# Designing Public Health Dissemination and Delivery Systems[1]

Peter S. Hovmand, PhD
Washington University in St. Louis
phovmand@wustl.edu

Matt Kreuter, PhD
Washington University in St. Louis
mkreuter@gwbmail.wustl.edu

James W. Deering, PhD
Kaiser Permanente
James.W.Dearing@kp.org

## Abstract

*There is increasing recognition in public health that achieving population level impact from even the successful translation of basic research to effective interventions is inherently challenging. Only a small percentage of initial interventions ever get implemented and of those very few do so at scale. A number of efforts have sought to reduce the research-practice gap in public health. This paper adds a promising tool to this endeavor by introducing the use of system dynamics for the design of public health dissemination and delivery (D&D) systems. We do so through two case studies. The first shows the role that system dynamics played in assessing the relative impact of different designs for a D&D system, while the second shows how system dynamics was used to help develop a conceptual framework of factors influencing the performance of a D&D system. Together, both projects highlight the contributions that relatively simple models can make in dissemination science and practice through the design, testing, and evaluation of public health D&D systems.*

Keywords: public health, implementation, scale-up

To achieve significant improvements in public health, interventions need to be effective, disseminated at scale, adopted, implemented, and sustained over time. Over the last 10 years, a growing realization has emerged that the problem of improving public health may have a lot more to do with dissemination, adoption and implementation of interventions than with developing new interventions. Fields such as implementation science and translational research have emerged in response to this realization, which have led problem and calls for brining in new methods from other fields (Institute of Medicine 2001; Reid et al. 2005; Woolf 2008; Proctor et al. 2011).

[1] This research was partially supported by the Bill & Melinda Gates Foundation, and the Health Communications Research Lab at Washington University in St. Louis.

Knowing how to successfully scale an innovation is not new. Companies successfully scale products and services all the time. It is not easy, but it is part of the routine process of any successful enterprise that attempts to achieve scale either through growth or replication. In public health, however, knowledge on how to scale innovations is relatively limited, and new approaches are needed for how to think about and solve the various issues that arise in scaling an innovation to address public health problems. Where companies such as Proctor & Gamble, Coca-Cola, General Motors, Microsoft, and Apple have all developed systems to make their products ubiquitous, similar systems for scaling up public health innovations are largely absent. To address this, public health researchers have started to look toward business to understand how to design and build better dissemination and delivery (D&D) systems (Dearing and Kreuter 2010).

From its onset, system dynamics has been used to understand the role of marketing, research and development, and supply chains (Forrester 1968; Sterman 2000; Roberts 1964), and emphasized the role of feedback in the design and management of such systems (Richardson 2011). While there has been growing interest in applying system dynamics to public health (Milstein, Homer, and Hirsch 2010; Homer et al. 2008; Milstein et al. 2007; Jones et al. 2006; Homer 1993), there has been little work done on the design of D&D systems for actual implementation and scaling up of public health interventions.

This paper highlights two applications of system dynamics to designing D&D systems. The first project focuses on the use of system dynamics to evaluate the conceptual designs of a public health dissemination support system; the second project focuses on the use of system dynamics to help develop a conceptual framework for assessing the readiness for scaling up interventions and achieving impact. Both projects highlight the unique role that system dynamics can play at the conceptual design phase.

## 1. Using Models for Analysis versus Design

Most applications of system dynamics in public health have focused on using system dynamics to analyze various policies and strategies with respect to specific outcomes, that is, focusing on questions such as what is the best prevention strategy? What is the best set of policies and programs to implement for improving clinical outcomes? And, what is the most cost effective intervention, strategy, or policy? For example, previous system dynamics health studies have looked at the dynamics of specific health conditions and risk factors (Homer et al. 2008; Ghaffarzadegen, Lyneis, and Richardson 2011; Jones et al. 2006), service delivery system dynamics (Levin and Roberts 1976; Lane and Husemann 2008), prevention strategies (Hassmiller Lich, Osgood, and Mahmoud 2010; Thompson and Tebbens 2007), the cost effectiveness of interventions (Tengs, Osgood, and Chen 2001; Tobias, Cavana, and Bloomfield 2010), and strategies for managing chronic disease (Homer et al. 2004).

Such efforts typically require significant time and money to develop models; their primary purpose is analysis. However, models can have other uses such as helping people better conceptualize a system (Richardson 2011), develop awareness of the important resource stocks (Warren 2004), designing better systems, and developing innovations. In this paper we highlight the use of system dynamics as a *system* design tool.

