Systems Science in Action: Impact on Health Practice and Policy

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Executive Summary

Introduction

Systems science methods have the unique potential to inform policy and practice where other research methods may not be feasible or practical. In contrast to methods that focus on a specific health issue, often in isolation from the broader environment, systems-level thinking employs a holistic perspective designed to explore interrelated, cross-sectoral, and dynamic system components. Using mathematical models, systems science methods can illustrate how a system and its components function, and the models can serve as virtual laboratories for exploring potential impacts of different interventions or policies within a variety of potential contexts. These models can indicate potential long-term impacts as well as unintended consequences, providing valuable information to decision-makers and implementers as they consider various policies and programs for implementation.

Much of the literature on systems science and health focuses on how systems science methods can be used to explore potential health impacts through potential policy or practice changes. However, the literature showing how findings from systems science research have actually been used to influence practice or policy decisions is more limited. This brief spotlights systems science research that has led to changes in practice or policy, drawing on examples from clinical preventive services, public health, and the broader social determinants of health. Specifically, the examples focus on the development of cancer screening recommendations, childhood obesity prevention policy, and transportation planning. A fourth example showcases research in progress on the use of systems science for a housing support program. By highlighting real-world applications, we illustrate how systems-level efforts have been, and can be, used to address complex health issues effectively.

Case 1: Modeling the Benefits and Risks of Cancer Screening Strategies to Inform Practice Recommendations

The U.S. Preventive Services Task Force conducts systematic reviews of the benefits and risks of a wide range of preventive services to provide primary care clinicians with evidence-based practice recommendations. To help inform revisions to colorectal and breast cancer screening recommendations, the Task Force commissioned the National Cancer Institute's Cancer Intervention and Surveillance Modeling Network (CISNET) to conduct decision support analyses using the CISNET family of cancer screening models.

CISNET used microsimulation modeling to examine numerous combinations of factors and the long-term impacts of various screening strategies, including their benefits, burdens, and risks. Microsimulation models were used to inform recommendations regarding age of screening initiation and cessation, and screening intervals. For example, in the 2009 analysis for breast cancer screening, the models led to the conclusion that biennial screening from ages 50 to 74 was more efficient than annual screening or earlier ages of screening initiation. This information helped guide the 2009 Task Force recommendation of biennial breast cancer screening from ages 50 to 74.

Case 2: Systems Thinking and Simulation Modeling to Inform Childhood Obesity Policy in Georgia

The Georgia Health Policy Center developed the Legislative Health Policy Certificate Program (LHPCP) to improve the policymaking process by helping state lawmakers think more broadly and deeply about health issues, utilizing a systems thinking framework. Legislators participating in the program used a system dynamics model to explore the impacts of potential policy changes on childhood obesity. The team identified interventions for inclusion in the model based on legislative feasibility and evidence of the intervention's impact on childhood physical activity, eating behavior, or weight.

Legislators' interaction with the model influenced their deliberations during the legislative session, with several LHPCP participants commenting that their experience with the model informed their discussions on childhood obesity policies. Legislators' participation in the program—along with several parallel efforts by various Georgia academic institutions and community organizations—contributed to passage of the Student Health and Physical Education (SHAPE) Act of 2009. The SHAPE Act requires the State Department of Education to collect and report fitness data annually for all students in grades 1 through 12, and to enforce physical education requirements in Georgia's school system.

Case 3: Use of Systems Science to Inform Policies Addressing the Social Determinants of Health: Transportation Planning

Acknowledging the role of transportation and the built environment in addressing public health issues, the transportation planning sector is increasingly developing policies that promote health and well-being—and using systems science methods to address the intersection of transportation and health issues. For example, the Integrated Transport and Health Impact Model (ITHIM) is a systems science tool that has been used to inform policy planning by examining the health effects of different transportation scenarios.

ITHIM was used in Oregon as part of a climate planning project aimed at reducing greenhouse gas emissions. The model quantified the health impacts of the top three greenhouse gas reduction strategies under consideration. Results from model indicated that all three of the potential strategies for reducing greenhouse gas emissions would result in health benefits—with the majority of the benefits deriving from increased active transportation. In May 2019, the state approved a greenhouse gas reduction strategy that included a key recommendation to promote built-environment design and infrastructure to encourage active transportation, including walking and cycling.

Case 4: On the Horizon—Use of Systems Science to Inform Policies Addressing the Social Determinants of Health: Research in Progress on Housing Interventions

Los Angeles County is conducting a research study to explore the cross-sector impacts of a permanent supportive housing initiative—Housing for Health (HFH)—using systems science methods. Permanent supporting housing provides chronically homeless individuals with housing and other supportive programs spanning multiple sectors, including physical and mental health care, substance abuse treatment, and social services.

