Seminars in Perinatology 39 (2015) 416–423

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# Scaling-up impact in perinatology through systems science: Bridging the collaboration and translational divides in cross-disciplinary research and public policy

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ARTICLE INFO

*Keywords:*
Systems science
System dynamics
Group model building
Honduras
Maternal survival
Salud Mesoamerica 2015 Initiative

ABSTRACT

Despite progress over the past decade in reducing the global burden of newborn deaths, gaps in the knowledge base persist, and means of translating empirical findings into effective policies and programs that deliver life-saving interventions remain poorly understood. Articles in this issue highlight the relevance of transdisciplinary research in perinatology and calls for increased efforts to translate research into public policy and to integrate interventions into existing primary care delivery systems. Given the complexity and multi-causality of many of the remaining challenges in newborn health, and the effects that social and economic factors have over many newborn conditions, it has further been proposed that integrated, multi-sector public policies are also required. In this article, we discuss the application of systems science methods to advance transdisciplinary research and public policy-making in perinatology. Such approaches to research and public policy have been used to address various global challenges but have rarely been implemented in developing country settings. We propose that they hold great promise to improve not only our understanding of complex perinatology problems but can also help translate research-based insights into effective, multi-pronged solutions that deliver positive, intended effects. Examples of successful transdisciplinary science exist, but successes and failures are context specific, and there are no universal blueprints or formulae to reproduce what works in a specific context into different social system settings. Group model building is a tool, based in the field of System Dynamics, that we have used to facilitate transdisciplinary research and, to a lesser extent, policy formulation in a systematic and replicable way. In this article, we describe how group model building can be used and argue for scaling its use to further the translation of empirical evidence and insights into policy and action that increase maternal and neonatal survival and well-being.


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http://dx.doi.org/10.1053/j.semperi.2015.06.003

## Introduction

Progress in global perinatal health has expanded with increasing attention to collaboration across disciplines as well as to gains in our ability to understand systems—namely, recognizing the interconnectedness that links components across the continuum of care in maternal and child health, community- and facility-based intervention delivery strategies, scientific and community perspectives, as well as upstream and downstream risk factors.[1,2] However, gaps in our knowledge base still persist, and means of translating empirical findings into policies, programs, practices, and delivery platforms that achieve impact remain a challenge.

The articles in this issue summarize the "state of the art" in perinatology, highlight available empirical evidence, and identify major knowledge gaps in areas like adolescent health, family planning, maternal mental health, nutrition, and children's cognitive development, to name a few. In our view, the complexity of the challenges discussed here points toward the need for perinatology to further embrace transdisciplinary approaches to research and to expand the applications of systems science to shape and influence directions in which research becomes translated into policies, prevention programs, and delivery mechanisms that address the challenges discussed here.

Many of the unsolved challenges faced by perinatology today are characterized by scientific and technological complexity and by a plurality of views and perspectives about the most effective solutions for scaling-up impact. As is the case for many other complex scientific challenges, research collaboration and transdisciplinary research are required for science to be able to transcend the limits of one specific field, and integrate the knowledge produced by multiple disciplines. It is in this respect that the languages of transdisciplinary research and collaborative policy-making meet the language and methods of systems science.

In this article, we describe the application of systems science methods and tools that can increase the value for money of transdisciplinary research in perinatology. Our goals are two-fold; we will first describe the ways in which systems science frameworks and methods can support transdisciplinary research and its translation into public policy-making. Then, we will depict a case in which systems science methods—system dynamics and group model building—were applied to the complex challenge of maternal survival in a developing country setting.