Although analysis of policies and strategies can also be thought of as policy design and strategy design respectively, the primary emphasis of such activities is oriented toward maintaining the current system as opposed to a more fundamental transformation of the system

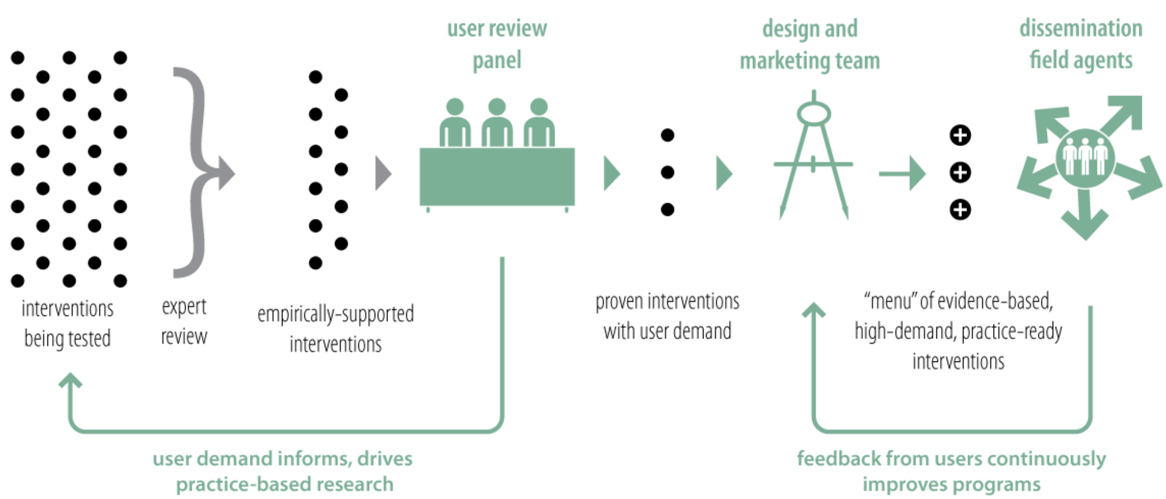
(Lane 2001, 2001). However, system dynamics has a rich set of applications where models are used to design new systems including (e.g., business models, supply chains). In such applications, simulation models play an important role for early and quick prototyping, testing, and revising of ideas. Heuristically, models serve as a boundary object (Black and Andersen 2012) or generative metaphor (Schön 1979) that help the designers change their interpretation of a situation, reframe a problem, and innovate, or provide designers with a new pattern language (Alexander et al. 1977).

The use of models for system design differs from the more prevalent practice of analysis in that the emphasis of using models for design is on rapidly evolving the *structure* of a system. It is the difference between assessing (analyzing) the influence of different policies through parameter changes and additions/subtractions of feedback loops, and considering (designing) the performance characteristics of different systems.

## 2. Designing a Dissemination Support System

The first project began as exploration to test via computer simulation how a conceptual framework for a dissemination support system might work (see Figure 1). The developers were concerned about a prevailing idea in public health that all effective interventions should be implemented as is, while there is much research and practice evidence that adaptation, not adoption, is the rule. The developers pointed out that few if any interventions were evaluated in terms of demand for the intervention by end users. Moreover, those that were in demand were generally not ready for mass distribution. Drawing from research and examples from industry, the developers hypothesized that the addition of (1) a user demand review panel, (2) design and marketing teams, and (3) dissemination field agents would significantly improve the rate that effective interventions were adopted and implemented because these additional actors would, on the strength of their market and practice knowledge, effectively adapt the research product into a market-compatible innovation.

Figure 1. Conceptual framwork for a proposed dissemination support system




While individual components of this system had been tested in empirical pilot studies, what was not known is how the overall system might work, what the relative contribution of each component might be, and where to invest the next set of resources for further development and testing. It was in this context that the system dynamics team was approached with the goal of developing a simulation model to test various designs of the proposed dissemination support system.

Over the next 12 months, the modeling team worked with the developers through a series of unstructured group model building sessions to conceptualize, formulate, and review the analysis of different designs shown in Figures 2 through 5. Each design was represented as a separate model with health innovations entering the system from the left and moving progressively toward the right and eventually being adopted and implemented by end-users. A co-flow structure was used to keep track of key two attributes: effectiveness of the innovation and demand for the innovation.

Figure 2 illustrates the main stock-flow structure of business as usual case consisting of expert review panels. In this model, the prevailing assumption is that reviewing the published empirical studies by an expert panel and making recommendations on best practices is sufficient for getting innovations adopted and implemented. This model serves as the basis for subsequent comparisons. The model in Figure 3 adds to the "business as usual" case user review panels. User review panels consider whether or not there is actual demand for the innovation. The model Figure 4 adds design and marketing teams.