The study uses a participatory systems modeling approach, in which stakeholders develop visualizations of how HFH affects various elements of the system (service utilization, costs, and outcomes across the health, criminal justice, and the social service sectors). The model can be used to analyze a number of policy-relevant scenarios, for example, analyzing the consequences of increasing a particular type of service linkage, such as substance use treatment. Once the study is completed, decision makers can use the model and results to better understand the systemic impact of these interventions, explore how best to coordinate service provision, and identify which services may need additional support to improve intervention effectiveness and ensure system sustainability.

Concluding Remarks

Systems science has the potential to inform policy and practice in the areas of health services and public health, and increasingly in multi-sectoral interventions to address the social determinants of health. Given its holistic and systems-level approach, systems science can play an important role in addressing health-related policies as shown in the examples above. While the examples in this brief are not intended to provide an exhaustive review, by spotlighting cases where systems science research has successfully been used to influence policy or practice, we hope to demonstrate the compelling value of appropriate use of systems science methods in exploring and addressing complex health issues at the policy and program levels.

Introduction

Evidence-based practice and policy remain a central tenet in efforts to improve the public's health and well-being. At the same time, discussions regarding what constitutes evidence persist. While randomized controlled trials (RCTs) have been upheld as the gold standard for establishing an evidence base, a host of other research methods have received increased recognition, including quasi-experimental designs, observational studies, qualitative research, and realist evaluation.[1,2] One set of methods in particular, systems science methods, is garnering increased attention. Often serving as a complementary approach, systems science methods have the unique potential to inform policy and practice where other research methods may not be feasible or practical.[3,4,5]

Systems science methods encompass a range of approaches—such as agent-based modeling, complexity science, discrete event simulation, microsimulation, network analysis, and system dynamics modeling—that can be used to understand and address complex systems issues. In contrast to research methods that focus on a specific health issue, often in isolation from the broader environment, systems-level thinking employs a holistic perspective designed to explore interrelated, cross-sectoral, and dynamic system components.[6,7]

Overview of Systems Science Methods

Systems science methodologies provide a way to address complex problems by:

- examining the dynamic interrelationships of heterogeneous variables at multiple levels of analysis simultaneously, while
- studying the impact on the behavior of the system as a whole over time.

Systems science methods complement traditional analytic methods which are generally:

- used to identify linear relationships, but are also
- limited in their ability to set up and test a web of causal relationships.

Definitions of key systems science methods are listed in the glossary. An in-depth examination of specific systems science methods and when to use them is covered elsewhere in the literature.[8,9]

Using mathematical models that are developed based on the available evidence, systems science methods can illustrate how a system and its components function, and the models can serve as virtual laboratories for exploring a range of hypothetical scenarios.[10] Through simulation modeling, the potential impacts of different interventions or policies can be assessed within a variety of potential contexts. These models can indicate potential long-term impacts as well as unintended consequences, providing valuable information to decision-makers and implementers as they consider various policies and programs for implementation.[11,12]

Although their introduction to the field of health has been more recent, systems science methods have long been used in other sectors, such as engineering, business, and ecology.[13] Within health, systems science methods have been used in such areas as health care delivery as well as infectious and chronic disease epidemiology.[14,15] Building on these applications, there is great promise to expand the use of systems science methods to better inform policy and practice across the health field, from health services to public health to the broader social determinants of health.

As the U.S. health system is increasingly focused on prevention and population health—largely driven by the Patient Protection and Affordable Care Act—it must increasingly address the myriad factors that influence the public's health.[16,17] Such factors include food, housing, education, transportation, environment, and economic development. In a similar effort, the Robert Wood Johnson Foundation's Culture of Health initiative is setting a national agenda to improve health, equity, and well-being, engaging all sectors to address the complex social factors that impact health.[18]

Systems science methods are especially well-suited to explore the interrelated social, behavioral, economic, and environmental factors needed to build a Culture of Health.[19] Although their application in such efforts has not been widely adopted, systems science methodologies have significant potential for studying and addressing complex, systemic, and cross-sectoral issues through a transdisciplinary approach. And by examining various policy or practice options, along with their potential impacts, systems science methods can serve as an important tool to inform the decision-making process.

Much of the literature on systems science and health focuses on how systems science methods can be used to explore potential health impacts through potential policy or practice changes. However, the literature showing how findings from systems science research have actually been used to influence practice or policy decisions is more limited.[20]

This brief explores cases where systems science research has been used to inform health policy and practice. Drawing on examples from clinical preventive services, public health, and the broader social determinants of health, the brief spotlights systems science research that has led to changes in practice or policy. The examples focus on the development of cancer screening recommendations, childhood obesity prevention policy, and transportation planning. A fourth example showcases research in progress on the use of systems science for a housing support program. By highlighting real-world applications, we illustrate how systems-level efforts have been, and can be, used to address complex health issues effectively.

