Presidential address Albuquerque 2009

Diffusion of System Dynamics

Groucho Marx said “I refuse to be a member of any club that would have me as member.” The System Dynamics Society is the “club” of my first choice, and it is a great honor and privilege to speak in Albuquerque this morning as the Society’s President.

I assume that all of you have come here because you find something valuable in System Dynamics (SD). Most of us also see a great potential for further development of the field. We are growing toward this potential as if guided by Adam Smith’s “invisible hand.” Membership grows, the home office provides more services, teaching improves, papers and books are published, and projects are carried out. We have no exact measurements of activity and we do not know exactly how and why things happen.

Over the years there has been an ongoing discussion of how the “invisible hand” could be guided to stimulate rapid and healthy growth of the field. Spurred by Jay W. Forrester’s speech at the 50 year anniversary, there is an ongoing effort to hammer out a strategy for the Society. Strategy has also been the theme for many earlier presidential addresses. My version is to look at strategy through the lenses of the theory of diffusion of innovations.

I will follow a standard outline for a SD study:

Problem (P’) - working towards a vision,
Hypothesis (H) - diffusion,
Analysis (A) - structure and behavior,
Policy (P) - stimulate diffusion, and
Implementation (I) - cost effective cooperation.

The outline can be summarized by the acronym P’HAPI. I use this acronym to constantly remind myself and our students what the important steps of SD analysis are. Experience suggests that these steps are easily forgotten or confused. For your information, when you have said P’HAPI often enough, it sounds and feels like “Be happy.”

Before discussing diffusion, I share with you my definition of SD:

> *System Dynamics is a method for studying, designing, and managing feedback systems. The major motivation for the use of SD is an observed tendency to misperceive and mismanage such systems.*

my vision for System Dynamics:

> *SD is the preferred method whenever it is the most appropriate—in schools, in universities, in personal affairs, in business, and in society at large.*

and my interpretation of the mission for the System Dynamics Society:

> *In the SD Society members work together and for each other to provide services to advance the method and practice of SD.*

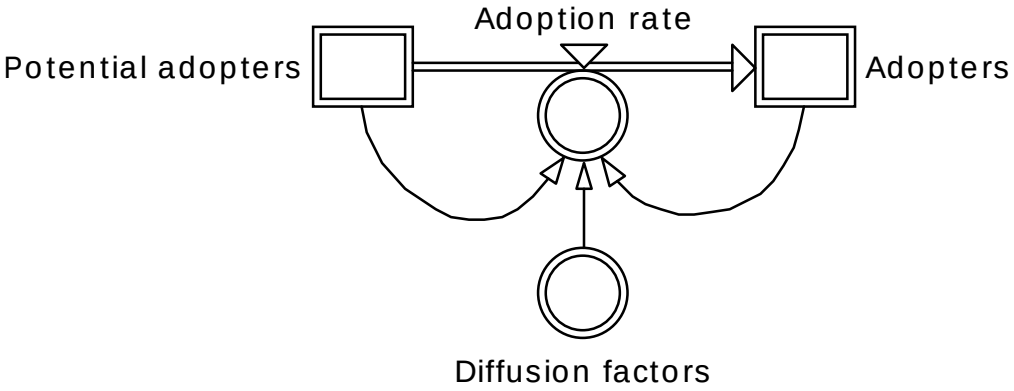
Problem: The field of System Dynamics has progressed for 52 years. Our visions for the future of SD may seem blurred and grand visions may seem impossible to realize. Should this be cause for frustration? My answer is no. Fields like statistics and economics have not been driven by clear visions about future applications. Like these fields, SD must move along the learning curve. The challenge is to identify policies that ensure desired development and diffusion of SD.

Before I go on, let me remind you of some recent events that witness the potential for SD. The examples are from teaching—a prime focus for this year's conference. Yaman Barlas, David Lane, and John Sterman all received prizes for excellent teaching. These prizes would not have been awarded unless they had something interesting to say in competition with other topics at their prestigious institutions. Our journal, the *System Dynamics Review* has reached a record high Impact Factor of 1.4, signaling that our articles are read and quoted. David Wheat wrote a chapter in a handbook on economics education, and I contributed a chapter in a handbook on fisheries management. Both contributions were invited from outside the field of System Dynamics. The Creative Learning Exchange is in the process of introducing an SD-based curriculum for math for middle schools. Finally, one week before this conference, the European Union made the final decision to fund a European Master's Program in SD.