Figure 2. "Business as usual" case with expert review panels

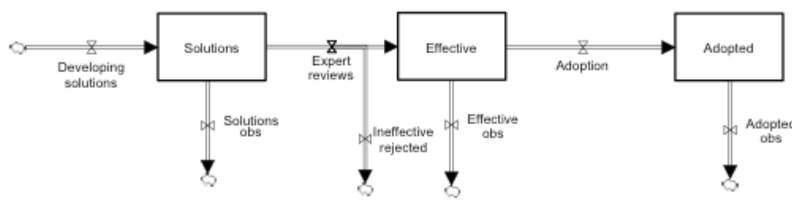



Figure 3. Addition of user demand review panels

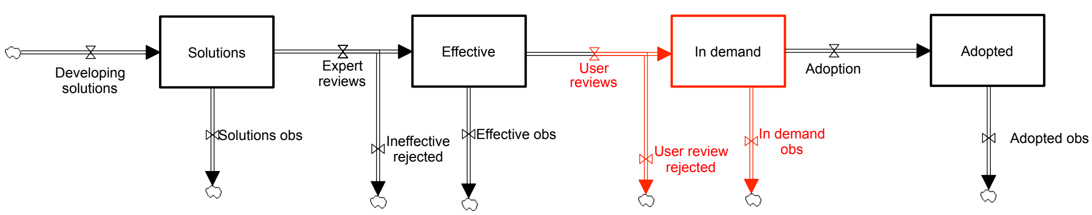



Figure 4. User demand review panels with the addition of design and marketing teams

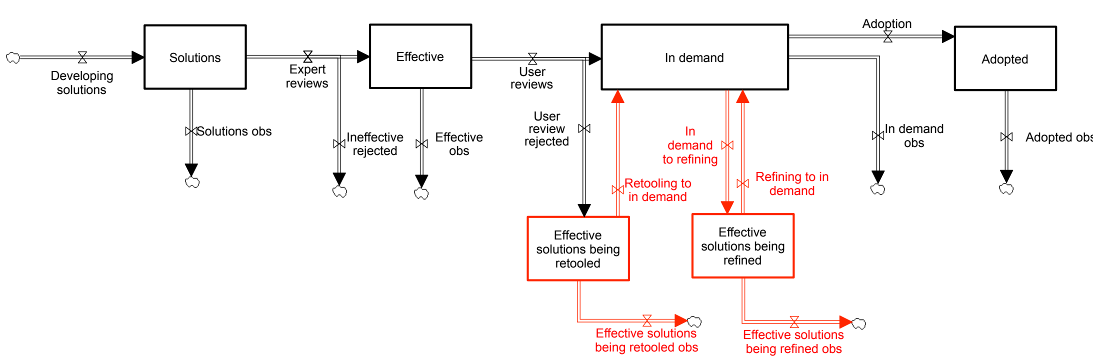
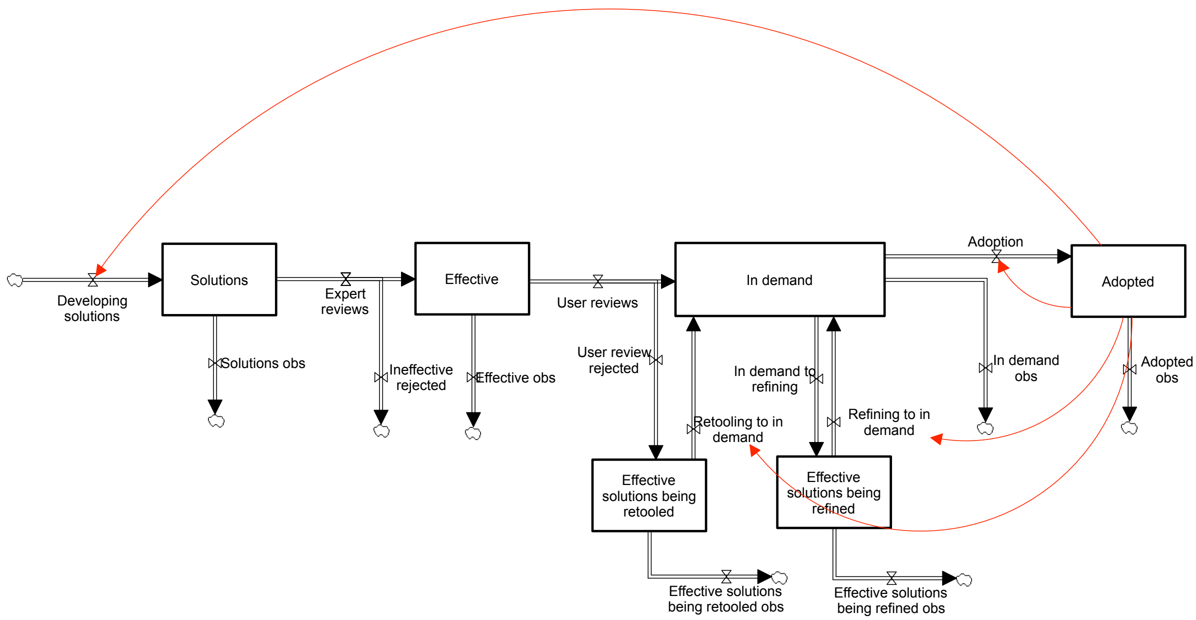