Case 1: Modeling the Benefits and Risks of Cancer Screening Strategies to Inform Practice Recommendations

In this example, we focus on how systems science was used to inform secondary prevention practice recommendations. Secondary prevention includes clinical preventive services for early detection of diseases so that steps may be taken to improve health outcomes. While preventive services are generally beneficial, they may also present risks, such as complications from invasive screening procedures, misdiagnoses or overdiagnoses, or overtreatments. The U.S. Preventive Services Task Force was established to conduct systematic reviews of the benefits and risks of a wide range of preventive services to provide primary care clinicians with evidence-based practice recommendations on use of these services.

Overview of Modeling Effort and Impact

To help inform revisions to colorectal cancer screening recommendations in 2008 and 2016, along with breast cancer screening recommendations in 2009 and 2016, the Task Force commissioned the National Cancer Institute's Cancer Intervention and Surveillance Modeling Network (CISNET) to convene working groups to conduct decision support analyses using the CISNET family of cancer screening models.[21,22,23,24,25] While RCTs are considered the gold standard in providing evidence of screening effectiveness, RCTs are limited in their ability to examine:

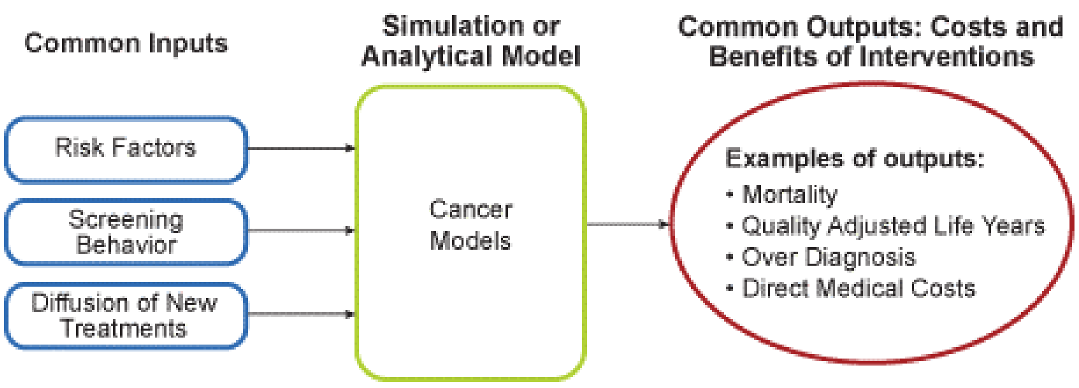
- complex combinations of factors like screening modalities, age of screening initiation and cessation, and screening intervals;
- long-term impacts of different screening regimens; and
- potential risks of the screening regimens outside the controlled environment and selected populations.

To generate information to complement evidence from RCTs, CISNET:

- drew on observational studies (alongside information from RCTs and other scientific literature) in its information synthesis to incorporate data on the risks of screening regimens in the general population; and
- used microsimulation modeling to examine numerous combinations of factors and the long-term impacts of various screening strategies, including their benefits, burdens, and risks.

CISNET employed a comparative modeling approach to reconcile results from different models by sharing a set of common population inputs and common sets of intermediate and final outputs across all models.[26] An illustration of the common inputs and outputs for the CISNET models is shown in Figure 1.

Figure 1. General Formulation of the Cancer Intervention and Surveillance Modeling Network (CISNET) Models



Source: CISNET website: https://cisnet.cancer.gov/modeling

In CISNET's 2009 analysis for breast cancer screening, the team modeled and compared 20 different screening strategies with varying ages of screening initiation and cessation and screening frequencies, complementing a systematic review of the literature conducted by the Task Force. These microsimulation models were used to inform recommendations regarding age of screening initiation and cessation and screening intervals for breast cancer screening. In the 2009 analysis, all six CISNET microsimulation models led to the conclusion that biennial screening from ages 50 to 74 was more efficient than annual screening or earlier ages of screening initiation. This information helped guide the 2009 Task Force recommendation of biennial breast cancer screening from ages 50 to 74.

Implications for Broader Application

The use of CISNET models to inform the Task Force's clinical practice recommendations provides an instructive example of how systems science models can be used to inform policy and practice, particularly within a collaborative framework. Indeed, one of the barriers to increased use of systems science methods in population health planning pertains to the difficulty in implementing collaborative efforts.[27] Given that independent modeling efforts may generate disparate results, decision makers may find it challenging to reach conclusive policy decisions based on the varied results. By using a comparative modeling approach, a collaborative effort can systematically compare and reconcile results across models. When there is consensus across the board, such an approach can improve the credibility of modeling results. When consensus is lacking, comparative modeling can highlight areas where more research is needed.