## Barriers to scaling-up impact and intersectoral action

There are a variety of system behaviors that pose challenges for understanding and scaling-up impact in perinatology that call for a complex adaptive systems perspective.[3] Furthermore, these challenges are rarely just one type of problem. Scaling-up impact in perinatology typically involves addressing a number of different types of problems including building up individual and organizational learning capacity, developing consensus on the issues that need to be addressed across disciplines and sectors, analysis of policy options and implementation strategies, development of monitoring systems that enable rapid cycles of learning and program improvement, and restructuring of a system to support the funding and implementation of programs that are cost-effective and sustainable.[4,5] In particular, Swanson, et al.[5] argue for the use of systems thinking tools to support health system strengthening via the development of "simple rules" or widely accepted guidelines that can be flexibly applied and locally innovated. For example, efforts to address curable diseases versus prevent acute life-threatening conditions (e.g., clinical care versus community prevention) can have surprising feedback effects that bias a health care system toward higher cost, less efficiency, and greater health disparities.[6] Or, donor initiatives to vertically fund some initiatives can "crowd out" other health sectors or services.[7]

What makes these challenges to scaling-up impact especially difficult is the fact that the consequences of initiatives to improve some health outcomes in one sector often depend on tangible and intangible resources in another sector including skilled workforce, transportation infrastructure, logistics, information systems, good governance, etc. As the demands for these resources grow, shortages appear and create "limits to growth" that are well understood in business and industry.

Addressing these challenges requires new ways of thinking across sectors, anticipating the consequences and risks to successful scale up, and developing robust and effective intersectoral collaborations. Central to all three of these requirements is the need for transdisciplinary collaboration—across disciplines, experience, governments, private–public sectors, and ultimately communities—in order to achieve the desired population-level health benefits of advances in perinatology.

## Transdisciplinary science and collaboration

Transdisciplinary science is a form of team science where individual scientists and/or research organizations come together across disciplines to solve a particular problem, integrating their approaches and, in the process, creating a new understanding that transcends disciplinary boundaries.[8] This form of collaboration oftentimes leads to shared conceptual frameworks that integrate and transcend the individual research and practice perspectives among the various research teams and organizations.[9,10] This *emergent perspective* is what distinguishes transdisciplinary research from other forms of cross-disciplinary collaboration. A good example of where this is needed to accelerate progress in perinatology is in the prevention of preterm birth, given rising rates of preterm birth around the world and knowledge of few effective preventive interventions.[11]

## Systems science

Systems science encompasses a set of methods for understanding systems and their behavior including social network analysis and computational modeling approaches such as agent-based modeling and system dynamics modeling.

Systems science methods have been used to advance our understanding in public health on a wide range of topics including tobacco control and prevention policy, cancer prevention and treatment, infectious disease, childhood obesity, and violence against women.[12–19]

While public health efforts have largely focused on overall population health, systems science methods have also been seen as a way of strengthening health care systems and improve access and quality of care.[20–23] System science methods complement existing methods of inquiry by explaining how various elements of a system interact and combine to generate larger, emergent behaviors. For example, systems science methods can help identify and explain how interventions in one part of a system can propagate and undermine outcomes in another part of a system, why diseases and misinformation spread in some communities and not others, determine where the "tipping points" for scaling-up interventions might be, explain "worse before better" scenarios, and identify "leverage points" where small changes can have large effects.

Typical of system science methods is a focus on how multiple sectors interact over time by representing systems as formal mathematical models that capture the underlying assumptions of each subsystem, set of actors, etc. As such, systems science methods explicitly attempt to synthesize knowledge and assumptions across multiple domains and perspectives, and have proven especially valuable for representing complex problems spanning multiple sectors.

While there are a wide variety of system science methods available for studying and understanding complex adaptive systems, there is often a sense that these methods tend to be abstract in their analysis. A frequent desire is to see specific examples of how one or more of these tools were used to deliver tangible benefits for a group of stakeholders. In this article, we therefore focus in the next section on illustrating the application of a specific method, system dynamics using participatory group model building methods.

## System dynamics

System dynamics is a way to understand system behavior through the use of informal causal maps and formal models with computer simulation.[24] System dynamics has a formal set of diagraming conventions that maintain a strong correspondence between the visual representations and underlying computer models that can be simulated.[25]

Examples of these diagraming conventions include informal causal maps, causal loop diagrams, and stock and flow diagrams. To introduce diagraming, we present two versions of a "concept model"[26] used in the case example discussed later in the article. In system dynamics, a concept model is a special type of computer simulation model that is specifically developed to introduce people unfamiliar with system dynamics to its conventions. Importantly, concept models are small and deliberately flawed in ways that provoke interaction within a group, and typically are used as part of an interactive group exercise or "script."[26]

