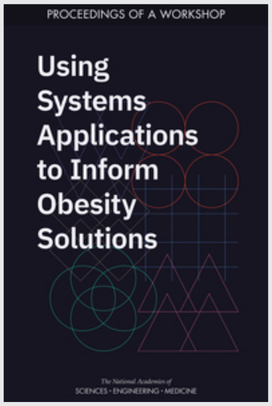

Using Systems Applications to Inform Obesity Solutions: Proceedings of a Workshop (2021)

DETAILS

96 pages | 6 x 9 | PAPERBACK
ISBN 978-0-309-68172-8 | DOI 10.17226/25900

CONTRIBUTORS

Emily A. Callahan, Rapporteur; Roundtable on Obesity Solutions; Food and Nutrition Board; Health and Medicine Division; National Academies of Sciences, Engineering, and Medicine

SUGGESTED CITATION

National Academies of Sciences, Engineering, and Medicine 2021. *Using Systems Applications to Inform Obesity Solutions: Proceedings of a Workshop*. Washington, DC: The National Academies Press. https://doi.org/10.17226/25900.

Using Systems Applications to Inform Obesity Solutions

PROCEEDINGS OF A WORKSHOP

Emily A. Callahan, *Rapporteur*

Roundtable on Obesity Solutions

Food and Nutrition Board

Health and Medicine Division

The National Academies of
SCIENCES · ENGINEERING · MEDICINE

THE NATIONAL ACADEMIES PRESS
Washington, DC
www.nap.edu

THE NATIONAL ACADEMIES PRESS 500 Fifth Street, NW Washington, DC 20001

This activity was supported in part by the Academy of Nutrition and Dietetics; Alliance for a Healthier Generation; American Academy of Pediatrics; American College of Sports Medicine; American Council on Exercise; American Society for Nutrition; Banner Health; Bipartisan Policy Center; Blue Cross and Blue Shield of North Carolina Foundation; General Mills, Inc.; Intermountain Healthcare; The JPB Foundation; The Kresge Foundation; Mars, Inc., National Recreation and Park Association; Nemours; Novo Nordisk; Obesity Action Coalition; The Obesity Society; Partnership for a Healthier America; Reinvestment Fund; Robert Wood Johnson Foundation; SHAPE America; Society of Behavioral Medicine; Wake Forest Baptist Medical Center; Walmart; WW International; and YMCA. Any opinions, findings, conclusions, or recommendations expressed in this publication do not necessarily reflect the views of any organization or agency that provided support for the project.

International Standard Book Number-13: 978-0-309-68172-8
International Standard Book Number-10: 0-309-68172-3
Digital Object Identifier: https://doi.org/10.17226/25900

Additional copies of this publication are available from the National Academies Press, 500 Fifth Street, NW, Keck 360, Washington, DC 20001; (800) 624-6242 or (202) 334-3313; http://www.nap.edu.

Printed in the United States of America

Suggested citation: National Academies of Sciences, Engineering, and Medicine. 2021. *Using systems applications to inform obesity solutions: Proceedings of a workshop*. Washington, DC: The National Academies Press. https://doi.org/10.17226/25900.

The National Academies of
SCIENCES • ENGINEERING • MEDICINE

The **National Academy of Sciences** was established in 1863 by an Act of Congress, signed by President Lincoln, as a private, nongovernmental institution to advise the nation on issues related to science and technology. Members are elected by their peers for outstanding contributions to research. Dr. Marcia McNutt is president.

The **National Academy of Engineering** was established in 1964 under the charter of the National Academy of Sciences to bring the practices of engineering to advising the nation. Members are elected by their peers for extraordinary contributions to engineering. Dr. John L. Anderson is president.

The **National Academy of Medicine** (formerly the Institute of Medicine) was established in 1970 under the charter of the National Academy of Sciences to advise the nation on medical and health issues. Members are elected by their peers for distinguished contributions to medicine and health. Dr. Victor J. Dzau is president.

The three Academies work together as the **National Academies of Sciences, Engineering, and Medicine** to provide independent, objective analysis and advice to the nation and conduct other activities to solve complex problems and inform public policy decisions. The National Academies also encourage education and research, recognize outstanding contributions to knowledge, and increase public understanding in matters of science, engineering, and medicine.

Learn more about the National Academies of Sciences, Engineering, and Medicine at **www.nationalacademies.org**.

The National Academies of

SCIENCES • ENGINEERING • MEDICINE

Consensus Study Reports published by the National Academies of Sciences, Engineering, and Medicine document the evidence-based consensus on the study's statement of task by an authoring committee of experts. Reports typically include findings, conclusions, and recommendations based on information gathered by the committee and the committee's deliberations. Each report has been subjected to a rigorous and independent peer-review process and it represents the position of the National Academies on the statement of task.

Proceedings published by the National Academies of Sciences, Engineering, and Medicine chronicle the presentations and discussions at a workshop, symposium, or other event convened by the National Academies. The statements and opinions contained in proceedings are those of the participants and are not endorsed by other participants, the planning committee, or the National Academies.

For information about other products and activities of the National Academies, please visit www.nationalacademies.org/about/whatwedo.

PLANNING COMMITTEE ON USING SYSTEMS APPLICATIONS TO INFORM OBESITY SOLUTIONS[1]

CHRISTINA ECONOMOS (*Co-Chair*), Co-Founder and Director, ChildObesity180; Professor and New Balance Chair in Childhood Nutrition, Friedman School of Nutrition Science and Policy, Tufts University
NICOLAAS (NICO) PRONK (*Co-Chair*), President, HealthPartners Institute; Chief Science Officer, HealthPartners, Inc.; and Adjunct Professor, Harvard T.H. Chan School of Public Health
JAMY D. ARD, Professor, Department of Epidemiology and Prevention and Department of Medicine, Wake Forest University Baptist Medical Center
SARA CZAJA, Professor of Gerontology in Medicine, Weill Cornell Medicine
BRUCE Y. LEE, Professor, Health Policy and Management, City University of New York Graduate School of Public Health; Executive Director, Public Health Informatics, Computational, and Operations Research
DOUGLAS LUKE, Irving Louis Horowitz Professor in Social Policy and Director of the Center for Public Health Systems Science, Washington University in St. Louis
DAVID MENDEZ, Associate Professor, Department of Health Management and Policy, University of Michigan School of Public Health
DANIEL RIVERA, Professor of Chemical Engineering and Program Director of the Control Systems Engineering Laboratory, Arizona State University
STELLA YI, Assistant Professor, Department of Population Health, New York University Grossman School of Medicine

Health and Medicine Division Staff

LESLIE J. SIM, Roundtable Director (*through December 2020*)
HEATHER DEL VALLE COOK, Roundtable Director
AMANDA NGUYEN, Program Officer
CYPRESS LYNX, Research Associate
MEREDITH YOUNG, Research Associate
ZARIA FYFFE, Senior Program Assistant

[1]The National Academies of Sciences, Engineering, and Medicine's planning committees are solely responsible for organizing the workshop, identifying topics, and choosing speakers. The responsibility for the published Proceedings of a Workshop rests with the workshop rapporteur and the institution.

ROUNDTABLE ON OBESITY SOLUTIONS[1]

NICOLAAS (NICO) PRONK (*Chair*), HealthPartners Institute and HealthPartners, Inc., Bloomington, Minnesota
CHRISTINA ECONOMOS (*Vice Chair*), ChildObesity180 and Tufts University, Boston, Massachusetts
IHUOMA ENELI (*Vice Chair*), American Academy of Pediatrics, Columbus, Ohio
SHARON ADAMS-TAYLOR, The School Superintendents Association, Alexandria, Virginia
KATIE ADAMSON, YMCA of the USA, Washington, DC
JAMY D. ARD, Wake Forest University, Winston-Salem, North Carolina
ELLEN BECKJORD, UPMC Health Plan, Pittsburgh, Pennsylvania
ROBIN P. BLACKSTONE, University of Arizona, Phoenix
HEIDI MICHELS BLANCK, Centers for Disease Control and Prevention, Atlanta, Georgia
JEANNE BLANKENSHIP, Academy of Nutrition and Dietetics, Washington, DC
SARA N. BLEICH, Harvard T.H. Chan School of Public Health, Boston, Massachusetts
DON W. BRADLEY, Duke University, Durham, North Carolina
HEIDI F. BURKE, Greater Rochester Health Foundation, Rochester, New York
JAMIE BUSSEL, Robert Wood Johnson Foundation, Princeton, New Jersey
DEBBIE I. CHANG, Blue Shield of California Foundation, San Francisco
MERRY DAVIS, Blue Cross and Blue Shield of North Carolina Foundation, Durham
JENNIFER FASSBENDER, Reinvestment Fund, Philadelphia, Pennsylvania
AMENDA FISHER, Walmart, Rogers, Arkansas
GARY D. FOSTER, WW International, New York, New York
DAVID FUKUZAWA, The Kresge Foundation, Troy, Michigan
TODD GALATI, American Council on Exercise, San Diego, California
ALLISON GERTEL-ROSENBERG, Nemours Children's Health System, Washington, DC
MARJORIE A. INNOCENT, National Association for the Advancement of Colored People, Baltimore, Maryland
JOHN JAKICIC, University of Pittsburgh, Pennsylvania
ELIZABETH A. JOY, Intermountain Healthcare, Salt Lake City, Utah
SCOTT I. KAHAN, The George Washington University, Washington, DC

[1] The National Academies of Sciences, Engineering, and Medicine's forums and roundtables do not issue, review, or approve individual documents. The responsibility for the published Proceedings of a Workshop rests with the workshop rapporteur and the institution.

PETER T. KATZMARZYK, Pennington Biomedical Research Center, Baton Rouge, Louisiana
CATHERINE KWIK-URIBE, Mars, Inc., Germantown, Maryland
THEODORE KYLE, The Obesity Society, Pittsburgh, Pennsylvania
LISEL LOY, Bipartisan Policy Center, Washington, DC
MONICA VALDES LUPI, The Kresge Foundation, Troy, Michigan
KELLIE MAY, National Recreation and Park Association, Ashburn, Virginia
STACY MOLANDER, Partnership for a Healthier America, Washington, DC
MYETA M. MOON, United Way Worldwide, Alexandria, Virginia
STEPHANIE A. MORRIS, SHAPE America, Reston, Virginia
JOSEPH NADGLOWSKI, JR., Obesity Action Coalition, Tampa, Florida
MELISSA NAPOLITANO, The George Washington University, Washington, DC
PATRICIA NECE, Obesity Action Coalition, Alexandria, Virginia
MEGAN NECHANICKY, General Mills, Inc., Minneapolis, Minnesota
COURTNEY P. PAOLICELLI, Food and Nutrition Service, U.S. Department of Agriculture, Alexandria, Virginia
BARBARA PICOWER, The JPB Foundation, New York, New York
SUE P. POLIS, National League of Cities, Washington, DC
AMELIE G. RAMIREZ, Salud America!, San Antonio, Texas
TOM RICHARDS, American Council on Exercise, Arnold, Maryland
NANCY E. ROMAN, Partnership for a Healthier America, Washington, DC
SYLVIA ROWE, SR Strategy, LLC, Washington, DC
LAURIE STRADLEY, Alliance for a Healthier Generation, Asheville, North Carolina
SUSAN Z. YANOVSKI, National Institute of Diabetes and Digestive and Kidney Diseases, National Institutes of Health, Bethesda, Maryland
LESLIE PLATT ZOLOV, Novo Nordisk, Plainsboro, New Jersey

Health and Medicine Division Staff

LESLIE J. SIM, Roundtable Director (*through December 2020*)
HEATHER DEL VALLE COOK, Roundtable Director
AMANDA NGUYEN, Program Officer
CYPRESS LYNX, Research Associate
MEREDITH YOUNG, Research Associate
ZARIA FYFFE, Senior Program Assistant
ANN L. YAKTINE, Director, Food and Nutrition Board

Consultant

WILLIAM (BILL) H. DIETZ, The George Washington University, Washington, DC

Reviewers

This Proceedings of a Workshop was reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise. The purpose of this independent review is to provide candid and critical comments that will assist the National Academies of Sciences, Engineering, and Medicine in making each published proceedings as sound as possible and to ensure that it meets the institutional standards for quality, objectivity, evidence, and responsiveness to the charge. The review comments and draft manuscript remain confidential to protect the integrity of the process.

We thank the following individuals for their review of this proceedings:

JENNIFER FASSBENDER, Reinvestment Fund
JILL REEDY, National Institutes of Health
BONNIE SPRING, Northwestern University Feinberg School of Medicine

Although the reviewers listed above provided many constructive comments and suggestions, they were not asked to endorse the content of the proceedings, nor did they see the final draft before its release. The review of this proceedings was overseen by **RUSSELL R. PATE,** University of South Carolina. He was responsible for making certain that an independent examination of this proceedings was carried out in accordance with standards of the National Academies and that all review comments were carefully considered. Responsibility for the final content rests entirely with the rapporteur and the National Academies.

Contents

APPENDIXES

Boxes and Figures

BOXES

FIGURES

1

Introduction

A virtual workshop titled Using Systems Applications to Inform Obesity Solutions, held on September 16, 2020, was convened by the Roundtable on Obesity Solutions, Health and Medicine Division, National Academies of Sciences, Engineering, and Medicine. This workshop built on a prior roundtable workshop (held in April [Part 1] and June [Part 2] 2020), which introduced complex systems thinking and explored systems science approaches to obesity solutions. The September 2020 workshop explored various systems science approaches (i.e., methodologies and tools) and support structures that could guide future obesity research and action, and featured examples of how these approaches can inform decision making within policy and program areas.[1] Workshop speakers discussed the support structures (e.g., data sources, modeling expertise, training, and partnerships and collaborations) that encourage and engage researchers and decision makers to use systems science approaches to better understand the causes of and solutions to the obesity epidemic. Note that throughout this proceedings, the terms systems science "applications," "approaches," "methods," and "models" are used interchangeably to describe analytical

[1] The planning committee's role was limited to planning the workshop, and the Proceedings of a Workshop was prepared by the rapporteur as a factual account of what occurred at the workshop. Statements, recommendations, and opinions expressed are those of individual presenters and participants and are not necessarily endorsed or verified by the National Academies of Sciences, Engineering, and Medicine. They should not be construed as reflecting any group consensus.

BOX 1-1
Workshop Statement of Task

A planning committee of the National Academies of Sciences, Engineering, and Medicine will organize a 1-day public workshop that will feature invited presentations and discussions to build on a previous workshop on complex systems science by exploring (1) various modeling approaches that could guide future obesity research and action, and (2) the structures needed to support the use of these approaches for researchers and policy and programmatic decision makers across society.

Workshop presentations will provide examples of systems applications (e.g., participatory modeling, group model building, system dynamics, social network analysis, network science, cost effectiveness, and agent-based modeling) related to ongoing obesity research studies. The workshop will feature examples of how various types of modeling can inform decision making within policy and program areas (e.g., by highlighting the application and evaluation of these models in research and practice).

Presentations will also include discussions about the support structures (e.g., data sources, systems/modeling expertise and resources, training, partnerships and collaborations, effective communications) to encourage and engage researchers and decision makers in using systems modeling techniques to more effectively and efficiently understand the causes of and solutions to the obesity epidemic.

methodologies and tools. (See Appendix D for a glossary of terms used herein.) The workshop's Statement of Task is in Box 1-1.[2]

INTRODUCTORY REMARKS

Nicolaas (Nico) Pronk, president of HealthPartners Institute, chief science officer at HealthPartners, Inc., and chair of the Roundtable on Obesity Solutions, welcomed participants and provided a brief overview of the roundtable. He explained that the roundtable engages leaders and voices from diverse sectors and industries (e.g., academia, government, health and health care, business, finance, media, education, child care, philanthropy, nonprofit) to help solve the nation's obesity crisis. Through meetings, public workshops, reports, and four innovation collaboratives, he continued, the roundtable provides a venue for ongoing dialogue on critical and emerging issues in obesity prevention, as well as treatment and weight maintenance.

[2] The workshop agenda, presentations, and other materials are available at https://www.nationalacademies.org/event/09-16-2020/using-systems-applications-to-inform-obesity-solutions-a-workshop (accessed December 28, 2020).

It applies a policy, systems, and environmental change lens; focuses on sustainable, equitable strategies for addressing obesity-related disparities; and explores and advances effective solutions.

Pronk described the workshop as part of a strategic planning process designed to develop a roadmap for the roundtable to inform action-oriented solutions. This process has included a group model-building exercise with roundtable members, he elaborated, and featured the prior workshop mentioned above, which emphasized the importance of applying multisector systems perspectives when implementing obesity solutions. Pronk clarified that the goal of the workshop documented in this proceedings was to encourage and engage diverse stakeholders to use systems science approaches by highlighting the real-world application of these approaches to inform decisions related to obesity solutions.

ORGANIZATION OF THIS PROCEEDINGS

This proceedings follows the order of the workshop agenda (see Appendix A), chronicling its sessions in individual chapters. Chapter 2 presents a practitioner's perspective on the promises and pitfalls of systems science approaches. Chapter 3 reviews the usefulness of these approaches for stakeholders in different sectors, including those in the business and private sector and communities, as well as policy makers. Chapter 4 summarizes reflections from the workshop organizers, as well as comments from a final speaker who recapped the workshop highlights and suggested next steps for improving the understanding and use of systems science approaches for obesity solutions. Appendix B is a list of acronyms and abbreviations used in this proceedings and Appendix C provides the biographical sketches of the workshop speakers and the moderators.

2

The Promises and Pitfalls of Systems Science Approaches: A Practitioner's Perspective

Highlights from the Presentation of Jack Homer

- Useful systems science models can correctly identify intervention impacts even if their baseline predictions are imprecise, which means that they can be good decision-making tools even if they are not forecasting tools.
- Qualitative mapping and group model building are systems science approaches that have value in enriching the modeling process, but are unreliable as stand-alone tools for predicting intervention outcomes.
- Systems science models that have adequate breadth (i.e., number of interacting concepts) and detail are more useful for decision makers relative to models that are either overly narrow or broad and/or include too little or too much detail.
- Systems models focused on the dynamics of equity and social justice can be developed but will require sufficient data to make these concepts operational and relate them to other social determinants of health.
- An ideal systems science modeling project follows best practices for building, testing, and documenting models and their outputs; anchors models to well-established datasets and the best studies; enlists analysts to extract data as well as statisticians who can help interpret the data; includes stakeholders, decision makers, and subject-matter experts as advisers on

modeling teams; keeps other thought leaders in the loop; and involves junior modelers as apprentices.

The workshop's opening session featured a speaker who discussed the application of systems science approaches to complex public health issues such as obesity and reviewed opportunities and challenges associated with stakeholders' use of systems science models. Jack Homer, a 40-year veteran of system dynamics modeling and director of Homer Consulting, covered several topics in his presentation: (1) requirements for a useful and reliable systems model, (2) the roles of qualitative mapping and group model building in systems science efforts, (3) levels of evidence and the "possibility frontier" for reliable models, (4) system dynamics models that either focus on or include obesity, (5) concepts of equity and social justice in systems science models, and (6) characteristics of effective modeling projects.

Homer explained that public health stakeholders want to make decisions that will stand the test of time and avoid shortsightedness, but he acknowledged the challenge for models given the uncertainties in social systems that hamper precise forecasting. He referenced statistician George Box's famous quote that "All models are wrong, but some are useful" to highlight a key characteristic of useful models—that they can correctly anticipate intervention impacts even if their baseline predictions are imprecise; that is, models can be good decision-making tools even if they are not forecasting tools (Homer and Hirsch, 2006; Sterman, 2002). He added that sensitivity analyses to assess the level of confidence in a model's results often reveal that its policy conclusions are robust despite uncertainty in point predictions.

Homer compared three simulation approaches to systems science modeling—system dynamics simulation, discrete event simulation, and microsimulation (individual actors without interaction)/agent-based (individual actors with interaction) models (Borshchev and Filippov, 2004; Luke and Stamatakis, 2012). He underscored that despite different methods and emphases (see Figure 2-1), all three approaches agree that models must be testable, focused, and scientifically developed (Homer, 1996; Levy et al., 2011).