Figure 5. User demand review panels with design and marketing teams and delivery teams




Design and marketing teams take effective innovations that have no demand from potential users and retool them to increase demand, as well as refine innovations that are in demand to enhance their overall appeal to end users. The model in Figure 5 adds delivery teams that essentially function as agents similar to marketing, pharmaceutical and real estate agents that help match end users to innovations, but importantly, also provide feedback to intervention developers and design and marketing teams.

As part of the modeling process, two metrics were found to be especially useful for assessing the performance of this dissemination support system. First, the average time from developing a solution to diffusion represented how long it would take from the time of introducing an intervention to its spread throughout an adopting population. This represented the delay often discussed in diffusion of innovation literature reflecting how long it takes to get effective interventions into regular use. The second metric was the ratio of the number of solutions that had to be developed for every effective intervention adopted, which reflected the overall efficiency of the system. Typical ratios cited from industry are on the order of 1000:1, so the overall goal was to find a design of a system that could significantly improve this overall efficiency ratio.

Each model was then simulated to assess the steady-state characteristics for average time from development to diffusion, and the ratio of solutions developed for every effective solution adopted. As a part of the modeling process, it became apparent to the developers that part of the effectiveness of design and marketing teams as well as delivery teams could be in their ability to correct the errors introduced from expert review panels and user demand review panels. That is, these panels may not be perfect in identifying effective solutions and solutions that are in demand, and thus pass on solutions downstream that should ideally have been filtered out. To address this, we considered both a “best case” scenario where panels did not make mistakes, and a “worst case” scenario where panels were wrong 50% of the time and passed on solutions that were not effective (in the case of expert review panels) or not in demand (in the case of user demand reviews).

Table 1. Results from simulation analysis of different designs of dissemination support systems

| | Average time from developing solution to adoption and implementation (years) | | Ratio of solutions developed for every effective solution implemented | |
|---|---|---|---|---|
| **Model** | ***"Best case"*** | ***"Worst case"*** | ***"Best case"*** | ***"Worst case"*** |
| "Business as usual" | 21 | 110 | 33 | 132 |
| + user review panels | 4 | 62 | 145 | 156 |
| + user review panels<br>+ design and marketing teams | 5 | 14 | 16 | 27 |
| + user review panels<br>+ design and marketing teams<br>+ dissemination field agents | 5 | 13 | 16 | 25 |

Table 1 shows the results from the simulation analysis. Overall, the full combination of different components had the best result, but was only marginally better than having only user review panels combined with marketing and design teams. One of the key insights from this simulation was realizing that the addition of dissemination field agents, which was thought to have an obvious benefit, needed more exploration.

Developing the simulation model helped the developers to not only become more precise in their operational definitions of their conceptual model, but also discover more nuanced dynamics about how different designs functioned. In addition to realizing that the role of dissemination field agents may need further exploration, the modeling-as-design process also helped the team draw a formal distinction in the roles of design and marketing teams, and realize that what may be a transient benefit may not have much impact on overall steady-state performance of a dissemination support system.

## 3. Assessing Readiness of a Distribution System for Scale-up

The second project began as a follow up to a year of an extensive literature review; key informant interviews from industry, government, and major foundations; and review of publically available applied tools that organizations have developed to assess organizational readiness for global health distribution and scale-up. One of the major outcomes from this first year of research was a concept model of factors associated with successful scale-up of health innovations and the realization that the complexity of global systems involved could benefit from formal modeling and simulation. This led to reshaping the goal for the second year to focus on developing two separate prototype simulation models, an agent based model and a system dynamics simulation model, with the general purpose exploring the potential of using simulation models to assess different scale-up scenarios.