Figure 1 depicts a causal loop diagram (CLD) of a concept model of scaling up a childhood vaccination program. The directed arcs represent hypothesized causal relationships, with the pluses and minuses representing the direction of association between the two variables. For example, the *more* trained staff there is, the *faster* one can be vaccinating children, all other things being equal; and, by the same logic, the *fewer* trained staff there are, the *slower* the vaccination of children, all other things being equal. The CLD in Figure 1 highlights a number of balancing and reinforcing feedback loops that affect the scale up of the vaccination program. For example, one needs to have trained staff to recruit and train new staff. So the more staff one has that are trained, the

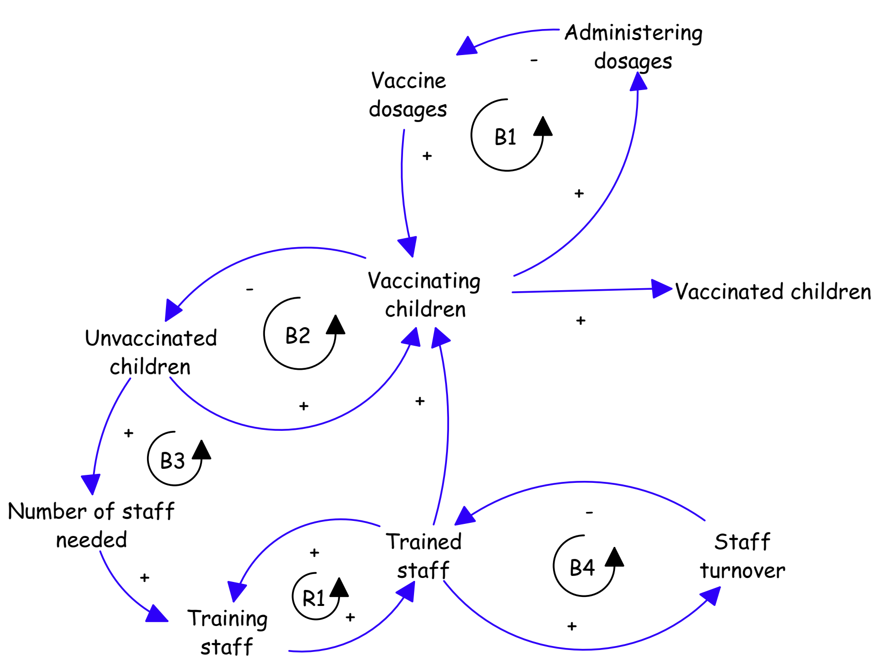


**Fig. 1 – Example of a system dynamics causal loop diagram of scaling up a vaccination program.[33]**

faster one can recruit and train additional staff, which in turn leads to even more trained staff. This forms a *reinforcing feedback loop* (labeled R1 in Fig. 1). But, the more trained staff one has, the more people leave due to turnover, which reduces the number of trained staff, which in turn forms a *balancing feedback loop* (labeled B1 in Fig. 1). The trend in the number of trained staff therefore depends on which of these feedback loops is dominating the behavior of trained staff.

A stock and flow diagram corresponding to Figure 1 is shown in Figure 2. This has essentially the same information as Figure 1, but distinguishes variables by whether or not they are accumulations or stocks (shown as boxes), flows or transitions between stocks (variables under the double triangles or valves), or auxiliary and constant variables. The clouds in Figure 2 represent the material and information boundaries of the system. There is slightly more detail in Figure 2 as the model shown in it can be simulated on a computer. This distinction between stocks and flows is important because stocks represent the resources needed for scaling up along with the accumulated impacts of activities, while flows represent the pathways whereby impact is achieved.

The use of formal models that can be simulated has many benefits during all stages of problem solving and implementation in complex systems: from initial conceptualization of the system and structuring of the problem to designing interventions to implementation and ongoing monitoring, evaluation, and learning. Specifically, computer simulation allows researchers, stakeholders, and policy makers to

- Test the model and build confidence in the assumptions underlying a model
- Understand system behavior
- Identify leverage points
- Design and compare different interventions and policy options
- Weigh the tradeoffs between different interventions
- Test the sequence and timing of interventions
- Assess the sensitivity of outcomes to uncertainties and potential risks
- Compare predicted behavior and against actual system behavior as an evaluation framework.