Homer went on to contrast systems science models, which he described as quantitative simulation approaches, with systems maps, which he described as qualitative pictures that can be useful even though they have limitations. As an example, he showed the UK Foresight Tackling Obesities: Future Choices Project Report (2007) systems map illustrating factors that contribute to obesity, pointing out that the map is expansive and causal but unfocused and untestable (United Kingdom Government Office for Science, 2007). According to Homer, a map is an unreliable tool for drawing behavioral inferences; however, formal testing can bridge the gap from structure to behavior.

System Dynamics (SD) Simulation	Discrete Event Simulation	Micro-simulation or Agent-based models
• Compartmental (lumped) • Stock-flow cascades, feedback loops • Continuous time (longer time horizon) • Deterministic, but sensitivity testing gives an envelope of possibilities • 1 run: seconds at most.	• Stochastic, operationally detailed • Discrete time (shorter time horizon) • 1 run can be fast, but many runs required for summary findings.	• Micro-sim: individual actors without interaction (large N) ➢ Diverse patterns of attributes by individual • Agent-based: individual actors with interaction ➢ Diverse patterns of interaction (networks) ➢ Emergence of group or spatial clusters • 1 run: often 1 hour or more.

FIGURE 2-1 Comparison of characteristics of three simulations approaches to systems science modeling.
SOURCE: Presented by Jack Homer, September 16, 2020.

Homer shared three quotes that he described as being representative of the debate about the roles of qualitative mapping and group model building in systems science efforts (Siokou et al., 2014) (see Box 2-1). These quotes, he suggested, convey that both approaches have value in enriching the modeling process but are unreliable for predicting intervention outcomes.

Homer then turned to quantified simulation models and practical considerations for their reliability. He described a conceptual diagram illustrating the "possibility frontier" of reliable modeling, which he characterized as a depiction of modeling choices and their feasibility and value (see Figure 2-2). The number of interacting concepts in a model (i.e., breadth) increases as one moves up the y-axis, he explained, and the number of subcategories per concept (i.e., level of detail) increases as one moves along the x-axis. The dotted line in the figure represents the possibility frontier, he continued, beyond which lies a "black box" area of models that are overly broad and overly detailed. He stated that these models are limited by a lack of sufficient data to support all of their assumptions and are too difficult to validate, modify, and understand.

Homer next described types of reliable models within the possibility frontier, from models of general theory (rich in concepts but with little operational detail) to models that explore patterns of disparity (with few interacting variables but highly disaggregated by subpopulations and subgroups). He maintained that the "policy sweet spot" is marked by models with adequate breadth and detail to be useful for decision makers.

BOX 2-1
Quotes About the Roles of Qualitative Maps and Group Models

"Qualitative mapping introduces circular causality and provides a medium by which people can externalize mental models and assumptions and enrich these by sharing them" (Wolstenholme, 1999).

"We agree that system description through mapping can be a useful activity. It improves the process of thinking about the structure underlying a problem. However, maps are notoriously unreliable tools for behavioral inference. Only through formal testing can one solidly bridge the gap from structure to behavior" (Homer and Oliva, 2001).

"Participatory or group modeling was created to enrich and strengthen the modeling process, not water it down or simplify it. It wasn't supposed to be a way to shortcut the hard work of modeling, nor to open the door to using maps instead of testable, quantitative models" (G. Richardson, quoted in Homer, 2019b).

SOURCE: Presented by Jack Homer, September 16, 2020.

Homer then described a conceptual diagram for thinking about how a model's level of evidence (i.e., reliability, graded as A, B, or C) is related to its scope and the time required for its development. The broader the model's scope, he explained, the longer it takes to achieve a high (A) level of evidence. A narrow model might take only days or weeks to achieve a high level of evidence, he elaborated, whereas a broader model could take months or years to achieve that same level.

According to Homer, artificial intelligence and machine learning could accelerate the process of achieving a high level of evidence so that broad models could be developed more quickly, but these techniques cannot fully bridge the gap. Machine learning enables mining of large databases for statistical regularities, he explained, but correctly inferring causation from these statistical regularities is unlikely. He added that artificial intelligence cannot fully overcome the challenges of incomplete data and incompatible datasets. Therefore, he asserted, science will continue to be a back-and-forth process between hypotheses, data, and the desire for parsimony, and he highlighted the role of human judgment in this process.

Homer moved on to describe a system dynamics model that he developed with the Centers for Disease Control and Prevention's (CDC's) Division of Nutrition, Physical Activity, and Obesity in 2005. He explained that this model of the U.S. population stratified by sex and single-age cohorts shows how caloric imbalances translate to upward and downward flows in

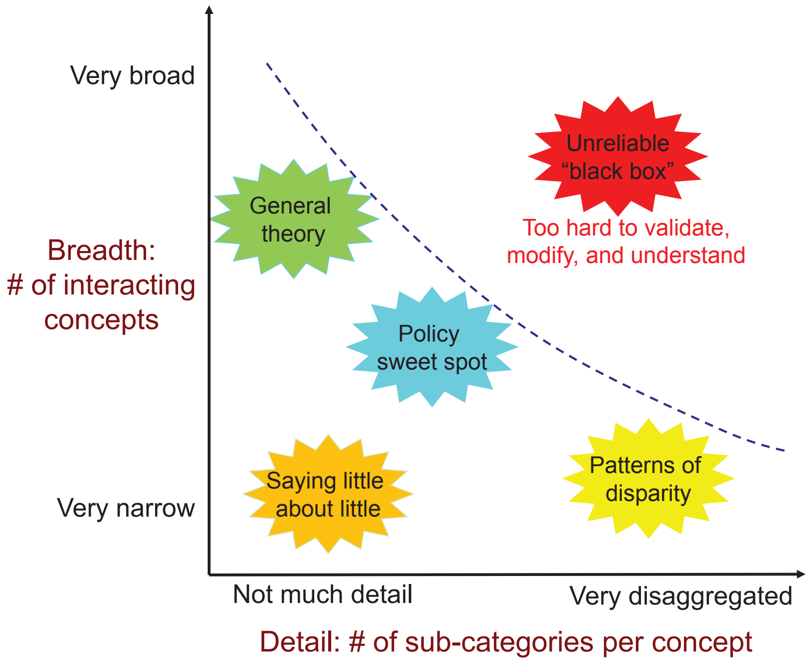

FIGURE 2-2 The "possibility frontier" of reliable modeling.
SOURCE: Presented by Jack Homer, September 16, 2020.

body mass index (BMI) categories and explains trajectories in obesity and severe obesity over time by sex and age group. The model, he elaborated, was informed by 30 years of longitudinal data from the U.S. Census and the National Health and Nutrition Examination Survey (NHANES) and by data on 1-year weight changes among adults and children, which he said provided key information about the BMI upflow and downflow rates (Homer et al., 2006).

Homer next cited results from the 2005 system dynamics model mentioned above, which he characterized as a fairly confident step forward given the level of data available at the time. First, the model indicated that the caloric imbalance responsible for the increased prevalence of obesity from 1970 to the 2000s was only about 1 or 2 percent, or less than 50 calories per day, within any given age, sex, and BMI category. Second, Homer reported that the impacts of changing environments on adult obesity take decades to manifest fully through the "carryover effect" built into the aging structure. Thus, he explained, preventive interventions may take longer than expected to produce results. Third, the model suggested that youth interventions are likely to have a relatively small impact on future adult obesity. Finally, Homer reported, the model indicated that ideal policy responses would combine preventive interventions with effective weight loss options for people with obesity (Homer et al., 2006). Homer remarked that other modelers who took a similar calorie-based, “BMI transitions” approach reached similar conclusions about caloric imbalances (Fallah-Fini et al., 2014; Wang et al., 2007). He encouraged researchers to use whatever modeling technique they find useful as long as it produces reliable answers that can help decision makers.

Homer then referenced several other system dynamics models that have focused either on obesity (such as models of individual weight management) or on topics in which obesity plays a role (such as models of food market transformation, diabetes onset and progression, cardiovascular disease development, and the relationship of social determinants of health to county-level morbidity and mortality) (Hamid, 2009; Hirsch et al., 2014; Jones et al., 2006; Milstein and Homer, 2020; Struben et al., 2014). He noted that some systems models stratify populations by race, class, or gender to describe the associated differences and project the impact of targeting an intervention to one subpopulation or another. However, he observed, he is aware of no published systems model focused directly on the dynamics of equity and social justice. He suggested that if one could model the social forces that reinforce inequity and undermine justice, then those results could help identify opportunities to reverse these forces.

Homer described a preliminary model along these lines (see Figure 2-3). This high-level model, he explained, depicts community actions and conditions involved in the response to a shock such as the Great Recession or the coronavirus pandemic, and can indicate a community’s resilience or ability to rebound. The model is based loosely on CDC’s Healthy People 2030 Well-Being Framework, he added, and includes concepts such as vital conditions, urgent services capacity, civic muscle (i.e., capacity for action and investment), and equity. In this preliminary model, he elaborated, postshock decisions about how to allocate civic muscle have long-term effects. For example, Homer continued, previous levels of equity may never be regained if this is not made a high priority. He qualified his description of this model by characterizing it as suggestive and not yet ready for “prime time,” as it lacks operational detail and includes only rough estimates of some key parameters. He called for local case studies and longitudinal data to advance the model from a thought-provoking “toy” to a more serious tool.

In closing, Homer drew on his previous modeling experiences to suggest a blueprint for what he described as an ideal systems science modeling project—to which substantial funding and more than 1 year of time are allocated. First, he urged adherence to best practices for model building, testing, and documentation (Homer, 2019a; Rahmandad and Sterman, 2012). Best practices exist for conducting systems modeling, he elaborated,

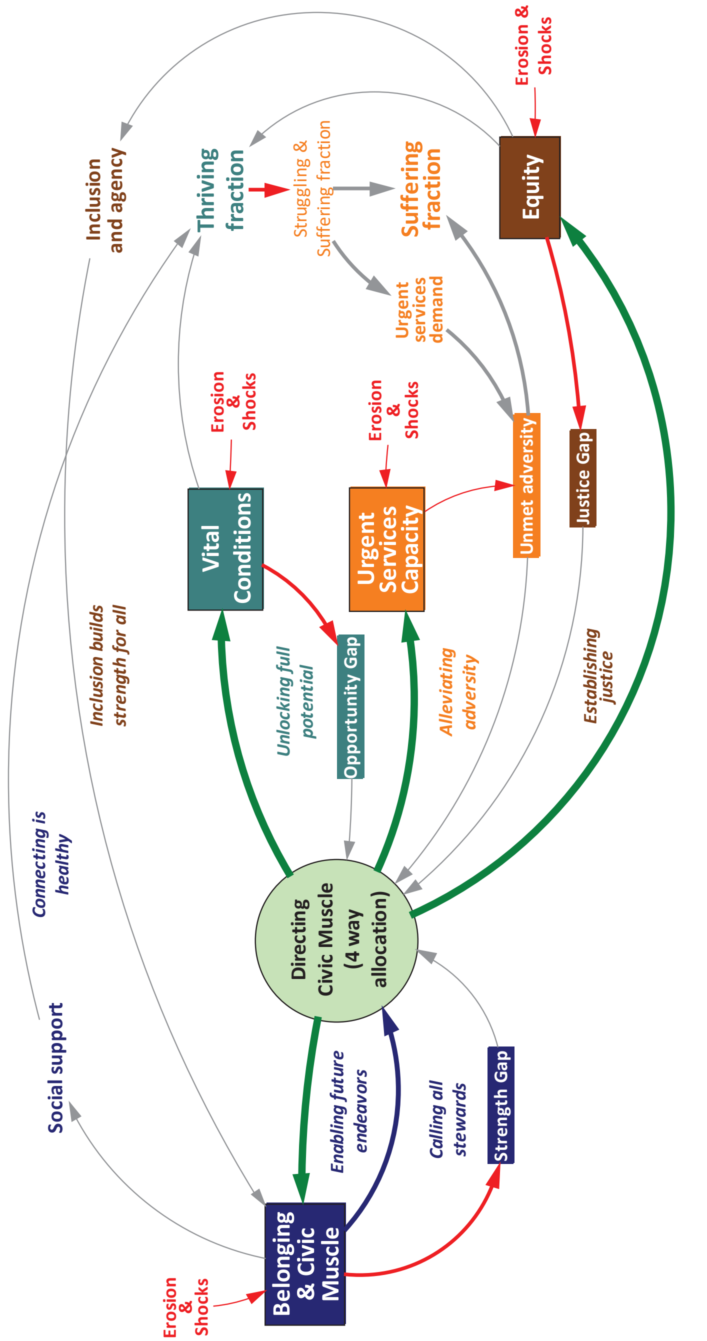

FIGURE 2-3 Work in progress for ReThink Health.
SOURCES: Presented by Jack Homer, September 16, 2020; Milstein and Homer, 2020. Image used with permission of The Rippel Foundation.

as well as for reporting outputs and documenting models so that others can replicate and verify them. Second, he suggested anchoring models to well-established datasets (such as NHANES or the Behavioral Risk Factor Surveillance System) and the best studies, explaining that a core of well-accepted longitudinal data helps a modeling effort establish respect and credibility. Third, he encouraged enlisting analysts to extract data, as well as statisticians who can help interpret the data. Fourth, he called for including stakeholders, decision makers, and subject-matter experts as advisers on modeling teams to help ensure that the models produced will reflect their concerns and knowledge. Fifth, he encouraged engaging other thought leaders around the country and the world who can serve as allies and intermediaries as modelers work with decision makers. Finally, Homer appealed for involving junior modelers as apprentices and helping them gain experience with all of the intricacies of large projects aimed at providing input for public policy.

3

Exploring the Usefulness of Systems Science Approaches for Stakeholders in Different Sectors

Highlights from the Presentations of Individual Speakers

- Project Play's pursuit of its mission to help stakeholders build healthy communities through sport has been enhanced by the use of systems science models. The suite of systems science models called the Virtual Population Obesity Prevention Labs indicated that getting at least half of the youth population more active could avert billions of dollars in health care costs and lost productivity and save millions of years of life. Another simple calculator has been used to calculate how individual parks contribute to property values, health care savings, informed decisions on environmental and public spending, and job creation in the community. These modeling outputs have supported billions of dollars in public investment in sport and recreation assets and helped unlock or shape more than $55 million in foundation and corporate grants to support healthy communities through sport. (Tom Farrey, Bruce Y. Lee, Dev Pathik)
- Applications of systems science approaches to improve food environments in Baltimore, Maryland, have helped stakeholders better address and understand a community's complexities, virtually test different policies and interventions, facilitate communications and engagement within a community, and bring together diverse groups of people. Specifically, agent-based

models were used to simulate the effects of an urban agriculture tax credit and of warning labels on sugar-sweetened beverages, and a system dynamics model was used to test four different potential scenarios for an ordinance on staple foods. (Sarah Buzogany, Joel Gittelsohn, Bruce Y. Lee)

- The SALURBAL (Salud Urbana en América Latina [Urban Health in Latin America]) project conducted three regional workshops to engage policy makers in participatory group model building aimed at exploring healthy eating and urban mobility and transport in Latin American cities. These workshops led to a local application that used participatory group model building to evaluate the effect of a transportation intervention on health. The workshops also led to the development of two policy-oriented, agent-based models: one for use in exploring the effects of specific policy strategies on ultra-processed food purchases, and the other for investigating the effects of urban transport and mobility strategies on mode share, physical activity, and air pollution. (Ana Diez Roux, Brent Langellier, Felipe Montes Jimenez)

The workshop's main session comprised three panels of speakers who discussed the usefulness of systems science approaches for stakeholders in different sectors involved in the development of solutions to address obesity. Jamy Ard, professor in the Department of Epidemiology and Prevention and the Department of Medicine at the Wake Forest University Baptist Medical Center, moderated the first panel, during which speakers discussed engaging the business and private sector in systems science approaches. Sara Czaja, professor of gerontology in medicine at Weill Cornell Medicine, moderated the second panel, focused on communities. Stella Yi, assistant professor in the Department of Population Health at the New York University Grossman School of Medicine, moderated the third panel, which highlighted policy makers.

THE BUSINESS AND PRIVATE SECTOR: PROJECT PLAY

In the first panel, three speakers discussed a business case study of Project Play, an effort designed to address the U.S. obesity epidemic by building healthy communities through sport.

Tom Farrey, executive director of The Aspen Institute's Sports & Society Program, reported that Project Play began with a conversation about how the space of sport activity (a component of the realm of physical activity) could be organized to help more youth be active on a regular basis so as to make a meaningful contribution to addressing obesity in the United States. Project Play's mission is to help stakeholders build healthy communities through sport, Farrey clarified, noting that this mission is sometimes misconstrued as an effort to simply grow sport participation. Although growing participation in sports is something that Project Play's leaders desire, he explained, its agenda is not always fully aligned with the youth sport space. As an example, he pointed to the resumption of youth travel for sport tournaments relatively early in the COVID-19 pandemic, noting that Project Play's perspective at that point was to postpone this kind of activity.

Project Play's endeavor to organize the U.S. sport system to produce more optimal health outcomes began with a focus on children aged 12 and younger, Farrey recounted, with the aim of ensuring that every child has the opportunity to engage in structured or unstructured sport regardless of zip code or ability. During the remainder of his presentation, he described three steps that the initiative has taken in pursuit of that aim.

The first step, Farrey said, was to compile and organize existing research on the individual- and community-level benefits of physical activity and participation in sports. He shared graphics showing examples of lifelong health benefits for physically active youth (see Figure 3-1) and benefits for residents of active communities (see Figure 3-2). These graphics, he explained, are used in appeals to stakeholders to make physical activity and participation in sports a public priority.

According to Farrey, this research informed the development of a playbook called Sport for All, Play for Life, the nation's first cross-sector "framework for action" for youth (aged 12 and younger) sport (The Aspen Institute, 2015). The playbook, he elaborated, was an outgrowth of 2 years of information gathering and roundtable discussions with hundreds of stakeholders and thought leaders, during which the best ideas were elicited and distilled into an attractive, easy-to-read document. The values of health and inclusion are integrated throughout the playbook, he observed, to highlight the goal of every child having an opportunity to be active through sport. He added that the playbook highlights eight sectors that touch children's lives—national sport organizations, business/industry, technology/media, public health, community recreation, education, policy makers and civic leaders, and parents—and presents eight strategies (and 40 activation ideas) to apply in those sectors to encourage more children to be active through sport.

Farrey then reviewed the eight strategies, beginning with putting children at the center of designing sport experiences (see Box 3-1). Youth sports are usually designed by adults, he pointed out, but children's voices can be incorporated by asking them what kinds of experiences they want. He noted that Project Play is developing electronic surveys to collect feedback from youth (a tactic used by video game companies) to inform the development of

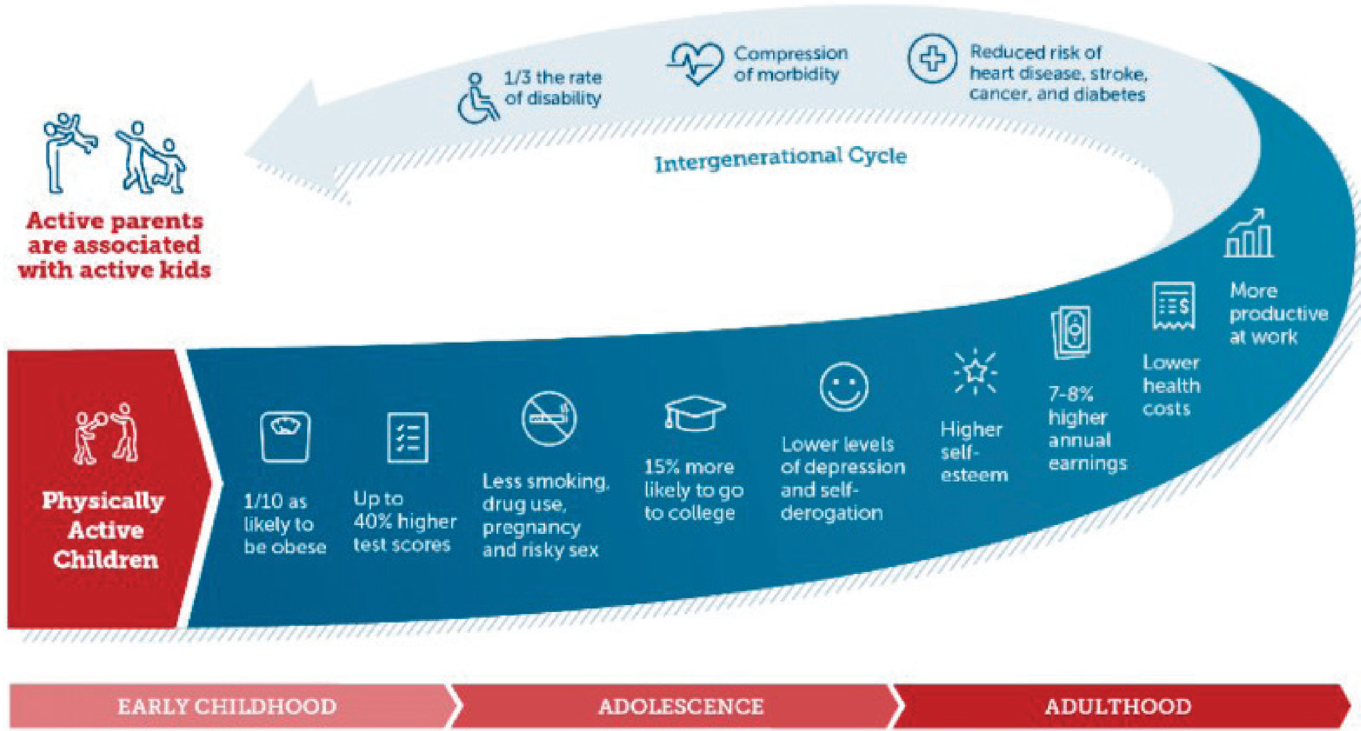

FIGURE 3-1 Lifetime benefits of physical activity.
SOURCES: Presented by Tom Farrey, September 16, 2020; The Aspen Institute, 2015. Figure used with permission of The Aspen Institute's Project Play.