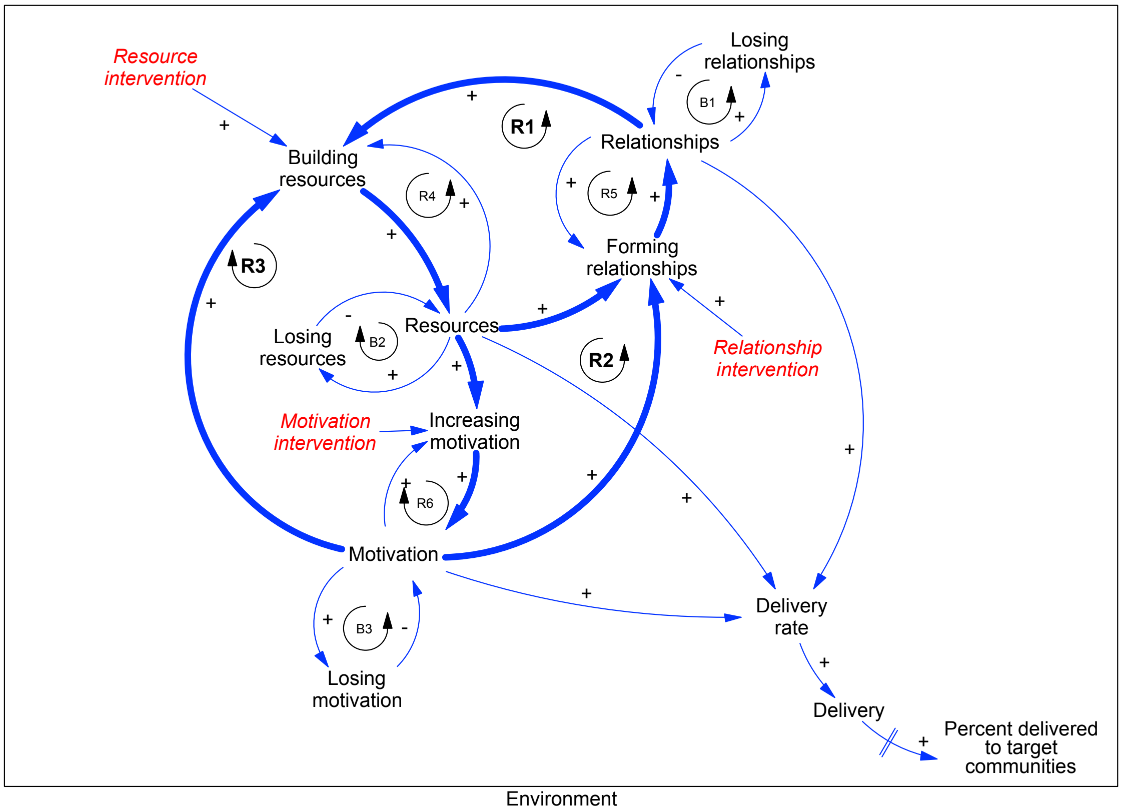
This second case focuses on the system dynamics simulation model. The primary goal of the system dynamics simulation model was to test the logical consistency of the conceptual framework and develop a better understanding of the potential leverage points for intervention since the various stakeholders in global health intervention -- funders, large intermediary organizations like the World Health Organization, and ministries of health in low-income countries—all have choices that they can make to strengthen or modify a planned intervention so that it works more effectively or more efficiently. The model was developed over the course of five months in parallel to separate agent-based modeling effort, and then presented for review to a group of experts including academics, program officers, and program directors from various non-profit and governmental organizations. The format of the review consisted of a 2-day meeting that providing some overall context for the models, and then two sets of parallel sessions for the agent based model and system dynamics model where participants.

On the first day, half the participants were in the system dynamics session where they were introduced to the model, raised questions about the model and method, and provided additional structures through a facilitated structure elicitation exercise. These changes were incorporated into a second version of the model, overnight, and shared with the second half of the participants on the second day.

The initial model (see Figure 6) depicts four major factors influencing delivery of innovations: resources, relationships, motivation, and environment. Environment is shown as a box around the entire system to reflect the assumption that environment affects the entire system. This is modeled by having the environment influence both the inflows and outflows of the main stocks. However, while resources, relationships, and motivation are endogenous, environment is by definition exogenous. In addition to considering the major feedback loops of the proposed framework for assessing readiness, the model also introduced several interventions to change the system.

The model was initially tested with a number of standard tests including extreme conditions, boundary adequacy, behavior reproduction, construct validity against the key informant data, and the expert review. After testing and revision, the model was subjected to a number of analyses. It was quickly found that the system was generally biased toward innovations not scaling up. Somewhat surprisingly, inter-organizational relationships tended to be a relatively weak influence in this system, which depended on collaborative and coordinating activity across a team of organizations. Conventional wisdom holds that network structure plays an important role in the spread of ideas; certain structures facilitate spread; others do not, based on characteristics such as density of connections and where in a system of units an innovation is seeded (Hinz, Skiera, Barrot, & Becker 2011). However, in this case, it turned out that overall, networks alone do not drive the system at the aggregate level. In comparison, organizational capacity and organizational motivation played a much greater role in increasing the delivery rate in addition to improving relationships.

