioral and social science research across NIH
- **Integrate** behavioral and social science research more fully into the NIH health research
- **Improve** understanding, treatment, and prevention of disease
OBSSR’s Strategic Priorities

- “Next generation” basic science
- Interdisciplinary research
- Systems-thinking approaches to health
- Population impact

See Mabry et al, AJPM 2008
What does OBSSR do?

- Develops **funding initiatives** for research
- Provides opportunities for **training and career development** for behavioral and social scientists
- Organizes **conferences, workshops, and lectures**

SYSTEMS SCIENCE AT OBSSR
Health: From Cells to Society

Macro social level

Global economic and geopolitical level

National and state level

Community and workgroup level

Individual, family, and social group level

Organ level

Cellular level

Molecular level

Genomic level

Micro biological level

Lifespan

Adapted from Glass & McAtee, 2006
What is Systems Science?

- “Systems science” refers to a family of methodologies
- SS methodologies enable the study of complex problems
- SS methodologies are used to represent the complexities of a problem in a tractable form by simplifying it while retaining the salient characteristics
- SS methodologies aim to address the “big picture” of a complex problem as well as the components that make up the system
- **Modeling and simulation** characterize much if not most of the systems science methodologies
- SS methods do not replace, but complement traditional linear, reductionist methods
- Can have hybrid SS method or statistical/simulation combos
Systems Science approaches appreciate the complexity, context, dynamic nature, and emergent phenomena associated with the problem under study.

- **SS methodologies include**
  - Computational/mathematical modeling
  - Agent-based modeling
  - Dynamic modeling (including System Dynamics)
  - Network Analysis

- **Related Terms:**
  - Complexity science
  - Complex adaptive systems
  - Non-linear dynamics
Some General Characteristics of SS Methodologies

- Capture dynamic behavior of the system (change over time)
- Capture bidirectional relationships (aka feedback loops)
- Capture non-linear relationships (threshold behavior, worse-before better)
- Capture time-delayed effects,
- Foresee unintended consequences
- Observe Emergent properties – individual behavior leads to aggregate outcome
- Enable virtual experimentation – in silico laboratories
  Can generate hypotheses for empirical testing
Model purposes

- Making mental models explicit – i.e., communication of situational understanding and strategies
- Enhance understanding of relationships and system sensitivities
- Identification of unintended consequences
- Exploration: Identification of research gaps, prioritizing
- Assessment and comparison of “course of action” options
- Extrapolation – i.e., forecasting; point prediction is darn near impossible for behavioral/social models!
Historical Perspective

- Systems science grew out of a variety of disciplines (computer science, operations research, engineering, physics, mathematics)
- The technology revolution has enabled systems science methodology for the masses
- Picked up by sociology and biology
- Now gaining ground in BSSR/health arena
SYSTEMS SCIENCE  FOAS AT OBSSR
## OBSSR-Led Funding Opportunities in SS

<table>
<thead>
<tr>
<th>Announcement Number</th>
<th>Title</th>
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<tr>
<td>PAR-11-314</td>
<td>System Science and Health in the Behavioral and Social Sciences</td>
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<td>PAR-11-315</td>
<td></td>
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<tr>
<td>PAR 10-145 (R01)</td>
<td>Social Network Analysis and Health</td>
</tr>
<tr>
<td>PAR 10-146 (R21)</td>
<td><em>EXPIRED – can resubmit to above</em></td>
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See handout for more FOA’s
These funding announcements (R01, R21) encourage basic and applied research projects that propose to:

- develop basic and applied projects utilizing systems science methodologies relevant to human behavioral and social sciences and health.
- This FOA is intended to encourage a broader scope of topics to be addressed with systems science methodologies, beyond those encouraged by existing open FOAs.
- Research projects applicable to this FOA are those that are either applied or basic in nature (including methodological development),
- Must have a human behavioral and/or social science focus, and feature systems science methodologies.

**NIDA NOT PARTICIPATING**


**Dissemination and Implementation Research in Health (R01/R03/R21) PAR-10-038/039/040**

This funding announcements encourage research projects that identify, develop, and refine effective and efficient methods, structures, and strategies to disseminate and implement research-tested health behavior change interventions and evidence-based prevention, early detection, diagnostic, treatment, and quality of life improvement services into public health and clinical practice settings.

- 11 ICs plus OBSSR participating
- Knowledge to support the broader D&I of interventions (e.g. cost and financing of the intervention, provider training, availability of resources, monitoring the quality of intervention delivery) has remained outside the scope of large-scale clinical trials. Few empirically-supported models exist to guide dissemination and implementation of evidence-based interventions in the U.S. and abroad.


Open Funding Opportunity Announcements at NIH in Systems Science

http://obssr.od.nih.gov/pdf/Funding_opportunity_Announcements_in_systems_science_April_2012.pdf

SEE HANDOUT
OTHER SYSTEMS SCIENCE ACTIVITIES
ISSH provides week long intensive training to BSSR Investigators

http://obssr.od.nih.gov/training_and_education/issh/index.html

- Purpose: to prepare investigators to feature systems science methodologies in their NIH grant applications

- Annual course with rotating host site and faculty

- Competitive application process – all levels eligible from Ph.D. candidate through full professor

- Features three methodological tracks: system dynamics modeling, agent based modeling, social network analysis

- Call for applications is posted to the NIH BSSR-Systems Science Listserv - contact mabryp@od.nih.gov to join
SBP13
International Conference on Social Computing, Behavioral-Cultural Modeling, and Prediction
http://sbp2013.org/
Washington, DC
April 2-5, 2013
Call for Papers, tutorials, cross-fertilization roundtables
Full papers submitted (10 pages) – full paper November 2012
Published in LNCS – hardbound proceedings
Trying to get more in the Health Track
AAHB

American Academy of Health Behavior

http://www.aahb.org/Mtgs_Future.php

Santa Fe, New Mexico

March 17-20, 2013

Conference theme: Systems Thinking And Design In Health Behavior Research
Society of Behavioral Medicine
2013 Annual Meeting & Scientific Sessions
March 20-23, 2013
Hilton San Francisco Union Square
San Francisco, CA

http://www.sbm.org/meetings/future

Stay tuned for systems science panel
Obesity and Systems Science

OBSSR is a member of NCCOR  [www.nccor.org](http://www.nccor.org)

COMNet – international network of obesity modelers

CompMod – U.S. focused on policy interventions

Envision is COMNet, CompMod and other teams  
[www.nccor.org/envision](http://www.nccor.org/envision)

SPORT – Johns Hopkins University Global Center on Childhood Obesity. $16M effort funded by NICHD and OBSSR. Rapid response pilot funds  
E-Source
Behavioral and Social Sciences Research
http://www.esourceresearch.org/

• 20 interactive chapters on methodological issues in behavioral and social science research.
• Systems science chapters are under consideration
mHealth = Mobile Health

Sponsored by NIH and industry (i.e., QualComm, Verizon)

December 3-5, 2012, Gaylord Resort, National Harbor, Washington, DC

http://www.mhealthsummit.org/
NIH 2012 mHealth Summer Institute


- DEADLINE  March 23, 2012
- Training for investigators to learn mHealth research
- Work in interdisciplinary teams
- Northeastern University July 30-August 3, 2012
• On-line learning resources to enhance skills needed to perform transdisciplinary, team-based translational research
• Designed for diverse audiences, including senior investigators, junior investigators, and institutional development officers

http://teamscience.net/about.html
Network on Inequality, Complexity, and Health (NICH)

- A multidisciplinary leadership network of expert researchers who together will establish the feasibility, utility, and importance of applying complex systems approaches to health disparities and related aspects of population health.
  - develop an inventory of areas of health disparities research that appear amenable to the application of complex systems approaches
  - identify data needs
  - analytical challenges, and
  - areas where strategic development is particularly promising.

http://obssr.od.nih.gov/scientific_areas/social_culture_factors_in_health/health_disparities/index.aspx#NICH

Contact: Helen Meissner meissneh@od.nih.gov
NIH Common Fund

http://commonfund.nih.gov/

• Cross-cutting research areas
• Transformative Research Program (TR01)
• Director’s Pioneer Award
• Director’s New Innovator

The Bioinformatics and Computational Biology program, which supports the National Centers for Biomedical Computing, aims to develop novel, cutting-edge software and data management tools to effectively mine the vast wealth of biomedical data generated from sophisticated modern laboratory techniques and facilitate data sharing between researchers.
Other Agencies to Consider

• FDA’s Center for Tobacco Products
  http://cancercontrol.cancer.gov/nih-fda/
Final Thoughts on Systems Science

Volunteer to review – grants, manuscripts
- For Systems Science and Health in the BSS PAR-11-314/315, send email to: tdrgon@csr.nih.gov BE SURE to put “System Sciences – reviewer” in the subject line.

Join the BSSR-Systems Science Listserv
- To join, contact the listowner, Patty Mabry at mabryp@od.nih.gov

Videocast archive, Symposia Series on Systems Science and Health
http://obssr.od.nih.gov/training_and_education/videocast/videocast.aspx#ssh
Funding Opportunity Announcements in Systems Science and Other Relevant Information

Compiled by Patricia L. Mabry, Office of Behavioral and Social Sciences, National Institutes of Health mabryp@od.nih.gov

Last updated: April 2, 2012 available at: http://obssr.od.nih.gov/pdf/Funding_opportunity_Announcements_in_systems_science_April_2012.pdf. Best used in conjunction with Patty’s "resource page" for grant applicants. The electronic version of this document has hyperlinks to each announcement. If the electronic version is not available you can search by funding opportunity announcement number using the NIH Guide to Grants and Contracts: http://grants.nih.gov/grants/oer.htm

NIH Funding Opportunity Announcements (FOA's)

NIH-NSF joint solicitation: Core Techniques and Technologies for Advancing Big Data Science & Engineering (BIGDATA) Solicitation 12-499 Mid-Scale Projects Full Proposal Deadline Date: June 13, 2012; Small Projects Full Proposal Deadline Date: July 11, 2012. NOTE: OBSSR is a participating component of NIH on this solicitation, but our name was inadvertently omitted. I am trying to have it added back – PM.

PAR-11-314 PAR-11-315 Systems Science and Health in the Behavioral and Social Sciences (R01, R21) Expires 9/8/14
PAR-10-145 PAR-10-146 Social Network Analysis and Health (R01, R21) One receipt date per year. Expires 5/11/12

PAR-10-136, PAR-10-137 Behavioral and Social Science Research on Understanding and Reducing Health Disparities (R01, R21) Expires May 2013


PA-10-106 (R13) Scientific Meetings for Creating Interdisciplinary Teams Expires January 2013

PA-09-216 (R01) Mechanisms Underlying the Links between Psychosocial Stress, Aging, the Brain and the Body. Expires 9/8/12

PA-10-235 (R21) Climate Change and Health: Assessing and Modeling Population Vulnerability to Climate Change. Last receipt date: 05/24/12

PA-10-129 (R01) PA-10-130 (R21) Drug Abuse Aspects of HIV/AIDS

PA-09-236 (R01) PA-09-237 (R21) HIV/AIDS, Drug Use, and Vulnerable Populations in the US. Expires 9/8/12

PA-10-236 (R01) Health Promotion Among Racial and Ethnic Minority Males

PA-10-038 (R01) PAR-10-039 (R21) PAR-10-040 (R03) Dissemination and Implementation Research in Health,

PA-11-138 (R01) PA-11-139 (R03) PA-11-140 (R21) Economics of Retirement. Expires May 8, 2014

PA-11-087 (R01) PA-11-088 (R03) PA-11-089 (R21) Research on Alcohol-Related Public Policies such as Those Detailed in the Alcohol Policy Information System (R01)

PAR-11-208 (R01) NLM Express Research Grants in Biomedical Informatics

PA-11-238 (R01) PA-11-239 (R21) PA-11-240 (R03) Spatial Uncertainty: Data, Modeling, and Communication

PA-11-230 (R01) PA-11-231 (R21) PA-11-232 (R03) Epidemiology of Drug Abuse

PAR-12-001 (R01) Collaborations with National Centers for Biomedical Computing (R01)


NIH COMMON FUND http://commonfund.nih.gov/

- The NIH Common Fund has FOAs in Health Economics; Details on new initiatives and funding announcements are under development. See http://commonfund.nih.gov/healtheconomics/overview.aspx

- NIH Director's Early Independence Award – skip the post doc; $250K yr/5 yrs

- NIH Director's New Innovator Award – supports exceptionally creative new investigators who propose highly innovative projects that have the potential for unusually high impact http://commonfund.nih.gov/newinnovator/faq.aspx#a1

- NIH Director's Pioneer Award supports individual scientists of exceptional creativity who propose pioneering – and possibly transforming approaches – to major challenges in biomedical and behavioral research

- NIH Director's New Transformative R01 (TR01) Award - supports exceptionally innovative, high risk, original and/or unconventional research projects that have the potential to create or overturn fundamental paradigms.
NIH Scientific Contacts in Systems Science

Office of Behavioral and Social Sciences Research (OBSSR): Patty Mabry mabryp@od.nih.gov; Mike Spittel spittelm@od.nih.gov

National Cancer Institute (NCI): Elizabeth Ginexi lginexi@mail.nih.gov; David Berrigan (NCI) berrigad@mail.nih.gov; Rocky Feuer (NCI) feuerr@mail.nih.gov

National Heart Lung and Blood Institute (NHLBI): Lawton Cooper cooperls@mail.nih.gov


National Institute on Alcohol Abuse and Alcoholism (NIAAA) Gregory.Bloss@nih.gov

National Institute on Biomedical Imaging and Bioengineering (NIBIB): Grace Peng penggr@mail.nih.gov

Eunice Kennedy Shriver National Institute on Child Health and Human Development (NICHD): Regina Bures (NICHD) buresrn@mail.nih.gov

National Institute on Drug Abuse (NIDA) Bethany Deeds deedsb@nida.nih.gov; Peter Hartsoc phartsoc@nida.nih.gov

National Institute on Mental Health (NIMH) Beverly Pringle bpringle@mail.nih.gov

National Institute for General Medical Sciences (NIGMS): Irene Eckstrand (MIDAS) eckstrai@nigms.nih.gov; Stephen Marcus marcusst@mail.nih.gov

NIH Contacts for programmatic interest in systems science and cyberinfrastructure:

National Cancer Institute:

- In response to the changing health communication landscape brought on by technologies and new media. We hope to engage scholars from multiple disciplines, including communication, systems science, anthropology/ethnography, computational linguistics, and public health
  - Some areas of focus: Measurement issues, impact of social media on health behavior, implications on clinical care, Implications for health communication program planning, Digital Divide and health disparity

Contact: Sylvia Chou, PhD, MPH, Program Officer, 301.435.2842, chouws@mail.nih.gov

Abdul R Shaikh, PhD, MHS
shaikhab@mail.nih.gov

Health Communication and Informatics Research Branch
Division of Cancer Control and Population Sciences, National Cancer Institute

Other grant opportunities


BSSR-Systems Science Listserv This is a read-only list. Postings concern the intersection of three areas: behavioral and social sciences research (BSSR), systems science, and health. Postings include relevant information on funding opportunities at NIH, NSF, CDC; training opportunities; conferences; and articles of interest. To join, contact the list owner, Patty Mabry at mabryp@od.nih.gov. Please include full contact info including name, title, degrees, organizational affiliation (including department), address, and email address. Also include a very brief statement of research interests.