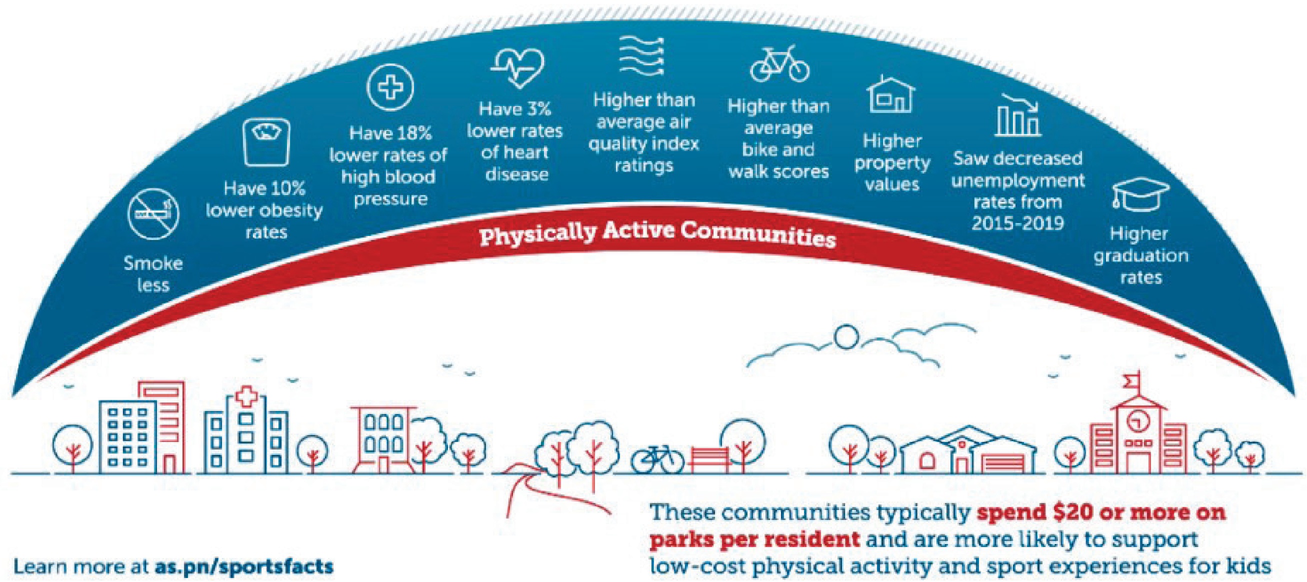

FIGURE 3-2 Benefits to residents of active communities.
SOURCES: Presented by Tom Farrey, September 16, 2020; The Aspen Institute, 2020b. Figure used with permission of The Aspen Institute's Project Play.

BOX 3-1
Eight Strategies of Sport for All, Play for Life: A Cross-Sector Framework for Action for Youth (aged 12 and younger)

1. Ask kids what they want
2. Reintroduce free play
3. Encourage sport sampling
4. Revitalize in-town leagues
5. Think small
6. Design for development
7. Train all coaches
8. Emphasize prevention

SOURCES: Presented by Tom Farrey, September 16, 2020; The Aspen Institute, 2015.

youth sport programs. The second strategy, Farrey continued, is to reintroduce free play. The third is to encourage sport sampling, which he described as promoting multisport play and introducing youth in underserved communities to a wide variety of sports, as well as pushing back on the trend of asking children to specialize in a single sport at an early age. The fourth strategy is to revitalize in-town, local sport leagues. According to Farrey, these sport structures are more accessible than travel teams, which he said tend to limit participation to high-income, two-parent families, yet they still deliver many of the benefits of sport. The fifth strategy is to think small, which Farrey illustrated with the example of brokering shared-use agreements to use community spaces creatively. The sixth strategy is to design for development, which means anchoring a sport system in the principles of developmentally appropriate play. This strategy, Farrey explained, ties into the seventh strategy, which is to train all coaches. He observed that U.S. youth sports have traditionally been administered by well-meaning but untrained volunteers who would benefit from learning how to make sport a positive experience for youth, such as by recognizing the differences in their physical, mental, and emotional capacities at different ages. The final strategy, Farrey said, is to emphasize prevention. He explained that this strategy emerged to address parents' concern about their children sustaining physical and emotional injuries from participating in sport. Recognizing that barrier to participation led Project Play to realize that it should give parents the confidence that sport can be a health-building experience.

Farrey next shared an aspirational model for sustained participation in sport, where the priority for children up to at least age 12 is physical literacy, emphasizing fundamental movement skills and a focus on the ability, confidence, and desire to be active. This foundation sets the stage for future sport participation, he said, regardless of whether that participation is at a recreational, competitive, or elite level.

Farrey went on to describe Project Play's second step in pursuing its mission, which was mobilizing organizations. This effort began with the convening of a summit, at which then U.S. Surgeon General Vivek Murthy issued a call to action on the value of youth sport for promoting physical activity and public health. Since then, Farrey recalled, Project Play has conducted "state of play" audits that help communities assess where they are and how they could design investments and policies that would mobilize stakeholders to activate and improve the quality of play in their communities. Project Play also convenes stakeholders to share knowledge, Farrey continued, highlighting an annual summit that invites leaders from the eight sectors to share new tools, projects, and resources. In addition, the summit showcases the release of an annual State of Play report, which features trend data on sport participation in youth aged 6–12 and 13–17, stratified by sport, income, and gender.

Farrey next described the Project Play Summit 2020, which convened some of the largest and most influential organizations in the Project Play network to discuss how they could collectively invest in increasing youth activity levels. Although many of the organizations are competitors, Farrey remarked, they banded together to develop initiatives such as howtocoachkids.org, the nation's first free resource aggregating coaching materials for any organization to use with its coaches. Another initiative was the Healthy Sport Index,[1] he continued, which helps parents and stakeholders assess the relative risks and benefits of participating in the 10 most popular sports for high school students. He explained that an expert committee developed the index by aggregating data on each sport's level of physical activity, safety (based on injury rates), and psychosocial development, and then evaluated and weighted the data to create an interactive dial that stakeholders can use to assign the relative importance they place on each of the three factors and receive suggestions for which sports might be most suitable for individual adolescents.

Farrey then described the final step—mobilizing parents. He highlighted a media campaign introduced in August 2019 called "Don't Retire, Kid," launched with the help of Kobe Bryant and ESPN, which directed parents to advice and resources related to maintaining youth participation in sports. Research suggests that most children play sports for an average of 2.9 years, he noted, and typically stop by age 11 (The Aspen Institute, 2019).

Bruce Y. Lee, professor of health policy and management at the City University of New York Graduate School of Public Health and Health

[1] See https://healthysportindex.com (accessed November 4, 2020).

Policy and executive director of Public Health Informatics, Computational, and Operations Research (PHICOR), began his portion of the presentation by reiterating that the initial premise of Project Play is straightforward in that it aims to tackle the epidemic of youth physical inactivity and also increase youth participation in sports by working with communities. However, because the scope of the physical inactivity problem is complex, he asserted, it warrants a highly energetic, organized, and coordinated operation like Project Play. According to Lee, it is important for decision makers to understand the magnitude and scope of a problem so that they can rank it relative to other priorities. He pointed out that decision makers benefit from information that quantifies the impact of a problem, as well as the potential value of different types of interventions, but that providing this information is a challenge when the problem is complex.

Lee described a suite of systems science models called the Virtual Population Obesity Prevention (VPOP) Labs (developed by PHICOR), highlighting their utility for helping decision makers grapple with the complexity of problems related to diet or physical activity and their potential solutions. In these agent-based models, which he likened to a SimCity™ for obesity prevention, each person is represented by a computational agent whose actions may be influenced by others but are ultimately determined by individual freedom of choice (a concept known as autonomous decision making). Agents also exhibit basic complex adaptive behavior and learning, he added, which means they can learn from the past or do things differently depending on previous events.

VPOP uses a synthetic population that was built using U.S. Census data, Lee continued, and each agent has characteristics that include age, gender, race/ethnicity, socioeconomic status, home assignment, school assignment, height, and weight. The initial model was built for Baltimore, he noted, and the same structure then informed model building for additional cities, as well as the entire United States. He explained that modelers can assign the agents a daily schedule of activities, behaviors, and decisions that mimic a real person's patterns, and each agent is also assigned a personalized metabolic model. The metabolic model attempts to represent what happens within the human body when calories are ingested, he elaborated, which can result in a daily weight increase or decrease (depending on caloric expenditure), as well as a change in body mass index (BMI) over time.

Lee reported that his team attached the metabolic model and agent characteristics to an embedded clinical and economic outcomes model representing key health conditions potentially associated with changes in BMI (Fallah-Fini et al., 2017). In this model of clinical and economic outcomes for different BMIs over a lifetime, each agent had probabilities of developing diabetes, cardiovascular disease, or cancer over time, he elaborated, and accrued varying levels of medical costs and productivity losses based on the health condition(s) that developed and the health care resources that the agent consumed. He added that this work led to a general model representing all youth in the United States, which simulated the economic and health impact of increasing physical activity in that segment of the U.S. population (Lee et al., 2017).

Lee reported that at present, fewer than one-third of U.S. youth maintain the Sports & Fitness Industry Association's recommended "active to a healthy level" (i.e., 25 minutes of physical activity three times per week). Results from Lee's model suggested that increasing this number to at least 50 percent of the current youth population would avert billions of dollars in medical care costs and lost productivity. This savings could then eventually occur for every group of children that reached the 8–11 age range (see Figure 3-3). The model was also used to explore the effect of varying the type of physical activity, Lee added, and showed that the more vigorous the physical activity, the greater was the amount of savings. To illustrate this point, he stated that if 75 percent of U.S. children aged 8–11 were to reach the goal of "active to a healthy level," $16.6 billion in direct medical costs and $23.6 billion in lost productivity could be averted. If all U.S. children in this age group achieved that goal, overweight and obesity in youth would decrease by 15 percent, and $26.3 billion in direct medical costs and $36 billion in lost productivity would be averted.

The model's results are shared with stakeholders, Lee said, to make the point that getting more youth active can avert billions of dollars in medical costs and lost productivity and save millions of years of life. He asserted that even achieving the Centers for Disease Control and Prevention's (CDC's) recommended physical activity levels among 100 percent of youth is "not unachievable" because the activity level threshold is not high, and achieving this goal could result in averting $51.5 billion in direct medical costs, $69 billion in productivity losses, and saving 37.5 million years of life (Lee et al., 2017). These savings, he noted, including fewer youth with overweight and obesity, were calculated for specific geographic regions of Project Play so that the potential benefits could be tailored to those regions with significant disparities in access to coaches, facilities, mentors, and financial resources. He highlighted particular reports from southeast Michigan, western New York, and the greater Rochester and Finger Lakes region (Ralph C. Wilson, Jr. Foundation, 2020).

The panel's third speaker, Dev Pathik, chief executive officer and founder of the Sports Facilities Companies, described his company's mission to improve the health and the economic vitality of communities. The company pursues this mission, he elaborated, by serving as a trusted resource for communities that want to plan, fund, develop, or manage youth and amateur community-based sport and recreation facilities. He explained that the Sports Facilities Companies advises municipalities and

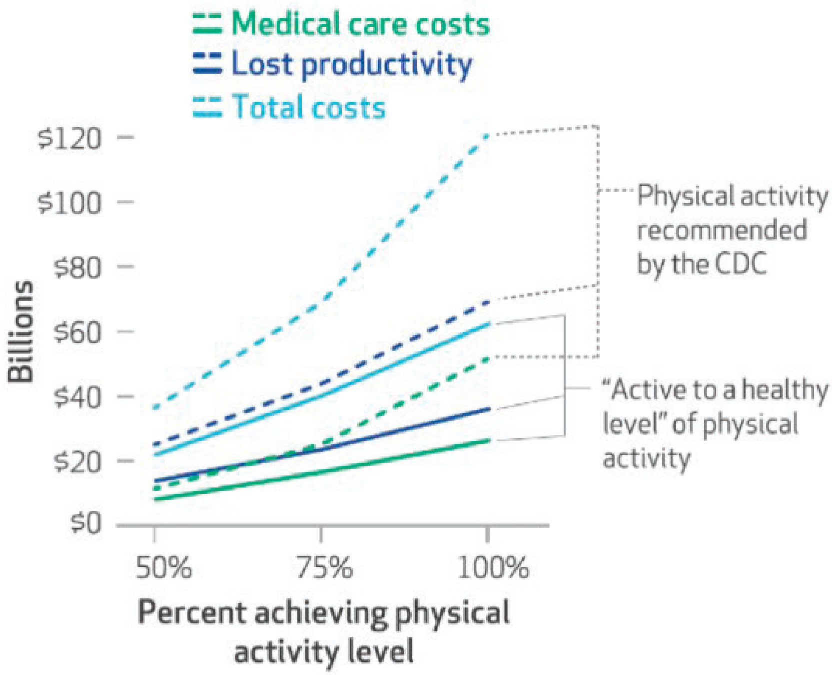

FIGURE 3-3 U.S. costs averted annually by increasing levels of children's participation in physical activity.
NOTES: CDC = Centers for Disease Control and Prevention. For people aged 6 years and above, being physically "active to a healthy level," as defined by the Sports & Fitness Industry Association, is defined as 25 minutes of high-calorie-burning physical activity three times per week. For those aged 6–17, CDC recommends at least 60 minutes of moderate physical activity each day.
SOURCES: Presented by Bruce Y. Lee, September 16, 2020; Lee et al., 2017. Figure used with permission from Project Hope.

large institutions on infrastructure planning and resource allocation so that they can activate their objectives around sport and recreation using a market research–driven process. According to Pathik, as the organization has recognized the significance of the impact of sport with regard to positive health and social outcomes across the lifespan, greater emphasis has been placed on considering lower-income populations and providing universal access to sport and recreation. Pathik added that the work of his organization is a good example of how practitioners can react to a systems science approach. He noted that the organization has revised its approaches as a result of its engagement in the work of Project Play and the systems science modeling described earlier in the presentation by Lee.

Pathik next reviewed five access factors for healthy communities, emphasizing that infrastructure plays a role in these factors, which are intended to improve health and social outcomes for youth. The first factor is safe and free spaces to play, such as a safe neighborhood where youth can move about and engage in recreational activities. A second factor is activity-focused urban design, which Pathik explained using example measures such as the interconnectivity of recreation and sport assets and walkability. A third factor he cited is the utilization and programming of school assets and sport and recreation facilities. A fourth is investing in multigenerational programs and events. Finally, the fifth factor is multimodal transportation. According to Pathik, these five access factors help communities think more broadly about how they participate in, contribute to, and fund or use partnerships to promote wellness among their residents.

Pathik noted that the last recession brought significant defunding of parks and recreation, which prompted the private sector to capitalize on opportunities in that marketplace. But without the programming previously offered by parks and recreation departments, he explained, facilities that may still be well maintained are now more expensive for people to use. He argued that the loss of public commitment to funding sport and recreation at the programmatic level results in a system oriented toward capitalism, which provides a place to play but lacks the programmatic structure to help youth develop competence and confidence to engage in physical activity for a lifetime.

To build political will for investment in and activation of sport and recreation infrastructure that can reach those most in need, Pathik advocated for a multistakeholder approach. A major medical partner is indispensable to such an approach, he maintained, noting that medical partners are interested in sport and recreation facilities not simply because of sports medicine but because these facilities provide venues for wellness and prevention programming and opportunities to engage with individuals and tailor their products and services. Pathik mentioned parks and recreation directors as another important group of stakeholders. They typically have little influence in the budgeting cycle, he explained, but they are well versed in the programs they offer and can provide metrics to indicate how those programs are being used by youth.

Pathik reported that to equip and empower parks, recreation directors, and advocates to express the value of sport and recreation, the Sports Facilities Companies and the Florida Recreation & Park Association produced calculators that generate reports on how individual parks contribute to property values, health care savings, informed decisions on environmental and public spending, and job creation in the community. The calculators are available for every park in Florida, he noted, and will soon be available for parks in California and Kansas. According to Pathik, this is the kind of ground-level data that systems science modeling has inspired the organization to try to activate, and it has resulted in billions of dollars of public investment in sport and recreation assets.

Farrey concluded the panel's presentation with a summary of Project Play's impact since the 2015 launch of its Sport for All, Play for Life playbook. Based on a 2018 survey of Project Play Summit attendees, more than 100 organizations have taken actions guided by the playbook, he reported. ESPN created an "access to sport" prong in its Corporate Citizenship program and has informed Disney's strategies, Farrey continued, and cities and counties have begun to design grants and policies based on the playbook's eight strategies (see Box 3-1). Project Play has helped unlock or shape more than $55 million in foundation and corporate grants, he noted, as community stakeholders have recognized opportunities for investment in youth access to sports and revised their programs accordingly. He highlighted this investment as an outcome of a systems science approach to generating relevant data to share with business leaders and community stakeholders. Farrey also highlighted Project Play's role in helping shape the U.S. Department of Health and Human Services' first-ever National Youth Sports Strategy,[2] a resource for policy makers and decision makers in youth sports. Lastly, he emphasized recent data indicating that, relative to 1 year ago, more children—in every income category—are playing sports, fewer are physically inactive, and more coaches are being trained (The Aspen Institute, 2020a). He stressed that these accomplishments are the result of the broad network of organizations that have participated in Project Play activities and introduced an array of aligned programs.

PANEL AND AUDIENCE DISCUSSION

Following their presentations, Farrey, Lee, and Pathik addressed a participant's question about using systems science modeling to help avoid exacerbating disparities in access to sports and shared examples of increasing access to sports in underresourced communities.

Addressing Disparities in Access to Sports

Pathik mentioned that the number of children who receive free or reduced-price lunches is a metric used by the Sports Facilities Companies as a proxy to determine how many children need help accessing opportunities for sport in a given community. The organization begins by assessing whether the community's budget is adequate to sponsor access to sport and

[2] See the National Youth Sports Strategy at https://health.gov/our-work/physical-activity/national-youth-sports-strategy (accessed November 6, 2020).

recreational activities for that number of children, he explained, noting that this is a starting point. Lee added that while trend and correlational data are useful, the right models can help account for the interaction between people's individual characteristics and the contextual systems in which they live, which affect the ability to access physical activity.