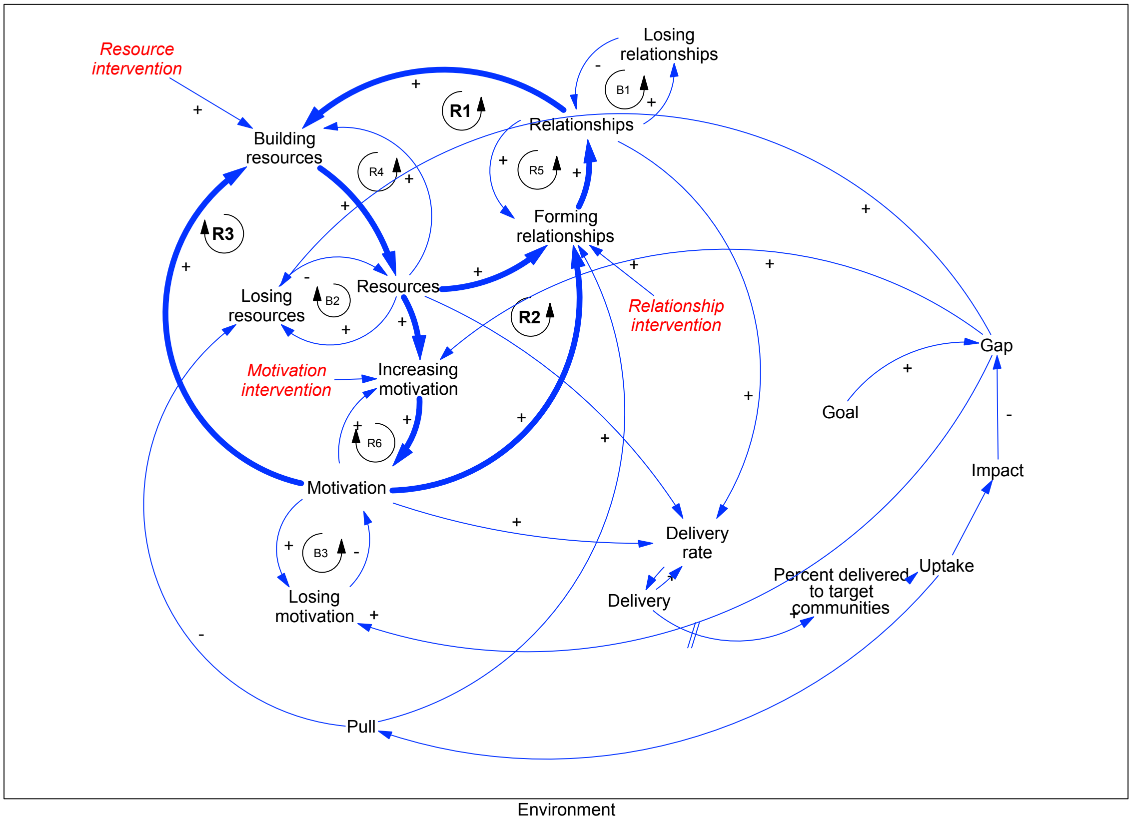
**Figure 6.** Initial system dynamics model for assessing readiness to scale-up innvations based on conceptual framework from literature reviews, review of assesment tools, and key informant interviews.




The expert panel review also pointed out the importance of demand or "pull" for successful health innovation scale-up (Dearing and Kreuter 2010). These structures were included in the model (see Figure 7) and resulted in a different set of behaviors from the first version. Whereas the previous version always produced the S-shaped diffusion pattern when scale-up was successful, the revised structure led to a more dynamically complex system where some factors played a more important role in scale-up (motivation and resources) than relationships. Specifically, interventions in motivation and resources could both produce S-shaped patterns whereas interventions to strengthen relationships could only produce goal-seeking patterns.

The general conclusions from the expert panel review were favorable for this stage of modeling. Comparisons between the system dynamics model and agent based model led to the conclusions that: (1) system dynamics models were advantageous for identifying where to intervene, while agent based models were more suited to understanding the details of specific interventions; (2) system dynamics models helped people understand the aggregate system more broadly than agent based models; (3) agent based models were better for modeling the specific structures of social networks and actor rules; and (4) the inductive nature of system dynamics modeling-as-design made assumptions more transparent and increased the ability of participants to assess those assumptions and hence its "trustworthiness", which was itself something that contributed to trusting the model more (i.e., by understanding its limitations better). System dynamics modeling, again due to its technical ability of enabling participants to modify a model in real time, is more participative and hence engaging than actor based modeling.

**Figure 7.** Revised system dynamics model for assessing readiness to scale-up innvations based on input from expert review




The experts also felt that the model was missing structures that influenced sustainability of implementation after scale-up. This is a model boundary issue. In the initial scope of the model, sustainability was explicitly excluded from consideration because it was seen as being outside the scope of the research focus. However, the experts reviewing the model disagreed with this decision and felt that it would add an important dimension to the overall understanding of scale-up.