Hypothesis: The figure below shows the Bass diffusion model (1969). It can reproduce reference modes of both growth and stagnation. I have used array symbols to differentiate adoption in universities, schools, consulting firms, businesses, and organizations. This complicates the model in that adopters can influence the adoption rates of each other. Strategies must consider theses causal links, which Kim Warren has described in a model developed for the Strategy Committee.

The Bass model, however, is not explicit about what influences aggregate diffusion factors. That is why I turn to the diffusion literature which provides empirical information about underlying factors of importance for diffusion. These are the factors that we can and should work to change to promote healthy growth of the field.

Analysis: Numerous studies lend support to the Bass model. Bass' paper from 1969 is one of the ten most frequently cited papers in the history of *Management Science*. Equally central is Everett Rogers' book from 1995 which has been cited more than 20,000 times according to Google Scholar. It provides huge amounts of empirical data on diffusion and on diffusion factors of importance for the diffusion of SD.



The number one diffusion factor is the *value* of SD to adopters. Assuming SD is the appropriate method, *quality* of analysis determines *value*. Success requires *quality* in all steps of an SD study summarized by the acronym P'HAPI. Problem formulation, hypothesis, and analysis (P'HA) are the basic steps of standard science. Policy analysis (P) is the operations research part of SD. *Quality* requires identification of leverage points in the first place and fine tuning in follow-up studies. Finally, implementation (I) goes beyond the standard repertoire of operations research. Adoption may require conceptual change among adopters. Policies must be cost effective also after implementation costs are accounted for. Uncertainty and risk must be limited.

The second diffusion factor, *complexity*, hinders conceptual change and increases uncertainty and risk for adopters. If policy recommendations are not understood by a decision maker, it seems risky and even irresponsible to follow advice.

How conscious are we about *complexity*? Each year in my introductory class at the University of Bergen I show the students a causal loop diagram from one of the early SD conferences. Different from most presentations, I give the students 2 silent minutes

to figure out the number of feedback loops. Answers range from 1 to 6 loops. We all suspect that this cannot be an effective diagram. But what about all our presentations that we think of as simple and good—do they really work for potential adopters?

This raises important questions. How could models be simplified without losing their *value*? What are effective ways to teach conceptual change? How can remaining risks be addressed?

The third diffusion factor, *compatibility* between SD studies and existing practices, facilitates conceptual change and reduces implementation costs, and perceived risks, as well as potential conflict. How do we increase *compatibility*? We should explore and explain how SD adheres to scientific principles; for instance, explore SD as a practical version of advanced Baysian statistics. The same basic method applies to consulting as well as academic work. To promote diffusion, a first step is to build knowledge about current thinking and practices of potential adopters. To some extent we may adapt to current practices, without, however, giving up what is *valuable* with SD and without applying the method where it is inferior.

The fourth diffusion factor, e*xperience* with SD, reduces perceived risks for adopters even when conceptual change has not taken place. Furthermore, *experience* may motivate conceptual change. *Experience* typically relies on direct contact between adopters and potential adopters. *Experience* may also be obtained by low cost trials.

There are good reasons to think that all these factors are important for the diffusion of System Dynamics. As a limited test of both diffusion factors and the Bass model I will consider citations to SD papers and books in publications on the internet. These data are also interesting in themselves as an update of the status of SD. The data are not exhaustive and you should be aware that numbers of citations reflect age of publications, where published, potential interest in particular topics; and numbers may ignore multiple publications. First I consider data from Google Scholar.

The first nine publications in the table show citations to publications on basic SD methodology. The total number of citations is considerable and gives an impression of the amount of interest in SD methodology.

The next nine publications illustrate more specific points. John D. Sterman’s paper on modeling managerial behavior is cited unusually often. One possible reason for this is

that papers based on laboratory experiments are easily perceived as *compatible* with standard science.