NIH Regional Seminars on Program Funding and Grants Administration

Each year, the Office of Extramural Research (OER) sponsors two NIH Regional Seminars on Program Funding and Grants. These seminars are intended to help demystify the application and review process, clarify Federal regulations and policies, and highlight current areas of special interest or concern. NIH policy, grants management, review and program staff provide a broad array of expertise and encourage personal interaction between themselves and seminar participants. The seminars are appropriate for grants administrators, researchers new to NIH, and graduate students.

http://grants.nih.gov/grants/seminars.htm#upcoming

OR, consider having NIH come to your institution: http://grants.nih.gov/grants/presenter.htm
A Basic Primer on System Dynamics (SD) Modeling

Kristen Hassmiller Lich, Ph.D., MHSA
Assistant Professor
Department of Health Policy and Management
UNC – Chapel Hill, Gillings School of Global Public Health
klich@unc.edu

With thanks to:
Andrew Jones, at the Sustainability Institute,
who provided a bunch of these slides (most of the entertaining ones!!!); www.sustainabilityinstitute.org
Agenda

• What are important contributors to complexity?
• System Dynamics (what and why)
• The general approach
• Key tools for building models
  – Causal loop diagrams
  – Stock and flow models
• Benefits of modeling

• GOAL: To share my perspective on the value of SD and to teach you enough so that you can understand as you read more!
Complex problems

• There is a difference between detail complexity and dynamic complexity

• Dynamic complexity arises because of:
  – Dynamics (things change over time)
  – Time delays between cause and effect
  – Nonlinear relationships
  – Interactions
  – Feedback loops (x increases y, which increases x…)
Tendency: Linear Thinking

A Traditional linear representation of student performance

- Teacher's Perception of Student Needs
- Teacher Time Allocation
- Student's Perceived Need for Help

Tendency: Linear Thinking

Complex problems

• There is a difference between detail complexity and dynamic complexity
• Dynamic complexity arises because of:
  – Dynamics (things change over time)
  – Time delays between cause and effect
  – Nonlinear relationships
  – Interactions
  – Feedback loops (x increases y, which increases x…)
  – Emergence of often counterintuitive system behavior
System Dynamics Methods can help!

- **System:**
  - “A functional whole, composed of a set of components, coupled together to function in a way that might not be apparent from the functioning of the separate component parts.”
  - Levine and Fitzgerald, 1992

- System Dynamics is a set of methods to help us map and model dynamically complex systems -- to learn about why they behave the way they do and how to improve them.
  - Encourages a different way of thinking about system behavior
  - Two key “tools” -- causal loop diagrams and stock and flow models
  - Rich, standardized language to describe and conceptualize systems
  - **50+ years’ of work improving methods to involve stakeholders in model building and utilization**
The result...
1. Define Problem
What is happening over time that we are concerned about?

• First be sure to identify your “client”

• Clearly articulate the problem you would like to focus on
  – What is the purpose of building and studying a model?
  – DO NOT focus on a symptom!
  – DO NOT model a whole system, just because you can!
First Steps...

• Who is the client?
  – State Division of Mental Health
  – Community
  – Hospital
  – Insurer
  – Ministry of Health

• What is the problem?
  – What is the root problem, the thing that is fundamentally undesirable?

• What is the outcome you would like to see?
  – Make this concrete and measurable – i.e., you would know it if you saw it
  – EG – End the growth in diabetes prevalence by 2025.
Hypertension

• Who is the client?
  – Community

• What is the problem?
  – There are too many avoidable medical events that are caused by uncontrolled BP in Durham county, and more needs to be done by the community to support the health of its population.

• What is the outcome you’d like to see?
  – A 30% reduction in medical events caused by uncontrolled BP in Durham county by 2020.
General Approach...

1. Define Problem
What is happening over time that we are concerned about?

2. List Factors
What are important drivers? Write as variables. Indicate any known direct causal connections.

- Of particular interest is your “reference mode” -- variables you will focus on over time to characterize your problem.
- Consider developing a model boundary chart:

<table>
<thead>
<tr>
<th>Endogenous</th>
<th>Exogenous</th>
<th>Excluded</th>
</tr>
</thead>
<tbody>
<tr>
<td>GNP</td>
<td>Population</td>
<td>Inventories</td>
</tr>
<tr>
<td>Consumption</td>
<td>Technological change</td>
<td>International trade (except with OPEC)</td>
</tr>
<tr>
<td>Investment</td>
<td>Tax rates</td>
<td>Environmental constraints</td>
</tr>
<tr>
<td>Savings</td>
<td>Energy policies</td>
<td>Nonenergy resources</td>
</tr>
<tr>
<td>Prices (real and nominal)</td>
<td></td>
<td>Interfuel substitution</td>
</tr>
<tr>
<td>Wages (real and nominal)</td>
<td></td>
<td>Distributional equity</td>
</tr>
<tr>
<td>Inflation rate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Labor force participation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Employment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unemployment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interest rates</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Money supply</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Debt</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy production</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy demand</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy imports</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

General Approach...

1. Define Problem
   What is happening over time that we are concerned about?

2. List Factors
   What are important drivers? Write as variables. Indicate any known direct causal connections.

3. Draw Reference Mode
   Graph behavior over time. Any other factors needed to explain trends? Does the pattern suggest any familiar structures?
We Start By Graphing Trends Over Time

- One major goal of systems thinking is to help you change some behavior in the world so you can attain your goal.
- Your goal can often be expressed as a change in some longer-term trend(s) with a “behavior-over-time” graph. A generic example is shown below.

Text version: The number of high particulate days has been rising over the past twenty years. It will continue to rise unless we can cause it to level out.
**Modes of behavior and archetypes: What do I mean by “Does the pattern suggest any familiar structures?”**

<table>
<thead>
<tr>
<th>Examples modes of behavior and archetypes:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Exponential growth</strong></td>
</tr>
<tr>
<td>(Produced by reinforcing loops)</td>
</tr>
<tr>
<td><img src="http://math.tutorvista.com/algebra/exponential-growth.html" alt="Exponential growth graph" /></td>
</tr>
<tr>
<td>Source: <a href="http://math.tutorvista.com/algebra/exponential-growth.html">http://math.tutorvista.com/algebra/exponential-growth.html</a></td>
</tr>
<tr>
<td><strong>Goal-seeking</strong></td>
</tr>
<tr>
<td>(Produced by balancing loops)</td>
</tr>
<tr>
<td><img src="http://www.systemswiki.org/index.php?title=Goal_Seeking_Model" alt="Goal-seeking graph" /></td>
</tr>
<tr>
<td><strong>Limits to growth</strong></td>
</tr>
<tr>
<td><img src="http://brianholmes.wordpress.com/2011/08/19/do-containers-dream-of-electric-people/" alt="Limits to growth graph" /></td>
</tr>
</tbody>
</table>
General Approach...

1. Define Problem
   What is happening over time that we are concerned about?

2. List Factors
   What are important drivers? Write as variables. Indicate any known direct causal connections.

3. Draw Reference Mode
   Graph behavior over time. Any other factors needed to explain trends? Does the pattern suggest any familiar structures?

4. Build A Dynamic Hypothesis and System Map
   This could be a causal loop diagram, a stock and flow model (or a combination of the two). In any case, it is a causal hypothesis about system behavior.
Causal Loop Diagrams Give a Language to Talk about Feedback and Make Our Assumptions Explicit

We start by looking for important causal relationships

Change in the **SAME** direction

\[ A \rightarrow^+ B \]

When A increases, B will tend to increase, all else equal. Or when A decreases B will tend to decrease, all else equal. They change in the same direction.

Change in the **Opposite** direction

\[ A \rightarrow^- B \]

When A increases, B will tend to decrease, all else equal. Or when A decreases B will tend to increase, all else equal. They move in the opposite direction.

Examples:

- **Houses** → **Residents** → **Traffic**
- **Traffic** → **Reported Desirably of Community** → **New Construction**
Parts of a “Feedback Loop Diagram”

1. Variable -- Important factors in the systems. Can go up or down.

2. Arrow -- Means one variable affects the next one in some direction, all else being equal.

3. Sign - “S” or “+” means the second variable changes in the same direction as the first. “O” or “-” would mean the opposite direction.

4. Type of loop -- R for reinforcing. B for balancing.

5. Name for the loop of positive results
A Feedback Loop That Builds On Itself Is Called a “Reinforcing Loop”

- They are also called positive feedback loops, virtuous cycles, vicious cycles, bandwagon effects, snowball effects
  - Changing a variable in one direction produces a response in the same direction of that variable.

Figure 1 in Repenning
Positive loop of reinforcement

More Than One Loop Can Intersect

Observation of the effort-results linkage by others

Figure 2 in Repenning

The diffusion process
Balancing loops are created when there are an odd number of negative links.

Balancing loops move the system towards a goal. They counteract change. Managers’ goal for commitment
... and Balancing Loops Can Calibrate the System

Figure 3 in Repenning
External sources of commitment as a balancing loop

Managers’ goal for commitment

Observation of the effort-results linkage by others

Commitment to the innovation

Effort allocated

Results

Reinforcement

Diffusion

R1

R2

Commitment gap

Normative pressures

Normative pressure from managers
Delays Can Have Profound Effects on Feedback Loops

• Dampen feedback by weakening signal

Modified Figure 1 in Repenning
Positive loop of reinforcement
Hints On Choosing Variables

• There is generally no final solution – no “right” number of variables

• How to pick which to include
  – Would the same basic dynamic exist if I took this out?
  – Would people understand the sequence better if I left it in?
  – Is this something I might be able to change?
Hints On Choosing Good Variable Names

• Use nouns or noun phrases
  – They can clearly go “up” or “down” -- it would work as an indicator on a behavior over time graph
  – For example, “interest in surgery” not “people became more interested in surgery” (which is a verb phrase)
  – “annual number of surgeries” not “more people got the surgery”

• Use phrases with a clear sense of direction
  – E.g., “interest in surgery” not “attitude towards surgery”
  – “Positive word of mouth” not “word of mouth”

• If you have picked good names an observer will assign the same - and + signs that you do.
Remember the modes of behavior? Well, these map to common “archetypical” system structure!

<table>
<thead>
<tr>
<th>Mode of behavior</th>
<th>Archetype</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exponential growth</td>
<td><img src="http://math.tutorvista.com/algebra/exponential-growth.html" alt="Exponential Growth" /></td>
</tr>
<tr>
<td>Limits to growth</td>
<td><img src="source" alt="Limits to Growth" /></td>
</tr>
<tr>
<td>Success to the successful</td>
<td><img src="source" alt="Success to the Successful" /></td>
</tr>
</tbody>
</table>

If you get stuck drawing a CLD...

Stock and Flow Diagrams

- Stocks represent accumulations and are generally measured in units (gallons, people, tons, etc.)

- Flows change the level of stocks and must be measured in units per time (gallons/day, people/month, tons/year, etc.) They often are verbs.

- Clouds represent factors outside our consideration at this point
Examples of Stock/Flow Diagrams

- People who are obese who do not do vigorous physical activity
- Adopting physical activity routine
- People who are obese who do vigorous physical activity
- Dropping routine

- Young trees
  - Seeding
  - Aging to Mid

- Middle-aged trees
  - Aging to Old

- Older trees
  - Dying
  - Harvesting
Examples of Stock/Flow Diagrams

Work to be done → Work in process

Work in process → Work really done

Work in process → Undiscovered rework

Undiscovered rework → rework discovery

Known rework → starting rework

Starting rework → doing work incorrectly

Doing work incorrectly → completing work

Completing work → beginning work

Beginning work → Work to be done
You can integrate CLD and stock and flow models...