## 4. Conclusions

Both models introduced here are relatively simple, and yet both highlighted the important role that system dynamics can play in conceptualizing and refining a design of dynamic and complex systems. In both cases, the process of formulating a simulation model forced a level of specification that the developers had not previously made, gave them a language for doing so, and provided a way to rigorously test the logical implications of their thinking. Of particular note in both projects was how much time was spent defining and redefining terms. This is not uncommon in a relatively new field as terms are still in flux. The difference that modeling makes is that one can quickly eliminate ways of operationalizing and measuring variables that are irrelevant.

At a more general level, both applications emphasize the role of modeling *in the design process.* System dynamics models are frequently discussed in the context evaluating different policies and strategies, and yet, the greatest role for system dynamics may be as a tool to help people understand and design simulations of sophisticated systems for anticipating and managing change. In this case, there were two different ways of representing design. In the first case, the focus was on building multiple simulation models to assess specific designs of different systems and evaluate their relative performance. In the second case, we developed a more abstract model to test a conceptual framework with respect to its hypothesized structure-behavior relationship, and assessed different designs of implementation scenarios.

Moreover, both projects highlighted the benefit of rapidly building and iterating a simulation model for refining how we think about dissemination and distribution systems, *and for doing so with experts who had no prior familiarity with system dynamics*. Somewhat unexpected was the similarity in both projects for the extensive need to clarify and define terms more precisely within the context of a formal simulation model. While this is quite common with formal modeling, what distinguished this application experience from other research by the first author was how frequently well-accepted definitions from the research literature were inadequate or failed outright in their logical consistency. The interpretation offered here is that this is symptomatic of a situation where the object of study (dissemination and distribution systems) are simply too difficult to study and theorize adequately without the aid of formal models.

While there are many approaches to developing formal simulation models, the ability of system dynamics models to be easily conveyed through the visual language of stocks-and-flows and feedback loops gives system dynamics a unique role to play in helping people to think in new and creative ways about such systems, and to develop a shared appreciation for their complexity.

Equally important is the fact that the visual representations can be quickly translated into running simulation models that help people learn. In the first example, this was evident in the fact that not only were multiple models developed relatively rapidly, but that this strategy was based on several previous models in early sessions that tried to represent all the designs in a single more generalizable model (somewhat analogous to the second example). That is, multiple strategies were attempted and scratched before settling on this particular approach. In the second case, the modeling was seen as an inductive means for giving the research team something to look at and critique early on, an aspect of system dynamics modeling-as-design that also provided important in rapidly incorporating feedback from the expert review session in the eventual day one meeting into the model during its second day.

In both cases, no one expected the models to be perfect or represent everything in the system. But being able to rapidly incorporate feedback and sometimes very substantial changes led to an intuitive understanding and appreciation of how the modeling could evolve into more sophisticated and empirically tested models in the future. The fact that one could work rapidly became a persuasive reason for people to engage further in the modeling, offer more and better feedback, and identify ways that they could use the existing models to think better about dissemination and distribution systems.

Building large and sophisticated simulation models will always be an essential and important part of system dynamics practice for major policy questions on health and other matters. However, building such models takes significant resources including time, money, and expertise, and presupposes that the end users of such models have a clear set of expectations that are stable enough to allow a completed model to be relevant when its completed.

In this paper, we have highlighted a different use of system dynamics modeling that focuses on modeling-as-design; a tool that can serve as an important boundary object for people to think, explore, and innovate. While much has been made in the past about the differences between qualitative and quantitative models (or causal maps versus simulation models if one likes), this focus has overshadowed the potential importance of small simulation models that can be rapidly built and developed to help people think better about a system. We may ultimately find that in the world of potential models that can be built and impact the world, many fall into this category of models as design and learning tools.

## References


Alexander, Christopher, Sara Ishikawa, Murray Silverstein, Max Jaconson, Ingrid Fiksdahl-King, and Shlomo Angel. 1977. A pattern language: Towns, Buildings, Construction. New York: Oxford University Press.

Alexander, Christopher, Sara Ishikawa, Murray Silverstein, Max Jaconson, Ingrid Fiksdahl-King, and Shlomo Angel. 1977. *A patter language: towns, buildings, construction.* New York: Oxford University Press.

Black, Laura J., and David F. Andersen. 2012. Using visual representations as boundary objects to resolve conflict in collaborative model-building applications. *Systems Research and Behavioral Science* 29:194-208.

Dearing, James W., and Matthew W. Kreuter. 2010. Designing for diffusion: How can we increase uptake of cancer communication innovations? *Patient Education and Counseling* 81S:100-110.