World Dynamics, *Limits to Growth* and updates to the latter have been cited a lot. Controversies illustrate that even Jay W. Forrester's model, which had only five stocks, was sufficiently *complex* to be misunderstood and rejected by many. Still it became very influential because of its importance and timely message. It was perceived as *valuable*. For obvious reasons to most of us, this study is still highly *valuable* and was recently recognized as such when Dennis L. Meadows received the Japan Prize—"one of the world's most prestigious awards in science and technology."

Citations to selected publications according to Google Scholar, June 29, 2009

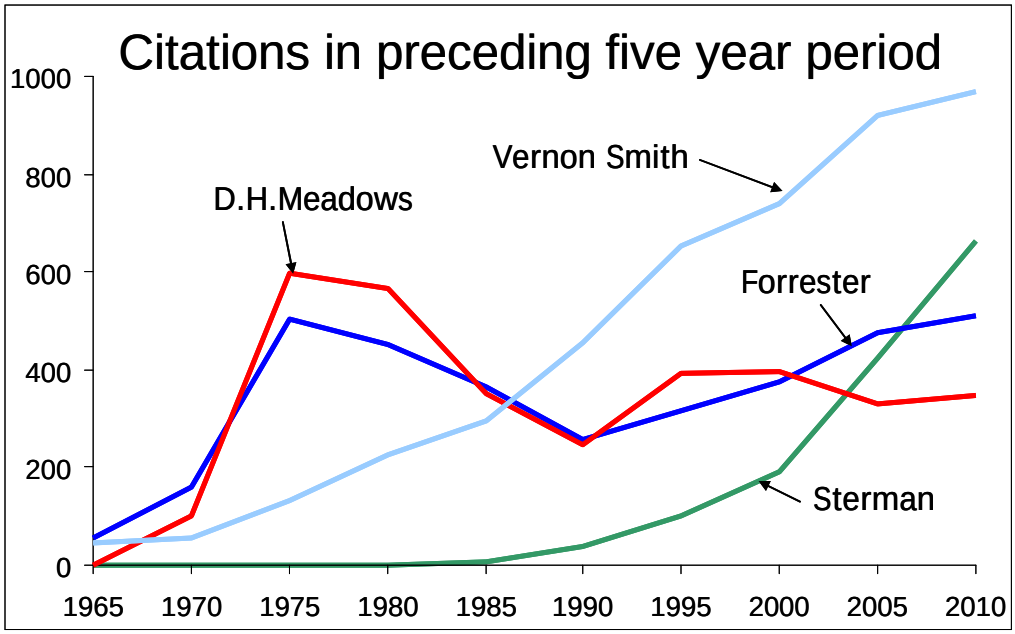
Forrester: *Industrial Dynamics*	4660
Sterman: *Business Dynamics*	2218
Forrester: *Principles of Systems*	1133
Richardson & Pugh: *Introduction to System Dynamics*	602
Vennix: *Group Model Building*	521
Forrester & Senge: *Tests for Building Confidence*	327
Roberts et al: *Introduction to Computer Simulation*	314
Wolstenholme: *System Enquiry*	248
Goodman: *Study Notes*	221
Sterman: *Modeling Managerial Behavior*	1247
Forrester*World Dynamics* / Meadows et al. *LtG* and updates	3472
Lee/Christopher/Beamon: 3 Supply chain studies	3040
Senge: *The Fifth Discipline*	12559
Richardson: *Feedback Thought*	402
Forrester: *Counterintuitive Behavior*	398
Ford: *Modeling the Environment*	260
Lyneis: *Corporate Planning*	184
Warren: *Competitive Strategy Dynamics*	141

The authors of the next "3 supply chain studies" are not system dynamicists. Their papers are widely cited indicating a high *value* of the underlying dynamic model. All three papers refer to Forrester's supply chain model. Hence, the basic science part (P'HA) was carried out within the field of SD, while much analysis is currently performed by people outside the field. This should contribute to the diffusion of SD. An

interesting question is if we have benefited as much as we could from for the great interest in the supply chain model.

Peter Senge's *Fifth Discipline* has by far received most citations of all SD publications according to Google Scholar. Likely reasons for this are the high *value* and apparently low level of *complexity* compared to most other SD publications. However, Senge's best-selling book did not lead to the demand for SD that some had hoped for. I speculate that limited *compatibility* with current thinking and practices, and lack of available *experience* has limited a deeper diffusion.