How to make your model quantitative

• Transform the diagrammed relationships into mathematical relationships, and develop a parameter list
• Estimate parameters based on data analysis, published evidence, or expert opinion
• Model verification (extreme value testing…)
• Sensitivity analysis/calibration
• Model testing (validation, see Sterman 2000)

• THIS SHOULD BE AN ITERATIVE PROCESS!
General Approach...

1. **Define Problem**
   What is happening over time that we are concerned about?

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   What are important drivers? Write as variables. Indicate any known direct causal connections.

3. **Draw Reference Mode**
   Graph behavior over time. Any other factors needed to explain trends? Does the pattern suggest any familiar structures?

4. **Build A Dynamic Hypothesis and System Map**
   This could be a causal loop diagram, a stock and flow model (or a combination of the two). In any case, it is a causal hypothesis about system behavior.

5. **ID Leverage Points**
   What are the levers for change (add to map)? What changes would lead to a more desirable behavior? What strategy could you use to achieve these changes?
How can CLDs motivate intervention?

- Think about ways to:
  - Reverse causal direction somewhere
  - Change a sign
  - Remove directionality
  - Decouple two variables
  - Tighten or loosen the connection between two variables
  - Alter delays
  - Add a loop whose effect cancels out the original one
How can CLDs motivate intervention?
How can CLDs motivate intervention?

Broad Dynamics of the Obesity Challenge

Prevalence of Vulnerability, Risk, or Disease

Engines of Growth
- R1 Spiral of poor health and habits
- R2 Parents and peer transmission
- R3 Media mirrors
- R4 Options shape habits shape options
- R5 Society shapes options shape society

Drivers of Growth

Potential Threats

Responses to Growth
- B1 Self-improvement
- B2 Medical response
- B3 Improving preventive healthcare
- B4 Creating better messages
- B5 Creating better options in beh. settings
- B6 Creating better conditions in wider environ
- B7 Addressing related health conditions

Health Protection Efforts

Obstacles

Resources & Resistance

Resources, Resistance, Benefits & Supports
- R6 Disease care costs squeeze prevention
- D6 Up-front costs undercut protection efforts
- B9 Defending the status quo
- B10 Potential savings build support
- R7 Broader benefits build support

CDC
How Can Stock-Flow Models Motivate Intervention?

• Consider each model flow
  – What variables affect that rate of flow?
  – Are any of these variables (or flows themselves) amenable to change?

• Draw these “leverage points” and related interventions right on the stock and flow diagram

• Simulate impact of intervention “scenarios” under alternate possible “realities” about the future
1. Define Problem
What is happening over time that we are concerned about?

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6. Test & Improve Theory
Get feedback from others. Find data. Act and observe real world results. Reflect.
Why Use System Dynamics Methods...

- Help us develop a shared understanding of the system
- Teach us to think differently about how systems behave (that is, in terms dynamics, circular causal feedbacks, accumulations, etc)
- Allow stakeholders to view the larger system they are embedded within
- Provide a framework for integrating what we know, and determining importance of what we don’t know
- Support identification of high impact leverage points
- Offer a virtual world in which to “try out” and compare policies
A Population Dynamics Model of Smoking Prevalence and Health Effects

David Mendez, PhD
University of Michigan
Compartment Model of Smoking Prevalence, Health Effects and Medical Costs

Figure 1. Male relative risk of death, current and former smokers, by age and smoking status

In the figure, the inputs are denoted as $\lambda_x, \mu_x$ for Policy Set $I_x$ and $\lambda_0, \mu_0$ for Policy Set $I_0$. The outputs include Survival Curve under Set $I_x$ and Survival Curve under Set $I_0$, with Comparison between them. The dynamics model is shown for Age 0-17, Age 18, and Age >18 across time.
Initiation and Cessation Feedbacks

AnyLogic Diagram
Effectiveness of MPOWER Policies on Initiation and Cessation Rates

<table>
<thead>
<tr>
<th>Policy</th>
<th>Description</th>
<th>Effect on Cessation (Relative Risk)</th>
<th>Effect on Initiation (Relative Risk)</th>
</tr>
</thead>
<tbody>
<tr>
<td>P (Protect)</td>
<td>Clean Air Laws</td>
<td>1.38$^5$</td>
<td>0.926</td>
</tr>
<tr>
<td>O (Offer Help)</td>
<td>Cessation Support</td>
<td>1.061</td>
<td>Not Applicable</td>
</tr>
<tr>
<td>W (Warn)</td>
<td>Mass Media and Package Warnings</td>
<td>1.25</td>
<td>0.8</td>
</tr>
<tr>
<td>E (Enforce)</td>
<td>Enforce Ad Bans</td>
<td>Not Available</td>
<td>0.94$^5$</td>
</tr>
<tr>
<td>R (Raise)</td>
<td>Raise Taxes</td>
<td>Price Elasticity = 0.375</td>
<td>Price Elasticity = - 0.7$^5$</td>
</tr>
</tbody>
</table>
Combined Effect of Cessation Policies

Combined Effect of Cessation Policies

$C_j'(worst - case) = (C_j \times \max E_i)$

Current Smokers

Policy A
$E_A$

Policy B
$E_B$
<table>
<thead>
<tr>
<th>joint distribution</th>
<th>independence</th>
<th>marginal dist</th>
<th>given</th>
<th>correlation matrix</th>
</tr>
</thead>
<tbody>
<tr>
<td>p00000</td>
<td>0.6010</td>
<td>0.5332</td>
<td>p1</td>
<td>0.1</td>
</tr>
<tr>
<td>p00001</td>
<td>0.0743</td>
<td>0.0592</td>
<td>p2</td>
<td>0.12</td>
</tr>
<tr>
<td>p00010</td>
<td>0.0904</td>
<td>0.0727</td>
<td>p3</td>
<td>0.15</td>
</tr>
<tr>
<td>p00100</td>
<td>0.0000</td>
<td>0.0081</td>
<td>p4</td>
<td>0.12</td>
</tr>
<tr>
<td>p01000</td>
<td>0.0280</td>
<td>0.0541</td>
<td>p5</td>
<td>0.1</td>
</tr>
</tbody>
</table>
| p01010 | 0.0035 | 0.0105 | Quit | 0.3990 | covariance matrix (calculated with given p's)
| p01100 | 0.0046 | 0.0128 | | | x1 | 0.0900 |
| p01110 | 0.0000 | 0.0014 | | | x2 | 0.0097 |
| p01000 | 0.0208 | 0.0727 | Indep Quilt | 0.4668 | x3 | 0.0214 |
| p01001 | 0.0000 | 0.0081 | | | x4 | 0.0067 |
| p00001 | 0.0000 | 0.0000 | | | x5 | 0.0090 |
| p00010 | 0.0000 | 0.0000 | | | covariance matrix (calculated)
| p01000 | 0.0000 | 0.0000 | | | x1 | 1.0000 |
| p01100 | 0.0000 | 0.0000 | | | x2 | 0.1000 |
| p10000 | 0.0000 | 0.0000 | | | x3 | 0.2000 |
| p10100 | 0.0000 | 0.0000 | | | x4 | 0.1000 |
| p11000 | 0.0000 | 0.0000 | | | x5 | 0.1000 |
| p11100 | 0.0000 | 0.0000 | | | covariance matrix (calculated)
| p11110 | 0.0000 | 0.0000 | | | x1 | 0.0900 |
| p11111 | 0.0000 | 0.0000 | | | x2 | 0.0097 |
| p11110 | 0.0000 | 0.0000 | | | x3 | 0.0214 |
| p11111 | 0.0000 | 0.0000 | | | x4 | 0.0067 |
| p11111 | 0.0000 | 0.0000 | | | x5 | 0.0090 |

Given correlation:

<table>
<thead>
<tr>
<th>x1</th>
<th>x2</th>
<th>x3</th>
<th>x4</th>
<th>x5</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0000</td>
<td>0.1000</td>
<td>0.2000</td>
<td>0.1000</td>
<td>0.1000</td>
</tr>
</tbody>
</table>

Given covariance (calculated):

<table>
<thead>
<tr>
<th>x1</th>
<th>x2</th>
<th>x3</th>
<th>x4</th>
<th>x5</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0900</td>
<td>0.0097</td>
<td>0.0214</td>
<td>0.0997</td>
<td>0.0900</td>
</tr>
<tr>
<td>0.0097</td>
<td>0.1056</td>
<td>0.0812</td>
<td>0.0106</td>
<td>0.0097</td>
</tr>
<tr>
<td>0.0214</td>
<td>0.0812</td>
<td>0.1275</td>
<td>0.0115</td>
<td>0.0107</td>
</tr>
<tr>
<td>0.0067</td>
<td>0.0106</td>
<td>0.0116</td>
<td>0.1056</td>
<td>0.0097</td>
</tr>
<tr>
<td>0.0090</td>
<td>0.0097</td>
<td>0.0107</td>
<td>0.0997</td>
<td>0.0900</td>
</tr>
</tbody>
</table>

Structural Model for Smoking Prevalence

\[
P_{a,t} = P_{a-1,t-1} \times (1 - \delta_{a-1,t-1}) \quad a = 1, \ldots, 110
\]

\[
P_{0,t} = \alpha_t
\]

\[
C_{a,t} = C_{a-1,t-1} \times (1 - \mu_{a-1,t-1}) \times (1 - \beta_{a-1,t-1}) \quad a = 19, \ldots, 110
\]

\[
C_{a,t} = 0 \quad a = 1, \ldots, 17
\]

\[
C_{18,t} = \gamma_t \times P_{i,18}
\]

\[
R_{(a_i,a_f),t} = \frac{\sum_{a=a_i}^{a_f} P_{a,t}}{\sum_{a=a_i}^{a_f} P_{a,t}}
\]

- \( P_{a,t} \): Size of cohort age \( a \) in year \( t \)
- \( C_{a,t} \): Current smokers of age \( a \) in year \( t \)
- \( R_{(a_i,a_f),t} \): Smoking prevalence between ages \( a_i \) and \( a_f \) in year \( t \)
- \( \delta \): Death rates for general population
- \( \beta \): Death rates for smokers
- \( \mu \): Smoking cessation rates
Structural Model of Smoking Prevalence

\[ P_{a,t} = P_{a-1,t-1} \times (1 - \delta_{a-1,t-1}) \quad a = 1, \ldots, 110 \]

\[ P_{0,t} = \alpha_t \]

\[ C_{a,t} = C_{a-1,t-1} \times (1 - \mu_{a-1,t-1}) \times (1 - \beta_{a-1,t-1}) \quad a = 19, \ldots, 110 \]

\[ C_{a,t} = 0 \quad a = 1, \ldots, 17 \]

\[ C_{18,t} = \gamma_i \times P_{i,18} \]

\[ R_{(a_i:a_f),t} = \frac{\sum_{a=a_i}^{a=a_f} C_{a,t}}{\sum_{a=a_i}^{a=a_f} P_{a,t}} \]

- \( P_{a,t} \) = Size of cohort age \( a \) in year \( t \)
- \( C_{a,t} \) = Current smokers of age \( a \) in year \( t \)
- \( R_{(a_i:a_f),t} \) = Smoking prevalence between ages \( a_i \) and \( a_f \) in year \( t \)
- \( \delta \) = Death rates for general population
- \( \beta \) = Death rates for smokers
- \( \mu \) = Smoking cessation rates
We estimated cessation rates from the observed NHIS prevalence data.
### NHIS – Smoking Prevalence Data

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<td>0.088</td>
<td>0.082</td>
<td>0.084</td>
<td>0.084</td>
<td>0.207</td>
<td>0.209</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2006</td>
<td>0.241</td>
<td>0.19</td>
<td>0.215</td>
<td>0.215</td>
<td>0.124</td>
<td>0.082</td>
<td>0.1</td>
<td>0.205</td>
<td>0.205</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Structural Model for Smoking Prevalence

\[ \mu_{a,t} = \begin{array}{c|c|c|c}
\text{Age (a)} & 18-30 & 31-50 & >50 \\
\hline
\text{Year (t)} & \rho_1 & \rho_2 & \rho_3 \\
1970-1980 & & & \\
1981- & \rho_4 & \rho_5 & \rho_6 \\
\end{array} \]


Source: National Health Interview Surveys. (CDC’s Tobacco Info-Trends in Adult Smoking.)
Estimation Results - Cessation Rates

<table>
<thead>
<tr>
<th></th>
<th>18-30</th>
<th>31-50</th>
<th>&gt;50</th>
</tr>
</thead>
<tbody>
<tr>
<td>1970-1980</td>
<td>−.00954</td>
<td>.007134</td>
<td>.045216</td>
</tr>
<tr>
<td>1981-</td>
<td>.00209</td>
<td>.021485</td>
<td>.059648</td>
</tr>
</tbody>
</table>

Corrected $R^2 = 0.988$
Observed vs Predicted Smoking Prevalence
All Ages

![Graph showing the observed vs predicted smoking prevalence over years.](image)
Observed vs Predicted Smoking Prevalence
Ages 18-24

Prevalence [%]

Year

Observed vs Predicted Smoking Prevalence
Ages 25-44
Observed vs Predicted Smoking Prevalence

Ages 45-64

Year

Prevalence

Observed vs Predicted Smoking Prevalence
Ages 65+

Year

Prevalence
Forecasted Overall Smoking Prevalence by Different Peak Prevalence at 18

Year
1995 2005 2015 2025 2035 2045 2055 2065 2075 2085 2095

Smoking Prevalence
0.1 0.12 0.14 0.16 0.18 0.2 0.22 0.24 0.26

p.p. 18 = .35
p.p. 18 = .30
p.p. 18 = .25
p.p. 18 = .20
Observed vs. Predicted Adult Smoking Prevalence in the US