Forrester, Jay W. 1968. Market growth as influenced by capital investment. *Industrial Management Review* 9:83-105.

Ghaffarzadegen, N., James M. Lyneis, and George P. Richardson. 2011. How small system dynamics models can help the public policy process. *System Dynamics Review* 27 (1):22-44.

Hassmiller Lich, Kristen, Nathaniel D. Osgood, and Amad Mahmoud. 2010. Using system dynamics tools to gain insight into intervention options related to the interaction between tobacco and tuberculosis. *Global Health Promotion* 14:7-20.

Homer, Jack B. 1993. A system dynamics model of national cocaine prevalence. *System Dynamics Review* 9 (1):49-78.

Homer, Jack B., Gary B. Hirsch, Mary Minniti, and Marc Pierson. 2004. Models for collaboration: how system dynamics helped a community organize cost-effective care for chronic illness. *System Dynamics Review* 20:199-222.

Homer, Jack B., Bobby Milstein, Kristine Wile, Parakash Pratibhu, Rosanne Farris, and Diane Orenstein. 2008. Modeling the local dynamics of cardiovascular health: risk factors, context, and capacity. *Preventing Chronic Disease* 5 (2):1-6.

Institute of Medicine. 2001. *Crossing the quality chasm: A new health system for the 21st century*. Washington, DC: National Academy Press.

Jones, Andrew P., Jack B. Homer, Dara L. Murphy, Joyce D. K. Essien, Bobby Milstein, and Donald A. Seville. 2006. Understanding diabetes population dynamics through simulation modeling and experimentation. *American Journal of Public Health* 96 (3):488-494.

Lane, David C. 2001. *Rerum cognoscere causas*: Part II--Opportunities generated by the agency/structure debate and suggestions for clarifying the social theoretic position of system dynamics. *System Dynamics Review* 17 (4):293-309.

Repeated Author. 2001. Rerum cognoscere causes: Part I-how do the ideas of system dynamics relate to traditional soscial theories and the voluntarism/determinism debate? *System Dynamics Review* 17:97-118.

Lane, David C., and E. Husemann. 2008. System dynamics mapping of acute patient flows. *Journal of Operational Research Society* (59):213-224.

Levin, Gilbert, and Edward B. Roberts. 1976. *The dynamics of human service delivery*. Cambridge, MA: Ballinger Publishing Company.

Milstein, Bobby, J. B. Homer, and Gary B. Hirsch. 2010. Analyzing national health reform strategies with a dynamic simulation model. *American Journal of Public Health* 100 (5):811-819.

Milstein, Bobby, Andrew Jones, Jack B. Homer, Dara Murphy, Joyce Essien, and Don Seville. 2007. Charting plausible futures for diabetes prevalence in the United States: a role for system dynamics simulation modeling. *Preventing Chronic Disease* 4 (3):1-8.

Proctor, E., H. Silmere, Raghavan, Peter S. Hovmand, G. Aarons, A. Bunger, R. Griffrey, and M. Hensley. 2011. Outcomes for implementation research: conceptual distinctions, measurement challenges, and research agenda. *Administration in and Policy in Mental Health* 38:65-76.

Reid, Proctor P., W. Dale Compton, Jerome H. Grossman, and Gary Fanjiang, eds. 2005. *Building a better delivery system: a new engineering/health care partnership*. Washington, DC: The National Academies Press.

Richardson, George P. 2011. Reflections on the foundations of system dynamics. *System Dynamics Review* 27 (3):219-243.

Roberts, Edward B. 1964. *The dynamics of research and development*. New York, NY: Harper and Row, Publishers.

Schön, Donald. 1979. Generative metaphor: A perspective on problem-setting in social policy. In *Metaphor and society*, edited by A. Ortony. New York.

Sterman, John D. 2000. *Business dynamics: Systems thinking and modeling for a complex world*: Irwin McGraw-Hill.

Tengs, Tammy O., Nathaniel D. Osgood, and Laurie L. Chen. 2001. The cost-effectiveness of intensive national school-based anti-tobacco education: results from the Tobacco Policy Model. *Preventive Medicine* 33:558-570.

Thompson, Kimberly M., and Radboud J. Duintjer Tebbens. 2007. Eradication versus control for poliomyelitis: an economic analysis. *Lancet* 369:1363-1371.

Tobias, Martin I., Robert Y. Cavana, and Ashley Bloomfield. 2010. Application of a system dynamics model to inform investment in smoking cessation services in New Zealand. *American Journal of Public Health* 100 (7):1274-1281.

Warren, Kim. 2004. Improving strategic management with the fundamental principles of system dynamics. *System Dynamics Review* 21 (4):329-350.

Woolf, Steven H. 2008. The meaning of translational research and why it matters. *JAMA* 299 (2):211-213.