## Group model building

This correspondence between diagraming conventions and computer simulations has led to the development of participatory group model building (GMB) methods as a way to engage stakeholders in the process of structuring problems, developing models, and ultimately participating in the analysis and implementation of policies.[27–29] While GMB has historically been used with professionals in government, business, and academics, these same tools have also been extended to engage stakeholders, develop

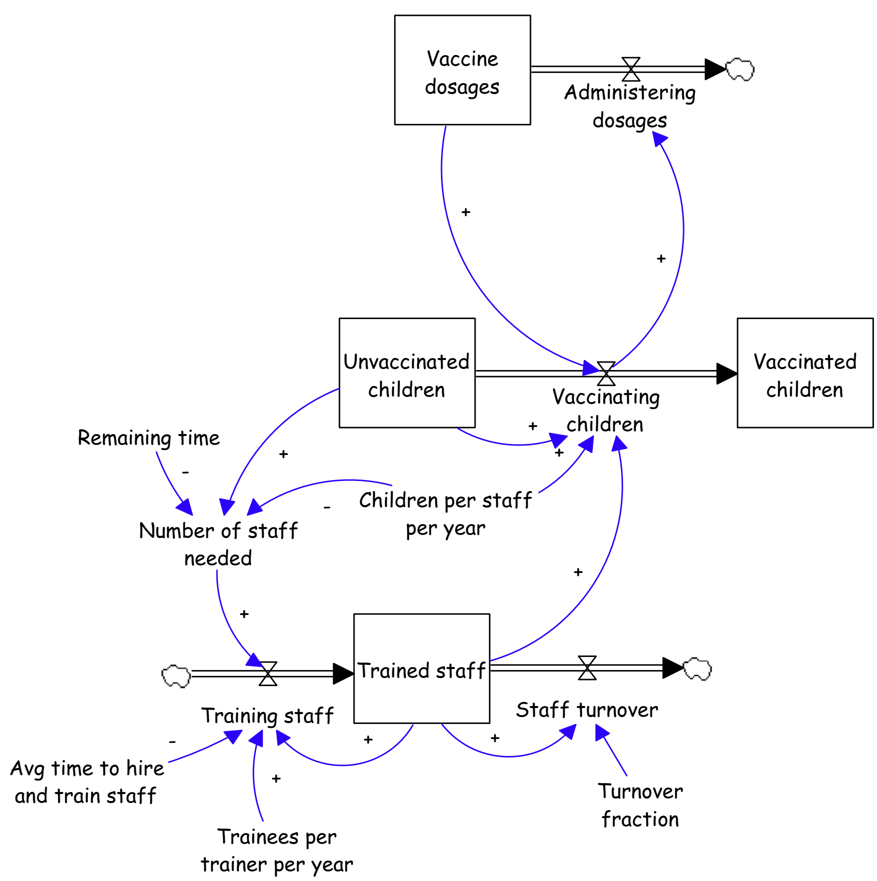


**Fig. 2 – Example of a system dynamics stock and flow diagram of scaling up a vaccination program.[33]**

collaborations in community settings, and design new programs and services including applications in child and maternal health.[30–33]

Some of the main benefits of using GMB with stakeholders include:

- *"Seeing a system"*. One of the greatest challenges for actors in any given system is being able to see the whole. Most actors only perceive a select view of their program, organization, or sector within a system. For example, professionals focused on prevention and improving quality of care may fixate on health care delivery systems, while community members in low-income neighborhoods and villages may be prioritizing income, farming, education of their children, or basic housing and nutrition needs. Diagrams of systems used in GMB help diverse stakeholders perceive expanded views of the system and components within the system that may be influencing their program, organization, or sector.
- *Identifying feedback mechanisms that link different sectors of a system*. For example, efforts to increase institutional delivery may be hindered by community perceptions that delivering in hospitals is associated with increased maternal mortality, and thereby delay acknowledging a complication and seeking care, which in turn leads to more complicated obstetric emergencies with less time to get appropriate care, and ultimately increased risk of maternal mortality, which "feeds back" to reinforce community perceptions that delivering in hospitals is where women "go to die." Identifying and understanding these types of feedback loops is *essential* to understanding the dynamic nature of interactions within systems, such as those that impact care-seeking behaviors. The explicit diagraming of feedback mechanisms in GMB with participants helps stakeholders recognize these important feedback mechanisms in a health system and helps them to think about the implementation and monitoring of interventions in new ways.
- *Study multi-causal, multi-level relations among system elements through a simulated experiential learning environment*. The very nature of systems means that it is often hard to understand the consequence of actions, as the effects are often delayed and interact with other changes. The common experiential learning environment from a formal simulation model in GMB allows stakeholders with different perspectives and experience to develop a common language around a shared metaphor or depiction of the system. It also helps stakeholders from many disciplines and sectors achieve consensus on common objectives, means, and targets for shared policy-making, programming, and action.
- *Mapping and assessing policy options when considering multiple points of intervention within a system*. There are many approaches to facilitating meetings and working with stakeholders to generate different policy options. However, without a model of the system, many ideas tend to focus on only some parts of the system while ignoring or failing to recognize others. In GMB, participants can use a causal map or formal model to identify and map various strategies, for example for reducing maternal mortality (see below).
- *Designing for implementation and scale up*. Many interventions that appear promising at pilot phases do not scale and thus fail to achieve impact. GMB can help program implementers identify and mitigate potential barriers to scale up. For example, GMB can help implementers anticipate potential constraints on specific system elements or interventions and then identify potential solutions to mitigate these barriers.

## Combining transdisciplinary science and intersectoral action

GMB provides replicable method to tackle gaps in perinatology by bringing together diverse stakeholders and expertise (including scientific expertise, policy expertise, program management expertise, frontline worker and community, and end-user expertise) around a model building process grounded in principles of system dynamics. A key feature of this process is that the informal maps and formal models with computer simulation serve as "boundary objects."[34,35]

Boundary objects are tangible representations (e.g., diagrams) that allow diverse stakeholders with different viewpoints (e.g., political perspectives and agendas, scientific expertise, and experiences in a community) to articulate dependencies between key concepts and representations, which *can be modified by all participants*.[34] When diagrams begin to function as boundary objects with a group, the discussion shifts from whether one person is right and the other is wrong, to a discussion about whether or not the diagram is correct, captures the relevant relationships, resolves a conflict, and so on.

Boundary objects are, in this sense, a negotiated metaphor that a group can use to generate new, design driven innovations. Schön[36] described such metaphors as generative metaphors because they allowed people to see something in a new way. Schön's example is of a product design team charged with inventing a new paintbrush where someone suddenly recognizes the paintbrush as not being an applicator, but a reservoir with a pump. This opens up for the group a new way of seeing how the paintbrush could function in and as a system.

While metaphors can be a rich source of inspiration for change, their creation can be haphazard and more of a trial and error process at best. GMB and the use of the language of system dynamics provide a disciplined language for creating and discussing boundary objects with a group, which can then be tested more formally and rigorously using a simulation model. Moreover, not only do boundary objects in GMB span different perspectives, *they are negotiated*. In this sense, GMB can simultaneously bring together transdisciplinary domains of expertise *and* address concerns about cross-disciplinary public policy and help teams reach consensus and commitment to action.[37,38]

The identification, sequencing, implementation, and evaluation of translational strategies can benefit from GMB to the extent that the latter can effectively contribute to the establishment and scaling up of new clinical practices, preventive programs, and public policies. GMB can also create the conditions of trust, collaboration, and experiential learning that can foster future collaborative practices. Finally, GMB can inform the identification of processes, indicators, and outcomes for monitoring and evaluation in order to optimize learning and impact.