In addition to reconciling disparate results, the comparative modeling approach has a number of other benefits. For example, establishing common inputs and outputs necessitates a certain transparency standard across models. A comparative modeling approach also emphasizes the level of uncertainty associated with different models and assumptions. Both transparency and clear reporting of assumptions and uncertainties are principles of good practice in decision analytic modeling.[28] Additionally, collaborative modeling allows for better information sharing, a richer learning environment, and improved error detection across models.[29]

Given the time and complex logistics required in collaborative modeling, a systematic modeling effort across different groups or organizations may not always be feasible. However, the use of a collaborative approach enables systems scientists and health experts to work together in a unified and comprehensive manner to best address critical public health questions.

Case 2: Systems Thinking and Simulation Modeling to Inform Childhood Obesity Policy in Georgia

Spurred by Georgia's relatively low standing in the national health rankings, the Georgia Health Policy Center developed the Legislative Health Policy Certificate Program (LHPCP), a multi-session series for state legislators that applies systems thinking to health policy issues.[30] The goal of the program is to improve the policy-making process by helping lawmakers think more broadly and deeply about health issues, utilizing a systems thinking framework. Since its inception in 2008, the LHPCP has provided educational sessions for more than 120 legislators and staff interested in health issues and policies.[31,32]

Overview of Modeling Effort and Impact

The LHPCP curriculum includes various systems thinking concepts, including system dynamics models, behavior-over-time graphs illustrating broader trends, and a six-question framework for evaluating health policy, including questions on stakeholders, trends, leverage points, mechanisms of action, and timing. Leading up to the 2009 legislative session, legislators participating in the program used these systems thinking concepts and a system dynamics model to explore the impacts of potential policy changes on childhood obesity; the model was updated with new data in 2014. The Georgia Health Policy Center developed the system dynamics model based on a national model framework of childhood obesity, presented in Figure 2.[33]

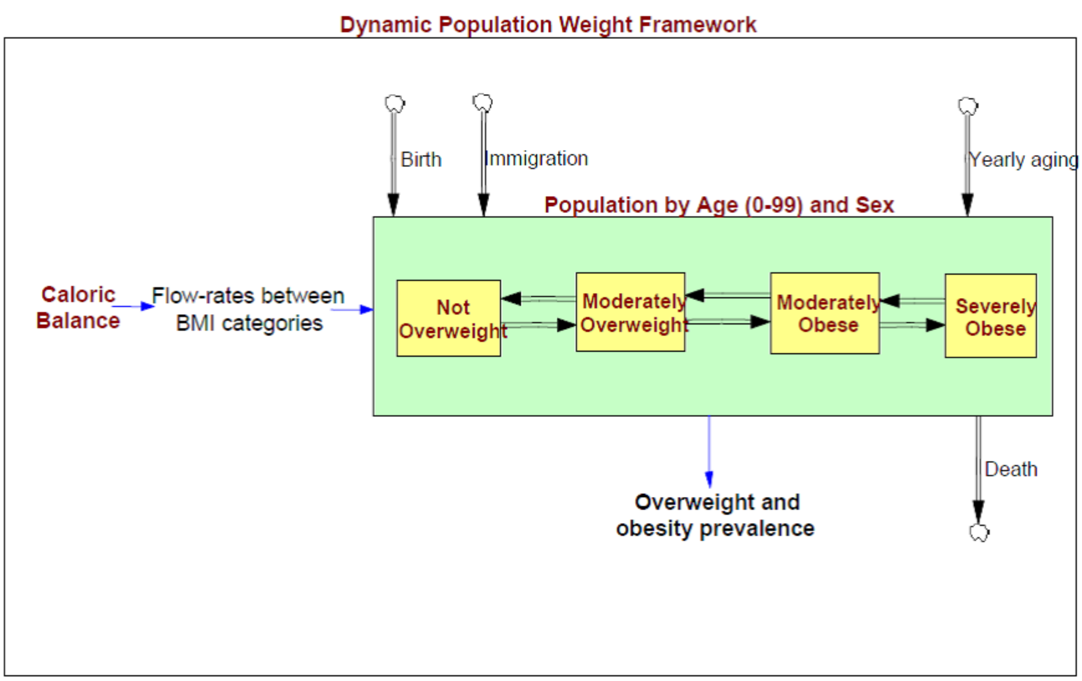
The national model framework was adapted for use in Georgia using data from several sources:

- the Georgia Youth Fitness Assessment pilot study;
- studies on childhood physical activity, nutrition, and obesity; and
- quantitative estimates by experts in the field regarding the proportion of the population to which the policy interventions would apply.