Farrey emphasized the importance of raising awareness of gaps in access through data and outreach to media, noting that many people otherwise tend to assume that most youth play sports. He highlighted that children from families with annual household incomes of ≤$25,000 play sports at half the rate of children from families with annual household incomes of ≥$100,000—a national metric that Project Play tracks annually (The Aspen Institute, 2019). That metric can be fine-tuned for a specific community, he added, based on the availability of local data.

Project Play's Work in Underresourced Communities

Farrey recounted the initiative's work in Harlem, where it surveyed children in schools to ask what sports they wanted to play and learned that hockey was of high interest. He said that Project Play then shared these results with the National Hockey League's (NHL's) closest team, the New York Rangers, and venue, Madison Square Garden, and connected them with schools to get floor hockey into many schools in East Harlem. Children in Detroit also expressed interest in hockey, Farrey recalled, but fewer than 1 percent were playing. He reported that the NHL and the Detroit Red Wings, together with other partners, developed a program to introduce floor hockey in schools, which will give tens of thousands of children the opportunity to try the sport.

Pathik shared an example from Rocky Mount, North Carolina, where the Sports Facilities Companies helped open an event center. The town debated about whether to locate the facility in a blighted downtown area or in the suburbs, where it would be near hotels and other destinations, and ultimately used a federally qualified census tract downtown to allow the project to qualify for new market tax credits. A federally qualified medical partner was built in the same area, Pathik added, which opened access to mammography services for women living nearby. He noted that prior systems science modeling data assessing the conditions and needs in that census tract were instrumental in the event center's placement in an area of high need.

COMMUNITIES: BALTIMORE, MARYLAND

In the second panel, three speakers discussed the use of systems science modeling in communities—specifically in Baltimore, Maryland—offering another example of coordination and partnership. The speakers, who took turns presenting as they covered different portions of the presentation, included Bruce Y. Lee, who had also spoken in the prior panel; Joel Gittelsohn, professor in the Center for Human Nutrition at the Johns Hopkins Bloomberg School of Public Health; and Sarah Buzogany, food resilience planner for the Baltimore Food Policy Initiative in the Baltimore City Department of Planning.

Lee began by sharing an outline for the presentation, which would begin with an overview of the Baltimore food system, followed by discussion of a specific community project and then three examples of how systems science modeling had informed potential policies and interventions in the city and engaged community and other stakeholders. He reminded participants that obesity is a systems problem that results from the interaction of multiple complex systems of factors, such as biological processes, behaviors, social networks, the environment, policies, economics, culture, and a variety of other factors. According to Lee, focusing on those various systems is important for addressing obesity but is something humans struggle to do because of the difficulty of discerning processes that are occurring beyond those with direct, immediate effects.

Lee briefly described the Global Obesity Prevention Center, previously housed at Johns Hopkins University, and its goal of using different types of systems science approaches to address the obesity epidemic. He stated that the Center consisted of an administrative core, a systems science core, an education and training program, and various domestic and international projects. One of its main initiatives was a multiscale, multicomponent intervention project (led by Gittelsohn) that ran for more than 5 years and addressed obesity in Baltimore City. According to Lee, the project's goal was to apply different systems science approaches to understand all of the complexities involved in Baltimore City's food system, as well as to use new systems science approaches such as systems mapping and systems science modeling.

Buzogany then discussed Baltimore's food system and food policy landscape and highlighted the benefits of the city's partnership with Johns Hopkins University and the Global Obesity Prevention Center. For the past 10 years, she said, the Baltimore Food Policy Initiative has driven the city's food policy agenda in partnership with and alongside residents, organizations, and partners such as Johns Hopkins. The relationships between these institutions and the city have been instrumental, she declared, because academic partners have used systems science modeling to help community stakeholders identify needs, understand the potential implementation of strategies and plans, and suggest viable policy solutions.

Buzogany stated that one of Baltimore's frames is to use food as a catalyst to address health, economic, and environmental disparities in healthy food priority areas. A "healthy food priority area," she explained, is a geographic area of the city where residents may face structural barriers to accessing healthy foods, adding that the phrase evolved from the term "food desert."[3] She noted that nearly one-quarter of the city's population lives in such areas, which are characterized by low healthy food availability scores, income levels at or below 185 percent of the federal poverty level, low vehicle availability among residents, and located at least one-quarter of a mile from a supermarket.

Next, Buzogany shared a map of healthy food priority areas in Baltimore. The map includes locations for hundreds of small grocery, corner, and convenience stores across the city, which she said often lack healthy foods (based on Healthy Food Availability Index scores), as well as public markets, supermarkets, urban agriculture sites, and food assistance sites (e.g., food pantries and distribution sites for summer meals). According to Buzogany, systems maps have helped the Baltimore Food Policy Initiative provide briefs for elected officials and generate neighborhood maps to help residents understand their food landscape. But because the maps are static, cross-sectional tools, she said, the initiative partnered with Gittelsohn to use the maps to explore policy questions such as the effect of a staple foods ordinance on food quality.

Buzogany highlighted the Baltimore Food Policy Initiative's eight-point healthy food environment strategy: (1) resident-driven processes, (2) corner and convenience stores, (3) supermarkets, (4) public markets, (5) food distribution and small businesses, (6) federal nutrition assistance, (7) urban agriculture, and (8) transportation gaps. By collaborating on systems science modeling efforts, she added, the initiative was able to understand how it could best implement strategies for improving the food environment within the focus areas of its healthy food environment strategy.

Gittelsohn discussed B'More Healthy Communities for Kids, a multilevel program implemented by the Global Obesity Prevention Center to improve access to, demand for, and consumption of healthier foods and beverages in low-income neighborhoods of Baltimore. He focused on the program's policy working group, which comprised the city's food policy director; its food resilience planner; and stakeholders in multiple sectors, including the city council, the city health department, city schools, the family league, parks and recreation, wholesale companies, and academia. Gittelsohn reported that the group engaged in a series of planning exercises and activities to consider and develop solutions for improving the city's food environment, with the goals of building the evidence base to support

[3] More information on "healthy food priority areas" can be found at https://planning.baltimorecity.gov/baltimore-food-policy-initiative/food-environment (accessed November 16, 2020).

healthier food environment policies in Baltimore City and sustaining activities initiated by the program. Gittelsohn noted that policy working group members asked him and his team to develop a systems science simulation model that would provide evidence for a proposed urban agriculture tax credit.

Buzogany observed that the city's urban agriculture efforts have increasingly focused on achieving equity, particularly racial equity. She shared an excerpt from Baltimore's 2019 sustainability plan to convey the city's intention to focus urban agriculture efforts on historically excluded populations: "A city where communities that have been historically excluded from access to land and to fresh, healthy, culturally-appropriate foods are those that benefit most from urban agriculture" (Baltimore Office of Sustainability, 2019, p. 51). The goals of the 2019 sustainability plan have a strong focus on land ownership, Buzogany emphasized, especially for Black farmers and other farmers of color. She observed that policies such as the urban agriculture tax credit were created to help put the city's vacant land to productive use and to support ownership by urban farmers without burdening them with large property tax bills.

Gittelsohn elaborated on the urban agriculture tax credit, recounting that city Councilman Pete Welch approached the Global Obesity Prevention Center about his proposed bill to provide a 90 percent tax reduction for owners of vacant lots who converted them to urban farms (i.e., the urban tax credit). The Center had an existing systems science agent-based model called the Baltimore Low Income Food Environment (BLIFE), which Gittelsohn said was modified to provide evidence in support of the potential impact of the bill. The BLIFE agent-based model focused on only one area (constituting about 10 percent) of the city, he explained, and modeled children's after-school food consumption and activity. He added that the model was parameterized with geographic information systems data from that geographic area, and also incorporated data on gender, age, height, weight, and home address for nearly 300 children residing in Baltimore, simulating their walking, physical activity, and food consumption habits. Results from the simulation modeling were provided to the city council as evidence of the potential impact of the urban farm tax credit, he said, and legislation was passed to establish the tax credit in Baltimore City.

Lee emphasized that although the BLIFE model was useful for testing different policies and interventions, expanding it to include all of Baltimore and incorporate more agent characteristics and aspects of the food environment enabled its use to develop larger-scale, agent-based models for any location in the city. He highlighted a second systems science model—an expanded model called VPOP, which Lee had discussed in the session's first panel—that uses geocoded data to represent key locations, such as households, large workplaces, schools, physical activity locations (e.g., parks, gyms, recreation centers), and food sources. The more than 1 million computational agents that were placed in the model represent the city's actual population, Lee emphasized, because the model's synthetic population was built using census data, and each agent has an age, gender, race/ethnicity, socioeconomic status, and other characteristics that map to those data. Lee reiterated his earlier comments to explain that as the agents move through daily activities and consume and expend energy, modelers can track population health outcomes, such as changes in BMI percentile, over time.

Lee recounted that the Baltimore City Health Department periodically contacted the Global Obesity Prevention Center to share potential policy interventions, such as placing warning labels on sugar-sweetened beverages in different combinations of grocery stores, corner stores, schools, and other settings where the beverages are available. The VPOP model forecasted the potential effect of the labels on purchasing and consumption of sugar-sweetened beverages. Lee reported that according to the model, a warning label would result in people choosing an alternative to sugary beverages 8 percent of the time, based on several studies that examined the efficacy of such labels (Lee et al., 2018). This finding was used as a baseline, he continued, to forecast the impact of having versus not having these labels at three different levels of efficacy—4 percent, 8 percent, and 12 percent—in three major cities (Lee et al., 2018). The model indicated that as the efficacy of warning labels increased, a greater decrease in the prevalence of obesity would occur, effects that were consistent in direction but not in size across the three cities. Lee explained that the heterogeneity of effects across cities resulted from differences in geographic layouts, types of food sources, and combinations of population BMI distributions and health conditions. He stressed that this heterogeneity shows the importance of using systems science models that explicitly represent the population and food environments in the target city of a policy or intervention.

Lee added that the VPOP model was also used to conduct a sensitivity analysis in which modelers varied factors such as warning label efficacy, population literacy rate, and corner store compliance (Lee et al., 2018) (see Figure 3-4). This is another important use of a systems science model, he noted, because it can forecast the outcomes of changing various aspects of a policy or the circumstances in which it is implemented. Sensitivity analyses help stakeholders identify potential drivers of a policy intervention, he explained, and he suggested that understanding such relationships may be even more important than predicting exactly what will happen. He cautioned against viewing systems science modeling as a "crystal ball," given that exact predictions may not be accurate but can provide a sense of what may be happening.

Next, Buzogany introduced a third example of applying systems science modeling to inform Baltimore community policy making: a systems science

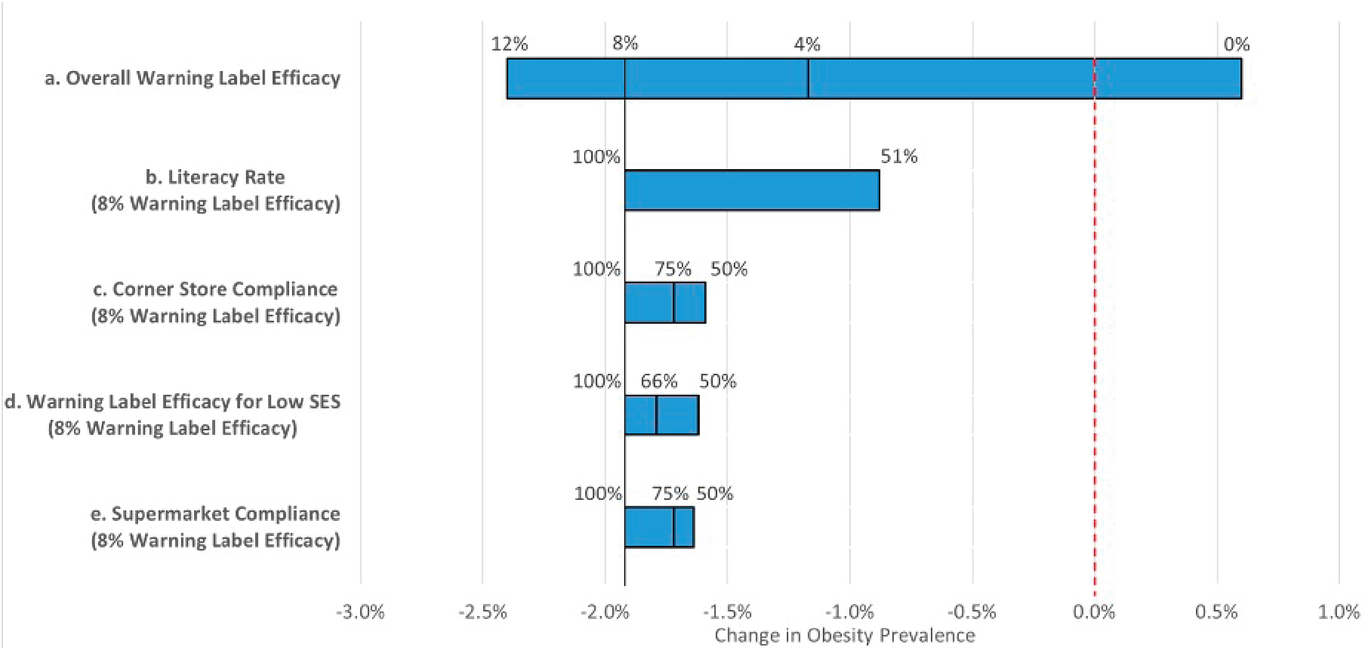

FIGURE 3-4 Comparing the impact of key model variables on change in obesity prevalence in Baltimore City.
NOTES: SES = socioeconomic status. This figure summarizes the sensitivity analyses used to investigate how varying different unknown factors affects the change in obesity prevalence for Baltimore City. Each factor analyzed is represented by a horizontal bar, where the width of each bar represents the range of impact on obesity prevalence across a range of values for that factor (listed above the bar). Additional lines on the bar represent mean obesity prevalence from intermediate factor values. The dotted line marks 0 percent change in obesity prevalence, or the change in obesity prevalence at the beginning of each scenario.
SOURCES: Presented by Bruce Y. Lee, September 16, 2020; Lee et al., 2018. Figure used with permission from Elsevier.

dynamics model for exploring the effects of a staple foods ordinance. Resident-driven policy is a key tenet of the city's healthy food environment strategy, she explained, and this tenet manifested in the creation of a group called Resident Food Equity Advisors. The advisers were tasked with co-creating policy with the city planning department and government, and they convened for 2 years to research and develop recommendations for small retailers, such as corner and convenience stores. One of the recommendations, Buzogany continued, was to require corner stores to carry a minimum stock of health-promoting foods. The group partnered with Gittelsohn to develop a systems science dynamics model to simulate the effects of a staple foods ordinance, which she highlighted as an exemplar of government, community, and academia co-contributing to a shared vision.

Gittelsohn elaborated on the systems science dynamics model, which he said enabled the group to simulate the inclusion of different foods and beverages in differing amounts in a potential Baltimore staple foods ordinance and then use the model to recommend modifications to the ordinance. He explained that a first step in the model's development was to create a flowchart of the different processes involved, such as factors and constructs relating to supply (i.e., food retailers), consumers, and the ordinance itself. Each variable in the flowchart could be changed, Gittelsohn added, and modelers manipulated the variables to simulate four scenarios in which Baltimore corner stores could implement a staple foods ordinance. The scenarios varied with regard to levels of required minimum stock and enforcement.

Gittelsohn reported that one of the model's outputs was a projection of weekly profits that corner stores could expect to realize if they implemented a staple foods ordinance under each of the four simulated scenarios. Three of the scenarios, he noted, were projected to turn a small yet significant profit, but one, the Supplemental Nutrition Assistance Program depth-of-stock requirements, was found to be burdensome to the point of being unsustainable in the simulation. Thus, he said, this scenario would likely cause implementing stores to go out of business quickly, essentially removing it from policy consideration. Gittelsohn cited other outputs from the modeling simulation as well, such as information about optimal food prices that would achieve the maximum profitability, amounts of foods to order from suppliers in order to optimize sales and profitability and minimize waste, and expected levels of waste and consumer demand.

Gittelsohn briefly listed the model's limitations, starting with the specificity of the parameterization data to Baltimore City. Because local consumers and retailers provided the data, he elaborated, modification would be necessary to make the model usable in other settings. He pointed out further that the model is focused on proximal effects of a staple foods ordinance and is not yet linked to more distal effects, such as obesity or health outcomes.

Lee summarized the panel presentations by reiterating that the Baltimore case study illustrates how systems science modeling can better address and illuminate the complexities of a community, serve as a virtual community for testing different policies and interventions, facilitate communications and engagement within a community, and bring diverse stakeholders together. He ended by emphasizing the value of collaboration between systems science modeling experts and community decision makers and stakeholders, which he said enables an iterative feedback loop that informs and improves study design, data collection, and modeling parameters and supports other types of research.

PANEL AND AUDIENCE DISCUSSION

Following the second panel's presentations, Lee, Buzogany, and Gittelsohn commented on how dynamic systems components influence systems science modeling efforts and answered participants' questions about validation of models, strategies for communities that want to get started with modeling, training and education to prepare decision makers for systems science modeling, and support for urban agriculture tax credit recipients.

The Influence of Dynamic Systems Components on Systems Science Modeling Efforts

Lee explained that one of the reasons for developing an explicit model that represents all of the processes, components, and mechanisms of a system is that changes in policies and priorities may occur. It is helpful for a model to represent what is happening on the ground in terms of the actual mechanisms and processes, he observed, because if policies or interventions change, then modelers can adjust what is happening to the mechanisms. On the other hand, he continued, when a model is highly tailored to a specific situation, changes in outcomes of interest warrant returning to the model to manipulate its inputs.

Gittelsohn referenced the experience of the systems science dynamics model on a staple foods ordinance as an example of an iterative process. The team discussed different expectations and policy needs, he explained, and evolved the type of staple foods ordinance it considered as needs and priorities changed within the city government. Buzogany highlighted the role of political will in enacting, implementing, and enforcing policy. She noted that leadership changes in Baltimore have led the Food Policy Initiative to consider policy options in terms of the degree of political will present to move them, adding that even if a model indicates that a policy will have the intended impact, political will is a critical moderating factor.

Validation of Systems Science Models

Lee responded to a question about how to validate a systems science model of an intervention for reducing the prevalence of obesity. Given that many factors drive the prevalence of obesity, he stressed the importance of validating multiple aspects of the model (i.e., direct and indirect effects) and using more than one measure to validate each aspect. He explained that ground-level data can be used to validate how model agents move about and make decisions, such as by reviewing historical and current food purchasing and consumption data and matching agent behaviors accordingly. Weight changes in a model's synthetic population can also be programmed, he added, to mirror historical changes in the prevalence of obesity. According to Lee, when modelers validate a model in multiple different ways to help ensure that it represents all that it is supposed to represent, they can feel more confident that the model will take into account all of the important factors and components when a new policy is introduced. He stressed that the validation process never stops because although a model cannot achieve 100 percent validation, it is still important to continue to generate evidence to increase confidence that it is representing what it is intended to represent.

Getting Communities Started with Systems Science Modeling

Gittelsohn discussed the groundwork involved in building relationships within Baltimore, explaining that the Johns Hopkins team has been working in Baltimore communities for at least 15 years toward the goal of improving the food environment and that the team's modeling efforts began 5 or 6 years ago. Part of the secret of advancing such a goal, he disclosed, is establishing relationships with people in the community, maintaining those relationships over an extended period of time, and demonstrating commitment to working for change. Also helpful, he added, was that the university had already conducted other interventions in the city's corner stores and carry-out restaurants, which provided data that contributed to the model-building activity. As for funding, he noted that CDC's Nutrition and Obesity Policy Research and Evaluation Network and the National Institutes of Health have interest in this type of work.

Buzogany highlighted Baltimore's proximity to Johns Hopkins University, noting that the Food Policy Initiative benefits from its relationship with the university and its access to models developed there. Lee urged participants not to be dissuaded if they are starting from scratch to build relationships in communities. He encouraged them to start at the micro level, such as by examining a small, 1- or 2-mile radius area of the community to assess what is happening. Doing so will keep the effort low-cost while giving community stakeholders a concrete example of simulation modeling, he elaborated, which could help ease them into investing resources to develop a broader model.