## The *Salud Mesoamerica 2015* Initiative (SM2015): The Honduras maternal survival case example

This section summarizes how systems dynamics and GMB were used to address a set of maternal health challenges in Honduras as part of a multi-country public–private health initiative—*Salud Mesoamerica 2015*.[39] The initiative aims to improve population health outcomes among women, neonates, and children in the poorest income quintile in rural Mesoamerica, a region covering the seven Central American nations and Mexico's southern states. The eight participating governments, the Bill and Melinda Gates Foundation (BMGF), the Carlos Slim Foundation, the Spanish Bilateral Agency, and the Inter-American Development Bank (IADB) finance the SM2015 initiative. The IADB is a recipient of funds and also functions as program manager and fiduciary agency.

### *Program features*

SM2015 uses a results-based funding mechanism. Participating countries design and implement up to three consecutive, 18-month programs, that start with the deployment or improvement of key inputs and processes, are followed by the production of key outputs and, finally end in a set of population-level desirable maternal, neonatal, and child health outcomes. Anticipated targets were negotiated between the IADB and each government to be measured at baseline and then independently measured at months 18, 36, and 54 using standardized protocols and indicators. Governments receive funding for this sequence of programs in the form of (1) an "investment tranche" financed by donors, that covers inputs, supplies, and equipment required for the achievement of targets, (2) a domestic financial counterpart funded *a priori* by each country's Ministry of Finance to cover costs not funded by donors, and (3) a performance-based incentive that is paid to each country's Ministry of Health after the agreed targets are met and verified independently. Performance is measured through household and facility surveys collected at baseline and then every 18 months, using a standard evaluation protocol administered by the University of Washington's Institute for Health Metrics and Evaluation.

This example is highlighted because the aspiration to scaling-up impact is explicit and has been inculcated into each country program. Since the innovations introduced by the SM2015 initiative are all integrated into existing primary care platforms, SM2015 has leveraged already available institutional mechanisms to deliver innovations at population scale. This approach also allows local adaptation, testing, learning, and improvement, while channeling additional and much needed funding into the strengthening of the existing primary health care system. Innovations that are being integrated into existing platforms include the use of zinc for the management of diarrhea and of micronutrient powders for chronic malnutrition, among others. The program also includes process innovations to improve performance in local settings such as the use of transportation vouchers for deliveries, social and financial incentives for frontline workers, and pay-for-performance of local providers.

### *SM2015 Honduras maternal mortality modeling*

To highlight the application of system dynamics and GMB, we now summarize our work to date with the IADB and the Honduran Ministry of Health. We will briefly present the system dynamics and GMB activities performed, the models that were developed, their primary purpose, the main insights gained, and cumulative outcomes to date. The emphasis of our work has been to build and deepen understanding among program stakeholders of the systems under change and to apply system dynamics and GMB to improve aggregate program performance and enhance the quality of policy-making in the country.

Starting in April 2012 and continuing through 2015, we have conducted a series of GMB workshops and complementary activities with a group of stakeholders representing the SM2015 Honduras program including staff from both the Ministry of Health (as policy maker and program implementer) and the IADB (as technical intermediary). In an initial stage, we familiarized the group with the language of system dynamics using the concept model shown in Figure 2.

Once the stakeholders were familiar with the language and basic tools of system dynamics, in a subsequent phase we used system dynamics and GMB to help them visualize the system in which program performance is produced, identify potential unintended consequences of proposed activities, improve the quality of risk management, better communicate the dynamic complexity of the activities being scaled up, support strategic decision making for future investment decisions by donors and governments, identify and prioritize leverage points, and adjust program implementation strategies.

The starting point for this stage of the process was the decision of the participants to deepen their understanding and analysis of Honduras' central priority in maternal health: institutional deliveries and emergency obstetric care. Since the 1980s Honduras has focused on addressing maternal mortality through prioritization of institutional deliveries as a key means to reduce mortality due to emergency obstetric complications.[40,41] Using the "three delays" framework [41] that was already familiar to participants, we created an initial "backbone" model to elicit information about how the current system was structured.[42]