Mendez and Warner, *AJPH*, 2004
Expanding the Model to Include Health Effects and Medical Costs
Using CPS II data, we postulated four logistic regression models, two describing male and female never-smokers and two characterizing male and female current and former smokers. The models are as follows:

For male and female never smokers:

\[
P(\text{Death} | \text{age}) = \frac{\exp(\beta_0 + \beta_1 \times \text{age})}{1 + \exp(\beta_0 + \beta_1 \times \text{age})}
\]

for male and female current and former smokers:

\[
P(\text{Death} | \text{age}, \text{yearsquit}) = \frac{\exp(\beta_0 + \beta_1 \times \text{age} + \beta_2 \times \text{yearsquit} + \beta_3 \times \text{age} \times \text{yearsquit})}{1 + \exp(\beta_0 + \beta_1 \times \text{age} + \beta_2 \times \text{yearsquit} + \beta_3 \times \text{age} \times \text{yearsquit})}
\]

for male and female current and former smokers.
## Estimation Results

**TABLE 1. Logistic regressions relating age and years quit to probability of death**

<table>
<thead>
<tr>
<th></th>
<th>Constant</th>
<th>Age</th>
<th>Years quit</th>
<th>Interaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male never smokers</td>
<td>-12.39</td>
<td>0.1155</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female never smokers</td>
<td>-11.94</td>
<td>0.1020</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male current and former smokers</td>
<td>-10.69</td>
<td>0.1044</td>
<td>-0.0919</td>
<td>0.0009</td>
</tr>
<tr>
<td>Female current and former smokers</td>
<td>-10.91</td>
<td>0.098</td>
<td>-0.0878</td>
<td>0.0009</td>
</tr>
</tbody>
</table>
Female relative risk of death, current and former smokers, by age and smoking status

Relative Risk

Age

Never Smokers
Former Smokers
Current Smokers
Male relative risk of death, current and former smokers, by age and smoking status

- Never Smokers
- Former Smokers
- Current Smokers

Relative Risk vs. Age

- Relative Risk scale: 0.5 to 4.0
- Age range: 40 to 80 years
Medical Costs “Proportional” to Relative Risk

We obtained medical cost by age for 1997 from Blue Cross Blue Shield of Michigan. We first estimated the cost by age for never smokers assuming that total medical cost due to smoking accounts for 9% of total medical expenditures in the year 2000.

\[ MC_C(a) = x \left[ MC_N(a) \right] . \]  
\[ (A22) \]

\[ MC_F(a, q) = MC_N(a) \left[ 1 + \frac{(x-1)(RR(a,q)-1)}{RR_c(a)-1} \right] \]  
\[ (A23) \]

\[ MC_O(a) = MC_N(a) \pi_N(a) + MC_C(a) \pi_C(a) + \sum_q MC_F(a,q) \pi_F(a,q) \]  
\[ (A24) \]

\[ \sum_a \left( MC_O(a) - MC_N(a) \right) P(a) \]  
\[ \sum_a MC_N(a) P(a) = 9\% \]  
\[ (A25) \]

\[ X = 1.32 \]
Model Applications
Smoking Prevalence Targets
Even if the initiation rate goes down to zero, cessation rates would still need to increase more than 3-fold to achieve 13% prevalence in 2010.

If the initiation rate drops down to 15% by 2010, cessation rates would need to increase more than 4-fold to achieve a 13% adult prevalence in 2010.

Mendez and Warner, *AJPH*, 2000

**Combinations of initiation and cessation rates would be necessary to achieve 13% adult smoking prevalence by 2010.**

- **Initiation rate by year 2010**
  - 0.1
  - 0.05
  - 0

- **Cessation rate increase factor by year 2010**
  - (with respect to 1999 values)

- **Initiation and cessation rates progress linearly from year 2000 towards year 2010 values**
Forecasted adult smoking prevalence under various initiation and cessation scenarios

<table>
<thead>
<tr>
<th>Estimate based on:</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2000</td>
</tr>
<tr>
<td>Current initiation (30%) and current cessation rates</td>
<td>22.2%</td>
</tr>
<tr>
<td>Initiation rate declines from 30% to 15% over the decade of 2000-2010, current cessation rate stays constant</td>
<td>22.2%</td>
</tr>
<tr>
<td>Initiation rate stays at 30%, cessation rates double over the decade of 2000-2010</td>
<td>22.2%</td>
</tr>
<tr>
<td>Initiation rate declines from 30% to 20% and cessation rates increase by 50% over the decade of 2000-2010</td>
<td>22.2%</td>
</tr>
<tr>
<td>Initiation rate declines from 30% to 15% and cessation rates double over the decade of 2000-2010</td>
<td>22.2%</td>
</tr>
</tbody>
</table>
What can the country achieve by emulating best performance?

Status Quo vs. Best Performance

*Mendez & Warner, AJPH, 2008*
BRFSS 2004 Adult Smoking Prevalence by State

- California: 14.7%
- Kentucky: 27.5%
- Utah: 10.4%
- National Average: 20.9%
Status Quo Rates

- The status quo initiation rate for the nation was taken to be 25%, consistent with the prevalence for the 18-24 age-group observed in recent years.
- Annual cessation rates for the status quo scenario were taken to be those we calculated previously: 0.21% for the 18-30 age-group; 2.15% for the 31-50 age-group; and 5.97% for individuals aged 51 and older.
- By using these age-group specific cessation rates we obtained an estimated 2.59% overall cessation rate in 2005 for the US.
California Rates

- California rates were estimated with data from the Behavioral Risk Factor Surveillance System (BRFSS) from recent years (2000-2004).
- California’s initiation rate was estimated to be 20%, an average of the 18-24 age-group prevalence from 2000 to 2004.
- Using BRFSS, we estimated a cessation rate of 3.33% for California.
Projections of U.S. adult smoking prevalence under status quo and California smoking initiation and cessation rates.

- **Init. Rate**  
  - Status Quo: 25%  
  - California: 20%

- **Cess. Rate**  
  - Status Quo: 2.59%  
  - California: 3.33%

**Dotted lines** - Rates are achieved immediately in 2006

**Continuous lines** - Rates are achieved gradually, by 2010

**Projections of U.S. adult smoking prevalence**

Even though prevalence continues to fall, if current initiation and cessation rates persist, adult prevalence will not fall much below 15%.

Under very optimistic conditions, assuming CA initiation and cessation rates, the country will not achieve California’s current prevalence level of 14.7% until after the year 2020.

Under the same optimistic conditions, the country will not achieve the “Healthy People 2010” target to 12% until after the year 2030.

Smoking prevalence carries with it tremendous inertia, and its trajectory cannot be altered substantially without considerable additional efforts.
Projections of U.S. adult smoking prevalence and number of smokers under status quo and California smoking initiation and cessation rates.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>2010</th>
<th>2020</th>
<th>2030</th>
<th>2040</th>
<th>2050</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Prev. (%)</td>
<td>No. of smokers (millions)</td>
<td>Prev. (%)</td>
<td>No. of smokers (millions)</td>
<td>Prev. (%)</td>
</tr>
<tr>
<td>Status quo</td>
<td>19.1</td>
<td>42.8</td>
<td>16.8</td>
<td>39.3</td>
<td>15.4</td>
</tr>
<tr>
<td>California rates achieved in 2006</td>
<td>18.1</td>
<td>40.7</td>
<td>14.4</td>
<td>33.7</td>
<td>12.3</td>
</tr>
<tr>
<td>California rates achieved by 2010</td>
<td>18.5</td>
<td>41.6</td>
<td>14.7</td>
<td>34.4</td>
<td>12.4</td>
</tr>
</tbody>
</table>

Setting a target of 14% for the year 2020 will provide an ambitious but potentially reachable goal.

With California rates, 44 years from now, there would be nearly 9 million fewer smokers under the status quo than if California smoking initiation and cessation rates were not achieved, implying a dramatic reduction in the mortality toll associated with smoking.
Status quo: IR=21.6%, CR=2.41% in 2008

25% Improvement in initiation and cessation: IR=16.2%, CR=3.01% by 2015

50% Improvement in initiation and cessation: IR=10.8%, CR=3.62% by 2015
## Input Parameters
### General Population

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Min</th>
<th>TPSAC Estimate</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proportion of Menthol among Initiators</td>
<td>0.35</td>
<td>0.40</td>
<td>0.45</td>
</tr>
<tr>
<td>Proportion of Menthol among Experimenters ($K_a$)</td>
<td>0.38</td>
<td>0.45</td>
<td>0.60</td>
</tr>
<tr>
<td>Ratio of “Proportion of Menthol Experimenters that become Established Smokers” / “…Non-menthol…..” ($K_5$)</td>
<td>1.00</td>
<td>1.68</td>
<td>1.85</td>
</tr>
<tr>
<td>Cessation Rates Ratio (Menthol/Non-menthol)</td>
<td>0.92</td>
<td>0.95</td>
<td>1.10</td>
</tr>
<tr>
<td>Mortality Risk Ratio (Menthol/Non-menthol)</td>
<td>0.80</td>
<td>1.00</td>
<td>1.20</td>
</tr>
<tr>
<td>Switching Rate from Menthol to Non-menthol (among Menthol smokers)</td>
<td>0.9%</td>
<td>1.8%</td>
<td>2.7%</td>
</tr>
<tr>
<td>Switching Rate from Non-menthol to Menthol (among Non-menthol smokers)</td>
<td>0.4%</td>
<td>0.8%</td>
<td>1.2%</td>
</tr>
</tbody>
</table>
### Results for the General Population Model

#### TPSAC Estimates

<table>
<thead>
<tr>
<th>General Population</th>
<th>TPSAC Estimates</th>
<th>Counterfactual</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initiative Age</td>
<td>18</td>
<td>18</td>
</tr>
<tr>
<td>Initiative Rate</td>
<td>21.8%</td>
<td>16.7%</td>
</tr>
<tr>
<td>Proportion of Menthol Initiation</td>
<td>40%</td>
<td>---</td>
</tr>
<tr>
<td>Proportion of Menthol Experimentation</td>
<td>45%</td>
<td>---</td>
</tr>
<tr>
<td>Experimentation to Initiation Ratio</td>
<td>Menthol/Non-Menthol</td>
<td>1.68</td>
</tr>
<tr>
<td>Background Cessation Rates</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;= 30</td>
<td>0.21%</td>
<td>0.21%</td>
</tr>
<tr>
<td>31-49</td>
<td>2.15%</td>
<td>2.15%</td>
</tr>
<tr>
<td>50+</td>
<td>5.96%</td>
<td>5.96%</td>
</tr>
<tr>
<td>Cessation Ratio Menthol/Non-Menthol</td>
<td>0.95</td>
<td>---</td>
</tr>
<tr>
<td>Menthol Mortality Multiplier</td>
<td>1</td>
<td>---</td>
</tr>
<tr>
<td>Probability of switching to Menthol</td>
<td>0.8%</td>
<td>---</td>
</tr>
<tr>
<td>Probability of switching to Non-Menthol</td>
<td>1.8%</td>
<td>---</td>
</tr>
</tbody>
</table>

#### TPSAC - Adult Smoking Prevalence

<table>
<thead>
<tr>
<th></th>
<th>2010</th>
<th>2020</th>
<th>2030</th>
<th>2040</th>
<th>2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>TPSAC - Adult Smoking Prevalence - Menthol</td>
<td>6.8%</td>
<td>5.5%</td>
<td>4.9%</td>
<td>4.6%</td>
<td>4.5%</td>
</tr>
<tr>
<td>TPSAC - Adult Smoking Prevalence - Non-Menthol</td>
<td>13.8%</td>
<td>10.5%</td>
<td>8.7%</td>
<td>8.0%</td>
<td>7.8%</td>
</tr>
<tr>
<td>TPSAC - Overall Adult Smoking Prevalence</td>
<td>20.5%</td>
<td>16.1%</td>
<td>13.6%</td>
<td>12.5%</td>
<td>12.3%</td>
</tr>
<tr>
<td>Counterfactual - Overall Adult Smoking Prevalence</td>
<td>20.4%</td>
<td>15.1%</td>
<td>11.9%</td>
<td>10.3%</td>
<td>9.7%</td>
</tr>
</tbody>
</table>

#### Cumulative Excess Deaths

<table>
<thead>
<tr>
<th></th>
<th>2010</th>
<th>2020</th>
<th>2030</th>
<th>2040</th>
<th>2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cumulative Excess Deaths among Menthol Smokers</td>
<td>172,743</td>
<td>1,601,751</td>
<td>2,777,684</td>
<td>3,804,560</td>
<td>4,696,753</td>
</tr>
<tr>
<td>Cumulative Excess Deaths among Current Smokers</td>
<td>300</td>
<td>44,526</td>
<td>151,132</td>
<td>325,292</td>
<td>587,675</td>
</tr>
<tr>
<td>Cumulative Excess Deaths among Former Smokers</td>
<td>0</td>
<td>-16,797</td>
<td>-48,419</td>
<td>-76,392</td>
<td>-70,064</td>
</tr>
<tr>
<td>Cumulative Excess Deaths among Never Smokers</td>
<td>-300</td>
<td>-10,547</td>
<td>-34,897</td>
<td>-84,310</td>
<td>-190,047</td>
</tr>
<tr>
<td>Total Cumulative Excess Deaths</td>
<td>0</td>
<td>17,182</td>
<td>67,817</td>
<td>164,590</td>
<td>327,565</td>
</tr>
</tbody>
</table>