Citations to Richardson's book on feedback thought and Forrester's paper on counterintuitive behavior of social systems show that the philosophy of SD and general insights from SD studies are perceived as *valuable*. The three last publications should all have large potential audiences, however, the number of citations are more modest. This may reflect that in spite of high *value*; *complexity, compatibility* and *experience* become more problematic the closer one gets to individual decision makers and their current practices. Publishing and referencing also tend to diminish the more practical applications are. I sense that our largest challenge is in developing a strong demand for SD from decision makers. Demand is an important driver for technological progress in general and SD should be no exception. This year's Application Award to Kenneth Cooper and Gregory Lee is encouraging.



Data produced by Cited Reference Search in the ISI Web of Science data base. Except for Sterman, the number of citations is slightly overestimated due to inclusion of a few citations to persons with same names.

Finally, I have used the ISI data base to see how citations have developed over time. Jay W. Forrester and Donella H. Meadows (first author of *Limits to Growth*) show parallel developments. Citations peak after the publications of *World Dynamics* and *Limits to Growth*. However, the peaks seem to be superimposed on long-term upward trends.

John D. Sterman's career starts later and citations to his works show stronger growth than for Forrester and Meadows. It is interesting to compare citations to Sterman to citations to 2002 Nobel laureate in economics Vernon L. Smith. Smith got the prize for having pioneered the use of laboratory experiments in the field of economics. Also he had to spend time arguing for a novel method while working his way along the learning curve. While he has not been a mainstream economist, he has cleverly managed to maintain a high degree of *compatibility* with mainstream economics. I believe his work opens up for future experimental investigations of *complex* dynamics and bounded rationality also in the field of economics.

The citations show patterns that are in line with the Bass diffusion model. Similar patterns can be seen for other system dynamicists as well. There are no apparent signs of stagnation. While this is cause for optimism, it should not divert attention away from the four vital diffusion factors: *value* (*quality*), *complexity*, *compatibility*, and *experience*. We can do even better!

Policy. The recent focus on strategy in the System Dynamics Society has led to a long list of initiatives to change diffusion factors in favorable directions. Inputs come from Jim Lyneis, Kim Warren's strategy report, Forrester's talk at the 50 year anniversary, previous presidential addresses, the listserv discussion in 2008, and others.

It seems fruitful to split the initiatives in three categories: SD method and practice, teaching for students and decision makers, and other initiatives. Within each category, initiatives should target all steps of the method P'HAPI and the four diffusion factors. The benefits of the initiatives will show up as more resources at the Society's web page, increased awareness of SD, higher quality, more activity, and higher demand for SD.

Implementation. The Strategy Committee will play a crucial role in collecting and prioritizing initiatives. Ex-officio members of the committee are the current and past president and the two presidents elect. This means that the committee will provide continuity, allowing tasks to be followed up over a longer time span than the one-year presidential term.

I see three ways in which the Strategy Committee can facilitate implementation. First, some tasks can be outsourced. The Policy Council has agreed that some money should be made available to good projects. An example could be a short and professional video presenting SD.

Second, some initiatives are not very costly and may be directly beneficial to those who carry them out. Examples are development of teaching material and guidelines for paper writing. These are task that most universities already spend time on, but typically less than desired. By cooperating, quality can increase and costs can be reduced. An instinctive reaction against such collaboration is that it will benefit competitors and particularly free-riding competitors. Michael E. Porter advises businesses to cooperate on cost reductions and compete in the market place. By jointly improving diffusion factors, everyone will benefit from healthy long-term growth.

Third, the Strategy Committee can identify more costly projects and announce these. Examples are textbooks and papers that deal explicitly with the four diffusion factors. By announcing such needs, for instance as themes for conferences and special issues of the journal, potential authors may be inspired to redirect their research activity.

I hope the above ideas can be useful to you, whatever use you make of SD. I also hope to have inspired you to contribute in the ways you can when the Strategy Committee or others in the System Dynamics Society announce needs for help.

Thank you for your attention.
Erling Moxnes