Training and Education to Prepare Decision Makers for Systems Science Modeling

The speakers responded to a question about the extent of training and education required to get started with systems science modeling. After noting significant variability in states' levels of understanding of and experience with systems science modeling, Lee suggested providing decision makers unfamiliar with modeling concepts with research articles that can help them understand how models can aid in decision making. He emphasized the importance of avoiding providing articles with complex, technical jargon, lest decision makers perceive modeling as an arcane, academic exercise. In addition to sharing research, he suggested simply talking to and discussing ideas with people.

Gittelsohn pointed out that stakeholders may not recognize the iterative, multistep process that occurs between deciding to develop a model and conducting a complex simulation. This is a participatory process, he explained, that includes substantial planning and discussion of concerns, main players, and key factors, and occurs before mathematical calculations and equations come into play. Gittelsohn also suggested emphasizing that the group model-building process involves community members and decision makers and is not exclusive to academics or researchers, so that all types of stakeholders understand the critical role of their participation in the process.

Lee reiterated Gittelsohn's point that systems science modeling is an iterative process, and added that stakeholders can begin by developing a relatively simple model. There is value in developing an initial, smaller conceptual model to help give people a better sense of the topic of interest, he elaborated, even though this initial model may lack certain data and not provide a perfect representation of every factor involved. Once the initial model has been developed, he continued, stakeholders can prioritize areas where more data are needed and then collect those data to feed into the model, making it increasingly more comprehensive as the cycle continues.

Support for Urban Agriculture Tax Credit Recipients

Buzogany responded to a question about how recipients of the urban agriculture tax credit were prepared to succeed in converting their land for agriculture. She cited three organizations that offer such support: Future Harvest, which has a beginner farmer training program that pairs novice farmers with existing farms to facilitate hands-on learning; the Farm Alliance of Baltimore City, a member organization (which includes more than 20 of the city's urban farms) that shares tools and expertise and advocates for policy change; and the Black Church Food Security Network, which organizes beginner farmer training through Black churches and networks.

POLICY MAKERS: SALURBAL

The third panel included three speakers who discussed the usefulness of systems science approaches for policy makers. The speakers shared experiences with policy maker engagement in an international collaborative initiative called SALURBAL (Salud Urbana en América Latina [Urban Health in Latin America]), which incorporates systems thinking and systems approaches to promote urban health and environmental sustainability in Latin American cities.

Ana Diez Roux, dean and distinguished university professor of epidemiology in the Drexel University Dornsife School of Public Health, opened the panel with an overview of the SALURBAL study's goals and aims. It is an initiative of the Urban Health Network for Latin America and the Caribbean, she explained, implemented by Drexel University and 14 partners based primarily in Latin America and funded through the Wellcome Trust's "Our Planet, Our Health" global initiative. Diez Roux cited the study's three goals: to create an evidence base for making Latin American (and other) cities healthier, more equitable, and environmentally sustainable; to engage policy makers and the public in a new dialogue about urban health and urban sustainability and implications for societal action; and to create a platform and network that will ensure continued learning and translation. She also described the study's four aims: to identify city and neighborhood drivers of health and health inequities among and within cities, based on an analysis of data pooled from various sources; to evaluate the health, environmental, and equity impacts of policies and interventions by capitalizing on natural experiments; to use systems thinking and simulation models to evaluate urban–health–environment links and plausible policy impacts; and to engage the scientific community, the public, and policy makers in disseminating and translating the study findings.

Diez Roux highlighted SALURBAL's systems thinking aim, noting that systems science approaches are integrated into the full context of the study as one of three methods (alongside observation and experimental evaluation) for obtaining evidence relevant to urban health. She explained that the researchers decided to apply systems science modeling to transportation policy and food policy, which were selected as the two areas of emphasis because feedbacks and dependencies (in the sense of people influencing each other through social norms) are critical to both. She added that both areas have high policy relevance globally and regionally, and have strong health–environment links that may operate in both directions, which means that the effects of policies will likely involve reinforcing or buffering loops or dependencies.

Diez Roux emphasized the uniqueness of the policy maker engagement component of the study's fourth aim, suggesting that its purpose is to ensure the study's policy relevance, as well as to promote new ways of thinking among policy actors and other stakeholders about the drivers of urban health and the types of policies and interventions that could improve health and sustainability in cities. She explained that the study has engaged policy makers in its systems science aim by including them in participatory group model-building activities conducted in three regional workshops, which she said simulated local applications of this participatory approach. The study will conduct a second policy maker engagement activity once development of two simulation models has been completed, she added, and then yielded to her fellow panelists to elaborate on these examples of policy maker engagement.

Brent Langellier, assistant professor of health management and policy at Drexel University, expounded on SALURBAL's participatory group model-building exercise and its two policy-oriented, agent-based models. He began by reiterating the study's systems thinking aim:

> To employ systems thinking and formal systems simulation models to (1) better understand the dynamic relations between the urban environment, health and environmental sustainability; and (2) identify the plausible impacts of selected policies under varying conditions and dynamic relations.

The terms "models" and "modeling" are used broadly in the study, he clarified, to describe its efforts to both map the systems that influence urban health and employ formal quantitative simulation models, which together can enhance understanding of potentially highly effective policy opportunities.

Langellier stressed that policy makers generally recognize the complexity of urban systems and accept this attribute of their cities. He outlined three policy-relevant aspects of this complexity: feedback loops (bidirectional relationships with two or more variables), interdependence (outcomes of one person are often not independent of outcomes of other people), and change over time (a policy's effect may depend on the state of a system). He encouraged the use of common tools and terminology to describe complex systems and explore their influences on health, noting that the first 2 years of the SALURBAL study were strongly focused on this objective.

Langellier elaborated on three group model-building workshops—one in Lima, Peru; one in São Paulo, Brazil; and one in Antigua, Guatemala—conducted with 62 policy stakeholders during the study's first 2 years. These stakeholders included academics, elected and administrative policy makers in spaces such as public health and planning agencies, and representatives from nongovernmental organizations that influence local policies. The outcomes of interest were healthy eating and mobility/transport in Latin American cities, Langellier continued, and the objectives were to engage policy stakeholders in SALURBAL, introduce systems thinking by explaining such concepts as feedback loops and describing how to depict complex systems, describe the structure and function of complex systems that drive both healthy eating and transport and explore their overlap, explore multisector influences on urban health, and identify policy solutions that recognize complex system influences on health outcomes.

According to Langellier, a critical component of the workshops was scripted activities to introduce systems thinking and work toward mapping systems by facilitating the transfer of participants' mental models to a more explicit form. The workshops began with an activity called "graphs over time," he recounted, which was intended to engage participants in framing a problem, initiating mapping, generating variables, and prioritizing the variables as preparation for creating causal loop diagrams. Participants were prompted to think of a factor that influences healthy eating in cities, and to draw one trajectory showing how they hoped that factor would change over time and another showing how they feared it would change over time.

Another scripted activity was the creation of causal loop diagrams, Langellier continued, in which participants were instructed to create such diagrams in small groups and then present them to the larger group. A synthesis activity followed in which the small groups worked with facilitators to synthesize their diagrams into a single causal loop diagram representing a hypothesis about the food system/transportation system factors that influence a healthy urban environment. This juncture, Langellier said, is where the diverse and often overlapping perspectives of stakeholders emerged as the synthesis model took shape, and participants quickly recognized the complexity and interconnectedness of the systems involved. Langellier shared an example of an initial causal loop diagram produced during one of the workshops (see Figure 3-5). He flagged feedback loops related to healthy food consumption in the bottom left of the graphic and compared them with feedback loops related to transport and mobility incidents, located in the top right of the graphic. Stakeholders naturally integrated these two realms without prompting from the facilitators, he recalled, which he said illustrated the concept of multisector influences.

Langellier explained that after the causal loop diagrams had been created, participants completed a final scripted activity called "action ideas,"

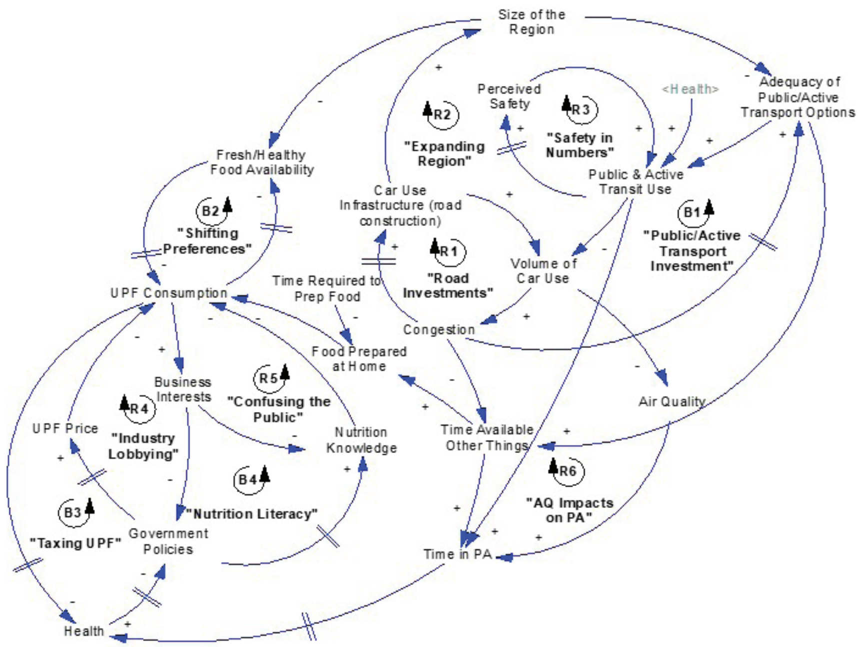

FIGURE 3-5 Example of a causal loop diagram developed by participants in a policy stakeholder workshop in Latin America.
NOTE: AQ = air quality; PA = physical activity; UPF = ultraprocessed food.
SOURCES: Presented by Brent Langellier, September 16, 2020; Langellier et al., 2019.

which he described as an opportunity to reflect on the system's structure and feedback loops and consider how they may influence the desired and undesired changes over time, helping to generate ideas for changes to the system to improve health outcomes. Those changes could take many forms, he clarified, such as adding or removing variables or feedback loops, or changing their magnitudes. After stakeholders had devised policy interventions, they added them to a 2 × 2 grid that ranked them by ease of implementation (easy or hard), as well as by level of impact (high or low). This exercise, Langellier observed, helped them consolidate the easy-to-implement, high-impact ideas, which in the workshops included advocating for food and transport, promoting cycling tours between healthy food sources in the city, and offering microcredit and credit assistance programs for urban farming.

Langellier shifted to a review of SALURBAL's two agent-based simulation models of urban policy, one focused on ultraprocessed food purchasing policy and the other on urban transport and mobility policy. He prefaced this discussion by noting that the stakeholder insights and action ideas generated during the group model-building workshops were important inputs into the formal model development, along with the research team's knowledge and literature reviews.

Langellier began with the ultraprocessed food purchasing model, explaining that it explored two questions. The first was how food labeling, advertising, and taxes can be combined most effectively to reduce purchasing of ultraprocessed food in Latin American cities. Langellier observed that there is currently much policy action on taxation, labeling, and advertising policies in numerous Latin American cities and countries. He characterized this as an opportunity to "strike while the iron is hot." He then shared the second question: whether policy effects vary across different population segments (high versus low income and educational attainment). Langellier explained that the model comprises adult females living in urban areas in Latin America who are the primary food purchasers in their households, and uses population demographics and ultraprocessed food purchasing data from Mexico City. He noted that those data could easily be replaced with data from any other urban area in Latin America, providing a flexible framework. The agents are organized in social networks, he continued, with ties more likely among agents of similar age, income, and education levels. He added that, because social influences and social norms are important drivers of dietary behaviors and are potentially important for policies aimed at reducing inequities, it was important for the model to account for interdependencies among people.

Langellier pointed out that as the model runs, ultraprocessed food purchasing is updated in response to social norms and social influence and to price, labeling, and advertising policies. He described three factors on which policy effects are based: price elasticities from Latin American countries (price changes relative to income), advertising (advertising elasticities), and labeling (based on a Chilean policy evaluation of the first comprehensive stoplight labeling policies in Latin America).

Moving from the structure of the model to its utility, Langellier reiterated that taxation and labeling policies are under consideration in several Latin American countries, and that policy effects are likely to vary with different contexts, levels, and combinations. He suggested that the food industry will probably respond to such policies with advertising, referencing a history of increased industry advertising and lobbying efforts to influence policy enactment and implementation. An increase in advertising can challenge efforts to evaluate the effects of a policy, he explained, because the change in advertising occurs concurrently with the policy change. Finally, Langellier stressed that developing the modeling infrastructure was helpful because modelers can quickly change the model's parameters—related to both the city and the tax or policy levels—making the model what he characterized as an urban food policy lab that can be applied to future policy proposals in different locations.

Langellier moved on to discuss the second agent-based model, which deals with urban transport and mobility policy. He described its purpose as modeling commuter decision making and behavior in a city inspired by Bogotá, Colombia, where there are five commuting modes: car, motorbike, bus and bus rapid transit (BRT), bicycle, and walking. He explained that because SALURBAL's intent is to explore interconnections among behavior, health, and the environment, this model can be used to explore how public transportation policies, taxation, and interventions to improve personal safety from crime affect mode share, physical activity, and air pollution.

The model is spatially explicit, Langellier pointed out, which accounts for residential segregation in a city, income inequity, and commutes between homes and workplaces. Additional features of the model's design include variance in car, motorcycle, and bicycle ownership by income; a realistic distribution of bus and BRT stops through the city; assignment of a safety variable to each mode based on available crime data; and population and environment factors informed by Bogotá data. Langellier also listed the rules for the urban transport and mobility policy model. Agents make a daily commute-to-work decision, he said, based on the modes of transportation available to them, their determination of the highest-utility mode (a function of travel time and cost), and their evaluation of the perceived safety of each mode (i.e., avoiding modes that they consider unsafe based on their threshold for safety).

Finally, Langellier echoed his earlier comment about the models' value in establishing modeling infrastructure to enable examination of specific policy proposals. He underscored that both models effectively integrate health aspects with outcomes of interest to policy makers in multiple sectors.

Felipe Montes Jimenez, associate professor in the Department of Industrial Engineering at the Universidad de Los Andes, shared a case study of an effort called TransMiCable that implemented cable car transport in a low-income, densely populated area of Bogotá. Implemented in 2018, the cable car system had more than 7.5 million passengers in its first year of operation. Montes Jimenez was involved in research designed to provide evidence for an urban development effort that implemented 16 projects aimed, for example, at improving facilities for recreational and cultural activities and making physical improvements to homes. He explained that the objective of the research was to evaluate the effect of the implementation of one of these projects—TransMiCable—in three areas: environmental and social determinants of health, physical activity (for both leisure and transport), and health outcomes (quality of life, respiratory diseases, and homicides). A key component of the evaluation, he elaborated, was its use of citizen science to identify, prioritize, and communicate the TransMiCable cable car intervention's negative and positive impacts on health and quality of life in the community, which Montes Jimenez said contributed to empowering the community and increasing its uptake of the intervention.

Montes Jimenez then described the evaluation's conceptual framework, explaining that the first step was to convene multisector stakeholders, including community members and academics. The stakeholders participated in a group model-building workshop where they engaged in scripted activities for the purpose of developing causal loop diagrams, he elaborated, that would complement the conceptual model and identify and explore policy alternatives within the TransMiCable evaluation. He reported that the first draft of the causal loop diagram seemed messy, but that concrete constructs and cause-and-effect relationships were deduced on closer examination and additional dialogue with participants. Montes Jimenez relayed that after the workshop, researchers held one-on-one interviews with several stakeholders to review the diagram, collect inputs on its feedback loops, and clarify terminology to accurately reflect the jargon of each discipline and sector. Following these interviews, the researchers revised the diagram so that it more clearly depicted four key aspects of the system (see Figure 3-6).

Montes Jimenez elaborated on these four aspects, beginning with health conditions. The updated diagram, he said, conveyed that social dynamics favor both physical activity promotion and the dynamics of transport that could influence mental health and leisure activities. He cited as a second aspect social and economic development, denoting social dynamics that could affect mobility, interurban displacement, and quality of life. Mobile phone apps track movements in a sample of people, he added, which helps researchers understand how the intervention is changing mobility in terms of travel time and quality. The third aspect, operationalization of TransMiCable, refers to the provision of an efficient service. Finally, Montes Jimenez described the fourth aspect, citizen's culture, as involving community participation and ownership of the intervention, as well as reinforcement of inclusive behaviors that nurture well-being and reduce vandalism and gender-based violence in the area where the cable cars operate.

Montes Jimenez ended his presentation with reflections on the TransMiCable evaluation. The involvement of multisector stakeholders led to a shared mental model of the system, he observed, represented by four domains that were previously undefined. He stressed that inviting policy makers to co-create the conceptual framework for research and project evaluation helped make them supportive of the evaluation's conduct and made its results visible for the city. He noted that a second cableway is intended to be added in the control area of the city as part of a second intervention. Lastly, he highlighted how the involvement of both policy makers and community members served to level the playing field by giving everyone the same opportunities to be heard and to contribute to a shared mental model that incorporated different points of view.

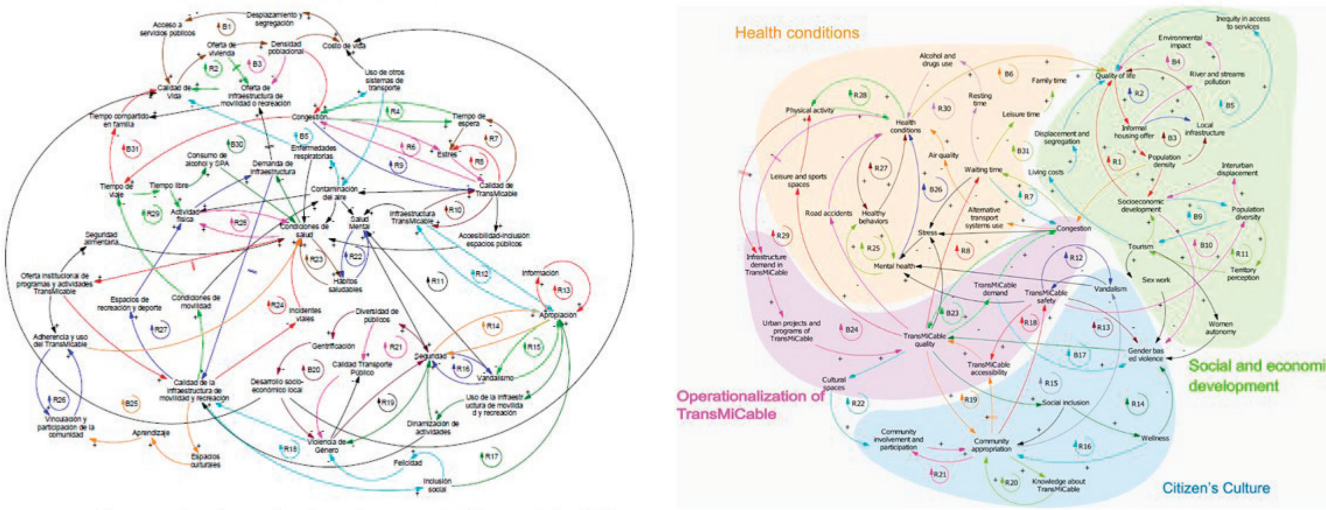

FIGURE 3-6 Causal loop diagram created during the TransMiCable group model-building workshop (left) and updated based on stakeholder interviews following the workshop (right).
SOURCES: Presented by Felipe Montes Jimenez, September 16, 2020; Sarmiento et al., 2020.

PANEL AND AUDIENCE DISCUSSION

Following the third panel's presentations, Diez Roux, Langellier, and Montes Jimenez commented on the origins of the Urban Health Network, modeling's role in informing policy making, modeling training for the public health workforce, and citizen science as a means of engaging communities in systems approaches. They also responded to participants' questions about SALURBAL's use of agent-based models versus system dynamics models to simulate intervention impacts, stakeholder feedback from group model-building workshops, and managing strong personalities in these workshops.