A team consisting of legislators, domain experts, and system dynamics experts participated in building the childhood obesity system dynamics model for Georgia. The team identified interventions for inclusion in the model based on legislative feasibility and evidence of the intervention's impact on childhood physical activity, eating behavior, or weight. The model was designed to estimate the impact of various policy interventions on the prevalence of childhood obesity in Georgia over a 20-year timeframe.

By considering various factors that affect transitions between different weight categories, legislators were able to test a given policy intervention or combination of policy interventions to see the potential impact on future prevalence of childhood obesity. Potential policy interventions ranged from mandating daily physical education in schools to requiring food served in the cafeteria to meet nutrition guidelines. The model facilitated legislators' discussion of policy interventions during the program, enabling them to rapidly test and simulate policy consequences.

Figure 2. National Obesity Model Framework



Source: Homer J, Milstein B, Dietz W, Buchner D, & Majestic E. (2006, July). Obesity population dynamics: exploring historical growth and plausible futures in the U.S. In *24th International System Dynamics Conference*.

Legislators' participation in the program—along with several parallel efforts by various Georgia academic institutions and community organizations working to advance nutrition and physical activity policies—contributed to passage of the Student Health and Physical Education (SHAPE) Act of 2009. The SHAPE Act requires the State Department of Education to:

- collect and report fitness data annually for all students in grades 1-12, and
- enforce physical education requirements in Georgia's school system.[34,35]

Legislators' interaction with the model influenced their deliberations during the legislative session, with several LHPCP attendees commenting that their experience with the model informed their discussions on childhood obesity policies.

Implications for Broader Application

For those considering similar legislative initiatives, the Georgia Health Policy Center offers several programmatic lessons, such as the importance of tailoring sessions to the stated needs of participants and ensuring that session content remains neutral and non-partisan.[36] Of particular note is the call to secure endorsement of legislative leadership, which is necessary to encourage legislators' involvement in the program—developing appropriate content for model building as well as participating in the modeling exercises and discussions.

This Georgia case study reveals valuable insights into the role systems science methods can play in policymaker education and the legislative process. Systems thinking provided legislators with a framework to consider health policies in broader terms and change the level of conversation around the policies. Notably, the childhood obesity model has stimulated conversations on how and why different policies affect outcomes differently and has helped policymakers engage in more productive discussions. As new data become available, the model can continue to be modified and used to further inform future policy development.

Systems Science Methods and the Social Determinants of Health

Over the last few decades, there has been mounting evidence that social factors play a powerful role in shaping health,[37,38] and there is growing interest in moving interventions upstream to address the social determinants of health.[39,40] This focus on social determinants is pivotal in moving the needle on population health and health inequity.[41]

As interventions increasingly address these broader social determinants, the causal pathways linking interventions and health outcomes become more complex and multifactorial, and the lag time until health effects manifest becomes more protracted.[42]

These issues of complexity and lag time present a number of challenges:

1) methodological: the complex pathways and long lead time make randomized trials difficult and expensive to perform,

2) pragmatic: the multisectoral collaborations required to implement complex interventions may falter due to divergent perspectives and conflicting goals of stakeholders across different sectors, and

3) political: funders and policymakers tend to prefer interventions with short-term results.

Systems science is uniquely positioned to play an important role in addressing these challenges:

1) modeling approaches can be used to address the complex causal pathways by compiling existing studies that form parts of the causal web into a unified whole, piecing together incremental contributions in the literature into a more complete understanding of the overall pathways;

2) systems science methods can also play an educational role, informing the dialogue among stakeholders and policymakers on these complex issues; and

3) simulation approaches can be used to address the lengthy lag times by exploring potential long-term scenarios.

Case 3: Use of Systems Science to Inform Policies Addressing the Social Determinants of Health: Transportation Planning

Transportation affects health in a myriad of ways, from air pollution produced by vehicles, to injuries and mortalities from traffic accidents, to changes in physical activity levels attributed to choices in travel modes. Acknowledging the role of transportation and the built environment in addressing public health issues, the transportation planning sector is increasingly developing policies that promote health and well-being—and using systems science methods to address the intersection of transportation and health issues.