#### Cumulative Excess Smoking Initiation

<table>
<thead>
<tr>
<th></th>
<th>2010</th>
<th>2020</th>
<th>2030</th>
<th>2040</th>
<th>2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cumulative Excess Smoking Initiation - Menthol</td>
<td>387,845</td>
<td>3,920,549</td>
<td>7,580,884</td>
<td>11,480,562</td>
<td>15,609,338</td>
</tr>
<tr>
<td>Cumulative Excess Smoking Initiation - Non-Menthol</td>
<td>-165,457</td>
<td>-1,632,015</td>
<td>-3,151,558</td>
<td>-4,770,461</td>
<td>-6,484,471</td>
</tr>
<tr>
<td>Total Cumulative Excess Smoking Initiation</td>
<td>222,388</td>
<td>2,288,534</td>
<td>4,429,326</td>
<td>6,710,101</td>
<td>9,124,867</td>
</tr>
</tbody>
</table>
### Table 3. Estimated Smoking Prevalence in 2020 and 2030 under Base Case Scenario

<table>
<thead>
<tr>
<th>WHO Region</th>
<th>Prevalence in 2010</th>
<th>Estimated prevalence in 2020 if no additional control policies are implemented after 2010</th>
<th>Estimated prevalence in 2030 if no additional control policies are implemented after 2010</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Best Case</td>
<td>Expected</td>
</tr>
<tr>
<td>AFRO</td>
<td>15.8</td>
<td>16.7</td>
<td>19.4</td>
</tr>
<tr>
<td>AMRO</td>
<td>20.5</td>
<td>17.0</td>
<td>18.0</td>
</tr>
<tr>
<td>EMRO</td>
<td>22.4</td>
<td>21.7</td>
<td>22.9</td>
</tr>
<tr>
<td>EURO</td>
<td>31.2</td>
<td>28.9</td>
<td>30.2</td>
</tr>
<tr>
<td>SEARO</td>
<td>20.1</td>
<td>18.3</td>
<td>18.7</td>
</tr>
<tr>
<td>WPRO</td>
<td>28.5</td>
<td>25.8</td>
<td>27.6</td>
</tr>
<tr>
<td>All Regions</td>
<td>23.7</td>
<td>22.1</td>
<td>22.7</td>
</tr>
</tbody>
</table>

### Table 4. Estimated Prevalence in 2020 and 2030 under MPOWER Policies with 100% Price Increase

<table>
<thead>
<tr>
<th>WHO Region</th>
<th>Prevalence in 2010</th>
<th>Estimated prevalence in 2020 with MPOWER package implemented in 2010 with 100% price increase</th>
<th>Estimated prevalence in 2030 with MPOWER package implemented in 2010 with 100% price increase</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Best Case</td>
<td>Expected</td>
</tr>
<tr>
<td>AFRO</td>
<td>15.8</td>
<td>11.6</td>
<td>12.1</td>
</tr>
<tr>
<td>AMRO</td>
<td>20.5</td>
<td>11.1</td>
<td>11.6</td>
</tr>
<tr>
<td>EMRO</td>
<td>22.4</td>
<td>13.9</td>
<td>15.1</td>
</tr>
<tr>
<td>EURO</td>
<td>31.2</td>
<td>17.1</td>
<td>18.2</td>
</tr>
<tr>
<td>SEARO</td>
<td>20.1</td>
<td>13.3</td>
<td>13.5</td>
</tr>
<tr>
<td>WPRO</td>
<td>28.5</td>
<td>19.2</td>
<td>19.4</td>
</tr>
<tr>
<td>All Regions</td>
<td>23.7</td>
<td>15.0</td>
<td>15.4</td>
</tr>
</tbody>
</table>
Initiation and Cessation Feedbacks
Initiation Feedback

\[ \text{InitRate} = \alpha + \beta (S \times (T - S)) \]

\( S \) = Stock of “New” Smokers

\( T \) = Stock of “Potential New” Smokers
Cessation Feedback

\[ \text{Cess Rate} = \gamma \times t + \delta \times \text{RDS} \]

RDS = Recently Dead Smokers
QUESTIONS?
Systems Thinking in the Legislative Health Policy Arena
Our Founding

Georgia Health Decisions
*with philanthropic funding*

Georgia Healthcare Provider Council

Georgia Health Policy Center

Georgia Business Forum on Health

Georgia’s Public Sector
Our Approach

Create the **RIGHT** environment to have **IMPORTANT conversations**

Build and **VALUE relationships**

Bring in **relevant information** that is integrated, translated, and interpreted from primary and secondary research, best practices, and thought leaders.
Our Approach

Continuously learn within and among Projects & Programs

Think systemically about Tough Problems

ADVOCATE for a way to approach problems rather than a specific solution

Find CREATIVE ways to teach others what we have learned
Legislative Health Policy Certificate Program

- Program for state lawmakers who want to improve their understanding of health and health care
- Use systems dynamics and systems thinking to encourage broader and more systemic approaches to policymaking
- More than 75 Georgia legislators and staff have attended the course and 43 have received certificates
Legislative Health Policy Certificate Program

• Eight educational sessions over nine months (2011: changed to 4 session; same number of hours)

• Topics chosen based on priorities set by participants

• Those who complete 6 of 8 sessions (2011: 3 of 4) receive Health Policy Certificate from Andrew Young School of Policy Studies
Legislative Health Policy Certificate Program
2008, 2009, & 2011

Core Sessions:
• Evaluating Health Policy: The Framework
• The Impact of Health Status on the State
• Financing Health Care: Challenges and Opportunities
• Health Coverage and Access to Care

Issue Specific Sessions:
• Children’s Behavioral Health
• The Mental Health System
• Addressing Georgia’s Trauma Care Network
• Public Health Challenges
• Interventions to Reduce Childhood Obesity
• Health Reform
• Healthcare Financing II: Program Specifics & Payer Interactions
Course Curriculum

<table>
<thead>
<tr>
<th>Core Sessions</th>
<th>Issue Specific Sessions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>3</td>
<td>7</td>
</tr>
<tr>
<td>4</td>
<td>8</td>
</tr>
</tbody>
</table>

- Health policy content
- Systems thinking skills
- Application
Advanced Health Policy Institute
High-Leverage Solutions for Health Care Financing

• Content:
  • Framing Issues
  • Systems Thinking
  • Conversational Capacity
  • Improvisational Leadership

• Year One (2011-2012):
  • 19 attended
  • 17 received certificates
The Iceberg - A Metaphor for the Level at Which We Interact with a System

- Events
- Patterns of Behavior
- Systemic Structure
- Mind-sets

Depth of Interaction

Source: Sustainability Institute, adapted from other versions from the organizational learning field
A Six-Question Framework for Evaluating Policy

1. **What** is the important (perhaps troublesome) trend related to health in Georgia? **What** is the shape of this trend over the past several years?

2. **Who** are the stakeholders concerned about the trend?

3. **Why** this trend (what’s the cause, what is responsible)?

4. **Where** is there leverage (some policy) to address the underlying cause of the trend?

5. **How** will it work? **How** will it play out over time? **How** might unintended consequences occur? **How** might the policy positively or negatively impact...
   a) Health status?
   b) State health spending?
   c) Health care system?
   d) Health equity?

6. **When** would the policy create an impact on health status? When would you see an improvement in some other indicators (i.e., spending, services)?
A Range of Systems Thinking Skill Sets

- Apply Systems Thinking Skills: 95-100%
- Build Simple Maps: 40-50%
- Build Simple Models: 15-20%
- Build Complex Models: 2%
Healthy and Chronic Population Discussion
CST Exercise with GA Legislators

- What strategies might reduce the number:
  - becoming at risk?
  - becoming afflicted?
  - dying?

- How might we return At Risk to Healthy & Safe?

- What might be the most effective way to limit the vicious cycle loop’s impact?

Current treatment strategies might create a **vicious cycle** (aka bad Reinforcing Loop!)
More demand & spending for treatments on the **Chronic Population** means less spending on the **At Risk Population** means more **Chronic Population** needing treatments.
Applying Systems Thinking to Address Childhood Obesity in Georgia
Background on the Collaborative Systems Inquiry

- GHPC received funding from the Georgia Health Foundation to build upon the work of the Legislative Health Policy Certificate Program (LHPCP)
- LHPCP participants chose childhood obesity as an issue about which they wanted to learn more
- A team of 12 (mostly volunteers) worked for five months on developing the model and supporting materials
- The Collaborative Systems Inquiry project provided a tool for legislators trained in basic systems thinking to have a more rigorous discussion about an important policy issue
Perspectives on Models: 
Voices from the Cynic to Mystic

Cynic
“It’s **only** a model!”
“The world is much **more complex**, so it’s not useful.”
“Our situation is **unique** so your model doesn’t apply.”

Realist
“I use models all the time to make decisions, they’re just implicit and usually untested.”
“I can use a model to make my assumptions **explicit**, share them, improve them, **and test them**.”
“It will improve our ability to rigorously discuss the issues!”

Mystic
“It can predict the future.”
“If I can just get everything into the model, then it will be perfect.”

“All models are wrong, some are useful!”
- Box & Deming
Collaborative Modeling

Experts provide Input to model
- Legislators & Staff
- Nutritionists
- Epidemiologists
- Physical Activity Experts
- Economists

Model is used to rigorously tests assumptions

The Process
- Develop Purpose
- Build/Revise Model
- Test Model
- Add/Revise Policies
- Test Policies
- Engage Policymakers

- Ni–os above 2 Z scores age 0 to 6 meses
- Ni–os below 2 Z scores aged 0 to 6 meses
- Ni–os being born moving above 2 Z scores age 0 to 6 meses falling below 2 Z scores age 0 to 6 meses
- Ni–os above 2 Z scores age 7 to 24 meses becoming 7 meses
- Ni–os below 2 Z scores age 7 to 24 meses falling below 2 Z scores age 7 to 24 meses
- Ni–os above 2 Z scores age 2 to 5 años becoming 6 años logic
- Ni–os below 2 Z scores age 2 to 5 años moving above 2 Z scores age 7 to 24 meses falling below 2 Z scores becoming 6 años logic
- Ni–os expected to change nutrition status

- Total births
- ni–os born below 2 Z scores falling % 7 to 24 meses
- ni–os expected to change nutrition status
System map: 
Children age and become obese

- Created in STELLA by isee systems
- The lab’s model assumes children are in different categories
  1. **Obese**: Severely Obese & Moderately Obese
  2. **Non Obese**: Moderately Overweight and Not Overweight
- They **age**, and within age categories, they can **stay the same** or **change categories**
- We will use the lab to examine different **interventions** to help children **stay not obese** or **become not obese**
Practice Field: Test Policies
Practice Field: Test Policies

Instructions

Controls
- Run
- Reset
- Reset All
- Reset Output

Intervention Details
- Review Goals
- Detailed Output

School Based Policies
- Physical Education
  - Keep status quo?
  - Add and/or Enforce reg?
  - Increase & Enforce PE reg?
  - Improve quality (more activity?)

- School Nutrition Policies
  - % of Schools w/o a la Carte Lunch Options

- After School Programs
  - % of Students in After School Progs

Community Based Policies
- Develop Safe Routes to School

Healthcare Based Policies
- Medicaid reimbursement for nutrition counseling

Main Performance Metrics
- Overall Obesity %
- Change % in Ann Cost/Child
- % Change in Obesity Prevalence
- Cume Savings $ from Intervention(s)

Obesity Cost/Child
- Annual Obesity Cost $1
- Cume Obesity Cost $51
- Change % in Ann Cost/Child
- % Change in Obesity Prevalence
- Cume Savings $332

Obesity Prevalence (pg 1) and Cumulative Costs of Obesity (pg 2) Comparative Graphs

Trend graph of Obese% by Age

Years
- 2008
- 2010
- 2012
- 2014
- 2016
- 2018

Obese % by Age Category - Bar Chart (pg 1) & Trend Chart (pg 2)

1: Ages 0 to 1
2: Ages 2 to 4
3: Ages 5 to 10
4: Ages 11 to 13
5: Ages 14 to 18
Legislator Comments

“We were able to drop political personas and discuss ideas based on merits, which almost never occurs in the political arena.”

“It takes the politics out of the conversation by focusing on the physics of the system.”

“If our colleagues had knowledge of the six-question framework, perhaps we would all do a better job.”

“We never get to look at the same information at the same time like this (senate/house/republican/democrat) and talk about what we want to do.”

“The model shows impact of change in a scientific way and the fast turnaround of rerunning the model is very helpful.”
Lessons Learned:

Educating Legislators Using Systems Thinking and Dynamic Modeling

- One size does not fit all

- Curriculum Design:
  - Must be perceived as nonpartisan in content and delivery
  - Focus on the state, whenever possible
  - Avoid being too academic, biased or paper-heavy
  - Leave plenty of time for discussion

- Risk Taking: Systems thinking was a gamble that paid off

- Bi-partisan, bi-chamber participation is best venue to candidly discuss issues

- Legislative staff proved invaluable in modeling process
Applying Systems Thinking

The following curve is instructive regarding how to apply system dynamics

There’s value to be added at many points along the curve!

Developed by Barry Richmond and isee systems
The GHPC’s Other Systems Work

- Collaborative Modeling to Reduce Low Birth Weight
- Systems Thinking for Georgia Injury Prevention
- Mapping
  - Interdisciplinary Collaboration
  - Dynamics in the Dual Eligible Population
  - Sustainability and Technical Assistance
- PRISM Model
- ReThink Health Evaluation
ExTrain™ Leadership & Management Training
- War Game Simulations for hands-on training.
- For planners and decision makers: Strategic visioning workshops suitable for senior-level executives as well as managers in operations, budgeting, resource allocation, finance, HR, etc.
- Leadership development for managers to build their leadership capacity, enhance business acumen, and gain a more cross-functional and enterprise-level view.