Origins of the Urban Health Network

According to Diez Roux, the Urban Health Network originated at Drexel University with a meeting among a handful of colleagues with personal connections to Latin America and shared research interests in urban health issues. The policy maker engagement piece was highly important from the start, she recalled, clarifying that the group's focus is not on research but on policy engagement. As the Urban Health Network grew and added members in different Latin American countries, she continued, an opportunity arose to apply for funding from the Wellcome Trust, which was interested in funding an international collaboration that involved policy maker engagement. That funding was critical, Diez Roux noted, for creating the Network's infrastructure and a platform for collaborating and generating evidence to support public policy. She remarked that a similar approach could work for connecting stakeholders in various U.S. metropolitan areas who have shared interests.

Modeling's Role in Informing Policy Making

Using COVID-19 models as an example, Langellier emphasized the importance of recognizing that although policy decisions do not always match what models may suggest should be done, the models are still influential in generating important insights that influence policy directly or indirectly (e.g., in the case of COVID-19 models by helping to clarify key aspects of the pandemic and how it evolves). COVID-19 models could be developed relatively quickly, he pointed out, because of decades of prior research and investment in the infrastructure needed to develop infectious disease models. In contrast, he pointed to chronic diseases, for which there is a long way to go to build modeling infrastructure that can be responsive to acute policy needs. He explained that a focus of the Urban Health Network's efforts to develop agent-based and group-based models is to enable the generation of policy-relevant evidence, but the Network is also building a modeling infrastructure that will facilitate faster responses to future policy decisions.

Modeling Training for the Public Health Workforce

Langellier mentioned a training program in systems thinking and a short course on group model building that were both offered at Drexel, noting that the latter was attended mainly by people from nongovernmental and government organizations who wanted to learn how to use these tools. He highlighted the critical importance of the Urban Health Network's funding support, which he said allowed it to prioritize the development of modeling infrastructure and capacity. Yi concurred and suggested that funding can also facilitate opportunities to convene and connect stakeholders for informal consensus building and discussion of shared interests and goals.

Community Engagement Through Citizen Science

Montes Jimenez commented on TransMiCable's citizen science component, whereby community members were invited to help researchers gather data by taking pictures of the environment surrounding the cable car location and observing barriers and facilitators for health. The purpose of the data gathering was to provide useful insights for policy makers, he explained, and ultimately to make agreements and commitments with them about follow-up actions for both the community members and the policy makers. Inviting the community members and policy makers to join in the modeling process made them aware of the initiative and helped them feel engaged in it, he continued, making it more inclusive and systemic because all of the actors participated and contributed to a shared outcome. He added that a citizen science model can foster longer-term sustainability of an intervention because it enables community ownership of an effort.

Use of Agent-Based Models to Simulate Intervention Impact

Langellier responded to a participant's question about the use of agent-based versus system dynamics models to simulate impacts of the SALURBAL intervention. He noted that SALURBAL collaborators are in the process of developing system dynamics models of obesity transitions in Latin American countries, but explained that agent-based models were chosen for the ultraprocessed food model for purposes of flexibility and for utility in addressing future research questions. The model will examine ultraprocessed food consumption as an outcome, he reminded participants, and although access to different types of food is an important factor, the model is not spatially explicit. But the agent-based framework will enable researchers to examine how the agents' ultraprocessed food purchasing behaviors are affected by social networks and social influence, he explained, which are drivers of dietary behaviors and thus are important to consider when developing policies to address social inequities. He pointed out that the model could be expanded in the future to a more choice-oriented framework whereby agents would choose between ultraprocessed and other types of foods.

Stakeholder Feedback from Group Model-Building Workshops

Diez Roux clarified that a range of health care providers, such as physicians and nutritionists, are part of the SALURBAL community, and remarked that the diversity of backgrounds among participants has enhanced the initiative's group model-building exercises. According to Diez Roux, feedback from these exercises indicated that participants had begun to apply systems thinking to their conceptualization of problems, and that they went away from the exercises with the intention of conducting similar activities at their own worksites. She asserted that this shift in participants' mindsets is extremely valuable, suggesting that this outcome may be even more valuable than the results generated from the formal simulation models.

Managing Strong Personalities in Group Model-Building Workshops

Montes Jimenez responded to a participant's question about how to prevent outspoken, opinionated participants in group model-building workshops from suppressing other participants' involvement in the activity. He explained that facilitators of group model-building workshops are trained to anticipate such situations, to which they may respond by ensuring that all participants have an opportunity to talk and provide feedback on ideas, or by placing participants in small, diverse groups. The goal of developing a shared mental model helps, he added, because it removes the focus from any individual's specific situation and views.

4

Reflections on Using Systems Science Applications to Inform Obesity Solutions

Highlights from the Presentations of Individual Speakers

- Three strategies for translating systems science modeling results for community partners are planning for dissemination at the outset of a project; creating highly visual, tailored resources; and emphasizing resources and tools that are interactive, dynamic, and explorable, such as interactive dashboards and visual before-and-after presentations. (Douglas Luke)
- It is important for participants in systems science modeling efforts to understand each other's roles, contributions, and goals for the effort, as well as each other's expectations and how their inputs will be used. (Sara Czaja)
- Developing different systems science models to explore the same issue (i.e., comparative models) and then comparing and contrasting their predictions and results can help inform an appropriate level of confidence in the potential outcomes of an intervention. (David Mendez)
- Health care providers would benefit from training in systems science that helps shape their perspectives about the context in which their prescribed interventions occur, and also reinforces their opportunity to play an influencer role within systems, such as by helping to link patients to community supports and resources. (Jamy Ard)

- Building relationships that lead to long-term, sustainable change in communities can start with an informal initial conversation and progress organically over time as parties discuss mutual interests in a particular population or topic area. (Stella Yi)
- A technique for initiating community and stakeholder engagement in a systems science modeling process is to invite them to draw path diagrams, an iterative process that ultimately results in the development of dynamic models that are useful for intervention and optimization. (Daniel Rivera)
- Most stakeholders harness only a small percentage of systems science modeling capabilities; predictions represent only a sliver of a model's capability. (Bruce Y. Lee)
- Much progress has been made with respect to the maturation of systems science models and the formation of a community of systems science stakeholders. Self-reflection and self-correction are valuable habits for stakeholders to practice to enable continued progress in the field of systems science. (Patty Mabry)

In the workshop's final session, its organizers shared their reflections from the workshop presentations and discussions. Each individual provided brief remarks on a variety of issues focused on encouraging and helping to support the use of systems science thinking and systems science approaches to address the complexity of obesity drivers and solutions. Following the organizers' remarks and a brief panel question-and-answer session, a closing speaker delivered final reflections on the workshop's discussions. Nicolaas (Nico) Pronk, president of HealthPartners Institute, chief science officer at HealthPartners, Inc., and adjunct professor of social and behavioral sciences at the Harvard T.H. Chan School of Public Health, and Christina Economos, co-founder and director of ChildObesity180 and professor and New Balance Chair in Childhood Nutrition at the Tufts University Friedman School of Nutrition Science and Policy, moderated the session.

REFLECTIONS AND DISCUSSION OF NEXT STEPS

Douglas Luke, Irving Louis Horowitz Professor in Social Policy and director of the Center for Public Health Systems Science at Washington University in St. Louis, commented on strategies for translating systems science modeling results and disseminating resources and tools to community partners. He outlined three points, attributing the first to his friend and colleague Ross Brownson. One of Brownson's key tenets, he noted, is to encourage the conduct of dissemination planning at the outset of a project instead of waiting until its completion. Luke highlighted the importance of ongoing dialogue with community partners about what type of resources they need to support their decision making.

Second, Luke pointed to several translational challenges or steps entailed in systems science modeling efforts. Modelers first translate for a scientific audience, he explained, as they consider how to convince epidemiologists or health economists, for example, about the reliability, validity, and utility of a model. The second translational step, he observed, occurs when modelers translate their learnings into data and wisdom that community planners and stakeholders can use, and he stressed that the tools and resources that are most helpful in this step are different from the typical outputs of a National Institutes of Health (NIH)-funded study. Luke appealed for highly visual resources that are tailored to the extent possible, commenting that policy makers are more likely to be engaged when they see a model's projections for their specific area of concern.

Third, Luke emphasized tools that are interactive, dynamic, and explorable. As an example of such a tool, he highlighted Lee's map of Baltimore (see Chapter 3), where the agents could be seen moving around. He also highlighted interactive dashboards that visually present a variety of information, maps, or other interfaces that show a physical area of interest; before-and-after presentations that display how an environment might look postintervention; and resources that allow people to explore what-if scenarios.

Sara Czaja, professor of gerontology in medicine at Weill Cornell Medicine, spoke about the importance of leveraging partnerships and multidisciplinary teams to address complex challenges. Given that systems science approaches involve the interaction of multisector stakeholders, she urged early planning for how the layers of participants will communicate effectively despite coming from different arenas. In terms of training and education, she continued, it is important for participants in systems science approaches to understand the roles and contributions of the various players, as well as their goals for the targeted effort.

Czaja also encouraged understanding and managing stakeholder expectations. For example, she stressed that it is important for systems science modelers to determine how community stakeholders' input will be used and to understand how this determination aligns with those stakeholders' expectations regarding the implementation of their inputs. She noted that, while it is not always feasible or even possible to integrate every input into a model, it helps if people understand that from the start.

Lastly, Czaja urged consideration of the importance of keeping people informed about progress and motivated, especially when efforts are complex and lengthy. She emphasized that people want to understand how they are making an important contribution to the process. Communication is key, she insisted.

David Mendez, associate professor in the Department of Health Management and Policy at the University of Michigan School of Public Health, assessed the utility of systems science modeling. The utility of these models, he postulated, depends on one's expectations for them. Systems science modeling helps solve a specific problem or answer a question, he elaborated, and modelers can incorporate various levels of complexity into a model to answer a specific question. The model becomes a representation of an idea, he continued, a hypothesis about the processes that govern the topic of interest. If one has a relatively narrow problem to address, he observed, the corresponding mental map and systems science model may not be as complex as one that shows all of the interconnections among the greater systems at play.

Mendez shared a challenge of his work in evaluating tobacco policy—that the impacts of policies of interest take a long time to materialize. Realizing that a model can help evaluate the range of time in which such policies will be successful, his team developed a model to gauge the overall mortality caused by smoking over time. By better understanding the magnitude of the problem, Mendez explained, the team was able to derive a set of robust policies for addressing that problem. He argued that even though unintended consequences are likely, it is important to use the best information available to make policy decisions now. He suggested the use of comparative models—different models for the same topic—to assess how they differ in their results, explaining that this approach can help inform a level of confidence in the potential outcomes derived from the modeling.

Jamy Ard, professor in the Department of Epidemiology and Prevention and the Department of Medicine at the Wake Forest University Baptist Medical Center and a member of the 2020–2025 Dietary Guidelines Advisory Committee, shared his perspective on the inclusion of systems thinking and modeling in the development of the Dietary Guidelines for Americans and on how using systems science approaches at the micro level affects his daily work as a clinician.

Food, nutrition, and the consequences of dietary intake for health are interrelated, Ard remarked, and manipulating one variable leads to a series of consequences that affect nutritional status and health trajectory in the context of disparities in obesity and other chronic diseases. Therefore, he maintained, the process of developing the Dietary Guidelines could naturally be all about systems. He observed, however, that the process of developing the Dietary Guidelines has historically taken a reductionist approach, whereby until recently, the recommendations have been based more on nutrients than on foods or dietary patterns. The challenge going forward, Ard suggested, is to integrate systems science approaches into the development of dietary guidance at both the population and individual levels. The 2020–2025 Dietary Guidelines Advisory Committee took a life-stage approach, he recounted, as it considered the science informing dietary guidance. Much more can be done, he argued, with regard to integrating a systems science approach into the nutrition science evidence base and the process of developing dietary recommendations to reduce the risk of chronic disease.

With regard to his role as a medical provider, Ard proposed that health care providers would benefit from training in systems thinking to help shape their perspectives on the context in which their prescribed interventions occur. He suggested that, upon learning about the web of systems influences that affect patients, clinicians might feel frustrated that their treatments or counseling will accomplish little because they cannot control the host of environmental and social influences that affect their patients' health behaviors. Nonetheless, he appealed for helping providers understand how even at the individual level they can play an influencer role within systems, such as by helping to link patients to community supports.

Stella Yi discussed the formative work involved in engaging stakeholders and community members in participatory group model building. According to Yi, the participatory systems science process is a tool for providing structure around collaboration that is aimed at addressing shared priorities. Speaking from her perspective as a health disparities researcher who has worked in partnership with Asian American communities and community-based organizations for more than 15 years, she noted that her group's long-term relationships with communities have enabled much dialogue about issues that are important to residents. These conversations served as a precursor, she said, to her team's current efforts to engage communities in group model-building exercises to learn about healthy diet and lifestyle behaviors among older Chinese and Mexican immigrant communities in Brooklyn.

Yi pointed out to participants that although it takes time and effort to foster the connections that lead to long-term, sustainable change in communities, they likely already have relationships with the communities that they seek to help. If not, she suggested that relationship building can start with an initial conversation and progress organically as the parties discuss mutual interests in a particular population or topic area. She acknowledged that this may sound simplistic, but argued that it is truly how relationships begin, and she noted that this model has worked well to enable her group to engage with communities that are underrepresented in the health literature and policy space. Different stakeholders have unique contributions to offer, Yi stressed, sharing an example in which her university provided data collection tools to community-based organizations that wanted to collect data but lacked the capacity to do so. At the same time, however, the organizations brought the essential assets of the trust of the community members, cultural and linguistic knowledge, and an understanding of how programs can be designed to be maximally successful for those they are designed to help. To end her remarks, Yi appealed for solutions that incorporate voices from diverse age, racial, and ethnic groups that mirror the makeup of the target population.

Daniel Rivera, professor of chemical engineering and program director of the Control Systems Engineering Laboratory at Arizona State University, offered suggestions for initiating community and stakeholder engagement in the systems science modeling process. These suggestions, he noted, were based on his viewpoint as a chemical engineer who works as a modeler in partnership with intervention and behavioral scientists to deliver optimized, personalized interventions related to behavioral medicine. Rivera maintained that, regardless of an intervention's outcomes of interest, issues of language (jargon) and domain expertise persist. Some degree of tension also typically exists, he added, and he shared a personal example in which his scientific understanding of the definition of an experiment had been broadened by working with behavioral scientists.

Rivera highlighted the usefulness of guiding groups to draw path diagrams, which he described as an iterative process that ultimately results in the development of systems science dynamical models that are used for intervention and optimization. Some theories of behavior are amenable to a dynamical systems interpretation, he continued, giving the example of an effort that developed a dynamical systems science model for social cognitive theory. Good path diagrams for this theory did not exist in the literature, he said, so his team developed a system dynamics model with a fluid analogy that has similarities to the stock-and-flow models used in system dynamics. The fluid model can be correspondingly expressed as a path diagram, he reported, which, thanks to his team's efforts, is now available for social cognitive theory.

Rivera echoed Jack Homer's comments from earlier in the workshop (see Chapter 2) about the balance between testable models and models that are "good enough." He pointed out that the goal is often to get to the simplest model that helps answer basic questions, and suggested that this goal is better than integrating every possible construct and contextual variable that could influence the outcome of interest.

Bruce Y. Lee, professor of health policy and management at the City University of New York Graduate School of Public Health and Health Policy and executive director of Public Health Informatics, Computational, and Operations Research, reviewed the purposes and capabilities of models and addressed the misconception that all models are the same, so only one model is needed for a given situation. He referenced the public conception that models for predicting COVID-19 mortality counts were "wrong" because they did not predict exactly what occurred, arguing that predictions represent only a sliver of a model's capability. Predicting the future is difficult, he pointed out, and he described the process of building a budget spreadsheet as an analogy for a model's inputs and purposes. One would not use a budget spreadsheet to predict how much money would be earned in 1 year, he stated, because too many variables are involved, whereas a budget spreadsheet would be useful to help conceptualize one's financial context and better understand the relative contribution of each line item to total spending. This latter use might involve checking receipts, he continued, which is analogous to data collection, and as more data are added, the budget model is revised. Moreover, he observed, an accountant or family members might be asked to weigh in, which he described as an example of modeling bringing people together to collect their inputs or inform them about what the model describes, ultimately refining the shared understanding of the situation and integrating other research methods and data.

To address a common misconception of stakeholders new to the modeling process that all systems science models are the same, Lee recalled cases in which people claimed that a model was not needed to address a particular question because they had already developed a model on that topic. He pointed out, however, that this would not be the way one would respond about a clinical trial; rather, more clinical trials would be conducted to examine similar outcomes in different populations and contexts. He emphasized that wide diversity exists within systems science approaches, and modelers sometimes use the same technique in different ways. Lee suggested that a problem or question would benefit from assessment by several modeling teams, with the results then being compared. Similarly, he observed, people's conceptualizations of a given problem or issue are diverse. He argued that this diversity can be explored by perspectives of a range of stakeholders, which can help modelers understand differences in the understanding of or access to information about a problem.

Lee concluded his remarks by proposing a change in the paradigm of how systems science modeling is used, asserting that most stakeholders harness only a small percentage of modeling capabilities.

PANEL AND AUDIENCE DISCUSSION

Following the reflections summarized above, the workshop organizers discussed early-life opportunities for introducing systems thinking, systems science models of the effects of taxing sugar-sweetened beverages, strategies for enabling novices to get started with modeling, and potential unintended consequences of defining obesity in systems science models.

Training in Systems Thinking: How Early?

Ard suggested that it is never too early to introduce systems thinking concepts, clarifying that such conversations do not necessarily have to use the term "systems thinking." Rather, he argued, they can simply convey the interconnectedness of the world, the effects of one's actions on others, and the effects on systems of actions at the population level. Yi mentioned the children's book *When a Butterfly Sneezes*, which helps learners recognize the systems nature of such common objects as a tree or the human body and describes the downstream effects of something as simple as the flap of a butterfly's wings. She noted that although the jargon of systems scientists can be intimidating, it describes a concept that is innately understood by the human brain. Luke suggested encouraging students to take a systems perspective on the world as they progress through school, and Pronk added that it may be helpful to call out systems thinking explicitly so that students recognize it in the context of their training and education. According to Lee, it is important for training to include an explanation of methods and their purpose so that people understand appropriate applications. Yi pointed out that much systems science modeling occurs in a vacuum, but that actual implementation of modeled interventions involves additional, on-the-ground factors and participation that result in decisions regarding the differences between efficacy and effectiveness. She stressed that the participation of multisector stakeholders can help make models more applicable to the real world with potentially enhanced sustainability and effectiveness. Czaja added that exposing people to other disciplines and ways of thinking can help prevent the formation of disciplinary siloes.

Mendez distinguished between systems thinking and systems science modeling. He agreed that early integration of systems thinking in education is important so that people understand how inputs flow into outcomes, as well as the concept of interconnectivity. With regard to the latter, he stressed the importance of recognizing that a problem is likely affected by a host of environmental determinants that may not all appear to be directly related to it. He suggested that moving from systems thinking to systems science modeling requires more formal, specialized training.

Systems Science Models of Taxing Sugar-Sweetened Beverages

Lee responded to a participant's question about the existence of systems science models examining the effect of taxing sugar-sweetened beverages on their consumption and ultimately on the incidence of obesity. He confirmed that such models exist, noting that the Global Obesity Prevention Center funded a pilot project at the University of California, Berkeley, to collect data on these taxes in various Bay Area municipalities. The goal was to use the data to help calibrate and also validate different models for predicting the outcomes of implementing these taxes, he explained, acknowledging that the issue is complicated because of the heavy media attention and public interest that these policy proposals tend to generate.

Getting Started with Systems Science Modeling

In response to a participant's question about how a novice can begin applying systems science modeling, Luke highlighted the value of social networking for identifying local experts who can help. Lee suggested a "happy hour approach," which involves trying to identify someone with crossover interests or experience working in the same discipline who can help bridge the gap between one's interests and systems science modeling.

Potential Unintended Consequences of Defining Obesity in Systems Science Models

A participant commented that some stakeholders have suggested that the use of weight status to assess health results in stigma and disordered eating, and asked whether assigning definitions for obesity in systems science models could have such unintended consequences. Lee replied that systems science models incorporate a host of factors and processes that affect the outcomes of interest, so there is rarely one factor, such as weight, that drives everything. He stated that the challenge is to ensure that the translation of a model's results emphasizes this multifactorial complexity to communicate the full story.