Overview of Modeling Effort and Impact

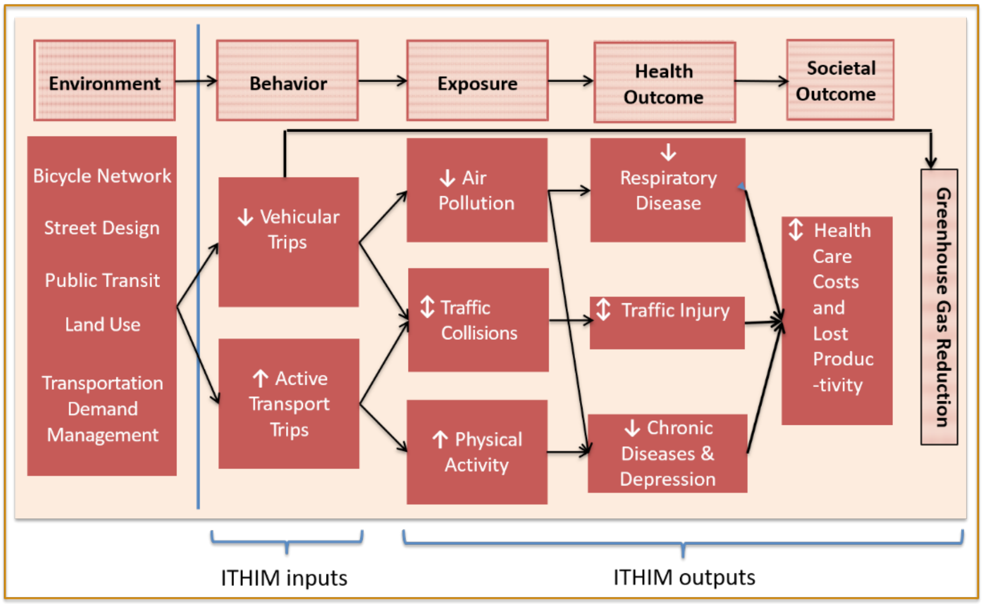
Transportation planners are familiar with the value that modeling can bring to the table in policy planning, as transportation and air quality models are commonly used in developing long-range transportation plans.[43] With the existence of rigorous models that quantify the impact of transportation policies on travel behavior and air quality, systems scientists can bridge the information gap between transportation strategies and health impacts by linking the results from existing transportation models to the development of new health models. This modular approach of using the outputs of an existing model to then serve as inputs for a new model is an effective means for developing transportation-health models. One such example is the Integrated Transport and Health Impact Model (ITHIM).[44,45]

ITHIM depicts three health pathways stemming from travel behavior: physical activity from active transportation, road traffic injuries, and air quality, as shown in Figure 3. The model takes in results from travel demand and air pollution models, supplements those results with other travel, health, and traffic injury data, and outputs health outcomes in terms of changes in mortality and disability adjusted life years (DALYs). Originally developed in England, the model has been adapted for use and field-tested broadly.

ITHIM was used in Oregon as part of a climate planning project aim at reducing greenhouse gas emissions. The Portland metropolitan regional government—Metro—requested a health impact assessment (HIA) to inform their Climate Smart Communities Scenarios Project.[46] The climate project examined different transportation and built environment scenarios—such as improving public transportation and discouraging car use through a carbon tax—to achieve target reductions in greenhouse gas emissions set by the Oregon Legislature in 2007.

The HIA used the model to quantify the health impacts of the top three strategies under consideration in the project. Results from the model estimated that all of the potential strategies for reducing greenhouse gas emissions would result in health benefits—with the majority of the benefits deriving from increased active transportation. Based on these results, the HIA included recommendations that Metro maximize active transportation opportunities and prioritize design and maintenance for non-automobile facilities.

Figure 3. Integrated Transport and Health Impact Model (ITHIM) Schematic



Source: Nicholas W, Vidyanti I, Caesar E, & Maizlish N. Implementing the City of LA's Mobility Plan 2035: Public Health Implications - Health Impact Assessment. Los Angeles County Department of Public Health, Center for Health Impact Evaluation. April 2018.

After considering the recommendations, Metro selected an emissions reduction scenario using the health criteria recommended in the HIA. The state approved this scenario in May 2015, which specifically included a key recommendation to promote built-environment design and infrastructure to encourage active transportation, including walking and cycling.[47,48]

Implications for Broader Application

Results from systems science models connecting transportation and health add an important dimension to regional transportation planning, giving urban and transportation planners the information they need to shape transportation policies that also promote health. While developing or adapting transportation-health models requires upfront investment by local jurisdictions, the models can continue to be used in subsequent planning efforts, as transportation planners have to periodically update their regional transportation plans.

Transportation planners have used systems science methods to provide insights into the links between transportation and health to inform their transportation planning in multiple jurisdictions in the U.S.[49,50] One of the key factors in achieving this level of uptake has been the relative maturity level of modeling within the transportation field, along with the motivation to integrate transportation and health in policy planning.