ExPlan™ Planning & Performance Management
- Allows managers and analysts to project future changes in the organization in order to design policies to cope with strengths, weaknesses, opportunities and threats.
- Experiment with alternative strategies in a risk-free simulation environment in the form of a comprehensive custom computer simulation model of your business structure, strategies, and industry environment.

Studio™ Business Simulation Creation
- Consulting: custom business simulation development by Powersim Solutions consultants
- Software: Powersim Studio™ - system dynamics modeling software - to build your own models
- Training Workshops: learn to create business simulations with Powersim Studio™

Select Clients of Powersim Solutions
- ExTrain™ Leadership & Management Training
- ExPlan™ Planning & Performance Management
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Powersim Solutions is a leading simulation-based management consulting and technology services company based in Washington D.C. Metro. We work closely with our global clients to help them formulate, authenticate, communicate, and implement strategic-level computer-based simulations.

Powersim Solutions provides active learning workshops using business war games. We run war games for both small and large groups (hundreds of participants).
Chairs: Elizabeth Ginexi, Patricia Mabry, Kristen Hassmiler Lich
Presenters: David Mendez, Karen Minyard, Imrana Umar

Materials for the preconference workshop will be available as handouts onsite. The attachment, citation and links listed below are recommendations to review prior to the workshop.

a) LINK to software:
Download Powersim Studio, 30 day demo software trial

b) Attached PDF describes a bit about Powersim Solutions.

c) American Journal of Community Psychology
Original Paper, Using system dynamics modeling to understand the impact of social change initiatives
Gary B. Hirsch, Ralph Levine and Robin Lin Miller
http://www.springerlink.com/content/m48g6mk265816r96/?MUD=MP

(d) System Dynamics Modeling: Population Flows, Feedback Loops and Health
http://obsr.od.nih.gov/news_and_events/lectures_and_seminars/systems_symposia_series/system_symposium_four/seminars.aspx
Using system dynamics modeling to understand the impact of social change initiatives

Gary B. Hirsch · Ralph Levine · Robin Lin Miller

Abstract Community psychologists have a long history of interest in understanding social systems and how to bring about enduring positive change in these systems. However, the methods that community psychologists use to anticipate and evaluate the changes that result from system change efforts are less well developed. In the current paper, we introduce readers to system dynamics modeling, an action research approach to studying complex systems and the consequences of system change. We illustrate this approach by describing a system dynamics model of educational reform. We provide readers with an introduction to system dynamics modeling, as well as describe the strengths and limitations of the approach for application to community psychology.

Keywords System dynamics modeling · Systems thinking · System change methods · Educational reform

Introduction

From its earliest days, community psychology put complex community systems at the front and center of its psychological science and action (Sarason, 2000). Salient themes in our field highlight our closely held commitment to understanding how social systems affect individual lives and how to bring about enduring positive change in these systems to benefit individuals. Located throughout our theory and practice are the core tenets of an orientation toward system change. Our theoretical frameworks (e.g., Kelly, 1968, 1987; Seidman, 1988; Trickett, Kelly, & Vincent, 1985) provide blueprints for thinking about how social systems structure individual lives, how community processes are sustained, and where levers of change might reside. Our action-oriented projects illustrate principles and tactics for advancing change among individuals by changing elements of families, schools, work places, neighborhoods, and communities.

The methods that community psychologists use to anticipate and evaluate the changes that result from system change efforts are less well developed than our interest in stimulating systems change might imply (see, for example, Luke, 2005). We continue to rely on methods that assume a very different kind of world than the one that is reflected in the settings in which we work. The unidirectional models we use to try to draw links between a set of variables and an outcome are not consistent with what we know about the complexity of the phenomena we hope to study. Rather than develop small scale complex models of what we believe actually happens over time, we willingly suspend our disbelief that an uncomplicated, linear, and unidirectional snapshot fairly represents those processes of interest as they actually seem to unfold. In this way, we permit methods to obscure complexity by seeking to reduce a
phenomenon to a simple set of linear pathways. We also limit our opportunity to understand paradoxical and counter-intuitive behavior, relegating these system behaviors to the black box of poor model fit. In choosing our tools, we too often elect to ignore the interdependencies among real world processes that might provide us insight into how best to approach the task of creating and evaluating system change.

In the current paper, we introduce readers to an alternative approach to model development and assessment that community psychologists might use to gain insight about system change. The approach is called system dynamics modeling and is part of a larger class of systems approaches to understanding and solving complex problems. We first provide readers with an overview of the system dynamic modeling approach and describe its origins and potential applications. We describe how system dynamics modelers understand systems and change. We then describe how models are built and the potential for including stakeholders in the process. Next we illustrate the approach by presenting an example derived from the area of school reform. We examine how the system dynamics model was developed to provide insight on how to plan for a school-based system change effort around curricular innovation. We conclude by highlighting the strengths and limitations of the approach for community psychologists.

**Systems, systems change, and system dynamics**

To help readers to understand what system dynamics methods bring to the task of designing and evaluating system change, we first define the key terms, “system” and “system change” from the vantage point of system dynamics. We then highlight how a system dynamics expert thinks differently about modeling problems from a traditionally trained psychologist.

**Defining the system in system dynamics**

A system is a functional whole, composed of a set of components, coupled together to function in a way that might not be apparent from the functioning of the separate component parts (Levine & Fitzgerald, 1992). Systems change deals with changing the root causes of a problem through actions, policies, and new infrastructure. Systems change is qualitatively different from changing the intensity of a few system components to make minor corrections when a system gets a bit out of line. Systems change occurs when there are substantial changes in the structural, relational, and institutional makeup of a system or its subsystems. From this standpoint, system change is akin to redesigning some or all of the major systems in a car; it is not akin to a tune-up to improve how well the car runs. From a system dynamics point of view, efforts to change systems carefully consider how components of a system are coupled together, and not just what the components are, for the coupling of components allows one to locate the root causes of problems. Also, by considering the coupling of system components, one can understand why at times systems change efforts produce no apparent change and at other times change occurs in directions that are counter to what we desire and intend.

**System dynamics modeling and thinking**

System dynamics modeling is an action research approach to studying complex systems, such as families, organizations, and communities. System dynamics grew out of work by Forrester and others at the Massachusetts Institute of Technology who were trying to understand complex organizational behavior (see, for example, Forrester, 1961). Historically, system dynamics has focused on comparatively tangible processes that have discrete boundaries such as sales and the production of goods. As the field of system dynamics has developed, however, it has expanded in focus from internal organizational and intra-organizational dynamics to encompass the complex dynamic phenomenon of the kind that interests community psychologists. It has been used to explore problems such as highway congestion (Goodman, 1974; Sterman, 2000), the dynamics of urban growth and decline (Alfeld & Graham, 1976; Forrester, 1969), implementation of innovations (Repenning, 2002), community health status (Hirsch & Immediato, 1998, 1999; Homer, Hirsch, Minniti & Pierson, 2004), and human service delivery, (Hirsch, 1976; Miller, Levine, Khamarko, Valenti, & McNall, 2006), among many other issues. In this sense, system dynamics has become a broadly applicable school of systems science that emphasizes both a system’s behavior and the feedback mechanisms that are assumed to underlie a system’s behavioral patterns.

System dynamics builds on diverse sources of data and on group process techniques to develop computer simulations that allow for virtual experimentation with system change policies. On the face of it, the process of using system dynamics to explore a problem appears quite simple. A modeler or model building team develops a visual representation of a problem, specifying what processes they hypothesize give rise to problematic behavior in a system (e.g., high rates of student failure). The modeler or team then develops a set of mathematical equations to represent the model. Next, the team explores the model’s behavior and various policy actions via computer simulation. By policy actions, system dynamics modelers refer to the operational policies and actions that individuals and
groups use to attain goals. Finally, the team, having derived insights into the consequences of various policy actions, initiates real-world change efforts. This seemingly simple effort reflects a highly refined set of methodological procedures and very different way of thinking about model building than most psychologists are trained to do.

Basic elements of system dynamics models

Before we describe how models are built, we highlight critical elements of system dynamic models to introduce readers to its basic vocabulary and principles. A comprehensive introduction is beyond the scope of this article, but many excellent texts (e.g., Sterman, 2000) and training programs exist to provide interested readers with a more thorough introduction.

System dynamics modelers think in terms of feedback processes to account for problematic behavior patterns. The notion of causation flowing in one direction is pervasive among the social sciences. A vast majority of conceptual and statistical tools, from logic models to structural equation models, almost always go through casual chains that move in one direction. On the other hand, systems thinking stresses chains of reciprocal, causal relations among the variables. To system dynamics modelers, loops that form a nexus of closed relationships become important units of analysis per se, having a purpose and differing in importance or dominance over time. The loop becomes a higher conceptual unit than the variables that make up the circular chain. To the system dynamics modeler, a given variable may be in more than one feedback loop. Consider a variable that is common to two loop processes. The first loop may come around to affect the common variable in a positive way, while at the same time a second loop may affect the common variable in a negative direction. With experience, students who learn system dynamics eventually think in terms of both the variables that are involved in pushing the system around and the loop processes in which these variables might be embedded.

To illustrate, consider Fig. 1A, which is an adaptation of a model of the dynamics of the classroom developed by Nancy Roberts (Roberts, 1976a, b). An educational researcher who may be interested in student performance in the classroom could develop a traditional multiple regression model of how well both teacher and students function in a classroom setting. A regression analysis could be performed by generating a list of variables that affect the dependent variable, in this case, Student Performance (see Fig. 1). The regression model assumes that Student Performance, designated as the dependent variable, does not affect the antecedent variables. However, rarely does one find a real world process characterized by non-recursive, reciprocal relationships among the variables. Figure 1A is an example of what we might call, “unidirectional thinking.”

A system dynamics modeler thinks about dynamic processes through closed loop or feedback thinking. Figure 1B, based on Robert’s work, shows an example of closed loop thinking applied to the variables shown in Fig. 1A. In this case, Student Performance is affected by the help given by the teacher, which in turn is a function of the teacher putting more time and resources toward helping...
the student. The allocation of resources itself is affected by both the Students’ Perceived Need for Help and the Teacher’s Perception of Student Needs. These two variables are in turn determined by the level of Student Performance. In this configuration, the direction of causation is partly reversed from the model represented in Fig. 1A. Student Performance is affected by the other variables, but Student Performance also directly and indirectly affects them. Figure 1B is composed of two closed loop processes, which in this case, appear to move Student Performance in the same direction. In this network of loops, there are no pure dependent variables. Every variable plays the role of a mediator. To a system dynamics modeler, the two loops in Fig. 1B, each composed of variables, are core elements in understanding the potential for controlling student performance.

Representing dynamic structures

Causal loops

Figure 1B is what system dynamics modelers call a causal loop diagram or a CLD. System dynamics modelers indicate the nature of the change relationship between two variables using a simple sign system. Consider the variables in Fig. 1B. If a change in one variable, such as Help Given, generates a change in the same direction in another variable, such as Student Performance, then one would put an “S” for same, or in some system dynamics circles a “+” at the head of the arrow going from the first variable to the second variable. On the other hand, if a change in a variable, such as Student Performance, moves a variable in the opposite direction, such as Teacher’s Perception of Student Needs, then one would put a “O” (for opposite) or an “-” at the head of the arrow drawn between those variables. In Fig. 1B, the “S” on the end of the arrow drawn between Help Given and Student Performance indicates that as the student receives increased help from the teacher, the student’s level of performance increases. The “O” on the end of the arrow drawn between Student Performance and Teacher’s Perception of Student Needs indicates that as the student’s levels of performance increases, the teacher begins to pay less attention to assessing the student’s needs. Again, “S” means going in the same direction and an “O” means going in the opposite direction.

Reinforcing and balancing loops

Rather than focus on the potential causal relations between two variables at a time (the trees), system dynamics modelers first focus on larger units of causation (the forest) by trying to ask “what is the purpose of this process?” The answer is frequently a causal loop mechanism. In the situation depicted in Fig. 1B, the teacher has a policy of monitoring student performance to determine the appropriate allocation of time to each student. The teacher tries to deal with a decrease in student performance by allocating more time to helping the student improve performance. In turn, improvements in student performance lead to changes in allocation of time to the student. In a sense, that is the big picture. The system dynamics modeler has identified at least one causal loop that attempts to accomplish the system’s task, in this case generating adequate levels of student performance.

Causal loops fulfill one of two principal functions. Balancing (B) loops attempt to counteract change. If one of the variables in the loop increases or decreases, this type of loop works to bring the system back to the status quo, just as a thermostat functions to maintain a steady temperature. On the other hand, reinforcing (R) loops amplify the directional change in any of the variables in the loop by prompting either growth or decay (e.g., accelerating achievement scores, declining school enrollments). In Fig. 1B, the model has two balancing (B) loops, indicating that the system modeled here acts to keep student performance in a state of equilibrium relative to whatever the desired goals are for student performance.

System dynamics modelers are particularly interested in identifying what happens when loops go into “collapse mode” or what some people call a vicious cycle. An example of a reinforcing loop that drives the system into collapse mode would be what might happen with the growth of alternative charter schools that receive public funds and are located alongside public schools in public school districts. As the funds are taken away from the district’s traditional public schools, quality of the existing programs in the traditional schools may decrease, causing more pressure to charter more alternative schools and divert more funding to the existing charter schools. In turn, more charter schools and increases to their funds leads to cutting the resources of the public school system’s traditional schools even more. Ultimately, this pattern resembles a vicious cycle. A system dynamics modeler would attempt to understand why other loops that should prevent a vicious cycle from occurring, such as loops that ought to encourage gains in quality in public schools, fail to operate in such a circumstance.