FINAL REFLECTIONS

Patty Mabry, interdisciplinary scientist at HealthPartners Institute, delivered final reflections on the workshop's discussions about applying systems science approaches to obesity solutions. She also included in her remarks additional content not covered by the speakers.

Mabry commended Homer's chart comparing characteristics of three simulation approaches for systems science modeling (see Figure 2-1 in Chapter 2), and added that an entire field of network science and its subfields exists within the column for microsimulation or agent-based models. She also referenced Homer's blueprint for an ideal, well-funded project, and suggested that another important component is providing tailored education to different stakeholders about appropriate uses and expectations of a model. She reminded participants that models are not reality; they are simplified versions of reality that provide a better understanding of complex problems. When models are developed with stakeholder input, she argued, they reflect the perspectives and experiences of those stakeholders.

Mabry next recalled Lee's presentation about the Virtual Population Obesity Prevention Labs and the synthetic population it built using census data. She referenced secondary sources of data for populating systems science models, including FIGSHARE; Research Triangle Institute's U.S.

Synthetic Household Population; Social Science One (data from private industry sources, such as Facebook); SyntheticMass (1 million synthetic electronic health records); and All of Us Research Hub, a new NIH research program that is collecting longitudinal data from participants of all backgrounds to support efforts to reduce health disparities and improve health equity, among other purposes.

Mabry touched on sources for data on social determinants of health, highlighting the NIH PhenX Toolkit and a number of additional sources on the Centers for Disease Control and Prevention's website (RTI International, 2020a,b). She pointed out that most data on social determinants of health are available at the aggregate level, and that individual-level measures are often not available.

Mabry then called participants' attention to work from Kevin Hall and colleagues that involved developing and validating a quantitative mathematical model of the dynamics of childhood growth and obesity (Hall et al., 2013). She supported reusing systems science models when appropriate, pointing to the Hall team's model as one that could be applied to other modeling efforts.

Mabry next emphasized the importance of spatial models, referencing the map of healthy food priority areas in Baltimore presented by Buzogany and SALURBAL's spatially explicit model of urban transport and mobility policy (see Chapter 3). Such models are important for understanding inequalities in health, she maintained, because the spatial environments for food and physical activity are critical factors in these inequalities.

Systems science methods are motivated by complexity in behavioral and social science data, Mabry stated, and she detailed aspects of this complexity: temporal properties, spatial properties, network structures, hierarchical and nested structures, feedback loops, variation at the individual and group levels, mediating and moderating variables, and nonlinear and nonparametric properties. She shared a figure depicting the complex context of health disparities and obesity (see Figure 4-1), in which a continuum of biological and social factors is portrayed as extending across the lifespan.

Mabry then reiterated the value of self-reflection and self-correction for enabling progress in modeling. Humans do not always solve complex problems, she suggested, because doing so takes hard work and complex solutions. She quoted a statement by advice columnist Ann Landers: "Opportunities are usually disguised as hard work, so most people don't recognize them." She maintained further that people tend to pursue low-hanging fruit—easy opportunities waiting to be seized and requiring little expenditure of effort. But that is not how most complex problems work, she insisted, urging participants to "go for the hard part." Mabry also highlighted *Thinking in Systems: A Primer*, a book by scientist Donella

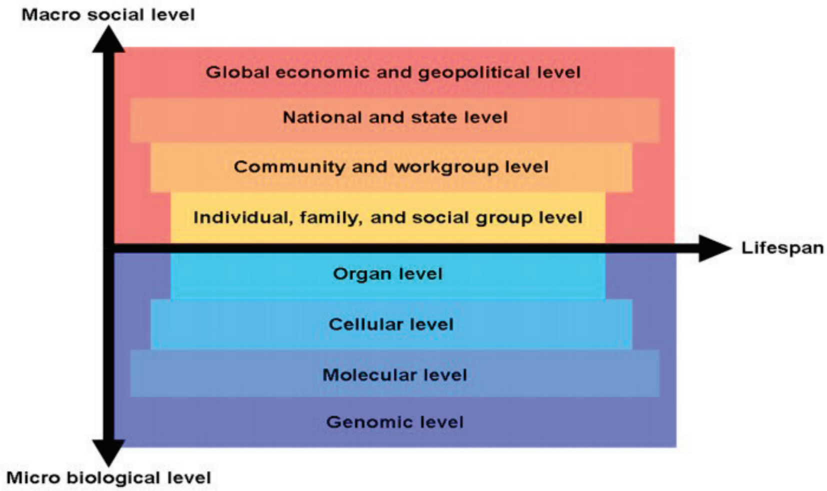

FIGURE 4-1 The complex context of health disparities and obesity: Health as a continuum of biological and social factors across the lifespan.
SOURCES: Presented by Patty Mabry, September 16, 2020; adapted from Glass and McAtee, 2006.

Meadows, as a good starting point for learning about systems thinking. According to Mabry, a key portion of this book is Chapter 6, in which the author explains that the easy places to intervene in a system will offer the lowest return on investment, while the most difficult places will net the greatest return.

Next, Mabry enumerated challenges in systems modeling that make it a difficult endeavor: finding appropriate sources of data, particularly longitudinal data; maintaining stakeholder engagement (i.e., with policy makers, health care systems, or businesses); dealing with impatience to produce actionable results, particularly for policy makers who have limited time in office; building interdisciplinary teams and communicating across disciplinary boundaries; doing what one knows instead of learning what one should do (i.e., lack of self-efficacy); relying too much on randomized controlled trials as the gold standard for evidence, because this is not the best method for every research problem or question; following through on the course of action that a model indicates, particularly when doing so runs counter to one's ideology; and dealing with the "prevention conundrum," which Mabry described as the difficulty of proving that an intervention indicated by a model avoided an impending fate. To illustrate this latter challenge, she recounted Lee's earlier example (see Chapter 3) of a model indicating that increasing physical activity to a certain level for at least half of the U.S. youth population would avert billions of dollars in medical care costs and lost productivity. It is difficult to convince people to take action based on these modeling results because they did not feel the pain of paying those billions of dollars, she explained, and they will not receive billions of dollars back in cash or some other tangible form by taking such action.

Mabry moved on to the topic of recruiting systems modeling teams, detailing various types of stakeholders and experts to consider including, such as health geographers or other experts who know how to integrate spatial information into models, modelers themselves, community members, and policy makers. She drew an analogy comparing these players to bricks and another player, interdisciplinary scientists, to the mortar between the bricks, emphasizing the importance of including team members who can facilitate communication across disciplinary boundaries.

Mabry closed her presentation with a list of additional resources for those who wish to delve further into systems modeling (see Box 4-1). She also outlined potential future directions for systems modeling efforts (see Box 4-2), emphasizing the value of building a community of systems scientists. She suggested that this latter good would be enabled by more coordination and perhaps a new society dedicated to the topic, and would benefit from increased sharing and repurposing of research assets. She also highlighted the need for funding to form community-based research relationships and to educate practitioners in the use of systems science to inform research priorities.

BOX 4-1
Additional Systems Science Resources

Course

- Modeling classes delivered by Nathaniel Osgood at the University of Saskatchewan (https://www.cs.usask.ca/faculty/ndo885/Classes/index.html, accessed December 3, 2020)

Websites and Organizations

- Computer Simulation and Advanced Research Technologies (http://www.csart-world.com, accessed December 3, 2020)
- National Collaborative on Childhood Obesity Research Envision (https://www.nccor.org/envision, accessed December 3, 2020)
- Society for Prevention Research 2007 Symposia Series on Systems Science and Health (https://www.preventionresearch.org/conferences/training/2007-symposia-series-on-systems-science-and-health, accessed December 3, 2020)
- Systems Science in Health (https://healthmodeling.org, accessed December 3, 2020)
- United Kingdom Prevention Research Partnership System-Science in Public Health and Health Economic Research (https://sipher.ac.uk, accessed December 3, 2020)

Publications and Books

- Kim, D. Forthcoming book on applications of modeling and simulation methods to public health and social epidemiology to be published by Wiley & Sons.
- Mabry, P. L., and R. M. Bures. 2014. Systems science for obesity-related research questions: An introduction to the theme issue. *American Journal of Public Health* 104(7):1157–1159.
- Meadows, D. H. 2008. *Thinking in systems: A primer*. White River Junction, VT: Chelsea Green Publishing Company.
- Sterman, J. D. 2006. Learning from evidence in a complex world. *American Journal of Public Health* 96(3):505–514.

SOURCE: Presented by Patty Mabry, September 16, 2020.

BOX 4-2
Potential Future Directions for Systems Modeling Efforts

- Addressing the root causes of inequalities in the distribution of obesity
- Fostering cross-sector stakeholder engagement
- Developing geographically explicit models and involving health geographers to explore disparities
- Procuring funding to form community-based research relationships
- Pressuring funders to support education for practitioners in the use of systems science to inform research priorities
- Undertaking more comparative modeling efforts
- Leveraging artificial intelligence and data science in modeling
- Using the resources available to keep learning
- Pursuing interdisciplinary collaborations
- Building a community of systems scientists and better coordinating and reusing research assets
- Realigning the incentives in the research system

SOURCE: Presented by Patty Mabry, September 16, 2020.

References

Baltimore Office of Sustainability. 2019. *The 2019 Baltimore sustainability plan*. https://www.baltimoresustainability.org/plans/sustainability-plan (accessed December 4, 2020).

Borshchev, A., and A. Filippov. 2004. *From system dynamics and discrete event to practical agent based modeling: Reasons, techniques, tools*. 22nd International Conference of the System Dynamics Society, Oxford, England.

Fallah-Fini, S., H. Rahmandad, T. Huang, R. Bures, and T. Glass. 2014. Modeling U.S. adult obesity trends: A system dynamics model for estimating energy imbalance gap. *American Journal of Public Health* 104(7):1230–1239.

Fallah-Fini, S., A. Adam, L. Cheskin, S. Bartsch, and B. Lee. 2017. The additional costs and health effects of a patient having overweight or obesity: A computational model. *Obesity (Silver Spring)* 25(10):1809–1815.

Glass, T. A., and M. J. McAtee. 2006. Behavioral science at the crossroads in public health: Extending horizons, envisioning the future. *Social Science & Medicine* 62(7):1650–1671.

Hall, K. D., N. Butte, B. Swinburn, and C. Chow. 2013. Dynamics of childhood growth and obesity: Development and validation of a quantitative mathematical model. *Lancet Diabetes & Endocrinology* 1(2):97–105.

Hamid, T. K. A. 2009. *Thinking in circles about obesity*. Copernicus. NY: Springer-Verlag.

Hirsch, G., J. Jomer, J. Trogdon, K. Wile, and D. Orenstein. 2014. Using simulation to compare 4 categories of intervention for reducing cardiovascular disease risks. *American Journal of Public Health* 104(7):1187–1195.

Homer, J. B. 1996. Why we iterate: Scientific modeling in theory and practice. *System Dynamics Review* 12(1):1–19.

Homer, J. B. 2019a. Best practices in system dynamics modeling, revisited: A practitioner's view. *System Dynamics Review* 35(2):177–181.

Homer J. B. 2019b. Group model building: A dialogue (with George Richardson). 2019. *SD Society Blog*. https://sdswisdom.wordpress.com/2019/09/09/group-model-building-a-dialogue (accessed December 3, 2020).

Homer, J. B., and G. B. Hirsch. 2006. System dynamics modeling for public health: Background and opportunities. *American Journal of Public Health* 96(3):452–458.

Homer, J. B., and R. Oliva. 2001. Maps and models in system dynamics: A response to Coyle. *System Dynamics Review* 17(4):347–355.

Homer, J. B., Homer Consulting, B. Milstein, W. Dietz, and D. Buchner. 2006. *Obesity population dynamics: Exploring historical growth and plausible futures in the U.S.* 24th International Conference of the System Dynamics Society, Nijmegen, The Netherlands.

Jones, A. P., J. Homer, D. Murphy, J. Essien, B. Milstein, and D. Seville. 2006. Understanding diabetes population dynamics through simulation modeling and experimentation. *American Journal of Public Health* 96(3):488–494.

Langellier, B. A., J. Kuler, E. Ballard, S. Slesinski, I. Stankov, N. Gouveia, J. Meisel, M. Kroker-Lobos, O. Sarmiento, W. Caiaffa, A. Diez Roux, and SALURBAL Group. 2019. Using community-based system dynamics modeling to understand the complex systems that influence health in cities: The SALURBAL study. *Health Place* 60:102215.

Lee, B. Y., A. Adam, E. Zenkov, D. Hertenstein, M. Ferguson, P. Wang, M. Wong, P. Wedlock, S. Nyathi, J. Gittselsohn, S. Falah-Fini, S. Bartsch, L. Cheskin, and S. Brown. 2017. Modeling the economic and health impact of increasing children's physical activity in the United States. *Health Affairs (Millwood)* 36(5):902–908.

Lee, B. Y., M. Ferguson, D. Hertsein, A. Adam, E. Zenkov, P. Wang, M. Wong, J. Gittelsohn, Y. Mui, and S. Brown. 2018. Simulating the impact of sugar-sweetened beverage warning labels in three cities. *American Journal of Preventive Medicine* 54(2):197–204.

Levy, D. T., P. Mabry, Y. Wang, S. Gortmaker, T. Huang, T. Marsh, M. Moodie, and B. Swinburn. 2011. Simulation models of obesity: A review of the literature and implications for research and policy. *Obesity Reviews* 12(5):378–394.

Luke, D. A., and K. A. Stamatakis. 2012. Systems science methods in public health: Dynamics, networks, and agents. *Annual Review in Public Health* 33:357–376.

Milstein, B., and J. Homer. 2020. Which priorities for health and well-being stand out after accounting for tangled threats and costs? Simulating potential intervention portfolios in large urban counties. *Milbank Quarterly* 98(2):372–398.

Rahmandad, H., and J. D. Sterman. 2012. Reporting guidelines for simulation-based research in social sciences. *System Dynamics Review* 28(4):396–411.

Ralph C. Wilson, Jr. Foundation. 2020. *State of play*. https://www.ralphcwilsonjrfoundation.org/state-of-play (accessed November 5, 2020).

RTI International. 2020a. *PhenX toolkit*. https://www.phenxtoolkit.org (accessed November 6, 2020).

RTI International. 2020b. *RTI synthetic household population*. https://www.rti.org/impact/rti-us-synthetic-household-population%E2%84%A2 (accessed December 4, 2020).

Sarmiento, O. L., D. Higuera-Mendieta, M. Wilches-Mogollon, L. Guzman, D. Rodríguez, R. Morales, D. Méndez, C. Bedoya, M. Linares-Vásquez, M. Arévalo, E. Martínez-Herrera, F. Montes, J. Meisel, A. Useche, E. García, C. Triana, A. Medaglia, P. Hessel, J. Arellana, C. Moncada, A. King, and A. Diez Roux. 2020. Urban transformations and health: Methods for TrUST—a natural experiment evaluating the impacts of a mass transit cable car in Bogotá, Colombia. *Front Public Health* 10(8):64.

Siokou, C., R. Morgan, and A. Shiell. 2014. Group model building: A participatory approach to understanding and acting on systems. *Public Health Research & Practice* 25(1).

Sterman, J. D. 2002. All models are wrong: Reflections on becoming a systems scientist. *System Dynamics Review* 18:501–531.

Struben, J., D. Chan, and L. Dubé. 2014. Policy insights from the nutritional food market transformation model: The case of obesity prevention. *Annals of the New York Academy of Science* 1331:57–75.

The Aspen Institute. 2015. *Sport for all, play for life: A playbook to get every kid in the game*. https://www.aspeninstitute.org/publications/sport-all-play-life-playbook-get-every-kid-game/ (accessed December 4, 2020).

The Aspen Institute. 2019. *State of play 2019: Trends and developments in youth sports*. https://www.aspeninstitute.org/publications/state-of-play-2019-trends-and-developments (accessed December 4, 2020).

The Aspen Institute. 2020a. *State of play 2020: Pre-pandemic trends, ages 6–12*. https://www.aspenprojectplay.org/state-of-play-2020/ages-6-12 (accessed November 6, 2020).

The Aspen Institute. 2020b. *Youth sports facts: Why youth sports matters*. https://www.aspenprojectplay.org/youth-sports-facts (accessed November, 2020).

UK (United Kingdom) Government Office for Science. 2007. *Tackling obesities: Future choices—obesity system atlas*. Foresight. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/295153/07-1177-obesity-system-atlas.pdf (accessed December 4, 2020).

Wang, Y. C., G. Colditz, and K. Kuntz. 2007. Forecasting the obesity epidemic in the aging U.S. population. *Obesity (Silver Spring)* 15(11):2855–2865.

Wolstenholme, E. F. 1999. Qualitative vs. quantitative modelling: The evolving balance. *Journal of the Operational Research Society* 50(4):422–428.

Appendix A

Workshop Agenda

Using Systems Applications to Inform Obesity Solutions:
A Virtual Workshop

Wednesday, September 16, 2020
Online via Zoom

Goals:

- Encourage and engage researchers and decision makers in using systems modeling techniques as an approach for better understanding of the obesity epidemic—both causes and solutions—more effectively and efficiently.
- Help inform decision making within policy and programmatic areas.
- Illustrate real-world applications.

INTRODUCTION

10:00 AM *Nicolaas (Nico) Pronk, Chair, Roundtable on Obesity Solutions*

THE PROMISES AND PITFALLS OF SYSTEMS MODELING: A PRACTITIONER'S PERSPECTIVE

10:05 *Jack Homer, Homer Consulting*

MAIN SESSION: THE USEFULNESS OF SYSTEMS MODELING FOR STAKEHOLDERS IN DIFFERENT SECTORS

10:30 **Business/Private Sector (Project Play)**
Moderator:
Jamy Ard, Wake Forest School of Medicine and Wake Forest Baptist Weight Management Center

Panel:
Tom Farrey, The Aspen Institute
Bruce Y. Lee, City University of New York
Dev Pathik, Sports Facilities Companies

11:30 **Break**

11:45 **Communities (Baltimore, Maryland)**
Moderator:
Sara Czaja, Weill Cornell Medical College

Panel:
Joel Gittelsohn, Johns Hopkins University
Bruce Y. Lee, City University of New York
Sarah Buzogany, City of Baltimore Department of Planning

12:45 PM **Lunch Break**

1:15 **Policy Makers**
Moderator:
Stella Yi, New York University Grossman School of Medicine

Panel:
Ana Diez Roux, Drexel University
Brent Langellier, Drexel University
Felipe Montes Jimenez, Universidad de Los Andes, Bogotá, Colombia

NEXT STEPS

2:15 Moderators:
Nicolaas (Nico) Pronk, Chair, Roundtable on Obesity Solutions; HealthPartners, Inc.
Christina Economos, Tufts University

Reflectors:
Doug Luke, Washington University in St. Louis
Sara Czaja, Weill Cornell Medicine
David Mendez, University of Michigan
Jamy Ard, Wake Forest School of Medicine and Wake Forest Baptist Weight Management Center
Stella Yi, New York University Grossman School of Medicine
Daniel E. Rivera, Arizona State University
Bruce Y. Lee, City University of New York

FINAL REFLECTIONS

3:15 *Patricia (Patty) Mabry, HealthPartners Institute*

CLOSING

3:40 *Christina Economos, Co-Vice Chair, Roundtable on Obesity Solutions*

3:45 **Adjourn**

Appendix B

Acronyms and Abbreviations

BLIFE	Baltimore Low Income Food Environment
BMI	body mass index
BRT	bus rapid transit
CDC	Centers for Disease Control and Prevention
NHANES	National Health and Nutrition Examination Survey
NIH	National Institutes of Health
PHICOR	Public Health Informatics, Computational, and Operations Research
SALURBAL	Salud Urbana en América Latina (Urban Health in Latin America)
VPOP	Virtual Population Obesity Prevention Labs

Appendix C

Biographical Sketches of Workshop Speakers and Moderators

Jamy D. Ard, M.D., is a professor in the Department of Epidemiology and Prevention and the Department of Medicine at the Wake Forest University Baptist Medical Center and the co-director of the Wake Forest Baptist Health Weight Management Center. He served as the chief resident in internal medicine at Duke University and received formal training in clinical research as a fellow at the Center for Health Services Research in Primary Care at the Durham VA Medical Center. Dr. Ard's research interests include clinical management of obesity and strategies to improve cardiometabolic risk using lifestyle modification, focusing on developing and testing medical strategies for the treatment of obesity in special populations, including African Americans, those with type 2 diabetes, and older adults. Since 1995, he has conducted research on lifestyle modification; participated in several major National Institutes of Health (NIH)-funded multicenter trials; and received research funding from a variety of federal and foundation sources, including NIH and the Robert Wood Johnson Foundation. His work has been published in numerous scientific journals and he has been a featured presenter at national and international conferences and workshops dealing with obesity. Dr. Ard has served on several expert panels and guideline development committees and is currently serving on the editorial board for the *American Journal of Clinical Nutrition* and the *International Journal of Obesity*. He received an M.D. and completed internal medicine residency training at the Duke University Medical Center.