Looking beyond the transportation field, systems scientists should adapt the complexity of systems science methods to the level of modeling maturity within a given field. Where the maturity level is low, using simpler models in the beginning can help introduce policymakers to the methodology and pave the way for more complex and realistic models. Conversely, in fields where domain-specific models are already in common use and familiar to policymakers—but with the link to health missing, systems scientists may consider using the modular approach to model development to provide this missing link to health. The modular approach makes good use of existing resources, cuts down on model development time, and increases stakeholder buy-in as it utilizes domain-specific models already familiar to those in the given field.

Case 4: On the Horizon—Use of Systems Science to Inform Policies Addressing the Social Determinants of Health: Research in Progress on Housing Interventions

Housing is recognized as an important determinant of health, and certain housing interventions have been found to improve health outcomes while reducing health care costs. Thus, housing policies targeting vulnerable populations that are likely to suffer from health problems have become a key component of policy agendas nationwide.[51] Chronic homelessness—a circumstance in which people struggle to remain housed often because of a disabling physical, mental, or substance use disorder—has become a particularly important health issue. Almost 90,000 people were considered chronically homeless in 2017.[52] Permanent supportive housing is an evidence-based intervention that has become a dominant approach to addressing chronic homelessness.[53,54]

Permanent supportive housing provides chronically homeless individuals with housing and other supportive programs spanning multiple sectors, including physical and mental health care, substance abuse treatment, and social services. Given the range of services and sectors involved, there are numerous obstacles that can impede successful implementation, such as:

(1) lack of coordination in delivering multiple intervention components (housing placement, financial subsidies, and supportive services), and

(2) the "wrong pocket" problem, in which some of the sectors investing in permanent supportive housing do not benefit from the program's success due to fragmented financing mechanisms.[55] For instance, a permanent supportive housing program may provide better linkages to substance abuse treatment, which may subsequently reduce emergency room use; yet despite having to invest additional resources to accommodate increased demand, the substance abuse treatment sector may not receive any of the financial savings from reduced emergency room use in the health care sector.

Systems science methods can help provide a holistic system description to:

1) yield greater understanding of how improved service coordination can impact individual and system-level outcomes, and

2) capture and visualize key cross-sector relationships and synergies, increasing the opportunity to develop less fragmented financing mechanisms, such as through cross-sector subsidies.

Research in Progress—Overview of Modeling Effort

Los Angeles County has a research project underway, funded by the Robert Wood Johnson Foundation's Systems for Action program, that is using systems science methods to explore the cross-sector impacts of Housing for Health (HFH)—a permanent supportive housing initiative.[56] The project seeks to improve the implementation of permanent supportive housing by coordinating disparate intervention components.

The study uses a participatory systems modeling approach, involving stakeholders from multiple sectors in the homeless systems of care. These stakeholders are involved in defining the problem to be modeled and developing visualizations of:

1) how HFH affects various elements of the system (service utilization, costs, and outcomes across the health, criminal justice, and the social service sectors), and

2) the system's feedback structure.

This information is used to develop a qualitative model, which then forms the basis of a quantitative model structure. Linked administrative data on homelessness are used to update the quantitative model systematically so that model assumptions are based on the latest available evidence.

The model can be used to analyze a number of policy-relevant scenarios related to the provision of permanent supportive housing in Los Angeles County. For example, the study can explore the cross-sector impacts and synergies created by increases in the number of clients served by HFH, or analyze the consequences of increasing a particular type of service linkage, such as substance use treatment or mental health treatment.

Research in Progress—Implications for Broader Application

Once the HFH study is completed, decision makers can use the results to understand the value (or costs) to their agencies of these types of housing programs, providing the opportunity to develop more effective financing mechanisms such as cross-sector subsidization. Other jurisdictions interested in implementing similar housing interventions can also use the generated systems science model to better understand the systemic impact of these interventions, explore how best to coordinate service provision, and identify which services may need additional support to improve intervention effectiveness and ensure system sustainability.

Concluding Remarks

Systems science has the potential to inform policy and practice in the areas of health services and public health, and increasingly in multi-sectoral interventions to address the social determinants of health. Given its holistic and systems-level approach, systems science can play an important role in addressing a host of health-related issues as shown in the previous examples of cancer screening, childhood obesity, transportation planning, and housing.

Key Considerations for Applying Systems Science Methods

As systems science methods receive increased attention, a few considerations regarding their use should be noted:

First, systems science methods are generally best used in coordination with other research methods, as they build on the best available evidence and provide a complementary approach to other quantitative and qualitative methods. The ability to develop systems science models depends on the availability of sufficient data and prior research to inform model development. Additionally, given that systems science methods are largely focused on modeling potential scenarios, they should not be interpreted as definitive predictions of the future.[57] Rather, they are best used as one of many tools in a larger toolbox of research methods to inform the decision-making process, coupled with other policy strategies.