Stocks and flows

System dynamics modelers distinguish between stocks (accumulations) and flows (decisions and actions). Psychologists, on the other hand, generally do not distinguish
between stocks and flows. In system dynamics, the stocks represent the accumulation of materials, energy, or information over time. A typical stock would be the number of teachers assigned to a school, the number of youth at risk of low academic attainment in a setting, the number of patients being served by a new clinic, or the level of experience with a new curriculum. In the psychological realm, stocks are processes that also take time to accumulate, such as aspiration, depression, prejudice, trust, power, attitudes, and beliefs. Flow variables represent the information processes and actions that change the value of the stocks. It is important to note that the only way a stock can change its level or intensity occurs through the action of one or more flow variables. Usually, stocks are what people follow or monitor over time. For instance, a state Department of Education may monitor scores on an achievement test in a given school district rather than monitor other potential indicators of student performance and school quality. For this reason, stocks are an essential feature of system dynamics models.

There are two major diagramming schemes used in system dynamics to convey the relationships among variables. The CLD, like the one found in Fig. 1B, makes it easy to locate the loop structure representing the root causes of the problem being studied. CLDs do not differentiate between the accumulating stocks and the flows that change those accumulations. Stock and flow diagrams provide a second way of representing the dynamics of the problem and are the basis for developing the model’s equations. Figure 2 shows an example of stocks and flows as well as their CLD counterparts. In Fig. 2A, the boxes are the stocks, in this case the Number of Students with Learning Problems and the (number) of Teachers. The four flow variables that change the stocks are represented by arrows that come in and out of the boxes and have spigots on them to signify the potential for controlling the rates of input or output. For instance, teachers flow out of the stock Teachers as a result of retirement, termination, quitting, or reassignment.

Now consider the differences between a stock and flow diagram and a CLD. Note that it is easier to tell where the loops are using a CLD representation. However, in Fig. 2A, one finds it easier to tell the difference between a stock variable and a flow variable. It takes time to hire and accumulate teachers, especially if there is turnover. Thus, one can see that a stock and flow representation points out the existence of lags in the system. The explicit modeling of lags or time delays in a system points out another critical difference between system dynamics and approaches that are more conventional within community psychology: our models typically do not explicitly acknowledge time delays.

**Fig. 2** Comparison of stock and flow and causal loop diagrams of same problem—student learning problems and teacher turnover. (A) Stock and flow diagram, and (B) Causal loop diagram.
Loop processes and changing the system

Why is this emphasis on specifying the underlying core structure via stocks, flows, and causal loops so important in system dynamics? If the loop structure helps to understand the problematic behavior patterns of a system, then the loop structure might help in the design and analysis of new policies and interventions that lead to desirable, long term solutions. System dynamics modelers use their models to explore how changes to the system might resolve the problem of interest.

A system dynamics modeler may suggest changes in a system by modifying its loop structure or creating a new loop process. Then the modeler can assess, via computer simulations, the impact of this new loop structure on how the system behaves. System dynamics modelers may also change the system by finding ways to block or slow the action of a loop that significantly contributes to the problem or by strengthening a loop that can counterbalance problem loops but that has not been able to operate effectively in the past.

An example of changing the loop structure and proposing one or more interventions can be illustrated by returning to the problem of helping students with learning problems and the problem of maintaining a supply of effective teachers in Fig. 2. The CLD version of the proposed feedback structure has been reproduced and augmented in Fig. 3. In this figure, the bolded arrows represent possible interventions that might be explored. First, one might attempt to cope with an increase in Teacher Workload by hiring more teachers (I). This, in effect, adds a connection between two variables in the model, Teacher Workload and the Desired Number of Teachers, creating a new model loop. The new loop is a balancing loop that is designed to deal with an increase in Teacher Workload and return workloads to manageable levels. It implies a new policy action in which the school monitors teacher workload and responds to increases in teacher workload through hiring.

Another possible intervention (II) might be to strengthen an existing balancing loop, one that serves to maintain the system in status quo. In the middle of the figure, there is a loop between hiring efforts and the number of teachers. Making the hiring process more efficient and responsive to a need to hire more teachers would strengthen the existing negative loop by speeding up how rapidly teacher hiring resulted in more teachers. An example of weakening a reinforcing loop that plays a key role in the dynamics of the problem would be to lighten the Teacher Workload by cutting down on non-essential tasks (III). As one can see from the figure, reducing the workload lowers Teacher Turnover. The Teacher Workload loop can become less dominant by finding ways to increase Teaching Effectiveness, such as developing a good mentoring system for inexperienced teachers.

Model building and exploration

We now turn to how these concepts are put together in the process of building and exploring the dynamic behavior of a model. In this section, we review how modelers collect and use data and how models are operationalized. We also discuss model building as a participatory process. For clarity, we present the process as if it proceeds in stages, when in fact model building typically proceeds iteratively. We do not discuss the technical details of developing model parameters, procedures for assessing model fit, and performing analyses. We refer readers to Graham (1980) and Sterman (2000) for an introduction to these topics.

Fig. 3 Use of loop structure for policy design to remedy student learning problems and teacher turnover

![Diagram showing loop processes and changes in system dynamics.](image-url)
Data sources

System dynamics uses a variety of techniques to develop and explore a model. Model building may rely on in-depth review of existing empirical and theoretical literature, collection of new qualitative or quantitative data, secondary data analyses, or on the experiences and opinions of people who are close to the process of interest. For instance, Homer and Milstein (2002) used multiple methods of inquiry to develop a model to look at the impacts of outside assistance, such as might be given by the CDC, on communities that might be afflicted by multiple diseases with multiple causes. Repenning (2002) used literature reviews and theory to examine why some companies that attempt to replicate new innovations fail and some are very successful, building his model exclusively from descriptions of variables in the literature. Lounsbury (2002) used epidemiological data and expert opinion to model the Michigan AIDS epidemic and changes in emphasis on care and treatment. Thus, system dynamics models may be built primarily on theory, extant knowledge, or data, or any combination of these.

A key characteristic of system dynamics is that one can combine quantitative and qualitative methods (Luna-Reyes & Andersen, 2003). System dynamics modelers, when given quantitative time series data, use fairly sophisticated estimation procedures to fit the system dynamics model to the data (see, for example, Peterson, 1980; Sterman, 2000). On the other hand, modelers may also include psychological and unmeasured processes for which there are not any time-ordered quantitative data. Modelers may use qualitative data to estimate trends in and behaviors of variables over time. For instance, modelers may have stakeholders plot curves to portray how variables qualitatively relate to one another over time. These plots can then be used to approximate functions.1

Operationalization of constructs and use of data

Assuming a model has been specified using CLDs or stocks and flows, system dynamics modelers face the challenge of operationalizing a model into equations in order to conduct simulations. Available simulation software allows modelers to develop the CLD and stock and flow diagrams directly on the screen, as well as the underlying equations of the model. Powersim (Bergen, Norway), STELLA (ISEE Systems, Lebanon, NH), and Vensim (Ventana Systems, Harvard, MA) are the three main simulation packages used by system dynamics modelers. Each is capable of allowing the modeler to sketch out non-linear relationships between variables, develop simultaneous model equations, and run model simulations.

To see how a modeler might apply available data and measures to specify model variables, consider Fig. 2. The dynamic picture suggests a mixture of variables that are not all equally easy to operationalize and quantify. There are two stocks in this figure, the number of teachers presently in the system and the number of students with learning problems. It may be trivial to obtain the size of the teaching staff over time from official personnel records. Students with Learning Problems might be a bit more difficult to measure, but once the construct is rigorously defined, such as the number of students who score below a defined level of performance, one can obtain records to estimate the number of students who teachers have found to have learning problems over time. Teacher Turnover, a flow or action variable, might be measured in turns of the number of teachers leaving per year or over some other unit of time. The hardest construct to measure in Fig. 2 may be Teaching Effectiveness, but measurement of this construct could be accomplished by developing a meaningful scale to represent the idea of effective teaching.2 That is, a model may not require an exact measure of how effective teaching in any particular school may be but require instead a scale of teaching effectiveness that has meaning logically and empirically.3 Finally, the Desired Number of Teachers could be assessed by talking to the school’s administrator or from formal documents suggesting a goal of having X number of teachers to teach Y number of classrooms.

As the prior example highlights, system dynamics modelers operate under a different paradigm than that of many social scientists developing models. Interest in discerning patterns over time, such as growth, overshoot, and collapse are a hallmark of the system dynamics method as opposed to a more intense interest in determining the statistical significance of a set of predictors or how much variance in the dependent variable any one predictor may explain. System dynamics focuses on explaining the structures that underlie the patterns in data over time. A valid, adequately detailed, and properly parameterized model will always fit the real world data fairly well. The true test of the model is that it can both reproduce the general pattern of behavior that the system exhibits in the real world and help the modeler and model users to understand what features of the system produce the pattern of behavior. Once they understand the source of that

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1 These patterns may also be used as reference modes. Reference modes are typical patterns of behavior that the system has been observed to produce.

2 One must be careful if the scales used are interval, because the time series patterns of Likert-type scales may differ from patterns generated by using a ratio scale technique. This problem has been addressed by Levine and Fitzgerald (1992).

3 In a recent project on health care, for example, we used meta-analytic data to quantify the average effectiveness of a particular type of program and the range of effectiveness.
behavior, they can determine how to deal with the problems it creates.

Working with stakeholders: group modeling efforts

System dynamics is intended to promote in-depth learning and insight about dynamically complex problems, so the methodology works especially well when individuals who initially hold diverse perspectives on an issue come to have a stake in the model by actively engaging in the model building process. For example, Van den Belt, a system dynamics modeler with a background in economics, has written an excellent text on what she calls “mediated modeling” to help build consensus among stakeholders who may not even care to meet others around the table (Van den Belt, 2004).

Modelers use a variety of techniques to build models in a participatory manner, such as creating model building teams composed of both modelers and substantive experts representing diverse points of view and using group process techniques such as scenario planning. Ideally, stakeholders should help formulate the problem behavior patterns to be modeled, evaluate the model’s assumptions and versions of the model runs, and also help discern the meaning and implications of computer simulations. In participatory model building, the stakeholders are typically trained and encouraged to do simulation runs on their own to find out for themselves how the model responds to ideas they might have about a new policy. The advantages to participatory model building cannot be overstated. As the constructs are refined, the modelers may obtain a better grasp on what the model should address by including stakeholders on the model-building team. Also, being asked to help in developing a model can be a very useful way to have people express and then challenge their cognitive maps or mental models of how the system works. It also makes explicit other participants’ cognitive maps, highlighting alternative sets of beliefs and values. Finally, as the model is generated from existing data, both researchers and participants can begin to understand what data are missing from the picture. This can lead to the design of new studies to obtain relevant data that were previously considered unimportant.

Once a model is up and running, having the participants generate and evaluate scenarios based on conditions that they have observed can lead to insight. Sometimes the output of the model matches the participants’ expectations. In this case it may help to validate the model in their minds. On the other hand, many models generate results that are counterintuitive. Perhaps a policy a participant favors works well at first and then becomes worse over time. An advantage of system dynamics models is that one can follow the logic of the model over time to see clearly why the expected results did not happen. The model may produce one or more unintended consequence that even those participants who know the system well could not have anticipated. This leads to better knowledge of the problem and impacts of policies.

Using system dynamics to understand system change in schools

To this point, we have discussed system dynamics in rather abstract terms. We now turn to a concrete example in which we describe how the first author worked with stakeholders to build a model of system change in schools. We briefly present the model and describe the process by which it was developed. The model we present concerns the process of changing schools by introducing innovations. Getting new curricula and other innovations adopted in schools is a notoriously difficult process.

The system dynamics modeling effort reported in this section arose from a conversation between Ted Sizer, a well-known educator and former Dean of the Harvard Graduate School of Education, and Jay Forrester, founder of the field of system dynamics who has devoted many years to its application to K-12 education. Sizer and Forrester pondered why adoption of innovation by schools has been so difficult and felt that there was a dynamic explanation in how innovations interact with all of the other things going on in schools. They felt that a better understanding of these dynamic phenomena could help to improve schools’ acceptance of new ideas.

The model building team and its goals

A working group was formed by Forrester and Sizer to examine the innovation process from a dynamic standpoint and included a system dynamics modeler, Gary Hirsch, several faculty from schools of education including one with extensive experience in system dynamics and K-12 education, the principal of a middle school organized around the principles of systems thinking, the director of a clearinghouse that provides systems curricula for schools, and a science teacher who has used system dynamics in his classroom.

The group first articulated the following goals for the curriculum innovation modeling: to identify factors that promote or hinder curriculum innovation and the adoption of new curricula; to develop an understanding of the dynamics of curriculum innovation and explain how the interaction of these factors over time can lead to successful innovations or innovations that fail to be adopted; to learn what characteristics of schools and school systems encourage or resist successful adoption of innovations; to identify policies and programs that serve as leverage points for increasing the likelihood of successful innovation; and,
to simulate the potential impact of those interventions and determine which combinations of policies and programs are likely to be most effective.

Defining the model

The work of the group and their consultant followed a classic sequence for system dynamics modeling efforts alluded to earlier. The first meeting was an open-ended session in which these goals and key variables were identified. This was initially a straightforward process of eliciting and explaining important factors. The discussion included some basic questions such as “What is an innovation?” and “What is successful adoption?” It was agreed that an innovation is a significant change in how a subject is taught rather than incremental change in content.