As a result of the various interactions that took place during the following year, participants became deeply engaged in developing increasingly sophisticated models, starting with prototype models and ending with a computer simulation model that is currently under calibration. Throughout the process, participants conducted a number of experiments using simulation models and acquired important group insights about the system. For instance, they realized that they could not just invest in a single leverage point within the system as they had been doing (e.g., increasing institutional delivery), but also needed to balance their investments across different parts of the larger health system (e.g., addressing transportation of women in rural areas or improving the quality of emergency obstetric care). As one of the participants put it, if policy was only focused in one part of the system without also investing in other points, the net result could simply be a shifting in mortality from one part of the system into another. Maybe even more importantly, participants realized that their mental models had primarily focused on reducing emergency obstetric complications through institutional deliveries. However, the recurrent use of system dynamics models to assess policy and program options led the participants to realize that there were certain elements in their current mental models that required adjustment. The latter was of critical importance for the results-based program funded through the SM2015 initiative and led directly to revising the design of existing policies to add, for instance, new focus for both maternal *and* neonatal survival at the community and facility levels.

Finally, the process has led to renewed interest in applying systems science to a wider range of social problems in Honduras. This is of particular relevance to discussions in this issue, such as the need to improve the quality and scope of public policy for complex perinatology challenges—such as adolescent health, maternal mental health, family planning, nutrition, optimizing child development, etc.—through the integration of perinatology goals into many policies and within several sectors. In the Honduran case discussed above, for example, the program team realized that sustained maternal survival is highly dependent on coverage of modern contraception and gains in girls' education, and thus can only be addressed through inter-sectorial policy-making. We believe that system dynamics and GMB will improve the likelihood that such interdisciplinary, or even transdisciplinary, efforts come to fruition and are effectively translated into integrated policy and sustained clinical and social program practice.

## Discussion

Given the slow and sometimes negligible pace at which research is translated into policies and programs that produce sustained impact at scale,[43,44] many have recommended the use of approaches to research that are participatory and that also employ a systems perspective.[45–47] We presented applications of systems dynamics and GMB, methods that are built on the language and tools of group dynamics and systems science. As such, these methods are promising to the growing field of team science and its related efforts at collaborative transdisciplinary research.

For many of the interventions and approaches discussed in this issue, the ultimate translational outcomes of interest are diverse measures of improved population health at national scale, and/or routine or sustained adoption of collective, healthy behaviors. In these two cases, system dynamics and GMB offer opportunities to engage with policy makers and other health system stakeholders to advance the complex process of translation from evidence into public policy, implementation, and sustained dissemination leading to health impact. The case we discussed from Honduras provides examples of key contextual elements, approaches lo learning, and the specific contributions of these system science approaches in public policy assessment and formulation as well as for program design, adaptation, and learning.

In the Honduras case, major advances in long-standing maternal survival challenges will require a better understanding of economic, community, and social environment factors. These factors in large part determine behaviors linked to the early identification of obstetric complications, the decisions to transport a pregnant woman to a facility, and the expression of preferences and beliefs about home versus institutional delivery. All of these elements need to be addressed and integrated into public policies that are not necessarily of the exclusive purview of the Ministry of Health and that will likely require consultation, coordination, and collaboration with other agencies and stakeholders involved in public policy and program implementation.[48–50]

Insights arising from the various maternal survival simulation models developed in Honduras indicate that the policy of institutional deliveries, while successful in its early stages, will only marginally reduce mortality if continued as is. Also, the simulation models indicate that any policy that focuses on a single element within the system will lead to a shift in maternal mortality from one part of the system to another, thus deepening long-standing, preventable health inequality.

Finally, the contextual factors mentioned above also have major policy implications for addressing issues outside the health sector, like the positive long-term effects that girls' education can have on increased maternal survival. In this case, an already complex challenge becomes even more so due to the inter-sectorial and cross-disciplinary nature of the challenge. Therefore, the effective translation of such types of evidence requires forms of collaborative, coordinated, and even integrated policy-making that are not the norm in many countries—developed and developing alike. System dynamics and GMB have been applied to these types of challenges in public policy and have shown positive effects. Given that several of the authors in this issue of Seminars in Perinatology have identified similar needs for the achievement of sustained impact at scale in perinatology, we expect systems science to further contribute to the collaboration needed for effective transdisciplinary public policy-making and program design and implementation leading to sustained impact at scale.

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