Second, even within systems science, a variety of models may be developed to address a particular issue. For example, a comparative modeling approach may be used to reconcile varying models and results, as shown in the cancer screening example, or a modular approach may be used to connect different models, as demonstrated in the transportation planning example. The use of simple systems tools, such as systems thinking skills, may also be an effective strategy to inform decision-making, either in place of, or as a precursor to, more complex mathematical models, as was shown in the childhood obesity prevention example which used several systems tools, including a six-question framework, to guide systems thinking. The use of simple systems tools may be especially appropriate in cases where there are limited resources for model development or given the readiness level of stakeholders.[58,59]

Third, the importance of collaborative efforts is a key consideration, including stakeholder involvement.[60] Engaging stakeholders through a participatory modeling approach provides crucial input to the model development process. Moreover, the inclusion of multi-sectoral perspectives is critical to developing holistic models, especially when addressing cross-sectoral health issues, as shown in the transportation planning and housing examples. Stakeholder engagement also provides an educational opportunity and engenders community ownership, which is integral to facilitating the use of research results in policy or program deliberations, as illustrated by the childhood obesity prevention example. At the same time, the value of health-related interventions, particularly those addressing cross-sectoral issues, may be enhanced through a systems approach and collaboration with systems science experts.

Despite its promise, systems science methodology has yet to become a mainstream tool in policy planning. Recent advances in data technologies present an opportunity to catalyze adoption of systems science methods in health policymaking.[61] For instance, innovations in technology are reducing barriers to data collection, storage, sharing, and linkage—generating a wealth of data that can inform model development. While the utilization of large and complex data ("big data") comes with its own practical and methodological challenges, systems science techniques are well-positioned to leverage big data to address social problems, as they are well suited to synthesizing heterogeneous data from multiple sectors. With new developments in local and national data infrastructure, as well as clearinghouses collecting health-related data (including upstream determinants of health), there is increased opportunity to accelerate the use of systems science methods in policy planning.[62]

As previously noted, much of the literature on systems science points to its potential for informing policy or practice, although documentation of these applications is more limited.[63] While the examples in this brief are not intended to provide an exhaustive review, by spotlighting cases where systems science research has successfully been used to influence policy or practice, we hope to demonstrate the compelling value of appropriate use of systems science methods in exploring and addressing complex health issues at the policy and program levels.

Glossary: Systems Science Methods Defined

Complexity Science: The study of complex systems characterized by non-linearity and the dynamic and interconnected relationships within the system.

Agent-based Modeling: Modeling of complex systems by examining how agents (individual system elements) behave and interact with each other to uncover emergent properties of the system. Often used to model biological processes, organizational behavior, and other processes where interactions between entities are important, such as the spread of infectious diseases through direct or indirect contact.

Discrete Event Simulation: Modeling of systems as a discrete sequence of events. Also called activity-based simulation. Assumes no change within the system between consecutive events. Often used to model business / operational processes, such as how operating room scheduling affects patient flow within a hospital.

Microsimulation: Modeling of systems as a collection of autonomous units / entities, with each entity having parameters representing individual preferences and tendencies. Within the health field, often used for simulating individuals' life histories and aggregating the results to obtain population-level prevalence of chronic diseases, life spans, and other relevant population health metrics. Outside the health field, often used in the transportation and econometrics fields.

System Dynamics Modeling: Modeling of non-linear processes based on a series of differential equations. Characterized by stocks and flows, feedback loops, and time delays. Often used to study system behavior at a macro level. Has various management and educational applications, such as analyzing assumptions about system behavior or gaining qualitative insight into how a system works.

Network Analysis: Analysis focusing on the relationships among entities, such as persons, organizations, or documents. Rooted in graph theory. Social Network Analysis, a subset of Network Analysis, investigates social structures, such as social media networks or disease transmission, using networks and graph theory.

Source: Luke DA & Stamatakis KA. Systems Science Methods in Public Health: Dynamics, Networks, and Agents. *Annu Rev Public Health*, 2012;33:357-376; and Robinson S. Simulation: The Practice of Model Development and Use. Chichester: Wiley, 2004.

About the Authors

Irene Vidyanti, Ph.D., M.Eng., is a Data Scientist/Modeler at the Los Angeles County Department of Public Health (LACDPH)—where she is also a Co-Investigator for the Housing for Health research study under the Systems for Action program—and a Collaborating Programmer with the University of Southern California's Schaeffer Center for Health Policy & Economics. Marya Khan, M.P.H., is a Senior Manager at AcademyHealth.

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