Sarah Buzogany, M.S., is the food resilience planner for the Baltimore Food Policy Initiative. She provides direct support to the food policy director and works to implement the Healthy Food Priority Area Strategy, analyze policies and best practices, and manage grants. Ms. Buzogany's major focus areas include equity in the food system, food environment mapping and analysis, food resilience and emergency response, and urban agriculture. Previously, she worked on sustainable agriculture policy at the state and national levels, managed a farmers' market, and researched innovative farmer-to-consumer and nutrition education models. Ms. Buzogany earned an M.S. in food policy and applied nutrition from Tufts University and holds bachelor's degrees in sustainable agriculture and Spanish from the University of Kentucky.

Sara J. Czaja, Ph.D., M.S., is a professor of gerontology and the director of the Center on Aging and Behavioral Research in the Division of Geriatrics and Palliative Medicine at Weill Cornell Medicine and an emeritus professor of psychiatry and behavioral sciences at the University of Miami Miller School of Medicine. She is also the director of the National Institutes of Health's Center for Research and Education on Aging and Technology Enhancement and the co-director of the Center for Enhancing Neurocognitive Health, Abilities, Networks, & Community Engagement. Dr. Czaja's research interests include aging-related cognition, technology, and work; caregiving; training; and functional assessment. She is a fellow of the American Psychological Association (APA), the Human Factors and Ergonomics Society, and the Gerontological Society of America. Dr. Czaja has served as the past president of Division 20 (Adult Development and Aging) of APA and as a member of several committees and boards of the National Academies of Sciences, Engineering, and Medicine. Dr. Czaja received the 2015 M. Powell Lawton Distinguished Contribution Award for Applied Gerontology from APA, the 2013 Social Impact Award for the Association of Computing Machinery, and the Franklin V. Taylor Award from Division 21 of APA, as well as numerous other awards from national organizations. Dr. Czaja holds an M.S. and a Ph.D. in industrial engineering from the State University of New York at Buffalo.

Ana Diez Roux, M.D., Ph.D., M.P.H., is the dean and a distinguished university professor of epidemiology in the Drexel University Dornsife School of Public Health. Before joining Drexel University, she served on the faculties of Columbia University and the University of Michigan, where she was the chair of the Department of Epidemiology and the director of the Center for Social Epidemiology and Population Health. Dr. Diez Roux researches the social determinants of population health and how neighborhoods affect health, the results of which have been highly influential in the policy debate on population health and its determinants. Recent areas of work include social environment–gene interactions and the use of complex systems approaches in population health. With funding from the National Institutes of Health and foundations, she has led large research and training programs in the United States and in collaboration with various institutions in Latin America, and has been the principal investigator of grants totaling more than $30 million. Dr. Diez Roux has been a member of the MacArthur Network on Socioeconomic Factors and Health, and was the co-director of the Network on Inequality, Complexity and Health. She earned an M.D. from the University of Buenos Aires, and holds a Ph.D. and an M.P.H. from the Johns Hopkins School of Hygiene and Public Health.

Christina Economos, Ph.D., M.S., is a professor, the New Balance Chair in Childhood Nutrition, and the chair of the Division of Nutrition Interventions, Communication, and Behavior Change at the Tufts University Friedman School of Nutrition Science and Policy. She leads a research team studying behavioral interventions, strategic communications, and promotion of physical activity using a systems approach to reduce childhood obesity. Dr. Economos has authored more than 150 scientific publications and is also the co-founder and the director of ChildObesity180, a unique organization that brings together leaders from diverse disciplines to generate urgency and find solutions to the childhood obesity epidemic. She is involved in national obesity and public health activities, and has served on four National Academies of Sciences, Engineering, and Medicine committees, including the Roundtable on Obesity Solutions and the Committee on an Evidence Framework for Obesity Prevention Decision Making. Dr. Economos earned a B.S. from Boston University, an M.S. in applied physiology and nutrition from Columbia University, and a Ph.D. in nutritional biochemistry from Tufts University.

Tom Farrey is the executive director of The Aspen Institute's Sports and Society Program, the mission of which is to convene leaders, facilitate dialogue, and inspire solutions that help sports serve the public interest. The program's signature initiative is Project Play, which, since 2013, has mobilized hundreds of organizations to build healthy communities through sports. A pioneering journalist, Mr. Farrey worked for 21 years with ESPN. His reports helped build the reputation of the television program *Outside the Lines*, which won two Emmy awards, an Edward R. Murrow award, and in 2014, the Alfred I. duPont–Columbia University award, which was ESPN's first. He is the author of the influential book *Game On: The All-American Race to Make Champions of Our Children*. Mr. Farrey is a graduate of the University of Florida.

Joel Gittelsohn, Ph.D., is a professor in the Center for Human Nutrition and the Global Obesity Prevention Center of the Department of International

Health at the Johns Hopkins Bloomberg School of Public Health. He is a public health nutritionist and a medical anthropologist who focuses on developing, implementing, and evaluating community-based programs for the primary prevention of chronic disease in disadvantaged ethnic minority populations. With more than 300 publications, Dr. Gittelsohn has led multiple food source–centered intervention trials aimed at improving the food environment and providing education needed to support healthy food choices and reduce obesity and diabetes in Native communities, in Baltimore City, and in Pacific Islander communities. He developed a multi-institutional program for diabetes prevention in seven First Nations schools and food stores, which has been extended to 11 American Indian communities, and includes worksites, social media, and policy components. Dr. Gittelsohn has conducted a series of intervention trials with corner stores, carry-outs, wholesalers, churches, and recreation centers in Baltimore City. These studies have shown success in increasing healthy food purchasing and consumption, reducing obesity, and improving the stocking and sales of healthier foods. More recently, he has begun to use systems science methods in his work, simulating policies to improve the urban food environment, and to engage and work with stakeholders in both urban and rural settings. Dr. Gittelsohn earned a Ph.D. from the University of Connecticut.

Jack Homer, Ph.D., is an expert in system dynamics simulation modeling, a former faculty member at the University of Southern California, and a full-time consultant to private and public organizations since 1989. His articles on modeling applications and methodology are frequently cited, and many are published in the books *Models That Matter* (2012) and *More Models That Matter* (2017). In the health sector, Dr. Homer has completed modeling projects for federal agencies including the Centers for Disease Control and Prevention (CDC), the National Institutes of Health, the Centers for Medicare & Medicaid Services, the U.S. Food and Drug Administration, the Veterans Health Administration, and foundations, think tanks, and state and county health departments. He has developed models for The Rippel Foundation's ReThink Health initiative since its inception in 2011. Dr. Homer is the recipient of several awards from the International System Dynamics Society, CDC, AcademyHealth, and the Applied Systems Thinking Institute. He holds a Ph.D. from the Massachusetts Institute of Technology, where he studied system dynamics and economics and wrote his dissertation on the adoption and evolution of new medical technologies.

Brent Langellier, Ph.D., M.A., is an assistant professor of health management and policy and a health disparities researcher using complex systems methods to understand the mechanisms that contribute to disparities and to identify policy levers to address disparities. He co-leads the systems working group of the Salud Urbana en América Latina (SALURBAL) study, in which a multidisciplinary team of researchers uses group-based and agent-based modeling to examine drivers of health in Latin American cities. Dr. Langellier earned an M.A. in Latin American studies and a Ph.D. in community health sciences from the University of California, Los Angeles.

Bruce Y. Lee, M.D., M.B.A., is a professor of health policy and management at the City University of New York Graduate School of Public Health. He is also the executive director and the founder of Public Health Informatics, Computational, and Operations Research, and a professor by courtesy at the Johns Hopkins Carey Business School. Previously, Dr. Lee has served as an associate professor of international health at the Johns Hopkins Bloomberg School of Public Health, the executive director of the Global Obesity Prevention Center, the director of operations research at the International Vaccine Access Center, an associate professor at the University of Pittsburgh, a senior manager at Quintiles Transnational, and a researcher in biotechnology equity at Montgomery Securities. He has been a principal investigator for projects supported by organizations including the Bill & Melinda Gates Foundation; the National Institutes of Health; the Agency for Healthcare Quality and Research; the Centers for Disease Control and Prevention; UNICEF (United Nations Children's Fund); The Global Fund to Fight AIDS, Tuberculosis and Malaria; and the U.S. Agency for International Development. Dr. Lee has served on numerous advisory boards and committees; has authored 3 books and more than 200 scientific publications; and has contributed to media outlets such as *Forbes*, *Time*, and *The Guardian*. He received a B.A. from Harvard University, an M.D. from Harvard Medical School, and an M.B.A. from the Stanford Graduate School of Business, and he completed internal medicine residency training at the University of California, San Diego.

Douglas Luke, Ph.D., is the Irving Louis Horowitz Professor in Social Policy and the director of the Center for Public Health Systems Science at Washington University in St. Louis. He focuses primarily on the evaluation, dissemination, and implementation of evidence-based public health policies. Over the past decade, Dr. Luke has used systems science methods, especially social network analysis and agent-based modeling, to address important public health problems. He published the first review papers on network analysis in public health in 2007 and on systems science methods in public health in 2012, and has authored books on multilevel modeling and network analysis. Under Dr. Luke's leadership, the Center for Public Health Systems Science has used network analysis to study the diffusion of scientific innovations, model the formation of organizational collaborations, and study the relationship of mentoring to future scientific collaboration. He has served as a member of the Institute for Public Health, the director of evaluation for the Institute of Clinical and Translational Science, a founding member of the Washington University Network of Dissemination and Implementation Researchers, and a member of an Institute of Medicine panel on the use of agent-based modeling for tobacco regulatory science. Dr. Luke holds a Ph.D. from the University of Illinois.

Patricia (Patty) L. Mabry, Ph.D., is an interdisciplinary scientist at HealthPartners Institute, where she applies cutting-edge research methodologies (e.g., modeling and simulation, data science, network science, artificial intelligence) to a variety of topics, including issues in health care, the biomedical research workforce, tobacco control, and health disparities. She is currently the principal investigator on a project to develop a quantitative simulation model to understand the best strategies for improving colorectal cancer screening. Dr. Mabry spent more than a decade at the National Institutes of Health (NIH), where she held senior positions in the Office of Disease Prevention and the Office of Behavioral and Social Sciences Research, and she founded the NIH systems science program. She was the founding executive director and a senior research scientist at the Indiana University Network Science Institute from 2015 to 2019, and started her career at the Medical University of South Carolina, where she conducted research on tobacco cessation. Dr. Mabry has published on tobacco cessation, tobacco policy modeling, systems science, and reproducibility, and she contributed to the 2014 Surgeon General's Report on the health consequences of smoking. She also co-led the Envision Collaborative Obesity Modeling Network, chaired the 3rd International Meeting on Social Computing Behavioral Modeling and Prediction, and chaired the federal interagency Tobacco Policy Modeling Meeting. Dr. Mabry has received awards for teaching and federal service, including the inaugural Applied Systems Thinking Award. She holds a Ph.D. in clinical psychology from the University of Virginia and is a fellow of the Society of Behavioral Medicine.

David Mendez, Ph.D., is an associate professor in the Department of Health Management and Policy at the University of Michigan School of Public Health. His research has focused on areas of smoking control, product and service quality on demand, and policies regarding residential radon using complex systems science research and methodologies. Dr. Mendez is associated with the Decision Sciences Institute and the Institute for Operations Research and the Management Sciences. He has served on two National Academies of Sciences, Engineering, and Medicine consensus study committees and one planning committee related to tobacco research and systems science approaches to improve population health. Dr. Mendez received a B.S. in civil engineering, an M.S. in applied statistics and operations research, and a Ph.D. in management science from Michigan State University.

Felipe Montes Jimenez, Ph.D., M.Sc., is an associate professor of the Department of Industrial Engineering at Universidad de Los Andes, the director of the Master in Analytics program, and the director of the Social and Health Complexity Center. His work is focused on applying computational and data-driven complex systems methods for exploring the social contagious nature of chronic diseases and epidemics, and he provides expertise in applying social network analysis, system dynamics, and agent-based models to characterize healthy behaviors in communities for informing interventions and policy making. Dr. Montes Jimenez also has experience as a consultant and a policy maker, and before his academic appointment, he was the director for quality assurance of higher education at the Ministry of Education of Colombia. He was recently awarded the Fogarty Global Health fellowship of the National Institutes of Health. Dr. Montes Jimenez holds an M.Sc. and a Ph.D. in industrial engineering from Universidad de Los Andes.

Dev Pathik is the chief executive officer and the founder of Sports Facilities Companies. In 2003, he founded the Sports Facilities Advisory (SFA), an industry leader in strategy, program planning, and project finance. Mr. Pathik has dedicated more than 25 years to the development of numerous businesses that empower and develop communities. His leadership has produced facilities that integrate traditional sports with special events, adventure sports, education, leadership development, and amusement to turn early concepts into financeable and sustainable facilities that make a difference in communities. Mr. Pathik's work and expertise have been featured by *The Wall Street Journal*, *Forbes*, *MarketWatch*, *SportsBusiness Journal*, *Sports Travel Magazine*, CNBC, NBC, The Aspen Institute's Sports and Society Program, the National Association of Sports Commissions, the National Recreation and Park Association, and many others. Prior to founding SFA, he founded Global Adventures, an international ecotourism company. Mr. Pathik holds a bachelor's degree from the University of Maryland.

Nicolaas (Nico) P. Pronk, Ph.D., M.A., FACSM, FAWHP, is the president of the HealthPartners Institute and the chief science officer at HealthPartners, Inc., and is an adjunct professor of social and behavioral sciences at the Harvard T.H. Chan School of Public Health and an affiliate professor of health policy and management at the University of Minnesota School of Public Health. His work is focused on connecting evidence of effectiveness with the practical application of programs, practices, policies, and systems for workplaces, care delivery settings, and communities. He develops new models to improve health and well-being at the research, practice, and policy levels, and his research interests include workplace health and safety, obesity, physical activity, and systems approaches to population health and well-being. Dr. Pronk served as the co-chair of the U.S. Secretary of Health and Human Services' Advisory Committee on National Health Promotion and Disease Prevention Objectives for 2030 (Healthy People 2030), and he served as a member of the Community Preventive Services Task Force. He is the founder and past president of the International Association for Worksite Health Promotion and has served on boards and committees at the National Academies of Sciences, Engineering, and Medicine; the American Heart Association; the Health Enhancement Research Organization; and others. Dr. Pronk is a widely published author and an international speaker on population health and health promotion. He received a Ph.D. in exercise physiology at Texas A&M University and completed postdoctoral studies in behavioral medicine at the Western Psychiatric Institute and Clinic at the University of Pittsburgh Medical Center.

Daniel E. Rivera, Ph.D., is a professor of chemical engineering and the program director of the Control Systems Engineering Laboratory at Arizona State University (ASU). In 1990, he joined the faculty in the Department of Chemical, Biological and Materials Engineering at ASU. Prior to joining ASU, Dr. Rivera was an associate research engineer in the control systems section of Shell Development Company. He has also been a visiting researcher with the Division of Automatic Control at Linköping University, Sweden; Honeywell Technology Center; the Saints Cyril and Methodius University in Skopje, Macedonia; the National Distance Learning University in Madrid, Spain; and the University of Almería in Andalucía, Spain. Dr. Rivera's research interests include the topics of robust process control; system identification; and the application of control engineering principles to problems in process systems, supply chain management, and prevention and treatment interventions in behavioral medicine. He was chosen as the 1994–1995 Outstanding Undergraduate Educator by the ASU student chapter of the American Institute of Chemical Engineers and was a recipient of the 1997–1998 Teaching Excellence Award from the College of Engineering and Applied Sciences at ASU. In 2007, Dr. Rivera was awarded a K25 Mentored Quantitative Research Career Development Award from the National Institutes of Health to study control systems approaches for fighting drug abuse. He was designated as a distinguished member by the Institute of Electrical and Electronics Engineers Control Systems Society in 2019. Dr. Pronk received a Ph.D. in chemical engineering from the California Institute of Technology in 1987 and holds an M.S. and a B.S. from the University of Rochester and the University of Wisconsin–Madison, respectively.

Stella Yi, Ph.D., M.P.H., is an assistant professor in the Department of Population Health at the New York University Grossman School of Medicine. She is a cardiovascular epidemiologist, and her research is grounded in the application of rigorous methods—including mixed methods, community-partnered systems science, and implementation science—to address issues and inform policy making and program implementation in real-world and community settings to improve health equity. Dr. Yi's specific areas of expertise are policy and community-partnered programs for urban immigrant populations, including Asian Americans; nutrition and lifestyle behaviors; and cardiometabolic disease. She holds a Ph.D. from the Johns Hopkins Bloomberg School of Public Health and an M.P.H. from the Yale School of Public Health.

Appendix D

Glossary

Agent-based modeling uses computer simulation to study complex systems from the ground up by examining how individual elements of a system (agents) behave as a function of individual properties, their environment, and their interactions with each other. Through these behaviors, emergent properties of the overall system are revealed (Luke and Stamatakis, 2012).

Community-based system dynamics differs from other group model building or participatory modeling approaches because of its explicit focus on developing systems thinking capabilities among community members, including an endogenous or feedback perspective, appreciation for nonlinear system behavior, and an emphasis on operational thinking (Hovmand, 2014).

Complex systems are made up of heterogeneous elements that interact with each other. The interactions of these elements produce a unique effect that is different from the effects of just the individual elements (Gallagher and Appenzeller, 1999).

Group model building is a participatory approach that is used to build the capacity of a group to use systems thinking to develop causal loop diagrams and other system dynamics models (Siokou et al., 2014).

Network analysis is a research method and scientific paradigm that focuses on the relationships among sets of actors. The actors can be any type of entity that can have a relationship or tie with other entities (e.g., persons, animals, organizations, countries, websites, documents, and even genes) (Luke and Stamatakis, 2012).

System dynamics is based on the premise that complex behaviors of a system result from the interplay of feedback loops, stocks and flows, and delays. The focus is on building models to represent the dynamic complexity of collective, often high-level, phenomena (Luke and Stamatakis, 2012).

Systems science approaches are a broad class of analytical approaches that aim to uncover the behavior of complex systems. A distinction is made between hard systems methods (e.g., quantitative dynamic model building) and soft systems methods (e.g., qualitative, action-based research methods) (Carey et al., 2015). Throughout the publication systems science "applications," "approaches," "methods," and "models" are used interchangeably to describe the analytical methodologies and tools defined here.

Systems thinking is a broad paradigm concerned with interrelationships, perspectives, and boundaries (Williams and Hummelbrunner, 2011).

REFERENCES

Carey, G., E. Malbon, N. Carey, A. Joyce, B. Crammond, and A. Carey. 2015. Systems science and systems thinking for public health: A systematic review of the field. *British Medical Journal Open* 5(12):e009002.

Gallagher, R., and T. Appenzeller. 1999. Beyond reductionism. *Science* 284:79.

Hovmand, P. 2014. *Community based system dynamics*. New York: Springer-Verlag.

Luke, D. A., and K. A. Stamatakis. 2012. Systems science methods in public health: Dynamics, networks, and agents. *Annual Review of Public Health* 33:357–376.

Siokou, C., R. Morgan, and A. Shiell. 2014. Group model building: A participatory approach to understanding and acting on systems. *Public Health Research & Practice* 25(1):e2511404.

Williams, B., and R. Hummelbrunner. 2011. *Systems concepts in action: A practitioner's toolkit*. Stanford, CA: Stanford University Press.