The next task of the group was to identify the factors that enable curriculum innovations to be successfully adopted in schools or to fail. Some of the factors identified were relatively straightforward such as the amount of time teachers have available for learning about and working with the new curriculum. Adopting a new curriculum competes with teachers’ many other responsibilities and lack of time may doom a curriculum innovation. Another factor was teacher motivation. Teachers’ motivation, in turn, depends on their past experience with innovation, the need for innovation that they perceive, an awareness of innovation going on elsewhere, and the stress experienced by teachers created by the combination of their day-to-day responsibilities and adopting new ways of doing things. The group also began talking about causal relationships between these variables.

The group also identified the mode of student evaluation as an important variable. Having the appropriate mode of student evaluation enables a school to both identify student needs that might be met by new curricula and the impact of innovations that are adopted. For example, the impact of an innovation designed to improve students higher-level thinking skills may not be adequately measured by multiple choice tests and may appear to offer little advantage over learning by rote. More elaborate methods of evaluation such as the preparation and presentation of student portfolios may be necessary to reflect higher-level skills. The group described structural flexibility as another co-requisite of innovation. Certain innovations, for example, may require different arrangements such as double-periods for certain types of exploratory exercises. A scheduling system that makes these changes easier will increase the likelihood that an innovation will succeed. Another important variable that came out of the group’s discussions was the trust between the schools and the community. Past successes will allow the community to give the school the necessary resources and to be patient while awaiting the results of the innovation. Past failures, on the other hand, may make the community members resistant to curriculum innovation because they do not trust the schools to implement it properly.

The working group was the principal source of this information. As suggested earlier, other modeling efforts may draw on a wider range of people and input. We certainly would have done so if we were working with a particular set of stakeholders in a real-world school system that needed to be informed about and invested in the process, as well as providing qualitative data.

As these factors were identified in a series of meetings, the modeler sketched CLDs that related the factors to each other. Figure 4 shows a sample of the work at this stage. In Fig. 4, the relationships among experience with innovation, teacher motivation, and curriculum innovations adopted are presented. The relationships in Fig. 4 form a reinforcing loop, explained earlier, in which a high level of teacher motivation will improve the chances of innovations being adopted and lead to better experience with innovation and a continued high level of motivation and receptivity to innovations in the future. Conversely, poor experience with innovation will reduce motivation and make it difficult to sustain effort on those innovations or have future innovations adopted.

Identifying the reference modes

The next step was to identify ‘reference modes’ or alternative patterns of behavior typically observed in the real world systems being modeled. The group discussed how innovations typically proceed. When innovations are successful does adoption proceed at a steady pace or in fits and starts? Is there sometimes an interim success as part of the curriculum is adopted followed ultimately by failure when the implementation process “runs out of steam” before the innovation is fully installed? Identifying the reference modes allowed us another check on the model to see that there were the necessary factors to explain the different trajectories that an innovation might take.

Figure 5 provides an overview of the complete model and shows how trust between schools and the community interacts with the other variables. Additional reinforcing loops through this trust variable enable success to build on success and cause failure to initiate a downward spiral that becomes an impediment to future innovation.

Developing stock and flow diagrams

The structure shown in Fig. 5 was then converted to a stock and flow diagram prior to creating the simulation model. A portion of the stock and flow model derived from this causal structure is shown in Fig. 6. Adding this level of specificity provoked more discussion about the exact nature of the relationships.
Fig. 4 Factors affecting teacher motivation

Fig. 5 Overview of factors affecting curriculum innovation

Fig. 6 Stock and flow structure related to curriculum innovation
Figure 6 shows a central part of the stock and flow structure for the curriculum innovation model. Curriculum Innovations Initiated depends on school system’s policy and the system’s capacity to deal with change. The fraction of Curriculum Innovations in Process that is adopted depends on the levels of Teacher Motivation and Structural Flexibility (e.g., ability of scheduling system to accommodate different-sized blocks of time). Innovations not adopted are discarded. Curriculum Innovations Adopted can remain in place for a considerable period of time until they become obsolete.

Simulating policy impacts

These stock and flow diagrams were then converted to a mathematical simulation model that could be used to pose “what if?” questions about different strategies for promoting the adoption of innovations. A software package called Vensim, mentioned earlier, was used to develop the simulation model. Vensim enables modelers to sketch out diagrams such as those shown in Figs. 4–6, develop an equation for each relationship represented by arrows in the diagrams, and then run simulations. Equations can include simple algebraic relationships or complex ones that include logical statements (IFTHEN-ELSE) and non-linear relationships that are drawn on graphs rather than being expressed algebraically. Simulations are done by starting with a specified set of initial conditions, using the equations to calculate changes that occur over the first time interval, updating the state of the system to reflect those changes, and then using the new system state to calculate the changes over the next time period.

As indicated above, many of the variables the group identified were deemed important, but there were no data from studies that could help with the model’s quantification. As we previously noted, it is not uncommon that the data available for variables that are central in understanding the dynamics of the problem have not been collected over time. System dynamics modelers will often use qualitative data instead because the variables in the model are essentially latent variables and need only be quantified enough to reproduce the pattern of behavior that has been observed by actors in the system. Figure 7 shows an example of one of the relationships developed with the working group’s help. This one relates the level of Teacher Motivation to the Fraction of Innovations Adopted. Motivation is scaled from zero to one. A high level of motivation will result in the maximum Fraction of Innovation Adopted while a low level of Teacher Motivation may keep any innovations from being adopted at all.

How is Teacher Motivation assumed to be affected over time? One determinant is the relationship between Experience with Innovation and its Effect on Teacher Motivation. Poor past experience with innovation will leave teachers relatively unmotivated to adopt new curricula. On the other hand, positive experiences may make them eager to do so. The model’s equations are written so that results of innovation over time falling below the expected impact will cause Experience with Innovation to take on a negative value Experience with Innovation can vary from values of –50 to +50. Better than expected results will produce a positive value. The working group helped develop the relationship shown below in Fig. 8 in which very negative Experience with Innovation will cause Teacher Motivation relative to adopting innovation to be 50% lower than if Experience with Innovation had been neutral. Very positive past Experience with Innovation (the cumulative effect of exceeding expectations over time) will result in Teacher Motivation that is 50% higher, all other things being equal.
Once the model was quantified, a series of simulations provided several insights, only a few of which space allows us to highlight here (see Hirsch, 1998 for a more complete discussion of the model and simulation results). For these simulations, starting values of community characteristics such as Trust between School and Community were chosen to be neutral and typical of the ‘‘average’’ community. The working group had a critical role in terms of reality-testing the results and helping to assess whether the model was responding appropriately or might still be lacking some elements.

Figure 9 shows the typical output from a simulation, a set of graphs that display the behavior of variables of interest over time. The graphs show the result of implementing a curriculum innovation by itself without doing anything to change the methods used for student evaluation or increasing structural flexibility.

Not surprisingly, as the graphs in Fig. 9 demonstrate, implementation of curriculum innovation on its own is likely to fail. The Impact of Innovation reaches a level that is significantly below the Level of Expected Impact. Expected Impact could reflect results that other school districts have achieved with that curriculum innovation or results promised by its proponents. Structural changes would have been needed to facilitate adoption. The Measured Impact of Innovation, reflecting both the Impact of

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**Fig. 9** Results of simulation with curriculum innovation alone (Curriculum innovation introduced at time = 0). (A) Graphs of impact on innovation in simulation with curriculum innovation alone, and (B) Graphs of community variables in simulation with curriculum innovation alone. Note that scales on vertical axes of all of these graphs correspond to the variables listed below the graphs in the same order. Thus in graph B, the first variable, Experience with Innovation, is plotted on a scale of −40 to +40. Trust Between School and Community and Teacher Motivation are plotted on scales of 0–0.6. The x-axis on all graphs is time in months.
Innovation and Mode of Student Evaluation, is essentially zero since the innovation is being evaluated with traditional methods in this simulation. Changes in the mode of student evaluation are necessary for the impact of innovation to be properly measured. The poor Experience with Innovation sets off a downward spiral of Trust between School and Community and Teacher Motivation that makes adoption impossible. Clearly, the results of this first simulation suggest that curriculum innovation needs to be coordinated with how students are evaluated and other structural changes. However, as the group found when they suggested a more comprehensive strategy, trying to do everything at once—implement a curriculum innovation, change the mode of student evaluation, and increase structural flexibility—also produces poor results. The simulation results revealed that doing everything at once leaves too little time for any one task and causes curriculum innovation to stretch out over an unacceptably long time period. As shown in Fig. 10, temporary success gives way to failure as teachers succumb to the stress of trying to do too much at once and Teacher Motivation falls. As a result, the innovation fails to meet expectations and is assumed to be a failure, setting off a downward spiral in the loops through Teacher Motivation and Trust Between Schools and the Community.

This result suggested another experiment. What if the school initiated changes in student evaluation and structural flexibility, but gave those changes 2 years to have their effect before undertaking the bulk of the curriculum innovation? The results shown in Fig. 11 suggest that delaying curriculum innovation for 2 years until the new mode of student evaluation and structural flexibility are in place helps to overcome this problem and allows enough time to then be concentrated on adopting the innovation. Successful Experience with Innovation helps keep Teacher Motivation and Trust Between Schools and the Community at a high level.

Explorations of this sort carried out with the model, often referred to as sensitivity analyses, provided some additional insights of where there might be sources of leverage. For example, changes in the amount of time devoted to the “traditional curriculum” can have a significant effect on the success of innovations. Introducing a policy that reduces the time devoted to the traditional curriculum, in addition to delaying the introduction of a new curriculum, produces even better results. With this policy addition, successful curriculum innovation will set another reinforcing loop in motion in which increases in students’ ability to learn will reduce the time required for the traditional curriculum even further and leave more time for the new curriculum. On the other hand, increases in the traditional curriculum, possibly required by “teaching to the test” in response to statewide high-stakes testing, will leave too little time for adopting innovation and cause attempts at innovation to fail at a time when they are badly needed. Other activities that seem like a good idea, such as professional development, can add to teachers’ time burden and indirectly serve as impediments to innovation.

Our illustration highlights how system dynamics creates opportunities for gaining insight about changing systems. For example, our group learned that curriculum innovations, especially in the form of large projects, are likely to fail unless they are undertaken in the context of the larger set of changes needed for them to succeed. Strategies work best when they focus on leverage points in a system. These leverage points are often found on reinforcing loops where they can help to promote growth processes or prevent downward spirals. In this example, leverage was achieved...
through coordinated and properly sequenced introduction of related innovations in structural flexibility and student evaluation that led to favorable conditions for curriculum innovation, successful innovation, and sustained conditions supporting further innovation. Working with the simulator to explore multiple “what if?” scenarios highlighted why it is essential to understand the systemic effects of changes, including possible unintended consequences, rather than simply focusing on their direct effects.

Conclusion

System dynamics provides community psychologists with a useful approach to modeling a system’s complexity and to understanding why it generates particular patterns of behavior. By better understanding what processes produce a system’s behavior, we gain insight into why particular system change efforts produce the effects that they do. As we have shown, system dynamics modeling also allows us to experiment with alternative change efforts and learn about the probable consequences of these efforts as a basis for policy and intervention planning.

System dynamics enables community psychologists to work with a range of variables including those that have been the subject of rigorous empirical research and others that people know from experience are important, but have not been as rigorously studied. By incorporating both types of variables into a model, system dynamics allows us to treat community members’ insights as equally valid as empirical research and submit these ideas to logical scrutiny. Further, we can test out community members’ ideas and beliefs about the causes of social problems and examine the conditions under which these might hold. Simulation is a valuable tool for testing the potential impact of interventions. It is too difficult for the unaided mind to understand how the complex interactions in systems will affect the efficacy of interventions and the possibility of unintended consequences that can worsen problems. Group model building techniques let real-world practitioners get involved in model-building and enhance their own understanding while keeping the work grounded in practical concerns.

System dynamics allows us to represent problems in terms of underlying causal structures amenable to intervention rather than treating them simply as a string of seemingly isolated variables. System dynamics provides a tool for understanding structures responsible for multiple community problems such as poverty, crime, and drug use rather than seeing them as separate entities (see, for example, syndemics work of Homer & Milstein, 2002). Models also enable a problem focus that crosses disciplinary boundaries and incorporates clinical, epidemiological, economic, political, and other variables in a framework that makes sense to professionals and community members tackling the problems in the real world. The ability of system dynamics to integrate diversity of perspectives into a single model is among its unique strengths.

System dynamics, like any approach, is not without its limitations, four of which we highlight here. First, although the models system dynamics produces may be more realistic representations of complex processes than are path...
diagrammatic models and though system dynamics can handle more complexity than traditional social science modeling approaches, system dynamics cannot capture the full complexity of a process. At some point, modelers must choose which system elements and interactions can produce useful insight about a problem and are feasible to handle in a single model. System dynamics can bring us closer to examining complex systems, though it cannot help us to do so perfectly.

Second, system dynamics models are also as good as the thinking and assumptions that underlie them. A principal reason for participatory, multisectoral, multidisciplinary model building and reliance on multiple forms of data is to make the assumptions that underlie models as credible as possible to as diverse an audience as possible. Yet, no model can fully satisfy all of its critics and system dynamics models are no exception. Third, model building requires skill and experience. Learning how to build and examine models can take many years of training, so community psychologists may not be able to apply these techniques without the assistance of a system dynamics collaborator. Fourth, system dynamics model results are not predictions. Rather, models allow us to play out a set of scenarios for change in ways that challenge the simple mental model of problems that our current methods of study force us to adopt. Yet, it is in these experiments that we can challenge our own thinking about how to create and evaluate planned efforts at system change.

References


